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NASA STANDARD

National Aeronautics and Space Administration
Washington, DC 20546-0001

NASA-STD-8719.12

Approved: 2010-1-29

Safety Standard for Explosives, Propellants, and Pyrotechnics

**MEASUREMENT SYSTEM IDENTIFICATION:
HYBRID - INCH-POUND AND METRIC**

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DOCUMENT HISTORY LOG

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This document is subject to reviews per Office of Management and Budget Circular A-119, Federal Participation in the Development and Use of Voluntary Standards (02/10/1998) and NPD 8070.6, Technical Standards (Paragraph 1.k).

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FOREWORD

This standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs. This standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities.

This standard has been reviewed and approved for NASA use in accordance with 29 CFR 1960.18 as a supplemental standard to OSHA 1910.109. This standard expands and updates requirements and criteria of NSS 1740.12. The following subject areas are changed or incorporated:

- Explosive Safety Officer roles and responsibilities.
- Criteria for:
  - Process safety management.
  - Equivalency and variance.
  - Explosives identification. Training certification. Explosive wastes. Fire extinguisher and symbol criteria. Fire reporting and training. Emergency withdrawal distances Electrical, Electromagnetic Radiation (EMR)/Radio Frequency(RF), lighting and Electrostatic Discharge (ESD). Laboratory safety and peroxide forming chemical management. Storage compatibility group, classification, interchange, intermodal, and holding yard. Vehicle and Ground Support Equipment (GSE) fire extinguisher.
  - Security requirements.
  - Energetic liquids applicability. Flammable/toxic vapor atmospheric dispersion. Solid rocket motor static test stand. Hazardous materials storage tank. Building, wall, earth covered and high performance magazines design. Licensed explosive locations. Ground support equipment, government and privately owned vehicles parking location. Hazard Division (H/D) 1.1, 1.2, 1.3, 1.4, 1.6, energetic liquid, airfield and heliport quantity distance. Unrelated employee public transportation route protection. Explosions and exposure risk management.
  - Site planning.
  - Maximum Credible Event (MCE) based Quantity-Distance (QD) Siting.
- Non-mandatory section includes additional site planning guidance, ESD sources, Electro-explosive Device (EED) and RF energy analysis, and H/D 1.1 effects at specified.
- Subject index.

This standard replaces and supercedes NSS 1740.12, August 1993.

Requests of information, corrections, or additions to this standard should be submitted via "Feedback" in the NASA Technical Standards System at **http://standards.nasa.gov**.

Bryan O'Connor
Chief, Safety and Mission Assurance

January 29, 2010
Approval Date

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Safety Standard for Explosives, Propellants, and Pyrotechnics

CHAPTER 1 SCOPE

1.1 Purpose.

This document prescribes the National Aeronautics and Space Administration (NASA) safety standards/procedures for operations involving explosives handling and processing. These operations are an integral part of explosives-related development and manufacturing activities. Safety of all explosive operations associated with NASA programs is an ongoing, primary concern and continually must be given high priority in all program direction and management. This document provides a uniform set of standards for all NASA installations involved in explosives storage, handling, or processing, and complies with the cardinal principle for explosive safety: expose the minimum number of people to the smallest quantity of explosives for the shortest period consistent with the operation being conducted.

1.2 Applicability.

1.2.1 This standard applies to NASA Headquarters and NASA Centers, including Component Facilities, and to the Jet Propulsion Laboratory and to other contractors to the extent specified in their contracts. Because this standard has been reviewed and approved for NASA use in accordance with 29 CFR 1960.18 as a supplemental standard to Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.109, therefore it takes the place of an OSHA regulation for those areas not covered by 29 CFR 1910.109.

1.2.2 Requirements in addition to, and that do not conflict with, those listed herein may be appropriate for inclusion in Center-specific explosives safety policies and procedures to address unique applications and situations not covered by this document. As provided for in NPR 8715.3B, it is the Explosive Safety Officer's (ESO) responsibility to assure that such additional requirements are developed and included in the Center's process.

1.2.3 This Standard is applicable to all NASA facilities engaged in the development, manufacturing, handling, storage, transportation (on/offsite), processing, testing, or use of explosives, or assemblies containing explosives. The standard provides procedures for operations involving explosives, propellants, and pyrotechnics and the safe management of such operations.

1.2.4 The design of all new explosives facilities, except those whose design phase is beyond Preliminary Design Review (PDR) or 30-percent completion at the publication of this document, shall conform to the requirements established herein and references as applicable. It is not the intent of NASA to change existing physical facilities arbitrarily to comply with these provisions, except as required by law. Existing facilities not in compliance with this document may continue to be used for the balance of their functional lives, as long as current operations present no significantly greater risk than that assumed when the facility was originally designed, and it can be demonstrated clearly that a modification to bring the facility into compliance is not feasible.

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In the case of a major renovation, however, the facility shall be brought into compliance with current standards (Requirement).

1.2.5 This standard governs the storage or handling of energetic liquids used for and in space launch vehicles, rockets, missiles, associated static test apparatus, and ammunition items.

1.2.6 This standard does not govern bulk storage of hazardous gases used for standard industrial purposes (e.g., medical, welding) and non-propellant uses/systems involving liquid oxygen and liquid hydrogen. For these materials and systems, follow appropriate NPD 8710.5, NASA Safety Policy for Pressure Vessels and Pressurized Systems, NASA-STD-8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems, appropriate Occupational Safety and Health Administration (OSHA), National Fire Protection Association (NFPA), American Society for Testing and Materials (ASTM) (ASTM MNL 36, Safe Use of Oxygen and Oxygen Systems), and American National Standards Institute (ANSI) (ANSI/AIAA G-095-2004, Guide to Safety of Hydrogen and Hydrogen Systems), requirements, standards, and guidance.

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CHAPTER 2 APPLICABLE DOCUMENTS/REFERENCE DOCUMENTS

2.1 Order of precedence.

Where this standard is adopted or imposed by contract on a program or project, the technical requirements of this standard shall take precedence, in the case of conflict, over the technical guidelines or requirements of cited and referenced documents, except those having the force of law (Requirement).

2.2 Applicable documents.

Applicable documents include some having the force of law but not cited in the body of this standard, as well as those cited in the body of this standard. The requirements of this standard do not take precedence over legal requirements. The documents cited in the body of this standard are incorporated to the extent specified. The specified technical requirements listed in the body of this standard shall be met whether or not the source document is listed in this section. Unless otherwise specified, the most recent version of each document cited shall be used. (Requirement).

2.2.1 Government documents. Specifications, standards, handbooks, drawings, and other publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issuances in effect on the date of invitation for bids or request for proposals shall apply (Requirement).

DEPARTMENT OF DEFENSE

MIL-C-043122, Flame Retardant Treated Cotton Sateen Cloth.

MIL-I-23659, Initiators, Electric, General Design Specification.

MIL-STD-398, Shields, Operational for Ammunition Operations, Criteria for Design and Tests for Acceptance, November 5, 1976.

Structures to Resist the Effects of Accidental Explosions, Departments of the Army, the Navy, and the Air Force, TM5-1300, NAVFAC P-397, AFM 88-22, Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Approved Protective Construction, DDESB Technical Paper 15, Department of Defense Explosives Safety Board, Alexandria, VA, February 2001.

Guide for Evaluating Blast Resistance of Non-Standard Magazines, HINDED-CS-S-95-01, U.S. Army Corps of Engineers, Engineering Support Center, Huntsville, AL, January 1995.

Methods for Predicting Primary Fragmentation Characteristics of Cased Explosives, U.S. Army Corps of Engineers Engineering Support Center, Huntsville, AL, HNC-ED-CS-98-1, January 1998.

Methods for Calculating Range to No More Than One Hazardous Fragment per 600 Square Feet, U.S. Army Corps of Engineers Engineering Support Center, Huntsville, AL, HNC-ED-CS-98-2, January 1998.

Copies of DoD documents are available from http://www.ddesb.pentagon.mil/.

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DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Occupational Safety and Health Standard, 29 CFR 1910 Subpart H Hazardous Materials, 1910.103, Hydrogen.

Occupational Safety and Health Standard, 29 CFR 1910 Subpart H Hazardous Materials, 1910.104, Oxygen.

Occupational Safety and Health Standard, 29 CFR 1910 Subpart H Hazardous Materials, 1910.106, Flammable and Combustible Liquids.

Occupational Safety and Health Standard, 29 CFR 1910 Subpart H Hazardous Materials, 1910.109, Explosives and Blasting Agents.

DEPARTMENT OF TRANSPORTATION

Department of Transportation Regulations, 49 CFR Chapter I Subchapter C, Hazardous Materials Regulations, Parts 171-179.

ENVIRONMENTAL PROTECTION AGENCY

Environmental Protection Agency Regulations, 40 CFR, Part 261 Identification and Listing of Hazardous Waste.

GENERAL SERVICES ADMINISTRATION

FILING CABINET, LEGAL AND LETTER SIZE, UNINSULATED, SECURITY, AA-F-358H, May 18, 2000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-STD-8719.11, Revision A, NASA Safety Standard for Fire Protection.

NASA Procedural Requirements (NPR) 8715.3C, with change 3, NASA General Safety Program Requirements.

NPR 1600.1, NASA Security Program Procedural Requirements.

NPR 8820.2F, Facility Project Requirements.

Note: Unless otherwise indicated, copies of the above NASA documents are available from any NASA Installation library or documentation repository, http://nodis.hq.nasa.gov/Welcome.html.

UNITED NATIONS

ST/SG/AC.10/1/Rev. 14, UN Recommendations on the Transport of Dangerous Goods Model Regulations, Twelfth Revised Edition, United Nations, New York, 2001.

Note: Copies of the above document are available from: http://www.iataonline.com/.

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2.2.2 Non-Government publications.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issuances in effect on the date of invitation for bids or request for proposals shall apply (Requirement).

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI Standard A156.3 (2001), Exit Devices.

ANSI Standard Z41 (1986), Personal Protection - Protective Footwear.

ANSI Standard 87.1 (1989), American National Standard for Occupational and Educational Personal Eye and Face Protection Devices.

ANSI Standard Z89.1 (1986), Industrial Head Protection.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 1/Division 2/Division 3 (2007).

ASME B56.1 (2004), Safety Standard for Low Lift and High Lift Trucks.

AMERICAN SOCIETY OF TESTING AND MATERIALS

ASTM D92 (2005), Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester.

ASTM F150 (2006), Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring.

ASTM F2412 (2005), Standard Test Methods for Foot Protection.

ASTM F2413 (2005), Standard specification for Performance Requirments for Foot Protection

INTERNATIONAL Air Transport Association, Dangerous Goods Regulations, Publication No. 9065-48, January 1, 2007.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

Technical Instructions for the Safe Transport of Dangerous Goods by Air, Publication No. 9284, January 1, 2007.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 9001-2000, International Standards Organization Quality Assurance.

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 13-2007, Standard for the Installation of Sprinkler Systems.

NFPA 15-2007, Standard for Water Spray Fixed Systems for Fire Protection.

NFPA 22-2007, Standard for Water Tanks for Private Fire Protection.

NFPA 25-2002, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.

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NFPA 30-2003, Flammable and Combustible Liquids Code.

NFPA 45-2004, Standard on Fire Protection for Laboratories Using Chemicals.

NFPA 50-2001, Standard for Bulk Oxygen Systems at Consumer Sites.

NFPA 69-2008, Standard on Explosion Prevention Systems.

NFPA 70-2005, National Electrical Code.

NFPA 77-2007, Recommended Practice on Static Electricity.

NFPA 101-2006, Life Safety Code.

NFPA 251-2006, Standard Methods of Tests of Fire Resistance of Building Construction and Materials.

NFPA 430-2004, Code for the Storage of Liquid and Solid Oxidizers.

NFPA 495-2006, Explosive Materials Code.

NFPA 505-2006, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation.

NFPA 780-2004, Standard for the Installation of Lightning Protection Systems.

(Copies of the above documents are available from: http://www.nfpa.org/codesonline/.)

NATIONAL SKEET SHOOTING ASSOCIATION

Official Rules and Regulations, Revised 2008.

Review of Literature Related to Human Spark Scenarios, B. D. Berkey, T. H. Pratt, and G. M. Williams, Hercules Inc., Missile Ordnance and Space Group, Allegheny Ballistics Laboratory, Rocket Center, WV.

Spark Ignition Hazards Caused by Charge Induction, J. E. Owens, Condux, Inc., Newark, DE.

2.3 Reference Documents.

These references are not cited in the body of this standard and are provided for reference only. They may be helpful in providing background information to the user.

2.3.1 Government documents - Reference

DEPARTMENT OF DEFENSE

DoD 6055.9-STD, Department of Defense Ammunition and Explosives Safety Standards, Undersecretary of Defense (Acquisition, Technology, and Logistics), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

Department of the Army, Safety Manual, DARCOM-R 385-100, Headquarters United States Army Materiel Development and Readiness Command, 5001 Eisenhower Avenue, Alexandria, VA 22333.

Prediction of Building Debris for Quantity-Distance Siting, DDESB Technical Paper 13, Department of Defense Explosives Safety Board, Alexandria, VA, April 1991.

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Blast Environment from Fully and Partially Vented Explosions in Cubicles, W. A. Keenan and J. E. Tancreto, TR-828, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

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, AD 411445.

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, AD B004152.

DEPARTMENT OF ENERGY

DOE/EV/06194, REV 4, DOE Explosive Safety Manual, U.S. Department of Energy, Assistant Secretary for Environment, Safety, and Health, Office of Quality Programs.

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.

DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Occupational Safety and Health Standard, 29 CFR 1910 Subpart H Hazardous Materials, 1910.119, Process Safety Management of Highly Hazardous Chemicals.

ENVIRONMENTAL PROTECTION AGENCY

Environmental Protection Agency Regulations, 40 CFR, Part 262 Standards Applicable to Generators of Hazardous Waste.

Environmental Protection Agency Regulations, 40 CFR, Part 264 Standards For Owners And Operators Of Hazardous Waste Treatment, Storage, And Disposal Facilities.

Environmental Protection Agency Regulations, 40 CFR, Part 265 Interim Status Standards For Owners And Operators Of Hazardous Waste Treatment, Storage, And Disposal Facilities.

FEDERAL AVIATION ADMINISTRATION

Federal Aviation Administration Regulations, 14 CFR, Part 77, Objects Affecting Navigable Airspace.

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2.3.2 Non-Government publications - Reference

AMERICAN SOCIETY OF TESTING AND MATERIALS

ASTM D-2240.91, Test Methods for Rubber Properties Durometer Hardness.

SOCIETY OF FIRE PROTECTION ENGINEERS

Engineering Guide, Predicting 1st and 2nd Degree Skin burns from Thermal Radiation, March, 2000.

OTHER PUBLICATIONS

Packaging Of Explosives — Is ESD Considered? E. E. Anspach and M. D. Evans, Arnold Air Force Base, TN.

The Use (and Misuse) of Bonding for Control of Static Ignition Hazards, R. A. Mancini, AMOCO Corporation, Naperville, IL.

Research on the Hazards Associated with the Production and Handling of Liquid Hydrogen, M.G. Zabetakis, and D.S. Burgess, U.S. Department of the Interior, Bureau of Mines, Report No. 5707, 1961.

Investigation of the Explosive Potential of the Hybrid Propellant Combinations N_2O_4/PBAN and CTF/PBAN, C. Wilton, AFRPL-TR-67-124, 1967.

Review of Safety Guidelines for Peroxidizable Organic Chemicals, R. J. Kelly, Chemical Health and Safety 1996, Sept/Oct, pp 28-36.

Standard for Storing and Using Peroxidizable Organic Chemicals, R. J. Kelly, and G. Miller, Lawrence Livermore National Laboratory Publication UCRL-AR-133218, Rev. 1 May, 1999.

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CHAPTER 3 DEFINITIONS AND ACRONYMS

3.1 Definitions used in this standard.

Aboveground Magazine. Any building or structure, except for an operating building, used for the storage of explosives. Aboveground magazines are all types of above grade (not earth-covered) magazines or storage pads. This includes storage in trucks, trailers, railcars, or cargo aircraft.

Administration Areas. Areas in which administrative offices are located and which function for the establishment as a whole in contrast to field offices.

Approved. Complying with the provision(s) of this document and with instructions and details issued by the ESO or with those of other approving agencies specified herein.

Arm. A general term that implies the energizing of electronic and electrical circuitry that, 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.

Auxiliary Building. Any building that supplements an operational building, line, or area but is not directly used for the productive activity. Examples of such auxiliary buildings are fan houses, valve houses, and similar units.

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 exposures.

Barricaded. To be protected by a barricade.

Bay. A location (examples: room, cubicle, cell, work area) that affords the level of safety and protection appropriate to the material and activity involved.

Blast Overpressure. The pressure, exceeding the ambient pressure, manifested in the shock wave of an explosion.

Blending. Mixing of solid materials (usually dry) by gravity flow, usually induced by vessel rotation.

Bonding. Process of connecting two or more conductive objects by means of a conductor.

Cell (High Performance Magazine (High Performance Magazine)). A reinforced concrete storage area in an HPM, separated from other cells by a specially designed non-propagation interior wall, with a removable reinforced concrete lid forming the roof. The entire HPM is earth-bermed.

Change House. A building provided with facilities for employees to change to and from work clothes. Such buildings may be provided with sanitary facilities, drinking fountains, lockers, and eating facilities.

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Classification Yard. A group of railroad tracks used for receiving, shipping, and switching railway cars.

Combustible Material/Fuels. Any material which, when ignited, will sustain burning.

Compatibility. 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.

Component. Any part of a complete item whether loaded with explosives (commonly called "live"), inert (not containing explosives), or empty.

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

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

Control Point. 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.

Counter Poise System. A buried loop or grid earth electrode grounding 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.

Debris Hazard. A hazard resulting from any solid particle thrown by an explosion or other strong energetic reaction. For aboveground explosions, debris refers to secondary fragments (see Paragraph 5.66.3).

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; a surface phenomenon with the reaction proceeding towards 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.

Deluge System. A quick-acting detection and water delivery system providing for a high volume of quenching water to cover hazardous points of an operation or areas where accidental ignition may be likely to occur.

Detonation. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure 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 which is originally

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of supersonic velocity. A detonation, when the material is located on or near the surface of the ground, is normally characterized by a crater.

Deviation. A variance that authorizes departure from a particular safety requirement that does not strictly apply or where the intent of the requirement is being met through alternate means that provide an equivalent level of safety. OSHA refers to this as an alternate or supplemental standard [NPR 8715.3].

Dielectric Breakdown. The failure of the insulating property of a material when the dielectric strength of the material has been exceeded and current flows through the material.

Dielectric Strength. The maximum electric field strength an insulating material can withstand without a failure of its insulating properties.

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 DSC curve; the energy input is substituted for ΔT and is plotted in the same manner as a normal Differential Thermal Analysis (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 while the substance and the reference material are subjected to a controlled temperature program. The record is the differential thermal analysis or DTA curve.

Drying. Removal of volatiles from ingredients or mixtures.

Dry Run. Rehearsal of a process without the presence of the associated hazard. The level of dry run activities is dependent upon effect of change to the hazard level of process.

Dunnage. Inert (though possibly flammable) material associated with the packaging, containerization, blocking and bracing, ventilation, stability of shipping, stacking and storage configuration.

Earth Bermed. Buildings constructed so that there is earth covering on above grade portion of building walls and no earth covering on the roof. The earth berm serves as a barricade designed to prevent sympathetic detonation between adjacent magazines from fragments and debris. The earth berm also serves to direct blast overpressures and debris.

Earth Covered Magazine (ECM). An aboveground, earth-covered structure intended for the storage of explosives, pyrotechnics, propellant, or UN Class 1 hazardous materials that meets soil cover depth and slope requirements of this Standard.

Earth Electrode Subsystem. A component of a lightning protection system that transfers the current of a lightning flash to the earth. The earth electrode system (e.g., ground rods, counterpoise, buried metal plates, or Ufer grounds) is connected to down conductors and is in direct contact with the earth.

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

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Electro-Explosive Device (EED). 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.

Electrostatic Discharge. This is an arcing of electric charge across a gap between two points not in contact or through a nonconductor when the voltage exceeds the dielectric breakdown voltage of the nonconductor. All static electricity hazards are initiated by this sudden energy release or discharge mechanism.

Electrostatic Energy. Storage of electric charge accumulated on almost any item regardless of size or properties. Its accumulation can result in an uncontrolled/unplanned discharge. A conductor will only store electrostatic energy if it is ungrounded.

Employee and Personnel. Any and all persons employed within the confines of the installation and all authorized transients.

Emulsions. A chemical system consisting of a liquid dispersed, usually in droplets of larger than colloidal size, in an immiscible liquid (with or without another supporting agent). Emulsions may also include suspended solid particles.

Energetic Liquid. A liquid, slurry, or gel, consisting of, or containing, an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration, or detonation.

Energetic Material. A material consisting of, or containing, an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration, or detonation.

Experimental Operating Procedure. A procedure prepared for conducting a specific experiment a limited number of times under close technical supervision.

Exploding Bridge Wire (EBW) Detonator. A detonator device utilizing an exploding wire to set off a secondary explosive charge, typically Pentaerythritol Tetranitrate (PETN) and Cyclonite (RDX). The bridge wire requires a very large electrical energy input over a very short time (typically a current rate of rise of 1,000 amps/microsecond) to explode, thus requiring a special high voltage capacitive discharge initiating circuit. It is inherently less sensitive than a primary explosive-initiated detonator, such as a conventional low voltage EED. EBWs are often used for combustion instability testing.

Explosive Donor. An explosion from a small device or explosive mass that may cause an adjacent explosive item or larger mass to react in such a manner as to yield measurable blast overpressure.

Explosive Wastes. Explosive materials or devices that are no longer useable or that are no longer wanted or needed and have no intended use (see 40 CFR 261).

Explosives. Term "explosive" or "explosives" includes any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation, or other suitable initiation, 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.

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Explosives Area. A restricted area specifically designated and set aside from other portions of an installation for the manufacturing, processing, storing, and handling of explosives.

Explosives Safety Officer (ESO). See paragraph 4.5.1.

Exposed Explosives. Explosives that are open to the atmosphere (such as unpackaged bulk explosives or disassembled or open components) and that are susceptible to initiation directly by static or mechanical spark, or create (or accidentally create) explosive dust, or give off vapors, fumes, or gases in explosive concentrations. This also includes exudation and explosives exposed from damaged items such as gun powder or rocket motors.

Exposed Site (ES). A location exposed to the potential hazardous effects (blast, fragments, debris, and heat flux) from an explosion at a potential explosion site (PES). The distance to a PES and the level of protection required for an ES determine the quantity of explosives permitted in a PES.

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 NASA.

Facility Management. Management staff of the facility operator.

Facility Operator. Organization having responsibility for conducting operations at a NASA facility.

Faraday Cage. A grounded conductive shell (usually of wire screen) completely surrounding a piece of equipment or an area of a facility in order to shield the interior from external electric fields and/or vice versa.

Faraday Cap. A cap applied to the connector end of an Electroexplosive Device (EED), e.g., an NSI, to provide an electromagnetic energy (EME) shield to prevent inadvertent firing from radio frequency (RF) sources. Some, but not all, Faraday caps also short out the bridgewire.

Field Office. An office required by operational supervision (e.g., foremen and line supervisors) in direct support of explosives operations.

Firebrand. A projected burning or hot fragment whose thermal energy has the potential for transfer to a receptor.

Fire Hazard Area. A location in which the primary but not necessarily the only hazard is that of fire including explosions of gas or vapor and air mixtures.

Fire-Resistive. A term used to indicate the ability of structures or materials to resist a fire to which they might be subjected without themselves becoming weakened to the point of failure.

Fire Retardant. A treatment or surface covering applied to combustible materials or structures to retard ignition or fire spread.

Fire Wall. A wall of fire-resistive construction designed to prevent the spread of fire from one side to the other. A fire wall may also be termed a “fire division wall.”

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Firing Pad. 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 38C (10F) and a vapor pressure not exceeding 280 kpa (41 psia) at 37.8C (100F). This is the definition as applied in this manual; it includes some materials defined as combustible liquids by the Department of Transportation (DOT).

Flash Point. The lowest temperature at which a liquid produces a sufficient concentration of vapor above it so that it forms an ignitable mixture with air (and therefore the lowest temperature at which a flame will propagate through the vapor of a combustible material to the liquid surface).

Fragmentation. Breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. Fragments may be complete items, subassemblies, pieces thereof, or pieces of equipment or buildings containing the items.

Grounding. Practice of providing an electrical path from one or more conductive objects to ground.

> *Note: The words "bonded" and "grounded" mean either that a bond or ground as defined has been deliberately applied, or that an electrically conductive path having a resistance adequately low for the intended purpose (usually 10^6 ohms or less) is inherently present by the nature of the installation.*

Hazard. Any condition that may result in the occurrence or contribute to the severity of an accident.

Hazard Analysis. Logical, systematic examination of an item, process, condition, facility, or system to identify and analyze the probability, causes, and consequences of potential or real hazards.

Hazardous Fragment. A hazardous fragment is one having an impact energy of 58 ft-lb or greater.

Hazardous Material. Any compound, mixture, element, or assemblage of material that, because of its inherent characteristics, is dangerous to manufacture, process, store, or handle.

High Density Traffic. Traffic routes having 10,000 or more car and/or rail passengers per day, or 2,000 or more ship passengers per day.

High Explosive. An explosive (as denoted by its Class and Division; e.g., 1.1 through 1.6) in which the transformation from its original composition and form, once initiated, proceeds with virtually instantaneous and continuous speed through the total mass, accompanied by rapid evolution of a large volume of gas and heat, causing very high pressure and widespread shattering effect.

High Explosive Equivalent or Explosive Equivalent (TNT Equivalent). Amount of a standard explosive that, when detonated, will produce a blast effect comparable to that which results at the same distances from the detonation or explosion of a given amount of the material for which

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performance is being evaluated. It usually is expressed as a percentage of the total net weight of all reactive materials contained in the item or system. For the purpose of these standards, TNT is used for comparison.

High Performance Magazine (HPM). An earth-bermed, 2-story magazine with internal non-propagation walls designed to reduce the maximum credible event (MCE).

Holding Yard. A holding area for rail cars, trucks, or trailers used for temporary storage of vehicles containing explosives and other dangerous materials prior to shipment or transfer to a more permanent storage area.

Hot Work (Thermal). Any operation requiring the use of a flame-producing device, an electrically heated tool, or a mechanical tool that can produce sparks, heat explosives, contaminate explosives, thereby providing an initiation stimulus.

Hypergolic. Self-igniting upon contact of fuel and oxidizer, without a spark or external aid.

Inert (As Applicable to Explosives). Containing no explosives or chemical agents. Material show no exothermic decomposition when tested by DSC or DTA. Moreover, the inert material shall show no incompatibility with energetic material with which it may be combined when tested by recognized compatibility tests. Inert material does not 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 (Requirement).

Inert Area. Any area other than an explosives area within an establishment.

Inert Components. Parts of a device that do not contain explosives or chemical agents.

Inhabited Building Distance (IBD). Minimum allowable distance between an inhabited building and an explosive facility. IBDs are used between explosives facilities and administrative areas, operating lines with dissimilar hazards, explosive locations and other exposures, and explosive facilities and installation boundaries, and define the restricted zone into which non-essential personnel may not enter.

Inhabited Buildings. A building or structure other than operating buildings, magazines, and auxiliary buildings occupied in whole or in part by human beings, or where people are accustomed to assemble, both within and outside of Government establishments. Land outside the boundaries or local restrictive easement estate of NASA establishments is considered as inhabited buildings (Requirement).

Interchange Yard. A location set aside for exchange of rail cars or trailers between a common carrier and NASA.

Intraline Distance (ILD). The minimum distance permitted between any two buildings within one operating line. ILDs are also used for separating certain specified areas, buildings, magazines, aircraft, and other locations even though actual line operations are not involved. ILD separation is expected to protect explosive materials in buildings from propagation detonation due to blast effects, but not against the possibility of propagation detonation due to fragments. Buildings separated by ILDs will probably suffer substantial structural damage.

Intraline Operations. Process accomplished within one operating line.

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Intermagazine Distance (IMD). Distance to be maintained between two explosives storage locations.

K-Factor. K is a constant that is used to determine separation distance by the formula $d = KW^{1/3}$, where W is the weight in pounds. The formula can be used to determine required distances between potential explosive sites (PESs) and exposed sites (ESs). This will normally appear as the letter "K" followed by a number, for example "K8," or "K30."

Laboratory Operations. Any operation in a laboratory where the total quantity of explosives in the room does not exceed 500 grams.

License. Formal documented permission from the ESO to operate a Licensed Explosive Location.

Licensed Explosive Locations. Locally licensed locations within NASA's control where explosives are used or stored for use (used for armories, ejection systems, gun clubs, and similar applications). Licensed Explosive Locations may include Division 1.1, 1.2, or 1.3 explosives only within the limitations of paragraph 4.25.9.1.12.10.

Liquid Propellant. Liquid and gaseous substances (fuels, oxidizers, or monopropellants) used for propulsion or operation of rockets and other related devices.

Loading Docks. Facilities at ground level or elevated structures designed and installed for transferring explosives and components to or from automotive vehicles or railway cars.

Low Traffic Density. Traffic routes having less than 400 cars and/or rail passengers per day or less than 80 ship passengers per day.

Magazine. A structure designed or specifically designated for the storage of explosives.

Magazine Distance. 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.

Mass Detonation/Explosion. Virtually instantaneous explosion of a mass of explosives when only a small portion is subjected to fire, severe concussion or impact, the impulse of an initiating agent, or to the effect of a considerable discharge of energy from an outside stimulus. Also refers to the instantaneous propagation of an explosion between multiple explosives items such that blast overpressure effects are combined into a single enhanced blast wave.

Maximum Credible Event (MCE). In hazards evaluation, the MCE from a hypothesized accidental explosion, fire, or agent release is the worst single event that is likely to occur from a given quantity and disposition of explosives, chemical agents, or reactive material. The event must be realistic with a reasonable probability of occurrence considering the explosion propagation, burning rate characteristics, and physical protection given to the items involved. The MCE evaluation on this basis may then be used as a basis for effects calculations and casualty prediction.

Medium Traffic Density. Traffic routes having 400 or more, but less than 10,000, car and/or rail passengers per day or 80 or more, but less than 2,000, ship passengers per day.

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Net Explosive Weight (NEW). The total quantity, expressed in pounds, of explosive material or pyrotechnics in an item.

Net Explosive Weight for Quantity Distance (NEWQD). The total quantity, expressed in pounds, of high explosive equivalency in each item to be used when applying quantity-distance criteria. The NEWQD is equal to the NEW unless hazard classification testing has shown that a lower weight is appropriate for Quantity Distance (QD) purposes. If the NEWQD is less than the NEW, the reason is usually that propellant or other substances do not contribute as much to the blast effects as the same amount of high explosives would.

Noncombustible. Not combustible. Will not ignite and burn if not continuously subjected to flame from another source.

Non-essential Personnel. Personnel not essential to, or involved with, the immediate operation presenting the energetic materials hazard.

Non-mass Explosion. Partial explosion of a mass of explosives when only a small portion is subjected to fire, severe concussion or impact, the impulse of an initiating agent, or to the effect of a considerable discharge of energy from an outside stimulus. Also refers to sequential propagation of explosions of multiple items with time delays such that blast overpressure effects do not combine from each individual explosion.

Normal Maintenance. Work performed on explosive devices to prevent deterioration and to correct minor defects not requiring renovation or major modification operations.

Operating Building. Any structure, except a magazine, in which operations pertaining to manufacturing, processing, or handling explosives are performed.

Operating Line. Group of buildings used to perform the consecutive steps in the loading, assembling, modification, normal maintenance, renovation, or salvaging of an item or in the manufacture of an explosive or explosive device.

Operational Shield. A barrier constructed to protect personnel, material, or equipment from the effects of a possible fire or explosion occurring at a particular operation.

Operator. A person assigned to perform a specific, generally continuing function on a production, maintenance, renovation, or disposal line or operation. Typically, the functions are performed at workstations or areas defined in a Standard Operating Procedure (SOP).

Operator Work Station. A specific location within a line or production area where an operator is assigned on a continuing basis to perform operations described in the relevant SOP.

Ordnance Storage Area. A designated area of explosive-containing facilities set aside for the exclusive storage or "warehousing" of explosives.

Passenger Railroad. Any steam, diesel, electric, or other railroad that carries passengers for hire.

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

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Potential Explosive Site (PES). Location of a quantity of explosives that will create a blast fragment, thermal, or debris hazard in the event of an accidental explosion of its contents. Quantity limits for ammunition and explosives at a PES are determined by the distance to an ES.

Propagation. Communication of an explosion (detonation or deflagration) from one potential explosion site to another by fire, fragment, or blast (shock wave) where the interval between explosions is long enough to limit the total overpressure at any given time to that which each explosion produces independently.

Propellant Liquid. Substances in fluid form (including cryogenics) used for propulsion or operating power for missiles, rockets, and other related devices (see Table XXIX). For the purpose of this standard, liquid fuels and oxidizers are considered propellants even when stored and handled separately.

Propellant Solid. Explosives compositions used for propelling projectiles and rockets and to generate gases for powering auxiliary devices.

Public Highway. Any street, road, or highway not under NASA custody used by the general public for any type of vehicular travel.

Public Traffic Route Distance: Distance to be maintained between a PES and any public street, road, or highway, navigable stream, or passenger railroad (includes roads on NASA Field Installations that are open to non-essential personnel or the public for thoroughfare).

Pyrotechnic Device. All devices and assemblies containing or actuated by propellants or explosives, with the exception of large rocket motors. Pyrotechnic devices include items such as initiators, ignitors, detonators, safe-and-arm devices, booster cartridges, pressure cartridges, separation bolts and nuts, pin pullers, linear separation systems, shaped charges, explosive guillotines, pyrovalves, detonation transfer assemblies (mild detonating fuse, confined detonating cord, confined detonating fuse, shielded mild detonating cord, etc.), thru-bulkhead initiators, mortars, thrusters, explosive circuit interruptors, and other similar items

Pyrotechnic Material. Explosive or chemical ingredients, including powdered metals, used in the manufacture of pyrotechnic devices.

Quantity Distance (QD). Quantity of explosives material and distance separation relationships which provide defined types of protection. These relationships are based on levels of risk considered acceptable for the stipulated exposures and are tabulated in the appropriate QD tables.

Renovation. That work performed on devices containing explosives, propellants, or pyrotechnics to restore them to a completely serviceable condition; usually involves the replacement of unserviceable or outmoded parts.

Restricted Area. Any area, usually fenced, at an establishment where the entrance and egress of personnel and vehicular traffic are controlled for reasons of safety.

Rocket. A complete device that derives its thrust from ejection of hot gases generated from propellants carried in the vehicle.

Rocket Motor. That portion of the complete rocket or booster that is loaded with solid propellant.

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Safety Analysis. A document prepared to systematically identify the hazards of a NASA 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.

Serviceable Explosive. Explosive in a condition which allows usage for its intended purpose.

Service Magazine. An auxiliary building used for the intermediate storage of explosives materials not exceeding the minimum amount necessary for safe efficient production.

Shunt. Electrically interconnecting various portions of EED circuitry to prevent the development of an electrical charge differential between the shunted parts.

Simultaneous Detonation. Detonation of separated quantities of explosives occurring so nearly at the same time that the effect on the surroundings is the same as if the several quantities were not separated and were detonated en masse.

Slurry. A chemical system consisting of suspended solid particles dispersed (not dissolved) in a liquid.

Small Arms Ammunition. Ammunition used in firearms of caliber up to and including caliber .60 and shotguns.

Solid Propellant. Solid compositions used for propelling projectiles and rockets and to generate gases for powering auxiliary devices.

Standard (Standing) Operating Procedure (SOP). A procedure prepared for operation of a facility or performance of a task on a routine basis.

Static Dissipative. Having a resistance of 10E6 to 10E12 ohms/square. This range of conductivity helps minimize tribocharging by bleeding off the charge at a safe rate.

Static Electricity. Electrification of materials through physical contact and separation, and various effects that result from the positive and negative changes so formed, particularly where they constitute a fire or explosion hazard.

Static Test Stand. Locations on which liquid propellant engines or solid propellant motors are tested in place.

Storage Compatibility. A relationship between different items of explosives and other dangerous materials whose characteristics are such that a quantity of two or more of the items stored or transported together is no more hazardous than a comparable quantity of any one of the items stored alone.

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

Substantial Dividing Wall. An interior wall designed to prevent simultaneous detonation of quantities of explosives on opposite sides of the wall.

Surface Resistivity. A measure specifying the resistance of a square section along the surface of the material that is usually specified in ohms per square unit.

Surveillance Inspection. Visual inspection of explosive stock.

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Suspect Car Track. A railway spur track where a car suspected of being in a hazardous condition can be examined prior to unloading of the explosive contents.

Temporary Holding Area. Designated areas for temporarily parking explosive laden transport trucks/railcars. QD and compatibility requirements apply.

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.

Transient. A person with official business on a production line or operation but who is not routinely assigned to a specific limited location. Typically, transients are roving supervisors, quality assurance, safety personnel, or maintenance personnel. Official visitors are considered transients.

Unserviceable Explosive. Explosive which cannot be used for its intended purpose.

Utilities. Those services such as water, air, steam, sewage, telephone, and electricity necessary to the operation of an establishment.

Waiver. An approved waiver that authorizes departure from a specific performance or operational requirement for a specified mission or period of time.

3.2 Acronyms

AGS	Above Ground Sites
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CADS	Cartridge Actuated Devices
CAS	Chemical Abstract
CFR	Code of Federal Regulations
CG	Compatibility Group
CNG	Compressed Natural Gas
CW	Continuous Wave
DDESB	Department of Defense Explosives Safety Board

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DNT	Dinitrotoluene
DoD	Department of Defense
DOT	Department of Transportation
DSC	Differential Scanning Calorimetry
DTA	Differential Thermal Analysis
DVA	Divinylacetylene
EBW	Exploding Bridge Wire
ECM	Earth Covered Magazine
EED	Electro-Explosive Device
EELP	Explosives, Energetic Liquids, and Pyrotechnics
EH&S	Environmental, Health, and Safety
EID	Electrically Initiated Device
EIDS	Extremely Insensitive Detonating Substance
ELCG	Energetic Liquid Compatibility Group
EME	Electromagnetic Energy
EMR	Electromagnetic Radiation
EOD	Explosives Ordnance Disposal
EPA	Environmental Protection Agency
ERP	Effective Radiated Power
ES	Exposed Site
ESD	Electrostatic Discharge
ESO	Explosives Safety Officer
ESQD	Explosive Safety Quantity Distance
FAE	Fuel-Air Explosive
GOV	Government Owned Vehicle

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GSA	Government Services Administration
GSE	Ground Support Equipment
H/D	Hazard Division
HAN	Hydroxyl Ammonium Nitrate
HC	Hexachloroethane
HE	High Explosive
HFD	Hazardous Fragment Distance
HPM	High Performance Magazine
IATA	International Air Transport Association
IAW	In Accordance With
IBD	Inhabited Building Distance
ICAO	International Civil Aviation Organization
IHE	Insensitive High Explosives
ILD	Intraline Distance
IMD	Intermagazine Distance
IMO	International Maritime Organization
IRFNA	Inhibited Red Fuming Nitric Acid
ISO	International Organization For Standardization
JP-10	Hydrocarbon Turbine/Ramjet Fuel
JPL	Jet Propulsion Laboratory
km	Kilometer
kPa	Kilopascal
kV	Kilovolts
LP	Liquid Petroleum
LOX	Liquid Oxygen

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MCE	Maximum Credible Event
MF	Multiplying Factor
MHE	Materials Handling Equipment
MILVAN	Military Van
MMH	Mono-Methyl Hydrazine
MON	Mixed Oxides Of Nitrogen
MSDS	Material Safety Data Sheet
MVA	Vinylacetylene
MWR	Morale, Welfare, Recreation
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NEQ	Net Explosive Quantity
NEW	Net Explosive Weight
NEWQD	Net Explosive Weight for Quantity Distance
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NIOSH	National Institute Of Occupational Safety And Health
NPR	NASA Procedural Requirements
NSI	NASA Standard Initiator
NSN	National Stock Number
OMI	Operations and Maintenance Instruction
OPF	Orbiter Processing Facility
OSHA	Occupational Safety And Health Administration
PADS	Propellant Actuated Devices
PBAN	Polybutadiene Acrylonitrile

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PDR	Preliminary Design Review
PEL	Permissible Exposure Limit
PES	Potential Explosive Site
PETN	Pentaerythritol Tetranitrate
POL	Petroleum, Oil, Lubricant
POV	Privately Owned Vehicle
PSI	Pounds Per Square Inch
PPE	Personal Protective Equipment
PSM	Process Safety Management
PRF	Pulse Repetition Frequency
PTR	Public Traffic Route
PWP	Plasticized White Phosphorus
QD	Quantity Distance
RF	Radio Frequency
RH	Relative Humidity
RDX	Cyclonite
RPSF	Rotation, Processing, and Surge Facility
RP1	Rocket Propellant, Combustible Liquid
S&A	Safe And Arm
SARD	Safety and Assurance Requirements Division (NASA Headquarters)
SCBA	Self-Contained Breathing Apparatus
SCG	Storage Compatibility Group
SOP	Standard Operating Procedure
SRB	Solid Rocket Booster
SRM	Solid Rocket Motors

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TEA	Triethyl Aluminum
TEB	Triethoxy Butane
TFE	Tetrafluoroethylene
THF	Tetrahydrofuran
TNT	Trinitrotoluene
TPA	Thickened Pyrophoric Agent
UDMH	Unsymmetrical Dimethylhydrazine
UL	Underwriters Laboratories
UNO	United Nations Organization
UV	Ultraviolet
WP	White Phosphorus

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CHAPTER 4 GENERAL REQUIREMENTS

4.1 Equivalency

This standard is not intended to prevent the use of systems, methods, devices, or measures of equivalent or superior quality, effectiveness, or safety in lieu of those prescribed by this standard. The ESO shall determine equivalency based on technical documentation submitted by the user. Note that equivalency analysis for quantity-distance requirements is addressed in paragraph 5.50.1.4 and following in the section on MCE.

4.2 Requirements Terminology

4.2.1 Shall: The word "shall" indicates that the rule is mandatory. Noncompliance with a "shall" statement requires approval of a waiver.

4.2.2 Should: The word "should" indicates that the rule is a recommendation, the advisability of which depends on the facts in each situation. Implementation of a "should" statement is at the discretion of the local officials.

4.2.3 Will: The word “will” indicates an anticipated consequence of an action, occurrence, or situation, not a requirement for action.

4.3 Safety Variance Process (see NPR 8715.3, NASA General Safety Program Requirements)

4.3.1 The primary objective of the NASA safety variance policy is to assure that NASA Headquarters maintains oversight of the Agency SMA requirements while providing the Centers and project managers with the authority and flexibility to accept reasonable risks necessary to accomplish their tasks.

4.3.2 The NASA safety variance policy is provided in, NPR 8715.3, paragraph 1.13. It applies to all Agency safety requirements unless otherwise specified in the appropriate requirements document. Variance policies developed for specific safety programs shall follow this policy (Requirement).

4.3.3 All requests for variance shall be submitted to NASA Headquarters (HQ) Safety and Assurance Requirements Division (SARD) accompanied by documentation as to why the requirement can not be met, the risks involved, alternative means to reduce the hazard or risk, the duration of the variance, and comments from any affected employees or their representatives (if the variance affects personal safety). Variances approved at the Center or program level can remain in place as long as Headquarters status reporting is current (Requirement).

4.3.4 The NASA variance process does not apply to Federal and State/local regulations (e.g., OSHA, Cal OSHA). Any variance of a Federal or State/local regulation must be approved by the appropriate Federal/State/local agency (e.g., NASA Alternate Safety Standard for Suspended Load Operations approved by OSHA). NASA Headquarters, Office of Safety and Mission Assurance (OSMA) /SARD shall review all proposed safety variances of Federal regulations before submittal for approval (Requirement).

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4.4 Process Safety Management (PSM).

NASA facilities having activities that involve the mixing, blending, extruding, synthesizing, assembling, disassembling and other activities involved in the making of a chemical compound, mixture or device which is intended to explode shall comply with the OSHA PSM standard (Requirement). Each NASA Explosive Safety Officer shall perform an independent hazard assessment of all laboratories and test facilities to ensure compliance with 29 CFR 1910.119 where required (Requirement).

4.5 Roles and Responsibilities.

4.5.1 Explosives Safety Officer (ESO). A trained and experienced person is designated as the ESO at each NASA Center to manage the Installation Explosives, Propellants, and Pyrotechnic Safety Program as specified in NPR 8715.3, paragraphs 3.11.3 and 3.11.4 (Requirement).

SECTION 4A OPERATIONAL EXPLOSIVES LIMITS

4.6 Minimum Use of Explosives.

The quantity of explosives at an operating location shall be the minimum necessary to carry out an operation in a safe and efficient manner (Requirement). When practical, this quantity shall be subdivided and adequately separated to prevent propagation of detonation or deflagration (Requirement). Supplies exceeding this minimum quantity shall be removed from the operating area (Requirement).

4.7 Maximum Permitted Quantity of Explosives.

In no case shall the quantity of explosives in an operating building exceed the maximum permitted by the Quantity-Distance (QD) criteria (Requirement). QD criteria and guidelines for application of these criteria are presented in Section 5 I of this document.

4.8 Determining Limit for Explosive Use.

Determining the limits for explosive materials operations requires a careful analysis of all facts including operation timing; transportation methods; size of the items; explosive, chemical and physical characteristics of the materials; building layout; and facilities design. Limits should be established for each operation rather than one building or total workplace capacity.

4.9 Additional Definitions for Explosive Limits.

Operational explosive limits need not be expressed only in units of weight or in the number of items such as rocket motors or explosive items; they may be expressed in terms of trays, boxes, racks, igniters, initiators, or any other unit that may be more easily observed and controlled.

4.10 Authority to Determine Operational and Personnel Limits.

Personnel and operational explosive materials limits shall be determined by the operating organization and approved by the ESO (Requirement).

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SECTION 4B PERSONNEL LIMITS

4.11 Principles for Establishing Personnel Limits.

4.11.1 The number of personnel at an operating location shall be the minimum consistent with safe and efficient operation (Requirement).

4.11.2 In establishing personnel limits, the following principles shall be followed:

4.11.2.1 Jobs not necessary to the performance of a hazardous explosives operation shall not be performed in the same location as the hazardous operation (Requirement). Personnel not needed for the hazardous operations shall not be allowed in hazardous locations (Requirement).

4.11.2.2 Personnel limits shall allow for necessary supervision and transients (Requirement).

4.11.2.3 Sufficient personnel shall be available to perform a hazardous operation safely and, in the event of accident, to obtain help and aid the injured (Requirement).

SECTION 4C LIMIT CONTROL

4.12 Posting and Recording

4.12.1 Maximum explosives and personnel limits for buildings, bays, rooms, cubicles, cells, and service magazines for each explosives area shall be recorded and maintained on file (Requirement).

4.12.2 A standardized placard stating the maximum amount of explosives and the maximum number of workers and transients permitted in the control unit at any one time shall be posted in a conspicuous place in all units containing explosives except as noted in paragraph 5.4.1 (Requirement).

4.12.2.1 Personnel and material limits and the placard shall be kept current and maintained for legibility (Requirement).

4.12.2.2 Placards shall be of sufficient size and color that they are readily visible by personnel entering the work area (Requirement). (*Note: See Section 5.3 for specific requirements.*)

4.13 Limit Review and Approvals

4.13.1 Management personnel with authority and jurisdiction over an operating bay or building shall review explosives and personnel limits for each location and shall recommend changes to the ESO as required (Requirement). When an operation changes, personnel and explosives weight limits shall be reviewed prior to resumption of operations, and limits shall be reestablished as required (Requirement).

4.13.2 Changes in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures by the ESO (see Section 4G, Operating Procedures) (Requirement).

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4.13.3 A procedure shall be established for the approval of temporary changes in explosives and personnel limits for an operating location (Requirement).

4.14 Personnel Controls.

A system shall be established to control the presence of personnel within explosives operating areas (Requirement).

SECTION 4D IDENTIFICATION OF LIVE AND INERT HARDWARE

4.15 Item Labeling.

4.15.1 All inert explosives shall be marked, labeled, stenciled, or tagged as to their status (explosives not identified as inert are assumed to be live) (Requirement).

4.15.2 As various explosives components in NASA's inventory are manufactured according to specifications of other agencies and used for other than flight hardware, they may be color-coded for use (red may designate "live" pyros). Various color coding schemes are currently in effect. Thus, in addition to training in color-coding differences, operating procedures shall contain information pertaining to color-coding where applicable (Requirement). When components are transferred from one program to another, necessary changes in color coding shall be coordinated prior to the transfer (Requirement).

SECTION 4E SECURITY REQUIREMENTS

4.16 Security Compliance Requirements.

4.16.1 All organizations having authority to obtain, use, and maintain arms, ammunition and explosives, and/or propellants and pyrotechnics, shall comply with the requirements of this document and with the current NASA security requirements established in NPR 1600.1 for the protection, control, and accountability of these assets (Requirement). These minimum requirements ensure the appropriate level of protection and serve to deny access to unauthorized personnel.

4.16.2 Transportation Security Requirements. Transportation of explosive materials and devices are in accordance with the transportation security requirements of 49 CFR 172.800.

SECTION 4F TRAINING

4.17 General Explosives Handling Training.

4.17.1 Personnel shall be properly trained before being assigned to any explosives operation or operating any explosives-carrying vehicle (Requirement).

4.17.2 The training for explosives work, which serves to assist in conducting work safely and developing safety awareness, shall include the following (Requirement):

4.17.3 Develop and maintain a safe attitude toward work with explosives.

4.17.4 Define and understand the potential hazards involved.

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4.17.5 Teach correct skills and procedures for safe performance of the task.

4.17.6 Prepare personnel for unexpected hazardous conditions and emergency situations.

4.17.7 Ensure that personnel read and understand the appropriate operating procedures.

4.18 Hazardous Materials Information and Training Programs.

4.18.1 Hazardous materials information and training programs shall be provided for personnel working with explosives and hazardous materials used in conjunction with explosives operation (Requirement).

4.18.2 Training shall include (Requirement):

4.18.2.1 Information on physical and health hazards.

4.18.2.2 The purpose and proper use of engineering controls, work practice controls, and protective equipment.

4.18.2.3 Labeling systems and Material Safety Data Sheet terms.

4.18.2.4 Detection methods for the presence or release of a hazardous material in work area.

4.19 Level of Required Training.

The ESO shall determine and document the level of training commensurate with the operation to be performed.

4.20 Supervisory Responsibility.

4.20.1 The line supervisor shall be responsible for the following (Requirement):

4.20.2 Determining the training required for the worker based on specific work assignments and determinations by the ESO of training requirements for operations being performed.

4.20.3 Verifying that the worker is adequately trained to perform the task safely and efficiently.

4.20.4 Ensuring that the worker can perform required emergency duties.

4.20.5 Providing on-the-job training for the workers.

4.20.6 Updating worker training requirements to conform to any changed requirements or to reflect changes in worker responsibilities.

4.21 Training and Certification Programs.

4.21.1 Each organization shall have a training certification program, including designation of a certifying official, approved by the ESO.

4.21.2 Training requirements are program specific, however:

4.21.2.1 After successfully completing training for an assignment, the worker shall be certified for that assignment for a specific period of time not to exceed three years (Requirement).

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4.21.2.2 Maintenance of certification shall be governed by the following items (Requirement):

4.21.2.2.1 At the end of the initial certification period, certification may be extended for subsequent specific time periods if:

4.21.2.2.1.1 The worker has successfully performed the task during the preceding six months and has read and understood the current operating procedures, or

4.21.2.2.1.2 The worker receives refresher training and is again determined to be certified by his/her certifying official.

4.21.2.2.2 Workers who do not demonstrate job proficiency or who violate safe practices shall be retrained in the specific area of weakness or shall have their certifications terminated (Requirement).

4.21.2.2.3 If an operating procedure is modified substantially, all personnel using that procedure shall be retrained in the use of the new procedure (Requirement).

4.21.2.2.4 A person shall not be permitted to continue working with explosives if the supervisor, with counsel from medical personnel, determines that the person is unable to perform the task safely (Requirement). Possible reasons include the following:

4.21.2.2.4.1 Physical injury or illness.

4.21.2.2.4.2 Disease.

4.21.2.2.4.3 Mental or emotional disturbances.

4.21.2.2.5 Loss of State driving privileges shall mandate automatic loss of explosives driving certification (Requirement).

4.21.2.2.6 Training records shall be maintained for each worker and shall include, for any required training (Requirement):

4.21.2.2.6.1 Description and dates of training received.

4.21.2.2.6.2 Description and dates of refresher training.

4.21.2.2.6.3 Certification review by supervisor.

4.21.2.2.7 The certifying official may temporarily, not to exceed one year, authorize an employee who has not completed the required training to perform the task if the following conditions are satisfied:

4.21.2.2.7.1 The supervisor determines that the employee has a working knowledge adequate to perform the task safely.

4.21.2.2.7.2 The work is directly supervised by a certified person.

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SECTION 4G OPERATING PROCEDURES

4.22 Requirements for Preparing and Controlling Procedures.

This section establishes requirements for preparing and controlling all procedures involving explosives operations under NASA control. This section, in compliance with NPR 8715.3, NASA General Safety Program Requirements, also specifies that operational procedures be generated by NASA for all explosives operations. The step-by-step reasoning process that is used in developing procedures will identify many safety-related areas that might be overlooked. 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 to be incorporated into the procedure.

4.23 Guidelines.

4.23.1 The following principles shall be used in creating operating procedures (Requirement).

4.23.2 Before Operation. Before initiation of any operation involving explosives, operating procedures shall be written and approved (Requirement).

4.23.3 Supervisory Responsibility. Supervisory personnel shall be responsible for enforcing provisions of all procedures used in their jurisdictions (Requirement).

4.23.4 Preparation.

4.23.4.1 Procedures shall be prepared by responsible personnel with knowledge of the operations involved (Requirement).

4.23.4.2 All items presented in the procedure and operational steps specified shall be checked for compliance with the standards of this document (Requirement).

4.23.4.3 The specific types of equipment and building or area in which the operation is to be conducted shall be designated in the procedure, when applicable (Requirement).

4.23.4.4 Supplemental procedures or sections shall be written when similar operations in the same area involve differences in equipment or process (Requirement).

4.23.4.5 Sufficient inspections, hold points, or verifications for safety and quality assurance professionals to determine compliance with critical steps (Requirement).

4.23.4.6 Each employee involved in an explosives operation shall have stop work authority (Requirement).

4.23.5 Audits.

4.23.5.1 An audit system to evaluate routinely the adequacy, availability, currency of, and compliance with procedures, and operator knowledge shall be established (Requirement).

4.23.5.2 Groups conducting audits in conjunction with the ESO should include personnel from areas other than the operating department or division using the procedure.

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4.24 Content of Operating Procedures.

4.24.1 The following is intended to specify procedures content, not format or organization. This standard does not restrict a NASA facility/operating contractor from developing its own system for preparing and distributing safety procedures. Distribution of procedures shall be controlled to ensure that each operating area has the most current revision, superseded or inactive procedures are removed from operating areas, and no operation is performed with a superseded, inactive, or unapproved procedure (Requirement).

4.24.2 Approval. All new, revised, and inactive operating procedures shall be reviewed and approved prior to use (Requirement). Levels of approval required should be based on the inherent risk in the operation and be established by the ESO (Requirement). Review and approval requirements shall include, as a minimum, line and safety organizations (Requirement). Inactive (dormant for a year), new, or revised procedures shall have a dry run prior to submission for approval (Requirement). A dry run is used to ensure procedures are valid.

4.24.3 Operating Procedures.

4.24.3.1 Introduction. The introduction to procedures should include the following:

4.24.3.1.1 A statement of the scope of the procedure, defining what facilities and equipment are covered.

4.24.3.1.2 The name of the department and/or individual responsible for the operation.

4.24.3.1.3 If the procedure serves as the basis for a deviation or waiver from any applicable standard, a statement to this effect and a specific reference to the standard involved.

4.24.3.2 Safety. The safety section of the procedure should present the following information or reference a safety manual that specifies the requirements:

4.24.3.2.1 General safety rules to be observed and techniques to be applied that will ensure safety of operations, prevent injury or illness to personnel, and prevent damage to equipment. In particular, this section of the Standard Operating Procedures (SOPs) should describe the personnel control features of the facility that protects personnel from exposure to hazardous operations, toxic materials, or tests.

4.24.3.2.2 Personnel number and explosive weight limits.

4.24.3.2.3 Additional or specific emergency controls not addressed by the facility emergency plan.

4.24.3.2.4 A description of the range of work authorized by the procedure.

4.24.3.2.5 Safety rules that are specific to the operation; e.g., color coding of components (if applicable).

4.24.3.2.6 Protective equipment that must be used during the operation.

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4.24.3.2.7 Emergency controls applicable to the operation that are not considered in the General Operating Procedures.

4.24.3.3 Operations.

4.24.3.3.1 The operations section should consist of sequential directions written or pictured in clear, concise steps that describe how to perform a particular operation.

4.24.3.3.2 If a particular operation requires that no other operation be performed simultaneously in the same work area, this requirement shall be clearly stated in the procedure.

4.24.3.3.3 Particular emphasis should be placed on safety interlocks and controls, and the proper use of these systems.

SECTION 4H LEVEL-OF-PROTECTION CRITERIA FOR SITING EXPLOSIVES ACTIVITIES

4.25 Facility Construction and Site Plan

4.25.1 General. It is NASA policy for management to use all available advances in protective construction to provide the safest work environment consistent with operational needs. The major objective in explosive facility planning, therefore, shall be to prevent or minimize the exposure of personnel and facilities to explosives hazards when performing NASA program activities. This policy establishes basic requirements for managers and directors at all organizational levels.

4.25.2 Facility Construction and Site Plan Review. The following plans shall be submitted for approval to the ESO (Requirement):

4.25.2.1 Explosive safety site plans and general construction plans for facilities or structures containing materials subject to the requirements of this standard, as well as modifications to these facilities.

4.25.2.2 General construction plans for facilities with activities not involving explosives, pyrotechnics, or other similar materials, but would be exposed to explosive hazards if not properly located in accordance with required Quantity Distance (QD). (See Paragraph 4.25.5.)

4.25.2.3 Information on major/high-visibility projects as requested by NASA Headquarters shall be sent to the Office of Safety and Mission Assurance for review prior to 30-percent reviews or Preliminary Design Reviews (PDRs).

4.25.3 Site Plan Requirements.

4.25.3.1 A facility site plan shall show protection provided against explosion propagation between adjacent bays or buildings and protection of personnel against death or serious injury from incidents in adjacent bays or buildings (Requirement).

4.25.3.2 If the protection of personnel and facilities would be greatly enhanced by having separate buildings sited to limit explosion propagation rather than using protective construction

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and separation of explosive units within one building, then facility site planning should reflect this fact.

4.25.3.3 Sufficient protective construction should be provided to harden a Potential Explosive Site (PES) to suppress explosion effects. Proper location of the Exposed Site (ES) in relation to the PESs protects against unacceptable damage and injuries in the event of an accident. Hardening of the PES may reduce the required QD when rationale or test results justify the reduction. This rationale shall accompany the site plan to be presented to the ESO and, when required, the NASA Headquarters Office of Safety and Mission Assurance (Requirement).

4.25.3.4 Appendix A provides general guidance on content to be covered in the site plan.

4.25.3.5 Atmospheric dispersion of flammable and/or toxic vapors shall be considered in the site plan (Requirement). A determination shall be made as to whether or not operational controls can be used to control potential hazards due to atmospheric dispersion of hazardous vapors (Requirement).

4.25.3.6 Solid Rocket Motor Static Test Stands. Quantity-distance requirements described for Hazard Division 1.3 materials consider fire and pressure rupture of containers in a storage situation. Hazards may increase during operational static testing of Hazard Division 1.3 propellants in a motor configuration (i.e., with nozzle or igniter in place). Overpressurization (pressure rupture) failure of a motor casing during operational testing may produce much more overpressure and fragmentation than in a storage incident. The facility site plan shall address these issues for motor test operations (Requirement). Siting of Solid Rocket Motor (SRM) static test stands shall comply with General Comment “e” of the Hazard Division 1.3 QD (Table XXIII) or with risk assessment requirements of Section 5K (Requirement).

4.25.4 Approval Authority.

4.25.4.1 Safety approval of site plans shall be obtained from the ESO prior to initiating concept design and changes (Requirement).

4.25.4.2 Site plans and changes to site plans shall be forwarded to the NASA Headquarters, Office of Safety and Mission Assurance, when required by Paragraph 4.25.2.3, after approval by the ESO (Requirement).

4.25.5 Building and Wall Structure Design.

4.25.5.1 Building Exteriors. The purpose of this section is to provide personnel the protection afforded by a properly and safely designed explosives facility. The primary goal is to protect personnel from fragments, falling portions of the structure and/or equipment, and to provide attenuation of blast pressures and structural motion to a level consistent with safety requirements.

4.25.5.2 Design of exterior wall and roof coverings of buildings containing explosives shall be prepared to minimize risk of combustion (Requirement).

4.25.5.3 Buildings shall be without basements and not more than one story high, except where required by process requirements (Requirement).

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4.25.5.4 Floors and Work Surfaces.

4.25.5.4.1 Floors and work surfaces in explosives facilities shall be constructed to facilitate cleaning and to preclude cracks or crevices in which explosives may lodge (Requirement).

4.25.5.4.2 Facilities where the atmosphere is expected to contain combustible dusts, or flammable vapors or gases, shall not have ferrous metal surfaces coated with aluminum paint due to potential sparking hazard (Requirement).

4.25.5.4.3 Floors, floor coverings, and floor treatments should be noncombustible except that vinyl, ethylene vinyl acetate, and similar floor coverings are acceptable where special characteristics are required such as conductivity.

4.25.5.5 Interior Walls, Roofs, and Ceilings.

4.25.5.5.1 Interior surface finishes of explosives-operating buildings should be smooth, fire-retardant material, free from cracks and crevices, and have joints taped or sealed. If painted, these should be covered with a hard gloss paint to facilitate cleaning and to minimize the impregnation of finished wall and ceiling material with explosives.

4.25.5.5.2 Horizontal ledges that might hold dust shall be avoided or beveled (Requirement).

4.25.5.5.3 Suspended ceilings shall not be used in explosives-operating buildings where explosive dust may be present (Requirement).

4.25.5.5.4 Explosives facility building roofs and walls shall be designed for protection of personnel and equipment via fire walls, operational shields, substantial dividing walls, blast resistant roofs, containment structures, and earth-covered magazines (Requirement). However, if an ordinary building is utilized and not specifically designed for explosives use, it shall be designed so that it is as light as practicable (weak) and so constructed and supported that it will vent an internal explosion with the formation of a minimum of large missiles (Requirement).

4.25.5.6 Fire Walls. Fire walls and openings in fire walls shall comply with requirements of local fire codes and associated NFPA standards (Requirement).

4.25.5.7 Substantial Dividing Walls.

4.25.5.7.1 Substantial dividing walls shall be designed in accordance with TM5-1300 or equivalent approved methods (see Section 5K) to prevent propagation of detonation by blast, fragmentation, or wall fragments (Requirement).

4.25.5.7.2 Openings in substantial dividing walls for any purpose are not recommended. When such openings are deemed necessary (e.g., to permit remote operation), the size shall not be larger than the minimum to permit safe passage of the item being transferred (Requirement). When the opening is not in use, the opening shall be provided with closures designed to the level of protection afforded by the wall (Requirement).

4.25.5.8 Protective Shields.

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4.25.5.8.1 Operational shields shall be designed for use in designated hazardous operations to provide protection to personnel, material, or equipment from the effects of a possible fire or explosion (Requirement).

4.25.5.8.2 Design of operational shields shall be in accordance with MIL-STD 398, TM5-1300, and/or Table VI (Requirement).

4.25.5.9 Emergency Exits and Fire Escapes.

4.25.5.9.1 General. As a minimum standard for NASA explosives-operating buildings and facilities, the latest edition of NFPA 101 and American National Standards Institute (ANSI) A156.3 shall be used as guides for constructing emergency exits and fire escapes (Requirement). When these standards conflict with the requirements of this chapter, the requirements of this chapter shall prevail (Requirement).

4.25.5.9.2 Building Exits. One properly located exit is sufficient for small cubicles or operating bays that have substantially constructed walls on three sides and where personnel limits are minimized for the task (no more than three persons). Otherwise, all buildings shall comply with the following conditions (Requirement):

4.25.5.9.2.1 At least two exits remote from each other (regardless of dimension) shall be provided for each operating room or building containing explosives (Requirement). Exception: Rooms or spaces not greater than 200 square feet, with an occupant load of not greater than three persons, and with a maximum travel distance to the room door of 25 feet.

4.25.5.9.2.2 Exits shall be at least 32 inches wide, considering only the net unobstructed (clear) width, without projections into the width, when the door is in the full open position (Requirement).

4.25.5.9.2.3 Exits should be spaced approximately equally about the perimeter of the building for immediate evacuation.

4.25.5.9.2.4 An exit should be located no more than 25 feet from any operator workstation. Each exit route should be planned to avoid obstructing the escape of personnel. Explosives should not be placed between personnel and exits. Each exit should open to the outside of the building and not into a hallway or another room.

4.25.5.9.2.5 Exits shall remain unlocked while personnel are in the facility and shall not be fastened with locks other than anti-panic catches or other quick-releasing devices (Requirement).

4.25.5.9.2.6 All interior doors should open in the direction of exit through the building and shall open upon unobstructed passageways (Requirement).

4.25.5.9.2.7 Blast doors that impede exit from the facility shall not be used on outside exits in place of emergency exits (Requirement).

4.25.5.9.3 Safety Chutes. Safety chutes shall be provided as exits from multistoried hazardous locations where rapid egress is vital and cannot otherwise be obtained (Requirement).

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4.25.5.9.4 Personnel Safe Havens. Personnel shelters, commonly referred to as safe havens, should be considered in new construction of explosives facilities. Properly designed and appropriately located, these safe havens would provide protection for operating personnel by minimizing the pressure leakage into a safe havens, provide adequate support for the contents of the structure, and prevent penetration to the safe haven by primary fragments and/or formation of fragments from the structure itself. (See TM5-1300.)

4.25.6 Barricades.

4.25.6.1 Use and design of a barricade, natural or artificial, to limit in a prescribed manner the effect of an explosion on nearby buildings or exposures shall be in accordance with DDESB Technical Paper 15 and the following minimum requirements (Requirement):

4.25.6.1.1 Materials for earthen barricades shall be reasonably cohesive (solid or wet clay or similar types of soil may not be used as they are too cohesive) and free from deleterious organic matter, trash, debris, and stones heavier than 10 pounds or larger than 6 inches in diameter. The larger stones shall be limited to the lower center of fills and shall not be used for earth cover over magazines (Requirement). The earthen material shall be compacted and prepared, as necessary, for structural integrity and erosion control (Requirement). If it is impossible to use a cohesive material, for example, in sandy soil, the barricade shall be finished with a suitable material to ensure structural integrity (Requirement).

4.25.6.1.2 Unless means are provided to control erosion, the slope of an earthen barricade shall be 2 or more horizontal to 1 vertical (Requirement). Currently approved earthen barricades having slopes no greater than 1-1/2 horizontal to 1 vertical remain approved.

4.25.6.1.3 For protection against high-velocity, low-angle fragments, determine the height, length, and location of a barricade as follows:

4.25.6.1.3.1 Height. Establish a reference point at the top of the far edge of one of the two stacks under consideration between which the barricade is to be constructed. The reference point, if the top of the stacks are not at the same elevation, shall be on the stack whose top is at the lower elevation. Draw a line from the reference point to the highest point of the other stack. Draw a second line from the reference point forming an angle of two degrees above the line. The top of the barrier shall be no lower than the two degree reference line (Requirement). To preclude building excessively high barricades, the barricade should be located as close as possible to the stack on which the reference point was established. When the stacks are of equal height, the reference point may be established on either stack. (See Figure 1.)

4.25.6.1.3.2 Length. The length of the barricade shall be determined as shown in Figure 2 (Requirement).

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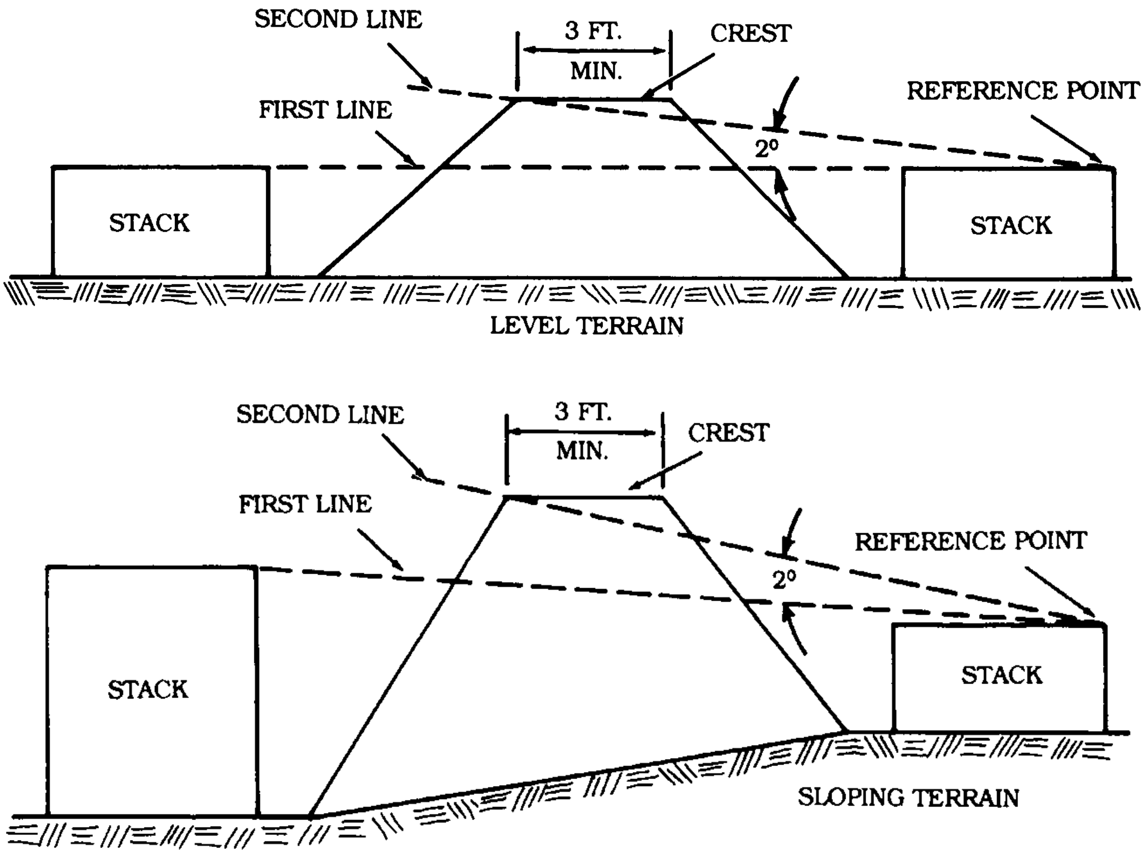

Figure 1. Determination of Barricade Height

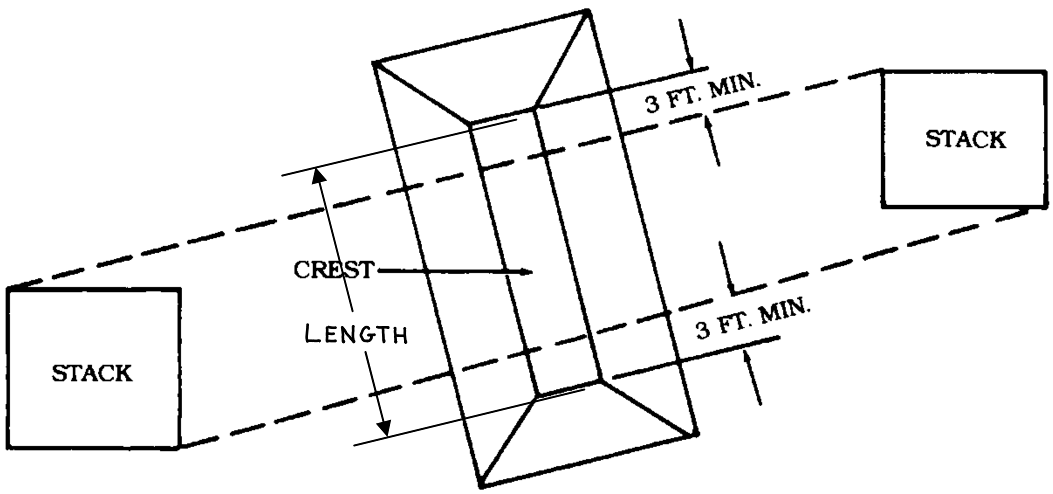

Figure 2. Determination of Barricade Length

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4.25.6.1.3.3 Location. For protection against high-velocity, low-angle fragments a barricade may be placed anywhere between the PES and the ES where conditions on its height and length are satisfied.

4.25.6.1.4 Overpressure Mitigation. General procedures to predict pressure mitigation versus barricade design and location have not been developed. However, based on direct experimental work, the overpressure loading on a surface area shielded by a barricade is reduced by 50 percent when the following length, height, and location conditions are satisfied:

4.25.6.1.4.1 Location. The barricade's standoff distance from the protected area shall be no greater than two barricade heights (Requirement).

4.25.6.1.4.2 Height. The top of the barricade shall conform to Figure 1 and be at least as high as the top of the protected area (Requirement).

4.25.7 Earth-covered magazines (ECM). The primary objective of an earth-covered magazine is to provide protection for its assets. To qualify for the default intermagazine distances (IMDs) in Table XV, a magazine, acting as an ES, must not collapse. Substantial plastic deformation of the magazine may occur. However, deflections should be limited within the air gap around the stored assets so that the deformed structure or its doors(s) do not strike the contents. ECM have three possible strength designations (7-bar, 3-bar, or Undefined). The strength of an ECM's headwall and door determines its designation. Due to their extreme sensitivities, special protective precautions shall be taken for compatibility group (CG) B explosive materials (Requirement).

4.25.7.1 Table XV, Part A, contains hazard factors for use in determining intermagazine siting for ECMs with headwall and blast door hardnesses of 7-Bar, 3-Bar, and Undefined. All ECMs in Table XV have the same earth cover requirements.

4.25.7.2 Minimum design considerations for ECMs in addition to blast loads.

4.25.7.2.1 Consider conventional (e.g., live, dead, snow) loads for the barrel of an arch-shaped ECM.

4.25.7.2.2 Consider conventional (e.g., live, dead, snow) and blast-induced loads for the roof of a flat-roofed ECM.

4.25.7.2.3 Consider conventional (e.g., live, dead, snow) loads for the rear wall of an arch-shaped ECM and for the rear and sidewalls of a flat-roofed ECM.

4.25.7.2.4 Consider blast-induced loads for the head wall and door of an ECM.

4.25.7.2.5 Materials for earth-cover over magazines shall meet the requirements for material for earthen barriers in paragraph 4.25.6.1.1 (Requirement).

4.25.7.2.6 The earth fill or earth cover between ECM may be either solid or sloped, but a minimum of 2 feet of earth cover shall be maintained over the top of each magazine (Requirement).

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4.25.7.2.6.1 If the specified thickness and slope of earth on magazines, as described in Paragraph 4.25.7.2.6, are not maintained, the magazine shall be repaired as soon as practical (not to exceed 90 days) or classified as an aboveground magazine (Requirement).

4.25.7.2.7 Magazines shall not be structurally weakened such that their asset protection capability is reduced (Requirement).

4.25.7.2.8 The NASA Center/Facility performing a siting or analysis shall determine whether the construction of a magazine being sited is equivalent to the requirements indicated on applicable drawings (Requirement).

4.25.7.3 Expected blast loads from an ECM.

4.25.7.3.1 The expected blast load on the head wall and door of an ES ECM oriented side-on to the side of a PES at a 1.25 $W^{1/3}$ distance (feet) is a triangular pulse with peak overpressure of 45 psi (3-bars) and impulse of $11.3 \cdot W^{1/3}$ psi-ms ($1.0 \cdot Q^{1/3}$ bar-ms).

4.25.7.3.2 The expected blast load on the head wall and door of an ES ECM oriented head-on to the rear of a PES at a distance of $2 \cdot W^{1/3}$ (feet) is a triangular pulse with peak overpressure of 100 psi (7-bars) and impulse of 13.9 $W^{1/3}$ psi-ms ($1.23 \cdot Q^{1/3}$ bar-ms).

4.25.7.3.3 The expected blast load on the roof of a flat-roofed ES ECM oriented rear-on to the front of a PES at a distance of $2 \cdot W^{1/3}$ (feet) is a triangular pulse with peak overpressure of 108 psi (7.5- bars) and impulse of $19 \cdot W^{1/3}$ psi-ms ($1.7 \cdot Q^{1/3}$ bar-ms).

4.25.7.4 ECM may store up to 500,000 lbs Net Explosive Weight (NEW) of Hazard Division 1.1 in accordance with Table XV. DDESB Technical Paper No. 15, Approved Protective Construction, provides listings of the various types of ECM that have been constructed over the years. These magazines are identified by their structural strength designator (i.e., “7-Bar,” 3’Bar,” or Undefined”). Table 4-1 of DDESB Technical Paper 15 lists the “7-Bar” and “3-Bar” ECM designs that are currently approved for new construction.

4.25.7.4.1 If an ECM’s drawing number(s) is not listed in DDESB Technical Paper 15, it shall be treated as an “Undefined” ECM until a structural analysis is performed to show that the ECM qualifies for another strength designation (Requirement).

4.25.7.4.2 For existing, arch-shaped “Undefined” ECM, the Guide for Evaluating Blast Resistance of Non-Standard Magazines (see references) may be used to determine whether an “Undefined” ECM could qualify as a “7-Bar” or a “3-Bar” ECM.

4.25.7.4.3 Certain ECM, aboveground magazines, and containers have been approved with reduced NEW and/or reduced QD, and these are also listed in Table AP1-4 of DDESB Technical Paper 15. The use and siting of these structures and containers shall meet all conditions/restrictions specified in the design and approval documentation, as described in DDESB Technical Paper 15 (Requirement).

4.25.8 High Performance Magazines (HPM). The primary objective of an HPM is to reduce the land encumbered by explosives safety quantity distances by limiting the maximum credible event (MCE) to a fraction of the total NEW stored in the HPM. Separation walls also provide

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protection against fire propagation between storage areas within the HPM. The HPM may be sited at the IMDs as shown in Table XV. Damage to assets depends on the donor NEW and the scaled separation distance K. IMD provides nearly complete asset protection between HPMs (MCE = 60,000 lbs maximum). However, damage may occur to ammunition in an HPM to about the K9 distance from a donor NEW > 350,000 lbs.

4.25.8.1 HP Magazine Storage Principles

4.25.8.1.1 Because of its construction, each storage cell of the HPM is treated as a separate magazine for the purposes of meeting storage and compatibility requirements. For the purpose of storage within an HPM, all Hazard Division 1.1 and 1.2 explosives are grouped into five HPM Sensitivity Groups. Within a cell, all current mixing and storage compatibility regulations, as defined in Section 5H, would apply.

4.25.8.1.2 The five HPM Sensitivity Groups are:

4.25.8.1.2.1 HPM Sensitivity Group 1 -- robust or thick-skinned.

4.25.8.1.2.2 HPM Sensitivity Group 2 -- non-robust or thin-skinned.

4.25.8.1.2.3 HPM Sensitivity Group 3 -- fragmenting.

4.25.8.1.2.4 HPM Sensitivity Group 4 -- cluster bombs/dispenser munitions.

4.25.8.1.2.5 HPM Sensitivity Group 5 -- other -- items that are prohibited or items for which HPM nonpropagation walls are not effective.

4.25.8.1.3 The allowable explosives weight in cells adjacent to cells containing HPM Sensitivity Groups 1, 2, and 3 explosives: 30,000 lbs in cell; 60,000 lbs in loading dock. The allowable explosives weight in cells adjacent to cells containing HPM Sensitivity Group 4 explosives: 15,000 lbs in cell (side – side); 60,000 lbs in loading dock. (See High Performance Magazine Definitive Drawings: NFESC 99220001-99220012.)

4.25.8.1.4 When HPM Sensitivity Groups are mixed, the most sensitive group shall determine the allowable explosives weight in an adjacent cell (Requirement). When H/D 1.3, 1.4, and 1.6 are stored with H/D 1.1 or 1.2, the sensitivity groups of the H/D 1.1 and 1.2 shall determine the storage requirements for explosives safety (Requirement).

4.25.8.1.5 For the purpose of assigning HPM Sensitivity Groups, an item should be placed into Group 1 when any two of the following criteria are met:

4.25.8.1.5.1 Explosive weight/empty case weight < 1

4.25.8.1.5.2 Case thickness > 0.4 inches

4.25.8.1.5.3 Case thickness/$NEW^{1/3}$ > 0.05 in/$lb^{1/3}$

4.25.9 Licensed Explosives Locations.

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4.25.9.1 The QD and level-of-protection criteria are not applicable or are modified in Licensed Explosives Locations (used for armories, ejection systems, gun clubs, and similar applications where explosives are used or stored for use). Explosives storage locations (not to be used as a means of avoiding safety requirements for explosives processing operations or for storage other than for the uses specified above, and, except as provided in paragraph 4.25.9.1.12.10, excluding Hazard Division 1.1 and 1.2), which are normally outside the Center's explosives storage area but within NASA's area of control, may be licensed locally. The requesting organization shall request the license in writing to the Center's ESO and revalidate the license annually (Requirement). The following conditions apply:

4.25.9.1.1 Licenses shall be issued by the ESO for justification and based on an analysis and an operations review (Requirement).

4.25.9.1.2 Each individual license shall be signed by the requesting organization and coordinated through the local ordnance storage facility operating organization, the local security forces resource protection office, and the local fire protection agency prior to being approved by the ESO (Requirement). The license shall be displayed at the licensed facility (Requirement).

4.25.9.1.3 Licensed compatibility groups shall not include groups A, K, and L (Requirement). Compatibility requirements specified elsewhere in this standard shall be followed (Requirement).

4.25.9.1.4 Small arms ammunition may be stored without regard to QD requirements provided it is stored in a safe meeting the requirements of Federal Specification AA-F-358H, Filing Cabinet, Legal and Letter Size, Uninsulated, Security, Class 5 or Class 6.

4.25.9.1.5 A minimum separation distance of 25 feet is required between licensed locations containing H/D 1.3 explosives and adjacent explosives operations, personnel, or other licensed locations containing H/D 1.3. Where 25 feet cannot be obtained, a 2-hour firewall, constructed in accordance with Paragraph 4.25.5.6, shall be provided (Requirement).

4.25.9.1.6 Maximum permitted quantities (explosive weight).

4.25.9.1.6.1 H/D 1.4: Minimum quantities essential to complete mission.

4.25.9.1.6.2 H/D 1.3: 100 pounds.

4.25.9.1.7 There shall be approved procedures for explosive use, which shall be provided to the ESO (Requirement).

4.25.9.1.8 The structure or room used to store explosives shall be locked when not occupied (Requirement).

4.25.9.1.9 Appropriate fire/chemical warning signs meeting the requirements of section 5.3 shall be posted. Security and other law enforcement services may be exempted from this requirement provided the following conditions are met: (1) storage is in a Class 6 safe in accordance with Government Services Administration (GSA) Federal Specification AA-358G or equivalent (as determined by the ESO), (2) quantities of material are reported to SARD or the ESO no less than annually, and (3) concurrence of the ESO and (fire) Authroity Having Jurisdiction (AHJ) are obtained. (Requirement).

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4.25.9.1.10 Fire protection requirements are provided in CHAPTER 5.

4.25.9.1.11 When necessary, dunnage shall be used to provide ventilation around explosive stocks and protect them from moisture and heat buildup (Requirement).

4.25.9.1.12 Safety Requirements for Specific Facilities and Explosives.

4.25.9.1.12.1 Armories and weapons issue points shall comply with the general license requirements listed in this standard (Requirement). The requirements for construction and positioning of clearing barrels, the delineation of associated safety zones and procedural requirements for the safe issuance, clearance, and turn-in of weapons shall be included in the appropriate NASA security manual, all of which require coordination from the appropriate explosive safety function (Requirement).

4.25.9.1.12.2 Control Tower. If required, store necessary quantities of H/D 1.3 pyrotechnics needed to conduct emergency operations at fixed and mobile control towers. Pyrotechnic projectors and pistols shall not be loaded unless the operational situation demands a state of immediate readiness (Requirement). Projectors and pistols shall be subject to the same safety and security as small arms weapons (Requirement). They shall be placed in a proper rack, locker, and box or compartment to prevent damage, unauthorized handling, theft, or accidental discharge (Requirement).

4.25.9.1.12.3 Survival/Rescue Equipment. A license is not required for assembled parachutes, survival and rescue kits, life rafts and life preservers containing authorized explosives when kept in personnel equipment rooms or life raft, survival equipment, and life support shops. A license shall be required for those areas in which survival equipment explosive components are stored (Requirement). Approved operating instructions shall be available for all survival/rescue shop operations involving explosive components and shall be provided to the ESO (Requirement).

4.25.9.1.12.4 Riot Control Items. If required, store riot control and smoke grenades (except white phosphorus “WP” grenades) with small arms ammunition in arms rooms and other such locations. However, if the arms room is collocated with a facility where personnel are under physical restraint or confinement, the National Fire Codes, Standard 101, Life Safety Code, applies. Do not store 40-millimeter grenades, pyrotechnics, tear gas, or chemical irritants in the room regardless of the QD class/division or compatibility, unless the arms room has protective features, which completely protect detainees from the effects of accidental explosives activation. Protective features include fragment barriers, blast doors, and exhaust fans. Qualified engineers shall evaluate capabilities of protective features (Requirement). Limit the quantity to the smallest amount needed to support approved contingency plans.

4.25.9.1.12.5 Egress Systems Maintenance Shops. When necessary, units may license a limited quantity of in-use egress explosive components of any class/division (excluding H/D 1.1/1.2) in the egress shop after removal from aircraft undergoing maintenance. Don't exceed the total number of complete sets for the number of aircraft in maintenance. The following special provisions apply:

4.25.9.1.12.5.1 Ejection seats and canopies with explosives components not undergoing actual maintenance shall be stored in a location separate from the maintenance area (Requirement).

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Ejection seats may only be stored in the maintenance area while maintenance is being conducted on other seats if all explosive components have been removed and stored separately.

4.25.9.1.12.5.1.1 Within the egress maintenance work area, the NEW limitations in Paragraph 4.25.9.1.6 apply to the number of seats and spare components undergoing maintenance at any one time.

4.25.9.1.12.5.1.2 Turn in unserviceable explosive components/items to the Center's ordnance storage area as quickly as possible to preclude build-up of unserviceable NEWQD (Requirement). Unserviceable NEWQD shall be counted against the total NEWQD of the licensed facility (Requirement).

4.25.9.1.12.6 Gun Systems and Maintenance Shops. When possible, remove ammunition from guns and gun systems before they are brought into a weapons maintenance facility for repair. Gun systems using drums do not require removal of ammunition if the feed system is mechanically safed to prevent ammunition from feeding into gun. QD requirements do not apply to gun system maintenance operations when explosives are limited to H/D 1.4 Class/Division and the using organizations ensure:

4.25.9.1.12.6.1 Each NASA Center shall establish procedures for both active and contingency facilities for clearing jammed guns (Requirement).

4.25.9.1.12.6.2 Guns or gun systems loaded with ammunition shall not be brought into the maintenance facility until needed to meet the work schedule and are to be removed immediately after repair (Requirement).

4.25.9.1.12.6.3 Precautions are established to prevent inadvertent firing.

4.25.9.1.12.6.4 Gun systems with live electrically initiated ammunition are grounded.

4.25.9.1.12.6.5 Gun system is pointed in the least hazardous direction.

4.25.9.1.12.6.6 Downloaded ammunition is removed from the building and returned to the Center's ordnance storage area as soon as possible.

4.25.9.1.12.6.7 Compliance with general explosives safety standards.

4.25.9.1.12.7 Incendiary Equipment and Document Destroyers. If necessary, store these items near the planned point of use to comply with emergency destruction plans. Establish quantities for each location by coordinating with the ESO and Center security representatives. The 100-pound H/D 1.3 Class/Division limit does not apply in this case. Limit quantity to the amount needed for emergency destruction plans. Training quantities are not authorized. Construct or protect storage rooms with noncombustible or fire-resistive material. If possible, store in nearby small low-cost structures (e.g., sheds, conex). Ensure adequate ventilation is provided. Maintain 50-foot firebreaks or vegetation control zones and locate at least 75 feet from any other building. Store replacement stocks in the base explosives storage area. Only trained personnel are allowed to prepare and activate these devices.

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4.25.9.1.12.8 Gun and Skeet Clubs. The explosives storage locations for clubs that operate on NASA property shall be licensed (Requirement). For skeet and trap ranges, the safety and range layout criteria established in the Official Rules and Regulations, Revised 2008, of the National Skeet Shooting Association shall apply (Requirement). A qualified member shall be designated to identify and enforce criteria (Requirement). A maximum of 100 pounds 1.3 Class/Division smokeless powder may be licensed where no hand loading is allowed, requirements of NFPA 495 are met and caution is exercised to prevent confinement of powder.

4.25.9.1.12.8.1 Hand Loading. The following safety requirements will be followed for hand-loading operations:

4.25.9.1.12.8.1.1 Hand-loading operations shall be conducted in a room or building used solely for this purpose (Requirement).

4.25.9.1.12.8.1.2 An approved local written procedure shall be developed and posted. Also refer to NPR 1600.1, NASA Security Program Procedural Requirements, for security requirements (Requirement).

4.25.9.1.12.8.1.3 Loading privileges shall be granted only to authorized personnel, trained in the use of hand loading equipment, safety provisions, and hazards involved (Requirement).

4.25.9.1.12.8.1.4 Safety goggles or face shields shall be worn during all loading operations (Requirement).

4.25.9.1.12.8.1.5 Members in training shall be strictly supervised (Requirement). A log shall be maintained of certifying instructors and each person who has satisfactorily completed the training (Requirement).

4.25.9.1.12.8.1.6 Smoking, matches, or flame-producing devices shall not be permitted in any loading or storage location (Requirement).

4.25.9.1.12.8.1.7 A ground bar with a resistance of 25 ohms or less shall be located at each entrance to the hand loading room (Requirement).

4.25.9.1.12.8.1.8 A sign requiring each person to touch the ground bar before entering the room shall be posted at the entrance to the room (Requirement).

4.25.9.1.12.8.1.9 The ground bar shall be maintained and inspected in accordance with NFPA 77 to ensure meeting the requirement of Paragraph 4.25.9.1.12.8.1.7 (Requirement).

4.25.9.1.12.8.1.10 Explosives and personnel limits shall be posted (Requirement).

4.25.9.1.12.8.1.11 No more than 10 pounds of propellants, 10,000 primers, and 5,000 assembled rounds shall be permitted in the hand loading room at one time (Requirement). These quantities are considered as part of the overall limits for the building.

4.25.9.1.12.8.1.12 Propellant storage lockers shall be provided (Requirement).

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4.25.9.1.12.8.1.13 Only quantities of propellant required to sustain a continuous operation shall be transferred to the loading point (Requirement).

4.25.9.1.12.8.1.14 Only one packing tray at a time shall be removed from primer storage (Requirement).

4.25.9.1.12.8.1.15 Unused components shall be repacked in their original containers and returned to the storage locker at the end of each loading operation (Requirement).

4.25.9.1.12.8.1.16 Unused lockers shall be locked (Requirement).

4.25.9.1.12.8.1.17 Tables used for hand loading shall be covered with a seamless, nonporous, non-sparking conductive material (Requirement).

4.25.9.1.12.8.1.18 Hand-loading equipment shall be permanently attached and bonded to a 25 ohm or less grounded tabletop (Requirement).

4.25.9.1.12.8.1.19 The grounding shall be tested twice a year and broken connectors repaired (Requirement).

4.25.9.1.12.8.1.20 Grounding system test results shall be documented (Requirement).

4.25.9.1.12.8.1.21 Ground conductors shall be visually inspected before each day's operation (Requirement).

4.25.9.1.12.8.1.22 Floors and walls shall be maintained free of cracks that could accumulate explosive dust and foreign materials (Requirement).

4.25.9.1.12.8.1.23 Good housekeeping practices shall be observed at all times (Requirement).

4.25.9.1.12.8.1.24 In case of a spill, all operations shall be stopped until the propellant is cleaned up (Requirement).

4.25.9.1.12.8.1.25 All salvaged propellant shall be placed in a metal container that contains water and is marked "Scrap Explosives" (Requirement).

4.25.9.1.12.8.1.26 All damaged components or complete rounds shall be put in separate, properly marked containers (Requirement).

4.25.9.1.12.8.1.27 Unserviceable items shall be separated from serviceable stocks (Requirement).

4.25.9.1.12.8.1.28 Qualified personnel shall dispose of unserviceable propellants, damaged rounds or components, and empty explosives containers as directed in Section 4I, Storage, Handling, and Disposal of Explosives Wastes (Requirement).

4.25.9.1.12.8.1.29 Only serviceable loading tools, dies, scales, powder measures, and so forth shall be used for hand loading operations (Requirement).

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4.25.9.1.12.8.1.30 Personnel protection shields shall be placed between all adjacent pieces of permanently attached hand loading equipment (Requirement). Shields shall be large enough to protect adjacent personnel (Requirement). Shields can be made of plywood, polycarbonate, or similar materials.

4.25.9.1.12.8.1.31 Bullet molding shall be performed outside the hand loading room.

4.25.9.1.12.9 Morale, Welfare, and Recreation (MWR) Activities. MWR activities such as aero clubs and boating activities are sometimes required to maintain and store commercial pyrotechnic signals. These items shall be controlled and stored using the same criteria as identified for 1.4/1.3 Class/Division (Requirement). Personnel shall be properly trained (Requirement). Storage locations shall be licensed in accordance with Paragraph 4.25.9.1 (Requirement). Technical data or manufacturer's data are sources for local written procedures.

4.25.9.1.12.10 Research and Development Laboratories. When necessary, Centers/Facilities may license a limited quantity, not to exceed 200 grams in each licensed location, of 1.1 Class/Division materials for research/testing in laboratories. For maximum quantities of other Class 1 Divisions use TNT equivalencies. A comparable quantity for the Class 1 Divisions (1.2, 1.3, 1.4, 1.5, and 1.6) is determined by the TNT equivalency. A fragmentation barrier consisting of a 0.25 inch thick mild steel plate shall be used for storage (Requirement).

4.25.9.1.12.10.1 Explosives used solely for a research/testing project shall be licensed only for the length of the project (Requirement).

4.25.9.1.12.10.2 Local written procedures shall be approved by the ESO prior to the explosive operation (Requirement).

SECTION 4I STORAGE, HANDLING, AND DISPOSAL OF EXPLOSIVES WASTES

4.26 Compliance Requirements.

The transportation, storage, treatment, and disposal of explosives wastes shall comply with Federal, State, local, and NASA regulations or requirements regarding hazardous wastes, including any site-specific permits, waivers, or interpretations (Requirement). All local Joint Operating and Support Agreements and Host/Tenant Agreements shall comply with these requirements (Requirement). Assistance and coordination regarding hazardous waste requirements can be obtained through the local Center’s environmental management office.

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CHAPTER 5 DETAILED REQUIREMENTS

SECTION 5A FIRE PROTECTION

5.1 General

This chapter establishes standard firefighting hazard identification measures for NASA Field Installations to ensure a minimum practicable risk in fighting fires of explosives, pyrotechnics, propellants, and similar hazardous materials. To provide a guide for firefighting forces, these explosively hazardous fires are divided into fire divisions in accordance with the relative danger encountered in fighting fires in which they are present. The fire divisions are identified by the numerals 1, 2, 3, and 4, each displayed on a distinctively shaped placard to improve visibility at long range. Firefighting procedures, training of firefighting personnel, use and maintenance of firefighting equipment and vehicles, provision of water supply and alarm system, first aid measures, and other measures required in firefighting are covered in Chapter 5 of NPR 8715.3 and NASA-STD-8719.11, NASA Safety Standard for Fire Protection.

5.2 Fire Protection Criteria

5.2.1 These fire protection criteria shall be required for all new facilities or for redesign of any existing facilities where changes in activities will result in a change to a more hazardous fire division (Requirement).

5.2.2 Automatic fire suppression systems shall be installed in all buildings containing high explosives with the exception of storage magazines (Requirement).

5.2.3 On the basis of maximum fire loss criteria and program mission interruptions and delays (risk analysis), the ESO may determine the type of fire suppression system.

5.2.4 Where fire suppression is required, each explosives bay shall have an individual feed with its controls protected (located so as to remain operable in the event of a detonation in any bay) outside the bay (Requirement).

5.2.5 Transmitted fire alarms shall distinguish between explosives and nonexplosive areas through the use of annunciator panels at safe locations (Requirement).

5.2.6 Unless otherwise directed by the ESO, a minimum of two serviceable fire extinguishers, suitable for the hazards involved, shall be provided for immediate use at any location where explosives are being handled (Requirement).

5.3 Fire Divisions

5.3.1 Table I lists the fire divisions numbered 1 through 4 which are synonymous with the Hazard Divisions 1.1 through 1.4 for explosives. The hazard decreases with ascending fire division numbers.

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Table I. Fire Divisions

Fire Division	Hazard Division	Hazard	Symbol Shape
1	1.1	Mass Explosion	Octagon
2	1.2	Explosion with Fragment Hazard	Cross
3	1.3	Mass Fire	Inverted Triangle
4	1.4	Moderate Fire	Diamond

5.3.2 Each of the four fire divisions is indicated by a distinctive symbol in order to be recognized by firefighting personnel approaching a fire scene. The applicable fire division number is displayed on each symbol.

5.3.3 For purposes of identifying these symbols from long ranges, symbols differ in shape as follows:

5.3.4 The background color of the fire symbol is orange. The color of each number identifying the applicable fire division is black.

5.3.5 The shape and size of the four fire division symbols and numbers are shown in Figure 3. For application on doors or lockers inside buildings, half-sized symbols may be used.

5.3.6 Fire symbol signs shall be the same shape as the fire symbol decal and made of noncombustible material so that in the event that the fire burns off the fire symbol or number, the fire department can still act based on the shape (Requirement).

5.3.7 Note that coordination and training for local jurisdictions may be required in order to ensure that first responders are aware of this use of fire symbols. This should be provided for in pre-fire planning and communication.

5.4 Display of Fire, Chemical, and/or Apply No Water Symbols.

5.4.1 Appropriate Fire, Chemical, and/or Apply No Water symbols (Figure 3 and Figure 4) shall be displayed on the exterior of all facility buildings and storage sites containing explosives, pyrotechnics, and similar hazardous materials (Requirement). They shall be displayed to make them easily visible for the greatest distance from each approach route of responding firefighter forces (Requirement). The Center Director may deviate from this requirement in accordance with NPR 8715.3 when security considerations may make it undesirable to identify explosives with Fire, Chemical, and/or Apply No Water symbols at the actual location. When this option is used, a pre-fire plan and communications between responding firefighting forces and the facility control function shall be in place (Requirement). In this case, Fire, Chemical, and/or Apply No Water symbols shall be posted on the interior of the building/storage site (Requirement). In lieu of posting every storage structure, facility managers may designate blocks or a single row of storage sites, aboveground magazines, or earth-covered magazines as areas requiring posting of only the appropriate Fire, Chemical, and/or Apply No Water symbol for the most hazardous material stored in the area or row. The symbols shall be located at the entrance to the block or row and shall be clearly visible to approaching fire response personnel (Requirement).

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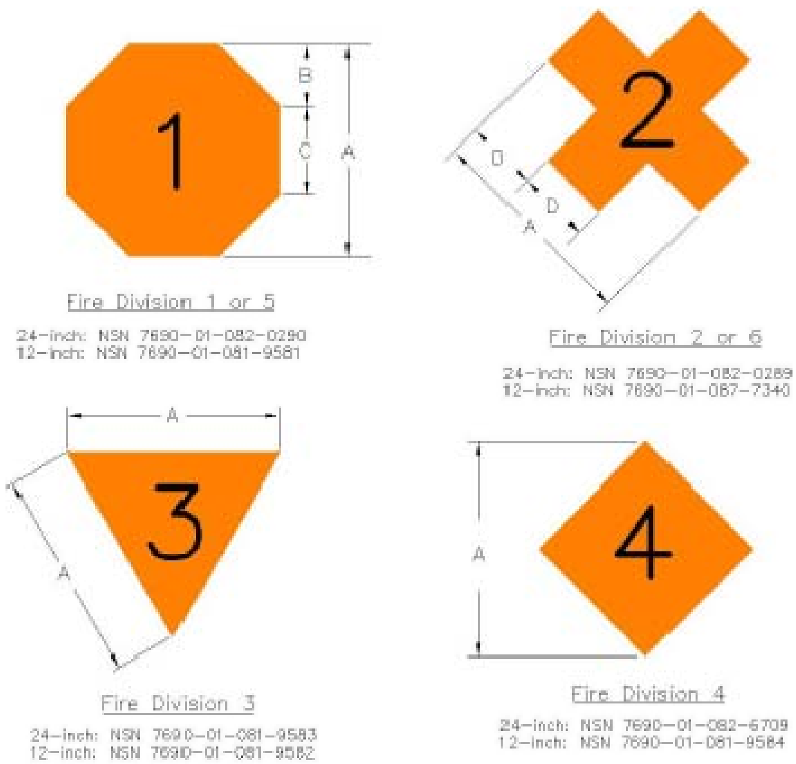
5.4.2 A master list of all storage explosive sites and their locations, fire symbols, chemical storage sites, and available empty storage sites shall be kept current and maintained by the local fire and security office (Requirement). This list shall be available to emergency response personnel (e.g., fire department, guard forces) at all times (Requirement).

5.4.3 Fire, Chemical, and/or Apply No Water symbols may be placed directly on the exterior of a building; however, removable placards or boards displaying the symbols may be preferred for facilities in which the explosive content is subject to frequent change. For long dimensional buildings with access from several directions, more than one symbol to a side may be necessary. The Fire, Chemical, and/or Apply No Water symbol displayed shall reflect the most hazardous material stored in the building or site (Requirement).

5.4.4 Facility warehouses and storage facilities used for storage of containers from which explosives have been removed, but which have not been decontaminated to remove explosive residue, shall be placarded with Fire, Chemical, and/or Apply No Water symbols consistent with the degree of hazard (Requirement).



Dimensions	Large Symbol		Small Symbol	
	inches	metric (mm)	inches	metric (mm)
A	24	610	12	305
B	7	178	3.5	89
C	10	254	5	127
D	8	203	4	102
Letters (height)	10	254	5	127
Letters (thickness)	2	51	1	25

Colors (per Federal Standard 595A or GSA Catalog)

Background: Orange #12246

Letters: Black # 17038

Figure 3. Fire Symbols

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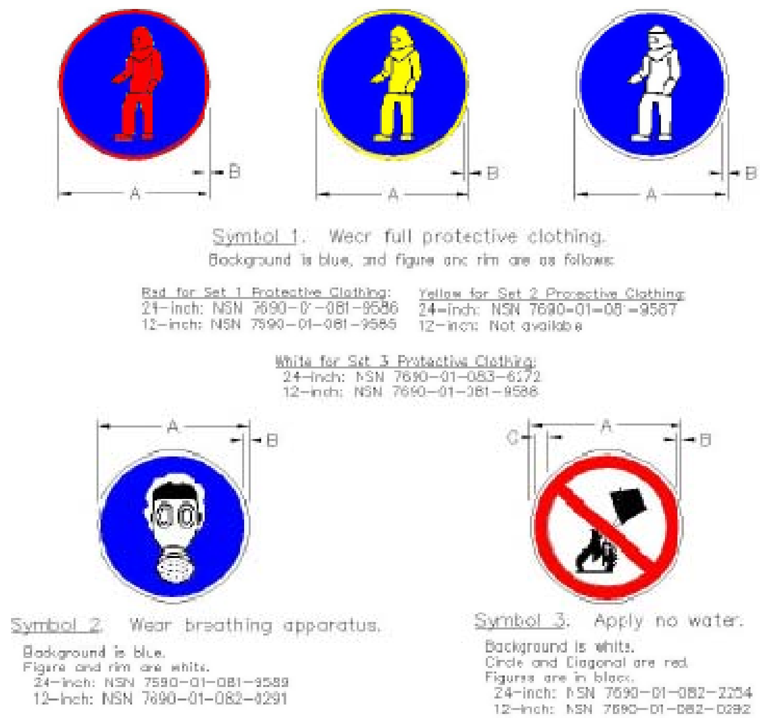

Dimensions	Large Symbol		Small Symbol	
	Inches	metric (mm)	Inches	metric (mm)
A	24	610	12	305
B	.5	13	.25	6
C	2	51	1	25

Colors (per Federal Standard 595A or GSA Catalog)

Red #11105 **White # 17875**

Blue #15102 **Black #17038**

Yellow #13538

Figure 4. Chemical and Apply No Water Symbols

5.4.5 All railroad cars and motor vehicles containing explosives, propellants, or pyrotechnics, while on NASA facilities, shall be provided with Fire, Chemical, and/or Apply No Water symbols or DOT labels/placards for identification of fire hazards (Requirement). Field Installation or facility railroad cars and motor vehicles that are not destined for off-site movement but are temporarily stored shall display at least two appropriate Fire, Chemical, and/or Apply No Water symbols (Requirement). Field Installation transport vehicles destined for off-site shipment and commercial railroad cars and motor vehicles shall have DOT placards displayed in accordance with DOT regulations when containing explosives and propellants or similar hazardous materials (Requirement).

5.5 Firefighting Procedures.

5.5.1 All fires starting in the vicinity of explosives or pyrotechnics shall be reported and an alarm sounded (Requirement). If the fire involves explosive materials or is supplying heat to the materials, personnel involved shall evacuate and seek safety (Requirement).

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5.5.1.1 Operational personnel shall be instructed, retrained, and reinstructed on the specific characteristics of the explosive materials and their reactions to heat/fire (Requirement). This training and recertification shall also include the technical aspect of the fire symbol system and actions to be taken in the event of a fire (Requirement).

5.5.1.2 The firefighting forces and other essential personnel shall be briefed before approaching the scene of the fire (Requirement). They shall be informed of the known hazards and conditions existing at the scene of the fire before proceeding to the location of the fire (Requirement).

5.5.2 All nonessential personnel shall be withdrawn to a predetermined location away from the fire at an adequate safe distance (Requirement). This also will allow a personnel head-count by supervisors to ascertain that all employees are safe and out of harm. Once all personnel are accounted for, this information shall be relayed to the fire scene commander (Requirement). For minimum allowable distances to be used, see Table II.

Table II. Emergency Withdrawal Distances for Nonessential Personnel

Hazard Division	Unknown Quantity	Known Quantity
Unknown, located in facility, truck, and or tractor trailer	Approximately ¾ mile (4,000 ft)	4,000 ft
Unknown, located in railcar	Approximately 1 mile (5,000 ft)	5,000 ft
1.1 (Explosive A) and 1.5 (See note 1)	Same as unknown facility, truck, trailer, or railcar as appropriate	- For transportation, use 2,500 ft minimum distance for 500 lb and below. - Above 500 lb, for rail cars use 5,000 ft minimum distance; otherwise use 4,000 ft minimum distance. For facilities, use 2,500 ft minimum distance for 15,000 lb and below. - Use 4,000 ft minimum distance for net explosive weights above 15,000 lb and less than or equal to 50,000 lb. - Above 50,000 lb, use d (distance) = 105 $W^{1/3}$.
1.2 (1.2.1, 1.2.2, and 1.2.3) Explosive A) and 1.6 (see note 1)	2,500 ft	2,500 ft
1.3 (Explosive B) (See note 2)	600 ft	Twice the IBD (Table XXI) with a 600 ft minimum range.
1.4 (Explosive C)	300 ft	300 ft

NOTES:

(1) For Hazard Division 1.1 and 1.2 items, if known, the maximum range that fragments and debris will be thrown (including the interaction effects of stacks of items, but excluding lugs, strongbacks, and/or nose and tail plates) may be used to replace the minimum range.

(2) For accidents involving propulsion units, it is not required to specify emergency withdrawal distances based upon the potential flight ranges of these items.

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5.5.3 Fires involving explosives and pyrotechnics shall be fought according to their fire division classification, the stage of the fire, and current procedures (Requirement). For additional firefighting requirements, see NASA-STD-8719.11.

5.5.3.1 Per NPR 8715.3, employees, other than trained professional firefighters, trained volunteers, or emergency response personnel, do not fight fires except in cases where the fire is incipient in nature.

5.5.3.2 The actions listed in Table III shall be followed for fires involving explosives and energetic liquids (Requirement).

5.5.3.3 The actions listed in Table IV shall be followed for fires involving toxic energetic liquids, pyrotechnics, and solid reactive components (Requirement).

Table III. Fire Division Hazards and Actions

Fire Symbol	Materials	Hazard	Action/Remarks.
1	1.1 H/D Explosives, incompatible Energetic Liquids, or Energetic Liquids having a specified TNT equivalence in Table XXIX or Table XXXI [(1)] and 1.5 H/D	Mass Explosion	1. Sound the alarm (call 911 or local emergency number). 2. Evacuate the area: For unknown quantities loaded on aircraft, truck, tractor, trailer, or facility, withdraw a minimum of 4,000 ft. For known quantities of explosives in the transportation mode, 500 pounds or less NEW, withdraw a minimum of 2500 ft. For more than 500 pounds, loaded on railcar, withdraw a minimum of 5,000 ft. For more than 500 pounds, all other modes of transportation, withdraw a minimum of 4000 ft. When located in a facility and the quantity is known, minimum withdrawal distances are: (1) 15,000 pounds NEW or less -- 2500 ft. (2) More than 15,000 pounds but no more than 50,000 pounds NEW -- 4,000 ft. (3) Above 50,000 pounds NEW use d (distance) = $105W^{1/3}$. 3. Provide information to responding firefighting forces (e.g., amount of explosives exposed to fire, location, headcount of employees, if rescue required). 4. If personnel safety is in doubt, take cover.
2	1.2 H/D explosives, Energetic Liquids having minimum fragment distances in Table XXIX (dependent on packaging)[(1)], and 1.6 H/D extremely insensitive detonating substances (EIDS)	Explosion with Fragments	1. Sound the alarm (call 911 or local emergency number) 2. Evacuate the area to at least 2500 ft (see Note 2). 3. Provide information to responding firefighting forces, (e.g., amount of explosives exposed to fire, location, headcount of employees, if rescue required). 4. Detonation of items could occur, provide protection from fragments. 5. Implement Fire Department Incident Management System.

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Fire Symbol	Materials	Hazard	Action/Remarks.
3	1.3 H/D explosives[(2)]	Mass Fire	1. Sound the alarm (call 911 or local emergency number). 2. Evacuate the area to twice the IBD with a minimum of at least 600 ft. 3. Provide information to responding firefighting forces (e.g., amount of explosives exposed to fire, location, headcount of employees, if rescue required). 4. If White Phosphorus (WP) is involved, smoke is liberated. WP may explode. Immerse Phosphorus in water or spray with water continuously. 5. For fires involving HC and incendiaries use dry sand or dry powder in early stages. 6. For fires involving pyrotechnics and magnesium incendiaries, protect adjacent facilities and equipment. Do not use carbon dioxide, Halon extinguishers, or water on or near explosives. Allow magnesium to cool unless upon flammable material. In this case, use a 2-inch layer of dry sand or powder on the floor and rake the burning material onto this layer and re-smother 7. Implement Fire Department Incident Management System.
4	1.4 H/D explosives	Moderate Fire	1. Sound the alarm (call 911 or local emergency number). 2. Evacuate the area to at least 300 ft. 3. Provide information to responding firefighting forces (e.g., amount of explosives exposed to fire, location, headcount of employees, rescue required). 4. Expect minor explosions and hot fragments. 5. Implement Fire Department Incident Management System.

GENERAL NOTES

(1) For accidents involving propulsion units, it is not required to specify emergency withdrawal distances based upon the potential flight range of these items.

NOTES

(1) Fires involving compatible energetic liquids and individual energetic liquids not having TNT equivalence or minimum fragment distances in Table XXIX or Table VI shall be fought in accordance with Table IV, MSDS, and NFPA requirements.

(2) For fragment producing items, if known, the maximum range that fragments and debris will be thrown may be used to replace the minimum evacuation distance.

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Table IV. Chemical Symbol Hazards and Actions

Chemical	CG[1]	Effect	Back-ground color	Bands	Characteristic	Clothing	Action
Nitrogen Tetroxide (N_2O_4), IRFNA, and Hydroxylammonium nitrate	K	Oxidizer	None	None	Highly toxic as aerosol/vapor	Full Protective Clothing. Set 1 (Red) (1)	1. Withdraw upwind. 2. If explosion does not occur, approach from upwind and extinguish fire. 3. Decontamination may be required. (10)
Hydrazine (N_2H_4, MMH, UDMH)	K	Fuel	None	None	Toxic as aerosol/vapor	Full Protective Clothing. Set 2 (Yellow) (2)	1. Withdraw upwind (see discussion for Fire Symbol 2 in Table III for withdrawal distances for hydrazines). 2. Approach from upwind and extinguish fire. 3. Decontamination may be required. (10)
Chloroacetophenone (CN) (6)(12)	G	Tear	Gray	Red			
Liquid Chloroacetophenone (CN) (6)(12)	G	Tear	Gray	Red			
O-Chlorobenzal-Malononitrila (6)(12) (CS), (CS1), (CS-2)	G	Tear	Gray	Red			
Combination CN and DM (6)(12)	G	Tear and Vomiting	Gray	Red			
Diphenylchloroarsine (DA) (6)	G	Vomiting	Gray	Red			
Titanium Tetrachloride (FM) (6)	G	Smoke	Lt Green	None			
Sulfur Trioxide Chlorosulfonic Acid (FS) (6)	G	Smoke	Lt Green	None			

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Chemical	CG[1]	Effect	Back-ground color	Bands	Characteristic	Clothing	Action
White Phosphorus (WP) (8)(9)	H	Smoke	Lt Green	None	Spontaneously flammable when exposed to air	Full Protective Clothing. Set 3 (White)(3)	1. Post fire guard until leaking phosphorus has been removed. 2. After removal of agents, post fire guard for two days for possible re-ignition.
Plasticized White Phosphorus (PWP) (8)(9)	H	Smoke	Lt Green	None			
Triethyl-Aluminum (TEA) (7)(11)	L	Smoke	Lt Green	None			
Signaling Smokes (4)	G	Smoke	Lt Green	None	Smoke, burns at high temperature	Breathing Apparatus (4)	1. Do not use water. 2. Do not look at burning material.
Pyrotechnic Material (PT) (4)(11)	G	Incendiary	Lt Red	None			
Thermite (TH) (4)(11)	G	Incendiary	Lt Red	None			
Hexachloroethane (HC) (4)(11)	G	Smoke	Lt Green	None			
Calcium Phosphide (4)(11)	L	Smoke	Lt Green	None			

[1] Compatibility Group

NOTES

(1) Set 1 consists of self-contained breathing apparatus, impermeable suit, or level A encapsulating suit in accordance with 29 CFR 1910 and NIOSH.

(2) Set 2 consists of self-contained breathing apparatus, coveralls, protective gloves, or level B encapsulating suit.

(3) Set 3 consists of flame resistant equipment and self-contained breathing apparatus. (Firefighting protective clothing and equipment are to be used where compatible with conditions of material or incident.)

(4) "Wear Breathing Apparatus" consists of a self-contained breathing apparatus. (Firefighting protective clothing and equipment may be used.)

(5) Reserved.

(6) Wear Set 2 protective equipment for emergency operations, when area contamination by an agent is suspected or when moving leaking items. Use to provide protection when removing a defective item from the vicinity of other explosives. (See Paragraph 5.4 above.)

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(7) Wear Set 3 protective equipment when area contamination by an agent is suspected or when moving leaking items. Use to provide protection when removing a defective item from the vicinity of other explosives. (See Paragraph 5.4 above.)

(8) For emergency response forces during emergency situations and for personnel handling unpackaged WP items, flame proof gloves, face shield, and covering for skin shall be available (Requirement). Leaks can be detected immediately by the smoke arising from the item. The greatest hazard is fire. Promptly immerse the item in water. Non-emergency workers shall evacuate the area and notify emergency response forces (Requirement).

(9) WP and PWP. Water supply, such as barrels, shall be immediately available when handling unpacked items (Requirement). Propylene glycol (RV antifreeze) may be used in the water. Do not mix a solution with more than 22% propylene glycol. Solutions of greater than 22% propylene glycol can produce flammable vapors when heated. When WP and PWP items are properly packaged, a water supply, such as hydrants or fire trucks with water, shall be available to emergency response (Requirement).

(10) For decontamination, the indicated protective clothing shall be worn (Requirement). Post the chemical hazard symbol. (Figure 3).

(11) Also post the fire direction symbol for "Apply No Water." This requirement is based on possible violent chemical reaction or danger of spreading the fire. Limited amounts of this material, such as flares in a survival kit, may be stored or maintained in a facility protected by a fire suppression system if approved by the Fire Department.

(12) Only the "Wear Breathing Apparatus" symbol needs be displayed where certain riot control agents are stored in arms rooms and similar locations.

5.5.4 Firefighters of fires involving ammunition and explosives shall have a thorough knowledge of the specific reactions of ammunition and explosives exposed to the heat or to the fire (Requirement). For Field Installations that rely on municipal or other firefighting organizations either on primary response or as a support unit, training as indicated in this document shall be provided to ensure safety of responding fire personnel (Requirement).

5.6 Storage of Water for Firefighting.

5.6.1 Storage of water for firefighting shall be in accordance with NFPA 22 and the minimum requirements for NASA explosive facilities operations commensurate with Field Installation and mission requirements (Requirement).

5.6.2 Storage of this water may be at any level.

5.6.3 Means shall be provided for replenishing expended water within 48 hours. The total quantity of stored water shall be replaced without using portable pumpers or emergency hose lines (Requirement).

5.6.4 Storage facilities for process and operations water should be located at not less than intraline distance (ILD) from operating buildings.

5.7 Automatic Sprinkler Systems.

5.7.1 Automatic sprinkler systems shall be provided in accordance with NFPA 13 and 15, NASA-STD 8719.11, and local NASA Field Installation and mission requirements (Requirement).

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5.7.2 Deluge systems, in addition to sprinklers, shall be provided for the protection of operating personnel in high hazard occupancies (Requirement). This determination can be established from safety hazard analysis performed by Field Installation system safety personnel. If a deluge system is recommended, the distribution outlets (e.g., nozzles, sprays, and heads) shall be located as close to the exposed surface of the explosive as possible, consistent with the outlet discharge pattern (Requirement). This would ensure immediate dousing of all parts of the machine or operation under extreme conditions.

5.7.3 Required water flow and pressure shall be determined for the hazard; deluge systems should be flow-tested periodically to ensure that they are in proper operating condition. Records of tests should be kept on file at the fire department (Requirement).

5.7.4 On deluge systems, the deluge valve shall be arranged for automatic and manual activation (Requirement). For explosives-operating buildings, manual activation devices shall be located at building exits and should be located at the operator stations when hazard analysis determines the risk to the operator to be acceptable (Requirement).

5.7.5 All explosive, pyrotechnic, and propellant operations shall be subjected to hazards analysis in order to identify potential fire/explosive threats and to assess the level of risk (Requirement). A potential fire hazard whose level of risk is unacceptable shall be mitigated by a high-speed deluge system (Requirement). This system can be capable of preventing propagation of a fire from one cell or bay when parallel explosive operations are in progress. This would provide not only protection to equipment but also minimal personal protection to workers and could prevent significant injury to the worker. The intent is to reduce the level of risk from radiant heat, causing an inadvertent ignition of an explosive or propellant. The deluge system shall be tested in accordance with NFPA 25, Inspection, Testing, and Maintenance of Water Based Fire Protection Systems; NASA-STD 8719.11, NASA Safety Standard for Fire Protection; and NFPA 15 (Requirement).

5.7.6 NFPA 13 and 15 should be consulted for basic installation requirements.

5.8 Vegetation Control

Vegetation around storage magazines, explosives operating facilities, test stands, and test areas should be controlled to minimize potential damage to the magazine or facility from grass, brush, or forest fires, or from erosion. A firebreak at least 50 ft wide and free from combustible material should be maintained around each aboveground magazine or facility processing or containing explosives. If the aboveground magazine or explosives facility exterior is fire resistant, the firebreak need not be devoid of vegetation, but growth shall be controlled by mowing to prevent rapid transmission of fire to the magazine or facility (Requirement). Maintenance of firebreaks around earth-covered magazines and cutting of grass covering these structures are not normally required, except around ventilators to prevent transmission of a fire into a structure.

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5.9 Safety Requirements in Specific Hazardous Areas

5.9.1 Parking of Motor Vehicles

5.9.1.1 Government owned vehicles (GOV) and motorized ground support equipment (GSE) parking areas shall be located a minimum of 100 ft from PESs. Temporary parking of GOVs and GSE, other than for loading or unloading, shall not be closer than 25 feet from PESs (Requirement). Temporary means the length of time for which the presence of the vehicle is essential to completion of a single task (e.g., a single work order number). The local ESO may reduce these parking requirements for licensed facilities.

5.9.1.2 Parking of privately operated vehicles (POV) shall be controlled to minimize fire and explosive hazards and prevent congestion in the event of emergency. (Requirement) Automobiles shall be parked in designated areas outside of restricted areas. They should not be parked close enough to a building to either enable the spread of fire from an automobile to the building or hinder access by firefighters. Parking areas for privately owned vehicles shall be separated from a PES by 100 ft minimum distance if they serve only the workers assigned to a single PES and ILD from all other PESs (Requirement). If they serve multiple PESs, the minimum distance shall be ILD (Requirement). Private vehicle parking in administrative areas shall be a minimum of public traffic route distance from the nearest PES (Requirement). Minimum fragment distance shall be maintained in all situations except for POV parking areas serving a single PES (Requirement). The local ESO may reduce these parking requirements for licensed facilities.

SECTION 5B ELECTRICAL, ELECTROMAGNETIC RADIATION, LIGHTNING PROTECTION, AND STATIC ELECTRICITY

5.10 Electrical Hazard Classes

5.10.1 Security, Communication, and Warning Systems. Where security and communication systems are to be installed, they shall comply with the provisions of the National Electrical Code (NEC) for the appropriate hazard class, division, and groups determined on a case-by-case basis (Requirement).

5.10.2 Electrical Equipment and Hazardous Locations. Electrical equipment and its installation at NASA facilities shall comply, as a minimum, with the requirements of the most recent edition of the NEC and OSHA, whichever is more restrictive (Requirement). The NEC, published by the NFPA as NFPA 70, does not address explosives specifically; however, Article 500 of the NEC, in its section on Hazardous (Classified) Locations, does establish standards for the design and installation of electrical equipment and wiring in atmospheres containing combustible dusts and flammable vapors and gases. NEC standards and this chapter are minimum requirements for NASA explosive facilities. The presence of hazardous energetic material; e.g., explosives, may or may not result in the presence or creation of a hazardous atmosphere (combustible dust, flammable vapor or gas) with respect to electrical equipment or wiring, as defined in NEC (NFPA 70), Article 500.

5.10.2.1 Facilities where explosives are stored or explosives operations performed shall be evaluated in accordance with the criteria of Article 500 of the NEC.

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5.10.2.2 Electrical equipment installed in any explosives location shall meet the requirements of the NEC for the classification of that location as determined in paragraph 5.10.2.1 (Requriement).

5.10.3 Explosive Equipment Wiring. To maintain maximum, long-term flexibility of use of facilities, wiring should be installed consistent with the most hazardous environment likely to be encountered in multiple uses over the lifetime of the facility.

> *Note: NASA facilities where explosives are involved shall meet the minimum requirements of Paragraph 5.11.4 for the installation and maintenance of electrical grounding (Requirement).*

5.10.3.1 All grounding mediums, including equipment grounding and bonding systems and lightning protection, should be bonded together as close to the grounding rod or counterpoise as possible.

5.10.3.2 Proper equipment grounding (equipment bonding conductor) will eliminate at least 95 percent of all grounding hazards if the equipment bonding conductor always provides a low-impedance ground-fault path. This assurance can be achieved only by proper installation, good maintenance, and routine testing of the ground loop impedance.

5.10.4 Electrical Power Lines. The following provisions shall apply to the separation of electric power lines and associated facilities from potential explosion sites (Requirement). Public Traffic Route and IBD separations shall be based on air blast overpressure only; fragment distances shall not be used (Requirement). These provisions are applicable for new construction only.

5.10.4.1 Electrical or magazine service lines required to be in proximity to an explosive's operating facility shall be no closer to that facility than the length of the lines between the poles/towers that support the lines unless effective means is provided to assure that energized lines cannot, on breaking, come in contact with the facility or its appurtenances (Requirement).

5.10.4.2 The towers/poles supporting electrical distribution lines (those carrying between 15 and 69 kV) and unmanned electrical substations shall be no closer to explosives exposures than public traffic route distances (Requirement).

5.10.4.3 The towers/poles supporting electrical transmission lines (those carrying 69 kV or more) and power houses serving vital utilities should be located no closer to explosives exposures than Inhabited Building Distance (IBD).

5.11 Lightning Protection

5.11.1 Policy. It is NASA policy to comply with the requirements of NFPA Standard 780 and 70 to provide minimum criteria for the design of lightning protection systems for facilities involved in the development, manufacturing, testing, handling, storage, maintenance, and disposal of explosives, pyrotechnics, and propellants. Even though not specifically covered by these two codes (NFPA 780 and 70), NASA facilities containing explosives shall require these references as basic criteria for lightning protection (Requirement).

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5.11.2 Required Lightning Protection.

5.11.2.1 Lightning protection systems identified in Paragraph 5.11.3, Approved Systems, shall be used in NASA facilities to provide protection from lightning to all explosives facilities (Requirement). Lightning protection especially is needed in explosives facilities where operations cannot be shut down during electrical storms and personnel evacuated.

5.11.2.2 No lightning protection is required for explosives facilities when the following conditions are met:

5.11.2.2.1 A lightning warning system is available to permit termination of operations and withdrawal of all personnel to IBD prior to the incidence of an electrical storm.

5.11.2.2.2 Earth-covered magazines are used for the storage of explosives and propellants in closed containers or in their approved shipping configuration, provided metallic ventilators, doors, and reinforcing steel are electrically bonded together and grounded. Bonding and surge protection of referenced standards also apply for such magazines.

5.11.2.2.3 Facilities containing explosives, pyrotechnics, and propellants or items or systems incorporating explosive components that cannot be initiated by lightning as determined by the responsible organizations. These facilities shall meet bonding and surge suppression requirements and not be subject to fire in the event of a lightning strike (Requirement).

5.11.3 Approved Systems. Four types of lightning protection systems are acceptable for NASA and contractor facilities for the protection of structures housing explosives, pyrotechnics, and propellants: overhead wires, masts, integral (see Paragraph 5.11.3.2), and Faraday cage lightning protection systems.

5.11.3.1 The minimum principles of protection for structures protected against direct lightning strikes are:

5.11.3.1.1 An air terminal shall be provided to intentionally attract the leader strike (Requirement).

5.11.3.1.2 A path shall be established connecting this terminal to earth with such a low impedance that the discharge follows it in preference to any other (Requirement).

5.11.3.1.3 A low resistance connection shall be made with the earth electrode subsystem (Requirement).

5.11.3.1.4 A low impedance interface shall be established between the earth electrode subsystem and earth (Requirement).

5.11.3.2 These conditions are met when a lightning discharge is permitted to enter or leave the earth while passing through only conducting parts of a structure. The conditions can be satisfied by one of two methods, each having specific applications. These methods are:

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5.11.3.2.1 Installation of an integral protection system consisting of air terminals interconnected with roof and down conductors to form the shortest practicable distance to ground.

5.11.3.2.2 Installation of a separately mounted protection system of one of two types: (1) a mast type consisting of a metal pole that acts as both air terminal and down conductor (a nonconductive pole may be used if provided with metal air terminals and down conductors connected to an earth ground); or (2) two or more poles supporting overhead guard wires connected to an earth electrode subsystem with down leads.

5.11.4 Grounding, Bonding, and Surge Protection.

5.11.4.1 Grounding. Resistance of 25 ohms or less to ground for a lightning protection system is the desired optimum. If 25 ohms resistance cannot be achieved with ground rods alone, a counterpoise system is acceptable even if it is greater than 25 ohms. A counterpoise shall be of No. 1/0 copper cable or equivalent material having suitable resistance to corrosion and shall be laid around the perimeter of structure in a trench not less than 2 feet deep at a distance not less than 3 feet nor more than 8 feet from the nearest point of the structure (Requirement).

5.11.4.2 Bonding. The bonding of metallic bodies is required to ensure that voltage potentials due to lightning are equal everywhere in the facility. The resistance of any metal object bonded to the lightning protection system shall not exceed 1 ohm to the grounding system (Requirement). The material used shall be compatible with the metallic mass and down conductor to minimize corrosion. NFPA 780 shall be used as minimum acceptable bonding requirements for NASA facilities (Requirement). Wires and connectors on lightning protection systems shall not be painted (Requirement). Fences shall have bonds across gates and other discontinuations and shall be bonded to the lightning protection system if they come within 6 feet of the system (Requirement). Railroad tracks that run within 6 feet of a structure shall be bonded to the structure's lightning protection system or its grounding system (Requirement). The lightning protection system shall be bonded to all grounding systems of the protected facility at the counterpoise or grounding rod outside the building (Requirement).

5.11.4.3 Surge Protection. A lightning protection system for structures housing sensitive materials such as initiators, pyrotechnics, and igniters shall be designed for surge protection as well as lightning strokes interception (Requirement). Nearby flashes will produce electromagnetic pulses that can be coupled into internal and external power, communication, and instrumentation lines. Consequently, one or more of the following shall be provided on all incoming metallic power, communication, and instrumentation lines to reduce transient voltages to a harmless level (Requirement):

- Lightning arrestors
- Surge arrestors
- Surge protectors
- Surge suppressors
- Transient power suppressors
- Fiber optic data lines
- Isolation transformers

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5.11.4.3.1 These power and communication lines shall enter the facility in shielded cables or in metallic conduits run underground for at least 50 ft from the structures (Requirement). In addition, intrusion detection systems, utilities lines (such as water, steam, and air conditioning), and other metallic lines shall run underground for at least 50 ft from the structure (Requirement). The NASA ESO may decide to use low-pass filters for added protection of specific, critical electronic loads.

5.11.5 Testing and Inspection.

5.11.5.1 General. Lightning protection systems shall be visually inspected semiannually and shall be tested once each year for electrical continuity and adequacy of grounding (Requirement). A record of results obtained from the tests, including action taken to correct deficiencies noted, shall be maintained at the installation (Requirement). Any system shall be considered deficient if electrical continuity does not exist (Requirement). Except where counterpoises are installed, systems shall be considered deficient if resistance to ground exceeds 25 ohms (Requirement).

5.11.5.2 Test Equipment. Only those instruments designed specifically for Earth-ground system testing are acceptable. The instrument shall be able to measure 25 ohms, plus or minus 10 percent, for ground resistance testing and 1 ohm, plus or minus 10 percent, for bonding testing (Requirement).

5.12 Explosives in Process During Electrical Storms

5.12.1 Upon notification of an approaching electrical storm (lightning flashes observed or forecasted to be within 5 nautical miles of operation, or less if determined by local operational requirements), personnel shall be evacuated from facilities where there is an explosives hazard that could be initiated by lightning (Requirement). Personnel shall be evacuated to an area that will provide protection commensurate with the hazard level (Requirement). Explosive operations requiring attention at all times shall continue to be performed by the minimum number of personnel consistent with safety requirements (Requirement). Any process involving explosives shall not be started unless absolutely necessary or unless the process can be completed prior to an anticipated storm (Requirement). There is no guarantee that lightning protection systems will provide the same degree of safety as a lightning-free environment.

5.12.2 The following locations (other than those licensed under Paragraph 4.25.9.1) require evacuation during electrical storms (Requirement) :

5.12.2.1 Explosives operating facilities without approved lightning protection systems and other locations within PTR distance of such facilities.

5.12.2.2 Test stands and launch pads.

5.12.2.3 Facilities located within ILD and containing exposed explosives, explosives dust or vapors, or unpackaged electrically initiated explosive devices, whether or not equipped with approved lightning protection systems (evacuate to nearest control room, building, or other safe haven type structure).

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5.12.2.4 Magazines, open storage sites, loading docks, explosive loaded vehicle holding pads or explosive loaded railroad cars on ungrounded tracks, that are not equipped with approved lightning protection systems and allocations within PTR distance of such structures, sites, vehicles, or cars.

5.12.3 Aircraft explosive loading or unloading operations shall be stopped at the same time that fueling and defueling operations are suspended (Requirement).

5.12.4 In an operating facility, evacuated personnel shall proceed to a suitable protective shelter located at ILD from operating buildings or other locations containing explosives (Requirement). A suitable protective shelter is one that will protect personnel from overpressures greater than 16 kPa (2.3 psi), structural collapse, and fragments in the event of explosion of any adjacent facility containing explosives. When such shelters are not available, personnel shall be withdrawn to places at IBDs from the hazardous location (Requirement).

5.13 Static Electricity and Control of ESD

5.13.1 General. This section covers methods for the control of static electricity for the purpose of eliminating or mitigating its fire and explosion hazard. See Paragraph 6.1 for discussions of environmental factors and sources of ESD. The generation of static electricity is not in itself a hazard. The hazard arises when static is allowed to accumulate, subsequently discharging as a spark across an air gap in the presence of highly flammable materials or energetic materials such as explosives, pyrotechnics, or propellants. This standard, supplemented by NFPA 77, sets forth the minimum requirements for control of static electricity for NASA explosive facilities.

5.13.2 Personnel Electrostatic Discharge Equipment and Conductive Floors.

5.13.2.1 Static dissipation devices such as leg straps (“legstats”), wrist straps (“wriststats”), or conductive shoes shall be worn when handling, installing, or connecting or disconnecting solid propellant, solid rocket motors, electro-explosive devices (EEDs), and pyrotechnics, including NASA Standard Initiator (NSI) when Faraday caps, shorting plugs, or firing line extension cables are removed (Requirement). These devices shall also be worn within 5 feet of exposed solid propellant grains (Requirement). Personnel wearing leg straps, one on each leg, or conductive shoes shall stand on a grounded conductive surface (Requirement). Personnel wearing wrist straps shall connect the lead clip to a facility/vehicle ground (Requirement).

> *Note: When standard ESD practices would impose an additional hazard to personnel or equipment, the ESO at each NASA center may, after assessing all additional hazards associated with the use or non-use of static dissipation devices, choose to process a variance in accordance with NPR 8715.3 to authorize departure from a specific performance or operational requirement for a specified mission, test or operation. Standard Industrial practices for controlling ESD hazards such as the “First Touch” method for controlling ESD may then be approved by the ESO for processes or tests.*

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Example: A process or test involves the use of cryogenic materials and a pyrotechnic device(s). The PPE required to protect the employees against the accidental spill of the cryogenic material prevents the use of standard ESD devices; e.g., wriststats, legstats or conductive shoes. The test procedure shall require the pyrotechnic device(s) remains shunted at all times during the operation requiring the employee(s) to wear the cryogenic PPE.

5.13.2.2 Personnel beginning operations in an electrostatic discharge (ESD) sensitive area shall check all personnel grounding devices for proper resistance by a calibrated ohm meter on a daily basis prior to beginning operations (Requirement).

5.13.2.3 The resistance of legstats and conductive shoes shall measure, between wearer and facility ground, 25,000 ohms and 1 megohm, respectively (Requirement).

5.13.2.4 A certified tester shall be used to verify the resistance between the ground point and the hand closest to the wrist wearing the wriststrap. The reading shall not exceed 10 megohms. (Requirement). A retest shall be made if the grounding device is removed (Requirement).

5.13.2.5 Test methods for legstats shall be the same as required for conductive shoes (Requirement). Tests methods for wrist straps shall use a wrist strap tester in accordance with manufacturer instructions (Requirement).

5.13.2.6 Conductive floors and conductive shoes, or alternative measures as specified within this section (5.13.2), shall be used for grounding personnel at operations where explosives such as primers, initiators, detonators, igniters, tracers, and pyrotechnic mixtures are exposed and have an electrostatic sensitivity of 0.1 joule or less, as well as where operations involve loose unpacked explosives with primers, exposed EEDs such as squibs and detonators, and electrically-initiated items with exposed electric circuitry (Requirement).

5.13.2.7 Conductive floor testing instruments shall meet the following requirements of ASTM F150-98, "Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring" (Requirement):

5.13.2.7.1 Maximum floor resistance shall be measured with a suitably calibrated ohmmeter, which may operate on a normal open-circuit output voltage of 500 volts direct current and a short circuit current of 2.5 milliamperes with an effective internal resistance of approximately 2 million ohms (Requirement). Minimum floor resistance shall be measured with a suitably calibrated ohmmeter appropriate for the task (Requirement).

5.13.2.7.2 Each electrode shall weigh 5 pounds and shall have a dry, flat, circular area 2-1/2 inches in diameter, which shall comprise a surface of aluminum or tin foil 0.0005- to 0.0001-inch thick, backed by a layer of rubber 1/4-inch thick and measuring between 40 and 60 durometer hardness as determined with a Shore type A Durometer (Requirement).

5.13.2.8 Conductive floors and footwear are not required throughout an entire building, bay, or room if the hazard remains localized. Conductive mats or runners may be used where required.

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5.13.2.9 Portable ground cables used for connecting ordnance items to the facility ordnance ground system shall be visually inspected prior to each use (Requirement).

5.13.2.9.1 Prior to each use, it shall be verified that an electrical continuity test has been conducted on the cable within the last 7 months (Requirement).

5.13.2.9.2 Once connected, a cable may remain continuously connected beyond the 7-month time period, but when disconnected, it shall be retested before being reused (Requirement).

5.13.2.9.3 Test methods for performing continuity tests of the ground cable shall involve connecting the leads from an ohmmeter to the ends of the ground cable (Requirement).

5.13.2.9.4 The size of the ordnance ground cable shall be sufficient to prevent the wire from breaking during the worst case conditions under which it will be used (Requirement). The connectors on these cables shall not be insulated (Requirement).

5.13.2.10 Test Record. Records shall be maintained of all required tests and their results (Requirement). The records may be kept by a log or other means designated by instruction (Requirement). Equipment requiring long time intervals between testing; e.g., ground cables, can be tagged to facilitate the inspection and retesting process.

5.13.3 Control of ESD. The objective of most static-corrective measures is to provide a means whereby charges separated for whatever reason are recombined harmlessly before sparking potentials are attained, or to avoid spark gaps where harmful discharges could occur. If hazardous static conditions cannot be avoided in certain operations, means shall be taken to assure that there are no ignitable mixtures at points where sparks may occur (Requirement). Some common practices of control and/or reduction of ignition hazards from ESD are as follows:

5.13.3.1 Bonding and Grounding (refer to Paragraph 5.13.4).

5.13.3.2 Except as specifically approved by the ESO, relative humidity (RH) in the operational area shall be determined and recorded prior to the start and every 4 hours during operations involving open rocket propellant grains, rocket motors with nonconductive cases, open flammable/combustible fluid systems, and Category A Electro-explosive Devices (EEDs) [when the Faraday cap is removed or firing circuits to EEDs are exposed] (Requirement).

5.13.3.2.1 At or below 50 percent RH:

5.13.3.2.1.1 Bonding, grounding, nonconductive materials, and personnel grounding devices shall be verified at less than 350 volts potential (Requirement).

5.13.3.2.1.2 Electrostatic scanning of personnel, materials, and hardware within ten feet of the operation, not to exceed 1-hour intervals, shall be performed during the operation and at any time additional personnel, equipment, or hardware are introduced into the immediate area, the RH goes lower, or the handling of nonconductive materials is required (Requirement). When RH falls to, or below, 50%, continuous RH monitoring shall be performed (Requirement).

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5.13.3.2.1.3 When operations are permitted at 30 percent RH or below, electrostatic scanning shall be accomplished at 10-minute intervals if the explosive material is exposed and 30-minute intervals if the explosive material is covered (Requirement). The maximum voltage potential shall be dependent upon the explosive material sensitivity to ESD (Requirement).

5.13.3.3 Ionization serves as an effective method for removing static charges from certain processes and/or operations. Ionization methods of removing static charges shall not be used in hazardous locations as defined in the NEC unless approved specifically for such locations by the ESO (Requirement).

5.13.3.4 Inerting, Ventilation, Relocation. Consult NFPA 69 and 77 for proper ventilation, inerting procedures, or relocation of operations to control ESD.

5.13.3.5 Temperature Control. Cold temperatures have been demonstrated to contribute to dielectric breakdown of propellants. In the right conditions, this could make a propellant more susceptible to ignition by ESD. ESD testing should be performed at a range of temperatures for propellant formulations so that data is available with which to write procedures and constraints. Increased relaxation time should be included as needed for the operations.

5.13.3.6 Minimize surface area contact to minimize triboelectrification.

5.13.3.7 Where possible, static dissipative materials/coatings should be provided that will not allow point-discharging and/or will slowly bleed off any accumulated charges in a manner that will reduce the buildup of sufficient charge for ESD spark discharge.

5.13.4 Equipment Grounding/Bonding.

5.13.4.1 General. The use of appropriate bonding and grounding practices is the first line of defense against ignition of an energetic material by static electricity. The generation of static electricity cannot be totally prevented, because its intrinsic origins are present at every interface. The effectiveness of a bond or ground whether provided through the use of an "added on" path or through the inherent charge dissipation properties of the equipment under consideration depends on the ability of the path to dissipate charge at a rate commensurate with the rate at which it is generated.

5.13.4.2 Bonding shall be provided for (Requirement):

5.13.4.2.1 Protection of equipment and personnel from the hazards of lightning discharges.

5.13.4.2.2 Establishment of fault current return paths.

5.13.4.2.3 Protection of personnel from shock hazards arising from accidental power grounds.

5.13.4.2.4 Prevention of static charge accumulation.

5.13.4.3 In the process of grounding of equipment, the following practices shall be followed:

5.13.4.3.1 Bonding straps shall be used to bridge locations where electrical continuity may be broken by oil on bearings, paint, or rust at any contact point(Requirement).

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5.13.4.3.2 Permanent equipment in contact with conductive floors or table tops is not considered to be adequately grounded. A permanent, visible ground shall be required (Requirement). Dual ground paths are recommended.

5.13.4.3.3 Static grounds shall not be made to gas, steam, or air lines, dry pipe sprinkler systems, or air terminals of lightning protection systems (Requirement).

5.13.4.3.4 When grounding explosives/propellants, ground cable shall be attached to explosive/propellant container (e.g., rocket motor case) first and then to building/facility ground (Requirement).

5.13.4.3.5 Static grounds can be made to conductive water pipes that have been tested and verified to be permanent and continuous, ground cones, buried copper plates, driven ground rods, or to down conductors of lightning protection systems as close to the ground rod or counterpoise as possible.

5.13.4.3.6 All ground systems shall be interconnected outside a structure if the structure is equipped with a lightning protection system (Requirement). The safest practice is to bond the systems as close to the ground rod or counterpoise as possible.

5.13.4.3.7 Bonding wires/cables and ground wire shall have adequate capacity to carry the largest currents that are anticipated (see the NEC) (Requirement).

5.13.4.3.8 Flexible conductors shall be utilized for bonds that are frequently connected and disconnected (Requirement).

5.13.4.4 The primary purpose of bonding and grounding is to ensure requirements of Paragraph 5.13.4.2 are met and thereby prevent the generation of an incendiary spark. The purpose of bonding and grounding practices is not to drain all charges to ground or to bring all objects in question to zero potential relative to ground. This explains the objectives of bonding and grounding practices (in some cases), but not the rationale. The distinction must be recognized in order to fully understand the application of these practices.

5.13.5 Hazards of Electromagnetic Radiation to Electroexplosive Devices (EEDs).

5.13.5.1 The requirements in this section are designed to preclude inadvertent EED initiation from radiated electromagnetic energy (see Paragraph 6.2 for additional details).

5.13.5.1.1 Calculations demonstrated in Paragraph 6.2 are valuable for evaluating a specific device and emitter; however, calculations can quickly become a difficult task for large numbers of devices. The following guidance may be used in lieu of specific calculations.

5.13.5.1.2 Maintaining a safe separation distance between the emitter and the EED provides protection. This distance is a factor of the effective radiated power (ERP) and frequency of the emitter. ERP is a product of the transmitter power and the gain of the transmitting antenna. Antenna gain is a measure of the power channeled by a directional antenna. It is usually provided in decibels (dB). Sometimes it is provided as a unitless number, G_t. Use the following formula to convert between G (dB) and G_t:

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$G_t = \log^{-1} [G (dB)/10] = 10^{[G (dB)/10]}$

Frequency is measured in hertz (Hz) or cycles per second.

Transmitter power, P_t, is expressed in watts (W). If a transmitter is pulsed, it will have both a peak and average P_t. Generally, peak P_t is the best number to use when determining ERP. However, pulsed systems with small pulse widths (less than 1 millisecond) may be more accurately represented by average power.

5.13.5.1.3 Table V shall be used as a guide in setting up safe separation distances between EEDs and the transmitting antenna of all RF emitters or determining the maximum power density allowable for an EED (Requirement). These calculations are based on "worst-case" assumptions, such as EEDs with a maximum no-fire sensitivity of 50 mW and far-field conditions. The far field of the antenna provides a more consistent power density environment than that found in the near field. Distances greater than R_{ff} are considered far field. Distances less than or equal to R_{ff} are near field. The following formula can be used to determine where the far field begins:

$$R_{ff} = \frac{2D^2 f}{c} \quad \text{where}$$

R_{ff} = distance, in meters, from transmitting antenna where the far field begins

D = largest dimension of the antenna, meters

f = frequency (Hz)

c = speed of light, 3 x 10^8 m/s

For near field conditions, contact the Radiation Control Officer.

5.13.5.1.3.1 Safe Separation Distance Criteria (See Table V and Figure 5)

5.13.5.1.3.1.1 Use Column A, Worst Case or Unknown Configuration, when EEDs are unshielded, or the leads or circuitry could inadvertently be formed into a resonant dipole or loop antenna, or the configuration of the EEDs is unknown.

5.13.5.1.3.1.2 Use Column B, Exposed EEDs, when EEDs are exposed due to maintenance, assembly, or disassembly or the item or operational vehicle, which contains the EED, is exposed due to maintenance assembly, or disassembly.

5.13.5.1.3.1.3 Use Column C, EEDs in Storage or Ground Transport in a Metal Container, when EEDs are stored or in a ground transport configuration inside a conductive (metal) container. This includes EEDs assembled in an operational configuration when the exterior containment provides a conductive shield.

5.13.5.1.3.1.4 Use Column D, EEDs in Storage or Ground Transport in a Nonmetal Container, when EEDs are stored or in a ground transport configuration inside a nonconductive (nonmetal) or Table V, column B, even though leadless EEDs are involved, since vehicle systems wiring could form a resonant antenna during installation.

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Table V. Recommended EED Safe Separation Distances and Power Densities

Column	A	B		C	D		E	F
Configuration of EED	Worst Case or Unknown	Exposed EED		EED in Storage or Transport (Metal Container)	(Non-metal Container)		EED in Or On Aircraft	Leadless EED
		Frequency	Formula		Frequency	Formula		
Recommended Separation Distance (or Formula for Distance)	Use Figure 2.3 or Column B	Up to 20khz	$D = .093 \times \sqrt{P_t G_t}$	$D = .093 \times \sqrt{P_t G_t}$	Up to 63kHz	$D = .093 \times \sqrt{P_t G_t}$	$D = .093 \times \sqrt{P_t G_t}$	D=10 feet
		20kHz to 2MHz	$D = 4.63\,f \times \sqrt{P_t G_t}$		63kHz to 2MHz	$D = 1.46f \times \sqrt{P_t G_t}$		
		2MHz to 48.5 MHz	$D = 9.26 \times \sqrt{P_t G_t}$		2 MHz to 48.5 MHz	$D = 2.93 \times \sqrt{P_t G_t}$		
		48.5 MHz to 4.85GHz	$D = \frac{450}{f} \times \sqrt{P_t G_t}$		48.5 MHz to 1.53 GHz	$D = \frac{142}{f} \times \sqrt{P_t G_t}$		
		4.85GHz to 45GHz	$D = .093 \times \sqrt{P_t G_t}$		1.53 GHz to 45 GHz	$D = .093 \times \sqrt{P_t G_t}$		
Recommended Maximum Power Density	$P_o = \frac{0.01W}{m^2}$	Up to 20kHz	$P_o = \frac{100W}{m^2}$	$P_o = \frac{100W}{m^2}$	Up to 63kHz	$P_o = \frac{100W}{m^2}$	$P_o = \frac{100W}{m^2}$	Not Applicable
		20kHz to 2 MHz	$P_o = \frac{.04}{f^2}$		63kHz to 2 MHz	$P_o = \frac{.4}{f^2}$		
		2MHz to 48.5 MHz	$P_o = \frac{0.01W}{m^2}$		2MHz to 48.5MHz	$P_o = \frac{0.1W}{m^2}$		
		48.5 MHz to 4.85 GHz	$P_o = 4.256 \times 10^{-6} \times f^2$		48.5MHz to 1.53GHz	$P_o = 4.256 \times 10^{-5} \times f^2$		
		4.85GHz to 45GHz	$P_o = \frac{100W}{m^2}$		1.53GHz to 45GHz	$P_o = \frac{100W}{m^2}$		

NOTES
In the formulas above:

D = distance (ft)
f = frequency (MHz)
P_t = transmitter power (W) ---
G_t = antenna gain. To convert from G (dB), use $G_t = \log^{-1}[G(dB)/10]$
P_o = maximum power density (W/m^2)

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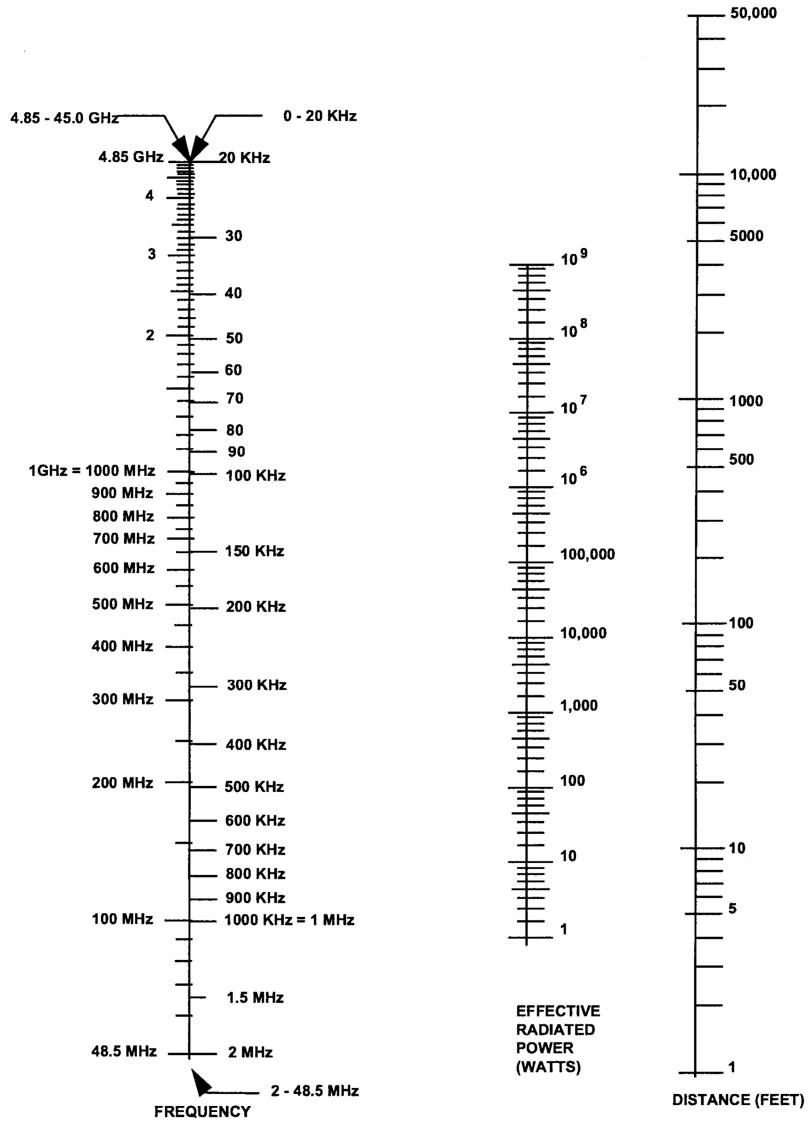

Figure 5. Recommended Safe Separation Distances for EEDs in Exposed Condition.

5.13.5.1.3.1.5 Use Column E, EEDs In or On Aircraft, when EEDs or the item or operational vehicle containing them are in a transport configuration inside cargo aircraft or externally loaded on an aircraft.

5.13.5.1.3.1.6 Use Column F, Leadless EEDs, when EEDs do not have lead wires and are in the original shipping configurations and/or containers. This does not include handling and/or installing leadless EEDs (column B applies). When handling and installing EEDs, apply the distance listed in Figure 5.

5.13.5.1.3.1.7 When unclear about the appropriate configuration and column to apply from Table V, use the most conservative; i.e., the greatest distance or largest power density.

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5.13.5.1.3.2 Maximum Power Density Criteria.

5.13.5.1.3.2.1 When electrical characteristics of the EEDs are not known or when the minimum safe separation distances cannot be complied with because of lack of real estate or other limitations, a power density and field intensity survey shall be made (Requirement). Compare the measured power density with the recommended maximum power density calculated from Table V. The measured power density shall be no greater than the recommended maximum power density (Requirement).

5.13.5.1.3.2.2 When more than one transmitter is operating in an area, each at a different frequency, the maximum allowable power density is the greatest power density calculated for each of the transmitters.

5.13.5.1.3.2.3 Approximate calculations for safe separation distances can also be made using the nomograph provided in Figure 5. Example 1 in Paragraph 6.2.17 illustrates how to apply this nomograph.

5.13.5.1.4 See Paragraphs 6.2.17 and 6.2.18 for examples of safe separation and power density calculations.

5.13.5.2 Use peak power for P_t except for pulsed systems with pulse widths less than one millisecond (ms). In this case, use the larger of 1) the average power or 2) (peak power) x (largest pulse width expressed in ms)/1 ms. Note: 1 ms = .001 seconds.

5.13.5.3 For EEDs with a no-fire sensitivity less than 50 mW and frequencies outside the ranges specified in Table V, contact NASA Headquarters, Safety and Assurance Requirements Division (SARD).

SECTION 5C LABORATORY SAFETY

5.14 General Laboratory Safety

5.14.1 The 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 (Requirement).

5.14.2 Laboratory work involving explosives materials shall be performed only in accordance with the provisions of written operating procedures (see Section 4G) (Requirement). Laboratory operations shall comply with the requirements of NFPA 45, "Fire Protection for Laboratories Using Chemicals," including the requirements for electrical equipment and wiring (Requirement).

5.14.3 The quantity of explosives present in the laboratory shall be the minimum required for the operations and shall be at or below assigned limits (Requirement). (Refer to Paragraph 4.25.9.) Storage material not in process is allowed provided it is secured when the laboratory is not occupied. The material shall be configured in a manner to preclude exceeding the Maximum Credible Event (MCE) (Requirement).

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5.14.4 Open flames shall be prohibited in laboratories where explosives or flammable solvent vapors are or may be present unless allowed by approved hazards assessment or procedure (Requirement).

5.14.5 Treatment of explosives wastes shall meet the requirements of Federal, State, and local EPA regulations (Requirement). 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) (Requirement). Even if a drain is designed to handle explosives, deliberate disposal of explosives in these drains shall be avoided (Requirement). These drains should be used only for the purpose of cleaning up explosives spills. Special care shall be exercised to prevent entrance of compounds into drains that may react with metals in the drain to form sensitive salts (e.g., picrates and picric acid) (Requirement).

5.14.6 Solvents or other substances that are flammable shall be protected against electrical sparks, heat, and open flames (Requirement). Suitable guards shall be provided for all glass or fragile equipment that must withstand reduced or elevated pressure (Requirement).

5.15 Safety Shields.

5.15.1 If a laboratory operation involves an explosion hazard, personnel shall be protected by safety shields or the operation shall be performed by remote control (Requirement). Table VI lists shields that have been tested and found acceptable for the indicated quantities of explosive. Shields listed in this table 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 VI. Safety Shields for Explosive Laboratory Operations

Shield	Minimum distance from explosives (inches)	Explosive limit
Leather gloves, jackets, or coats and plastic face shields	----	50 mg
1/8” tempered glass	5/16	50 mg
¼” Lucite/equivalent material	9/16	2.5 g
3/4” Lucite/equivalent material	9/16	10 g
5/8” Laminated resistant glass	3/4	20 g
1” Lexan/Lexguard	1-1/4	50 g
2 units each of 1” plate glass laminated with ½” polycarbonate with a 3/8” air gap between units (glass sides facing the explosive)	1-1/4	50 g (steel confined)

5.15.2 If an experiment presents a metal-fragment hazard (as opposed to a glass-fragment hazard), and the experiment cannot be conducted remotely, the proposed shield shall be tested

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and approved under conditions simulating an explosion in the experimental setup but with at least 125% of the anticipated explosive content (Requirement).

5.15.3 The shield shall be anchored to the hood frame or bench top when it is being used for protection against more than 5 g of TNT equivalent (Requirement).

5.15.4 Other shields may be used after successfully passing a test of 125% of the rated explosive charge being approved (Requirement).

5.15.5 For confined areas, a blast vent having less strength than the shield shall be provided (Requirement).

5.15.6 When explosives operations require personnel to reach around a shield to manipulate equipment, exposure shall be minimized (Requirement).

5.16 Heating Operations.

5.16.1 During synthesis, formulation, or experimental work, heat may be applied to initiate or maintain reaction, to increase solubility, or for other effects, if the principles below are followed.

5.16.1.1 Heat shall be applied indirectly using steam, a water bath, oil bath, or an approved laboratory electrical heating device such as a mantle (Requirement).

5.16.1.2 Utmost caution shall be exercised to ensure that reactive material does not come in direct contact with the heating elements (Requirement).

5.16.1.3 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 (Requirement). The heating device shall be mounted so it can be quickly separated from the reaction vessel without operator exposure (Requirement). Consideration should be given during design of the experiment to providing emergency cooling for the reaction vessel or its contents.

5.16.1.4 Heating of explosives with devices not incorporating the safety features of paragraph 5.16.1.5 shall be monitored at all times and the heating device turned off if the operator must leave for any reason (Requirement).

5.16.1.5 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 (Requirement). Systems capable of total containment of the effects of an explosion may be exempted from this requirement.

5.16.2 Periodic checks shall be made to ensure that an experiment is proceeding satisfactorily and that the apparatus is not boiling dry, malfunctioning, or otherwise encountering problems. (Requirement). In the case of remotely controlled operations, provisions shall be made for such observation, using equipment such as mirrors, television monitors, or similar devices. (Requirement).

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5.17 Laboratory Setups

5.17.1 Good workmanship and laboratory practice shall be exercised in making and operating laboratory setups, including the following requirements:

5.17.2 Equipment and apparatus shall be clean, in good condition, and in good working order (Requirement).

5.17.3 All glassware and apparatus shall be inspected for cracks, defects, and otherwise for suitability for service, before use (Requirement). Defective or damaged equipment shall be removed from service (Requirement).

5.17.4 Setups shall be geometrically and structurally stable (Requirement).

5.17.5 Work areas should be as neat and uncluttered as circumstances permit.

5.18 Low Concentration of Explosives in Solution.

5.18.1 When explosives are in a dilute solution, the characteristics of the solvent as well as those of the explosive shall be considered (Requirement).

5.18.2 Until the explosive is in solution, or if for any reason the explosive recrystallizes or precipitates out of solution, the safety guidelines for pure explosives shall apply (Requirement).

5.19 Explosives Sample Control.

5.19.1 Samples shall be delivered to the laboratory only at specific designated locations (Requirement).

5.19.2 Each sample shall be properly identified and labeled (Requirement).

5.19.3 Upon completion of the required tests or analyses, the sample shall be removed from the laboratory (Requirement).

5.19.4 All samples of new experimental explosive material submitted to a laboratory for analysis shall be accompanied by an information sheet giving available safety information to include, if known, hazard class division and compatibility group (Requirement).

5.20 Time Sensitive, Shock Sensitive, Peroxide Forming Chemical Management and Compatible Storage.

5.20.1 A wide variety of organic compounds spontaneously form peroxides by a free-radical reaction with molecular oxygen in a process of auto-oxidation.

5.20.1.1 Ethers are the most notorious in this regard.

5.20.1.2 Many others moieties are susceptible to the same process. Appendix B contains a comprehensive list of peroxide forming chemicals.

5.20.2 Table VII lists these moieties from most likely to form peroxides.

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Table VII. Moieties That Can Form Organic Peroxides.

1. Ethers and acetals with α-hydrogen	6. Vinyl alkynes with α-hydrogen	11. Secondary Alcohols
2. Alkenes with alyllic hydrogen	7. Alkylalkynes with α-hydrogen	12. Ketones with α-hydrogen
3. Chloroalkenes, fluoroalkenes	8. Alkylalkynes with tertiary α-hydrogen	13. Aldehydes
4. Vinyl halides, esters, ethers	9. Alkanes and cycloalkanes with tertiary hydrogen	14.Ureas, amides, and lactams with α-hydrogen atom on a carbon attached to nitrogen
5. Dienes	10. Acrylates, methacrylates	

5.20.3 Peroxides may explode when concentrated by evaporation or distillation, combined with compounds that create detonable mixture, or when disturbed by heat, shock or friction.

5.20.4 To minimize the hazard of peroxide formation, meticulously observe the following safety guidelines:

5.20.4.1 Any peroxidizable chemical with visible discoloration, crystallization, or liquid stratification shall be treated as potentially explosive (Requirement). Call Environment, Safety, and Health waste disposable office and the ESO for immediate assistance.

5.20.4.2 All containers of peroxide-forming chemicals shall be labelled with the date the chemical was received and the date the container was opened. (See Figure 6 for example of label.)

Warning-Peroxide Former

This material will form explosive peroxides during storage and must not be kept for more than _______ months after opening.

Date Received: _______________

Date Opened: ________________

Discard unopened containers 12 months after receipt. Call EH&S at XXX-XXXX for disposal.

DO NOT USE IF OPENED FOR MORE THAN ________ MONTHS.

Figure 6. Sample Label

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5.20.4.3 Flammable materials requiring refrigeration shall only be stored in a refrigerators approved for flammable storage.

Note: Refrigeration does not inhibit peroxide formation and may actually increase peroxide formation.

5.20.4.4 Containers shall be used or discarded by the manufacturer's expiration date, if the expiration date is available. If there is no expiration date stamped on the container, containers shall be discarded according to the schedule in paragraphs 5.20.6.4, 5.20.6.5, 5.20.6.7.2, and 5.20.6.7.3 below (Requirement).

5.20.4.5 An inventory of peroxide-forming chemicals in the laboratory shall be kept (Requirement). Quantities of peroxide-forming chemicals exceeding the need within the three or twelve month expiration period shall not be purchased (Requirement).

5.20.4.6 Peroxide-forming chemicals shall not be distilled to dryness (Requirement).

5.20.4.6.1 When possible, adding a non-volatile organic compound (such as mineral oil) can dilute the peroxides remaining after distillation.

5.20.4.6.2 Compounds listed in the tables shall always be tested for peroxides as described in reference 1 prior to distillation or evaporation (Requirement).

5.20.4.7 Rusted or stuck caps on a container of a peroxide-forming chemical shall not be forced (Requirement).

5.20.4.8 Glassware or containers that have been used with peroxide-forming compounds shall not be scraped or scrubbed if oily or crusty residue is present (Requirement).

5.20.5 Table VIII lists chemicals that form potentially explosive peroxides without concentrations.

Table VIII. Chemicals That Form Potentially Explosive Peroxides Without Concentration.[a]

Butadiene[b]	Chloroprene[c]
Divinyl acetylene	Isopropyl ether
Tetrafluoroethylene[b]	Vinylidene chloride

[a] Materials other than those listed may form peroxides. Review the references and contact your EH&S office for further information.
[b] When stored in an inhabited liquid monomer.
[c] When stored in a liquid monomer.

5.20.5.1 Materials may spontaneously form peroxides that will make the material shock- or heat-sensitive "on the shelf", that is, without any further concentrations through evaporation or distillation. A three-month storage limit shall be imposed on the materials and they shall be stored under nitrogen, if practical (Requirement).

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5.20.6 Table IX lists chemicals that form potentially explosive peroxides on concentration.

Table IX. Chemicals That Form Potentially Explosive Peroxides on Concentration. [a, b]

Acetal	Acetaldehyde
Benzyl alcohol	2-Butanol
Cyclohexanol	2-Cyclohexen-1-ol
Cumene	Decahydronaphthalene
Diethyl ether	Diethylene glycol dimethyl ether (Diglyme)
Dioxanes	Ethylene glycol dimethyl ether (Glyme)
4-Heptanol	Methyl acetylene
Methyl isobutyl ketone	3-Methyl-1-butanol
Methyl cyclopentane	2-Pentanol
4-Pentene-1-ol	1-Phenylethanol
2-Phenylethanol	2-Propanol (isopropanol)
Tetrahydrofuran	Tetrahydronaphthalene
Vinyl ethers	Other secondary alcohols

[a] Materials other than those listed may form peroxides. Review the references and contact EH&S for further information.
[b] Warning! May become unstable if concentrated intentionally or accidentally by the user.

5.20.6.1 Materials form peroxide levels that make the parent container shock sensitive only when the parent liquid is evaporated, which effectively concentrates the peroxides.

5.20.6.2 Peroxidizable chemicals have a propensity for exploding when used experimentally in operations such as distillation.

5.20.6.3 Volatile materials in Table VIII, such as diethyl ether, may evaporate if stored without a cap, and the resulting concentrated, peroxidized material may be shock sensitive.

5.20.6.4 Test chemicals in Groups 1 through 7 on Table VII within 12 months of receipt and every 6 months thereafter, and discard or deperoxidize, if necessary.

5.20.6.5 Test chemicals in Groups 8 through 14 on Table VII within 12 months of opening and every 6 months thereafter, and discard or deperoxidize if necessary.

5.20.6.6 Alcohol/water solutions do not form high concentrations of peroxides.

5.20.6.7 Table X lists chemicals that autopolymerize.

5.20.6.7.1 These chemicals may autopolymerize (and thus explode) when relatively small quantities of peroxides are formed.

5.20.6.7.2 Uninhibited chemicals shall be stored for ≤ 5 days (Requirement).

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5.20.6.7.3 If inhibited, chemicals may be stored for 12 months.

Table X. Chemicals That Autopolymerize.[a]

Acrylic acid	Acrylonitrile
Butadiene [b]	Chloroprene
Chlorotrifluoroethylene	Ethyl methacrylate
Styrene	Tetrafluoroethylene
Vinyl Acetate	Vinyl acetylene
Vinyl Chloride	Vinyl Pyridine

[a] Materials other than those listed may form peroxides. Review the references and contact EH&S for further information.
[b] When stored as a gas.

SECTION 5D CONCURRENT HAZARDOUS OPERATIONS

5.21 General

5.21.1 It is NASA policy consistent with operational requirements to provide limited exposure of the minimum number of people to the smallest quantity of explosives for the shortest period of time.

5.21.2 Recommended Practices and Precautions.

5.21.2.1 Unless a building or facility is specifically designed in accordance with TM5-1300 or equivalent approved methods (see Section 5K), for concurrent operations, permissible concurrent operations should be conducted in separate buildings located at the appropriate ILD from other operating buildings. When it becomes necessary to conduct concurrent operations in the same building, the operational layout shall be planned to segregate the primary hazards by substantial dividing walls, barricades, or other means to ensure maximum personnel protection (see Section 4C, Limit Control) (Requirement). Proposed segregation plans shall be approved by the local ESO (Requirement).

5.21.2.2 Multiple operations are not recommended within the same facility during hazardous operations involving high energetic materials with significant loss potentials, such as solid rocket booster motor segments. If operational necessity arises, however, special considerations to address the effects of noise levels, personnel stands, and personal air breathing or other equipment shall be evaluated to ensure the safety of operations and personnel emergency egress (Requirement). Proposed multiple operations plans shall be approved by the local ESO (Requirement).

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SECTION 5E HOUSEKEEPING

5.22 General

Structures containing explosives shall be kept clean and orderly (Requirement). A regular program of cleaning shall be carried on as frequently as local conditions require for maintaining safe conditions (Requirement). General cleaning shall not be conducted while hazardous operations are being performed (Requirement). Explosives should be removed from the area prior to general cleaning operations.

5.23 Precautions

5.23.1 The following are minimum precautions to be taken in explosives facilities cleaning operations:

5.23.2 Waste materials such as oily rags; hazardous waste such as combustible and explosive scrap; and wood, paper, and flammable packing materials shall not be mixed but shall be kept separately in carefully controlled, approved, and properly marked containers (Requirement). Containers shall be kept outside explosives facilities, except for containers that are required at workstations, and shall be emptied at least once each workday or shift (Requirement).

5.23.3 Containers for hazardous waste shall have covers, preferably self-closing (Requirement). Hazardous waste includes scrap powders, initiating or sensitive explosives or propellants, sweepings from explosive areas, and rags contaminated with these explosives or propellants.

5.23.3.1 These waste receptacles should have enough liquid, determined on the basis of material compatibility, to cover the scrap or rags.

5.23.3.2 If plastic bags are used as inserts, they shall be static dissipative and/or conductive and properly grounded (Requirement). Static-producing plastic bags shall not be allowed in sensitive explosive operations (Requirement).

5.23.4 Explosives, explosive dust, and other hazardous materials shall not be allowed to accumulate on structural members, radiators, heating coils, steam, gas, air, water supply lines, or electrical fixtures and equipment (Requirement).

5.24 Explosives Recovery and Reuse

All loose explosives recovered from sweeping floors of operating facilities shall be destroyed (Requirement). Explosives that are recovered from breakdown and cleanup operations shall be thoroughly inspected by operating supervisors and reused, screened, reprocessed, or destroyed as the situation warrants (Requirement). Explosives contaminated with dirt, dust, grit, or metallic objects shall be reprocessed to remove all foreign matter before reuse (Requirement).

5.25 Sweeping Compounds

5.25.1 Sweeping compounds containing wax or oil shall not be used on conductive floors (Requirement).

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5.25.2 Cleaning agents that include caustic alkalis shall not be used in locations containing “exposed explosives” because sensitive explosives compounds may be formed (Requirement).

5.25.3 Where there may be “exposed explosives” on the floor, hot water or steam is the preferred method of cleaning. When sweeping compounds are used, they shall be nonabrasive (Requirement).

5.25.4 Sweeping compounds may be combustible but shall not be volatile (Requirement). (Closed cup flash point shall not be less than 230 °F.)

5.25.5 The building or facility supervisor, foreman, or worker-in-charge shall prevent accumulations of excess explosives on materials and equipment (Requirement).

5.26 Smoking

5.26.1.1 Smoking, matches, open flames and spark-producing devices shall be prohibited inside of or within 50 feet of magazines or other explosives storage or operating areas and in all areas where liquid oxygen, liquid hydrogen, and other energetic liquid propellants and chemicals are present (Requirement).

5.26.1.2 Designated smoking areas beyond the 50 foot limit are subject to the following minimum precautionary measures:

5.26.1.2.1 Proper receptacles for cigarette and cigar butts and pipe heels shall be provided (Requirement).

5.26.1.2.2 Permanently installed electrical lighters of the push-button type that cut off when pressure is released shall be provided (Requirement).

5.26.1.2.3 Smoking shall be prohibited for personnel dressed in clothing/coveralls contaminated with explosives or flammable materials (Requirement).

5.26.1.2.4 Persons who work with toxic chemicals or containers or other toxic materials shall wash their hands before smoking (Requirement).

5.26.1.3 A “No Smoking” sign shall be posted at each entrance to an explosives facility or storage area (Requirement). Where applicable, a notice shall be posted that flame-producing devices must be turned over to the entry controller or placed in the container provided (Requirement).

5.26.2 Smoking shall be prohibited in, on, or within 25 feet of any motor vehicle, trailer, rail car, or material handling equipment loaded with explosives or similar hazardous material items (Requirement).

5.27 Prohibited Articles in Hazardous Areas

Except as provided in Section 5G, personnel shall not be permitted to carry cigarette lighters, matches, or any other flame or spark producing devices into hazardous materials restricted areas (Requirement).

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SECTION 5F PERSONAL PROTECTIVE EQUIPMENT

5.28 General.

5.28.1 In accordance with 29 CFR 1910.132, personal protective equipment (PPE) shall be issued to NASA employees at government expense in those situations where engineering controls, management controls, or other corrective actions have not reduced the hazard to an acceptable level or where use of engineering controls, management controls, or other techniques are not feasible (Requirement).

5.28.2 Pre-employment and pre-placement physical examinations shall include determination of the individual's ability to wear protective equipment that is required for the job (Requirement).

5.28.3 Each operation shall be analyzed by the qualified safety occupational health personnel to determine the need for any specific kinds of personal protective clothing or equipment (Requirement).

5.28.4 For special operations where employees are required to wear special clothing (e.g., explosive plant clothing, anti-contamination clothing, impervious clothing) a designated location for changing of clothes with suitable clothing lockers shall be provided (Requirement).

5.29 Clothing

5.29.1 Explosives coveralls (commonly referred to as powder uniforms) shall meet the following requirements:

5.29.2 Fasteners shall be nonmetallic (Requirement).

5.29.3 Coveralls shall be easily removable (Requirement).

5.29.4 Pockets shall be of the lattice type (Requirement).

5.29.5 Trouser legs, slacks, and sleeves should be tapered.

5.29.6 There shall be no cuffs on legs or sleeves (Requirement).

5.29.7 Coveralls shall extend over shoes/boots (Requirement).

5.29.8 The waist and neck should be fitted snugly to prevent ingress of powder dust, but not so tight as to cause skin irritation or dermatitis.

5.29.9 Cotton undergarments should be worn in any operation where the generation of static electricity would create a hazard (Requirement).

5.29.10 Garments shall be made from cloth in accordance with MIL-C-043122 or untreated cotton (Requirement).

5.30 Eye Protection

Suitable devices shall be worn by all personnel when working or visiting in eye hazard areas including aisles and hallways (Requirement). Industrial safety eyeglasses shall meet all the requirements of ANSI Standard Z87.1 (Requirement). Contact lenses cannot be considered as

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substitutes for appropriate eye protection. Contact lenses shall not be worn in work environments where there are chemicals, burners, smoke, dusts, particles, or molten metals (Requirement).

5.31 Hearing Protection

All personnel exposed to noise hazards, either intermittently or when assigned to a noise hazard area, shall wear hearing protection (Requirement). Safety Engineers and/or Industrial Hygienist Specialists shall review facilities at least annually to determine areas to be designated and posted as noise hazardous areas (Requirement).

5.32 Respiratory Protective Devices

Persons employed in dusty or toxic atmospheres where adequate ventilation or engineering controls are not feasible shall be provided with and required to wear respiratory protective devices approved by NIOSH for the particular hazard present (Requirement). Such equipment shall be maintained in serviceable condition and stored properly in lockers out of contaminated areas (Requirement). In situations where it has been medically determined that a worker is physically unable to perform work in a dusty or toxic atmosphere and cannot use respiratory protective devices, or conditions such as a growth of beard, sideburns, a skull cap that projects under the face piece, temple pieces on corrective spectacles, or goggles, or the absence of one or both dentures prevent a good face piece-to-face seal, that worker shall not be permitted to perform such tasks (Requirement).

5.33 Sweatbands

Operators shall wear sweatbands when necessary to avoid perspiration falling on material such as finely divided magnesium or aluminum, which may be ignited by moisture (Requirement). Where possible, these operations should be conducted in air-conditioned facilities.

5.34 Head Protection

Face shields shall be provided for personnel exposed to flying sparks, shavings, splashing liquids, or similar hazards (Requirement). Safety helmets or hard hats shall be worn when there is exposure to falling objects (Requirement). Bump hats may be worn in lieu of hard hats when working in confined spaces, but shall not be substituted for hard hats (Requirement). Safety hard hats shall comply with ANSI Z89.1 (including provisions for protection against electrical hazards when appropriate) (Requirement).

5.35 Conductive Footwear

Personnel who work upon conductive flooring, conductive mats, or conductive runners where explosives or flammable vapors are present shall wear nonsparking conductive footwear meeting requirements of standards ANSI Z41 (Requirement). Visiting personnel who enter these areas and who walk on conductive flooring materials shall also wear nonsparking conductive footwear (Requirement). Leg stats are acceptable for visitors or transients only as long as their basic footwear is of nonsparking construction. Exception: Personnel working on electrical equipment of facilities shall not wear conductive-sole shoes or other conductive footwear (Requirement).

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5.36 Conductive Footwear Specifications

5.36.1 Conductive shoes with conductive composition soles shall meet the requirements of ANSI Z41 (Requirement).

5.36.2 The maximum electrical resistance for each shoe, conductive rubber, or other type of conductive footwear shall not exceed 500,000 ohms when tested in accordance with ASTM F2412-05, Standard Test Methods for Foot Protection, with acceptance criteria per ASTM F2413-05, Standard Specification for Performance Requirements for Protective Footware (Requirement). Conductive shoes should be stored in lockers close to the room in which they are worn. Personnel who have been issued conductive footwear should not wear them from their place of work to their homes and return.

5.36.3 Testing of conductive shoes on individuals for use in explosives locations shall be made initially and daily thereafter to assure that the resistance from person to ground is less than 1 million ohms (Requirement). Tests shall not be performed in rooms where exposed explosives are present (Requirement).

5.37 Sparkproof Safety Shoes

The friction and shock of shoes on explosives materials and sparks from metal parts in shoes are potential hazards with all explosives materials.

5.38 Electrician's Safety Shoes

Electrical-hazards shoes made with a stitched and cemented construction and which are of good insulation shall be worn by employees performing electrical maintenance work indoors on 31- to 600-volt circuits and meet the requirements of ANSI Z41 (Requirement).

SECTION 5G TOOLING AND EQUIPMENT SAFETY

5.39 Hand Tool Safety

Only nonsparking tools shall be used in locations where sparks may cause a fire or explosion; e.g., for work in locations that may contain exposed explosives or hazardous concentrations of flammable dusts, gases, or vapors (Requirement).

5.40 Hot Work Permits

A written permit (Hot Work Permit) shall be required for temporary use of heat-producing equipment (e.g., welders, torches, soldering, heat guns) in the vicinity of operations involving explosives, flammable, or critical materials (Requirement).

5.41 Maintenance and Repairs to Equipment and Buildings

5.41.1 All new, newly modified, or repaired equipment to be used in hazardous operations shall be examined and actually tested by competent designated operating personnel and supervisors prior to use to assure safe working conditions (Requirement).

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5.41.2 If maintenance or repairs are to be conducted on equipment within the operating area, the local safety office shall verify that all exposed explosives and other static sensitive materials have been removed from the immediate work area (Requirement).

5.42 Electrical Testing of Explosives Components

5.42.1 Power Source.

5.42.1.1 Electrical (including electronics) test equipment shall use the weakest possible power source (Requirement). Battery-powered equipment should be used in lieu of a 110-volt source.

5.42.1.2 The power source shall be incapable of initiating the explosive item under test (Requirement).

5.42.1.3 Where a greater power source is required, positive means shall be provided to prevent delivery of power to the explosive item in quantities sufficient to initiate the item (Requirement).

5.42.2 Layout of Test Equipment.

5.42.2.1 Test equipment shall not be placed in hazardous atmospheres unless approved for such use (Requirement).

5.42.2.2 Operational shields shall be required for personnel protection unless the equipment is incapable of initiating the item being tested (Requirement).

5.42.2.3 The safest and most reliable means of attaining and retaining this initiating capability is to protect the test equipment, including leads, from electromagnetic radiation (EMR) and ESD (induction and radiation fields) and to provide the test equipment with a weak power source.

5.42.3 Use of Test Equipment.

5.42.3.1 Test equipment shall be operated only when in good working condition and by qualified personnel (Requirement).

5.42.3.2 Test equipment shall only be used for the purpose for which it was approved and designed (Requirement).

5.43 Heat Conditioning of Explosives Equipment

5.43.1 All ovens, conditioning chambers, dry houses, and similar devices and facilities shall be provided with dual independent automatic heat controls and pressure relief devices (Requirement).

5.43.2 For devices or facilities heated by steam only, the requirements for dual automatic heat controls may be satisfied by controlling the steam pressure with a reducing valve (with a maximum pressure of 5 psi, unless otherwise authorized) on the main building steam supply and a thermostat on the device or in the facility.

5.43.3 Heat-conditioning devices shall be constructed to effectively vent overpressure from internal explosion (Requirement).

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5.43.4 Blow-out panels, doors, and other venting apparatus should be restrained by barriers or catching devices to prevent excessive displacement in the event of an accidental explosion.

5.43.5 Heat-conditioning devices shall be effectively vented to permit the escape of dangerous gases that may evolve during the conditioning process (Requirement).

5.43.6 Steam shall be used as the heating medium for conditioning devices whenever practicable. If electric heating elements are used, the elements shall be so located that there is no possibility of contact with explosives or flammable materials (Requirement).

5.43.7 Air used for heating shall not be recirculated if the heating surfaces exceed a temperature of 228 °F or if the air contains materials that may collect on the heating elements (Requirement). Blades on fans for circulation of air shall be nonsparking material and if possible, the electric motor shall be installed on the exterior of the device (Requirement).

5.43.8 Electrical equipment and fixtures in or on a heat-conditioning device used in explosives or flammable materials operations shall be approved for the operation in the appropriate hazardous atmospheres (Requirement).

5.43.9 All noncurrent-carrying metal parts of a heat conditioning device shall be electrically interconnected and grounded (Requirement).

5.43.10 All heat-conditioning devices should be installed in an isolated location and arranged to afford maximum protection to personnel from the effects of an incident.

5.43.11 Heat-conditioning devices should be separated from each other by distance or protective construction to prevent an explosion incident in one device from propagating to an adjacent device.

5.43.12 Heat-conditioning device operating procedures shall include the following conditions:

5.43.12.1 The explosives materials in the device shall be limited to the type and quantity authorized for the specific device (Requirement).

5.43.12.2 The critical parameters of explosives compositions shall be known before processing in a heat-conditioning device (Requirement). The device shall not exceed established limits (Requirement).

5.43.12.3 Heat-conditioning device temperatures shall be checked during operation at specified intervals (Requirement). The checks should be conducted at more frequent intervals during periods of conditioning.

5.43.12.4 The conditioning devices, dusts, vacuum lines, and other parts subject to contamination by hazardous materials shall be cleaned prior to introducing a new or different item or composition for conditioning (Requirement).

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SECTION 5H EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS HAZARD CLASSIFICATION

5.44 Classification System

5.44.1 To ease identification of hazard characteristics and thus promote safe storage and transport of explosives, NASA shall use the system of explosives classification of the DOT, which is an implementation of the international system of classification devised by the United Nations Organization (UNO) for transport of dangerous goods (hereinafter referred to as "DOT classification," and explosives classes as "DOT Class 'X'" (Requirement). Additional information regarding explosives classification may be found at the following URL: https://www3.dac.army.mil/esidb/login/

5.44.2 The UNO classification system consists of nine hazard classes (See ST/SG/AC.10/1/Rev. 14). Thirteen compatibility groups are included for segregating explosives on the basis of similarity of characteristics, properties, and accident effects potential.

5.44.3 Most explosives are included in UN (and therefore DOT) Class 1. Some items that contain a small amount of explosives and also one or more other hazardous materials (and also some liquid propellants) might be assigned by DOT to a different class (2 through 9), based on the predominant hazard. Any item that contains explosives, but is assigned to other than Class 1 due to the predominant hazard, is considered to have a net explosive weight of zero for QD determinations. Even though such items are assigned to other than Class 1, they shall still have a storage compatibility group designation, and may be combined in storage with compatible Class 1 items (Requirement). When other than Class 1 explosives items are stored alone, the storage site shall be treated as a warehouse (Requirement). All segregation of hazardous materials shall be in accordance with the applicable OSHA regulations and the segregation and compatibility tables found in 49 CFR 177.848.

5.44.4 A hazard classification is assigned for each explosive item in the form and packaging in which it is normally stored and offered for transportation as cargo. The NASA organization sponsoring development of, or first adopting for use, an explosives item shall obtain a hazard classification in accordance with procedures required by 49 CFR 173.56 (Requirement).

5.44.4.1 When explosive items are not in the form and packaging in which they are normally stored and shipped, different hazard classifications may apply due to changes in spacing, orientation, confinement, and other factors. Sometimes testing of unpackaged components may be required in order to demonstrate the validity of classifications used for siting unpackaged explosive devices/components, or conservative assumptions must be made about the potential severity of an accidental explosion. In many cases, these "unpackaged" or "in-process" hazard classifications are established and approved as part of the site plan approval process with appropriate QD established through engineering analysis as described in Section 5K.

5.44.5 Class 1 is divided into six Divisions that indicate the character and predominance of associated hazards. For further refinement of this hazard identification system, a numerical figure (in parentheses) may be used to indicate the minimum separation distance (in hundreds of feet) for protection from debris, fragments, and firebrands when distance alone is relied on for

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such protection. This number is placed to the left of the Hazard Division (H/D) designators 1.1 through 1.3, such as (18)1.1, (08)1.2, and (02)1.3.

5.44.5.1 Mass-explosion (H/D 1.1). Items in this division are primarily a blast hazard and may be expected to mass-detonate when a small portion is initiated by any means. Items in Hazard Division 1.1 include bulk explosives, some propellants, demolition charges, some missile components, and some rockets.

5.44.5.1.1 Explosives in H/D 1.1 also generally present a fragmentation hazard, either from the case of the explosive device or from the packaging or facility in which the explosives are stored. Unless otherwise specified, a minimum distance of 1,250 ft shall be used to separate H/D 1.1 explosives NEWQD of 450 pounds or more from inhabited buildings (Requirement). For NEWQD less than 450 pounds, Paragraph 5.51.1.7 may be used. Some explosives items have been tested and demonstrated to have less than the specified 1,250 ft fragment hazard. In these instances, the minimum IBD may be given in parentheses where the hazard classification is listed, such as (07)1.1 for a 700 ft minimum IBD.

5.44.5.2 Non-mass explosion, fragment producing (H/D 1.2). H/D 1.2 items do not mass detonate when configured for storage or transportation if a single item or package is initiated. When these items function, the results are burning and exploding progressively with no more than a few reacting at a time. The explosion may throw fragments, firebrands, and non-functioned items from the point of initiation. Blast effects are limited to the immediate vicinity and are not the primary hazard.

5.44.5.2.1 The effects produced by the functioning of H/D 1.2 items vary with the size and weight of the item. For Centers co-located with the military, H/D 1.2 explosives items are separated into three subdivisions (1.2.1, 1.2.2, 1.2.3) in order to account for the differences in magnitude of these effects for purposes of setting quantity-distance criteria. The more hazardous items are referred to as H/D 1.2.1 items and have an NEWQD greater than 1.60 pounds. The less hazardous items, referred to as H/D 1.2.2, have an NEWQD less than or equal to 1.60 pounds per item. These two H/D 1.2 subdivisions are shown below with their definitions:

- H/D 1.2.1: NEWQD > 1.60 pounds;
- H/D 1.2.2: NEWQD < 1.60 pounds.

For H/D 1.2.3, see paragraph 5.44.5.2.4.) (For purposes of transportation, all labeling shall be as H/D 1.2 only.)

5.44.5.2.2 The maximum credible event (MCE) for a specific class/division 1.2.1 item is the largest quantity of explosives expected to explode at one time when a stack of those specific items is involved in a fire.

5.44.5.2.3 The QDs specified for H/D 1.2 explosives achieve the desired degree of protection against immediate hazards from an incident. Events involving H/D 1.2 items lob large amounts of unexploded components and subassemblies, which remain hazardous after impact. Such items are likely to be more hazardous than in their original state because of possible damage to fuse safety devices or other features by heat and impact. Many types of explosive devices that

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contain subcomponent explosives can be expected to be projected out to distances as great as the relevant IBDs.

5.44.5.2.4 H/D 1.2.3 (Unit Risk H/D 1.2) is a special storage subdivision for items that satisfy either of the following sets of criteria: items that do not exhibit any sympathetic detonation response in the stack test or any reaction more severe than burning in the external fire test, bullet impact test, and the slow cook-off test; or items that satisfy the criteria for H/D 1.6 except the item contains a non-EIDS device.

5.44.5.3 Mass fire (H/D 1.3). These items burn vigorously, and the fires are difficult to put out. Explosions are usually pressure ruptures of containers, which may produce fragments (especially missile motors), but do not produce propagating shock waves or damaging blast overpressure beyond IMD. A severe hazard of the spread of fire may result from tossing about of burning container materials, propellant, firebrands, or other debris. Depending on the amounts of burning explosive materials, their downwind toxic effects usually do not extend beyond IBDs.

5.44.5.4 Moderate fire - no blast (H/D 1.4). Items in this division present a fire hazard with no blast hazard and virtually no fragmentation and/or toxic hazard beyond the fire hazard clearance ordinarily specified for high-risk materials. This division includes items such as small arms ammunition without explosive projectiles, fuse lighters and squibs, colored smoke grenades, and explosive valves or switches.

5.44.5.5 Very insensitive explosives (H/D 1.5). This division comprises substances that have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport or storage.

5.44.5.6 Extremely insensitive explosives (H/D 1.6). This division comprises articles that contain only extremely insensitive detonating substances and that demonstrate a negligible probability of accidental ignition or propagation. Note: Fused H/D 1.6 explosive devices shall contain either an EIDS fuse or a nonexplosive fuse (fuse contains no explosives); otherwise the article is classified as Unit Risk Hazard Division 1.2 (H/D 1.2.3) (Requirement).

5.44.5.7 The following is a comparison of the "old" DOT class and the above listed classes:

New	Old
1.1	Class A
1.2	Class A or Class B
1.3	Class B
1.4	Class C
1.5	Blasting Agents
1.6	No Applicable Hazard Class

5.45 Storage Principles

5.45.1 The highest degree of safety in explosives storage could be assured if each item or division were stored separately. However, such ideal storage generally is not feasible. A proper balance of safety and other factors frequently requires mixing of several types of explosives in storage.

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5.45.2 Explosives shall not be stored together with dissimilar materials or items that present positive hazards to the explosives (Requirement). Examples are mixed storage of explosives with flammable or combustible materials, acids, or corrosives.

5.45.3 Different types, by item and division, of explosives may be mixed in storage provided they are compatible. Explosives are assigned to a compatibility group (CG) when they can be stored together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Considerations that were used in developing the CGs included but not limited to:

5.45.3.1 Chemical and physical properties.

5.45.3.2 Design characteristics.

5.45.3.3 Inner and outer packing configurations.

5.45.3.4 Quantity-distance (QD) division.

5.45.3.5 Net explosive weight (NEW).

5.45.3.6 Rate of deterioration.

5.45.3.7 Sensitivity to initiation.

5.45.3.8 Effects of deflagration, explosion, or detonation.

5.45.4 Subject to application of these standards and particularly to compatibility as defined herein, explosives may be mixed in storage when such mixing facilitates safe operations and promotes overall storage efficiency. Assignment of items to CGs requiring separate storage shall be minimized consistent with actual hazards presented and not based on administrative considerations or end use (Requirement).

5.45.5 As used in this standard, the phrase "with its own means of initiation" indicates that the explosive item has its normal initiating device assembled to it, and this device is considered to present a significant risk during storage. However, the phrase does not apply when the initiating device is packaged in a manner that eliminates the risk of causing detonation of the item in the event of accidental functioning of the initiating device, or when fused end items are so configured and packaged as to prevent arming of the fused end items. The initiating device may even be assembled to the explosives item provided its safety features preclude initiation of detonation of the explosives filler of the end item in the event of an accidental functioning of the initiating device.

5.46 Storage and Compatibility Groups (CG)

In view of explosives storage principles and the considerations for mixed storage, explosives are assigned to the appropriate one of 13 CGs (A through H, J, K, L, N, and S). Storage and CGs can also be assigned to hazardous materials in other (non-Class 1 explosives) DOT hazard classes under some circumstances.

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5.46.1 Group A. Initiating explosives. Bulk initiating explosives that have the necessary sensitivity to heat, friction, or percussion to make them suitable for use as initiating elements in an explosive train. Examples are wet lead azide, wet lead styphnate, wet mercury fulminate, wet tetracene, dry cyclonite (RDX), and dry pentaerythritol tetranitrate (PETN).

5.46.2 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 explosive train. Examples are detonators, blasting caps, small arms primers, and fuses.

5.46.3 Group C. Bulk propellants, propelling charges, and devices containing propellant with or without their means of ignition. Items that upon initiation will deflagrate, explode, or detonate. Examples are single-, double-, triple-base, and composite propellants and rocket motors (solid propellant).

5.46.4 Group D. Black powder, high explosives, and devices containing high explosives without their own means of initiation and without propelling charge, or a device containing an initiating explosive and containing two or more independent safety features. Explosives that can be expected to explode or detonate when any given item or component thereof is initiated except for devices containing initiating explosives with independent safety features. Examples are bulk trinitrotoluene (TNT), Composition B, black powder, wet RDX, or PETN.

5.46.5 Group E. Ammunition containing HE without its own means of initiation and containing or with propelling charge (other than one containing a flammable or hypergolic liquid). Examples are rockets or guided missiles.

5.46.6 Group F. Ammunition containing HE with its own means of initiation and with propelling charge (other than one containing a flammable or hypergolic liquid) or without a propelling charge.

5.46.7 Group G. Fireworks, illuminating, incendiary, and smoke, including hexachlorethane (HC) or tear-producing devices other than those that are water activated or which contain WP or flammable liquid or gel. Devices that, upon functioning, result in an incendiary, illumination, lachrymatory, smoke, or sound effect. Examples are flares, signals, incendiary or illuminating, and other smoke or tear-producing devices.

5.46.8 Group H. Devices containing both explosives and WP or other pyrophoric material. This group contains fillers, which are spontaneously flammable when exposed to the atmosphere. Examples are WP, plasticized white phosphorus (PWP), or other devices containing pyrophoric material.

5.46.9 Group J. Devices containing both explosives and flammable liquids or gels. This group contains 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 devices, fuel-air explosive (FAE) devices, and flammable liquid-fueled missiles.

5.46.10 Group K. Devices containing both explosives and toxic chemical agents. This group contains chemicals specifically designed for incapacitating effects more severe than lachrymation.

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5.46.11 Group L. Explosives not included in other compatibility groups. Devices having characteristics that do not permit storage with other types or kinds of explosives, or dissimilar explosives of this group. Examples are water-activated devices, prepackaged hypergolic liquid-fueled rocket engines, certain FAE devices, triethyl aluminum (TEA), TEB, and TEA/TEB, damaged or suspect items of any group, and explosives in substandard or damaged packaging in a suspect condition or with characteristics that increase the risk in storage. Types presenting similar hazards may be stored together but not mixed with other groups

5.46.12 Group N. Hazard Division 1.6 devices containing only extremely insensitive detonating substance (EIDS). If dissimilar Group N explosives are mixed together and have not been tested to assure non-propagation, the mixed explosives are considered to be Hazard Division 1.2, Compatibility Group D, for purposes of transportation and storage.

5.46.13 Group S. Explosives presenting no significant hazard. Explosives so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not hinder firefighting significantly. Examples are thermal batteries, explosive switches or valves, and other items packaged to meet the criteria of this group.

5.47 Mixed Storage

Explosives of different compatibility groups may only be mixed in storage as indicated in Table XI.

Table XI. 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					Z	X
G		Z	Z	Z	Z	Z	X					Z	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	Z	Z					X	X
S		X	X	X	X	X	X	X	X			X	X

NOTES

(1) The marking "X" at an intersection of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to Note 2, below.

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(2) The marking "Z" at an intersection of the above chart indicates that when warranted by operational considerations or magazine nonavailability, and when safety is not sacrificed, logically mixed storage of limited quantities of some items of different groups may be approved (See Note 7). These relaxations involving mixed storage shall be approved in writing by the ESO and are not considered waivers (Requirement). These items shall be kept packaged according to DOT shipping container specifications of Special Packaging Instructions, or equivalent (Requirement). Also these items shall not be opened in the magazine for the purpose of issuing unpacked explosives or components (Requirement). Outer containers shall not be opened except for the following actions (Requirement):
   (a) Opening outer containers for removal of inner packages. Complete any further processing of these items in an approved operating location.
   (b) Opening "lite" boxes for inventory purposes. Use of pneumatic nail guns is prohibited in the explosives storage location.
   (c) Opening containers of H/D 1.4 explosives to allow inspection. Unpack, inspect, and repack in the storage location if storage is limited to H/D 1.4 items.

(3) Equal numbers of separately packaged components of complete items of any single type of device may be stored together. When so stored, compatibility is that of the assembled item, that is, WP filler in Group H, HE filler in Groups D, E, or F, as appropriate.

(4) Group K shall be stored separately from other groups, and also may require separate storage within the group (Requirement). NASA Headquarters, SARD, shall determine which items under Group K may be stored together and those which must be stored separately.

(5) Items without explosives that contain substances properly belonging to another U.N. hazard class may be assigned to the same compatibility group as items containing explosives and the same substance, and be stored with them.

(6) The ESO may authorize devices designated “Practice” by National Stock Number (NSN) and nomenclature to be stored with the fully loaded device it simulates.

(7) The ESO may authorize the mixing of compatibility groups, except items in Groups A, K, and L in limited quantities (generally 1000 lbs or less).

(8) For purposes of mixing, all items shall be packaged in approved storage/shipping containers (Requirement). Items shall not be opened for purposes of issuing unpackaged items in storage locations (Requirement). Outer containers may be opened in storage locations for purposes of inventorying; for removing items still inside an approved inner package in limited amounts; and, for magazines storing only Hazard Division 1.4 items, unpacking, inspecting, and repacking the Hazard Division 1.4 devices.

(9) When using the “Z” mixing authorized by Note 2, articles of either compatibility Group B or F, each shall be segregated in storage from articles of other compatibility groups by means that prevent the propagation of Group B or F articles to articles of other compatibility groups (Requirement).

(10) If dissimilar H/D 1.6 N items are mixed together and have not been tested to ensure non-propagation, the mixed items shall be individually considered to be H/D 1.2.1 D or H/D 1.2.2 D based on their NEWQD or overriding fragmentation characteristics for purposes of transportation and storage (Requirement). When mixing CG N items with CG B through CG G or with CG S, see paragraphs 5.50.7.2.1, 5.50.7.2.4, 5.50.7.2.9, and 5.50.7.2.10 to determine the H/D for the mixture.

SECTION 5I QUANTITY DISTANCE REQUIREMENTS

5.48 General

This Section outlines explosives Quantity-Distance (QD) criteria and related standards for storing and handling explosives at NASA explosive facilities.

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5.49 Principles

5.49.1 The QD criteria and tables prescribe acceptable minimum separation distances for storing and handling explosives. They also state maximum quantities of the various class/division of explosives allowed in any one location. Explosives limits set up locally shall be no greater than needed for a safe and efficient operation (Requirement). Operations and personnel shall be located to minimize exposure to hazards (Requirement).

5.49.2 Where explosions are to be deliberately initiated, a greater degree of protection is normally needed. This may include maximum possible confinement of the explosion at the source, barricades adjacent to the explosives or exposed sites, greater separation distances, or other measures. This also could require "operational shielding" for personnel involved in evacuation of unprotected personnel from the area.

5.49.3 Separation of explosive locations is needed to minimize explosive hazards. Locations that contain explosives shall be separated from the following (Requirement).

5.49.3.1 Other locations that contain explosives and propellants.

5.49.3.2 Inhabited buildings, including structures or other places not directly related to explosives operations, where people usually assemble or work.

5.49.3.3 Public traffic routes.

5.49.3.4 Operating lines or buildings, including structures or other places where people usually assemble or work, that are directly related to explosives operations.

5.49.3.5 Petroleum, oil, and lubricant (POL) storage.

5.49.3.6 Utilities, buildings, and facilities.

5.49.3.7 Aircraft parking and storage areas, runways and approach zones, and taxiways.

5.49.3.8 Facility boundaries.

5.49.4 Magazine Siting Requirements. Magazines are sited relative to each other (i.e., IMD) so that communication of explosion from one to another is unlikely. Actual siting requirements are influenced both by the construction features of the magazines and the types and quantities of explosives they contain.

5.49.5 Hazardous energetic materials, including explosive and pyrotechnics materials, shall not be stored within an operating building except for the minimum quantities necessary to maintain individual operations (Requirement). Supplies above this limit shall be kept in service storage magazines located at ILD based on the net explosive weight of the explosives in the service storage magazine (Requirement).

5.49.6 If required by operational necessity, explosives that are part of the work in process within the operational building may be stored during nonoperational hours in operating buildings, provided the following requirements are strictly observed:

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5.49.6.1 Explosive limits shall not be exceeded (Requirement).

5.49.6.2 Compatibility requirements shall be met (Requirement).

5.49.6.3 Containers of bulk explosives or propellants shall be properly secured and covered (Requirement).

5.49.6.4 Processing equipment shall be empty and cleaned (Requirement).

5.49.6.5 The building shall be equipped with an automatic sprinkler system (Requirement).

5.50 Establishment of Quantity of Explosives and Distances

5.50.1 The bases for determining required separation distances are:

5.50.1.1 The H/D types and NEW of explosives present in an explosive facility.

5.50.1.2 The NEW of the H/D requiring the greatest separation establishes the QD for the facility when it is used for multiple operations.

5.50.1.3 The NEW for the High Performance Magazines (HPM) is based on its maximum credible event (MCE) (i.e., the sum of the contents of an individual open cell and the loading dock rather than the aggregate NEW for the entire magazine). The NEW for the HPM shall not exceed 60,000 lbs (Requirement).

5.50.1.4 An alternate siting approach based on testing and analysis to determine the MCE in lieu of applying QD tables shall be permitted for any explosives classification used as a propellant in space vehicle launch applications and associated ground testing provided all of the following requirements are met:

5.50.1.4.1 The responsible entity shall develop a test and analysis plan including modeling requirements and acceptance thresholds for QD siting based on MCE and submit it to the ESO and SARD for review and approval prior to implementation (Requirement).

5.50.1.4.2 The alternate MCE approach shall consider the maximum credible hazard associated with propagation, pressure waves, heat flux, fragmentation, reaction byproducts, and any other identified credible hazards of the explosives, and that hazard resulting in the greatest inhabited building distance (IBD) shall govern (Requirement). That is, for example, if the hazard associated with fragmentation extends further than that for heat flux, then fragmentation is the governing hazard.

5.50.1.4.3 Analysis shall include risk analysis as well as any modeling of the reaction and its effects required to demonstrate applicability of testing and extrapolations, and QD determination (Requirement).

5.50.1.4.4 The alternate MCE approach may take into account or require engineering and procedural controls, separation by time, distance, or barriers (for blast wave coalescence, heat flux, or other characteristics of the reaction), and actual material reaction characteristics.

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5.50.1.4.5 The alternate MCE approach shall take into account the actual reaction characteristics, whether greater or less than those in conventional models (Requirement).

5.50.1.4.6 Flight distances beyond the immediate facility need not be considered for propulsive units (see paragraph 5.50.3).

5.50.1.4.7 For those cases in which radiant heat flux governs:

5.50.1.4.7.1 Credible radiant heat flux scenarios for the heat source shall be base on actual material characteristics, source location, ignition scenarios, shielding, etc (Requirement). For example, the applicable heat flux profile for the case of a series of sequentially ignited burns of SRMs is considered to be the profile of the sum of the individual heat fluxes distributed over time.

5.50.1.4.7.2 IBD shall be no less than the distance which will prevent second degree burns (Requirement). This distance may be determined based on an exposure period less than the total burn duration, provided that the following conditions are met:

5.50.1.4.7.2.1 Credible escape/mitigation scenarios shall be developed and validated (Requirement). For example, exposure might be limited by personnel moving in a timely fashion to a safe haven behind a wall capable of withstanding the expected radiant heat flux for the full duration of the burn without ignition.

Note: Any other potential effects would be considered separately.

5.50.1.4.7.2.2 Training programs shall be developed and implemented to ensure that personnel are aware of the hazard and understand both what action is required of them and the importance that action be taken immediately (Requirement).

5.50.1.4.7.2.3 Exposure periods greater than t (seconds, in the following formula) shall not be acceptable (Requirement):

$$t = 200q^{-1.46}$$

where:

t = time (seconds) to blister

q = incident thermal radiation (kW/m^2) (Incident heat flux less than 1.8 kW/m^2 need not be considered.

Note: This formula is based on Equation 6 in the SFPE Engineering Guide, "Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation."

5.50.1.4.7.2.4 Buildings within conventional IBD arcs shall be capable of withstanding the expected radiant heat flux at their sited distance to the extent that they continue to provide protection to personnel (Requirement).

5.50.1.4.8 The final QD determination based on the MCE shall be submitted to the ESO and SARD for review and approval (Requirement). The planning and approval may be an iterative process.

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5.50.1.5 The bases for subdividing a quantity of explosives into smaller units for the purpose of QD reduction are provided below.

5.50.1.5.1 Separation by time. When two or more stacks of equal NEW detonate within short time intervals, the blast waves will coalesce. (A short time interval is defined as a time in milliseconds that is less than $4.0W^{1/3}$ of any one stack in lbs for lateral (side-to-side) target positions and less than $5.6W^{1/3}$ of any one stack in lbs for axial target positions.) The combined shock wave, after coalescence, will be that of a single detonation of a charge equal to the summation of the several stacks. When coalescence does not occur, the MCE for the stacks is equal to the NEW for one stack.

5.50.1.5.2 Separation by barriers. Barriers designed per the principles of DDESB Technical Paper 15 and Paragraph 4.25.6 will ensure no propagation between explosives stacks. When barriers are constructed per this guidance or when supported by test data, the MCE is equal to the NEW of the explosives stack with the largest QD requirement. Otherwise, QD computations shall be based upon the summation of NEW for all of the explosives stacks (Requirement). Barrier design shall include adequate standoff distances and take into account sensitivity of acceptor explosives) (Requirement).

5.50.2 The QD criteria for a potential exposure site – exposed site (PES-ES) pair, when both contain explosives, are determined by considering each location, in turn, as a PES and an ES. The quantity of explosives to be permitted in each PES shall be the amount permitted by the distance specified in the appropriate QD tables (Requirement). The separation distance required for the pair is the greater of the two separation distances. An exception is permitted for service magazines supporting an explosives operation (see below).

5.50.3 Flight ranges for units (e.g., rockets, missile motors, and cartridge or propellant actuated devices (CADS/PADS)) in a propulsive state shall be disregarded because it is impractical to specify QD separations that allow for their designed flight range (Requirement).

5.50.4 Separation distances are measured along straight lines. For large intervening topographical features such as hills, measure over or around the feature, whichever is shorter. For golf courses, measure to the nearest edge of the tee or green or to the centerline of fairways.

5.50.5 Measurements of distance for determining the maximum allowable quantity of explosives shall be made to the nearest part of an ES from (Requirement):

5.50.5.1 The nearest wall of the PES.

5.50.5.2 The exterior of the nearest intervening wall to the controlling explosives stack, when the PES is subdivided.

5.50.6 When an explosives conveyance (e.g., railroad car or motor vehicle) containing explosives is not separated from a PES in such a manner as to prevent mass detonation, then the conveyance and PES shall be considered as a unit and their NEW shall be summed (Requirement). The separation distance shall be measured from the nearest outside wall of the PES or conveyance, as appropriate, to an ES (Requirement). If the explosives are separated so that mass detonation will not occur, the separation distance shall be measured from the nearest controlling PES or conveyance to an ES (Requirement).

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5.50.7 Determination of Net Explosive Weight.

5.50.7.1 The quantity of explosives in a magazine, operating building, or other explosives site is considered to be the net explosive weight (NEW) of the controlling class of explosives contained therein (the class requiring the greatest separation). The total quantity of explosives in a facility is calculated as shown below. Where NASA Headquarters, SARD, has approved an HE equivalence for a propellant and/or pyrotechnic, then this HE equivalence may be used for determining NEW. In such cases, the sum of the HE plus the HE equivalence of the propellant and/or pyrotechnic is the applicable NEW.

5.50.7.1.1 Mass-explosion (H/D 1.1). The NEW is the total weight of all HE plus the total weight of all propellant in the H/D 1.1 items.

5.50.7.1.2 Non-mass explosion, fragment producing (H/D 1.2)

> *Note: The 1.2.1, 1.2.2, and 1.2.3 classifications are used only by those Centers co-located with the military, and never for transportation purposes.*

5.50.7.1.2.1 H/D 1.2.1. The NEW is the total weight of all HE plus the total weight of propellant in all H/D 1.2.1 items. In certain situations, the maximum credible event (MCE), as outlined in Paragraph 5.51.2.3, will be used as the basis for determining applicable QD.

5.50.7.1.2.2 H/D 1.2.2. The NEW is the total weight of all HE plus the total weight of propellant in all H/D 1.2.2 items.

5.50.7.1.2.3 H/D 1.2.3. The NEW is the total weight of all HE plus the total weight of propellant in all H/D 1.2.3 items. This material is treated as H/D 1.3, however, a minimum IBD applies, as outlined in Paragraph 5.51.2.12.

5.50.7.1.3 Mass fire, minor blast, or fragment (H/D 1.3). The NEW is the total weight of all HE, propellant, and pyrotechnics in all H/D 1.3 items.

5.50.7.1.4 Moderate fire, no blast, or fragment (H/D 1.4). The NEW is the total weight of all HE, propellant, and pyrotechnics in all H/D 1.4 items.

5.50.7.1.5 Explosive substance, very insensitive (with mass explosion hazard). (H/D 1.5). The NEW is the total weight of all HE plus the total weight of propellant in all H/D 1.5 items.

5.50.7.1.6 Explosive article, extremely insensitive (H/D 1.6). The NEW is the total weight of EIDS in all H/D 1.6 items. Note, however, that the weight of EIDS in a single H/D 1.6 item must also be considered, as specified in Table XXV, for determining QD.

5.50.7.1.7 Exclusions. Device fillers that do not contribute to explosive effects (e.g., colored and HC smoke, dyes, irritants, white phosphorus (WP), plasticized white phosphorus (PWP), and pyrophoric agent (TPA)) are excluded when determining NEW.

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5.50.7.1.8 If approved buffer configurations are provided, the NEW is the explosives weight of the largest stack plus, if applicable, the explosives weight of the buffer material, excluding the NEW of H/D 1.4.

5.50.7.2 Determining the Explosives Weight for Mixed H/Ds

5.50.7.2.1 The presence of H/D 1.4 does not affect the NEW of mixed H/D. However, for QD determinations, H/D 1.4 criteria shall be considered (Requirement).

5.50.7.2.2 When H/D 1.1 is mixed with any other H/D, the mixture is treated as H/D 1.1, except:

5.50.7.2.2.1 H/D 1.1 with H/D 1.2 (H/D 1.2.1,H/D 1.2.2, and H/D 1.2.3). Whichever of the following generates the largest QD is used: a) sum the NEW for H/D 1.1 and NEW for H/D 1.2 and treat the mixture as H/D 1.1, or b) the NEW of the mixture is the NEW of the H/D 1.2 subdivision requiring the largest QD.

5.50.7.2.3 H/D 1.1 with H/D 1.3. The NEW for H/D 1.1 and the NEW for H/D 1.3 are summed and the mixture treated as H/D 1.1, except:

5.50.7.2.3.1 Where testing has shown that H/D 1.1 components installed on H/D 1.3 items; e.g., Solid Rocket Motors (SRM) in operational configuration, in storage will not serve as an explosive donor for the H/D 1.3 to provide a significant explosive yield, the system may be be treated for QD purposes as H/D 1.3 using the NEW of the H/D 1.3. The NEWQD is determined by the single package test (UN Test 6a) or its equivalent.

5.50.7.2.4 H/D 1.1 with H/D 1.6. The NEW for H/D 1.1 and the NEW for H/D 1.6 are summed and the mixture treated as H/D 1.1.

5.50.7.2.5 H/D 1.2.1 with H/D 1.2.2 or H/D 1.2.3. The NEW for the mixture is the NEW of the subdivision requiring the largest QD.

5.50.7.2.6 H/D 1.2.2 with H/D 1.2.3. The NEW for the mixture is the NEW of the subdivision requiring the largest QD.

5.50.7.2.7 H/D 1.2.1 with H/D 1.2.2 with H/D 1.2.3. The NEW for the mixture is the NEW of the subdivision requiring the largest QD.

5.50.7.2.8 H/D 1.2 (H/D 1.2.1,H/D 1.2.2, and H/D 1.2.3) with H/D 1.3. The NEW for the mixture is the NEW of the H/D requiring the largest QD.

5.50.7.2.9 H/D 1.2 (H/D 1.2.1,H/D 1.2.2, and H/D 1.2.3) with H/D 1.6. The H/D 1.6 is treated as H/D 1.2.3 and the NEW determined in accordance with 5.50.7.2.5 through 5.50.7.2.7 above, as applicable.

5.50.7.2.10 H/D 1.3 with H/D 1.6. The NEW for the H/D 1.6 and the NEW for H/D 1.3 are summed and the mixture treated as H/D 1.3.

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5.51 Hazard Division QD Tables

5.51.1 Hazard Division 1.1

5.51.1.1 Inhabited Building Distance (IBD) (40-50 $W^{1/3}$ ft – 1.2 to 0.9 psi). The IBD shall be maintained between a PES and buildings or structures, other than operating buildings, occupied in whole or in part by human beings, both within and outside NASA establishments, including (but not limited to) schools, churches, residences (quarters), aircraft passenger terminals, stores, shops, factories, hospitals, theaters, cafeterias, post offices, and exchanges (Requirement). See Paragraph 6.3 for discussion of expected explosion effects at IBD. Locations to which the IBD applies also include the following:

5.51.1.1.1 Inhabited buildings, administrative and housing areas.

5.51.1.1.2 Center/facility boundaries.

5.51.1.1.3 Athletic fields and other recreation areas when structures are present.

5.51.1.1.4 Flight-line passenger service functions.

5.51.1.1.5 Main power houses providing vital utilities to a major portion of a center/facility.

5.51.1.1.6 Storehouses and shops that, by reason of their vital strategic nature, or high intrinsic value of their contents, should not be placed at risk.

5.51.1.1.7 Functions that, if momentarily put out of action, would cause an immediate secondary hazard by reason of their failure to function.

5.51.1.1.8 Public traffic routes with high traffic density (see Definitions section).

5.51.1.2 Separation Distances to Inhabited Buildings. Separation distances required from earth covered magazine (ECM) and other types of PESs to inhabited buildings are listed for various quantities of Hazard Division 1.1 in Table XII and shall be maintained (Requirement). Specified separations from ECM take into account reductions in blast overpressure attributable to the earth cover of the magazines.

5.51.1.3 Public Traffic Route Distance is the distance to be maintained between a PES and any public street, road, highway, navigable stream, or passenger railroad (includes roads on a NASA installation that are used routinely by the general public for through traffic). See Paragraph 6.3 for discussion of expected explosion effects at PTR distance and for applicable tables for distance requirements. PTR distance (24-30 $W^{1/3}$ ft; 2.3-1.7 psi) from ECM and other types of PESs listed for various quantities of Hazard Division 1.1 in Table XII, shall be applied to the following locations (Requirement):

5.51.1.3.1 Public traffic routes with medium and low traffic densities (see Definitions section).

5.51.1.3.2 On-Center roads. NASA Centers may provide Center/Facility-related personnel, transiting the ESQD arc of explosives areas protection less than 60 percent of IBD, provided:

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5.51.1.3.2.1 The risks are evaluated, documented, and per approved procedures, the Centers use appropriate methods to inform transients of potential risks (e.g., written acknowledgment of the risk by vendors or others with a recurring need to transit the ESQD, warning signs, flashing lights, physical barriers). The Center's decision to provide transients protection at less than 60 percent of IBD shall be based on (Requirement):

1. Operational necessity.
2. The operation being performed (e.g., static storage, maintenance, and production.
3. Operational activity cycle.
4. Alternate routes.
5. Traffic density.
6. Accident records.
7. Time interval of exposure.
8. Type and quantity of munitions in proximity to the area transited.
9. The closest distance from the area transited to the PES.
10. The need for Center-related personnel to transit the ESQD arc.

5.51.1.3.2.2 Reviewed as changes occur to either operations, which would increase the explosive safety risk, or the number of exposed individuals, and upon change of the approving authority.

5.51.1.3.3 All new construction of explosives storage and operating facilities, and any change in operations within existing facilities that increases the explosive safety risk, shall provide both the general public and Center/Facility-related personnel who are not involved in explosives-related operations protection equal to or greater than 60 % of IBD (Requirement).

5.51.1.3.4 Transient Use Facilities. Open air recreation facilities, where structures are not involved (such as ball diamonds and volleyball courts) and used for morale and health purposes on NASA Centers/Facilities and other NASA operationally controlled locations. When recreation facilities are solely for off-duty personnel at their work locations, neither blast nor fragment QD apply. This total relaxation of QD requirements applies only when the PES and the ES are related closely as with a security alert force and explosives facilities for which they are responsible. This relaxation may not be used to encourage the building of elaborate installations that substitute for properly located recreational facilities or to encourage the collocation of essentially unrelated work functions.

5.51.1.3.5 Training areas for unprotected personnel. They include observation points and instruction areas for small arms firing ranges and similar fixed facilities, including small classrooms, designed for occasional use coincident with use by groups or classes using the range. Separation or other protection is not required for those ammunition and explosives needed for any particular exercise in order to achieve realism in training, nor from explosives in necessary on-the-job training operations for explosives workers. This reduced requirement does not change the separation or other protection required from permanent magazines.

5.51.1.3.6 Aircraft passenger loading and unloading areas that do not include any structures.

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Table XII. Hazard Division 1.1 Inhabited Building and Public Traffic Route Distances (See Notes)

Net Explosive Weight (NEW) lbs	Distance in Feet to Inhabited Building From:				Distance in Feet to Public Traffic Route From:			
	Earth-Covered Magazine			Other PES	Earth-Covered Magazine			Other PES
	Front	Side	Rear		Front	Side	Rear	
Col 1	Col 2[1,8,9]	Col 3[1,8]	Col 4[2,8]	Col 5[3]	Col 6[4,8,10]	Col 7[5,8]	Col 8[6,8]	Col 9[7]
1	500	250	250	See note 3	300	150	150	See note 7
2	500	250	250		300	150	150	
5	500	250	250		300	150	150	
10	500	250	250		300	150	150	
20	500	250	250		300	150	150	
30	500	250	250		300	150	150	
40	500	250	250		300	150	150	
50	500	250	250		300	150	150	
100	500	250	250		300	150	150	
150	500	250	250		300	150	150	
200	700	250	250		420	150	150	
250	700	250	250		420	150	150	
300	700	250	250		420	150	150	
350	700	250	250		420	150	150	
400	700	250	250		420	150	150	
450	700	250	250		420	150	150	
500	1,250	1,250	1,250	1,250	750	750	750	750
600	1,250	1,250	1,250	1,250	750	750	750	750
700	1,250	1,250	1,250	1,250	750	750	750	750
800	1,250	1,250	1,250	1,250	750	750	750	750
900	1,250	1,250	1,250	1,250	750	750	750	750
1,000	1,250	1,250	1,250	1,250	750	750	750	750
1,500	1,250	1,250	1,250	1,250	750	750	750	750
2,000	1,250	1,250	1,250	1,250	750	750	750	750
3,000	1,250	1,250	1,250	1,250	750	750	750	750
4,000	1,250	1,250	1,250	1,250	750	750	750	750
5,000	1,250	1,250	1,250	1,250	750	750	750	750
6,000	1,250	1,250	1,250	1,250	750	750	750	750
7,000	1,250	1,250	1,250	1,250	750	750	750	750
8,000	1,250	1,250	1,250	1,250	750	750	750	750
9,000	1,250	1,250	1,250	1,250	750	750	750	750
10,000	1,250	1,250	1,250	1,250	750	750	750	750
15,000	1,250	1,250	1,250	1,250	750	750	750	750
20,000	1,250	1,250	1,250	1,250	750	750	750	750
25,000	1,250	1,250	1,250	1,250	750	750	750	750
30,000	1,250	1,250	1,250	1,250	750	750	750	750
35,000	1,250	1,250	1,250	1,310	750	750	750	785
40,000	1,250	1,250	1,250	1,370	750	750	750	820
45,000	1,250	1,250	1,250	1,425	750	750	750	855
50,000	1,290	1,290	1,250	1,475	775	775	750	995
55,000	1,330	1,330	1,250	1,520	800	800	750	910
60,000	1,370	1,370	1,250	1,565	820	820	750	940

Table XII is continued on the next page

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Table XII continued

Net Explosive Weight (NEW) lbs	Distance in Feet to Inhabited Building From: Earth-Covered Magazine Front	Side	Rear	Other PES	Distance in Feet to Public Traffic Route From: Earth-Covered Magazine Front	Side	Rear	Other PES
Col 1	Col 2[1,8,9]	Col 3[1,8]	Col 4[2,8]	Col 5[3]	Col 6[4,8,10]	Col 7[5,8]	Col 8[6,8]	Col 9[7]
75,000	1,475	1,475	1,250	1,685	885	885	750	1,010
80,000	1,510	1,510	1,250	1,725	905	905	750	1,035
85,000	1,540	1,540	1,250	1,760	925	925	750	1,055
90,000	1,570	1,570	1,250	1,795	940	940	750	1,075
95,000	1,595	1,595	1,250	1,825	960	960	750	1,095
100,000	1,625	1,625	1,250	1,855	975	975	750	1,115
110,000	1,740	1,740	1,290	1,960	1,045	1,045	770	1,175
120,000	1,855	1,855	1,415	2,065	1,110	1,110	850	1,240
125,000	1,910	1,910	1,480	2,115	1,165	1,165	890	1,270
130,000	1,965	1,965	1,545	2,165	1,180	1,180	925	1,300
140,000	2,070	2,070	1,675	2,255	1,245	1,245	1,005	1,355
150,000	2,175	2,175	1,805	2,350	1,305	1,305	1,085	1,410
160,000	2,280	2,280	1,935	2,435	1,370	1,370	1,160	1,460
170,000	2,385	2,385	2,070	2,520	1,430	1,430	1,240	1,515
175,000	2,435	2,435	2,135	2,565	1,460	1,460	1,280	1,540
180,000	2,485	2,485	2,200	2,605	1,490	1,490	1,320	1,565
190,000	2,585	2,585	2,335	2,690	1,550	1,550	1,400	1,615
200,000	2,680	2,680	2,470	2,770	1,610	1,610	1,480	1,660
225,000	2,920	2,920	2,810	2,965	1,750	1,750	1,685	1,780
250,000	3,150	3,150	3,150	3,150	1,890	1,890	1,890	1,890
275,000	3,250	3,250	3,250	3,250	1,950	1,950	1,950	1,950
300,000	3,345	3,345	3,345	3,345	2,005	2,005	2,005	2,005
325,000	3,440	3,440	3,440	3,440	2,065	2,065	2,065	2,065
350,000	3,525	3,525	3,525	3,525	2,115	2,115	2,115	2,115
375,000	3,605	3,605	3,605	3,605	2,165	2,165	2,165	2,165
400,000	3,685	3,685	3,685	3,685	2,210	2,210	2,210	2,210
425,000	3,760	3,760	3,760	3,760	2,250	2,250	2,250	2,250
450,000	3,830	3,830	3,830	3,830	2,300	2,300	2,300	2,300
475,000	3,900	3,900	3,900	3,900	2,340	2,340	2,340	2,340
500,000	3,970	3,970	3,970	3,970	2,380	2,380	2,380	2,380

NOTES

(1) Bases for Columns 2 and 3 distances:

1-45,000 lbs - debris hazard - lesser distances permitted if proved sufficient to limit hazardous debris to 1/600 ft^2.
Formula $d = 35W^{1/3}$ (blast overpressure) may be used if fragments and debris are absent.
45,000-100,000 lbs - blast overpressure hazard. Computed by formula $d = 35W^{1/3}$
100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 0.3955W^{0.7227}$
250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$

(2) Bases for Column 4 distances:

100,000 lbs - debris hazard - lesser distances permitted if proved sufficient to limit hazardous debris to 1/600 ft^2.
Formula $d = 25W^{1/3}$ (blast overpressure) may be used if fragments and debris are absent.
100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 0.004125W^{1.0898}$
250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$

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(3) Bases for Column 5 Distances:
1-30,000 lbs- fragments and debris hazard. Lesser distances permitted by paragraph 5.51.1.7.1.
30,000-100,000 lbs - blast overpressure hazard. Computed by formula $d = 40W^{1/3}$
100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 2.42W^{0.577}$
250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$
(4) Column 6 distances have the same hazard bases and are equal to 60 percent of Column 2 distances.
(5) Column 7 distances have the same hazard bases and are equal to 60 percent of Column 3 distances.
(6) Column 8 distances have the same hazard bases and are equal to 60 percent of Column 4 distances.
(7) Column 9 distances have the same hazard bases and are equal to 60 percent of Column 5 distances.
(8) Distances for NEWs between 30,000 and 250,000 lbs apply only for earth-covered magazines that are 26 ft. wide and 60 ft. long, or larger. For smaller earth-covered magazines, use other PES distances of Columns 5 or 9.
(9) Column 2 IBDs apply to all directions from High Performance Magazines. The maximum credible event in the HPM is used as the NEW (Column 1). The limit on the design MCE in an HPM is 60,000 lbs.
(10) Column 6 Public Traffic Route Distances apply to all directions from High Performance Magazines. The maximum credible event in the HPM is used as the NEW (Column 1). The limit on the design MCE in an HPM is 60,000 lbs.

5.51.1.4 ILD is the distance to be maintained between any two operating buildings and sites within an operating line, of which at least one contains or is designed to contain explosives, except that the distance from a service magazine for the line to the nearest operating building may be not less than the ILD required for the quantity of explosives contained in the service magazine. See Paragraph 6.3 for discussion of expected explosion effects at ILD.

5.51.1.4.1 ILD (with mandatory barricading - $9W^{1/3}$ ft; 12 psi) shall be applied to the following locations (Requirement):

5.51.1.4.1.1 Buildings housing successive steps of a single production, renovation, or maintenance operation.

5.51.1.4.1.2 Security alert force buildings.

5.51.1.4.1.3 Break rooms and change houses if they are part of an operating line and are used exclusively by personnel employed in operations of the line.

5.51.1.4.1.4 Temporary holding areas for trucks or railcars containing explosives to service production or maintenance facilities.

5.51.1.4.1.5 Field operations in magazine areas when performing minor maintenance, preservation, packaging, or surveillance inspection.

5.51.1.4.1.6 Unmanned auxiliary power facilities, transformer stations, water treatment and pollution abatement facilities, and other utility installations which serve the PES and are not an integral function in the PES, and loss of which would not create an immediate secondary hazard. These applications need not be barricaded. Exception: Unmanned auxiliary power generation or conversion facilities exclusively supplying power to the explosive storage area and security fence lighting may be located at fire protection distance from explosive facilities (50 ft for fire-resistant structures, 100 ft for non fire-resistant structures).

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5.51.1.4.1.7 Dunnage preparation and similar support structures housing nonexplosives operations if used only by personnel employed at the PES.

5.51.1.4.1.8 Service magazines that are part of operating lines. Distances are based on the quantity and type of explosives in the service magazine or magazines, not the operating building.

5.51.1.4.1.9 Exposures as indicated in the next paragraph if blast suppression and structure hardening provide comparable protection for personnel and equipment involved.

5.51.1.4.2 ILD (without barricading - $18W^{1/3}$ ft; 3.5 psi) shall be applied to the following locations (Requirement):

5.51.1.4.2.1 Surveillance, maintenance, and inspection buildings and labor intensive operations closely related to the PES.

5.51.1.4.2.2 Comfort, safety, and convenience occupied buildings exclusively in support of the PES (such as lunchrooms, motor pools, area offices, auxiliary fire stations, transportation dispatch points, and shipping and receiving buildings [not magazine area loading docks]).

5.51.1.4.2.3 Parallel operating lines from one another, whether or not barricaded, provided explosives involved in each operating line present similar hazards. The criticality or survivability of one or more of the operating lines may require that each line be given an inhabited building level of protection.

5.51.1.4.2.4 Operations and training functions that are manned or attended exclusively by personnel of the organization operating the PES. This includes break rooms, operation offices, and similar functions for organizations operating the facility. Training functions permitted this level of exposure (3.5 psi) include organized classroom and field training of personnel who may be required to engage in explosives work at the PES.

5.51.1.4.2.5 Auxiliary power and utilities functions. This category includes auxiliary power plants; compressor stations; electric power transformers; tool and consumable supplies storage and issue; and handling equipment service, battery charging, and minor repair. When such facilities serve an entire Center, or when loss of the facility will cause an immediate loss of vital function, the exposure level shall not exceed 1.2 psi (Requirement).

5.51.1.4.2.6 Minimum distance between separate groups of explosives-loaded aircraft. The use of intervening barricades is required to reduce further communication and fragment damage and eliminate the necessity for totaling net explosive weight (NEW). Loading explosives aboard aircraft can be accomplished with each group of aircraft without additional protection.

5.51.1.4.2.7 Service magazines that are part of operating lines. Distances are based on quantity and type of explosives in the service magazines, not the operating building.

5.51.1.4.2.8 Container stuffing and unstuffing operations that routinely support a PES. This applies only to main support functions set aside for support of manufacturing operations.

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5.51.1.4.2.9 Between explosive-loaded aircraft and those nonexplosives facilities that directly support the servicing and launching of an aircraft (that is, activities and their operating facilities that handle explosives on the flightline, prepare and service aircraft loaded with explosives, and those that fly aircraft). Direct flightline aircraft associated facilities may contain field offices, break rooms, training rooms, and equipment and supply rooms, as well as petroleum, oils, lubricants (POL) hydrant facilities and fire protection stations. Specifically excluded are morale, welfare, and recreation (MWR) facilities; design engineering; industrial facilities, including central logistics facility.

5.51.1.4.2.10 The intraline separation distances for explosives and nonexplosives buildings and sites within an explosives operating line listed in Table XIII for various quantities of Hazard Division explosives shall be observed (Requirement).

Table XIII. Hazard Division 1.1, Intraline Distances

Net Expl. Wt. (lb)	Distance in Feet			Net Expl. Wt. (lb)	Distance in Feet		
	Hazard Factor				Hazard Factor		
	Bar	Unbar	Notes		Bar	Unbar	Notes
	k=9	k=18			k=9	k=18	
50	33	66	1	20,000	244	489	
100	42	84		25,000	263	526	
200	53	105		30,000	280	559	
300	60	120		35,000	294	589	
400	66	133		40,000	308	616	
500	71	143		45,000	320	640	
600	76	152		50,000	332	663	
700	80	160		55,000	342	685	
800	84	167		60,000	352	705	
900	87	174		65,000	362	724	
1,000	90	180		70,000	371	742	
1,500	103	206		75,000	380	759	
2,000	113	227		80,000	388	776	
3,000	130	260		85,000	396	791	
4,000	143	286		90,000	403	807	
5,000	154	308		95,000	411	821	
6,000	164	327		100,000	418	835	
7,000	172	344		125,000	450	900	
8,000	180	360		150,000	478	956	
9,000	187	374		175,000	503	1,007	
10,000	194	388		200,000	526	1,053	
15,000	222	444		225,000	547	1,095	

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Net Expl. Wt. (lb)	Distance in Feet			Net Expl. Wt. (lb)	Distance in Feet		
	Hazard Factor				Hazard Factor		
	Bar	Unbar	Notes		Bar	Unbar	Notes
	k=9	k=18			k=9	k=18	
250,000	567	1,134		800,000	835	1,671	
275,000	585	1,171		900,000	869	1,738	
300,000	602	1,205		1,000,000	900	1,800	
325,000	619	1,238		1,500,000	1030	2,060	
350,000	634	1,269		2,000,000	1134	2,268	
375,000	649	1,298		2,500,000	1221	2,443	
400,000	663	1,326		3,000,000	1298	2,596	
500,000	714	1,429	2	3,500,000	1366	2,733	
600,000	759	1,518		4,000,000	1429	2,857	
700,000	799	1,598		5,000,000	1539	3,078	

NOTES

(1) For less than 50 pounds, less distance may be used when structures, blast mats and the like can completely contain fragment and debris. This table is not applicable when blast, fragments and debris are completely confined, as in certain test firing barricades.

(2) Quantities above 500,000 lbs NEW are authorized only for Energetic Liquids in accordance with requirements of Paragraph 5.51.15.

5.51.1.4.2.11 The distance required between an explosives-operating building and its service magazines is determined by the quantity of explosives in the service magazines irrespective of the quantity in the operating building. In order to apply barricaded ILD, barricades shall comply with Paragraph 4.25.6 or 4.25.6.1.3.3 as appropriate (see Paragraph 5.51.1.4.3.5.2) (Requirement).

5.51.1.4.2.12 ILD from ECM. Testing has shown some attenuation of the airblast overpressure occurs out the sides and rear of ECM and a slight increase out the front of an ECM, relative to the unconfined surface burst. The equivalent $9W^{1/3}$ (12 psi) barricaded ILD and $18W^{1/3}$ (3.5 psi) unbarricaded ILD from ECM, accounting for this attenuation, are given in Table XIV.

5.51.1.4.2.13 Barricaded ILD from ECM. Paragraph 5.51.1.4.3.5 provides criteria for the application of barricaded ILD from ECM.

5.51.1.4.2.14 ILD from HP Magazines. Test results show that the earth-bermed HP attenuates pressures relative to the unconfined surface burst configuration. The attenuation is similar to that shown for an ECM in Paragraph 5.51.1.4.2.12. The values shown in Table XIV for the front exposure also apply to the front of the HPM. The values shown in Table XIV for the side exposure also apply to the side and rear exposures of the HPM. The definition of “front” for ECM (see Paragraph 5.51.1.4.3.1) also applies to the HPM.

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Table XIV. Hazard Division 1.1, Intraline Distances from Earth-Covered Magazines

NEW (lb.)	K-9 Application (ft)			K-18 Application (ft)		
	Front [(1)]	Side [(2)]	Rear [(3)]	Front [(4)]	Side [(5)]	Rear [(6)]
50	35	25	20	60	60	45
100	45	30	30	80	75	55
200	60	40	35	100	95	70
300	65	45	40	120	105	80
400	75	50	45	130	120	90
500	80	55	50	140	125	95
600	85	60	50	150	135	100
700	90	60	55	160	140	105
800	90	65	55	170	150	110
900	95	70	60	175	155	115
1,000	100	70	60	180	160	120
1,500	115	80	70	210	185	135
2,000	125	90	75	230	200	150
3,000	145	100	85	260	230	175
4,000	160	110	95	290	255	190
5,000	170	120	100	310	275	205
6,000	180	125	110	330	290	220
7,000	190	135	115	340	305	230
8,000	200	140	120	360	320	240
9,000	210	145	125	370	330	250
10,000	215	150	130	390	345	260
15,000	245	175	150	450	395	295
20,000	270	190	165	490	435	325
25,000	290	205	175	530	470	350
30,000	310	220	185	560	500	370
35,000	325	230	195	590	525	390
40,000	340	240	205	620	545	410
45,000	355	250	215	640	570	425
50,000	370	260	220	660	590	440
55,000	380	265	230	680	610	455
60,000	390	275	235	700	625	470
65,000	400	280	240	720	645	480
70,000	410	290	245	740	660	495
75,000	420	295	255	760	675	505
80,000	430	300	260	780	690	520

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NEW (lb.)	K-9 Application (ft)			K-18 Application (ft)		
	Front (1)	Side (2)	Rear (3)	Front (4)	Side (5)	Rear (6)
85,000	440	310	265	790	705	530
90,000	450	315	270	810	715	540
95,000	455	320	275	820	730	545
100,000	465	325	280	840	745	555
125,000	500	350	300	900	800	605
150,000	530	370	320	960	850	650
175,000	560	390	335	1,010	895	700
200,000	585	410	350	1,055	935	745
225,000	610	425	365	1,090	975	795
250,000	630	440	380	1,135	1,005	840
275,000	650	455	390	1,170	1,040	890
300,000	670	470	400	1,200	1,070	935
325,000	675	520	465	1,240	1,135	1,035
350,000	680	570	530	1,270	1,200	1,130
375,000	685	615	600	1,300	1,265	1,230
400,000	690	665	665	1,330	1,330	1,330
500,000	715	715	715	1,430	1,430	1,430

NOTES
(NEW in lbs, d in ft)

(1) NEW $\leq$ 300,000 lbs $d = 10*NEW^{1/3}$

300,000 lbs < NEW $\leq$ 500,000 lbs $d = (13.659 - 1.6479*10^{-5}*NEW + 1.4358*10^{-11}*NEW^2)*NEW^{1/3}$
d $\leq$ 669 ft $NEW = d^3/1000$

669 ft < d $\leq$ 715 ft $NEW = 1.50138*10^8 - 6.73914*10^5*d + 1002.9*d^2 - 0.4938*d^3$

(2) NEW < 300,000 lbs d = 7*NEW1/3

300,000 lbs < NEW $\leq$ 400,000 lbs $d = (1.0848 + 1.986*10^{-05}*NEW)*NEW^{1/3}$

NEW > 400,000 lbs $d = 9*NEW^{1/3}$
d $\leq$ 469 ft $NEW = d^3/343$

469 ft < d < 663 ft NEW = 57,424 + 515.89*d
d > 663 ft $NEW = d^3/729$

(3) NEW < 300,000 lbs d = 6*NEW1/3

300,000 lbs < NEW < 400,000 lbs $d = (-3.059 + 3.0228*10^{-05}*NEW)*NEW^{1/3}$

NEW > 400,000 lbs $d = 9*NEW^{1/3}$
d $\leq$ 402 ft $NEW = d^3/216$

402 ft < d < 665 ft NEW = 148,160 + 379.7*d
d > 665 ft $NEW = d^3/729$

(4) NEW < 500,000 lbs d = 18*NEW1/3
d $\leq$ 1429 ft $NEW = d^3/5,832$

(5) NEW < 300,000 lbs d = 16*NEW1/3

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300,000 lbs < NEW ≤ 400,000 lbs $d = (9.9683 + 2.0135*10^{-05}*NEW)*NEW^{1/3}$

NEW > 400,000 lbs $d = 18*NEW^{1/3}$

d ≤ 1071 ft $NEW = d^3/4,096$

1071 ft < d < 1328ft NEW = -118,180 + 390.35*d

d > 1328 ft $NEW = d^3/5,832$

(6) NEW ≤ 100,000 lbs $d = 12*NEW^{1/3}$

100,000 lbs < NEW ≤ 300,000 lbs $d = (11.521 + 1.9918*10^{-06}*NEW + 2.0947*10^{-11}* NEW^2) *NEW^{1/3}$

300,000 lbs < NEW ≤ 400,000 lbs $d = (1.9389+ 4.0227*10^{-05}*NEW)*NEW^{1/3}$

NEW > 400,000 lbs $d = 18*NEW^{1/3}$

d ≤ 557 ft $NEW = d^3/1,728$

557 ft < d < 938ft NEW = -193,080+526.83*d

938 ft < d < 1328ft NEW = 60,778 + 255.83*d

d > 1328 ft $NEW = d^3/5,832$

5.51.1.4.3 Intermagazine Distances. Magazines for Hazard Division 1.1 shall be separated one from another in accordance with Table XV. See Paragraph 6.3 for discussion of expected explosion effects at intermagazine distance. Magazine orientation aspects of Table XV, Part A, involve the following considerations (Requirement):

5.51.1.4.3.1 When ECM containing Hazard Division 1.1 explosives are sited so that any one is in the forward sector of another, the two shall be separated by distances greater than the minimum permitted for side-to-side orientations (Requirement). The forward sector, or "front," of an ECM is that area 60 degrees either side of the magazine centerline (120° combined angle) with the vertex of the angle placed so that the sides of the angle pass through the intersection of the headwall and sidewalls (See Figure 7). The greater distances are required primarily for the protection of door and headwall structures against blast from a PES forward of the exposed magazine, and to a lesser extent due to the directionality of effects from the source. The rear sector, or "rear," of an ECM is that area 45 degrees either side of the magazine centerline (90° combined angle) with the vertex of the angle placed so that the sides of the angle pass through the intersection of the rear and side walls. Figure 8 illustrates the front (120°), side, and rear (90°) sectors of an ECM. When a blast wave is reflected from a surface at other than grazing incidence (side-on-orientation), the overpressure may be increased substantially over the free-field value. High reflected pressure and impulse can damage doors and headwalls and propel the debris into the ECM so that explosion is communicated by impact of such debris upon the contents.

5.51.1.4.3.2 Examples of siting rules relative to magazine orientations (illustrated in Figure 7) follow:

5.51.1.4.3.2.1 See Figure 7(a) and (b). Site A as a side-to-side ES. Site B as side-to-side ES. Orientations are to be thought of as from the PES to the ES.

5.51.1.4.3.2.2 See Figure 7(c). Site A as a side-to-front ES. Site B as a front-to-side ES.

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Table XV. Intermagazine Hazard Factors and Distances for Hazard Division 1.1

Use Part A of this table to find the hazard factor, K, corresponding to the type of PES and ES. Use the column for this hazard factor in Table XVI (Part B) to determine the appropriate distance for the net explosive weight in the PES.

Legend: S – Side; R – Rear; F – Front; B –barricaded; U – Unbarricaded; ECM – Earth-covered Magazine; AG – Aboveground; HPM – High Performance Magazine;; PES – Potential Explosion Site; ES – Exposed Site

Part A – Hazard Factors (K)[1]

FROM PES → / TO ES ↓		ECM				AG Magazine[3]			HP Magazine[7]	
		S	R	F(B)	F(U)	B	U		S,R	F[8]
ECM[2], (7 Bar)	S	1.25	1.25	2.75	2.75	4.5	4.5		1.25	2.75
	R	1.25	1.25	2	2	4.5	4.5		1.25	2
	FU	2.75	2	6	6	6	6		2.75	6
	FB[4]	2.75	2	4.5	6	4.5	6		2.75	6
ECM[2], (3 Bar)	S	1.25	1.25	2.75	2.75	6	6		1.25	2.75
	R	1.25	1.25	2	2	6	6		1.25	2
	FU	4.5	4.5	6	9	6	9		4.5	9
	FB[4]	4.5	4.5	6	6	6	6		4.5	6
ECM[2], (Undefined)	S	1.25[5] 2[6]	1.25[5] 2[6]	4.5[5] 6[6]	4.5[5] 6[6]	6	6		1.25	4.5
	R	1.25	1.25	2	2	6	6		1.25	2
	FU	6	6	6	11	6	11		6	11
	FB[4]	6	6	6	6	6	6		6	6
AG Magazine[3]	U	6	6	6	11	6	11		6	11
	B	6	6	6	6	6	6		6	6
HP Magazine[7]	S,R,F[9]	1.25	1.25	2.75	2.75	4.5	4.5		1.25	2.75

NOTES

(1) Except as noted, K-factors for ECMs and AG Magazines are applicable for NEW up to 500,000 lb. in the PES. NEW in an HPM Cell is limited to 250,000 lb.

(2) Descriptions of the earth-covered magazines are in Paragraph 4.25.6.1.3.3.

(3) Aboveground magazines are all types of above grade (not earth-covered) magazines or storage pads.

(4) Those barricades serve to mitigate both fragments and overpressure hazards. See Paragraph 4.25.6 for their requirements.

(5) Use this K-factor for NEW in PES up to 250,000 lb.

(6) Use this K-factor for NEW in PES above 250,000 lb.

(7) A description of the HPM is in Paragraph 4.25.8. The MCE in the HPM is 60,000 lbs.

(8) The unbarricaded front (entrance to Loading Dock) is a factor when the HPM is the PES because the MCE includes explosives at the loading dock. The K-factors have been determined accordingly.

(9) The storage areas in the HPM are barricaded on all sides and protected by a reinforced concrete cover. All directions are therefore considered to be Side, S, orientations when it is the ES.

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5.51.1.4.3.2.3 See Figure 7(d). Site each magazine as a front-to-front ES. Site C as a barricaded ES. Site A and B as unbarricaded ESs.

5.51.1.4.3.2.4 Two additional ECM orientations warrant analysis, namely:

5.51.1.4.3.2.4.1 See Figure 7(e). Site A as a side-to-front ES. Site B as a front-to-side ES.

5.51.1.4.3.2.4.2 See Figure 7(f). Site A as a side-to-front ES. Site B as a front-to-side ES.

5.51.1.4.3.3 Barricaded IMD from ECM. Paragraph 0 provides criteria for the application of barricaded IMD from ECM.

5.51.1.4.3.4 Other factors limiting an ECM storage area are:

5.51.1.4.3.4.1 Quantities above 500,000 lbs. NEW of Hazard Division 1.1 shall not be stored in any one storage location, except for energetic liquids (Requirement).

5.51.1.4.3.4.2 The distances given in Table XVI, Part B, for 100 lbs. NEW of Hazard Division 1.1 shall constitute the minimum required magazine spacing (Requirement)

5.51.1.4.3.5 Application of Barricaded ILD and Barricaded IMD from an ECM. Figure 8 illustrates the intermagazine relationships that can exist between an ECM and aboveground magazine and the intraline relationships that can exist between an ECM and a facility permitted to be at ILD or barricaded ILD from an ECM, when each contain H/D 1.1 explosives. Permissible ILD and barricaded ILD exposures are provided in Paragraphs 5.51.1.4 and 5.51.1.4.2. Siting criteria for aboveground magazines are provided in Table XV, Part A. The unbarricaded intermagazine or ILD, as applicable, shall apply to ECMs except as provided in paragraphs 5.51.1.4.3.5.1 and 5.51.1.4.3.5.2 (Requirement).

5.51.1.4.3.5.1 Front (120°) Sector of an ECM. Barricaded ILD or barricaded IMD, as applicable, may be applied from an ECM to an ES located within the ECM's 120° front sector, provided that an intervening barricade that meets construction criteria of Paragraph 4.25.6 is located between the ECM and the ES.

5.51.1.4.3.5.2 Side and Rear (90°) Sectors of an ECM. Barricaded ILD or barricaded IMD, as applicable, may be applied if an ECM's earth cover meets construction criteria of Paragraphs 4.25.7.2.5 through 4.25.7.2.6, (it then qualifies as a barricade).

5.51.1.4.3.6 Standards given in Paragraphs 5.51.1.4.3.1 through 0 apply only to the storage of Hazard Division 1.1 explosives. Existing ECM, regardless of orientation, meeting the construction and barricading requirements of Paragraph 4.25.6.1.3.3 and DDESB Technical Paper 15 (and sited one from another for a minimum of 100 pounds NEW of Hazard Division 1.1), may be used to their physical capacity for the storage of Hazard Divisions 1.2, 1.3, and 1.4 provided distances to other exposures comply with applicable QD tables.

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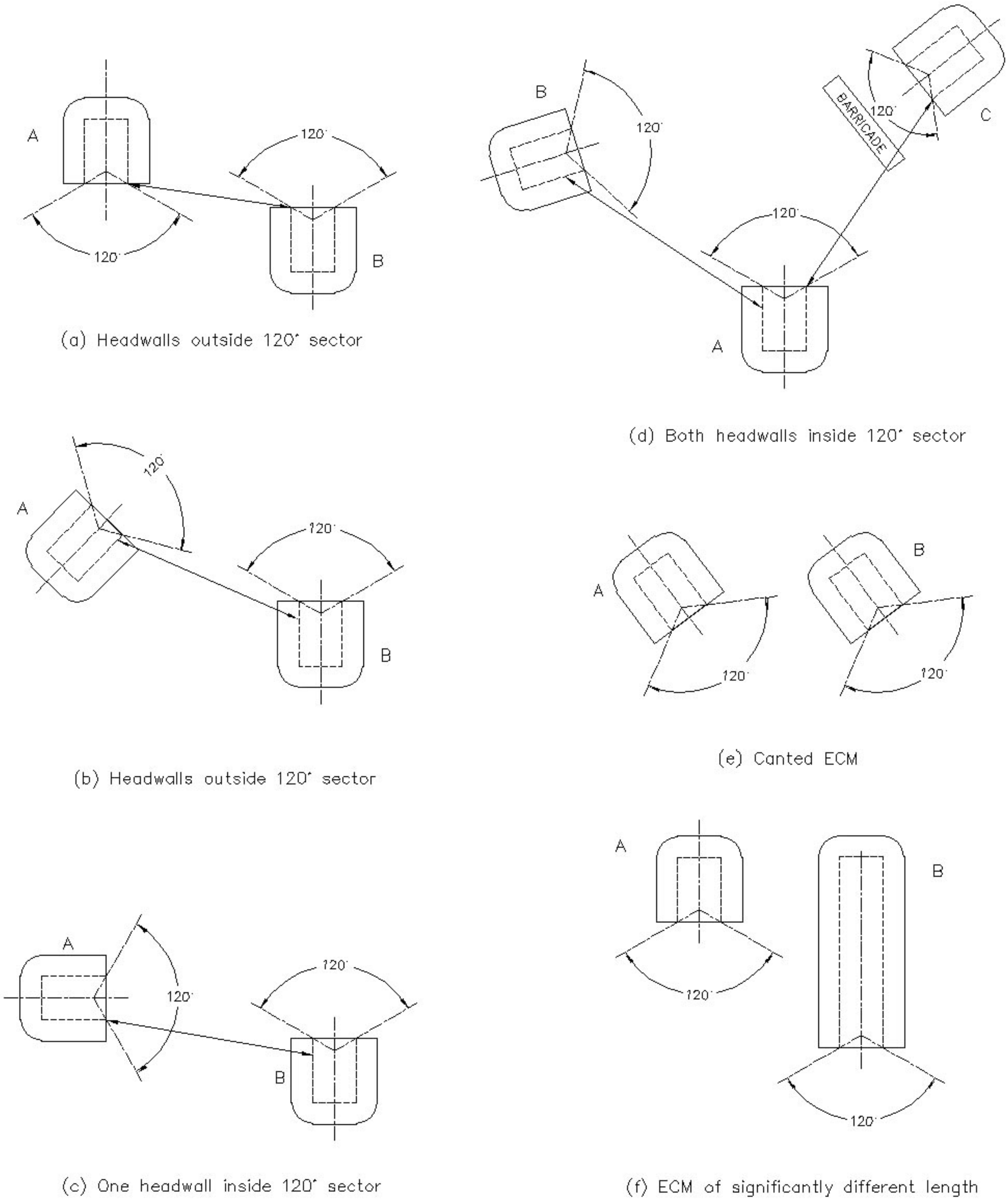

Note: See Table XV for applicable separation distances between ECM.

Figure 7. Orientation Effects on Intermagazine Distance.

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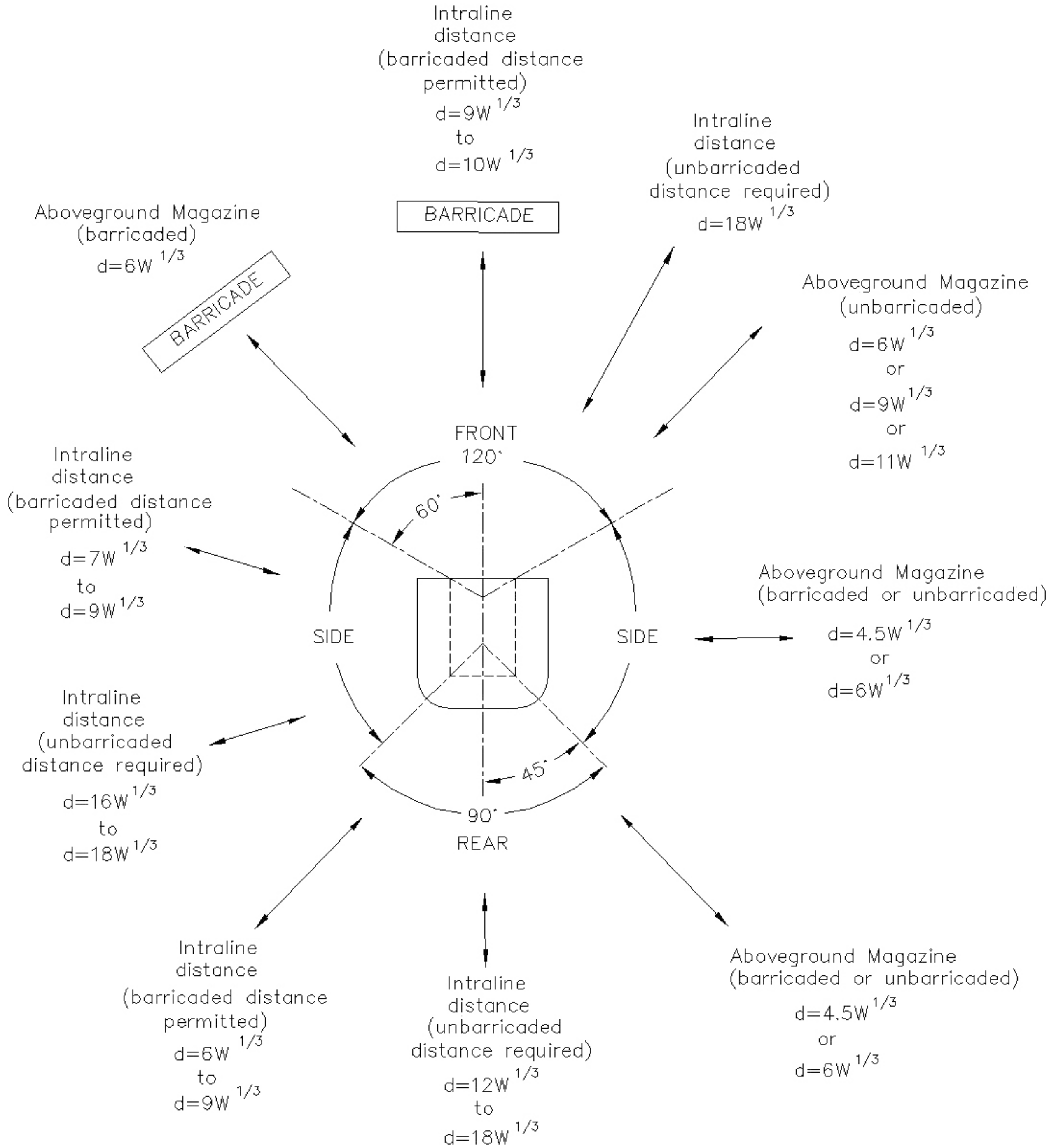

Notes:

(1) See 5.51.1.4 for application of ILD and barricaded ILD from an ECM.
(2) See 5.51.1.4.4.5 for application of barricaded ILD and barricaded Intermagazine distances from an ECM.
(3) See 5.51.1.4.1 and 5.51.1.4.2 for permissible intraline and barricaded intraline exposures.

Figure 8. Orientation Effects on ILD Intermagazine Distance

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Table XVI. Intermagazine Hazard Factors and Distances for Hazard Division 1.1 Part B - Distance in Feet (Sheet 1).

Net Expl. Wt. (lb)	Hazard Factor (K) from Part A										
	1.1	1.25	2	2.75	4	4.5	5	6	8	9	11
100	7	7	9	13	19	21	23	28	37	42	51
110	7	7	10	13	19	22	24	29	38	43	53
120	7	7	10	14	20	22	25	30	39	44	54
140	7	7	10	14	21	23	26	31	42	47	57
150	7	7	11	15	21	24	27	32	43	48	58
170	7	7	11	15	22	25	28	33	44	50	61
190	7	7	11	16	23	26	29	34	46	52	63
220	7	8	12	17	24	27	30	36	48	54	66
250	7	8	13	17	25	28	31	38	50	57	69
280	7	8	13	18	26	29	33	39	52	59	72
310	7	8	14	19	27	30	34	41	54	61	74
350	8	9	14	19	28	32	35	42	56	63	78
390	8	9	15	20	29	33	37	44	58	66	80
440	8	10	15	21	30	34	38	46	61	68	84
500	9	10	16	22	32	36	40	48	63	71	87
560	9	10	16	23	33	37	41	49	66	74	91
630	9	11	17	24	34	39	43	51	69	77	94
700	10	11	18	24	36	40	44	53	71	80	98
790	10	12	18	25	37	42	46	55	74	83	102
890	11	12	19	26	38	43	48	58	77	87	106
1,000	11	13	20	28	40	45	50	60	80	90	110
1,100	11	13	21	28	41	46	52	62	83	93	114
1,200	12	13	21	29	43	48	53	64	85	96	117
1,400	12	14	22	31	45	50	56	67	89	101	123
1,500	13	14	23	31	46	52	57	69	92	103	126
1,700	13	15	24	33	48	54	60	72	95	107	131
1,900	14	15	25	34	50	56	62	74	99	111	136
2,200	14	16	26	36	52	59	65	78	104	117	143
2,500	15	17	27	37	54	61	68	81	109	122	149
2,800	16	18	28	39	56	63	70	85	113	127	155
3,100	16	18	29	40	58	66	73	87	117	131	160
3,500	17	19	30	42	61	68	76	91	121	137	167
3,900	17	20	31	43	63	71	79	94	126	142	173
4,400	18	20	33	45	66	74	82	98	131	147	180

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Net Expl. Wt. (lb)	Hazard Factor (K) from Part A										
	1.1	1.25	2	2.75	4	4.5	5	6	8	9	11
5,000	19	21	34	47	68	77	85	103	137	154	188
5,600	20	22	36	49	71	80	89	107	142	160	195
6,300	20	23	37	51	74	83	92	111	148	166	203
7,000	21	24	38	53	77	86	96	115	153	172	210
7,900	22	25	40	55	80	90	100	119	159	179	219
8,900	23	26	41	57	83	93	104	124	166	187	228
10,000	24	27	43	59	86	97	108	129	172	194	237
11,000	24	28	44	61	89	100	111	133	178	200	245
12,000	25	29	46	63	92	103	114	137	183	206	252
14,000	27	30	48	66	96	108	121	145	193	217	265
15,000	27	31	49	68	99	111	123	148	197	222	271
17,000	28	32	51	71	103	116	129	154	206	231	283
19,000	29	33	53	73	107	120	133	160	213	240	294
22,000	31	35	56	77	112	126	140	168	224	252	308
25,000	32	37	58	80	117	132	146	175	234	263	322
28,000	33	38	61	84	121	137	152	182	243	273	334
31,000	35	39	63	86	126	141	157	188	251	283	346
35,000	36	41	65	90	131	147	164	196	262	294	360
39,000	37	42	68	93	136	153	170	203	271	305	373
44,000	39	44	71	97	141	159	177	212	282	318	388
50,000	41	46	74	101	147	166	184	221	295	332	405
56,000	42	48	77	105	153	172	191	230	306	344	421
63,000	44	50	80	109	159	179	199	239	318	358	438
70,000	45	52	82	113	165	185	206	247	330	371	453
79,000	47	54	86	118	172	193	215	257	343	386	472
89,000	49	56	89	123	179	201	223	268	357	402	491
100,000	51	58	93	128	186	209	232	278	371	418	511
110,000	53	60	96	132	192	216	240	287	383	431	527
120,000	54	62	99	136	197	222	247	296	395	444	543
140,000	57	65	104	143	208	234	260	312	415	467	571
150,000	58	66	106	146	213	239	266	319	425	478	584
170,000	61	69	111	152	222	249	277	332	443	499	609
190,000	63	72	115	158	230	259	287	345	460	517	632
220,000	66	75	121	166	241	272	302	362	483	543	664
250,000	69	79	126	173	252	283	315	378	504	567	693
280,000	72	82	131	180	262	294	327	393	523	589	720

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Net Expl. Wt. (lb)	Hazard Factor (K) from Part A										
	1.1	1.25	2	2.75	4	4.5	5	6	8	9	11
310,000	74	85	135	186	271	305	338	406	541	609	744
350,000	78	88	141	194	282	317	352	423	564	634	775
390,000	80	91	146	201	292	329	365	438	584	658	804
440,000	84	95	152	209	304	342	380	456	608	685	837
500,000	87	99	159	218	317	357	397	476	635	714	873
560,000	91	103	165	227	330	371	412	495	659	742	907
630,000	94	107	171	236	343	386	429	514	686	772	943
700,000	98	111	178	244	355	400	444	533	710	799	977
790,000	102	116	185	254	370	416	462	555	740	832	1017
890,000	106	120	192	265	385	433	481	577	770	866	1058
1,000,000	110	125	200	275	400	450	500	600	800	900	1100
1,100,000	114	129	206	284	413	465	516	619	826	929	1136
1,200,000	117	133	213	292	425	478	531	638	850	956	1169
1,400,000	123	140	224	308	447	503	559	671	895	1007	1231
1,500,000	126	143	229	315	458	515	572	687	916	1030	1259
1,700,000	131	149	239	328	477	537	597	716	955	1074	1313
1,900,000	136	155	248	341	495	557	619	743	991	1115	1362
2,200,000	143	163	260	358	520	585	650	780	1040	1171	1431
2,500,000	149	170	271	373	543	611	679	814	1086	1221	1493
2,800,000	155	176	282	388	564	634	705	846	1128	1269	1550
3,100,000	160	182	292	401	583	656	729	875	1166	1312	1604
3,500,000	167	190	304	418	607	683	759	911	1215	1366	1670
3,900,000	173	197	315	433	630	708	787	944	1259	1417	1731
4,400,000	180	205	328	451	655	737	819	983	1311	1475	1803
5,000,000	188	214	342	470	684	769	855	1026	1368	1539	1881
5,600,000	195	222	355	488	710	799	888	1065	1421	1598	1953
6,300,000	203	231	369	508	739	831	923	1108	1478	1662	2032
7,000,000	210	239	383	526	765	861	956	1148	1530	1722	2104
7,900,000	219	249	398	548	797	896	996	1195	1593	1792	2191
8,900,000	228	259	414	570	829	933	1036	1243	1658	1865	2280
10,000,000	237	269	431	592	862	969	1077	1293	1724	1939	2370
11,000,000	245	278	445	612	890	1001	1112	1334	1779	2002	2446
12,000,000	252	286	458	630	916	1030	1145	1374	1832	2060	2518
14,000,000	265	301	482	663	964	1085	1205	1446	1928	2169	2651
15,000,000	271	308	493	678	986	1110	1233	1480	1973	2220	2713

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5.51.1.5 Fragment Distances.

5.51.1.5.1 Primary fragment distance minima are to protect personnel in the open; firebrand distance minima are to protect facilities. Since firebrands are burning fragments with the potential to ignite other sites or facilities, the firebrands and fragments have the same distance, which shall be applied to (Requirement):

5.51.1.5.1.1 Center boundaries, unless manifestly inapplicable (e.g., unsuitable terrain, government land not open to the public). For locations where installation boundary lines are penetrated by inhabited building QD arcs, the Center shall certify that conditions do not exist for the application of inhabited building protection to the encumbered area and shall establish procedures to monitor the area for any change in that status (Requirement).

5.51.1.5.1.2 Administration and housing areas.

5.51.1.5.1.3 Athletic and other recreation areas except as described below.

5.51.1.5.1.4 Flight-line passenger service functions.

5.51.1.5.1.5 Main powerhouses providing vital utilities to a major portion of the Center.

5.51.1.5.1.6 Storehouses and shops that, by reason of their vital, strategic nature, or the high intrinsic value of their contents, should not be placed at risk.

5.51.1.5.1.7 Functions that, if momentarily put out of action, would cause an immediate secondary hazard by reason of their failure to function.

5.51.1.5.1.8 Private vehicles parked in administrative areas.

5.51.1.6 Examples when minimum fragment and firebrand distances need not be applied are:

5.51.1.6.1 Recreation or training facilities if these facilities are for the exclusive use of personnel assigned to the PES.

5.51.1.6.2 Related and NASA-controlled support functions for which intermagazine and ILDs are the usual protection levels.

5.51.1.6.3 Maintenance, supply, and training facilities, and operations offices for the service of the logistics and operations functions of aircraft carrying explosives.

5.51.1.6.4 Between PES and relatively static inert storage areas, including parking areas for dead storage of government aircraft or vehicles.

5.51.1.6.5 Between facilities in an operating line; between operating lines; and between operating lines and storage locations that normally are separated by IBDs to protect workers and insure against interruption of production.

5.51.1.7 The minimum distance for protection from hazardous fragments shall be based on primary and secondary fragments from the PES and the population and/or traffic density of the

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ES (Requirement). It is defined as the distance at which the density of hazardous fragments becomes 1 per 600 ft^2.

Note: This distance is not the maximum fragment range. Secondary fragments include debris such as that from structural elements of the facility and from non-confining process equipment likely to rupture into enough pieces to significantly contribute to the total number of expected fragments. Primary and secondary fragments include items discussed in paragraph 5.66. Analyses and/or tests approved by SARD may be used to determine minimal distances for both primary and secondary fragments. DDESB Technical Paper No. 13 is an example of a method to determine minimal distances for building debris, while U.S. Army Corps of Engineers Reports HNC-ED-CS-98-1 and 98-2 provide similar information for primary fragments (see Section 2, Applicable Documents). In the absence of appropriate analyses and/or tests, default hazardous debris distances defined below apply.

5.51.1.7.1 For populous locations; i.e., those areas and/or functions identified in Paragraph 5.51.1.1, where government, contractor employees, dependent, and/or public personnel are located, the minimum distance shall be that distance at which fragments, including debris from structural elements of the facility or process equipment, do not exceed a hazardous fragment density of one hazardous fragment per 600 ft^2 (56 m^2) (Requirement). If this distance is not known, the following shall apply (Requirement):

5.51.1.7.1.1 For all types of Hazard Division 1.1 in quantities $\leq$ 450 lbs NEW, the hazardous fragment distance (HFD), which equates to IBD, shall be determined as follows (Requirement):

5.51.1.7.1.1.1 For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, use "Earth-Covered Magazine" distances shown in Table XII as discussed in Paragraph 5.51.1.1. Intraline criteria shall be in accordance with 5.51.1.4.2.10 (Requirement).

5.51.1.7.1.1.2 For Hazard Division 1.1 in an Undefined ECM, where the loading density [NEW (lbs)/internal magazine volume (ft^3)] is $\leq$ 0.028 lbs/ft^3, use "Earth-Covered Magazine" distances shown in Table XII, as discussed in Paragraph 5.51.1.1. Intraline criteria shall be in accordance with 5.51.1.4.2.10 (Requirement).

5.51.1.7.1.1.3 For Hazard Division 1.1 in an Undefined ECM where the loading density is > 0.028 lbs/ft^3, use "Earth-Covered Magazine - Side and Rear" distances of Table XII and for front exposure, apply the greater of "Earth-Covered Magazine - Front" IBD distance of Table XII or the HFD from Table XVII for the NEW in the ECM. PTR is 60 percent of IBD or HFD, as applicable. Intraline criteria shall be in accordance with Paragraph 5.51.1.4.2.10 (Requirement).

5.51.1.7.1.1.4 Where ECM, regardless of structural designation, have been designed, analyzed, or tested to have a reduced IBD and have been approved by NASA Headquarters, SARD, use the approved IBD. PTR is 60 percent of IBD. Intraline criteria shall be in accordance with Paragraph 5.51.1.4.2.10 (Requirement).

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Table XVII. Hazard Division 1.1 Hazardous Fragment Distances

NEW (pounds)	HAZARDOUS FRAGMENT DISTANCE (Feet)	NEW (pounds)	HAZARDOUS FRAGMENT DISTANCE (Feet)
<0.5	236	80	638
1	291	85	643
2	346	90	648
4	401	95	652
6	433	100	658
8	456	125	744
10	474	150	815
15	506	175	875
20	529	200	927
25	546	225	973
30	561	250	1014
35	573	275	1051
40	583	300	1085
45	593	325	1116
50	601	350	1145
55	609	375	1172
60	616	400	1197
65	622	425	1220
70	628	450	1243
75	633	>450	1250

NOTES

(1) NEW < 100 Pounds: Hazardous Fragment Distance = 291.3 + [79.2 x ln(NEW)];
NEW ≥ 100 Pounds: Hazardous Fragment Distance = -1133.9 + [389 x ln(NEW)];
NEW in pounds, Hazardous Fragment Distance in feet, with a minimum distance of 236 feet; ln is natural logarithm.

(2) NEW = exp [(Hazardous Fragment Distance/79.2) - 3.678]; Hazardous Fragment Distance < 658 feet;
NEW = exp [(Hazardous Fragment Distance/389) + 2.914]; 658 feet ≤ Hazardous Fragment Distance < 1250 ft;

(3) NEW in pounds, Hazardous Fragment Distance in feet; exp [x] is e^x.
Use of equations given in Notes (1) and (2) to determine other Hazardous Fragment Distance-NEW combinations is allowed.

(4) Public traffic route distance is 60 percent of Hazardous Fragment Distance.

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5.51.1.7.1.1.5 For Hazard Division 1.1 in a structure (excluding ECM) capable of stopping primary fragments, but which can contribute to the debris hazard, use hazardous debris and PTR distances found in Table XIX. Intraline criteria shall be in accordance with Paragraph 5.51.1.4.2.10 (Requirement). Structures that are capable of stopping primary fragments include all heavy wall (H) and heavy wall/roof (H/R) aboveground sites (AGS), as defined in the Legend for Table XXI. Doors and other openings through which primary fragments could exit shall be capable of stopping primary fragments from exiting the facility or shall be barricaded in accordance with Paragraph 4.25.6 to trap primary fragments that could exit the facility (Requirement).

5.51.1.7.1.1.6 For Hazard Division 1.1 in the open or in a structure incapable of stopping primary fragments, use HFD listed in Table XVII. Intraline criteria shall be in accordance with Paragraph 5.51.1.4.2.10 (Requirement). Structures (other than ECM) that are capable of stopping primary fragments include all heavy wall (H) and heavy wall/roof (H/R) aboveground sites (AGS), as defined in the Legend for Table XXI. All other structures (other than ECM) are considered incapable of stopping primary fragments. PTR is 60 percent of HFD.

5.51.1.7.1.1.7 For bare explosives in the open, distance is computed by the formula $d=40W^{1/3}$.

5.51.1.7.1.2 For Hazard Division 1.1 NEWs in the range 451 to 30,000 lbs, HFD shall be determined according to the below criteria (Requirement). Public traffic route distance is 60 percent of the HFD, and intraline criteria, as applicable, shall be in accordance with Paragraph 5.51.1.4.2.10 or 5.51.1.4.3 (Requirement).

5.51.1.7.1.2.1 The minimum HFD shall be 1250 ft, as shown in Table XII (Requirement). Lesser distances are permitted if supported by a structural analysis. Existing facilities sited at 1,235 ft or 1,245 ft per past standards may be considered to be in compliance with the 1,250 ft minimum requirement.

5.51.1.7.1.2.2 For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, use "Earth-Covered Magazine" distances shown in Table XII, as discussed in Paragraph 5.51.1.1.

5.51.1.7.1.2.3 For Hazard Division 1.1 in an Undefined ECM, where the loading density is $\leq$ 0.028 lbs/ft^3, use "Earth-Covered Magazine" distances shown in Table XII, as discussed in Paragraph 5.51.1.1.

5.51.1.7.1.2.4 For Hazard Division 1.1 in an Undefined ECM with minimum internal dimensions of 26 feet wide by 60 ft long, use "Earth-Covered Magazine - side and rear" distances of Table XII and "Other PES" distance of Table XII for the front exposure.

5.51.1.7.1.2.5 For Hazard Division 1.1 in an Undefined ECM where the loading density is > 0.028 lbs/ft^3 and internal dimensions are less than 26 feet wide by 60 ft long, use "Other PES" distances of Table XII for front, side, and rear exposures.

5.51.1.7.1.2.6 For bare explosives in the open, distance is computed by the formula $d=40W^{1/3}$.

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5.51.1.7.1.3 For Hazard Division 1.1 NEWs > 30,000 lbs, HFD shall be in accordance with Table XII (Requirement). Lesser distances are permitted if supported by a structural analysis. PTR is 60 percent of HFD and intraline criteria, as applicable, shall be in accordance with Paragraph 5.51.1.4.2.10 or 5.51.1.4.3 (Requirement). The following apply to use of the reduced "Earth-Covered Magazine" distances shown in Table XII for the NEW range between 30,000 lbs and 250,000 lbs (Requirement):

5.51.1.7.1.3.1 For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, where internal dimensions are a minimum of 26 feet wide by 60 ft long, use "Earth-Covered Magazine" distances shown in Table XII.

5.51.1.7.1.3.2 For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, where internal dimensions are less than 26 feet wide by 60 ft long, use "Other PES" distances of Table XII for front, side, and rear exposures.

5.51.1.7.2 For sparsely populated locations; i.e., those populous locations where the personnel exposure is no greater than addressed in Paragraph 5.51.1.7.2.1, the minimum 1,250 ft fragment distance may be reduced to 900 ft if certain specific conditions exist as follows:

5.51.1.7.2.1 No more than 25 persons are located in any sector bounded by the sides of a 45-degree angle, with the vertex at the PES, and the 900 ft and 1,250 ft arcs from the PES.

5.51.1.7.2.2 The NEW of the PES does not exceed 11,400 lbs.

5.51.1.7.3 For public traffic routes, the minimum fragment and debris distance for Hazard Division 1.1 explosives shall be based on the traffic density considered at three levels: high traffic density, medium traffic density, and low traffic density, averaged over a normal (non-holiday) week in terms of number of passengers during a 24-hour period (Requirement). Minimum fragment distance reductions based on sparse population considerations addressed in Paragraph 5.51.1.7.2 do not apply to public traffic routes.

> *Note: In applying criteria other than the default values for high, medium, and low traffic densities (which are based on car (and rail) speed of 50 mile/hour , and a ship speed of 10 mile/hour), considerations such as the following need to be taken into account to establish acceptable exposure: speed of vehicles, number of passengers per vehicle, protection afforded by the vehicle, variation in daily traffic levels in relation to explosives activities, and seasonal traffic trends. The default value of two passengers per car may be used to estimate traffic density.*

5.51.1.7.3.1 High Traffic Density. IBD criteria apply (Paragraph 5.51.1.7.1).

5.51.1.7.3.2 Medium Traffic Density. 60% of the specified minimum fragment distance for IBD applies. Medium traffic density criteria for minimum fragment distance apply, as a minimum, to recreational activity that is extensive and occurs on a regular basis.

5.51.1.7.3.3 Low Traffic Density. No minimum fragment distance is required. Minimum distance shall be based on blast criteria (K24/K30) only (Paragraph 5.51.1.3).

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5.51.1.7.3.4 For other exposures that are permitted at public traffic route separation distances (Paragraph 5.51.1.3), fragment and debris distance minima for Hazard Division 1.1 explosives shall be at least 60% of the specified minimum fragment distance for IBD (Requirement).

5.51.2 Hazard Division 1.2.

5.51.2.1 General. The H/D 1.2 hazard classification is given to items configured for storage and transportation that do not mass detonate when a single item or package in a stack is initiated. Explosions involving the items result in their burning and exploding progressively with no more than a few at a time reacting. These reactions will typically project fragments, firebrands, and unexploded items from the explosion site. Blast effects are limited to the immediate vicinity and are not the primary hazard.

5.51.2.1.1 Small quantities of H/D 1.2.1 ($\leq$ 450 pounds NEW), in certain packaging configurations, react in a manner more typical of an H/D 1.1 event. When located in structures that stop primary fragments, but which generate a secondary debris hazard (e.g., certain ECM and hardened structures), the structural damage and debris hazards produced from these events again are more characteristic of an H/D 1.1 explosion, rather than the progressive nature of an H/D 1.2.1 event, as described above. When the NEW and the MCE of the packaged H/D 1.2.1 items fall within the ranges specified in equation {NEW $\leq$ MCE $\leq$ 450 lbs}, the H/D 1.2.1 shall be treated as H/D 1.1 and the criteria of Paragraph 5.51.1.7.1.1.1, as applicable, shall be used (Requirement). If they fall outside the ranges of the equation, then the criteria of Table XXI shall be applied (Requirement).

5.51.2.2 The effects produced by the functioning of H/D 1.2 items vary with the size and weight of the item. H/D 1.2 explosives items are separated into two subdivisions in order to account for the differences in magnitude of these effects for purposes of setting quantity-distance criteria. The more hazardous items are referred to as H/D 1.2.1 items and have an NEWQD greater than 1.60 pounds. The less hazardous items, referred to hereafter as H/D 1.2.2, have an NEWQD less than or equal to 1.60 pounds. These two H/D 1.2 subdivisions are shown below with their definitions:

H/D 1.2.1:	NEWQD > 1.60 pounds
H/D 1.2.2:	NEWQD $\leq$ 1.60 pounds

It is important not to exaggerate the significance of the value of 1.60 pounds used above. It is based on a break point in the database supporting the quantity-distance relationships and tables and the NEWQD of the items tested. If comprehensive data are available for a particular item, then the item may be placed in that category of H/D 1.2 supported by the data and allocated the relevant quantity-distances.

5.51.2.3 The Maximum Credible Event (MCE) for H/D 1.2.1 is the NEWQD of an item times the number of items in three unpalletized, outer shipping packages, unless a different MCE is demonstrated by testing or analogy.

5.51.2.4 The quantity distances specified for H/D 1.2 explosives achieve the desired degree of protection against immediate hazards from an incident. Events involving H/D 1.2 items lob large amounts of unexploded rounds, components, and subassemblies, which remain hazardous after impact. Such items are likely to be more hazardous than in their original state because of

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possible damage to fuse safety devices or other features by heat and impact. Furthermore, it is impractical to specify quantity distances that allow for the maximum possible flight ranges of propulsive items.

5.51.2.5 Table XVIII, Table XIX, Table XX, and Table XXI provide the appropriate IBDs (IBD), public traffic route distances (PTR), and ILDs (ILD) for H/D 1.2.1 and H/D 1.2.2 explosives. When H/D 1.2.1 items are stored in structures which may contribute to the debris hazard, the IBD is determined by using the larger of the following two distances: either that given in Table XVIII for the appropriate explosive weight (number of items x NEWQD) or that given in Table XIX for the appropriate MCE.

5.51.2.6 IMDs are dependent upon the types of structures acting as both the Potential Explosion Site (PES) and the Exposed Site (ES). Table XXI provides a matrix of all the appropriate separations for the various combinations of ES and PES.

5.51.2.7 PTR distances in Table XVIII, Table XIX, Table XX, and Table XXI give consideration to the transient nature of the exposure in the same manner as for H/D 1.1. PTR distance is computed as 60% of the IBD for items in this hazard division, with a minimum distance equal to the IMD given in Table XXI for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L) in Table XXI.

5.51.2.8 ILD given in Table XVIII, Table XIX, Table XX, and Table XXI take into account the progressive nature of explosions involving these items (normally resulting from fire spread), up to the magnitude of the MCE, and the ability to evacuate personnel from endangered areas before the progression involves large numbers of items. Exposed structures may be extensively damaged by projections and delayed propagation of explosions may occur due to the ignition of combustibles by projections. ILD is computed as 36% of the IBD for items of this H/D, with a minimum distance equal to the IMDs given in Table XXI for the applicable PES-ES combination.

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Table XVIII. Hazard Subdivision 1.2.1 Quantity-Distances (IBD, PTR, ILD) for Explosives with NEWQD > 1.60 Pounds

EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3,4] (ft)	PTR [5] (ft)	ILD [6] (ft)	EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3,4] (ft)	PTR [5] (ft)	ILD [6] (ft)
				7,000	1033	620	372
2	200	200	200	8,000	1055	633	380
5	200	200	200	9,000	1074	644	387
10	200	200	200	10,000	1091	654	393
20	200	200	200	15,000	1154	693	416
40	200	200	200	20,000	1199	719	432
60	200	200	200	25,000	1233	740	444
80	224	200	200	30,000	1260	756	454
100	268	200	200	40,000	1303	782	469
150	348	209	200	50,000	1335	801	481
200	404	242	200	60,000	1362	817	490
300	481	289	200	70,000	1384	830	498
400	535	321	200	80,000	1402	841	505
600	610	366	220	90,000	1419	851	511
800	662	397	238	100,000	1434	860	516
1,000	702	421	253	150,000	1489	894	536
1,500	774	464	279	200,000	1528	917	550
2,000	824	494	297	250,000	1558	935	561
2,500	862	517	310	300,000	1582	949	569
3,000	893	536	322	350,000	1601	961	577
3,500	919	551	331	400,000	1619	971	583
4,000	941	565	339	450,000	1633	980	588
5,000	978	587	352	500,000	1646	988	593
6,000	1008	605	363	>500,000	Note 4	Note 5	Note 6

NOTES

(1) Explosive Weight = Number of Items x NEWQD.

(2) IBD = -735.186 + [237.559 x (ln(Number of items x NEWQD))] – [4.274 x (ln(Number of items x NEWQD))^2], with a minimum of 200 ft; IBD in feet, NEWQD in pounds; ln is natural logarithm. [71 < explosive weight]

(3) Number of items x NEWQD = exp[27.791 – (600.392 – 0.234 x IBD)$^{1/2}$]; IBD in feet, NEWQD in pounds; exp (x) is e^x. [200 < IBD < 2016]

(4) Use of equations given in Notes (2) and (3) to determine other IBD-weight combinations is allowed.

(5) PTR = 60% of IBD with a minimum distance equal to the IMD given in Table XXI for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L) in Table XXI. For other structures as either ES or PES, see Table XXI.

(6) ILD = 36% of IBD with a minimum distance equal to the IMD given in Table XXI for the applicable PES-ES combination. For structures other than AGS(L) as either ES or PES, see Table XXI.

GENERAL COMMENTS

(1) The quantity-distance criteria for H/D 1.2.1 items are based on the hazards from primary fragments. When stored in structures which may contribute to the debris hazard (secondary fragments), the IBD for H/D 1.2.1 items whose MCE is greater than 31 pounds is determined by using the larger of the following two distances: those given in this table for the appropriate Explosive Weight or those given in Table XIX for the appropriate MCE. Structures that may contribute to the debris hazard for storage of H/D 1.2.1 explosives include: (a) all earth-covered magazines (ECMs) – Frontal exposure only. Side and rear exposures have fixed minimum distances for IBD; (b) all aboveground sites (AGSs)—Including heavy

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wall (H), heavy wall/roof (H/R), and light wall (L) as defined in Table XXI, unless data/analyses are provided to show that the structural debris contribution is less. Note that ILD and PTR are based on 36% and 60%, respectively, of the applicable IBD as determined in this note with the following minimum distances: ILD minimum distances are given in Table XXI for applicable PES-ES combinations and PTR minimum distances are given in Table XXI for AGS(L).

(2) See Table XXI for a summary of Intermagazine Distances (IMD) and minimum distances for ILD and PTR.

Table XIX. Hazardous Debris Distances for H/D 1.2.1 Items Stored in Structures Which Can Contribute to the Debris Hazard

MCE (lbs)	HAZARDOUS DEBRIS DISTANCE[1,2] (ft)	PTR[4] (ft)	ILD[5] (ft)
≤ 31	200	200	200
35	249	200	200
40	301	200	200
45	347	208	200
50	388	233	200
75	546	328	200
100	658	395	237
125	744	446	268
150	815	489	293
175	875	525	315
200	927	556	334
225	973	584	350
250	1014	608	365
275	1051	631	378
300	1085	651	391
325	1116	670	402
350	1145	687	412
375	1172	703	422
400	1197	718	431
425	1220	732	439
450	1243	746	447
>450	1250	750	450

NOTES

(1) Hazardous Debris Distance = -1133.9 + [389 x ln(MCE)]; [31 < MCE ≤ 450]
MCE in pounds, Hazardous Debris Distance in feet with a minimum distance of 200 ft; ln is natural logarithm.

(2) MCE = exp [(Hazardous Debris Distance/389) + 2.914]; [200 < Hazardous Debris Distance ≤ 1250]MCE in pounds, Hazardous Debris Distance in feet; exp [x] is e^x.

(3) Use of equations given in Notes (1) and (2) to determine other Hazardous Debris Distance-MCE combinations is allowed.

(4) PTR = 60% of IBD with a minimum distance equal to the IMD given in Table XXI for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L) in Table XXI. For other structures as either ES or PES, see Table XXI.

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(5) ILD = 36% of IBD with a minimum distance equal to the IMD given in Table XXI for the applicable PES-ES combination. For structures other than AGS(L) as either ES or PES, see Table XXI.

GENERAL COMMENTS

(1) The quantity-distance criteria for H/D 1.2.1 items are based on the hazards from primary fragments. When stored in structures which may contribute to the debris hazard (secondary fragments), the IBD for H/D 1.2.1 items whose MCE is greater than 31 pounds is determined by using the larger of the following two distances: those given in Table XVIII for the appropriate Explosive Weight or those given in this table for the appropriate MCE. Structures that may contribute to the debris hazard for storage of H/D 1.2.1 explosives include: (a) all earth-covered magazines (ECMs) – Frontal exposure only. Side and rear exposures have fixed minimum distances for IBD; (b) all aboveground sites (AGSs)—Including heavy wall (H), heavy wall/roof (H/R), and light wall (L) as defined in Table XXI, unless data/analyses are provided to show that the structural debris contribution is less. Note that ILD and PTR are based on 36% and 60%, respectively, of the applicable IBD as determined in this note with the following minimum distances: ILD minimum distances are given in Table XXI for applicable PES-ES combinations and PTR minimum distances are given in Table XXI for AGS(L).

(2) See Table XXI for a summary of IMD and minimum distances for ILD and PTR.

Table XX. Hazard Subdivision 1.2.2 Quantity-Distances (IBD, PTR, ILD) for Explosives with NEWQD < 1.60 Pounds

EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3,4] (ft)	PTR [5] (ft)	ILD [6] (ft)	EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3,4] (ft)	PTR [5] (ft)	ILD [6] (ft)
1	100	100	100	7,000	366	220	132
2	100	100	100	8,000	376	226	135
5	100	100	100	9,000	385	231	139
10	100	100	100	10,000	394	236	142
20	100	100	100	15,000	427	256	154
40	113	100	100	20,000	451	271	162
60	123	100	100	25,000	471	282	169
80	131	100	100	30,000	487	292	175
100	138	100	100	40,000	514	308	185
150	152	100	100	50,000	535	321	193
200	162	100	100	60,000	553	332	199
300	179	107	100	70,000	568	341	204
400	192	115	100	80,000	581	349	209
600	211	127	100	90,000	593	356	214
800	226	136	100	100,000	604	362	217
1,000	238	143	100	150,000	647	388	233
1,500	262	157	100	200,000	678	407	244
2,000	279	168	101	250,000	703	422	253
2,500	294	176	106	300,000	723	434	260
3,000	306	183	110	350,000	741	445	267
3,500	316	190	114	400,000	757	454	272
4,000	325	195	117	450,000	771	462	277
5,000	341	205	123	500,000	783	470	282
6,000	355	213	128	>500,000	Note 4	Note 5	Note 6

NOTES

(1) Explosive Weight = Number of Items x NEWQD.

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(2) (IBD = 101.649 - [15.934 x (ln(Number of items x NEWQD))] + [5.173 x (ln(Number of items x NEWQD))^2], with a minimum of 100 ft; IBD in feet, NEWQD in pounds; ln is natural logarithm. [20 < Explosive Weight]

(3) Number of items x NEWQD = exp [1.5401 + (-17.278 + 0.1933 x IBD)$^{1/2}$]; IBD in feet, NEWQD in pounds; exp (x) is e^x. [100 <IBD < 1240]

(4) Use of equations given in Notes (2) and (3) to determine other IBD-weight combinations is allowed.

(5) PTR = 60% of IBD with a minimum distance equal to the IMD given in Table XXI for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L) in Table XXI. For other structures as either ES or PES, see Table XXI.

(6) ILD = 36% of IBD with a minimum distance equal to the IMD given in Table XXI for the applicable PES-ES combination. For structures other than AGS (L) as either ES or PES, see Table XXI.

GENERAL COMMENTS

(1) The quantity-distance criteria for H/D 1.2.2 items are based on the hazards from primary fragments.

(2) See Table XXI for a summary of Intermagazine Distances (IMD) and minimum distances for ILD and PTR.

Table XXI. Summary of Hazard Subdivisions 1.2.1, 1.2.2, and 1.2.3 Quantity-Distances

To EXPOSED SITE (ES)		From POTENTIAL EXPLOSION SITE (PES)				
		ECM		AGS		
				(H)	(H/R)	(L)
		S or R	F			
ECM (7 bar/3 bar) (IMD)	S	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	R	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FU	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FB	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
ECM (Undefined) (IMD)	S	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	R	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FU	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
	FB	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
AGS (H/R) (IMD)	U or B	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
AGS (H or L) (IMD)	U or B	0 (note 1)	200/300/100	200/300/100	0 (note 1)	200/300/100
ILD [5]		0 (Note 1)	Note 2	0 (Note 1)	0 (Note 1)	Note 2
PTR [5]		200/300/100	Note 3	Note 3	Note 3	Note 3
IBD [5]		200/300/100	Note 4	Note 4	Note 4	Note 4

(NOTE: all distances are in feet)

LEGEND

S—Side; R—Rear; F—Front: B—Barricaded; U—Unbarricaded; FU—Front Unbarricaded; FB—Front Barricaded.

ECM—Earth-Covered Magazine (7-bar, 3-bar, undefined refers to the strength of the headwall).

AGS—Aboveground site; aboveground, non earth-covered magazine or structure.

AGS (H)—Aboveground site, Heavy Wall; Buildings with wall thickness $\geq$ 12 inches of reinforced concrete; as an ES, door shall be barricaded if it faces a PES.

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AGS (H/R)—Aboveground site, Heavy Wall and Roof; AGS (H) with roof thickness > 5.9 inches of reinforced concrete; as an ES, door shall be barricaded if it faces a PES; side/rear exposures may or may not be barricaded.

AGS (L)—Aboveground site, Light; Light structure, open stack, truck, trailer, or railcar.

IMD—Intermagazine Distance; ILD—Intraline Distance.

PTR—Public Traffic Route Distance; IBD—Inhabited Building Distance.

NOTES

(1) Practical considerations such as firefighting and security shall dictate specific separation distances as specified by the NASA Center.

(2) ILD = 36% of IBD with a minimum distance equal to the IMD given in this table for the applicable PES-ES combination.

(3) PTR = 60% of IBD with a minimum distance equal to the IMD given in this table for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L).

(4) For H/D 1.2.1 items, use the larger of the two applicable values given in Table XVIII and Table XIX; for H/D 1.2.2 items use Table XX.

(5) See Paragraph 5.51.2.12 for H/D 1.2.3.

(6) When the NEW and the MCE of the packaged H/D 1.2.1 items fall within the ranges specified in equation {NEW $\leq$ MCE $\leq$ 450 lbs}, the H/D 1.2.1 shall be treated as H/D 1.1 and the criteria of Paragraph 5.51.1.7.1.1.1, as applicable, shall be used (see Paragraph 5.51.2.1.1).

GENERAL COMMENTS

(1) For PES-ES combinations where three distances are given, the first refers to a PES containing H/D 1.2.1 items with an MCE < 100 pounds, the second to a PES containing H/D 1.2.1 items with an MCE $\geq$ 100 pounds, and the third refers to a PES containing H/D 1.2.2 items. Where three IMDs are given, the IM Distance from a PES containing only H/D 1.2.3 items to an ES containing other than H/D 1.2.3 is K11 based on the NEWQD of a single item of the largest (greatest NEWQD) H/D 1.2.3 item in the PES.

(2) For an ES containing only H/D 1.2.3 items, the IMD from any PES to such an ES is 0 (Note 1).

5.51.2.9 When storing mixed subdivisions of H/D 1.2 explosives (H/D 1.2.1 and H/D 1.2.2), the following rule shall apply (Requirement): Consider each subdivision separately and apply the greater of the two distances. The general mixing rules for H/D 1.2 explosives are given in Table XXII.

5.51.2.10 For reasons of operational necessity, limited quantities of H/D 1.2.2 items may be stored in facilities such as hangars and manufacturing or operating buildings without regard to quantity distance if fragmentation shielding is be provided.

5.51.2.11 Unit Risk H/D 1.2 is a special storage subdivision (H/D 1.2.3) for explosives that satisfy either of the following sets of criteria:

5.51.2.11.1 Explosives that satisfy the criteria for H/D 1.6 with the exception of containing a non-EIDS device, or

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Table XXII. Hazard Subdivisions 1.2.1, 1.2.2, and 1.2.3 Mixing Rules

HAZARD SUB-DIVISION INVOLVED	DISTANCES TO BE APPLIED
1.2.1	Apply HD 1.2.1 distances[1]
1.2.2	Apply HD 1.2.2 distances[2]
1.2.3	Apply HD 1.2.3 distances[3]
1.2.1 + 1.2.2	Apply greater of two distances
1.2.1 + 1.2.3	Apply greater of two distances
1.2.2 + 1.2.3	Apply greater of two distances

NOTES

(1) H/D 1.2.1 distances given in Table XVIII, Table XIX, and Table XXI.
(2) H/D 1.2.2 distances given in Table XX and Table XXI.
(3) H/D 1.2.3 distances given in Table XXIII (See Paragraph 5.51.2.12)

5.51.2.11.2 Explosives that do not exhibit any sympathetic detonation response in the stack test (United Nations (UN) Test 6(b)) or any reaction more severe than burning in the external fire test (UN Test 6(c)), bullet impact test (UN Test 7(j)), and the slow cook-off test (UN Test 7(h)).

5.51.2.12 The IBD for Unit Risk H/D 1.2 (H/D 1.2.3) shall be determined using Table XXIII (H/D 1.3 Quantity-Distances) for the NEWQD of the H/D 1.2.3 item multiplied by the number of items present, but with a minimum IBD determined as follows (Requirement): If the items are in a structure that can interrupt primary fragments and can contribute debris, the minimum IBD shall be the hazardous debris distance given in Table XIX for an MCE equal to the NEWQD of a single item. If the items are in the open or in a light structure that will not interrupt primary fragments, the minimum IBD shall be the hazardous primary fragment distance based on the H/D 1.1 hazardous fragment area number density criteria applied to a single H/D 1.2.3 item. PTR for H/D 1.2.3 shall be equal to 60% of IBD. ILD shall be computed as 36% of IBD, with a minimum distance equal to the IMD (Requirement). IMD shall be as given in Table XXI (Requirement). For any specific quantity or distance determination, as an alternative to the preceding H/D 1.2.3 QD criteria, when an increase in the allowable quantity or a reduction in the required distance will result, items hazard classified as H/D 1.2.3 may be treated as follows: If the single-item NEWQD is greater than 1.6 pounds, consider the items as H/D 1.2.1 (use the total NEWQD present, with an MCE equal to the NEWQD of one item). If the single-item NEWQD is equal to or less than 1.6 pounds, consider the items as H/D 1.2.2, based on the total NEWQD present.

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Table XXIII. Hazard Division 1.3 Quantity-Distances[1,2]

NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)	NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)	NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)
1,000	75	50	90,000	295	195	540,000	618	409
2,000	86	57	92,000	296	196	550,000	623	411
3,000	96	63	94,000	297	197	560,000	627	413
4,000	106	69	96,000	298	198	570,000	632	415
5,000	115	75	98,000	299	199	580,000	636	418
6,000	123	81	100,000	300	200	590,000	641	420
7,000	130	86	110,000	307	205	600,000	645	422
8,000	137	91	120,000	315	210	610,000	649	424
9,000	144	96	130,000	322	215	620,000	654	426
10,000	150	100	140,000	330	220	630,000	658	428
12,000	159	105	150,000	337	225	640,000	662	430
14,000	168	111	160,000	345	230	650,000	667	432
16,000	176	116	170,000	352	235	660,000	671	435
18,000	183	120	180,000	360	240	670,000	675	437
20,000	190	125	190,000	367	245	680,000	679	439
22,000	195	130	200,000	375	250	690,000	684	441
24,000	201	134	210,000	383	255	700,000	688	443
26,000	206	138	220,000	390	260	710,000	692	445
28,000	210	142	230,000	398	265	720,000	696	447
30,000	215	145	240,000	405	270	730,000	700	449
32,000	219	147	250,000	413	275	740,000	704	451
34,000	224	149	260,000	420	280	750,000	708	453
36,000	228	151	270,000	428	285	760,000	712	455
38,000	231	153	280,000	435	290	770,000	716	457
40,000	235	155	290,000	443	295	780,000	720	459
42,000	238	157	300,000	450	300	790,000	724	461
44,000	242	159	310,000	458	305	800,000	728	463
46,000	245	161	320,000	465	310	810,000	732	465
48,000	247	163	330,000	473	315	820,000	735	467
50,000	250	165	340,000	480	320	830,000	739	469
52,000	252	167	350,000	488	325	840,000	743	471
54,000	254	169	360,000	495	330	850,000	747	472
56,000	256	171	370,000	503	335	860,000	750	474
58,000	258	173	380,000	510	340	870,000	754	476
60,000	260	175	390,000	518	345	880,000	758	478
62,000	262	177	400,000	525	350	890,000	761	480
64,000	264	180	410,000	533	355	900,000	765	482
66,000	266	182	420,000	541	361	910,000	769	484
68,000	268	183	430,000	549	366	920,000	772	486
70,000	270	185	440,000	556	371	930,000	776	487
72,000	272	186	450,000	564	376	940,000	779	489
74,000	274	187	460,000	571	381	950,000	783	491
76,000	276	188	470,000	579	386	960,000	786	493
78,000	278	189	480,000	586	391	970,000	790	495
80,000	280	190	490,000	593	395	980,000	793	496
82,000	284	191	500,000	600	400	990,000	797	498
84,000	287	192	510,000	605	402	1,000,000	800	500
86,000	290	193	520,000	609	404			
88,000	293	194	530,000	614	407			

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NOTES

(1) Items shall be placed in this hazard division if they qualify for assignment to it after evaluation in accordance with Section 5H.

(2) For reasons of operational necessity, limited quantities of items in this hazard division, such as document destroyers, signaling devices, riot control explosive devices, and similar equipment may be stored without regard to quantity-distance in accordance with fire protection regulations in facilities such as hangars, arms rooms, and manufacturing or operating buildings.

(3) The same distances are used for IBD and PTR.

(4) The same distances are used for aboveground IMD and ILD. Earth-covered buildings may be used to their physical capacity for this hazard division provided they comply with the construction and siting requirements for Hazard Division 1.1. Earth-covered magazines used to store only Hazard Division 1.3 items shall be sited for a minimum of 100 lbs of Hazard Division 1.1 items using Table XX and Table XV.

GENERAL COMMENTS

(1) For quantities less than 1,000 lbs, the distances specified for 1,000 lbs shall be used. The use of lesser distances may be approved when supported by test data and/or analysis.

(2) Linear interpolation of NEW quantities between table entries is permitted.

(3) For quantities above 1,000,000 lbs, the values given above shall be extrapolated by means of cube-root scaling as follows:

(4) For inhabited building distance (IBD) and public traffic route (PTR) distance, use $D = 8W^{1/3}$.

(5) For aboveground IMD and ILD, use $D = 5W^{1/3}$.

(6) List of items (examples only): Military pyrotechnics; solid propellants in bulk, in containers, or in ammunition items; and nontoxic chemical ammunition.

(7) For solid rocket motor static test stands, use TNT equivalents, $D = 24W^{1/3}$ for workers, and IBD from Table XII for all others, when uncertainties are identified during pre-test reviews. When no uncertainties are identified, use distances for 1.3 quantities per the table.

5.51.2.13 For storage of mixed Unit Risk H/D 1.2 (H/D 1.2.3) explosives, the NEWQD for the H/D 1.2.3 items shall be multiplied by the corresponding number of H/D 1.2.3 items and use Table XXII with a hazardous fragment distance based on the largest hazardous fragment distance for the H/D 1.2.3 explosives in storage (Requirement). When H/D 1.2.3 explosives are located with any other Hazard Division 1.2 subdivision, the distances given in Table XXII shall be used (Requirement). When H/D 1.2.3 explosives are located with any other H/D explosives, the H/D 1.2.3 explosive shall be considered H/D 1.2 (H/D 1.2.1 or H/D 1.2.2, according to NEWQD) for quantity-distance purposes (Requirement). The mixing rules provided in Paragraphs 5.50.7.1 and 5.50.7.2 above shall then be applied to the combination of the hazard divisions (Requirement).

5.51.3 Hazard Division 1.3

Hazard Division 1.3 includes items that burn vigorously with little or no possibility of extinguishment in storage situations. Explosions normally will be confined to pressure ruptures of containers and will not produce propagating shock waves or damaging blast overpressure beyond the magazine distance specified in Table XXIII. A severe hazard of spread of fire may result from tossing about of burning container materials, propellant, or other flaming debris. In a HD 1.3 event, some HE or HE components may become propulsive and travel well beyond IBD.

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5.51.4 Hazard Division 1.4

5.51.4.1 H/D 1.4 explosives present a fire hazard with minimal blast, fragmentation, or toxic hazards. Facilities for storage and handling of these items shall be located in accordance with Table XXIV (Requirement).

5.51.4.2 Items hazard classified as H/D 1.4S (see Compatibility Group Paragraph 5.46.13) may be stored (including associated handling) without regard to the QD criteria in Table XXIV.

Table XXIV. Hazard Division 1.4 Quantity-Distances

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft) [1]	Magazine Distance (ft) [1]	
				Aboveground[2]	Earth-covered
For quantities up to 3000 lb[3, 4]	75	75	50	50	0 out the Sides & Rear; use Aboveground Magazine distance out the Front
For quantities larger than 3000 lb (no upper limit specifically required for safety reasons)	100	100	50 (100 if combustible construction[5])	50 (100 if combustible construction[5])	

NOTES

(1) Magazines storing only H/D 1.4 explosives may be located at these magazine or ILDs from all other magazines or operating buildings regardless of the hazard division or quantity of explosives authorized in those adjacent structures. Because the H/D 1.4 explosives may be destroyed as the result of a mishap involving the assets in those adjacent structures, application of this provision shall be accepted by the NASA Center on a case-by-case basis with consideration given to the value of H/D 1.4 assets at risk.

(2) H/D 1.4 explosives may be stored in a secure general supplies warehouse area rather than in an explosives storage area provided they are enclosed in an appropriate magazine or a Class 5 or 6 security file cabinet meeting the requirements of GSA Specification AA-F-358H. Such a structure shall be separated from all other warehouses by aboveground magazine distance.

(3) For reasons of operational necessity, limited quantities of H/D 1.4 explosives, such as small arms ammunition and riot control munitions, may be stored without regard to QD within facilities such as hangars, arms rooms, and operating buildings. Alternatively, operationally necessary H/D 1.4 explosives may be stored in small magazines external to those facilities without regard to QD.

(4) See Paragraph 5.50.7.2.1 for the applicability of H/D 1.4 quantity-distance criteria and the determination of NEW when H/D 1.4 and other Hazard Division explosives are located in the same site.

(5) Wood frame structures are an example of combustible construction. Concrete, masonry, and metal structures are examples of noncombustible construction.

5.51.5 Hazard Division 1.6.

5.51.5.1 Quantity-distance separations for Hazard Division 1.6 explosives shall be based on the storage location and configuration (Requirement). This information is detailed in Table XXV and footnotes thereto. A maximum of 500,000 NEW shall be permitted at any one location (Requirement). Any special storage configuration and siting approved for Hazard Division 1.1 explosives may be used for storage of like explosive weights of Hazard Division 1.6 explosives.

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Table XXV. Quantity-Distance Criteria for Hazard Division 1.6 Explosives

NEW (lbs)	IBD or PTR (ft)	Aboveground IMD or ILD (ft)	NEW (lbs)	IBD or PTR (ft)	Aboveground IMD or ILD (ft)
100	37	23	75,000	337	211
200	47	29	80,000	345	215
300	54	33	85,000	352	220
400	59	37	90,000	359	224
500	64	40	95,000	365	228
600	67	42	100,000	371	232
700	71	44	110,000	383	240
800	74	46	120,000	395	247
900	77	48	125,000	400	250
1,000	80	50	130,000	405	253
2,000	101	63	140,000	415	260
3,000	115	72	150,000	425	266
4,000	127	79	160,000	434	271
5,000	137	86	170,000	443	277
6,000	145	91	175,000	447	280
7,000	153	96	180,000	452	282
8,000	160	100	190,000	460	287
9,000	166	104	200,000	468	292
10,000	172	108	225,000	487	304
15,000	197	123	250,000	504	315
20,000	217	136	275,000	520	325
25,000	234	146	300,000	536	334
30,000	249	155	325,000	550	344
35,000	262	164	350,000	564	352
40,000	274	171	375,000	577	361
45,000	285	178	400,000	589	368
50,000	295	184	425,000	601	376
55,000	304	190	450,000	613	383
60,000	313	196	475,000	624	390
65,000	322	201	500,000	635	397
70,000	330	206			

NOTES

(1) The same distances are used for aboveground IMD and ILDs. Earth-covered magazines may be used to their physical capacity for this hazard division, provided they comply with the construction and siting requirements for Hazard Division 1.1.

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(2) For quantities less than 100 lbs, the required distances shall be those specified for 100 lbs. The use of lesser distances may be approved when supported by test data and/or analysis.

(3) Interpolation is permitted. For IBD and public traffic route (PTR) use $D = 8W^{1/3}$. For aboveground IMD and ILD use $5W^{1/3}$.

(4) Unit risk distance for airblast applies as a minimum; that is, for IBD or PTR, $D = 40W^{1/3}$ and for aboveground IMD or ILD, $D = 18W^{1/3}$, based on a single round of ammunition.

(5) For Hazard Division 1.6 items packed in nonflammable pallets or packing, stored in earth-covered steel or concrete arch magazines when acceptable to the NASA Center on a site-specific basis, the following quantity-distance criteria apply, unless Table XXV permits a lesser distance requirement; IBD and PTR -- 100 ft; aboveground IMD and ILD -- 50 ft; earth-covered IMD -- No specified requirement.

5.51.6 Classification Yards.

5.51.6.1 For protection of the classification yard from external explosions, separation distances shall be at least the applicable magazine distance (Requirement).

5.51.6.2 Specific QD separation is not required from the classification yard to targets other than explosives locations when the classification yard is used exclusively for:

5.51.6.2.1 Interchanging of trucks, trailers, or railcars between the common carrier and the receiving, dispatching, classifying, and switching of cars.

5.51.6.2.2 NASA activity.

5.51.6.2.3 Conducting external inspection of motor vehicles or railcars, or opening of free rolling doors of railcars for the purpose of removing documents and making a visual inspection of the cargo.

5.51.6.3 If the yard is used at any time for any purpose other than listed in Paragraph 5.51.6.2, above, such as placing or removal of dunnage or explosives items into or from railcars, QD tables apply.

5.51.7 Interchange Yards. Truck, trailer, or railcar interchange yards are not subject to QD regulations when they are used exclusively:

5.51.7.1 For the interchange of vehicles or railcars containing explosives between the commercial carrier and NASA activities.

5.51.7.2 To conduct external inspection of the trucks, trailers, or railcars containing explosives.

5.51.7.3 To conduct visual inspection of the external condition of the cargo in vehicles (such as trucks, trailers, and railcars) that passed the external inspection. If the yards are used at any time for any purpose other than above, applicable QD tables apply (see Paragraph 5.50.6).

5.51.8 Loading Docks. Detached loading docks which normally service multiple facilities are sited on the basis of use. When servicing magazines, they shall be separated from the magazines by IMDs (Requirement). When servicing operating buildings, they shall be separated from the operating buildings by ILDs (Requirement).

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5.51.9 Railcar and Truck Holding Yards

5.51.9.1 Generally, railcar holding yards shall be laid out on a unit railcar-group basis with each group separated by the applicable aboveground magazine distance (Requirement).

5.51.9.2 If the railcar holding yard is formed by two parallel ladder tracks connected by diagonal spurs, the parallel tracks and the diagonal spurs shall be separated by applicable aboveground magazine distance for the unit-group quantities of explosives (Requirement).

5.51.9.3 If the railcar holding yard is a "Christmas tree" arrangement, consisting of a ladder track with diagonal dead-end spurs projecting from each side at alternate intervals, the spurs shall be separated by the applicable aboveground magazine distance for the net weight of explosives in the railcars on the spurs (Requirement).

5.51.9.4 Generally, truck holding yards shall be laid out on a unit truck-group basis with each group separated by the applicable aboveground magazine distances (Requirement).

5.51.9.5 Both railcar and truck holding yards shall be separated from other facilities by the applicable IBD, PTR, ILD or IMD QD criteria (Requirement).

5.51.9.6 In addition to the temporary parking of railcars, trucks, or trailers containing explosives, holding yards may also be used to interchange trucks, trailers, or railcars between the commercial carrier and the NASA activity and to conduct visual inspections.

5.51.10 Railcar and Truck Inspection Stations.

5.51.10.1 Vehicle and cargo inspections shall be performed for all incoming shipments of Class 1 explosives, excluding H/D 1.4, upon entering the Center/Facility (Requirement). Specific QD separations are not required for inspection stations; however, they should be as remote as practicable from hazardous or populated areas. Activities that may be performed at the inspection station after railcars or motor vehicles containing explosives are received from the delivering carrier and before further routing within the installation are:

5.51.10.1.1 External visual inspection of the railcars or motor vehicles.

5.51.10.1.2 Visual inspection of the external condition of the cargo packaging in vehicles (such as trucks, trailers, and railcars) that have passed the external inspection indicated in Paragraph 5.51.10.1, above.

5.51.10.1.3 Interchange of trucks, trailers, or railcars between the common carrier and the NASA activity.

5.51.10.2 If any activities other than the above are conducted at the inspection station, QD applies.

5.51.10.3 Any railcars or trucks suspected of being in a hazardous condition shall be isolated, consistent with applicable QD separation for the hazard class and explosives quantity involved, before any other action (Requirement).

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5.51.11 Explosives Transportation Mode Change Locations. Movement and transfer of NASA-titled explosives shall be in compliance with national, international, and host country-specific transportation regulations (Requirement). QD criteria apply to all transfer operations involving NASA-titled explosives except for:

5.51.11.1 Roll-on/roll-off operations (not involving lifting); and,

5.51.11.2 Off-installation MILVAN/ISO container inter/intramodal transfers (involving highway and rail modes only) where containers are not stored or other operations are performed.

5.51.12 Storage Tanks for Hazardous Materials.

5.51.12.1 Large permanent storage facilities are of primary concern when applying quantity-distance (QD) criteria to storage tanks. For installation of smaller tanks, it may be desirable to weigh the cost of distance and/or protective construction against the strategic value of the stored material, the ease of replacement in the event of an accident, and the potential environmental impact. Reduced distances may be approved if these losses are accepted by the appropriate NASA Center, if the tanks are sited, and if spill containment is provided so other exposures are not endangered.

5.51.12.2 Small quantities of POL and other hazardous materials used for operational purposes require no specific separation distance for explosives safety; however, operating procedures shall be implemented to limit adverse environmental impacts in the event of an accidental explosion (Requirement).

5.51.12.3 Unprotected, aboveground storage tanks shall be separated from other PESs at IBD per Table XII, as a minimum, and shall be diked (Requirement).

5.51.12.4 Unprotected service tanks, which provide sole support to aboveground explosives storage and operating complexes and are supplied by a pipe system designed to resist potential blast and fragments, may be sited at incremented IMD distances with a minimum distance of 400 ft, provided:

5.51.12.4.1 A dike system, meeting the requirements in NFPA 30, is provided; and,

5.51.12.4.2 The NASA Center accepts the possible loss of the tanks and any collateral damage that a fire might cause as a result of the tanks being punctured by fragments.

5.51.12.5 A service tank supporting a single PES shall be separated, at a minimum, from that PES by the greater of the appropriate NFPA fire protection distance or the required distance between the PESs (Requirement).

5.51.12.6 Distances less than those for unprotected tanks may be used when an aboveground storage tank is provided sufficient protection from blast and fragment hazards to prevent rupture or collapse.

5.51.12.7 Buried tanks and buried pipelines shall be separated from aboveground buildings or stacks containing explosives of Hazard Divisions 1.2, 1.3, and 1.4 by a minimum distance of 80

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ft, and from explosives in Hazard Division 1.1 by a minimum of the K3 distance of 80 ft (Requirement).

5.51.12.8 It is not practical to specify QD criteria that cover all configurations involving tank storage facilities. Each case shall be assessed on a site specific basis to take account of crater, blast, ground shock, debris hazards, and potential adverse environmental impacts (Requirement).

5.51.13 Airfields and Heliports.

5.51.13.1 This section applies to explosives, which are under the control and custody of NASA personnel, at or near airfields and heliports. Its provisions do not apply to explosives items installed on aircraft or contained in survival and rescue kits such as flares, signals, egress system components, squibs, and detonators for jettisoning external stores, engine-starter cartridges, fire extinguisher cartridges, destructors in electronic equipment, explosives components of emergency equipment, and other such items or materials necessary for safe flight operations.

5.51.13.2 Aircraft loaded with the explosives, given in Paragraphs 5.51.13.2.1 through 5.51.13.2.3 below, are exempt from quantity-distance requirements when evaluated as a PES:

5.51.13.2.1 H/D 1.2.2 - gun ammunition, 30 mm or less.

5.51.13.2.2 H/D 1.3 - Captive missiles or aircraft defensive flare/chaff.

5.51.13.2.3 H/D 1.4 - explosives.

5.51.13.3 These aircraft shall be parked in designated aircraft parking areas that meet airfield criteria (Requirement).

5.51.13.4 Uploading and downloading of explosives shall be conducted in explosives sited aircraft parking areas with the exception of explosives listed in Paragraphs 5.51.13.2.1 through 5.51.13.2.3 (Requirement). These items can be uploaded and downloaded at the designated aircraft parking areas provided that the quantity of explosives involved in the operation is limited to a single aircraft load.

5.51.13.5 These QDs are applied in conjunction with airfield clearance criteria as prescribed by NASA Centers and Federal Aviation Regulations (see Section 2, Applicable Documents) as follows (Requirement):

5.51.13.5.1 For airfields and heliports used exclusively by NASA, explosives loaded aircraft parking areas, explosives cargo areas, alert hangars, and shelters may be located within the airfield clearance zone insofar as these QD standards are concerned, except in the explosives prohibited areas as described in Paragraph 5.51.13.6.

5.51.13.5.2 For airfields and heliports not used exclusively by NASA, explosives loaded-aircraft parking areas, explosives cargo areas, alert hangars, and shelters shall be located as prescribed in Table XXVI and Table XXVII (Requirement). (Refer to Table XXVII first.)

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Table XXVI. Hazard Division 1.1 - Quantity-Distance for Explosives Loaded Aircraft Parking Areas

Net Expl. Wt. (lb)	Distance in ft for specific targets indicated in Table XXVII.	Net Expl. Wt. (lb)	Distance in ft for specific targets indicated in Table XXVII.
50	111	6,300	554
58	116	7,400	585
69	123	8,700	617
81	130	10,000	646
95	137	12,000	687
110	144	14,000	723
130	152	16,000	756
150	159	19,000	801
180	169	22,000	841
210	178	26,000	889
250	189	31,000	942
290	199	37,000	1,000
340	209	43,000	1,051
400	221	51,000	1,113
470	233	60,000	1,174
560	247	70,000	1,236
660	261	83,000	1,309
770	275	97,000	1,378
910	291	110,000	1,437
1,000	300	130,000	1,520
1,200	319	150,000	1,594
1,400	336	180,000	1,694
1,700	358	210,000	1,783
2,000	378	250,000	1,890
2,300	396	300,000	2,008
2,800	423	350,000	2,114
3,300	447	410,000	2,229
3,800	468	480,000	2,349
4,500	495	500,000	2,381
5,300	523	--	--

NOTES

(1) To protect against low-angle, high-speed fragments, barricades shall be provided; however, these distances shall not be reduced.

(2) The distance given for 0 to 50 pounds NEW constitutes the minimum spacing permitted.

(3) The minimum distance for Hazard Division 1.1 of 1,250 ft (see Paragraph 5.51.1.7) does not apply to targets for which this table is used.

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Table XXVII. Application of Explosives Safety Distances (Airfields and Heliports) (Table entries refer to the notes below)

To:	From:				
	Explosives Loaded Aircraft Parking Area	Explosives Cargo Area	Explosives Storage Facility	Explosives Operating Facility	Ready Explosives Storage Facility
Explosives Loaded Aircraft Parking Area	3a	3a	5	5	3a
Explosives Cargo Area	3a	3a	3	3	3a
Explosives Storage Facility	3	3	3	3	3
Explosives Operating Facility	4	4	4	4	4
Ready Explosives Storage Facility	3	3	3	3	3
Inhabited Building	1	1	1	1	1
Public Traffic Route & Taxiway (joint NASA-Non-NASA use)	2	2	2	2	2
Runway (joint NASA-Non-NASA use)	1	1	1	1	1
Runway/Taxiway (NASA use only)	None	None	11	2	None
Aircraft Parking Area	10	10	6	6	10
Aircraft Passenger Loading/Unloading Area	7	7	7	7	7
Recreation Area	8	9	9	9	8

NOTES

(1) Use appropriate IBD.

(2) Use appropriate public traffic route distance.

(3) For Hazard Division 1.1 explosives, use appropriate IMD. For Hazard Division 1.2 (1.2.1, 1.2.2 and/or 1.2.3), apply Note 10, below.

(a) For Hazard Division 1.1 explosives, use appropriate IMD. For Hazard Division 1.2 (1.2.1, 1.2.2, and/or 1.2.3), apply Note 10, below. Protects against simultaneous detonation of explosives on adjacent aircraft, but does not prevent serious damage to aircraft and possible propagation of detonation due to fragments, debris, or fire.

(4) Use appropriate ILD.

(5) Use Table XXVI distances for mass-detonating items and appropriate public traffic route distances for nonmass-detonating items.

(6) Use Table XXVI distances for NASA aircraft parking areas, and appropriate IBD for non-NASA aircraft parking areas.

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(7) Use appropriate public traffic route distances for locations in the open where passengers enplane and deplane; use appropriate IBD if a structure is included where passengers assemble, such as a passenger terminal building.

(8) No distance required to recreational areas that are used exclusively for alert personnel manning the explosives loaded aircraft. Other recreational areas where people are in the open shall be at appropriate public traffic route distance. When structures, including bleacher stands, are a part of such area, appropriate IBD shall be used.

(9) Recreational areas, where people are in the open, shall be at appropriate public traffic route distance. When structures, including bleacher stands, are part of such area, appropriate IBD shall be used.

(10) Within these areas of airfields and heliports exclusively used by NASA, the separation of aircraft parking areas from explosives loaded aircraft parking areas and their ready explosives storage facilities and explosives cargo areas are considered to be a NASA Center function approved by the ESO. At joint NASA/non-NASA use airfields and heliports, the explosives loaded aircraft parking areas and its ready explosives storage facilities and explosives cargo area shall be separated from non-NASA aircraft as specified in Note 6, above.

(11) Use $18W^{1/3}$ distances from side or rear of standard earth-cover magazine to taxiway; use public traffic route distance from front of earth-covered magazines or any other storage locations to taxiways; use public traffic route distance from all storage locations to runways.

5.51.13.6 Measurement of Separation Distances. In applying Table XXVI and Table XXVII, distances shall be measured as follows (Requirement):

5.51.13.6.1 Loaded Aircraft to Loaded Aircraft. Measure the shortest distance between explosives on one aircraft to explosives on the adjacent aircraft.

5.51.13.6.2 Explosives Location to Taxiways and Runways. Measure from the nearest point of the explosives and explosives location to the nearest point of the taxiway and to the centerline of the runway.

5.51.13.7 Explosives Prohibited Areas. All explosives shall be prohibited in any area under approach and departure zones of all fixed and rotary wing aircraft landing facilities (NASA, other Federal, joint use, and civil) (Requirement). The approach and departure zone surface or areas for aircraft are those so designated and described in detail for the various types of facilities in NASA airfield and airspace criteria directives. In general, the approach and departure zone begins near the end of a runway or landing area and extends outward to a given distance along, and symmetrically on each side of, the extended runway centerline or the aircraft approach axis of a heliport. Such zones flare uniformly from the landing area outward to a prescribed limit.

5.51.14 Utilities Installations. Permanent NASA-controlled underground utilities installations (excluding building service lines) shall be separated from explosives locations containing Class 1.1 materials according to Table XXVIII (Requirement).

5.51.14.1 Utilities installations (aboveground and underground) that are privately owned or operated shall be separated from explosives locations by at least public traffic route distances (Requirement). If these installations include structures, they shall be separated from explosives facilities by IBD (Requirement).

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Table XXVIII. Quantity-Distance Separation for Protection of Underground Service Installations

Quantity of explosives (maximum pounds)	Distance (Feet)
100	80
200	80
500	80
1,000	80
2,000	80
5,000	80
10,000	80
20,000	85
50,000	110
100,000	140
250,000	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 pounds. (D = distance in feet; W = weight in pounds)

5.51.15 Energetic Liquids.

5.51.15.1 Scope and Application. This section applies to the storage of energetic liquids (listed in Table XXIX) in all types of containers, including rocket and missile tankage. Laboratory Quantities shall be stored and handled as prescribed in Sections 4C and 5C (Requirement).

Note: The required quantity-distances (QD) are only based on the energetic liquids' energetic reaction (blast overpressure and container fragmentation). These QD requirements do not consider the toxicity or potential down-wind hazard. Therefore, QD may not be the only factor that needs to be considered when selecting a location for storage and operations of energetic liquids.

5.51.15.2 Concept. These QD standards were developed on the premise that the applicable NASA Center will ensure that the materials of construction are compatible with the energetic liquids, facilities are of appropriate design, fire protection and drainage control techniques are employed, and other specialized controls (such as nitrogen padding, blanketing, and tank cooling) are used when required.

5.51.15.2.1 When additional hazards associated with explosives are involved, the safety distances prescribed in other sections of Paragraph 5.51 shall be applied, as appropriate (Requirement).

5.51.15.2.2 These standards are based upon the estimated credible damage resulting from an incident, without considering probabilities or frequency of occurrence.

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Table XXIX. Hazard Classifications and Minimum QD for Energetic Liquids

Energetic Liquid	OSHA/NFPA Fuel[1] or Oxidizer[2] Class	DoD Storage Hazard Class	Minimum QD[3]
Hydrogen Peroxide, > 60%	3 or 4[4]	5.1 (LA)	800[5] ft or Table XXXIII.
IRFNA	3	8 (LA)	Table XXXIII.
Nitrogen Tetroxide/MON	2	2.3 (LA)	Table XXXIII.
Liquid Oxygen	N/A	2.2 (LA)	Table XXXIV
Gaseous Oxygen	N/A		Table XXXVI
RP-1	II	3 (LB)	Table XXXII
JP-10	II	3J (LB)	Table XXXII
Liquid Hydrogen	N/A	2.1 (LB)	Table XXXV
Hydrazine, > 64%	II	8 (LC)	800[5] or 300[6] ft or Note 7
Aerozine 50 (50%N_2H_4/50% UDMH)	I B	6.1 (LC)	800[5] or 300[6] ft or Note 7
Methylhydrazine	I B	6.1 (LC)	800[5] or 300[6] ft or Note 7
UDMH	I B	6.1 (LC)	Table XXXII
Ethylene Oxide	I A	2.3 (LD)	H/D 1.1 QD[8] with TNT Equiv = 100%, or 800[5] or 300[6] ft
Propylene Oxide	I A	3 (LD)	H/D 1.1 QD8 with TNT Equiv. = 100%, or 800[5] or 300[6] ft
Nitromethane	I C	3 (LE)	Use H/D 1.1 QD with TNT Equiv. = 100%[9] or Table XXXII
Hydroxylammonium Nitrate (HAN)	2	8 (LE)	800[5] ft or Table XXXIII.
XM-46 (HAN Monopropellant)	N/A	1.3C (LE)	800[5] ft or use H/D 1.3 QD
Otto Fuel II	III B	9 (LE)	Table XXXII
Halogen Fluorides (ClF_3/ClF_5)	4	2.3 (LE)	Table XXXIII.
Liquid Fluorine	4	2.3 (LE)	Table XXXIII.
Nitrogen Trifluoride	4	2.2 (LE)	Table XXXIII.
Nitrate esters (NG, TMETN, DEGDN, TEGDN, BTTN)	N/A	1.1 D (LE)	Use H/D 1.1 QD with TNT Equiv. = 100%

NOTES

(1) Flammable or combustible liquid classification index based on flash point and boiling point versus criteria as specified in 29 CFR 1910.106 and NFPA 30 Flammable and Combustible Liquids Code. Primary descriptor is a Roman numeral, possibly with an additional letter.

(2) NFPA oxidizer classification index as described in NFPA 430, Code for the Storage of Liquid and Solid Oxidizers. Descriptor is an ordinary number.

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(3) Positive measures for spill containment/control shall be taken for isolated storage of energetic liquids in accordance with applicable OSHA and NFPA guidance (referenced in Table XXXII through Table XXXIV). For flammable energetic liquids and liquid oxidizers where only minimum blast or fragment distances are specified, applicable OSHA and/or NFPA guidance referenced in Table XXXII and Table XXXIII, respectively, shall also be used.

(4) Hydrogen peroxide solutions of concentration greater than 91% are NFPA Class 4 oxidizers.

(5) Shall be used as a default value, unless otherwise hazard classified, when the material is packaged in small (non-bulk) shipping containers, portable ground support equipment, small aerospace flight vehicle propellant tanks, or similar pressure vessels that provide heavy confinement (burst pressure greater than 100 psi).

(6) Shall be used as a default value, unless otherwise hazard classified, when the material is packaged in small (non-bulk) shipping containers (DOT 5C or equivalent), portable ground support equipment, small aerospace flight vehicle propellant tanks, or similar pressure vessels providing a lower level of confinement (burst pressure less than or equal to 100 psi) and if adequate protection from fragments is not provided by terrain, effective barricades, nets, or other physical means (lightweight building construction is not adequate). If protection from fragments is provided, use the IBD/PTR Protected Distance column of Table XXXV.

(7) For large ready, bulk, or rest storage tanks (as defined in Paragraphs 5.51.15.7.3.3, 5.51.15.7.3.5, and 5.51.15.7.3.6), use Table XXXV.

(8) Where there is a reasonable risk of vapor cloud explosion of large quantities (for example, in bulk tank storage).

(9) Technical grade nitromethane in unit quantities of 55 gallons or less in DOT-approved containers listed in 49 CFR173.202 may be stored as flammable liquids (Table XXXII) provided the following apply:
   (a) Packages are stored only one tier high.
   (b) Packages are protected from direct rays of sun.
   (c) Packages have a maximum storage life of two years, unless storage life tests indicate product continues to meet purchase specifications. Such tests are to be performed at one-year intervals thereafter.

(10) For underwater static test stands, when operated at hydrostatic pressure above 50 psig, or for propellant tanks or other vessels having burst pressures of greater than 100 psig without acceptable pressure relief devices (unless otherwise hazard classified). For underwater test stands, the TNT equivalence (MCE) should include the total propellant weight in all pumps and plumbing, as well as the weight of propellant held in tankage (under the test cell hydrostatic pressure) unless acceptable mitigation measures such as fuel line detonation arrestors and/or fuel tank isolation/barricading are used (as determined by hazard analysis).

(11) Should be used as a default value, unless otherwise hazard classified, when the material is packaged in small vehicle propellant tanks, small (non-bulk) shipping containers, portable ground support equipment, or similar pressure vessels that provide relatively heavy confinement (burst pressure between 50 – 100 psig) without acceptable pressure relief devices.

5.51.15.3 Determination of Energetic Liquids Quantity.

5.51.15.3.1 The total quantity of energetic liquids in a tank, drum, cylinder, or other container shall be the net weight of the energetic liquids contained therein (Requirement).

5.51.15.3.2 When storage containers are not separated from each other by the appropriate distance or are not so subdivided as to prevent possible accumulative involvement, the quantity shall be considered as the total of all such storage containers (Requirement).

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5.51.15.3.3 Quantity of energetic liquids in the associated piping shall be included to the points that positive means are provided for interrupting the flow through the pipe, or interrupting a reaction in the pipe in the event of an incident (Requirement).

5.51.15.3.4 When the quantities of energetic liquids are given in gallons, the conversion factors given in Table XXX may be used to determine the quantity in pounds.

Table XXX. Factors to Use When Converting Gallons of Energetic Liquids into Pounds

Item	Pounds per gallon	At Temperature °F
Chlorine Pentafluoride	14.8	77
Chlorine trifluoride	15.1	77
Ethyl alcohol	6.6	68
Ethylene oxide	7.4	51
Fluorine (liquid)	12.6	-306
HAN Monopropellants	11.9	77
HAN solution (25 to 95 wt %)	10.0 to 13.4	68
Hydrazine	8.4	68
Hydrogen peroxide (90 percent)	11.6	77
JP-10	7.8	60
Liquid hydrogen	0.59	-423
Liquid oxygen	9.5	-297
Monomethyl hydrazine	7.3	68
Nitrogen tetroxide	12.1	68
Nitrogen trifluoride	12.8	-200
Nitromethane	9.5	68
Otto Fuel II	10.3	77
Propylene oxide	7.2	32
Red fuming nitric acid (IRFNA)	12.9	77
RP-1	6.8	68
UDMH	6.6	68
UDMH/hydrazine	7.5	77

NOTE

Conversion of quantities of energetic liquids from gallons to pounds: Pounds of energetic liquids = gallons X density of energetic liquids in pounds per gallon.

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5.51.15.4 Measurement of Separation Distances.

5.51.15.4.1 Separation distances shall be measured from the closest hazard source (containers, buildings, segment, or positive cutoff point in piping, whichever is controlling) (Requirement).

5.51.15.4.2 When buildings containing a small number of cylinders or drums are present or when quantities of energetic liquids are subdivided effectively, distances may be measured from the nearest container or controlling subdivision.

5.51.15.5 Hazard Classification of Energetic Liquids. Replacement of the old Hazard Group (I - IV)/Compatibility Group (A - F) classification scheme (referenced in NSS-1740.12) for liquid propellants with United Nations (UN) hazard classification nomenclature as defined in Recommendations on the Transport of Dangerous Goods (Reference (d)) has been approved. Thus, the main hazard classification designator for energetic liquids is Class 1 (explosives), Class 2 (compressed or liquefied gases), Class 3 (flammable liquids), Class 4 (flammable solids, self-reactive materials), Class 5 (oxidizers), Class 6 (toxic/infectious substances), Class 7 (radioactive), Class 8 (corrosive), or Class 9 (miscellaneous). The design and logistics of modern rocket/missile systems sometimes require that consideration be given to permitting storage or operations involving energetic liquids in a storage structure containing solid explosives. For example, it may be necessary to store hydrocarbon-fueled missiles containing high explosives with fueled configurations not containing explosives. When two energetic liquids might each be compatible with certain explosives, but incompatible with each other, a two-part compatibility group designation is assigned to an energetic liquid.

5.51.15.5.1 The first element is the standard storage and transportation Compatibility Group (CG) designation. The alpha designations are the same as the CG designations for UN Hazard Class 1, with the same definitions. However, for storage and handling on NASA facilities, a CG may also be assigned to an energetic liquid in a Hazard Class other than Class 1. The absence of a CG indicates incompatibility with solid explosives.

5.51.15.5.2 The second element is a new Energetic Liquid Compatibility Group (ELCG) designation. The ELCG applies to mixed storage of energetic liquids or explosives components containing energetic liquids. The ELCG is specified in parentheses as the last element of the hazard classification. The ELCG designations and definitions are:

LA - Energetic liquids that are strong oxidizers, mainly of acidic character. These materials may cause or contribute to the combustion of other material, possibly resulting in serious flare fires or explosions. Includes, but is not limited to, nitrogen tetroxide and mixed oxides of nitrogen (MON), inhibited red fuming nitric acid (IRFNA), liquid oxygen (LO_2), hydrogen peroxide (H_2O_2), and gels, slurries, or emulsions of the above.

LB - Energetic liquids that are readily combustible when exposed to, or ignited in the presence of an oxidizing agent, but that are not strong reducing agents. Some may be hypergolic with group LA materials. Includes, but is not limited to, hydrocarbons such as kerosenes and strained ring ramjet fuels; liquid hydrogen (LH_2); and gels, slurries, or emulsions of the above.

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LC - Energetic liquids that are readily combustible when exposed to, or ignited in the presence of an oxidizing agent, and are also strong reducing agents. These will likely be hypergolic with group LA substances. Includes, but is not limited to, hydrazines and other amines; and gels, slurries, or emulsions of the above.

LD - Energetic liquids that act mainly as combustible fuels, similar to groups LB and LC, when exposed to, or ignited in the presence of oxidizing agents but that may act as oxidizers in some combinations. They may be a monopropellant with the right catalyst, or may be pyrophoric and ignite upon release to the atmosphere. Examples are ethylene and propylene oxides, and boranes.

LE - Energetic liquids having characteristics that do not permit storage with any other energetic liquid. They may react adversely with either fuels (reducing agents) or oxidizers. Examples are nitromethane, nitrate ester based formulations such as Otto Fuel II, liquid monopropellants containing hydroxyl ammonium nitrate (HAN), halogen fluorides (ClF_3 and ClF_5) and fluorine, and gels, slurries, or emulsions of the above.

5.51.15.5.3 Different energetic liquids in the same ELCG may be stored together with the exception of dissimilar liquids of Group LE. Mixed storage is prohibited between energetic liquids of different ELCG designations, with one exception: liquids of groups LB and LC should not be stored together if possible, especially for storage areas containing primarily materials of group LB; however, mixed storage is permitted if circumstances dictate. This compatibility scheme is reflected in the hazard classification for the hydroxyl ammonium nitrate based liquid propellant XM-46:

1.3C(LE)

This hazard classification reflects CG “C” which indicates the propellant can be stored in the same magazine with CG “C” solid propellants, and since CG “C” can be mixed in storage with CG ”D” (see Table XI), CG “D” high explosive projectiles could also be present. On the other hand, hydrocarbon fuel such as JP-10 would not be permitted in this storage scenario, because its ELCG (LB) indicates incompatibility with the liquid gun propellant (LE).

5.51.15.5.4 Complete NASA hazard classification assignments for current energetic liquids are shown in Table XXIX.

5.51.15.5.5 Each new energetic liquid, or new non-bulk packaging configuration of an energetic liquid, developed by a NASA organization or adopted for NASA use, shall be examined and assigned a hazard classification in accordance with Department of Transportation Procedures (Requirement).

5.51.15.6 The QD criteria described below include separation requirements for bulk quantities and, in some cases, minimum distances for pressure vessels and other commercial packaging. If the hazards of a particular new packaging configuration are not adequately addressed by the separations prescribed in the following tables, a different minimum distance may be assigned during the hazard classification process and indicated parenthetically, in hundreds of feet, as the first element of the hazard classification. For example, if a new liquid oxygen pressure vessel configuration is hazard classified: “(10)2.2(LA),” a minimum distance of 1,000 ft would apply

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for IBD and public traffic route distance, rather than the minimum distance specified in Table XXIX.

5.51.15.7 QD Standards. Since many energetic liquids are not classified as UN Class 1 explosives, conventional QD storage criteria do not generally apply to these materials. At the same time, the (non-Class 1) UN transportation hazard classifications for many energetic liquids appear to be inappropriate and/or inadequate for application to storage safety (based on available accident and test data). For example, hydrazine has a UN hazard classification of 8 (corrosive), while it also is subject to dangerous fire and explosive behavior. Thus, the implementation of QD criteria for energetic liquids is based on an independent determination of the predominant hazard presented by the material in the storage environment. The following standards are applicable to energetic liquids used for propulsion or operation of missiles, rockets, and other related devices.

5.51.15.7.1 The minimum distance requirements provided in Table XXIX, Table XXXII, Table XXXIII, Table XXXIV, and Table XXXV shall be followed for storage of bulk quantities, and in some cases, pressure vessels and other commercial packaging of energetic liquids (Requirement). In general, storage of different energetic liquids shall be separated by the minimum distance required by the material requiring the greatest distance (Requirement). In addition, positive measures shall be taken to control the flow of energetic liquids in the event of a leak or spill, in order to prevent possible fire propagation or accumulation of flammable liquids near other storage, and/or to prevent mixing of incompatible energetic liquids (except for specific hazardous locations as identified in Paragraphs 5.51.15.7.3.1, 5.51.15.7.3.2, 5.51.15.7.3.3, and 5.51.15.7.3.7) (Requirement). Explosives equivalence applies for some materials as indicated in Table XXIX and Table XXXI. Fragment hazards govern for some materials in certain packaging configurations.

5.51.15.7.2 For specific hazardous locations as defined in Paragraphs 5.51.15.7.3.1 through 5.51.15.7.3.8, explosives equivalency may apply. If so, consult Table XXIX and Table XXXI with the combined energetic liquids weight subject to mixing and use distances found in Table XII and Table XIII or fragment criteria specified in Paragraph 5.51.1.5, as appropriate. Use weight of explosives equivalent in Table XII and Table XIII or Paragraph 5.51.1.5, as appropriate. QD standards for other conditions and explosive equivalents for any combination not contained in Table XXIX or Table XXX shall be determined by the controlling NASA Center (Requirement).

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Table XXXI. Energetic Liquid Explosive Equivalents[1, 2, 3, 4, 5]

ENERGETIC LIQUIDS	TNT EQUIVALENCE	
	STATIC TEST STANDS	RANGE LAUNCH
LO_2/LH_2	*See Note 6*	*See Note 6*
LO_2/LH_2 + LO_2/RP-1	Sum of (see Note 6 for LO_2/LH_2) + (10% for LO_2/RP-1)	Sum of (see Note 6 for LO_2/LH_2) + (20% for LO_2/RP-1)
LO_2/RP-1	10 %	20% up to 500,000 pounds plus 10% over 500,000 pounds
IRFNA/UDMH [7]	10%	10%
N_2O_4/UDMH + N_2H_4 [7]	5%	10%
N_2O_4 liquid oxidizer + PBAN solid fuel (Hybrid propellants)	15% [8]	15% [8]
Nitromethane (alone or in combination)	100%	100%
Otto Fuel II	100% [9]	
Ethylene Oxide	100% [10]	100% [10]

NOTES

(1) The percentage factors given in the table are to be used to determine equivalencies of energetic liquids mixtures at static test stands and range launch pads when such energetic liquids are located aboveground and are unconfined except for their tankage. Other configurations shall be considered on an individual basis to determine equivalencies.

(2) The explosives equivalent weight calculated by the use of this table shall be added to any weight aboard before distances can be determined from Table XII and Table XIII.

(3) These equivalencies apply also for the following substitutions:
   (a) Alcohols or other hydrocarbons for RP-1.
   (b) H_2O_2 for LO_2 (only when LO_2 is in combination with RP-1 or equivalent hydrocarbon fuel).
   (c) MMH for N_2H_4, UDMH, or combinations of the two.

(4) For quantities of energetic liquids up to but not over the equivalent of 100 pounds of explosives, the distance shall be determined on an individual basis by the applicable NASA Center. All personnel and facilities, whether involved in the operation or not, shall be protected by operating procedures, equipment design, shielding, barricading, or other suitable means.

(5) Distances less than intraline are not specified. Where a number of prepackaged energetic liquid units are stored together, separation distance to other storage facilities shall be determined on an individual basis by the applicable NASA Center, taking into consideration normal hazard classification procedures.

(6) Explosive equivalent weight for LO_2/LH_2 is the larger of:
   (a) The weight equal to $8W^{2/3}$ where W is the weight of LO_2/LH_2, or
   (b) 14 percent of the LO_2/LH_2 weight.

(7) For these calculations, use the total weight of LO_2/LH_2 present in the launch vehicle, or the total weight in test stand run tankage and piping for which there is no positive means to prevent mixing in credible mishaps. When it can be reliably demonstrated that the maximum credible event involves a lesser quantity of energetic liquids subject to involvement in a single reaction, the lesser quantity may be used in determining the explosive equivalent yield. When siting is based on a quantity less than the total energetic liquids present, the maximum credible event and associated explosive yield analysis shall be documented in an approved site plan (see Section 4H).

(8) These are hypergolic combinations.

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(9) Explosive equivalency of the hybrid rocket system N_2O_4 liquid oxidizer combined with PBAN solid fuel was evaluated in 200-pound tests (see Section 2 Applicable Documents). These tests indicate a maximum TNT equivalency of 15% for an explosive donor accident scenario, 5% for a high velocity impact scenario, and less than 0.01% (negligible) for static mixing (tower drop) failures.

(10) See Note 10 of Table XXIX.

(11) See Note 8 of Table XXIX.

Table XXXII. QD Criteria for OSHA/NFPA Class I – III Flammable and Combustible Energetic Liquids Storage in Detached Buildings or Tanks[1,2]

Quantity	IBD/PTR (ft)	ILD/Aboveground Intermagazine Distance (IMD) (ft)
Unlimited[3]	50[4,5]	*Note 6*

NOTES

(1) Other guidelines for diking, tank or container construction, tank venting, and facility construction apply (except for Class III B combustible liquids, e.g.; Otto Fuel II). Refer to 29 CFR 1910.106 and NFPA 30 Flammable and Combustible Liquids Code for further guidance on liquid storage and fire protection.

(2) Refer to 29 CFR 1910.106 and NFPA 30 Flammable and Combustible Liquids Code for definition and explanation of OSHA/NFPA classification of flammable and combustible liquids.

(3) Guidelines on interior storage configuration (for container storage inside buildings) also apply with the following exceptions: (a) If the storage building is located at least 100 ft from any exposed building (under the direct jurisdiction of a fire protection organization) or property line; or (b) If the storage building is located at least 200 ft from any exposed building (not under the direct jurisdiction of a fire protection organization) or property line; or (c) for combustible liquids that do not exhibit sustained burning in bulk form; e.g., Otto Fuel II, as determined through ASTM D 92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup or comparable testing. Refer to 29 CFR 1910.106 and NFPA 30 Flammable and Combustible Liquids Code for further guidance on liquid storage and fire protection.

(4) For container storage inside of a building, IBD/PTR distances may be less than 50 ft (to a minimum of 10 ft) if the storage building is constructed of fire-resistive exterior walls having an NFPA Fire Resistance rating of two hours or more according to NFPA 251.

(5) For large tank storage, QD may be 25 feet for tank capacities up to 100,000 gallons, and 37.5 feet for capacities between 100,001 and 500,000 gallons.

For flammable liquids container storage inside of a building, ILD/Aboveground IMD is 50 ft (except as in Note 4), or for adjacent incompatible oxidizer storage, distances specified for energetic liquid oxidizers (Table XXXIII) or oxygen (Table XXXIV). For flammable liquids storage in fixed or large portable tanks, ILD/Aboveground IMD is either (1) for compatible energetic liquids, equal to one sixth of the sum of the diameters of the two adjacent tanks, or distances specified in Note 5 for adjacent container storage inside of a building; or (2) for adjacent incompatible oxidizer storage, distances specified for energetic liquid oxidizers (Table XXXIII) or oxygen (Table XXXIV). Earth-covered magazines may be used to their physical capacity for storing flammable energetic liquids provided they comply with the construction and siting requirements for Hazard Division 1.1. The earth-covered magazines shall be sited for a minimum of 100 lbs of Hazard Division 1.1 items using Table XIV and Table XV.

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Table XXXIII. QD Criteria for Energetic Liquid Oxidizer (excluding Liquid Oxygen) Storage in Detached Buildings or Tanks[1, 2]

NFPA Oxidizer Class[3]	Quantity (lbs)	IBD/PTR/ILD/Aboveground IMD (ft)
2	up to 600,000	50
3	up to 400,000	75
4[4,5]	≤ 50	75
	70	76
	100	79
	150	84
	200	89
	300	98
	500	114
	700	128
	1,000	147
	1,500	175
	2,000 [6]	200
	3,000	246
	5,000	328
	7,000	404
	10,000	510
	15,000	592
	20,000	651
	30,000	746
	50,000	884
	70,000	989
	100,000	1114
	150,000	1275
	200,000	1404
	300,000	1607
	500,000	1905

NOTES

(1) Quantity-distance requirements do not apply to storage of NFPA Class 2 and 3 oxidizers in approved fixed tanks.

(2) Other requirements for interior storage configuration, building construction, diking, container materials, and facility venting, and similar needs also apply. Refer to NFPA 430 Code for the Storage of Liquid and Solid Oxidizers for further guidance on oxidizer storage and fire protection.

(3) Refer to NFPA 430 Code for the Storage of Liquid and Solid Oxidizers for definition and explanation of NFPA classification of oxidizers.

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(4) Multiple tanks containing NFPA Class 4 oxidizers may be located at distances less than those specified in the table; however, if the tanks are not separated from each other by 10 percent of the distance specified for the largest tank, then the total contents of all tanks shall be used to calculate distances to other exposures.
(5) Notes for NFPA Oxidizer Class 4:
   (a) $W \leq 10{,}000$ lbs, Distance = $149.3*W^{(-0.41+0.059*\ln(W))}$
   (b) $W > 10{,}000$ lbs, Distance = $24*W^{1/3}$
   (c) Use of equations given in (a) and (b) to determine distances for other quantities (W) is allowed.
(6) NFPA 430 requires sprinkler protection to be provided for storage of greater than 2,000 pounds of NFPA Class 4 oxidizers inside of a building.

Table XXXIV. QD Criteria for Liquid Oxygen[1, 2]

	IBD/PTR (ft)	ILD/Aboveground IMD (ft)
Unlimited[3]	100	100 [4]

NOTES

(1) Distances do not apply where a protective structure having an NFPA fire resistance rating of at least two hours according to NFPA 251 interrupts the line of sight between the oxygen system and the exposure. Refer to 29 CFR 1910.104 and NFPA 50 Standard for Bulk Oxygen Systems at Consumer Sites for further guidance
(2) Additional guidelines relating to equipment assembly and installation, facility design (diking), and other fire protection issues also apply. Refer to 29 CFR 1910.104 and NFPA 50 Standard for Bulk Oxygen Systems at Consumer Sites for further guidance.
(3) QD is independent of oxygen quantity.
(4) Minimum ILD/IMD distance between adjacent compatible energetic liquids storage is 50 ft.

Table XXXV. QD Criteria for Liquid Hydrogen and Bulk Quantities of Hydrazines[1]

Propellant Weight (pounds)	IBD/PTR		ILD/Aboveground IMD (ft) [6,7]
	Unprotected (ft)[2, 3]	Protected (ft) [4,5]	
0--100	600	80	30
200	600	100	37
300	600	113	42
400	600	122	46
500	600	130	49
600	600	136	51
700	600	141	53
800	600	145	54
900	600	149	56
1,000	600	153	57
2,000	600	176	66
3,000	600	191	72

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Propellant Weight (pounds)	IBD/PTR		ILD/Aboveground IMD (ft) [6,7]
	Unprotected (ft) [2, 3]	Protected (ft) [4,5]	
4,000	600	202	76
5,000	600	211	79
6,000	600	218	82
7,000	600	224	84
8,000	600	230	86
9,000	600	235	88
10,000	603	239	90
15,000	691	258	97
20,000	760	272	102
25,000	819	283	106
30,000	870	292	110
35,000	916	301	113
40,000	958	308	116
45,000	996	315	118
50,000	1,032	321	120
60,000	1,096	332	124
70,000	1,154	341	128
80,000	1,206	349	131
90,000	1,255	357	134
100,000	1,300	364	136
125,000	1,400	379	142
150,000	1,488	391	147
175,000	1,566	403	151
200,000	1,637	412	155
250,000	1,764	429	161
300,000	1,800	444	166
350,000	1,800	457	171
400,000	1,800	468	175
450,000	1,800	478	179
500,000	1,800	487	183
600,000	1,800	503	189
700,000	1,800	518	194
800,000	1,800	530	199
900,000	1,800	542	203
1,000,000 [8]	1,800	552	207
2,000,000	1,800	626	235
3,000,000	1,800	673	252

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Propellant Weight (pounds)	IBD/PTR		ILD/Aboveground IMD (ft)[6,7]
	Unprotected (ft)[2, 3]	Protected (ft)[4,5]	
4,000,000	1,800	708	266
5,000,000	1,800	737	276
6,000,000	1,800	761	285
7,000,000	1,800	782	293
8,000,000	1,800	800	300
9,000,000	1,800	817	306
10,000,000	1,800	832	312

NOTES

(1) Positive measures shall be taken to prevent mixing of hydrogen or hydrazines and adjacent oxidizers in the event of a leak or spill.

(2) Distances are necessary to provide reasonable protection from fragments of tanks or equipment that are expected to be thrown in event of a vapor phase explosion.

(3) $10,000 < W \leq 265,000$ lbs, Unprotected Distance = $28*W^{1/3}$. Also W = (Unprotected Distance/28)^3.

(4) The term "protected" means that protection from fragments is provided by terrain, effective barricades, nets, or other physical means.

(5) Distances are based on the recommended IBDs given in the Bureau of Mines, Department of the Interior Report No. 5707, dated 1961 (see Section 2, Applicable Documents), and extrapolation thereof (2 cal/cm^2 on 1 percent water vapor curve). Curve fit of the data yields Protected Distance = $-154.1 + 72.89*[\ln(W)] - 6.675*[\ln(W)]^2 + 0.369*[\ln(W)]^3$.

Also $W = \exp[311.367 - 215.761*[\ln(\text{protected distance})] + 55.1828*[\ln(\text{protected distance})]^2 - 6.1099*[\ln(\text{protected distance})]^3 + 0.25343*[\ln(\text{protected distance})]^4]$.

(6) ILD/Aboveground IMD distances in this column apply for adjacent compatible (ELCG LB or LC) storage; for adjacent incompatible (other ELCG) storage, use IBD distances shown in previous columns. Earth-covered magazines may be used to their physical capacity for storing hydrogen provided they comply with the construction and siting requirements for Hazard Division 1.1. The earth-covered magazines shall be sited for a minimum of 100 lbs of Hazard Division 1.1 items using Table XIV and Table XV.

(7) Distances are an average of 37.5 percent of "protected" column.

(8) Extrapolations above 1,000,000 pounds extend well outside data from which the original QD tables were derived (Bureau of Mines, Department of the Interior Report No. 5707, dated 1961); however, they are supported by independent calculations and knowledge of like phenomena.

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Table XXXVI. Recommended Distances Between Bulk Gaseous Oxygen Storage and Flammable Gases Stored Above Ground

	Flammable Gas	Quantity	Distance	
			ft	m
NFPA 50 (see Section 2, Applicable Documents)	Liquefied hydrogen	Any	75	22.5
	Other liquefied gases	≤ 100 gal (3785 L) ≥ 100 gal (3785 L)	25	7.5
29 CFR 1910.104 (see Section 2, Applicable Documents)	Nonliquefied or dissolved gases	≤ 25 000 ft^3 (708 m^3) (NTP) > 25 000 ft^3 (708 M^3) (NTP)	25 50	7.5 15
	Compressed, liquefied, and others in low-pressure gas holders	< 500 ft^3 (142 m^3) ≥ 5000 ft^3 (142m^3)	50 90	15 27

5.51.15.7.3 Specific Hazardous Locations. Aside from the fact that the energetic liquids differ from each other, as explained for the above groups, the predominant hazard of the individual energetic liquids can vary depending upon the location of the energetic liquid storage and the operations involved. In order of decreasing hazard, these conditions are:

5.51.15.7.3.1 Launch Pads. These involve research, development, testing, and space exploration launchings. Operations at these facilities are very hazardous because of the proximity of fuel and oxidizer to each other, the frequency of launchings, lack of restraint of the vehicle after liftoff, and the possibility of fallback with resultant dynamic mixing on impact. Launch vehicle tankage is involved and explosive equivalents shall be used (Table XXXI) to determine QD from Table XII, Table XIII, or criteria specified in Paragraph 5.51.1.5, as appropriate, with the combined energetic liquids weight subject to mixing except as provided in Paragraph 5.51.15.7.3.4 (Requirement).

5.51.15.7.3.2 Static Test Stands. Although these can involve experimental operations, the units remain static and are subject to better control than launch vehicles. Except when run tankage for fuel and oxidizer are mounted one above the other, it may be possible to separate the tankage to reduce the hazard over that for the rocket or missile on the launch pad. Explosive equivalents shall be used (Table XXXI to determine QD from Table XII, or fragment criteria specified in Paragraph 5.51.1.5, as appropriate) with the combined energetic liquids weight subject to mixing as determined by hazard analysis (Requirement). The hazard analysis (maximum credible event) shall include assessment of a test article explosion with associated fragment, overpressure, and

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thermal flux effects (Requirement). The amount of energetic liquids held in run tanks can be excluded from consideration if the test stand meets the following criteria:

5.51.15.7.3.2.1 All tanks are American Society of Mechanical Engineers (ASME) certified and designed and maintained in accordance with Section VIII Division 1/Division 2/Division 3 of the ASME Code.

5.51.15.7.3.2.2 For cryogenic propellants, all tanks are constructed with double wall jacketing.

5.51.15.7.3.2.3 The configuration of the test stand is such that the thrust measuring structure load cell (heavily built structure) is between the engine and the run tanks so as to prevent fragments from puncturing the tanks in case of engine malfunction.

5.51.15.7.3.2.4 Each feed line contains two remotely operated valves to shut off energetic liquids flow in the event of a malfunction.

5.51.15.7.3.3 Ready Storage. This storage is relatively close to the launch and static test stands; normally it is not involved directly in feeding the engine as in the case with run tankage, which is an integral part of all launch and test stand operations. The explosive equivalents shall be used (Table XXXI to determine QD from Table XII, Table XIII, or fragment criteria specified in Paragraph 5.51.1.5, as appropriate) with the combined energetic liquids weight subject to mixing if the facility design does not guarantee against fuel and oxidizer mixing and against detonation propagation to, or initiation at, the ready storage facility when a mishap occurs at the test stand, on the ground at the launch pad, or at the ready storage areas (Requirement). Otherwise, fire and fragment hazards shall govern (Table XXIX, Table XXXII, Table XXXIII, Table XXXIV, and Table XXXV) (Requirement).

5.51.15.7.3.4 Cold-flow Test Operations. Fire and fragment hazards shall govern (Table XXIX, Table XXXII, Table XXXIII, Table XXXIV, and Table XXXV) if the design is such that the system is closed except for approved venting, the system is completely airtight, fuel and oxidizer never are employed concurrently, and each tank has a completely separate isolated system and fitting types to preclude intermixing, and the energetic liquids are of required purity (Requirement). Otherwise, explosive equivalents (Table XXXI) shall be used with the combined energetic liquids weight (Requirement).

5.51.15.7.3.5 Bulk Storage. This is the most remote storage with respect to launch and test operations. It consists of the area, tanks, and other containers therein, used to hold energetic liquids for supplying ready storage and, indirectly, run tankage where no ready storage is available. Fire and fragment hazards govern (Table XXIX, Table XXXII, Table XXXIII, Table XXXIV, and Table XXXV) except in special cases as indicated in Table XXIX and Table XXXI.

5.51.15.7.3.6 Rest Storage. This is temporary-type storage and most closely resembles bulk storage. It is a temporary parking location for barges, trailers, tank cars, and portable hold tanks used for topping operations when these units actually are not engaged in the operation; and for such vehicles when they are unable to empty their cargo promptly into the intended storage container. Fire and fragment hazards govern (Table XXIX, Table XXXII, Table XXXIII, Table XXXIV, and Table XXXV) except in special cases as indicated in Table XXIX and Table XXXI.

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The transporter becomes a part of that storage to which it is connected during energetic liquids transfer.

5.51.15.7.3.7 Run Tankage (Operating Tankage). This consists of the tank and other containers and associated piping used to hold the energetic liquids for direct feeding into the engine or device during operation. The contents of properly separated "run tanks" (operating tankage) and piping are normally considered on the basis of the pertinent hazards for the materials involved, except for quantities of incompatible materials that are or can be in a position to become mixed. Explosive equivalents shall be used (Table XXXI) for quantities of such materials subject to mixing unless provisions of Paragraphs 5.51.15.7.3.2.1 through 5.51.15.7.3.2.4 are satisfied (Requirement).

5.51.15.7.3.8 Pipelines. A 25-foot clear zone to inhabited buildings shall be maintained, as a minimum, on each side of pipelines used for energetic liquids (excluding flammable or combustible liquids that exhibit normal fire hazards such as RP-1, JP-10, and Otto Fuel II). Table XXIX, Table XXXIII, Table XXXIV, and Table XXXV apply, as appropriate (Requirement).

5.51.15.8 Contaminated Energetic Liquids.

5.51.15.8.1 Caution shall be exercised in the storage and handling of contaminated energetic liquids (Requirement). Such contamination may increase the degree of hazard associated with the energetic liquids.

5.51.15.8.2 Energetic liquids known to be contaminated or in a suspect condition shall be isolated and provided separate storage from all other energetic liquids pending laboratory analysis for verification of contamination and disposition requirements, if any (Requirement).

SECTION 5J TRANSPORTATION, MATERIALS HANDLING EQUIPMENT, AND SHIPMENT OF EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS

5.52 General Transportation Requirements

This section gives safety requirements for the transportation of explosives and for the safe operation of vehicles and materials handling equipment in explosives locations. These requirements comply with Department of Transportation (DOT) regulations.

5.53 Motor Vehicle Transportation Requirements

5.53.1 All motor vehicle shipments are governed by DOT and shall comply with DOT, State, and municipal regulations (Requirement).

5.53.2 Before any motor vehicle designated for movement over public highways may be loaded with explosives or ammunition (DOT Class 1, all Divisions) or other dangerous similar articles, the vehicle shall be inspected and approved by a qualified explosive vehicle inspector (Requirement).

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5.53.3 Explosives shall not be transported in the cab or any other portion of the vehicle occupied by personnel (Requirement).

5.53.4 Motor vehicles for explosives shipment, such as cargo type trucks and truck-tractor drawn semi trailer vans, are the preferred means of explosives transportation. Vehicles used for transporting explosives shall meet the following requirements (Requirement):

5.53.4.1 Special precautions shall be taken to avoid ignition of the material by the exhausts of vehicles (Requirement).

5.53.4.2 The lighting system shall be electric, with batteries and wiring so located that they will not come into contact with containers of explosives (Requirement).

5.53.4.3 The interior of the cargo area shall have all exposed ferrous metal covered with nonsparking material when transporting scrap and bulk explosives (Requirement). If the explosives consist of shipments packaged for shipment in accordance with DOT specifications, the ferrous metal need not be covered. Where a top is required, it shall be of noncombustible or flame-proof material (Requirement). Whenever tarpaulins are used for covering explosives, they shall be secured by means of rope or wire tiedowns (not nails) (Requirement).

5.53.4.4 All vehicles shall be equipped with two (2) each Class 4A: 60BC rated portable fire extinguishers when transporting DOT Class 1 explosives (Requirement).

5.53.4.5 Vehicles (including flat-bed type), partly or completely loaded, shall have the lading blocked, braced, chocked, tied down, or otherwise secured to prevent shifting during transit, as determined by the ESO, and inspected by a qualified explosives inspector (Requirement).

5.53.4.6 Vehicles shall not be left unattended unless they are parked in a properly designated area (Requirement). When an operator leaves a vehicle in a properly designated area, the brakes shall be set and wheels chocked (Requirement).

5.53.4.7 When transporting electro-explosive devices (EEDs), full consideration shall be given to the inherent hazards where vehicles are equipped with transmitters or other electromagnetic radiation sources (Requirement). EEDs shall always be transported in their packaged configuration (Requirement).

5.53.4.8 Explosives shall not be grounded to the transport vehicle (Requirement).

5.53.5 Requirements for placarding of vehicles transporting explosives are provided in paragraph 5.4.5.

5.54 Surface, Air, and Water Transportation Regulations

The transportation of explosives by rail, air, vessel, and public highway shall comply with DOT regulations CFR Title 49 Sections 173.52, 174.81, 175.78, 176.83, and 177.848 (Requirement), and those transported by air shall comply with International Civil Aviation Organization (ICAO) “Technical Instructions for the Safe Transport of Dangerous Goods by Air” and International Air Transport Association (IATA) “Dangerous Goods Regulations” (Requirement).

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5.55 Materials Handling Equipment for Explosives.

5.55.1 General

5.55.1.1 Specification, operation, and maintenance of materials handling equipments shall be in accordance with this standard and OSHA and NFPA regulations (Requirement).

5.55.1.2 Trucks with end-operating platforms or pedals shall be equipped with platform guards of heavy iron, heavy steel plate or materials of equal strength (Requirement). The guards should be 18 inches high on the sides and should extend beyond the platform or pedal to protect the operator.

5.55.1.3 Overhead guards shall meet the requirements of ASME B56.1 for forklift trucks of all types (Requirement).

5.55.2 Battery-Powered Equipment.

5.55.2.1 Battery-powered equipment and its use in hazardous locations shall comply with OSHA and NFPA standards and be appropriately labeled for ready identification (Requirement).

5.55.2.2 Types E, EE, ES, and EX (defined in NFPA 505) rated battery-powered equipment are satisfactory for handling all classes of explosives packed in accordance with DOT.

5.55.2.3 Type EE and ES equipment shall not be used at Class I or Class II, Division I hazardous locations (Requirement).

5.55.2.4 Type EX equipment is the only equipment approved for use at specifically named Class I, Group D or Class II, Group G hazardous location (see NFPA 505).

5.55.2.5 Fire extinguisher requirements are provided in Paragraph 5.53.4.4.

5.55.3 Gasoline, Diesel-Powered, Compressed Natural Gas (CNG) and Liquid Propane (LP)-Gas-Powered Equipment.

5.55.3.1 Approved explosives handling gasoline, diesel-powered, CNG, and LP-gas-powered equipment can be used for all classes of explosives, provided the explosives are not located in a hazardous location as defined by NFPA and OSHA, the explosives are not exposed, and there is no explosives dust present. Equipment operating within 25 feet of exposed explosives shall meet the following precautionary measures and devices requirements (Requirement):

5.55.3.1.1 Equipped with backfire deflectors of the oil bath or screen type attached on the throat of the carburetor.

5.55.3.2 A tight fitting fuel cap, properly vented.

5.55.3.3 A flame arrester installed in the fill pipe.

5.55.3.4 If required, a deflector plate installed to prevent any overflow from the fuel tank from reaching the motor or the exhaust pipe.

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5.55.4 Fire extinguisher requirements are provided in Paragraph 5.53.4.4.

5.56 Refueling Procedures

5.56.1 Gasoline and diesel-powered equipment shall not be refueled inside warehouses but outside 20 ft from a building that is inert and 90 ft from an explosive facility (Requirement).

5.56.2 During gasoline refueling, an electrically continuous path to ground shall be maintained between the tank being filled and the tank being emptied (Requirement).

5.56.3 The entire system shall be grounded before the refueling is begun (Requirement).

5.56.4 No smoking or open flame shall be allowed within 50 ft of the refueling operation (Requirement).

5.56.5 Motors of fork truck and/or the refueling truck shall be turned off before refueling begins (Requirement).

5.57 Storage of Gasoline, Diesel-Powered, or LP-Gas Powered Equipment

5.57.1 Gasoline, diesel-powered, or LP-gas-powered equipment shall not be stored in buildings containing explosives or on explosives loading docks where explosives are present (Requirement).

5.57.2 A central storage located at an approved safe distance and at least 50 ft from buildings is preferred. Storage areas for LP-gas-powered equipment should have continuous mechanical ventilation from the floor level.

5.58 Storage of Battery-Powered Equipment

5.58.1 When necessary for efficient operation, battery-powered materials handling equipment (MHE) permitted for use in the building or magazines containing explosives materials may be temporarily stored in magazines containing packaged explosives provided the following conditions are met:

5.58.2 Periods of idle storage do not exceed 4 days.

5.58.3 After each workday, MHE shall be inspected and removed from the building if hot brakes, leaking oil, or fluid are found to be present (Requirement).

5.58.4 Battery cables shall not be disconnected in explosives storage locations due to the possible arcing when terminals separate (Requirement).

5.58.5 MHE shall be packed and secured at the maximum distance from the explosives (Requirement).

5.58.6 MHE shall not be stored in an operating building containing explosives because of the increased hazards of loose or exposed explosives (Requirement).

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5.59 Operating Requirements

5.59.1 A distance of at least three truck lengths shall be maintained between trucks in operation (Requirement).

5.59.2 Riders, lunch boxes, newspapers, extra clothing, and similar items, shall not be permitted on lift trucks at anytime (Requirement).

5.59.3 When MHE is used as a personnel lift, approved safety pallets/work platforms shall be used (Requirement).

5.59.4 Trucks used outside after dark shall have red reflectors on the rear and be equipped with headlights front and rear (Requirement).

5.59.5 Loads on tines of forklifts shall not extend more than one-third of the height of the top tier of containers above the load backrest (Requirement).

5.60 Preparing Explosives and Pyrotechnics for Shipment

5.60.1 Packaging Regulations. The general regulations governing the marking, packing, and shipping of explosives are set forth in DOT regulations, and IATA and ICAO regulations if applicable.

SECTION 5K EXPLOSION HAZARDS AND EXPOSURE RISK MANAGEMENT

5.61 Introduction

5.61.1 In the assessment of the hazard associated with a given situation, the principal effects of the explosive output to be considered are blast pressure, primary and secondary fragments, thermal hazards, and toxicity hazards. Variances are available as an alternative to the Quantity-Distance (QD) requirements published in the QD tables in this document. Upon approval by the ESO and subsequent review by the NASA Headquarters Office of Safety and Mission Assurance, these distance requirements may be reduced if either of the two following conditions are met:

5.61.1.1 Engineering risk assessment or testing/analyses of blast, fragment, and thermal hazards show acceptable exposure as defined in this section; or

5.61.1.2 Use of protective construction and/or substantial dividing walls, designed in accordance with TM5-1300 or equivalent approved methods, or protective shields/barricades (as described in Paragraphs 4.25.5.7 and 4.25.5.8) reduce blast, fragment, and thermal hazards to acceptable levels.

5.62 Risk Management Process

Explosives safety criteria in this Standard specify minimum acceptable standards for explosives safety. Departure from this explosives safety standard shall only result from operational necessity and all risks associated with the departure must be completely understood and accepted by the appropriate approval authority (Requirement). The following principles apply: (1) Accept no unnecessary risk, (2) Make risk decisions at the appropriate level, (3) Accept risk

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when benefits outweigh the costs, (4) Integrate risk management into NASA planning at all levels. Refer to Figure 9 for methods on eliminating or reducing risk to support the six-step process of Operational Risk Management.

1. Identify the Hazard. A hazard can be defined as any real or potential condition that can cause mission degradation, injury, illness, death to personnel or damage to or loss of equipment or property. Experience, common sense, and specific risk management tools help identify real or potential hazards.

2. Assess the Risk. Risk is the probability and severity of loss from exposure to the hazard. The assessment step is the application of quantitative or qualitative analyses to determine the level of risk associated with a specific hazard. This process defines the probability and severity of a mishap that could result from the hazard based upon the exposure of personnel or assets to that hazard.

3. Analyze Risk Control Measures. Investigate specific strategies and tools that reduce, mitigate, or eliminate the risk. Effective control measures reduce or eliminate one of the three components (probability, exposure, or severity) of risk.

4. Make Control Decisions. Decision makers at the appropriate level choose the best control or combination of controls based on the analysis of overall costs and benefits.

5. Implement Risk Controls. Once control strategies have been selected, an implementation strategy needs to be developed and then applied by management and the work force. Implementation requires commitment of time and resources.

6. Supervise and Review. Risk management is a process that continues throughout the life cycle of the system, mission, or activity. Leaders at every level must fulfill their respective roles in assuring controls are sustained over time. Once controls are in place, the process must be periodically reevaluated to ensure their effectiveness.

Figure 9. Six-Step Process of Operational Risk Management.

5.63 Blast Wave Phenomena

5.63.1 The violent release of energy from a detonation in a gaseous medium gives a sudden pressure increase in that medium. The pressure disturbance, termed the blast wave, is characterized by an almost instantaneous rise from the ambient pressure to a peak incident pressure. This pressure increase, or shock front, travels radially from the burst point with a diminishing velocity that always is in excess of the sonic velocity of the medium. Gas molecules making up the front move at lower velocities. This latter particle velocity is associated with a "dynamic pressure," or the pressure formed by the winds produced by the shock front.

5.63.1.1 As the shock front expands into increasingly larger volumes of the medium, the peak incident pressure at the front decreases and the duration of the pressure increases.

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5.63.1.2 If the shock wave impinges on a rigid surface oriented at an angle to the direction of propagation of the wave, a reflected pressure is instantly developed on the surface and the pressure is raised to a value that exceeds the incident pressure. The reflected pressure is a function of the pressure in the incident wave and the angle formed between the rigid surface and the plane of the shock front.

5.64 Partially Confined Explosions

When an explosion occurs within a structure, the peak pressure associated with the initial shock front will be extremely high and, in turn, will be amplified by reflections within the structure. In addition, the accumulation of gases from the explosion will exert additional pressures and increase the load duration within the structure. The combined effects of both pressures eventually may destroy the structure if it is not strengthened sufficiently or adequate venting for the gas and the shock pressure is not provided, or both. For structures that have one or more strengthened walls, venting for relief of excessive gas or shock pressures, or both, may be provided by means of openings in or frangible construction of the remaining walls or roof, or both. This type of construction will permit the blast wave from an internal explosion to spill over onto the exterior ground surface. These pressures, referred to as exterior or leakage pressures, once released from their confinement, expand radially and act on structures or persons, or both, on the other side of the barrier.

5.65 Expected Effects – Hazard Division 1.1

5.65.1 Conventional Structures. Conventional structures are designed to withstand roof snow loads of 30 pounds per square foot (1.44 kilopascals) and wind loads of 100 miles per hour (161 kilometers per hour). The loads equate to 0.2 pounds per square inch (psi). Airblast overpressure at Hazard Division 1.1 barricaded ILD is 12 psi (82.7 kPa); at unbarricaded ILD is 3.5 psi (24 kPa); and at IBD is 0.9 to 1.2 psi (6.2 to 8.3 kPa). Comparing these loads with the design capacity, it is evident that conventional buildings will be damaged even at IBD. Conventional structures, which include aboveground storage facilities, contribute little to propagation protection from either blast or fragments. Propagation protection is provided by distance and/or barricading. The amount of damage to be expected at various pressure levels is described in Paragraph 6.3.

5.65.2 Earth-Covered Magazines. The earth-covered magazines identified in Paragraph 4.25.6.1.3.3, separated one from another by the minimum distances required by Table XV, provide virtually complete protection against propagation of explosion by blast, fragments, and fire; however, there may be some cracking of concrete barrels and rear walls, possible severe cracking and some spalling of front walls, and some damage to doors and ventilators.

5.65.3 High Performance Magazines. The high performance magazine (HPM) identified in Paragraph 4.25.8, with the minimum intermagazine separation distances required by Table XV, provides virtually complete protection against propagation of explosion by blast, fragments, and fire. The story-2 transfer area is enclosed by a pre-engineered metal building, which may be severely damaged. The amount of damage to be expected at various pressure levels is described below. Unless special design requirements are imposed, access to ammunition items at less than $30W^{1/3}$ feet from a donor explosion requires extensive cleanup and mobile crane.

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5.66 Fragments

5.66.1 An important consideration in the analysis of the hazard associated with an accidental explosion is the effect of the fragments generated by the explosion. These fragments are known as primary or secondary fragments depending on their origin.

5.66.2 Primary fragments are formed as a result of the shattering of the explosive container. The container may be the casing of conventional munitions, the kettles, hoppers, and other metal containers used in the manufacture of explosives; the metal housing of rocket engines; and similar items. These fragments usually are small in size and travel initially at velocities on the order of thousands of feet per second.

5.66.3 Secondary fragments are formed as a result of high blast pressures on structural components and items in close proximity to the explosion. These fragments are somewhat larger in size than primary fragments and travel initially at velocities on the order of hundreds of feet per second.

5.66.4 A hazardous fragment is one having an impact energy of 58 ft-lb (79 joules) or greater.

5.67 Thermal Hazard

5.67.1 General. The energetic materials used by NASA all produce an exothermic reaction defined either as a deflagration or a detonation. A deflagration is an exothermic reaction that propagates from the burning gases to the unreacted material by conduction, convection, and radiation. In this process, the combustion zone progresses through the material at a rate that is less than the velocity of sound in the unreacted material. In contrast, a detonation is an exothermic reaction that is characterized by the presence of a shock wave in the material that establishes and maintains the reaction. A distinctive difference is that the reaction zone propagates at a rate greater than the sound velocity in the unreacted material. Every material capable of detonating has a characteristic velocity that is under fixed conditions of composition, temperature, and density.

5.67.2 Permissible Exposures. Personnel shall be provided protection that shall limit thermal fluxes to 0.3 calories per square centimeter per second (12.56 kilowatts per square meter) when hazard assessments indicate the probability of accidental explosions is above an acceptable risk level as determined on a case-by-case basis by the NASA Center concerned (Requirement).

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CHAPTER 6 NOTES.

(This section contains information of a general or explanatory nature that may be helpful but is not mandatory.)

6.1 Environmental Conditions and Common Sources of ESD (Supplemental to Paragraph 5.13.1)

6.1.1 The development of electrical charges may not be a potential fire or explosion hazard. There must be a discharge or sudden recombination of separated positive and negative charges. In order for static to be a source of ignition, five conditions must be fulfilled:

6.1.1.1 A mechanism for generating static electricity must be present.

6.1.1.2 A means of accumulating or storing the charge so generated must exist. Composite solid rocket motor cases or liquid propellant tankage that are non-conductive could provide this means. The composite in such components therefore needs to be conductive.

6.1.1.3 A suitable gap across which the spark can develop must be present.

6.1.1.4 A voltage difference sufficient to cause electrical breakdown or dielectric breakdown must develop across the gap.

6.1.1.5 A sufficient amount of energy must be present in the spark to exceed the minimum ignition energy requirements of the flammable mixture.

6.1.2 Some common sources of ESD are:

6.1.2.1 Nonconductive power or conveyor belts in motion.

6.1.2.2 Moving vehicles.

6.1.2.3 Motions of all sorts that involve changes in relative position of contacting surfaces, usually of dissimilar liquids or solids.

6.1.3 Human spark ignition of flammable gases, vapors, dusts, or explosives and propellants is a significant concern in NASA explosives and industrial facilities. A key consideration in the analysis of an explosives operation or process is the determination of the degree of hazard associated with human spark scenarios and the mechanisms by which the ESD is generated, stored, and discharged. The amount of energy that can be generated is usually a function of the charge generation characteristics of the clothing and footwear of the person involved. Energy storage is dependent on the capacitance of the body, while the energy discharged is controlled largely by the bodies resistance and the configuration of the point of discharge. Further technical information on this subject can be found in the "Review of Literature Related to Human Spark Scenarios," by Brian D. Berkey, Thomas H. Pratt, and George M. Williams, Hercules Incorporated, Missile, Ordnance and Space Group, Allegheny Ballistics Laboratory, Rocket Center, WV.

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6.1.4 A less well-recognized source of ESD produces hazards caused by static sparking from semi conductive liquids or the human body as a result of a phenomenon called "induction charging." This phenomenon can cause fires in flammable gas/air or vapor/air mixtures and involves static electrification of a nonconductor which, in turn, creates induced charges. For further information on this phenomenon and a summary paper of the following topics, see "Spark Ignition Hazards Caused by Charge Induction," by J. E. Owens, Condux, Inc., Newark, DE. Topics include:

6.1.4.1 Special characteristics of induction charging.

6.1.4.2 Six incidents in which induction charging resulted in a fire.

6.1.4.3 Protective measures that were taken against charge induction.

6.2 EED Initiation from Electromagnetic Radiation (Supplemental to Paragraph 5.13.5)

6.2.1 EEDs are typically designed to be initiated by low levels of electrical energy. As such, they are susceptible to unintentional ignition by many forms of direct or induced electrical energy such as from lightning discharges, static electricity, or tribo-electric (friction-generated) effects. Another aspect of this hazard is the accidental initiation of EEDs by radio frequency (RF) energy due to ground and airborne emitters. Electromagnetic energy can be either conducted or radiated. Conducted electromagnetic energy is imposed on circuits from other subsystems or sources by various methods. Examples are inductive or capacitive coupling from other cabling, sneak ground circuits, defective components or wiring, or errors in design. Hazards from static electricity to EEDs in explosive items occur mainly in ground operations. Some airborne incidents attributed to static electricity probably were due to induced effects from lightning strikes or to stray energy from onboard equipment. Susceptibility to electromagnetic radiation (EMR) is dependent on a number of variables. Among these are the no-fire sensitivity level of the EED; the configuration of the leads, circuit, or installation; and the frequency and power density of the EMR environment. The primary means for ensuring EMR does not cause inadvertent EED initiation is by limiting the power density to levels below the no-fire sensitivity threshold of the EEDs.

6.2.2 Ordnance with electrically initiated devices (EIDs) may be inadvertently ignited during, or experience degraded performance characteristics after, exposure to the external radiated electromagnetic energy (EME) for either direct RF induced actuation or coupling to the associated firing circuits.

6.2.3 RF energy of sufficient magnitude to fire or dud EIDs can be coupled from the external EME via explosive subsystem wiring or capacitively coupled from nearby radiated objects. The possible consequences include both hazards to safety and performance degradation. Ordnance includes weapons, rockets, explosives, EIDs themselves, squibs, flares, igniters, explosive bolts, electric primed cartridges, destructive devices, and jet assisted take-off bottles.

6.2.4 The accidental firing of EIDs by RF energy is not a new concern. Commercial manufacturers of blasting caps have warned their customers for many years about the potential hazard involved in using electrically fired blasting caps in the vicinity of radio transmitters. Most EIDs employ a small resistive element called a bridge wire. When the EID is intentionally

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fired, a current pulse is passed through the bridge wire, causing heating and resultant initiation of the explosive charge. RF induced currents will cause bridge wire heating that may inadvertently fire the EID. Interface wiring to the EID generally provides the most efficient path for RF fields to couple energy to the bridge wire. However, RF energy can also fire extremely sensitive devices, such as electric primers, as a result of capacitive coupling from nearby radiated objects. RF energy may also upset energized EID firing circuits, causing erroneous firing commands to be sent to the EID. Non-bridge wire types of EIDs are being increasingly used for many ordnance applications. The electrothermal behavior of these devices differs considerably from bridge wire devices; many have much faster response times and exhibit non-linear response characteristics.

6.2.5 The response of an EID to an RF energy field, and the possibility of detonation, depend on many factors. Some of these factors are transmitter power output, modulation characteristics, operating frequency, antenna propagation characteristics, EID wiring configuration (such as shielding, length, and orientation), and the thermal time constant of the device.

6.2.6 The purpose of verification methods is to show that electroexplosive subsystems will not inadvertently operate and EIDs will not inadvertently initiate or be dudded during handling, storage, or while installed in the system. Assessment of the immunity of an EID is based upon its no-fire threshold. For acceptance, it should be demonstrated that any pick-up in an EID circuit in the specified EME will not exceed a given level expressed as a margin in dB below the maximum no-fire threshold sensitivity for the EID concerned. The maximum no-fire threshold is defined in terms of the level at which no more than 0.1% of the devices will fire at a 95% confidence level when a stimulus is applied for a period of time at least ten times the time constant of the device. The maximum no-fire threshold can also be defined in accordance with MIL-I-23659. Furthermore, there should not be any RF-induced interference to energized firing circuits that results in an unintentional firing command or stimulus to the EID in the specified EME. Acceptable performance is demonstrated as the margin in dB below the malfunction or switching threshold for an electronic component or system.

6.2.7 The required margins distinguish between safety (16.5 dB) and other applications (6 dB) and allow for measurement uncertainties, such as test instrumentation, EME levels, system configuration, or other items affecting measurement accuracy.

6.2.8 An important parameter, which often does not receive adequate attention in safety evaluations, is the thermal time constant of the EID. The temperature rise of EID bridge wires to a current step can be modeled as an exponential. The time constant is the point in time on an exponential curve where the exponent equals minus one and 63% of the final temperature value has been reached. Typical time constants for bridge wire devices have been found to be between 1 and 20 milliseconds. Heating and cooling time constants are similar. Time constants are not routinely determined as standard practice.

6.2.9 Most instrumentation techniques in use are slow responding, particularly with respect to 1 millisecond. They will produce reasonable results for high duty cycle waveforms such as voice communications. For pulsed radar signals, these techniques rely on a long-term effect called thermal stacking, which is related to average power. Each pulse causes a small amount of heating followed by a relaxation period where some cooling occurs. After several thermal time

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constants, the temperature of the EID bridge wire reaches an equilibrium condition with some small temperature excursions about the equilibrium point.

6.2.10 This concept works well when the pulse width and pulse period are small compared with the time constant; for example, a 1 microsecond pulse and a 1 millisecond period with a 20 millisecond EID time constant. However, radars exist with pulse widths well over 1 millisecond and pulse rates may be low or not even relevant due to phased-array operation where consecutive pulses may be at completely different azimuth and elevation positions. Some examples follow. If a radar has a 5 millisecond pulse width and a 1 millisecond time constant EID is under consideration, the thermal element will essentially reach equilibrium during a single pulse and average power is irrelevant. The radar can be treated as continuous wave. If the radar has a 20 millisecond inter-pulse period (50 Hz pulse repetition frequency), a 1 millisecond thermal element will cool completely between pulses for practical purposes and no thermal stacking takes place. Under this condition, the energy in the pulse is important for pulses that are short compared to the time constant, and the peak power is important for pulses that are long compared to the time constant. Current instrumentation may not provide reliable results for these situations, and analytical techniques or special calibrations may be necessary to correct results.

6.2.11 EIDs with thermal response times less than or equal to the radar pulse width are referred to as "pulse-sensitive" or "peak power-sensitive" devices. Examples include conducting composition devices, thin film devices, and semiconductor junction devices.

6.2.12 When the thermal time constant of an EID is known, calculations can be made to assess responses for varying emitter parameters. If the response of an EID is known for CW or, equivalently, for a pulse that is long compared to the thermal time constant ($\geq$ 10 times the time constant), a meaningful response figure for a particular pulsed emitter can be obtained by using the following multiplying factor (MF) for peak power in the pulse.

$$MF = \frac{1 - e^{\frac{-t_2}{\tau}}}{1 - e^{\frac{-t_1}{\tau}}}$$

Where

t_1 = radar pulse width
t_2 = radar pulse interval = 1/PRF (pulse repetition frequency)
τ = EID time constant

6.2.13 For example, if an EID with a 100 sec time constant has a maximum no-fire power of 1 watt CW at the operating frequency of a radar with a 30 sec pulse width and 1000 sec pulse interval, the MF is:

$$MF = \frac{1 - e^{\frac{-1000}{100}}}{1 - e^{\frac{-30}{100}}} = 3.86$$

6.2.14 Therefore, the maximum no-fire level for the EID for peak pulse power is 3.86 watts. Similarly, the MF can be used with known responses from radiated fields. If the installed EID is

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known to be capable of tolerating 100 mW/cm^2 for a CW field, then it is reasonable to assume it can tolerate 386 mW/ cm^2 peak power density for the particular radar. Similar calculations can be made to compare peak electric fields, voltages, and currents to CW parameters; however, the square root of MF must be used to obtain correct values. If a 16.5 dB margin exists for the CW field, then the same 16.5 dB margin exists for the calculated pulsed field.

6.2.15 When the EID time constant is short compared to both the emitter pulse width and pulse interval, the MF approaches one as expected, indicating that a single emitter pulse has the same effect as CW.

6.2.16 The Franklin Research Institute developed the following equations to evaluate the energy absorbed by the leads attached to an EID. The leads form an "aperture" by which the electromagnetic energy is captured.

6.2.16.1 Case 1. Pin-to-Pin, For an aperture of small size with respect to wavelength ($\lambda/2$ greater than A) the power coupled to the EID as a function of frequency may be expressed as:

$$W = \frac{4.67x10^4 A^2 P}{\pi \lambda^2 R_t}$$

Where :

W = Power density coupled to the EID (Watts)
A = Area of aperture formed by the input leads to the EID (meters^2)
P = Power density incident on EID leads (watts/meter^2)
R_t = Resistance of the EID (ohms)
λ= Wavelength of transmitter frequency (meters) ($c = 3 X 10^8/f$)
f = Frequency (Hz)

6.2.16.2 For an aperture of large size (perimeter of leads greater than $\lambda/2$)

$$W = \frac{D\lambda^2 P}{4\pi}$$

Where: D = directivity of loop

6.2.16.3 For worst-case calculations, a composite directivity of three known antenna configurations, the unterminated rhombic, the long wire, and the circular loop are used. These directivities can be approximated by:

$$D = 0.353\frac{l}{\lambda} + 1.5 \quad \text{for} \quad \frac{l}{\lambda} \leq 1.7$$

$$D = 1.24\frac{l}{\lambda} \quad \text{for} \quad \frac{l}{\lambda} \geq 1.7$$

6.2.17 Example 1. (Supplemental to Paragraph 5.13.5.1.4). Use Figure 5 or the proper formula in Table V to find the recommended safe separation distance for the following conditions:

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Condition of EED: Exposed.
Transmitter frequency = 300 MHz.
Average transmitter power = 1000 watts.
Antenna gain = 15dB.

When using the nomograph:

Step 1. Mark the point where 300 MHz lies on the frequency scale.

Step 2. Determine the effective radiated power (ERP) by multiplying P_tG_t where P_t = 1000 watts (given)

$G_t = \log^{-1}$ [G(dB/10) = $\log^{-1}$ [15/10] = $\log^{-1}$ 1.5 (or G_t = 31.6)
P_tG_t = (1000) (31.6) = 31,600 watts.

Mark this spot on the effective radiated power scale.

Step 3. Draw a straight line through the points established in Steps 1 and 2 to the distance scale.

The recommended safe separation distance, about 250 ft, is read where the line intersects the distance scale.

When using the formula:

Step 1. Find the proper column and formula from Table V. Since the EED is exposed and the frequency is 300 MHz, the applicable formula is:

$$D = \frac{450}{300} \times \sqrt{P_t G_t}$$

Step 2. Determine P_tG_t where
P_t = 1000 watts (given),
GdB = 15
$G_t = \log^{-1}$ [G(dB/10] = 31.6
P_tG_t = (1000) (31.6) = 31,600 watts
Step 3. Substitute these values into the formula:

$$D = \frac{450}{300} \times \sqrt{3160} = 267\,feet$$

6.2.18 Example 2: Is EED exposure within the maximum allowable power density, given the following conditions?

Actual measured power density = 450 W/m^2.

Condition of EED: In nonmetallic containers. Frequency: 200 MHz.

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Step 1. Find the proper column and formula in Table V. Since the frequency is 200 MHz, the proper formula to determine maximum safe power density is: $P_0 = 4.256 \times 10\text{-}5 \times f^2$.

Step 2. Solve the equation: $P_0 = 4.256 \times 10^{-5} \times (200)2$ which yields $P_0 = 1.7\ W/m^2$.

Therefore, the EED exposure (450 W/m^2) is more than the computed maximum safe power density.

6.3 Expected Effects of Hazard Division 1.1 (Supplemental to Paragraph 5.51.1)

6.3.1 Barricading will reduce significantly the risk of propagation of explosion and injury to personnel by fragments. It may not have a significant effect on blast waves due to reformation of the wave downstream of the barricade. It also may provide only limited protection against delayed propagation of explosion caused by fire resulting from high angle firebrands. Exposed structures containing equipment of high monetary value or of critical mission importance or wherein personnel exposure is significant may require hardening for necessary protection of personnel and equipment.

6.3.2 Barricaded Aboveground Magazine Distance - $6W^{1/3}$ ft ($2.4Q^{1/3}$m) - 27 psi (186.1 kPa)

6.3.2.1 Unstrengthened buildings will be destroyed completely.

6.3.2.2 Personnel at this distance or closer will be killed by direct action of blast, by being struck by building debris, or by impact against hard surfaces.

6.3.2.3 Transport vehicles will be overturned and crushed by blast.

6.3.2.4 Explosives loaded vessels will be damaged severely, with propagation of explosion likely.

6.3.2.5 Aircraft will be destroyed by blast, thermal, and debris effects.

6.3.3 Barricaded ILD - $9W^{1/3}$ ft ($3.6Q^{1/3}$m) - 12 psi (82.7 kPa).

6.3.3.1 Unstrengthened buildings will suffer severe structural damage approaching total destruction.

6.3.3.2 Severe injuries or death to occupants of the ES may be expected from direct blast, building collapse, or translation.

6.3.3.3 Aircraft will be damaged beyond economical repair both by blast and fragments. If the aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.

6.3.3.4 Transport vehicles will be damaged heavily, probably to the extent of total loss.

6.3.3.5 Direct propagation of explosion between two explosives locations is unlikely when barricades are interposed between them to intercept high velocity low angle fragments.

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6.3.3.6 Improperly designed barricades or structures may increase the hazard from flying debris or may collapse in such a manner as to increase the risk to personnel and equipment.

6.3.4 Unbarricaded Aboveground Magazine Distance - $11W^{1/3}$ ft ($4.4Q^{1/3}$m) - 8 psi (55.3 kPa).

6.3.4.1 Unstrengthened buildings will suffer damage approaching total destruction.

6.3.4.2 Personnel are likely to be injured seriously due to blast, fragments, debris, and translation.

6.3.4.3 There is a 20-percent risk of eardrum rupture.

6.3.4.4 Explosives loaded vessels are likely to be damaged extensively and delayed propagation of explosion may occur.

6.3.4.5 Aircraft will be damaged heavily by blast and fragments; destruction by ensuing fire is likely.

6.3.4.6 Transport vehicles will sustain severe body damage, minor engine damage, and total glass breakage.

6.3.5 Unbarricaded ILD - $18W^{1/3}$ ft ($7.2Q^{1/3}$m) - 3.5 psi (24 kPa).

6.3.5.1 Direct propagation of explosion is not expected.

6.3.5.2 There is some possibility that delayed communication of an explosion may occur from fires, or as a result of equipment failure at the ES.

6.3.5.3 Damage to unstrengthened buildings will be of a serious nature and approximately 50 percent or more of the total replacement cost.

6.3.5.4 There is a 1-percent chance of eardrum damage to personnel.

6.3.5.5 Personnel injuries of a serious nature are likely from fragments, debris, firebrands, or other objects.

6.3.5.6 Cargo ships would suffer damage to decks and superstructure from being struck by fragments and having doors and bulkheads on the weather deck buckled by overpressure.

6.3.5.7 Aircraft can be expected to suffer considerable structural damage from blast. Fragments and debris are likely to cause severe damage to aircraft at distances calculated from the formula $18W^{1/3}$ when small quantities of explosives are involved.

6.3.5.8 Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter-resistant window glass.

6.3.5.9 Control. Many situations arise in which control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical. Use of such construction to withstand blast overpressure is encouraged if it is more economical than

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distance alone, or if sufficient distance is not available to prevent the overpressure from exceeding this level.

6.3.6 Public Traffic Route Distance (under 100,000 lbs HE) $24W^{1/3}$ ft ($9.6Q^{1/3}$m) - 2.3 psi (15.8 kPa).

6.3.6.1 Unstrengthened buildings can be expected to sustain damage approximately 20 percent of the replacement cost.

6.3.6.2 Occupants of exposed structures may suffer temporary hearing loss or injury from secondary blast effects such as building debris and the tertiary effect of displacement.

6.3.6.3 Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and fragmentation characteristics thereof.

6.3.6.4 Vehicles on the road are likely to suffer little damage unless hit by a fragment or unless the blast wave causes momentary loss of control.

6.3.6.5 Aircraft are likely to suffer some damage to appendages and sheet metal skin from blast and possible fragment penetration; however, the aircraft may be expected to be operational with minor repair.

6.3.6.6 Cargo-type ships are likely to suffer minor damage to deck structure and exposed electronic gear from blast and possible fragment penetration, but such damage may be expected to be readily repairable.

6.3.6.7 Control. The risk of injury or damage due to fragments for limited quantities of explosives at the PES can be reduced by barricading. Also, many situations arise when control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical.

6.3.7 Public Traffic Route Distance (over 250,000 lbs HE) $30W^{1/3}$ ft ($12Q^{1/3}$m) - 1.7 psi (11.7 kPa)

6.3.7.1 Unstrengthened buildings can be expected to sustain damage approximately 10 percent of the replacement cost.

6.3.7.2 Occupants of exposed unstrengthened structures may suffer injury from secondary effects such as building debris.

6.3.7.3 Aircraft in landing and takeoff status may lose control and crash.

6.3.7.4 Parked military and commercial aircraft likely will sustain minor damage due to blast but may be expected to remain airworthy.

6.3.7.5 Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and fragmentation characteristics thereof.

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6.3.7.6 Control. The risk of injury or damage due to fragments for limited quantities of explosives at the PES may be reduced by barricading or application of minimum fragment distance requirements.

6.3.8 Inhabited Building Distance $40W^{1/3}$ ft - $50W^{1/3}$ ft ($16Q^{1/3}$ - $20Q^{1/3}$m) - 1.2 psi - 0.90 psi (8.3 kPa - 6.2 kPa).

6.3.8.1 Unstrengthened buildings can be expected to sustain damage up to about 5 percent of the replacement cost.

6.3.8.2 Personnel in buildings are provided a high degree of protection from death or serious injury, with injuries that do occur principally being caused by glass breakage and building debris.

6.3.8.3 Personnel in the open are not expected to be injured seriously directly by the blast. There could be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and the fragmentation characteristics thereof.

6.3.8.4 Control. Glass breakage and structural damage can be reduced by means such as orientation by keeping the surface area of exposed glass panels to a minimum and the use of blast-resistant windows.

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APPENDIX A SITE PLANNING GUIDANCE

A.1 SCOPE

A.1.1 Scope. This Appendix is not a mandatory part of this standard. The information contained herein is intended for guidance only.

A.2 DEFINITIONS

A.2.1 Site Planning Process. The process of performing and documenting an analysis of planned and existing facilities and operations involving explosives, energetic liquids and pyrotechnics (EELP) or occurring within the hazard zones created by EELP. The process may include evaluations of blast, fragment, thermal flux, and glass breakage hazards; protective construction; grounding, bonding, and lightning protection systems; electrical installations; natural or man-made terrain features; or other operations or local requirements.

A.3 GENERAL GUIDELINES

A.3.1 These evaluations should be completed as early as possible in the facility design review process. Effective site planning relies heavily on explosive 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 NASA community. (Ref. NPR 8820.2)

A.4 DETAILED GUIDELINES

A.4.1 Site Plan Contents. Provide specific information on a proposed project and the results of the above analysis.

A.4.2 When to perform a Site Plan analysis.

A.4.2.1 New PES or ES, which includes new construction for the manufacturing, handling, storage, maintenance, EELP waste treatment, or testing.

A.4.2.2 When major modifications are planned for existing facilities (PES) used for the purposes above and the modifications involve:

A.4.2.2.1 The introduction of a new hazard (i.e., people or EELP causing a reduction of explosive limits in adjacent structures).

A.4.2.2.2 The introduction of additional hazard(s).

A.4.2.2.3 Increased net explosive weight (NEW above previously sited quantity.

A.4.2.3 When planned facilities or operations (ES not involving EELP) are exposed to blast, fire or fragment hazards due to changes in operations or facility usage.

A.4.2.4 When a reasonable doubt exists regarding possible exposure hazards.

A.4.2.5 When an existing facility has never had formal siting approval or the approved site plan cannot be located.

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A.4.2.6 When establishing facilities for intentional detonation.

A.4.2.7 NEW quantity is more than amount authorized for “license” facility.

A.4.3 Site Plan should include:

A.4.3.1 Exact distances between the closest wall or corner of the facility or explosive item, whichever is controlling.

A.4.3.1.1 Other facilities

A.4.3.1.1.1 Firefighting water towers/reservoirs should be located at a minimum distance determined by the formula $d = 40W^{1/3}$, where d is the distance in feet and W is the explosive weight in pounds.

A.4.3.1.2 Facility boundaries

A.4.3.1.3 Public transportation routes

A.4.3.1.4 Electrical transmission and distribution lines

A.4.3.1.5 Electrical substations

A.4.3.2 Identify all other facilities, including their occupancy (how many, how often), use (type of support provided and relationship to new or to-be-modified facility), and QD requirements within the IBD arc of the new or to-be-modified facility.

A.4.3.3 List NEW and H/D with breakdown by room and bay, if appropriate.

A.4.3.4 The NEW and H/D of the EELP items in other facilities encompassed by the IBD of the new or to-be-modified facility.

A.4.3.5 The NEW, classes, and divisions of the EELP items in facilities having IBDs that include the new or to-be-modified facility.

A.4.3.6 Anticipated personnel limits for the new or to-be-modified facility. A breakdown by room or bay would be expected.

A.4.3.7 A brief description of the EELP or non-EELP analysis to be performed in each facility.

A.4.3.8 When engineered protection is used to reduce separation distance requirements, a summary of the design procedures used should be provided. The summary should include a statement of the protection category (TM5-1300) to be provided, NEW, design loads, material properties, structural behavior assumptions, and references. This shall be provided to NASA Headquarters, SARD, for approval per Paragraph 5.61.

A.4.3.9 Electromagnetic radiation restrictions, requirements and safe separation distances from dangerous levels of extraneous electricity, fields around high tension electrical wires, and radio frequency (RF) transmitters shall be identified when electro-explosive devices (EED) are involved.

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A.4.3.10 Vapor dispersion should be considered for systems involving energetic liquids and a risk analysis should be completed to determine operational controls needed to control the hazard.

A.4.3.11 Fencing and Placarding Restricted Areas. Fencing required for security or other purposes should not be placed closer to magazines than magazine distance nor closer to explosives operating buildings than ILD.

A.4.3.12 A glass breakage assessment.

A.4.3.13 Detailed drawings for Lightning protection.

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APPENDIX B PEROXIDE FORMING CHEMICALS

Table B-1. Peroxide Forming Chemicals.

Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
1,1-dichloroethylene	(2-ethoxyethyl)-o-benzoyl	1,1-dichloroethylene	2-butanol
1-Octene	(E-phenoxypropionyl) chloride	1,3-butadiene	acetaldehyde
1-Pentene	1-(2-chloroethoxy)-2-phen-oxyethane	1-buen-3-yne	aluminum ophorite explosive
2-chloro-1,3-butadiene	1-(2-ethoxyethoxy)ethyl acetate	2-chloro-1,3-butadiene	amatol
acetal	1,1,2,3-tetrachloro-1,3-butadiene	2-propenenitrile	ammonal
acetaldehyde	1,1-diethoxyethane	2-vinylpyridine	ammonium nitrate
acetaldehyde diethyl acetal	1,2,3,4-tetrahydronaphthalene	4-vinylpyridine	ammonium perchlorate
butadiene	1,2-bis(2-chloroethoxy) ethane	acetic acid	ammonium picrate
cellosolves	1,2-bis(2-chloroethoxy)ethane	acrylic acid	benzoyl peroxide
chloroprene	1,2-dibenzyloxyethane	acrylonitrile	butyl tetryl
cumene	1,2-dichloroethyl ether	butadiene	calcium nitrate
cyclohexene	1,2-diethoxyethane	buten-3-yne	copper acetylide
cyclopentene	1,2-epoxy-3-isopropoxypropane	chlorobutadiene	cumene
diacetylene	1,2-epoxy-3-phenoxypropane	chloroethene	cyanogen bromide
decahydronaphthalene	1,3,3-trimethoxypropene	chloroethylene	cyanuric triazide
decalin	1,3-butadiene	chloroprene	cyclohexane
	1,3-dioxane	chlorotrifluoroethylene	cyclotrimethylenetrinitramine
dicyclopentadiene	1,3-dioxepane	cyanoethylene	dicyclopentadiene
diethyl ether	1,4 dioxane	ethenyl acetate	diethyl ether
diethylene glycol	1,5-p-methadiene	ethenyl ether	dinitroethyleneurea
diethylene glycol dimethyl ether	1-ethoxy-2-propyne	ethyl methacrylate	dinitroglycerine
diisopropyl ether	1-ethoxynaphthalene	ethylene oxide	dinitrotoluene
dimethyl ether	1-octene	methyl methacrylate	dinitrophenol
dioxane	1-pentene	MVA	dinitrophenolates
divinyl acetylene	1-phenylethanol	phenethyl alcohol	dinitrophenyl hydrazine
divinyl ether	1-propyne	propylene oxide	dioxane

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	2,2-diethoxypropane	styrene	dipicryl sulfone
DVA		tetrafluoroethylene	dipicrylamine
ether	2,4-dichlorophenetole	TFE	DNT
ethylene glycol dimethyl ether	2,4-dinitrophenetole	vinyl acetate	erythritol tetranitrate
ethylene glycol ether acetates	2,5-hexadiyn-1-ol	vinyl acetylene	ether
ethylene glycol monoethers	2-bromomethyl ethyl ether		ethyl ether
furan	2-butanol	vinyl chloride	ethyl vinyl ether
isopropyl ether	2-chlorobutadiene	vinyl cyanide	ethylene glycol dimethyl ethyl vinyl ether
methyl acetylene	2-cyclohexen-1-ol	vinyl pyridine	fulminating gold
methyl isobutyl ketone	2-ethoxyethyl acetate	vinylidene chloride	fulminating platinum
methylacetylene	2-ethylacrylaldehyde		fulminating silver
MVA	2-ethylbutanol		fulminating mercury
p-dioxane	2-ethylhexanal		gelatinized nitrocellulose
picric acid	2-heptanone		guanyl nitrosamine
potassium amide	2-hexanol		guanyl nitrosamino guanylidene
potassium metal	2-methoxyethanol		guanyltetrazene
sodamide	2-methoxyethyl vinyl ether		heavy metal azide
sodium amide	2-methyltetrahydrofuran		hexanite
styrene	2-pentanol		hexanitrodiphyenylamin e
tetrafluoroethylene	2-pentanone		hexanitrostilbene
tetrahydrofuran	2-penten-1-ol		hexogen
tetrahydronaphthalene	2-phenylethanol		hydrazine
tetralin	2-propanol		hydrazinium nitrate
tetrahydronaphthalene	3,3-dimethoxypropene		hydrazoic acid
TFE	3-bromopropyl phenyl ether		isopropyl ether
THF	3-ethoxypropionitrile		lead azide
vinyl acetate	3-methoxy-1-butyl acetate		lead mannite
vinyl chloride	3-methoxyethyl acetate		lead mononitroresorcinate
vinyl ethers	3-methyl-1-butanol		lead picrate

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
vinylacetylene	3-methyl-1-butyl acetate		lead salts
vinylidene chloride	3-pentanone		lead styphnate
vinylpryidene	4,5-hexadien-2-yn-1-ol		magnesium ophorite
	4-heptanol		magnesium perchlorate
	4-methyl-2-pentanol		mannitol hexanitrate
	4-methyl-2-pentanone		mercury tartrate
	4-penten-1-ol		mercury fulminate
	4-vinyl cyclohexene		mercury oxalate
	acetal		mercury oxalate
	acetaldehyde		mononitrotoluene
	acetaldehyde diethyl acetal		nitrated carbohydrate
	acrlein		nitrated glucoside
	acrolein		nitrated polyhydric alcohol
	acrylamide		nitrocycol
	acrylonitrile		nitrogen trichloride
	ally amine		nitrogen triiodide
	allyl alcohol		nitroglycerin
	allyl chloride		nitroglycide
	allyl esters		nitroguanidine
	allyl phenyl ether		nitromethane
	allyl sulfide		nitronium perchlorate
	alpha-methyl-benzyl alcohol		nitroparaffins
	anhydrous ether		nitrotoluene
	b,b-oxydipropionitrile		nitrourea
	b-bromophenetole		organic nitramines
	b-chlorophenetole		organic amine nitrates perchloric acid
	benzoate		organic peroxides
	benzyl 1-naphthyle ether		picramic acid
	benzyl alcohol		picramide
	benzyl ether		picratol
	benzyl ethyl ether		picric acid
	benzyl methyl ether		picryl chloride
	benzyl n-butyl ether		picryl fluoride

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	benzyol-n-butyl ether		polynitro aliphatic compounds
	bis(2-chloroethyl) ether		potassium metal
	bis(2-ethoxyethyl) adipate		potassium nitroaminotetrazole
	bis(2-ethoxyethyl) ether		potassium perchlorate
	bis(2-ethoxyethyl) phthalate		robenozic acid
	bis(2-methoxyethoxy)ethyl ether		silver acetylide
	bis(2-methoxyethyl) adipate		silver azide
	bis(2-methoxyethyl) carbonate		silver fulminate
	bis(2-methoxyethyl) ether		silver styphnate
	bis(2-methoxyethyl) phthalate		silver tetrazene
	bis(2-n-butoxyethyl) phthalate		sodatol
	bis(2-phenoxyethyl) ether		sodium amatol
	bis(4-chlorobutyl) ether		sodium azide
	bis(chloromethyl)		sodium dinitro-o-cresolate
	bis(chloromethyl) ether		sodium nitrate/potassium nitrate (mixture)
	b-isopropoxypropionitrile		sodium perchlorate
	b-methoxypropionitrile		sodium picramate
	boron trifluoride etherate		styrene
	butadiene		syphnic acid
	buten-3-yne		tetranitrocabazole
	butylaldehyde		tert-butyl hydroperoxide
	certain organometallics		tetra hydrofuran
	cesium metal		tetraze
	chloroacetaldehyde diethyl acetal		tetrytol
	chloroethylene		THF
	chloromethyl methyl ether		TNT
	chloroprene		triethylene glycol divinyl ether
	cumene		trimethylolethane
	cyclic ethers		trimonite
	cyclohexanol		trinit

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	cyclohexene		trinitroanisole
	cyclooctene		trinitrobenzene
	cyclopentadiene dimer		trinitrobenzoic acid
	cyclopentene		trinitrocresol
	cyclopropyl methyl ether		trinitrophloroglucinol
	decahydronaphthalene		trinitroresorcinol
	decalin		trinitrotoluene
	di(1-propynyl) ether		urea ammonium nitrate
	di(2-propynyl) ether		urea nitrate
	diacetylene		vinyl chloride
	diallyl ether		vinylidene chloride acetylides
	dibenzocyclopentadiene		
	dibutyl ether		
	dicyclopentadiene		
	diethoxymethane		
	diethyl acetal isoamyl benzyl ether		
	diethyl ether		
	diethyl ethoxymethylenemalonate		
	diethyl fumarated		
	diethyl ketone		
	diethylene glycol dimethyl ether		
	diethylmethane		
	diethylpyrocarbonate		
	diglyme		
	dimethoxymethane		
	dimethyl keteneketone		
	di-n-propoxymethane		
	dioxane		
	dioxolane		
	diozane		
	ether		
	ethoxyacetophenone		
	ethyl - ethoxypropionate		

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	ethyl ether		
	ethyl methyl ether		
	ethyl vinyl ether		
	ethylene glycol dimethyl ether		
	ethylene glycol ether acetate		
	furan		
	furan methyl acetylene		
	furan p-phenylphenetone		
	glyme		
	idene		
	indene		
	IPA(Indole-3-propionic acid)		
	isoamyl ether		
	isobutane		
	isobutyl vinyl ether		
	isophenyl alcohol		
	isophorone		
	isopropanol		
	isopropyl 2,4,5-trichlorophenoxyacetate		
	isopropyl acetone		
	isopropyl benzene		
	isopropyl-2,4,5-trichlorophenyoxy acetate		
	ketones with an alpha hydrogen		
	limonene		
	m,o,p-diethoxybenzene		
	metal alkoxides		
	methacrylic acid		
	methoxy-1,3,5,7-cyclooctane		
	methyl acetylene		
	methyl cyclopentane		
	methyl isobutyl ketone		
	methyl p-(n-amyloxy)benzoate		
	methylacetylene		

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	methylcyclopentane		
	methyl-I-butyl ketone		
	misc. compounds with allylic structures		
	misc. compounds with vinyl group		
	m-methylphenetole		
	m-nitrophenetole		
	n-amyl ether		
	n-butyl phenyl ether		
	n-butyl vinyl ether		
	n-hexyl ether		
	n-methylphenetole		
	n-propyl ether		
	n-propyl isopropyl ether		
	n-propylether		
	o,p-ethoxyphenyl isocyanate		
	o,p-iodophenetole		
	o-bromophenetole		
	o-chlorophenetole		
	o-methylanisole		
	oxybis(2-ethyl acetate)		
	oxybis(2-ethyl benzoate)		
	p-(n-amyloxy) benzoyl chloride		
	p-bromophenetole		
	p-chloroanisole		
	p-chlorophenetole		
	p-dibenzyloxybenzene		
	p-di-n-butoxybenzene		
	p-dioxane		
	penten-1-ol		
	perchloric acid		
	phenoxyacetyl chloride		
	phenyl o-propyl ether		
	p-isopropoxypropionitrile		

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Peroxide Hazard from Prolonged Storage	Peroxide Hazard from Concentration or Deemed Peroxidizable	Peroxide Hazard due to Polymerization Initiation	Shock Sensitive Materials
	potassium tert-butoxide		
	p-phenylphenetone		
	propyne		
	rubidium metal		
	sodium 8,11,14-eicosatetraenoate		
	sodium 9,11,14-eicosa		
	sodium ethoxyacetylide		
	tert-butyl ethyl ether		
	tert-butyl methyl ether		
	tetrahydronaphthalene		
	tetraene		
	tetrahydrofuran		
	tetrahydronaphthalene		
	tetranoate		
	tetrahydrofuran		
	tetrahydropyran		
	triethylene glycol diacetate		
	triethylene glycol dipropionate		
	vinyl bromide		
	vinyl ethers		
	vinyl propionate		
	vinylenecarbonate		
	vinylidene dichloride		

NOTE

This table lists common names and other names used for the same chemicals. Many of the names used here are not in common use; they were used at one time or another for the chemical. This list is not meant to be all-inclusive, but to give an idea about the number of potential chemicals that are capable of forming peroxides, polymerizing, or that are shock sensitive. Several of the chemicals listed shock sensitive are sensitive to a detonation only, but are still deemed shock sensitive in the literature. This list is a compilation of numerous lists from various universities, national labs, etc. Those Centers that use Chemical Abstract (CAS) numbers only as a basis for occupational health MSDSs may be at a disadvantage. It has been found that the CAS numbers may be hard to find, because the systems being used do not have cross reference capabilities to other names, but only have direct access using the common name of the chemical or the CAS number.

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APPENDIX C KEYWORD INDEX

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