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SAFETY STANDARD FOR EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS

Office of Safety and Mission Assurance
Washington, D.C. 20546

NASA EXPLOSIVE SAFETY STANDARDS MANUAL

PREFACE

EFFECTIVE DATE:

The NASA Explosive Safety Standards Manual is the central Agency document containing policy and safety requirements which define the NASA Explosives, Propellant, and Pyrotechnics Safety Program. This manual is intended to serve as a general framework to structure the more specific and detailed requirements for Headquarters, Program, and Field Installations Directors.

This manual primarily addresses explosives safety; however, some health aspects are included to assist field installation safety personnel in interactions with the health program. Health guidance is available in NASA documents disseminated by the NASA Occupational Health Office.

This manual contains the minimum explosives, propellant, and pyrotechnics safety requirements. Additional explosive safety publications have been developed, whose instruction are either too detailed for inclusion in this manual or that require special distribution.

The policies of this manual apply: (1) to all NASA organizations, elements, entities, or individuals; (2) to all NASA systems and facilities; and (3) during all phases of the life cycle of systems or facilities.

This manual is not a direct instruction to NASA contractors, but provides guidance to the responsible NASA contracting officer. For contractors, it is applicable (as appropriate) through contract clauses in conformance with the NASA Procurement Regulation (e.g., Part 1, Subpart 52 and Part 14, Subpart 6). It applies to the Jet Propulsion Laboratory (JPL) as directed by NMI 1410.3, “Application of the NASA Management Directives System to the Jet Propulsion Laboratory.” Non-NASA, non-contractor personnel will follow the provisions of this manual when on NASA property. This manual shall not supersede more stringent requirements imposed by individual NASA organizations and OSHA.

This manual is issued in looseleaf form and will be revised by page changes.

Comments or suggestions concerning the application of these requirements to specific projects should be referred to the National Aeronautics and Space Administration Headquarters, Director, Safety and Risk Management Division, Office of the Associate Administrator for Safety and Mission Assurance, Washington, DC 20546.

Charles Mertz
Acting Associate Administrator for
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CHAPTER 1. INTRODUCTION

100 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 and explosives-related development and manufacturing activities. Safety of all explosives 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 handling or processing.

101 SCOPE

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

b. 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. In the case of a major renovation, however, the facility must be brought into compliance with current standards.

102 POLICY

a. <u>Site Plans</u>. Site plans shall be reviewed and approved in accordance with Chapter 5, Level-of-Protection Criteria for Siting Explosives Activities.

b. <u>Safety Variance (Deviations and Waivers)</u>. NASA variances do not apply to Federal and applicable State/local regulations (e.g., OSHA, CALOSHA). These regulations apply to NASA operations in full. The Headquarters safety variance policy applies to all Headquarters safety requirements unless otherwise specified in the appropriate requirements document (See NHB 1700.1(V1), "NASA Safety Policy and Requirements Document.")

c. Procedures. Each request for a Deviation/Waiver shall contain the following information:

(1) Description of condition.

(2) Safety standard requiring deviation/waiver.

(3) Reason why compliance cannot be achieved.

(4) Steps taken to provide protection.

(5) Statement of whether equivalent safety is provided and, if not, assessment of the residual risk (attach copy of Hazard Analysis/Risk Assessment).

(6) Any proposed corrective action and schedule.

(7) Duration of deviation/waiver.

(8) Comments from affected employees or their representative.

CHAPTER 2. EXPLOSIVES AND PERSONNEL LIMITS AND CONTROL

200 OPERATIONAL EXPLOSIVES LIMITS

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

b. In no case shall the quantity of explosives permitted in an operating building exceed the maximum permitted by the Quantity-Distance (QD) criteria. QD criteria and guidelines for application of these criteria are presented in Chapters 7 and 8 of this document.

c. 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.

d. 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.

e. Operational explosive limits shall not be established on the basis of the maximum quantity of explosives allowable as defined by the existing QD separation to nearby exposures, but will be determined by the minimum quantities required for the operation.

f. Personnel and operational explosive materials limits will be determined by the operating organization and approved by the Authority Having Jurisdiction (AHJ) and responsible safety office.

201 PERSONNEL LIMITS

The number of personnel at an operating location shall be the minimum consistent with safe and efficient operation. In establishing personnel limits, the following principles shall be followed.

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

b. Personnel limits shall allow for necessary supervision and transients.

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

d. Placards stating the maximum number of workers and transients permitted at any one time and the maximum amount of explosives materials and their classes/divisions shall be posted in a conspicuous place in all buildings, cubicles, cells, rooms, and service magazines containing explosives and similar material.

e. Personnel and material limits and the placard must be kept current and maintained for legibility.

f. Personnel limits need not be posted in storage magazines, magazine areas, and transfer points. Material limits need only be posted in storage magazines for which the limit is not the same as that for other magazines in the block.

g. Placards must be of sufficient size and color that they are readily visible by personnel entering the work area. (NOTE: Use local or Department of Defense (DoD) placards.)

202 LIMIT CONTROL

a. Posting and Recording.

(1) 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 rooms, bays, and buildings containing explosives.

(2) Maximum explosives and personnel limits for all buildings and bays for each explosives area shall be recorded and maintained on file.

b. Limit Review and Approvals.

(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 as required. When an operation changes, personnel and explosives weight limits shall be reviewed prior to resumption of operations and limits shall be reestablished as required.

(2) Changes in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures by the AHJ (see Chapter 4, Operating Procedures).

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

c. Personnel Controls. A system shall be established to control the presence of personnel within explosives operating areas.

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CHAPTER 3. TRAINING

300 GENERAL

Personnel shall be properly trained before being assigned to any explosives operation or operating any explosives-carrying vehicle. The training for explosives work, which serves to assist in conducting work safely and developing safety awareness, shall include the following:

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

b. Define and understand the potential hazards involved.

c. Teach correct skills for safe performance of the task.

d. Prepare personnel for unexpected hazardous conditions.

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

f. Provide employee hazardous materials information and training programs for personnel working with explosives and hazardous material used in conjunction with explosives operation. Training shall include:

    (1) Information on physical and health hazards.

    (2) The purpose and proper use of engineering controls, work practice controls, and protective equipment.

    (3) Labeling systems and Material Safety Data Sheet (MSDS) terms.

    (4) Detection methods for the presence or release of a hazardous material in the work area.

301 SUPERVISORY RESPONSIBILITY

The supervisor shall be responsible for the following:

a. Determining the training required for the worker (or researcher).

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

c. Ensuring that the worker can perform required emergency duties.

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

e. Continually updating worker training.

f. AHJ with guidance from the safety office will determine level of training commensurate with operation being performed.

302 TRAINING AND QUALIFICATION PROGRAMS

Each organization shall have a training and qualification program. Guidance is provided in the following section:

a. After successfully completing training for an assignment, the worker should be qualified for that assignment for a specific period of time. Maintenance of qualification should be governed by the following items:

(1) At the end of the initial qualification period, qualification may be extended for subsequent specific time periods if:

(a) The worker has successfully performed the task during the preceding 6 months and has read and understood the current operating procedures, or

(b) The worker receives refresher training and is again determined to be qualified by his/her supervisor.

(2) Workers who do not demonstrate job proficiency or who subsequently violate safe practices should be retrained in the specific area of weakness.

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

(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. Possible reasons include the following:

(a) Physical injury or illness.

(b) Disease.

(c) Mental or emotional disturbances.

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

(5) Records should be maintained for each worker, including:

(a) Description and dates of training received.

(b) Description and dates of refresher training.

(c) Reading and understanding of standard operating procedures.

(d) Attendance at safety meetings and participation on safety committees.

(e) Qualification review by supervisor.

(6) The supervisor may temporarily authorize an employee who has not completed the required training to perform the task if the following conditions are satisfied:

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

(b) The work is directly supervised by a qualified person.

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CHAPTER 4. OPERATING PROCEDURES

400 REQUIREMENTS

This section establishes requirements for preparing and controlling all procedures involving explosives operations under NASA control. This section, in compliance with NHB 1700.1(V1), "NASA Safety Policy and Requirements Document," also specifies that operational procedures must 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 problem 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 incorporation into the procedure.

401 GUIDELINES

The following general guidelines shall be used in creating operating procedures:

a. Before Operation. Before initiation of any operation involving explosives, operating procedures shall be written and approved.

b. Supervisory Responsibility. Supervisory personnel shall be responsible for enforcing provisions of all procedures used in their jurisdictions.

c. Preparation.

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

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

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

NOTE: Supplemental procedures or sections shall be written when similar operations in the same area involve differences in equipment or process.

d. Audits.

(1) An audit system shall be established that will evaluate routinely the adequacy, availability, and currency of procedures. Audits also should include an evaluation of operator knowledge and compliance with procedures.

(2) Groups conducting audits in conjunction with the Installation Safety Office should include personnel from areas other than the operating department or division using the procedure.

402 CONTENT OF OPERATING PROCEDURES

The following is intended to specify procedures content, not format or organization. Each NASA facility/operating contractor can develop its own system for preparing safety procedures. Distribution of procedures shall be controlled to ensure that each operating area has the most current revision. Superseded or inactive procedures shall be removed from operating areas. No operation shall be performed with a superseded, inactive, or unapproved procedure.

a. Approval. All new, revised, and inactive operating procedures shall be reviewed and approved prior to use. Levels of approval required should be based on the inherent risk in the operation and be established by AHJ. Review and approval requirements shall include, as a minimum, line and safety organizations.

NOTE: Inactive (dormant for a year), new, or revised procedures shall have a dry run prior to submission for approval. A dry run is used to ensure procedures are valid.

b. Operating Procedures.

(1) Introduction. The introduction to procedures should include the following:

(a) A statement of the scope of the procedure, defining what facilities and equipment are covered.

(b) The name of the department and/or individual responsible for the operation.

(c) 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.

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

(a) 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 (SOP's) should describe the personnel control features of the facility that protect personnel from exposure to hazardous operations, toxic materials, or tests.

(b) Personnel number and explosive weight limits.

(c) Additional or specific emergency controls not addressed by the facility emergency plan.

(d) A description of the range of work authorized by the procedure.

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

(f) Protective equipment that must be used during the operation.

(g) Emergency controls applicable to the operation that are not considered in the General Operating Procedures.

(3) Operations.

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

(b) 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.

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

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CHAPTER 5. LEVEL-OF-PROTECTION CRITERIA FOR SITING EXPLOSIVES ACTIVITIES

500 FACILITY CONSTRUCTION AND SITE PLAN

501 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.

502 FACILITY CONSTRUCTION AND SITE PLAN REVIEW

The following plans shall be submitted for approval to the Authority Having Jurisdiction (AHJ) and NASA Field Installation Safety Office:

a. Explosive safety site plans and general construction plans for facilities or structures containing explosives, pyrotechnics, and propellants, as well as modifications to these facilities.

b. General construction plans for facilities with activities not involving explosives, pyrotechnics, or other similar materials, but that would be exposed to explosive hazards if not properly located in accordance with required Quantity Distance (QD). (See paragraph 1000.)

NOTE: Information on major/high-visibility projects as requested by NASA Headquarters will be sent to the Headquarters Safety Office for review prior to 30-percent reviews or Preliminary Design Reviews (PDR's).

503 SITE PLAN REQUIREMENTS

a. A facility site plan shall show protection provided against explosion propagation between adjacent bays or buildings as well as protection of personnel against death or serious injury from incidents in adjacent bays or buildings.

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

(503)

c. 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 PES's protects against unacceptable damage and injuries in the event of an accident. These factors may reduce the required QD when rationale or test results justify the reduction. This rationale must accompany the site plan to be presented to the AHJ and Field Installation Safety Office and, when required, the NASA Headquarters Safety Office.

504 APPROVAL AUTHORITY

a. Safety approval of site plans must be obtained prior to initiating concept design and changes.

b. Site plans and changes to site plans will be forwarded to the NASA Headquarters Safety Office, when required by paragraph 502, after approval by the AHJ and Field Installation Safety Office.

505 APPLICABILITY OF CRITERIA

a. <u>Explosives Limits</u>. Working explosives limits shall never exceed the minimum required for efficient, safe operation. (See Chapter 2, Explosives and Personnel Limits and Control.)

b. <u>Areas Where Criteria Are Not Applicable</u>. The QD and level-of-protection criteria are not applicable in the following areas:

(1) Facilities in which experimental or laboratory-type operations are conducted and where no more than 500 grams of explosives are involved; however, adequate distance must be provided between the laboratory and other buildings containing explosives, (with the distance based on the quantity of explosives in those buildings). Such operations include, but are not limited to, small-scale formulations work; chemical, physical, and thermal analysis; and sensitivity tests.

(2) Experimental and laboratory facilities are exempt from QD criteria where operations involving explosives in quantities of 10 grams or less are conducted under AHJ-approved Standard Operating Procedures (SOP's).

506 ESTABLISHING QUANTITY OF EXPLOSIVES AND DISTANCES

a. <u>General</u>. The principles and tables presented in this document shall be used to determine the following:

(1) The total quantities of explosives in adjacent magazines, operating buildings, or other explosives facilities that must be applied to QD tables.

(2) The levels of protection required for different types of facilities.

(3) The minimum separation distances required for the facilities, as determined from the nearest point in the PES to the nearest point in the ES. This separation is based on the desired level of protection and total quantities of explosives.

b. Loading Docks. Separated loading docks shall be cited on the basis of use. When servicing magazines, separated loading docks must be separated from the magazines by inter-magazine distances. When servicing operating buildings, they must be separated from operating buildings by intraline distances. The following are minimum distances for the specific operation:

(1) Intraline distance from an explosive operating line or workshop which is not served by the dock, installation boundary, and other unrelated facilities.

(2) Magazine distance from other loading docks.

(3) The quantity of Class 1.1 materials at one loading dock shall not exceed 250,000 pounds, except that two rail cars containing more than 125,000 pounds per car are permitted.

(4) Inhabited Building Distance (IHBD) for unrelated facilities.

507 RAIL CAR AND TRANSPORT VEHICLES

Explosives-loaded rail cars, motor vehicles, or any other transport vehicles in holding yards shall be considered as aboveground magazines for QD purposes and shall be kept in groups. Each group shall be limited to a maximum of 250,000 pounds of 1.1 high explosives.

a. When a rail car receiving yard or point is provided for the interchange of cars containing explosives between the common carrier and the facility rail system, QD provisions do not apply, provided that the cars are moved expeditiously to a suitable location.

b. When inspection of an explosives-loaded rail car indicates that it may be in a hazardous condition, the rail car should be moved at once to a suspect car spur track or an isolated section of track. This spur or section of track shall be accessible directly from the inspection point. The distance between the spur or track and facility boundaries, classification yards, inhabited buildings, administration areas, operating buildings, magazines, inert storage locations, and public traffic routes shall be the IHBD, which is determined by the maximum quantity of explosives that the facility can receive in one rail car. Only one car shall be permitted at this location at any time.

c. Incoming explosives-laden motor vehicles shall be inspected at a station located remotely from hazardous and populated areas.

508 PETROLEUM, OIL, AND LUBRICANT HANDLING AND STORAGE FACILITIES

a. Underground gasoline storage facilities and their dispensing pumps shall be sited at least 300 feet from the nearest explosives facilities, except for facilities involving Class 1.4 materials. For Class 1.4 materials, this minimum distance shall not be less than 100 feet.

b. Aboveground gasoline storage facilities and their dispensing pumps shall be separated from Class 1.1 and Class 1.3 material facilities by 1,800 feet or IHBD, whichever is less. The minimum distance shall not be less than 450 feet. These distances do not apply to a mobile unit dispensing retail quantities of gasoline. Retail quantities may be dispensed from mobile units (containing not more than 600-gallon tanks) at a minimum distance of 90 feet from explosive facilities.

c. Dispensing pumps must be of the approved safety type.

d. Aboveground storage of gasoline in drums shall conform to the requirements of the latest edition of National Fire Prevention Association (NFPA) 30.

e. Steel tanks built on or above the surface of the ground and utilized primarily for storage of petroleum, oil, and lubricants (POL) can be considered as underground for QD purposes if they are earth-mounded and hardened sufficiently to resist expected explosion effects from a PES.

509 WHARF YARD

Separation of a wharf yard from the pier that it serves by a distance clearly sufficient to prevent immediate propagation of an explosion by using a QD = ($11W^{1/3}$) will be impractical in many cases. In such cases, the wharf yard will be considered as part of the ship or barge unit and added to it for computation of the total amount of explosives for QD purposes. The outer circle of the wharf yard then shall be considered as the ship unit boundary for computing applicable QD requirements.

510 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 5-1. Utilities installations (aboveground and underground) that are privately owned or operated shall be separated from explosives locations by at least public traffic route distances. If these installations include structures, they shall be separated from explosives facilities by IHBD.

511 AIRFIELDS AND HELICOPTERS

Explosives, pyrotechnics, and other similar materials will not be located within the aircraft prohibited areas at airfields or heliports. This is the minimum distance specified in QD tables depending on net explosive weight of the donor building/facility. If an aircraft is to transport explosives, an aircraft parking area located at specified QD should be set aside and designated for loading and unloading of explosives. In applying QD prescribed in QD tables, distances shall be measured as follows:

a. Loaded aircraft to loaded aircraft — measure the shortest distance between explosives on adjacent aircraft.

b. Explosives location to taxiway and runways — measure from the nearest point of the explosives location to the nearest point of taxiway and to the centerline of the runway or the runway extended.

512 ELECTRICAL HAZARD CLASSES

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

b. 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. 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.

NOTE: 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, for the purpose of this chapter.

(1) When the area classification is determined in accordance with this chapter and the proposed electrical equipment does not meet classification requirements, then the using organization will provide a technical justification to the AHJ and Field Installation Safety Office for review and approval.

c. Hazardous Locations. Definitions of Class I, Class II, and Class III Hazardous Locations are as follows for NASA explosive facilities:

(1) Class I Locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

(a) Class I, Division 1 — Locations where the hazardous atmosphere is expected to be present during normal operations.

(b) Class I, Division 2 — Locations in which volatile flammable liquids or gases are handled, processed, or used, but in which they will normally be confined within closed containers or closed systems from which they can escape only in the case of accidental rupture or breakdown of the container or system. The hazardous condition will only occur under abnormal conditions.

(2) Class II Locations are those that are hazardous because of the presence of combustible dust.

(a) Class II, Division 1 — Locations where combustible dust may be in suspension in the air under normal conditions in sufficient quantities to produce explosive or ignitable mixtures.

(b) Class II, Division 2 — Locations in which combustible dust will not normally be in suspension in the air, and normal operations will not put dust in suspension, but where accumulation of dust may interfere with the safe dissipation of heat from electrical equipment and be ignited by arcs, sparks, or burning material from the equipment.

(3) Class III Locations are those that are hazardous because of the presence of easily ignitable fibers or flyings, but in which the fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures.

(a) Class III, Division 1 — Locations in which easily ignitable fibers or materials producing combustible flyings are handled, manufactured, or used.

(b) Class III, Division 2— Locations where easily ignitable fibers are stored or handled.

d. NASA Special Hazardous Occupancies. It is necessary to have knowledge of the properties of explosives involved in order to ensure assignment of NASA facilities to the proper Hazardous Locations class and group. Minimum requirements include sensitivity to heat and spark and thermal stability. If the properties of an explosive are such that Class I, Class II, Class III, or all three provide inadequate protection under prevailing conditions, use of any of the following approaches is acceptable:

- Intrinsically safe equipment.
- Purged or pressurized equipment.
- Temperature limited equipment.
- Exclusion of electrical equipment.
- Isolation of equipment from hazardous atmosphere by means of dust, vapor, or gas-free enclosure with surface temperatures positively maintained at safe levels.

(1) Where flammable/combustible gases will be present, locations will be classified as Class I locations if either a Division 1 or 2 situation can exist. Recognize that a Division 2 Hazardous Location normally exists in the vicinity of a Division 1 Hazardous Location.

(2) Where explosives, propellants, or pyrotechnic dusts will be present, locations will be classified as Class II locations if a Division 1 or 2 condition can exist.

(3) The following is a list of typical Hazardous Locations and their corresponding NEC classifications:

Location Description	NEC Classification
Magnesium or aluminum powder weighing, mixing, blending, with or without other ingredients present	Class II, Division 1, Group E
Component assembly area — no measurable dust or vapor	Ordinary hazard (permanent wiring and lighting — Class II, Division 2, Group G)
Storage of explosives in approved DOT packages	Ordinary hazard (permanent wiring and lighting — Class II, Division 2, Group G)

e. Equipment for Hazardous Locations. When the hazardous classification has been determined for an area, equipment installed in that area shall meet the requirements of the NEC for that classification.

f. 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 will meet the minimum requirements of paragraph 514d for the installation and maintenance of electrical grounding.

(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.

(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.

(3) The NEC recognizes paragraph 514d(1), (2), and (3) as fundamentals. For example, Sections 250 and 251 state that the ground-fault path shall be permanent and continuous, and shall have

impedance sufficiently low to limit voltages between enclosures and their surroundings and to facilitate the operation of the circuit protective devices.

NOTE: Understanding the minimum grounding requirements of the NEC requires familiarity with the NEC language. Much of the confusion for grounding requirements is created because the NEC contains three definitions for the word "grounding" The following chart will help in clarification.

Conductor	Function
Equipment bonding conductor	Connects enclosures together. (Not necessarily to ground)
System bonding jumper	Connects system conductor to equipment bonding conductor. (Not necessarily to ground)
Earthing conductor	Connects equipment, or the system, or both to their surroundings. (Earth or building steel)

The first definition, the most important of the three "grounding" functions, can be better understood if it is considered as "equipment bonding," which means connecting all electrical enclosures together.

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

(1) Electrical or magazine service lines required to be in proximity to an explosives 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.

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

(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 IHBD.

513 FIRE PROTECTION

a. General. This chapter establishes standard fire fighting 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 fire fighting 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.

Fire fighting procedures, training of fire fighting personnel, use and maintenance of fire fighting equipment and vehicles, provision of water supply and alarm system, first aid measures, and other measures required in fire fighting are covered in Chapter 9 of NHB 1700.1(V1) and NSS 1740.11, "NASA Safety Standard for Fire Protection."

b. Fire Protection Criteria. 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 class.

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

(2) The AHJ on the basis of maximum fire loss criteria and program mission interruptions and delays (risk analysis) may determine the type of fire suppression system.

(3) 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.

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

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c. Fire Divisions.

(1) Fire divisions numbered 1 through 4 are synonymous with the Hazard Classes 1.1 through 1.4 for explosives.

(2) Fire Division 1 indicates the greatest hazard. The hazard decreases with ascending fire division numbers as follows:

Fire Division	Hazard
1	Mass Detonation
2	Explosion With Fragment Hazard
3	Mass Fire
4	Moderate Fire

(3) Each of the four fire divisions is indicated by a distinctive symbol in order to be recognized by fire-fighting personnel approaching a fire scene. The applicable fire division number is displayed on each symbol. For purposes of identifying these symbols from long ranges, symbols differ in shape as follows:

Fire Division	Symbol Shape
1	Octagon
2	Cross
3	Inverted Triangle
4	Diamond

(4) The background color of the fire symbol is orange. The color of each number identifying the applicable fire division is black. This requirement is in accordance with the Department of Transportation (DOT).

(5) The shape and size of the four fire division symbols and numbers are shown in Figure 5-1. For application on doors or lockers inside buildings, half-sized symbols may be used.

d. Display of Fire Symbols.

(1) Appropriate fire symbols shall be displayed on all facility buildings and storage sites containing explosives, pyrotechnics, and similar hazardous materials. They will be displayed in such a manner as to

make them easily visible to approaching fire-fighting personnel from the maximum practicable distance. 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 symbol for the most hazardous material stored in the area or row. The symbols must be located at the entrance to the block or row, and must be clearly visible to approaching fire response personnel.

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

(3) Fire 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 symbol displayed shall reflect the most hazardous material stored in the building or site.

(4) Facility warehouses and storage facilities used for storage of containers from which explosives have been removed, but the containers have not been decontaminated to remove explosive residue, shall be placarded with a fire symbol consistent with the degree of hazard.

(5) All railroad cars and motor vehicles containing explosives, propellants, or pyrotechnics, while on NASA facilities must be provided with fire symbols or DOT labels/placards for identification of fire hazards. 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 symbols. Field Installation transport vehicles destined for off-site shipment and commercial railroad cars and motor vehicles will have DOT placards displayed in accordance with DOT regulations when containing explosives and propellants or similar hazardous materials.

e. Fire Fighting Procedures.

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

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

(2) All nonessential personnel shall be withdrawn to a predetermined scene away from the fire at an adequate safe distance. 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. For minimum allowable distances to be used, see Table 5-2.

(3) Fires involving explosives and pyrotechnics will be fought according to their fire division classification, the stage of the fire, and current procedures specified by the NASA component concerned.

(4) Fires involving Fire Symbol 3 include Hazard Class 1.3 and Class 1.4, propellants and explosives. Operating personnel in the area should do everything possible to prevent the spread of a minor fire that does not involve the explosive itself if it appears there is a chance to control it. If the fire is out of control or involves explosives or propellants, then personnel should activate the deluge system and fire alarm without incurring undue personal hazard. Fire in Class 1.3 materials produces intense radiant heat over a wide area and can propagate to other explosives quickly. Extreme caution should be taken by the fire fighting organization.

(5) For Field Installations that rely on municipal or other fire fighting organizations either on primary response or as a support unit, training as indicated in this document will be provided to ensure safety of responding fire personnel.

f. Storage of Water for Fire Fighting.

(1) Storage of water for fire fighting shall be in accordance with NFPA Standard 13 and the minimum requirements for NASA explosive facilities operations commensurate with Field Installation and mission requirements.

(2) Storage of this water may be partly or totally in elevated gravity tanks, or in tanks or reservoirs at or below ground level. These tanks and reservoirs should be located at a minimum of Inhabited Building Distance based upon the formula $d = 40W^{1/3}$, where d is the distance in feet and W is the equivalent net weight of Class 1.1 explosives in pounds.

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

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

g. Automatic Sprinkler Systems.

(1) Automatic sprinkler systems should be provided in accordance with NFPA 13 and 15, NSS 1740.11, and local NASA Field Installation and mission requirements.

(2) Deluge systems, in addition to sprinklers, should be provided for the protection of operating personnel in high hazard occupancies. 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 (nozzles, sprays, heads, etc.) should be located as close to the exposed surface of the explosive as possible, consistent with the outlet discharge pattern. This would ensure immediate dousing of all parts of the machine or operation under extreme conditions.

(3) Required water flow and pressure should 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.

(4) On deluge systems, the deluge valve shall be arranged for automatic and manual activation. 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.

(5) All explosive, pyrotechnic, and propellant operations will be subjected to hazards analysis in order to identify potential fire/explosive threats and to assess the level of risk. A potential fire hazard whose level of risk is unacceptable will be mitigated by a high-speed deluge system. 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"; NFPA 72E; NSS 1740.11, "NASA Safety Standard for Fire Protection"; and NFPA 15.

(6) NFPA 13 and 15 should be consulted for basic installation requirements.

h. Vegetation Control. Vegetation around storage magazines and explosives operating facilities 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 15 meters 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 must be controlled by mowing to prevent rapid transmission of fire to the magazine or facility. 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.

514 LIGHTNING PROTECTION

a. Policy. It is NASA policy to comply with the requirements of NFPA Standard 78 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 (NEPA 78 and 70), NASA facilities containing explosives will require these references as basic criteria for lightning protection.

b. Required Lightning Protection.

(1) Lightning protection systems identified in paragraph 514c, Approved Systems, shall be used in NASA facilities to provide protection from lightning to all explosives facilities. Lightning protection especially is needed in explosives facilities where operations cannot be shut down during electrical storms and personnel evacuated.

(2) No lightning protection is required for explosives facilities when the following conditions are met:

(a) A lightning warning system is available to permit termination of operations and withdrawal of all personnel to IHBD prior to the incidence of an electrical storm.

(b) Earth-covered magazines 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.

(c) 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 must meet bonding and surge suppression requirements and not be subject to fire in the event of a lightning strike.

c. 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 (2) below), and Faraday cage lightning protection systems.

(1) The minimum principles of protection for structures protected against direct lightning strikes are:

(a) An air terminal must be provided to intentionally attract the leader strike.

(b) A path must be established that connects this terminal to Earth with such a low impedance that the discharge follows it in preference to any other.

(c) A low resistance connection must be made with the Earth electrode subsystem.

(d) A low impedance interface must be established between the Earth electrode subsystem and Earth.

(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:

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

(b) 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.

d. Grounding, Bonding, and Surge Protection.

(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.

(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. The material used shall be compatible with the metallic mass and down conductor to minimize corrosion. NFPA 78 shall be used as minimum acceptable bonding requirements for NASA facilities. Wires and connectors on lightning protection systems shall not be painted. 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. Railroad tracks that run within 6 feet of a structure shall be bonded to the structure's lightning protection system or its grounding system. The lightning protection system shall be bonded to all grounding systems of the protected facility at the counterpoise or grounding rod outside the building.

(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. 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:

- Lightning arrestor.
- Surge arrestor.
- Surge protectors.
- Surge suppressor.
- Transient power suppressor.
- Fiber optic data lines.
- Isolation transformers.

These power and communication lines shall enter the facility in shielded cables or in metallic conduits run underground for at least 50 feet from the structures. 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 feet from the structure. The NASA AHJ may decide to use low-pass filters for added protection of specific, critical electronic loads.

e. Tanks and Towers. Tanks and towers mounted on the roof or adjacent to buildings requiring lightning protection shall be grounded in accordance with requirements listed in DARCOM-R 385-100, Chapter 8 (see Appendix C, reference h).

f. Testing and Inspection.

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

(2) Test Equipment. Only those instruments designed specifically for Earth-ground system testing are acceptable. The instrument must 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.

515 EXPLOSIVES IN PROCESS DURING ELECTRICAL STORMS

When explosive facilities are required to be evacuated during periods of electrical storms, any explosive operation requiring attention at all times shall continue to be manned by the minimum number or personnel consistent with safety requirements. Any process involving explosives shall not be started unless absolutely necessary or unless the process can be completed prior to an anticipated storm.

516 LABORATORY SAFETY

a. General.

(1) Local safety standards covering all laboratory practices and procedures shall be formulated, approved by AHJ, and adopted. SOPs will be developed to standardize laboratory work involving explosives, chemicals, pyrotechnics, and propellants and other similar hazardous materials.

(2) Laboratory safety standards shall consider the following recommended standards:

(a) Safe Practice Pamphlet No. 60, “Chemical Laboratories,” National Safety Council.

(b) “Guide for Safety in the Chemical Laboratory,” Chemical Manufacturer’s Association, Inc.

(c) Material Safety Data Sheets (MSDS), Chemical Manufacturer’s Association, Inc.

(d) 29 CFR 1910.1450, “Occupational Exposure to Hazardous Chemicals in Laboratories.”

(e) National Bureau of Standards Handbooks 48, 55, 60, 63, 73, and 92.

(f) “Chemical Safety Manual Source Material Essential References,” J. T. Baker Chemical Company.

(g) NFPA 45, “Fire Protection for Laboratories Using Chemicals.”

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b. Storage.

(1) Each lab facility should have approved storage rooms for bulk chemicals and one for lab equipment and apparatus.

(2) All storage rooms shall be well ventilated and lighted, shall be provided with adequate emergency exits, and shall be separated from other parts of the lab by adequate fire walls (minimum 2-hour-rated fire wall).

(3) Openings in fire walls shall be protected by approved automatically closing doors.

(4) Storage rooms shall be protected by permanently installed automatic Class B fire extinguishers or sprinklers.

(5) Personnel deluge showers and emergency eye lavages shall be installed in or accessible to all chemical storage rooms.

(6) An inventory of chemical supplies shall be maintained for control of old stock for replacement, ordering of new materials, and disposal of out-dated chemicals or explosives.

(7) Chemicals or explosives that might react to produce dangerous fumes or explosions must be stored so that they will not mix in the event of a leak or spill.

(8) Volatile liquids must be stored away from heat sources and out of direct rays of sunlight.

(9) Flammable liquids shall be stored in approved-type flammable storage cabinets and grounded to the building ground system. Each container must be legibly marked or labeled and should be closed when not in use.

(10) Explosives must be stored separately from other materials. All explosives and other hazardous materials must be stored outside the laboratory building in separate facilities that meet construction and QD requirements.

(11) Where refrigeration is required for any flammable or explosive chemical, an ice chest of approved design or explosion-proof mechanical refrigerator shall be used. Ventilation, as required, will be provided.

(12) Good housekeeping must be practiced at all times. Each laboratory/room must be kept neat, orderly, and free of hazardous amounts of explosives and chemical contamination. Corridors must be kept clean; floors, shelves, and work areas shall be kept free from all unnecessary apparatus and chemicals. Spills shall be cleaned up immediately, and broken glassware shall be placed in separate, specially marked receptacles.

c. Laboratory Techniques.

(1) Before starting a new research project involving explosives, pyrotechnics, or propellants, laboratory technicians must identify the health and safety hazards of all chemicals/explosives to be used and produced and the hazards of the reactions that may occur.

(2) SOP's and emergency procedures for malfunctions and unexpected or uncontrolled reactions that might occur should be established and practiced.

(3) Simultaneous chemical investigation of incompatible materials such as fuels and oxidizers, or acids and cyanides shall not be conducted by one person, nor in adjacent work areas that are not separated in a manner to prevent mixing.

(4) Upon vacating a laboratory on completion of a project, all scientists, lab operators, or technicians must check for and complete decontamination to ensure that the next occupant will not encounter any unforeseen hazard created by unused or spilled explosives or chemicals.

(5) Working alone outside of normal supervised hours is not permitted when "hands on" work is being performed on hazardous energetic materials.

d. Protective Clothing. All NASA laboratory facilities shall maintain an adequate supply of approved protective clothing and equipment.

e. Pressure Processes.

(1) Autoclaves and other pressure equipment containing explosives or other hazardous chemicals shall be placed in separate cubicles/bays that are designed to confine and direct the force of possible explosions away from personnel and facilities. Walls for this purpose must be designed in accordance with TM5-1300, "Structures to Resist the Effects of Accidental Explosions."

(2) Pressurization of containers of explosives or other hazardous materials must be accomplished by remote control regardless of container size.

(3) Pressure vessels shall be constructed, inspected, and tested in accordance with American Society of Mechanical Engineers (ASME) codes and NMI 1710.3.

(4) Means shall be provided for safe release of positive pressure or vacuum from a pressure vessel prior to opening.

(5) SOP's shall be developed covering use of pressure vessels.

f. Flammable Liquids.

(1) The minimum standards for flammable liquids for NASA facilities will be NFPA 30, OSHA 1910.106, and the standards set forth in this chapter.

(2) The quantity of flammable liquids stored in laboratories shall be kept to the minimum required for safe, efficient operation but never more than one work shift's supply. Amounts above this shall be stored in separate approved facilities.

(3) Except where prohibited by technical considerations, flammable liquids shall be stored in and dispensed from approved safety containers.

(4) Operations involving volatile, flammable liquids shall be performed behind protective shields, under hoods, or within trays or other suitable containers that will maintain control of fires should they occur.

(5) Flammable liquids shall be kept away from ignition sources such as exposed electric heating elements, open flame, and electrical wiring and equipment that is not approved for use in Class I hazardous locations.

(6) If flammable liquids must be heated in the laboratory, water, steam, or electrical heat shall be utilized.

g. Electrical Equipment and Wiring.

(1) Electrical wiring and equipment and installation methods shall be in accordance with paragraph 512b, Electrical Equipment and Hazardous Locations, of this document.

(2) A certification of electrical safety by a qualified NASA or contractor safety engineer based on a hazard analysis will be accepted in lieu of approval by a recognized testing agency if equipment approved by such an agency is unavailable, and if the certification and analysis are maintained at the responsible facility directorate or local safety office until the equipment is withdrawn from service.

h. Disposal of Waste Materials.

(1) All waste containers must be properly marked for identification.

(2) Volatile, flammable liquids shall never be poured down a sink, basin, or drain.

(3) A sufficient number of proper containers shall be provided for various waste materials to preclude mixing of materials that may result in a chemical reaction, fire, or explosion.

(4) Materials such as cyanides, which are capable of evolving poisonous gases either alone or as a result of a reaction with other materials, shall not be emptied into drains or sewers. A chemist or other qualified person shall supervise these disposal operations in accordance with local NASA safety regulations.

(5) Disposal and storage for disposal also are dictated by established Center waste management procedures to ensure compliance with environmental regulations. These procedures shall be coordinated with NASA Field Installation environmentalists.

i. Explosives Safety for Laboratories.

(1) The personnel limits and quantity of explosives used in any NASA laboratory facility must be established by the operating organization and approved by the responsible safety office. Where operations involve explosives, pyrotechnics, propellants, severe fire hazards, or toxic materials, personnel exposure must be limited to the minimum number of personnel, for the minimum time, consistent with safe and efficient operation.

(2) Laboratory operations involving explosives must be separated from those not involving explosives by approved operational shields or barriers.

(3) Particularly hazardous laboratory operations involving explosives must be performed by remote control with the operator protected by an approved operational shield or barrier.

(4) Ovens used for drying samples of explosives must be equipped with explosion latches and be designed to vent an internal explosion safely. Ovens may be used without protecting devices if adjacent operations are protected by barriers of accepted QD.

(5) The QD's between laboratories and adjacent exposures are set forth in Tables 5-3 and 5-4.

517 BUILDING AND WALL STRUCTURE DESIGN

a. 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 attenuation of blast pressures and structural motion to a level consistent with safety requirements.

(1) Exterior wall and roof coverings of buildings containing explosives should be constructed of noncombustible materials.

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

(3) Roofs and walls shall comply with construction requirements of TM5-1300.

b. Floors and Work Surfaces.

(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.

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

(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 such as conductivity are required.

c. Interior Walls. Roofs. and Ceilings.

(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.

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

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

(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. 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.

d. Fire Walls. Fire walls and openings in fire walls must comply with requirements of local fire codes, Fire Prevention Manual, and associated NFPA standards.

e. Substantial Dividing Walls.

(1) Substantial dividing walls will be designed in accordance with TM5-1300 to prevent propagation of detonation by blast, fragmentation, or wall fragments.

(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. When the opening is not in use, the opening shall be provided with closures designed to the level of protection afforded by the wall.

f. Protective Shields and Barricades.

(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.

(2) Design of operational shields will be in accordance with Table 5-5.

(3) Use and design of a barricade, natural or artificial, to limit in a prescribed manner, the effect of an explosion or nearby buildings or exposures will be in accordance with HNDM-1110-1-2.

518 EMERGENCY EXITS AND FIRE ESCAPES

a. General. As a minimum standard for NASA explosives-operating buildings and facilities, the latest edition of NFPA 101, "Life Safety Code," and ANSI Safety Code A156.3, "Building Exits," will be used as guides for constructing emergency exits and fire escapes. When these standards conflict with the requirements of this chapter, the requirements of this chapter shall prevail.

b. 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 must comply with the following conditions:

(1) At least two exits remote from each other (regardless of dimension) will be provided for each operating room or building containing explosives. *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.

(2) Exits shall be at least 32 inches wide. In determining the egress width for a doorway for the purpose of calculating capacity, only the clear width of the door when the door is in the full open position shall be measured. Clear width shall be the net, unobstructed width of the door opening without projections into such width.

(3) Exits should be equally spaced about the perimeter of the building for immediate evacuation.

(4) Exits 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.

(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.

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

(7) Blast doors are prohibited on outside exits in place of emergency exits.

(518)

c. Safety Chutes. Safety chutes will be provided as exits from multistaired hazardous locations where rapid egress is vital and cannot otherwise be obtained.

d. 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 shelter, 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.)

519 STATIC ELECTRICITY

a. General. This section covers methods for the control of static electricity for the purpose of eliminating or mitigating its fire and explosion hazard. 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.

b. Personnel Electrostatic Discharge Equipment and Conductive Floors.

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

(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.

(3) The resistance of legstats and conductive shoes should measure, between wearer and facility ground, 25,000 ohms and 1 megohm.

(4) Wriststats resistance should measure, between wearer and wriststat ground clip, 25,000 ohms and 1 megohm. A retest shall be made if the grounding device is removed.

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

(6) Conductive floors and conductive shoes 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.

(7) Conductive floors are required where operations involve:

(a) Loose unpacked explosives with primers.

(b) Exposed EED's such as squibs and detonators.

(c) Electrically-initiated items with exposed electric circuitry.

(8) Conductive floor testing instruments shall meet the following requirements of ASTM D-2240-91, "Test Methods for Rubber Properties Durometer Hardness."

(a) 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. Minimum floor resistance shall be measured with a suitably calibrated ohmmeter appropriate for the task.

(b) 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.

(9) 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.

(10) Portable ground cables used for connecting ordnance items to the facility ordnance ground system shall be visually inspected prior to each use. Prior to each use, it shall be verified that an electrical continuity test has been conducted on the cable within the last 7 months.

(a) For each cable, an electrical continuity test must have been performed within 7 months prior to each use. Once connected, a cable may remain continuously connected beyond the 7-month time period, but when disconnected, it must be retested before being reused.

(b) 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.

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

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

520 ENVIRONMENTAL CONDITIONS

The development of electrical charges may not be in itself 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:

a. A mechanism for generating static electricity must be present.

b. A means of accumulating or storing the charge so generated must exist.

c. A suitable gap across which the spark can develop must be present.

d. A voltage difference sufficient to cause electrical breakdown or dielectric breakdown must develop across the gap.

e. A sufficient amount of energy must be present in the spark to exceed the minimum ignition energy requirements of the flammable mixture.

521 CONTROL OF ESD

a. 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.

b. If hazardous static conditions cannot be avoided in certain operations, means must be taken to assure that there are no ignitable mixtures at points where sparks may occur.

c. Some common recommended practices of control and/or reduction of ignition hazards from ESD are as follows:

(1) Bonding and Grounding (refer to paragraph 522).

(2) Humidification. Humidification for preventing ESD accumulations and subsequent discharges is usually effective if the relative humidity is above 60 percent. Some materials such as metallic powders and some pyrotechnic mixtures, however, cannot be exposed to air with 60-percent relative humidity because of the possibility of spontaneous ignition.

(3) Ionization.

(a) Ionization serves as an effective method for removing static charges from certain processes and/or operations.

(b) Ionization methods of removing static charges must not be used in hazardous locations as defined in the NEC unless approved specifically for such locations by the AHJ.

(4) Inerting, Ventilation, Relocation.

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

(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.

(6) Minimize surface area contact to minimize triboelectrification.

(7) Where possible, anti-static 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.

522 EQUIPMENT GROUNDING/BONDING

a. <u>General</u>. 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.

b. In terms of the results to be achieved, bonding is necessary for:

(1) Protection of equipment and personnel from the hazards of lightning discharges.

(2) Establishment of fault current return paths.

(3) Protection of personnel from shock hazards arising from accidental power grounds.

(4) Prevention of static charge accumulation.

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

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

(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. Dual ground paths are recommended.

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

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

(5) Static grounds can be made to water pipes that are 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.

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

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

(8) Flexible conductors will be utilized for bonds that are frequently connected and disconnected.

d. The primary purpose of bonding and grounding is to ensure requirements of 522b(1) through (4) 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.

523 CONCURRENT HAZARDOUS OPERATIONS

a. General. 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.

b. Recommended Practices and Precautions.

(1) Unless a building or facility is specifically designed in accordance with TM5-1300 for concurrent operations, permissible concurrent operations should be conducted in separate buildings located at the appropriate intraline distance from other operating buildings. When it becomes necessary to conduct concurrent operations in the same building, the operational layout will be planned to segregate the primary hazards by substantial dividing walls, barricades, or other means to ensure maximum personnel protection (see paragraph 202, Limit Control).

(2) Multiple operations are not recommended practices within the same facilities 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, etc., and personal air breathing equipment will be evaluated to ensure the safety of operations and personnel emergency egress.

524 COMMON SOURCES OF ESD

a. Some common sources of ESD are:

(1) Nonconductive power or conveyor belts in motion.

(2) Moving vehicles.

(3) Motions of all sorts that involve changes in relative position of contacting surfaces, usually of dissimilar liquids or solids.

b. 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 to determine 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 body 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.

c. A less well-recognized source of ESD produces hazards caused by static sparking from semiconductive 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:

(1) Special characteristics of induction charging.

(2) Six incidents in which induction charging resulted in a fire.

(3) Protective measures that were taken against charge induction.

525 HOUSEKEEPING

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

(525)

b. Precautions. The following are minimum precautions to be taken in explosives facilities cleaning operations:

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

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

(a) These waste receptacles should have enough liquid, normally water or oil if these do not present a hazard, to cover the scrap or rags.

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

(3) 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.

c. Sweeping Compounds.

(1) Sweeping compounds containing wax or oil will not be used on conductive floors.

(2) Cleaning agents that include caustic alkalies must not be used in locations containing "exposed explosives" because sensitive explosives compounds may be formed.

(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 must be nonabrasive.

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

NOTE: The building or facility supervisor, foreman, or worker-in-charge shall prevent accumulations of excess explosives on materials and equipment.

526 SMOKING

a. Measures shall be taken to prohibit indiscriminate smoking in NASA explosives and hazardous materials facilities. Smoking shall be prohibited in any explosives storage or operating area, except as permitted below:

(1) Smoking may be approved by the cognizant safety office for designated and posted “authorized smoking areas.” A certification by the safety organization and/or local fire department will be displayed in each designated smoking location.

(2) Designated smoking areas shall have the following minimum precautionary measures:

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

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

(c) Matches or flame-producing devices will not be allowed in explosives facilities or explosives storage areas.

(d) An approved fire extinguisher as determined by safety or fire department personnel shall be provided.

(e) Smoking shall be prohibited to personnel dressed in clothing/coveralls contaminated with explosives or flammable materials.

(f) Persons who work with toxic chemicals or containers or other toxic materials must wash their hands before smoking.

(g) A “No Smoking” sign will be posted at each entrance to an explosives facility or storage area. 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.

b. Smoking shall be prohibited in, on, or within 50 feet of any motor vehicle, trailer, rail car, or material handling equipment loaded with explosives or similar hazardous material items.

527 PERSONAL PROTECTION CLOTHING AND EQUIPMENT

a. General. In accordance with NHB 1700.1(V1), Chapter 10, protective clothing and equipment (PCE) will 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.

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

In determining requirements for PCE, each operation shall be analyzed to determine the need for and specific kinds of personal protective clothing or equipment. Cotton undergarments should be worn in any operation where the generation of static electricity would create a hazard.

Special operations where employees are required to wear special clothing (explosive plant clothing, anti-contamination clothing, impervious clothing, etc.) requires a designated location for changing of clothes with suitable clothing lockers provided.

b. Clothing. Explosives coveralls (commonly referred to as powder uniforms) must meet the following requirements:

(1) Fasteners shall be nonmetallic fasteners.

(2) Coveralls shall be easily removable.

(3) Pockets should be of the lattice type.

(4) Trouser legs, slacks, and sleeves should be tapered.

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

(6) Coveralls should extend over shoes/boots.

(7) 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.

(8) Garments should be made from tightly woven, smooth fabric.

c. Eye Protection. Suitable devices must be worn by all personnel when working or visiting in eye hazard areas including aisles and hallways. Industrial safety eyeglasses shall meet all the requirements of ANSI Standard Z87.1. Contact lenses cannot be considered as substitutes for appropriate eye protection. Contact lenses will not be worn in work environments where there are chemicals, burners, smoke, dusts, particles, or molten metals.

d. Hearing Protection. All personnel exposed to noise hazards, either intermittently or when assigned to a noise hazard area, must wear hearing protection. 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.

e. 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. Such equipment shall be maintained in serviceable condition and stored properly in lockers out of contaminated areas. 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 facepiece, temple pieces on corrective spectacles, or goggles, or the absence of one or both dentures prevent a good facepiece-to-face seal, that worker shall not be permitted to perform such tasks.

f. 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. Where possible, these operations should be conducted in air-conditioned facilities.

g. Head Protection. Face shields shall be provided for personnel exposed to flying sparks, shavings, splashing liquids, or similar hazards. Safety helmets or hard hats shall be worn when there is exposure to falling objects. Bump hats may be worn in lieu of hard hats when working in confined spaces, but shall not be substitutes for hard hats. Safety hard hats must comply with ANSI Z89.1 and, if specifically for protection against electrical hazards, ANSI Z89.2 shall apply.

h. Conductive Footwear. Personnel who work upon conductive flooring, conductive mats, or conductive runners where explosives or flammable vapors are present must wear nonsparking conductive footwear meeting requirements of standards ANSI Z41.1-1967 (or latest revision). Visiting personnel who enter these areas and who walk on conductive flooring materials must also wear nonsparking conductive footwear. Leg stats are acceptable for visitors or transients only as long as their basic footwear is of nonsparking construction. Personnel working on electrical equipment of facilities are prohibited from wearing conductive-sole shoes or other conductive footwear.

(527)

i. Conductive Footwear Specifications. Conductive shoes with conductive composition soles shall meet the ANSI Z41.1-1967, Safety Standard for Men's Safety-Toe Footwear.

(1) The maximum electrical resistance permitted for each shoe, conductive rubber, or other type of conductive footwear is 450,000 ohms. 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.

(2) 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. Tests must not be performed in rooms where exposed explosives are present.

j. 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.

k. Electrician's Safety Shoes. Electrical-hazards shoes made with a stitched and cemented construction and which are of good insulation must be worn by employees performing electrical maintenance work indoors on 31- to 600-volt circuits and meet the requirements of ANSI Z41.1-1967 and Z41-4EH76.

528 HAND TOOL SAFETY

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

529 HOT WORK PERMITS

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

530 SAFETY REQUIREMENTS IN SPECIFIC HAZARDOUS AREAS

a. 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. Supplies above this limit shall be kept in service storage magazines located at intraline distance based on the net explosive weight of the explosives in the service storage magazine.

(530)

b. If required by operational necessity, explosives that are part of the work in process within the operational building may be stored during non-operational hours in operating buildings, provided the following requirements are strictly observed:

(1) Explosive limits shall not be exceeded.

(2) Compatibility requirements shall be met.

(3) Containers of bulk explosives or propellants shall be properly secured and covered.

(4) Processing equipment shall be empty and cleaned.

(5) Building shall be equipped with an automatic sprinkler system.

531 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 intraline distance.

532 PARKING OF PRIVATELY OWNED VEHICLES

a. Parking of privately owned vehicles shall be controlled to minimize fire and explosion hazards and prevent congestion in the event of emergency. Automobiles shall be parked in designated areas outside of restricted areas. They should not be parked close enough to a building to either enable spread of fire from an automobile to the building or hinder access by fire fighters.

b. Parking areas for privately owned vehicles will be separated from potential explosion sites by unbarricaded intraline distance if they serve only the workers assigned to a particular line or area. Private vehicle parking in administrative areas will be a minimum of public traffic route distance from the nearest potential explosion source. Minimum fragment distance for this application may not be reduced.

533 ELECTRICAL STORMS

a. On notification of an approaching electrical storm, personnel shall be evacuated from facilities where there is an explosives hazard that could be initiated by lightning. Such locations include:

(1) Explosives operating facilities without approved lightning protection systems and other locations within intraline distance of such facilities.

(2) Facilities containing explosives dust or vapors, whether or not equipped with approved lightning protection systems and locations within intraline distance of such buildings.

(3) Magazines, open storage sites, or loading docks that are not equipped with approved lightning protection systems; vehicles and railroad cars on ungrounded tracks containing explosives; and locations within magazine distance of such structures, sites, vehicles, or cars.

(4) Locations (with or without lightning protection) where operations involving electro-explosive devices are being performed.

b. In an operating facility, evacuated personnel shall be retired to approved protection shelters located at intraline distance from operating buildings or other hazardous locations. When such shelters are not available, personnel shall be withdrawn to places at IHBD's from the hazardous location.

534 PROHIBITED ARTICLES IN HAZARDOUS AREAS

Except as provided in paragraphs 524 and 527, personnel shall not be permitted to carry cigarette lighters, matches, or any other flame-producing devices into hazardous materials restricted areas.

535 EXPLOSIVES RECOVERY AND REUSE

All loose explosives recovered from sweeping floors of operating facilities shall be destroyed. 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. Explosives contaminated with dirt, dust, grit, or metallic objects will be reprocessed to remove all foreign matter before reuse.

536 MAINTENANCE AND REPAIRS TO EQUIPMENT AND BUILDINGS

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

b. If maintenance or repairs are to be conducted on equipment within the operating area, Safety must verify that all exposed explosives and other static sensitive materials have been removed from the immediate work area.

537 ELECTRICAL TESTING OF EXPLOSIVE COMPONENTS

a. Power Source.

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

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

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

b. Layout of Test Equipment.

(1) Test equipment should not be placed in hazardous atmospheres unless approved for such.

(2) Operational shields are required for personnel protection unless the equipment is incapable of initiating the item being tested.

(3) The safest and most reliable means of attaining and retaining this initiating incapability 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.

c. Use of Test Equipment.

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

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

538 HEAT CONDITIONING OF EXPLOSIVES — EQUIPMENT

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

(538)

b. For devices or facilities heated by steam only, the requirements for dual automatic heat controls shall be satisfied if the steam pressure is controlled by 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.

c. Heat-conditioning devices shall be constructed to effectively vent overpressure from internal explosion.

d. 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.

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

f. 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 where there is no possibility of contact with explosives or flammable materials.

g. 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. 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.

h. 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.

i. All noncurrent-carrying metal parts of a heat conditioning device shall be electrically interconnected and grounded.

j. 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.

k. 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.

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

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

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

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

(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.

539 EXPLOSIVES FACILITY SITING AND DESIGN CRITERIA REFERENCES

In addition to this standard, the following documents may be used as resources for the siting and design of explosives facilities:

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

b. DOE/TIC-11268, "A Manual for the Prediction of Blast and Fragment Loading of Structures," U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120.

c. DoD 6055.9-STD, "Department of Defense Ammunition and Explosives Safety Standards," Assistant Secretary of Defense (Manpower, Installations, and Logistics), Chairman, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331.

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

e. AD 411445, "Industrial Engineering Study to Establish Safety Design Criteria for Use In Engineering of Explosives Facilities and Operations," Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

(539)

f. AFWL-TR-74-102, "The Air Force Manual for Design and Analysis of Hardened Structures," Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; AD B004152, Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314.

g. HNDM-1110-1-2, "Suppressive Shields, Structural Design and Analysis Handbook," U.S. Army Corps of Engineers, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807.

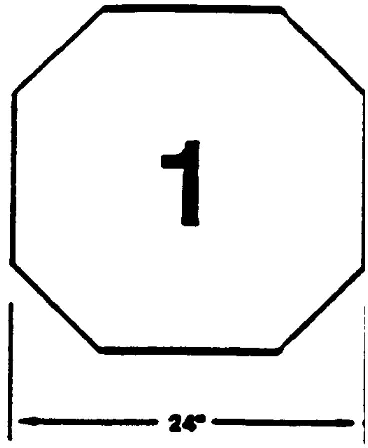
h. DARCOM-R 385-100, "Safety Manual," Department of the Army, Headquarters United States Army Materiel Development and Readiness Command, 5001 Eisenhower Avenue, Alexandria, VA 22333.

i. 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.

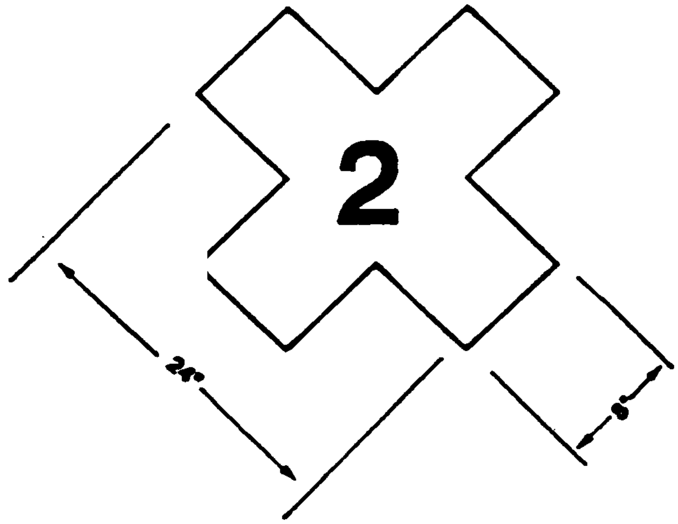
Table 5-1. Quantity-Distance Separation for Protection of Underground Service Installations.

Quantity of explosives (maximum pounds)	Distance	
	Meters	Feet
100	26	80
200	26	80
500	26	80
1,000	26	80
2,000	26	80
5,000	26	80
10,000	26	80
20,000	28	85
50,000	36	110
100,000	46	140
250,000	62	190

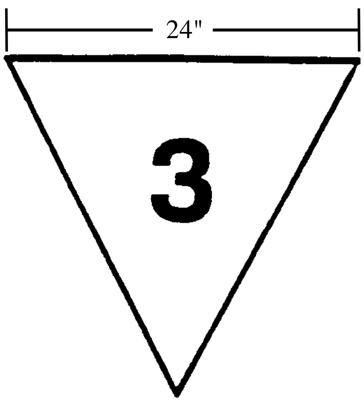
NOTE: If the potential donor building is designed to contain the effects of an explosion, the formula $D = 3.0\ W^{1/3}$ can be used to determine separation distances for less than 20,000 pounds.



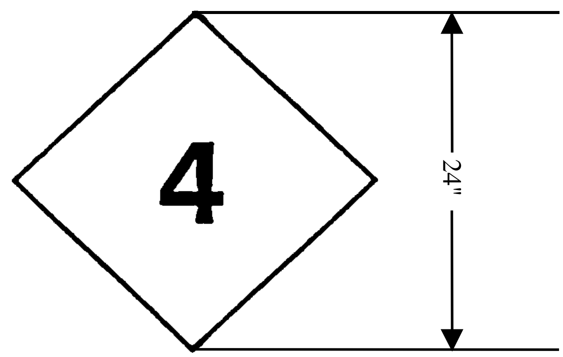
FIRE DIVISION 1
(HAZARD CLASS 1.1)



FIRE DIVISION 2
(HAZARD CLASS 1.2)



FIRE DIVISION 3
(HAZARD CLASS 1.3)



FIRE DIVISION 4
(HAZARD CLASS 1.4)

BACKGROUND: **Orange #12245 (See Fed. Std. 595A or GSA Catalog)**

NUMBERS: **10” high and 3” thick: Black #17038 (See Fed. Std. 595A or GSA Catalog)**

Figure 5-1. Fire Symbols.

Table 5-2. Withdrawal Distances.

Fire Symbol	Public Withdrawal Distance (Feet)	Special Requirements
1	2,000	Use inhabited building distance for quantities greater than 100,000 lbs.
2	1,800	
3	600	Use inhabited building distance for quantities greater than 100,000 lbs.
4	300	

Table 5-3. Class 1.1 - Quantity Distance (Laboratories).

Quantity of Explosives		Distance in Feet		
Pounds (Over)	Pounds (Not Over)	Inhabited Building	Public Traffic Route	Intraline
0	1	40	25	20
1	2	50	30	25
2	5	70	40	30
5	10	90	55	35
10	20	110	65	45
20	30	25	25	25
30	40	140	85	55
50	80	125	75	50
40	50	150	90	60

Table 5-4. Class 1.3 - Quantity Distance (Laboratories).

Quantity of Explosives		Unbarricaded Distance in Feet		
Pounds (Over)	Pounds (Not Over)	Inhabited Building	Public Traffic Route	Intraline
0	5	10	10	10
5	10	15	15	15
10	20	20	20	20
20	30	25	25	25
30	50	30	30	30
50	80	35	35	35
80	100	40	40	40
100	150	45	45	45
150	200	50	50	50

Table 5-5. Safety Shields for Explosives Laboratory Operations[1,2,3]
(See Reference i).

Shield	Minimum distance from explosive (cm)	Explosives limit
Leather gloves, jackets or coats, and plastic face shields	-	50 mg.
3 mm tempered glass	8	50 mg.
7 mm Lucite/equivalent material	15	2-1/2 g
20 mm Lucite/equivalent material	15	10 g
15 mm laminated resistant glass	20	20 g
25.4 mm Lexan/Lexguard	30	50 g
2 units each of 25.4-mm plate glass laminated with 12.4-mm polycarbonate with a 9.5-mm air gap between units (glass sides facing the explosive)	30	50 g (steel confined)

NOTES:

1. Listed shields have been tested and found acceptable for the indicated quantities of explosives.

2. Shields were not tested for metal fragment penetration unless specifically indicated.

3. Table is using 1.1 as basis for distances.

CHAPTER 6. EXPLOSIVES, PYROTECHNICS, AND SOLID PROPELLANTS

600 EXPLOSIVES HAZARD CLASSIFICATION SYSTEM

a. The hazard classification system consists of nine divisions for dangerous goods with ammunition and explosives included in United Nations Organization (UNO) Class 1, Explosives. These ammunition and explosives hazard divisions (see paragraph 606) are based on the character and predominance of the associated hazards and the potential for causing personnel casualties or property damage (see Chapter 5, paragraph 506a).

b. The hazard classification system is to be applied in explosives development, manufacture, test, maintenance, storage, handling, transportation, and loading and unloading of vehicles and aircraft. The class and divisions identify hazards and are used to determine the levels of protection for personnel and property from the effects of fires and explosions. The separation of the hazard class into divisions does not always mean that the different items in a division may be stored together. This would depend upon the requirements of storage compatibility grouping, discussed in paragraph 607, Explosives Storage Compatibility Groups. Also, some items may appear in more than one division depending on the degree of confinement or separation, type of packaging, storage configuration, and state of assembly.

c. A numerical figure (in parenthesis) is used when required to indicate the minimum separation distance (in hundreds of feet) for protection from debris, fragments, and firebrands. This number will be placed to the left of the division designator 1.1 through 1.3 such as (18) 1.1, (08) 1.2, and (06) 1.3 (see Figure 6-1). A minimum as shown in applicable tables will be used for all items in Division 1.2. For Divisions 1.1 and 1.3, a minimum distance number is required where the ranges of hazardous fragments and firebrands exceed the distances specified for inhabited buildings in the applicable Quantity-Distance (QD) tables in Chapter 8.

601 CLASS 1, DIVISION 1 (1.1 Mass-Detonating)

a. 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.

b. Items in Class/Division 1.1 include bulk explosives and some propellants.

602 CLASS 1, DIVISION 3 (1.3 Mass Fire)

a. Items in this division are those that burn vigorously with little or no chance of extinguishment in storage configurations. Explosions normally will be confined to pressure ruptures of containers and will not produce propagating shock waves or damaging blast overpressures beyond the magazine distances specified in Table 8-3. A severe hazard of the spread of fire may result from tossing about the burning container materials, propellant, firebrands, or other debris. Toxic effects usually do not go beyond inhabited building distances.

b. This division includes items such as solid propellant compositions determined by card gap tests TB700-2 to have a detonation sensitivity value less than 70 cards.

603 CLASS 1, DIVISION 4 (1.4 Moderate Fire, No Blast)

a. Items in this division present a fire hazard with no blast hazard and virtually no fragmentation hazard beyond the fire hazard clearance ordinarily specified for high-risk materials. Separate facilities for storage and handling of this division should not be less than 100 feet from other facilities, except those of fire-resistive construction, which may be 50 feet from each other.

b. This division includes items such as small arms ammunition without explosive projectiles, fuse lighters and squibs, colored smoke grenades, and explosive valves or switches.

604 AMMONIUM PERCHLORATE (Classes and Storage Compatibility Group)

a. Ammonium perchlorate particle size 15 microns or less, 1.1 Group D.

b. Ammonium perchlorate particle size over 15 microns in original shipping container or equivalent, 1.4 Group L.

c. Ammonium perchlorate particle size over 15 microns not in original shipping container or equivalent, exposed to fire hazards only or exposed to detonation hazards from a source at more than intraline distance, 1.3 Group D.

d. Ammonium perchlorate particle size over 15 microns not in original shipping container or equivalent, exposed to detonation hazards from a source at less than intraline distance, 1.1 Group D.

NOTE: The above Class/Division, Compatibility Groups for Ammonium Perchlorate are not those used by the Department of Transportation (DOT) in 49 CFR for shipment of ammonium perchlorate.

605 DEPARTMENT OF TRANSPORTATION CLASSIFICATION

a. Definition of Class 1 Explosive. An explosive means any substance or article, including a device, which is designed to function by explosion (i.e., an extremely rapid release of gas and heat) or which, by chemical reaction within itself; is able to function in a similar manner even if not designed to function by explosion, unless the substance or article is otherwise classed under provision of 49 CFR 173.50. Class 1 explosives are divided into six divisions as follows:

(1) Division 1.1 consists of explosives that have a mass explosion hazard.

(2) Division 1.2 consists of explosives that have a projection hazard but not a mass explosion hazard.

(3) Division 1.3 consists of explosives that have a fire hazard and either a minor blast hazard or minor projection hazard or both, but not a mass explosion hazard.

(4) Division 1.4 consists of explosives that present a minor explosion hazard. The explosive effects are largely confined to the package and no projection of fragments is expected. An external fire must not cause instantaneous explosion of almost the entire contents of the package.

(5) Division 1.5 consists of very insensitive explosives. This division is comprised of 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. The probability of transition from burning to detonation is greater when large quantities are transported in a vessel.

(6) Division 1.6 consists of extremely insensitive articles that do not have a mass explosive hazard. This division comprises articles that contain only extremely insensitive detonating substances and demonstrate a negligible probability of accidental initiation or propagation. The risk from articles in this division is limited to explosion of a single article.

NOTE: 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**

606 EXPLOSIVE STORAGE COMPATIBILITY GROUPS

a. Storage Principles.

(1) All explosives and explosive items are assigned to storage compatibility groups (SCG's) for storage, maintenance, and transportation at and between NASA facilities.

(2) Different types of explosives may be mixed in storage if they are compatible by item and division. Explosives are assigned to an SCG when they can be stored together without significantly increasing either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident.

b. Compatibility Groups. In development, these various factors are considered but are not limiting:

(1) Chemical and physical properties.

(2) Design characteristics.

(3) Inner and outer packaging configuration.

(4) Hazard classification.

(5) Net Explosive Weight (NEW).

(6) Rate of deterioration.

(7) Sensitivity to initiation.

(8) Effects of deflagration, explosion, or detonation.

NOTES: **Subject to application of these standards and particularly to compatibility as defined herein, explosives should be mixed in storage only when such mixing will facilitate safe operations and promote overall storage efficiency.**

As used in these standards, the phrase "with its own means of initiation" indicates that the explosive item has its normal initiating device assembled to it that presents a significant risk during storage. The phrase does not apply, however, when the initiating device is packaged to eliminate the risk of detonating the explosive in the event of accidental functioning of the initiating device, or when fuzzed end items are so configured and packaged as to prevent inadvertent arming of the fuzzed end items. The initiating device

(606b)

may even be assembled to the explosive item provided its safety features preclude initiation or detonation of the explosive filler of the end item in the event of an accidental functioning of the initiating device.

607 STORAGE COMPATIBILITY GROUPS

In accordance with explosives storage principles and considerations for mixed storage, explosives are assigned to one of the following 12 SCG's.

a. 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, and dry Pentaerythritol Tetranitrate (PETN).

b. Group B. Detonators and similar initiating devices - 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 safe/arm without two or more safing-features.

c. Group C. Bulk propellants, propelling charges, and devices containing propellant with or without their own means of ignition - Items that upon initiation will deflagrate, explode or detonate. Examples are single, double, triple-base, and composite propellants, rocket motors (solid propellant).

d. Group D. Black powder, a high explosive (HE), or a device containing an initiating explosive and two or more independent safety features - Explosives that can be expected to explode or detonate when any given item/component thereof is initiated.

e. Group E. Not normally found in NASA installations.

f. Group F. Devices (fuzed) with or without propelling charges. Examples are sounding devices and similar items having an in-line explosive train in the initiator.

g. Group G. Fireworks, illuminating, incendiary, and smoke (including Hexachloroethane (HC)), or tear-producing devices other than those that are water-activated or contain white phosphorus (WP) or flammable liquid or gel - Functioning of these devices results in an incendiary, illumination, lachrymatory, smoke, or sound effect. Examples are flares, signals, incendiary or illumination devices, igniters, and other smoke-producing devices.

h. Group H. Not normally found in NASA installations.

i. Group J. Not normally found in NASA installations.

j. Group K. Not normally found in NASA installations.

k. Group L. Devices not included in other compatibility groups - Devices having characteristics that do not permit storage with other types of material. Examples are water-activated devices, prepackaged hypergolic liquid-fueled rocket engines, fuel-air explosive devices (FAE), (thickened Triethyl Aluminum (TEA)), and damaged or suspect items of any group. Types preventing similar hazards (i.e., oxidizers with oxidizers, fuels with fuels, etc.) may be stored together but not mixed with other groups.

l. Group S. Items presenting no significant hazard - Devices so designed or packed that when in storage all hazardous explosive effects are confined and self-contained within the item or package. An incident may destroy all items in a single pack, but must not be communicated to other packs so all are destroyed. Examples are thermal batteries, explosive switches or valves, Safe and Arming (S&A) devices, and other items packaged to meet the criteria of this group.

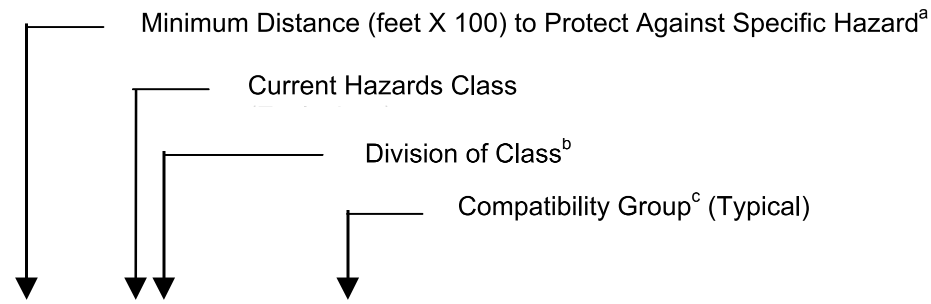
608 MIXED STORAGE

a. Mixing of SCG's is permitted as indicated in Figure 6-2 and Table 6-1.

b. Items from SCG's C, D, F, G, and S may be combined in storage provided the net quantity of explosives in the items or in bulk does not exceed 1000 pounds per storage site. These items must be packaged in accordance with approved drawings.

609 COLOR-CODING

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, e.g., "Red" designates live explosives, or "Blue" for inert explosives. Note that this system of color-coding is not the only one in use, e.g., Flight Hardware will not be painted. This requires that in addition to training in color-coding differences, Operating Procedures will contain information pertaining to color-coding where applicable.



(18)	1.1	D
(08)	1.2	
(06)	1.3	C
	1.4	S

[a]Varies with type of explosive.

[b]Class divisions:
- 1.1 Mass detonating
- 1.2 Non mass detonating, fragment producing.
- 1.3 Mass fire
- 1.4 Moderate fire, no blast

[c]Chapter 8, Section 809c(3)

Figure 6-1. Application of Hazard Classification System.

Groups	A	B	C	D	E	F	G	L	S
A	x	z							z
B	z	x							x
C			x	z	z		z		x
D			z	x	x				x
E			z	x	x				x
F						x			x
G			z				x		x
L								x	
S	z	x	x	x	x	x	x		x

NOTES:

- An "x" in a block of the above chart indicates that these groups may be combined in storage; otherwise, mixing is either prohibited or restricted according to the following paragraphs.
- A "z" in a block of the above chart indicates that when warranted by operational considerations or magazine unavailability, and when safety is not sacrificed, these groups may be combined in storage.
- No mark in a block indicates that combined storage is not permitted.

Figure 6-2. Storage Compatibility Mixing Chart.

Table 6-1. Storage Compatibility Groups for Explosives and Explosives-Containing Devices.

Group A - Initiating exposives

- Black powder
- CP (5-Cyanotetrazolpentaamine Cobalt III Perchlorate) (pellets)
- Lead azide
- Lead styphnate
- Mercury fulminate
- Nitrocellulose (dry)
- Tetracene
- TATNB (Triazidotrinitrobenzene)

Group B - Detonators and similar initiating devices

- Blasting caps
- Booster pellets (when packaged in nonpropagating arrays)
- Detonators including EBWs and slappers
- Explosive bolts
- Fragmenting actuators
- Igniters
- MDF (mild detonating fuse) detonator assemblies)
- Pressure cartridges
- Primers
- Squibs

Group C - Bulk propellant, propellant charges, and devices containing propellants with or without their own means of initiation

- Smokeless powder
- Pistol and rifle powder
- Rocket-motor solid propellants

Group D - High explosives (HE and devices containing explosives without their own means of initiation

- Ammonium Picrate
- Baratol
- Boracitol
- Compositions A, B, and C (all types)
- Cyclotols (not to exceed a maximum of 85% RDX)
- DATB (diaminotrinitrobenzene)
- Detonating cord (primacord or mild detonating fuse)
- bis-Dinitropropyl adipate
- bis-Dinitropropyl glutarate
- bis-Dinitropropyl maleate
- Dinitropropane
- Dinitropropanol
- Dinitropropyl acrylate monomer (DNPA)
- Dinitropropyl acrylate polymer (PDNPA)
- Elastomeric plastic bonded explosives
- Explosive D
- HMX (Cyclotetramethylene tetranitramine) (wet)
- HMX/wax (formulated with at least 1% wax)
- HNS (Hexanitrostilbene)
- Linear-shaped charge
- Methyl dinitropentanoate
- Nitrocellulose (wet)
- Nitroguanidine
- Octol
- Pentolite
- PETN (Pentaerythritol tetranitrate) (wet)
- PETN desensitized (dry)
- PETN/extrudable binder
- Plastic Bonded explosives, PBX (a Group D explosive formulated with a desensitizing plastic binder)
- Potassium picrate
- RDX (Cyclotrimethylene trinitramine) (wet)
- TATB (Triamino trinitrobenzene)
- TATB/DATB mixtures
- Tetryl
- TNT (Trinitrotoluene)

Table 6-1. Storage Compatibility Groups for Explosives and Explosives-Containing Devices. (Continued)

Group E - Explosives devices without their own means of initiation and with propelling charge.

Artillery ammunition
Rockets (e.g., M66 LAW)

Group F - Explosives devices with detonators and detonating trains assembled to the devices.

Group G - Devices that produce an incendiary, illumination, lachrymatory, smoke, or sound effect

Smoke pots (when in lots of 50 or more)
Flares
Incendiary ammunition.

Group L - Explosives or ammunition not included in other compatibility groups

Damaged or suspect explosives devices or containers
Explosives that have undergone severe testing.

Group R - High explosives materials more sensitive than Group D but less sensitive than Group A

CP (5-Cyanotetrazolpentaamine Cobalt III Perchlorate) (powder)
HMX (Cyclotetramethylene tranitramine) (dry)
PETN (Pentaerythritol tetranitrate) (dry)
RDX (Cyclotrimethylene trinitramine) (dry).

Group S - Explosives, explosives devices, or ammunition presenting no significant hazard

Propellant, cartridge-actuated devices (which yield a nonfragmenting, nonflame-producing, controlled reaction).

Examples include the following:
Cable cutters
Cartridge actuated valves
Linear actuators (e.g., dimple, piston, bellows motors)
Safety fuse
Small arms ammunition
Smoke pots or similar smoke devices (when in lots of less than 50).

Group X - Experimental explosives, explosives of temporary interest, newly synthesized compound, new mixtures, and some salvaged explosives.

Group Y - Material and systems that need not be stored or labeled as explosives unless they are near other explosives that could initiate them.

When near explosives, Group Y material becomes Group D unless otherwise indicated.

FEFO/SOL(35 wt% or less FEFO in ethyl acetate)
FEFO/solution
Group D explosives in inert solvents (explosive concentration not exceeding 25 wt%)
Nitrates; treat as Group C when with other explosives
Perchlorates; treat as Group C when with other explosives
Picric acid (containing at least 10 wt% water and in less than 11 kg lots)
Small arms ammunition classified for shipment by DOT as ORM-D (Other Regulated Material-Class D) rather than Class C Explosives. Normally consists of ammunition not exceeding 50 caliber for handguns and rifles and 8 gauge for shotguns.

CHAPTER 7. LIQUID PROPELLANTS

700 LIQUID PROPELLANTS

a. Scope and Application. This section applies to the storage of liquid propellants in all types of containers, including rocket and tankage, in quantities greater than a single shipping container such as one 55-gallon drum or one 500-pound (net weight) cylinder.

b. Determination of Propellant Quantity.

(1) The total quantity of propellant in a tank, drum, cylinder, or other container shall be the net weight of the propellant contained therein. When storage containers are not separated one from the 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. Quantity of propellant in associated piping must be included such 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.

(2) When incompatible propellants are not separated by the required distances, or provisions are not made to prevent their mixing, the combined quantity of the two shall be used. See Table 7-1 to determine if explosive equivalents apply.

(3) Table 7-2 lists conversion factors (gallons to pounds) for various liquid propellants.

(4) When propellants (compatible or incompatible) at a specific location are stored so that the possibility of accumulative involvement is limited positively to the quantity of propellant in any one of the divided storage sites, Quantity-Distance (QD) separation does not apply between such storage sites. The propellant content of the storage site requiring the greatest distance shall be used to determine the separation to be maintained between propellant locations or other targets.

(5) Separation distances shall be measured from the closest hazard source (containers, buildings, segments, or positive cutoff point in piping, whichever is controlling).

701 LIQUID PROPELLANT HAZARD GROUPS

Liquid propellant presents various types and degrees of hazards. Based on these hazards, the following propellant groupings are established:

a. Group I (Fire Hazard). Materials in this group are considered to be the least hazardous. They have a fire-hazard potential and require separation distances specified in Table 7-3. When Group I materials are stored with more hazardous materials under conditions described in paragraph 703, Tables 7-1 and 7-6 will be used to determine Trinitrotoluene (TNT) equivalency.

b. Group II (Serious Fire Hazard). Materials in this group are strong oxidizers. Serious fires may result when Group II propellants come in contact with materials such as organic matter due to vigorous oxidation or rapid combustion. Table 7-4 specifies quantity limitations and minimum distance requirements for this group. When Group II materials are stored with more hazardous materials under conditions described in paragraph 703, Liquid Propellant Storage, Tables 7-1 and 7-6 will be used to determine TNT equivalency.

c. Group III (Pressure Rupture, Vapor Phase Explosion, Fragments). Hazards with this group are primarily from pressure rupture of the storage container, resulting from fire, deflagration, or vapor-phase explosion. Hazardous fragmentation of the container, its protective structure, or other nearly material may be produced by pressure rupture of the storage container or a vapor-phase explosion. Table 7-5 specifies quantity limitations and minimum distance requirements for this group. When Group III materials are stored with more hazardous materials under conditions described in paragraph 703, Liquid Propellant Storage, Tables 7-1 and 7-6 will be used to determine TNT equivalency.

d. Group IV (Mass Detonating, Severe Fragments). The hazards from materials in this group are the same as for mass-detonating explosives (e.g., blast overpressure and fragments from the container and surrounding equipment and material). Table 7-6 will be used to determine QD requirements.

702 SPECIFIC HAZARDOUS LOCATIONS

The major hazard of the individual propellant can vary depending upon the location of the propellant storage and the operations involved. In order of decreasing hazards, these conditions are:

a. Range Launch Pads. These pads involve research, development, testing, and space exploration launchings. Operations at these facilities are very hazardous because of the close proximity of fuel and oxidizer to each other, the frequency of launches, lack of restraint of the vehicle after liftoff, and the possibility of fallback with resultant dynamic mixing on impact. Launch vehicle tankage is involved here and explosive equivalents (Table 7-1) shall be used to determine QD's (Table 7-6).

b. Static Test Stands. Although static test stands can involve experimental operations, the units remain static and are subject to better control than dynamic ones. Except where run tankages for fuel and oxidizer are mounted one above the other, it is possible to separate the tankage or to provide larger margins of safety to reduce the hazard from that for a rocket or missile on a launch pad. These larger margins of safety are provided when using tankage heavier than flight weight tankage. Except as provided in paragraph 703b, explosives equivalents (Table 7-1) must be used to determine QD's (Table 7-6).

c. Ready Storage. Ready storage may be located at a minimum of intraline distance from launch and static test stands, based on the propellant requiring the greater distance (Tables 7-3, 74, and 7-5). Normally, the propellant from ready storage is not fed directly into an engine, as is the case with run tankage (see f, below). As stated in paragraph 703c, explosive equivalents must be used for propellants in ready storage 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 or launch pad.

d. Cold-Flow Test Operations. Fire and fragment hazards (Tables 7-3, 7-4, and 7-5) govern if the design is such that the system is closed (except for approved venting), is completely airtight, fuel and oxidizer are never employed concurrently and each has a completely separate isolated system, and propellants are of required purity. Otherwise, as stated in paragraph 703c explosive equivalents must be used to determine QD's.

e. Bulk Storage. This is the most remote storage with respect to launch and test operations, as it is never directly connected to any of them. It consists of the area, tanks, and other containers used to hold propellants for supplying ready storage and, indirectly, run tankage when no ready storage is available. Individual bulk storage facilities must be separated from each other and from unrelated exposures in accordance with Tables 7-3, 7-4, 7-5, and 7-6. If positive measures are not taken to prevent mixing as stated in paragraph 703c, explosive equivalents as stated in paragraph 703c must be used to determine QD's.

f. Run Tankage. Run tankage (operating tankage) consists of the tank and/or other containers and associated piping used to hold the propellants for direct feeding into the engine or device during operations (see c, above).

g. Pipelines. A distance of 25 feet free of inhabited buildings will be maintained on either side of the pipelines used for the transfer of Groups II and III propellants between unloading points and storage areas or between storage areas and points of use.

703 LIQUID PROPELLANT STORAGE

a. Compatible Storage. Compatible storage of propellants of different hazard groups will be separated from other exposures by the greater intragroup storage distance. For propellants that may be mixed together without increasing the hazard, see Table 7-2.

b. Incompatible Storage. Separation distance between propellants of different compatibility groups will be the inhabited building distance for the propellant quantity and group that requires the greater distance, except where they are effectively subdivided by intervening barriers or where other positive means, e.g., shutoff valves, for preventing mixing is provided. Where prevention of mixing is assured, incompatible storage will be separated from each other by intragroup distance. If different hazard groups are involved, the group requiring the greater distance will be the controlling one.

c. Where incompatible mixing is not prevented by intervening barriers or positive means, the TNT equivalency of the mix using Table 7-1 will be calculated and the distances of Table 7-6 apply.

Table 7-1. Liquid Propellant Explosive Equivalents [1, 2, 3, 4, 5, 6]

Propellant Combinations	Static Test Stands	Range Launch Pads
LO_2/LH_2 or B_5H_9 + an oxidizer	60%	60%
LO_2/LH_2 + LO_2/RP-1	(60% for LO_2/LH_2) Sum of (10% for LO_2/RP-1)	(60% for LO_2/LH_2) Sum of (20% for LO_2/RP-1)
LO_2/RP-1or LO_2/NH_3 or B_5H_9 + a fuel	10%	20% up to 500,000 pounds plus 10% over 500,000 pounds

[1] The percentage factors given in the table are to be used to determine the equivalencies of propellant mixtures at static test stands and range launch pads when such propellants are located aboveground and are unconfined except for their tankage. Other configurations shall be considered on an individual basis to determine the equivalencies.

[2] The explosive equivalent weight calculated by the use of this table shall be added to any nonnuclear explosive weight aboard before distances can be determined for Tables 8-1 and 8-2.

[3] These equivalencies apply also when the following substitutions are made:
a. Alcohols or other hydrocarbons may be substituted for RP-1.
b. C_2H_4O may be substituted for any propellant.

[4] Use LOX/RP-1 distances for pentaborane plus a fuel and LOX/LH_2 distances for pentaborane plus oxidizer.

[5] For quantities of propellant up to but not over the equivalent of 100 lbs (45 kg) of explosives, the distance shall be determined on an individual basis by the Safety Office. All personnel and facilities, whether involved in the operation or not, shall be adequately protected by proper operating procedures, equipment design, shielding, barricading, or other suitable means.

[6] Distances less than intraline are not specified. Where a number of prepackaged liquid propellant units are stored together, separation distance to other storage facilities shall be determined on an individual basis, taking into consideration normal hazard classification procedures.

Table 7-2. Factors To Be Used When Converting Gallons of Propellant Into Pounds*, and Propellant Hazard and Compatibility Groupings.

Item	Hazard [1] & Storage [2] Grouping	Pounds/gallon	At temperature °F
Anhydrous Ammonia	I/C	5.1	68
Aniline	I/C	8.5	68
Bromine Pentafluoride	II/A	20.7	68
Chlorine Trifluoride	II/A	15.3	68
Ethyl Alcohol	I/C	6.6	68
Ethylene Oxide	III/D	7.3	68
Fluoride (Liquid)	II/A	12.6	-336
Furfuryl Alcohol	I/C	9.4	68
Hydrocarbon Fuel JP-4	I/C	6.35	60
Hydrocarbon Fuel JP-5	I/C	6.84	60
Hydrogen Peroxide (90%)	II[3]/A	11.6	68
Hydrazine	III/C	8.4	68
Isopropyl Alcohol	I/C	6.6	68
Liquid Hydrogen	III/C	0.59	-423
Liquid Oxygen	II/A	9.5	-297
Methyl Alcohol	I/C	6.6	68
Mono Methyl Hydrazine	III/C	7.3	68
Monopropellant NOS-58-6	I/C	9.46	68
Nitromethane	IV[5]/F[4]	9.5	68
Nitrogen Tetroxide	I/A	12.1	68
Oxygen Difluoride	II/A	12.7	-229
Ozone Difluoride	II/A	14.6	-297
Pentaborane	III/D	5.2	68
Perchloryl Fluoride	II/A	12.0	68
Red Fuming Nitric Acid (III A)	I/A	12.5	68

Table 7-2. Factors To Be Used When Converting Gallons of Propellant Into Pounds*, and Propellant Hazard and Compatibility Groupings. (Continued)

Item	Hazard [1] & Storage [2] Grouping	Pounds/gallon	At temperature °F
RP-1	I/C	6.8	68
Tetranitromethane	IV/F	13.6	78
Triethyl Boron B	I/D	5.8	73
UDMH	III/C	6.6	68
UDHM/Hydrazine	III/C	7.5	68

* Conversion of quantities of propellants from gallons to pounds: Pounds of propellant = Gallons x density of propellant in pounds per gallon.

[1] For some of the materials listed, the toxic hazard may be an overriding consideration. Consult applicable regulations and, if necessary, other authorities or publications for determination of toxic siting criteria.

[2] All propellants in a compatibility group are considered compatible. Groupings are not to be confused with ammunition and explosives compatibility groupings with like letters.

- Nitromethane is chemically compatible with compatibility storage Group C liquid propellants, but due to difference in hazards, should be stored separately.

- Technical grade or better nitromethane in unit quantities of 55 gallons or less in DOT 17E or C drums may be stored as Hazard Group II provided:

  - Drums are stored only one tier high.
  - Drums are protected from the direct rays of the sun.
  - Drums have a maximum storage life of 2 years unless life tests indicate product meets purchase specification at that time. Such test are to be repeated at 1-year intervals thereafter.

Table 7-3. Hazard Group I.

Pounds of Propellant				Pounds of Propellant			
		Inhabited buildings, public traffic routes, and incompatible Group I storage	Intragroup and compatible Group I storage			Inhabited buildings, public traffic routes, and incompatible Group I storage	Intragroup and compatible Group I storage
Over	Not Over	Distance in feet	Distance in feet	Over	Not Over	Distance in feet	Distance in feet
Column 1	Column 2	Column 3	Column 4	Column 1	Column 2	Column 3	Column 4
0	100	30	25	5,000	6,000	80	60
100	200	35	30	6,000	7,000	85	65
200	300	40	35	7,000	8,000	85	65
300	400	45	35	8,000	9,000	90	70
400	500	50	40	9,000	10,000	90	70
500	600	50	40	10,000	15,000	95	75
600	700	55	40	15,000	20,000	100	80
700	800	55	45	20,000	25,000	105	80
800	900	60	45	25,000	30,000	110	85
900	1,000	60	45	30,000	35,000	110	85
1,000	2,000	65	50	35,000	40,000	115	85
2,000	3,000	70	55	40,000	45,000	120	90
3,000	4,000	75	55	45,000	50,000	120	90
4,000	5,000	80	60	50,000	60,000	125	95

Table 7-3. Hazard Group I. (Continued)

Pounds of Propellant				Pounds of Propellant			
		Inhabited buildings, public traffic routes, and incompatible Group I storage	Intragroup and compatible Group I storage			Inhabited buildings, public traffic routes, and incompatible Group I storage	Intragroup and compatible Group I storage
Over	Not Over	Distance in feet	Distance in feet	Over	Not Over	Distance in feet	Distance in feet
Column 1	Column 2	Column 3	Column 4	Column 1	Column 2	Column 3	Column 4
60,000	70,000	130	95	500,000	600,000	185	140
70,000	80,000	130	100	600,000	700,000	190	145
80,000	90,000	135	100	700,000	800,000	195	150
90,000	100,000	135	105	800,000	900,000	200	150
100,000	125,000	140	110	900,000	1,000,000	205	155
125,000	150,000	145	110	1,000,000	2,000,000	235	175
150,000	175,000	150	115	2,000,000	3,000,000	255	190
175,000	200,000	155	115	3,000,000	4,000,000	265	200
200,000	250,000	160	120	4,000,000	5,000,000	275	210
250,000	300,000	165	125	5,000,000	6,000,000	285	215
300,000	350,000	170	130	6,000,000	7,000,000	295	220
350,000	400,000	175	130	7,000,000	8,000,000	300	225
400,000	450,000	180	135	8,000,000	9,000,000	305	230
450,000	500,000	180	135	9,000,000	10,000,000	310	235

Table 7-4. Hazard Group II.

Pounds of Propellant				Pounds of Propellant			
		Inhabited buildings, public traffic routes, and incompatible Group II storage	Intragroup and compatible Group II storage			Inhabited buildings, public traffic routes, and incompatible Group II storage	Intragroup and compatible Group II storage
Over	Not Over	Distance in feet	Distance in feet	Over	Not Over	Distance in feet	Distance in feet
Column 1	Column 2	Column 3	Column 4	Column 1	Column 2	Column 3	Column 4
0	100	60	30	10,000	15,000	195	95
100	200	75	35	15,000	20,000	205	100
200	300	85	40	20,000	25,000	215	105
300	400	90	45	25,000	30,000	220	110
400	500	100	50	30,000	35,000	225	110
500	600	100	50	35,000	40,000	230	115
600	700	105	55	40,000	45,000	235	120
700	800	110	55	45,000	50,000	240	120
800	900	115	60	50,000	60,000	250	125
900	1,000	120	60	60,000	70,000	255	130
1,000	2,000	130	65	70,000	80,000	260	130
2,000	3,000	145	70	80,000	90,000	265	135
3,000	4,000	150	75	90,000	100,000	270	135
4,000	5,000	160	80	100,000	125,000	285	140
5,000	6,000	165	80	125,000	150,000	295	145
6,000	7,000	170	85	150,000	175,000	305	150
7,000	8,000	175	85	175,000	200,000	310	155
8,000	9,000	175	90	200,000	250,000	320	160
9,000	10,000	180	90	250,000	300,000	330	165

Table 7-4. Hazard Group II. (Continued)

Pounds of Propellant				Pounds of Propellant			
		Inhabited buildings, public traffic routes, and incompatible Group II storage	Intragroup and compatible Group II storage			Inhabited buildings, public traffic routes, and incompatible Group II storage	Intragroup and compatible Group II storage
Over	Not Over	Distance in feet	Distance in feet	Over	Not Over	Distance in feet	Distance in feet
Column 1	Column 2	Column 3	Column 4	Column 1	Column 2	Column 3	Column 4
300,000	350,000	340	170	1,000,000	2,000,000	470	235
350,000	400,000	350	175	2,000,000	3,000,000	505	255
400,000	450,000	355	180	3,000,000	4,000,000	535	265
450,000	500,000	360	180	4,000,000	5,000,000	555	275
500,000	600,000	375	185	5,000,000	6,000,000	570	285
600,000	700,000	385	190	6,000,000	7,000,000	585	295
700,000	800,000	395	195	7,000,000	8,000,000	600	300
800,000	900,000	405	200	8,000,000	9,000,000	610	305
900,000	1,000,000	410	205	9,000,000	10,000,000	620	310

Table 7-5 Hazard Group III.

Pounds of Propellant		Inhabited buildings, public traffic routes, and incompatible Group III storage – Distance in feet		Intragroup and Compatible Group III storage – Distance in feet
Over	Not Over	Unprotected	Protected	
Column 1	Column 2	Column 3	Column 4	Column 5
0	100	600	80	30
100	200	600	100	35
200	300	600	110	40
300	400	600	120	45
400	500	600	130	50
500	600	600	135	50
600	700	600	140	55
700	800	600	145	55
800	900	600	150	60
900	1,000	600	150	60
1,000	2,000	600	175	65
2,000	3,000	600	190	70
3,000	4,000	600	200	75
4,000	5,000	600	210	80
5,000	6,000	600	220	80
6,000	7,000	600	225	85
7,000	8,000	600	230	85
8,000	9,000	600	235	90
9,000	10,000	600	240	90
10,000	15,000	1,200	260	95
15,000	20,000	1,200	275	100
20,000	25,000	1,200	285	105
25,000	30,000	1,200	295	110
30,000	35,000	1,200	300	110

Table 7-5 Hazard Group III. (Continued)

Pounds of Propellant		Inhabited buildings, public traffic routes, and incompatible Group III storage – Distance in feet		Intragroup and Compatible Group III storage – Distance in feet
Over	Not Over	Unprotected	Protected	
Column 1	Column 2	Column 3	Column 4	Column 5
35,000	40,000	1,200	310	115
40,000	45,000	1,200	315	120
45,000	50,000	1,200	320	120
50,000	60,000	1,200	330	125
60,000	70,000	1,200	340	130
70,000	80,000	1,200	355	130
80,000	90,000	1,200	360	135
90,000	100,000	1,200	365	135
100,000	125,000	1,800	380	140
125,000	150,000	1,800	395	145
150,000	175,000	1,800	405	150
175,000	200,000	1,800	415	155
200,000	250,000	1,800	425	160
250,000	300,000	1,800	440	165
300,000	350,000	1,800	455	170
350,000	400,000	1,800	465	175
400,000	450,000	1,800	475	180
450,000	500,000	1,800	485	180
500,000	600,000	1,800	500	185
600,000	700,000	1,800	515	190
700,000	800,000	1,800	530	195
800,000	900,000	1,800	540	200
900,000	1,000,000	1,800	550	205
1,000,000	2,000,000	1,800	630	235

Table 7-5 Hazard Group II. (Continued)

Pounds of Propellant		Inhabited buildings, public traffic routes, and incompatible Group III storage – Distance in feet		Intragroup and Compatible Group III storage – Distance in feet
Over	Not Over	Unprotected	Protected	
Column 1	Column 2	Column 3	Column 4	Column 5
2,000,000	3,000,000	1,800	675	255
3,000,000	4,000,000	1,800	710	265
4,000,000	5,000,000	1,800	740	275
5,000,000	6,000,000	1,800	760	285
6,000,000	7,000,000	1,800	780	295
7,000,000	8,000,000	1,800	800	300
8,000,000	9,000,000	1,800	815	305
9,000,000	10,000,000	1,800	830	310

Table 7-6. Space Distances for Separation of Propellant Static-Testing, Launching, and Storage Sites From Other Facilities

Weight of explosives or Group IV propellant in pounds	Distance in feet from propellant and explosives hazard			
	To Inhabited Buildings	To Public Traffic Routes	Intraline	
Column 1	Column 2	Column 3	Column 4	Column 5
Not Over			Barricaded	Unbarricaded
100	190	115	40	80
200	235	140	50	100
300	270	160	60	120
400	295	175	65	130
500	320	190	70	140
600	340	205	75	150
700	355	215	80	160
800	375	225	85	170
900	390	235	90	180
1,000	400	240	95	190
1,500	460	275	105	210
2,000	505	305	115	230
3,000	580	350	130	260
4,000	635	380	140	280
5,000	685	410	150	300
6,000	730	440	160	320
7,000	770	460	170	340
8,000	800	480	180	360
9,000	835	500	190	380
10,000	865	520	200	400
15,000	990	595	225	450
20,000	1,090	655	245	490

Table 7-6. Space Distances for Separation of Propellant Static-Testing, Launching, and Storage Sites From Other Facilities. (Continued)

Weight of explosives or Group IV propellant in pounds	Distance in feet from propellant and explosives hazard			
	To Inhabited Buildings	To Public Traffic Routes	Intraline	
Column 1	Column 2	Column 3	Column 4	Column 5
Not Over			Unbarricaded	Unbarricaded
25,000	1,170	700	265	530
30,000	1,245	745	280	560
35,000	1,310	785	295	590
40,000	1,370	820	310	620
45,000	1,425	855	320	640
50,000	1,475	885	330	660
55,000	1,520	910	340	680
60,000	1,565	940	350	700
65,000	1,610	965	360	720
70,000	1,650	990	370	740
75,000	1,685	1,010	385	770
80,000	1,725	1,035	390	780
85,000	1,760	1,055	395	790
90,000	1,795	1,075	400	800
95,000	1,825	1,095	410	820
100,000	1,855	1,115	415	830
125,000	2,115	1,270	450	900
150,000	2,350	1,410	475	950
175,000	2,565	1,540	500	1,000
200,000	2,770	1,660	525	1,050

Table 7-6. Space Distances for Separation of Propellant Static-Testing, Launching, and Storage Sites From Other Facilities. (Continued)

Weight of explosives or Group IV propellant in pounds	Distance in feet from propellant and explosives hazard			
	To Inhabited Buildings	To Public Traffic Routes	Intraline	
Column 1	Column 2	Column 3	Column 4	Column 5
Not Over			Unbarricaded	Unbarricaded
4,000,000	7,935	4,760	1,470	2,940
5,000,000	8,550	5,130	1,585	3,170

Where solid propellants or other explosives are present, TNT equivalents for liquid propellants must be increased by corresponding amounts in order to determine required distance in feet from propellant explosive hazard when the following substitutions are made for combinations listed in Table 7-5:

a. Alcohols, or other hydrocarbons for RP-1.

b. H_2O_2, F, BrF_5, CIF_3, or O_3F_2 for LO_2.

c. Monomethylhydrazine for hydrazine or Unsymmetrical Dimethyl hydrazine (UDMH).

d. Ethylene oxide for any propellant.

e. Ammonia for any fuel, and a hypergolic combination results.

f. Pentaborane plus a fuel for LO_2LH_2.

Table 7-7. Factors for Blast Effects[a].

Equivalent Mix Weight, W (lb)	Formulas for Computing Distance to Inhabited Buildings (ft)	Distance to Public Traffic Routes (ft)
0 – 100 000 100 000 – 250 000 250 000 – 1 000 000	$40W^{1/3}$ $2.42W^{0.577}$ $50W^{1.3}$	$24W^{1/3}$ $1.452W^{0.577}$ $30W^{1/3}$

[a] From DOD 6055.9, Table 9-1, Notes 3 and 7.

Table 7-8. Recommended Distances Between Bulk Gaseous Oxygen Storage and Flammable Gases Stored Aboveground

	Flammable Gas	Quantity	Distance	
			ft	m
NFPA Specifications[a]	Liquefied hydrogen	Any	75	22.5
	Other liquefied gases	$\leq$ 100 gal (3785 L)	25	7.5
		$\geq$ 100 gal (3785 L)		
	Nonliquefied or dissolved gases	$\leq$ 25 000 ft^3 (708 m^3) (NTP)	25	7.5
		> 25 000 ft^3 (708 M^3) (NTP)	50	15
OSHA requirements[b]				
	Compressed, liquefied, and others in low-pressure gas holders	< 500 ft^3 (142 m^3)	50	15
		$\geq$ 5000 ft^3 (142 m^3)	90	27

[a]NFPA 50.
[b]CFR TITLE 29.

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CHAPTER 8. QUANTITY-DISTANCE REQUIREMENTS FOR CLASS 1 EXPLOSIVES

800 GENERAL

This chapter outlines explosives Quantity-Distance (QD) criteria and related standards for storing and handling explosives at NASA explosive facilities.

801 PRINCIPLES

a. 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 will be no greater than needed for a safe and efficient operation. Operations and personnel will be located to minimize exposure to hazards.

b. 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, etc. This also could require "operational shielding" for personnel involved in evacuation of unprotected personnel from the area.

c. Separation of explosive locations is needed to minimize explosive hazards. Locations that contain explosives will be separated from the following:

(1) Other locations that contain explosives and propellants.

(2) Inhabited buildings, including structures or other places not directly related to explosives operations where people usually assemble or work.

(3) Public traffic routes.

(4) Operating lines or buildings, including structures or other places where people usually assemble or work that are directly related to explosives operations.

(5) Petroleum, oil, and lubricant (POL) storage.

(6) Utilities, buildings, and facilities.

(7) Aircraft parking and storage areas, runways and approach zones, and taxiways.

(8) Facility boundaries.

802 QUALITY-DISTANCE DETERMINATION

a. The location of explosives facilities with respect to each other and to other exposures shall be based on the total quantity of explosives in each facility. When the total quantity is so subdivided that an incident involving any of the subdivisions will not produce simultaneous initiation of others, the Net Explosive Weight (NEW) of the mass-detonating explosives in the largest subdivision shall apply.

b. Separation distances shall be measured from the closest hazard source (containers, buildings, segments, or positive cutoff point in piping, whichever is controlling).

c. Where rail cars, motor vehicles, or any other transport vehicles containing explosives are so located with respect to an explosives facility that simultaneous detonation can occur, the total quantity of explosives in the facility and the transportation vehicles must be considered as a unit for QD purposes.

803 QUANTITY OF EXPLOSIVES DETERMINATION

The total quantity of explosives in a magazine, operating building, or other explosives facility shall be the net weight of the explosives calculated upon the following bases (such calculations are intended for use with the tables in this standard):

a. Mass-Detonating Explosives.

(1) NEW.

b. Non Mass-Detonating Explosives.

(1) Propellants — The net propellant weight.

(2) Pyrotechnic Items — The sum of the weight of the pyrotechnic composition and the explosives involved.

(3) Bulk Metal Powders and Pyrotechnic Composition — The sum of the net weights of metal powders and pyrotechnic composition in containers.

c. When Class/Divisions 1.1 and 1.2 are located in the same site, determine the distance for the total quantity considered first as Division 1.1 and then as Division 1.2. The required distance is the greater of the two. When Division 1.1 requirements are controlling, the high explosive (HE) equivalence of the Division 1.2 items may be added to the total explosive weight of Division 1.1 items to determine the NEW for Division 1.1 distance determination.

d. When Class/Divisions 1.1 and 1.3 are located in the same site, determine the distances for the total quantity considered first as Division 1.1 and then as Division 1.3. The required distance is the greater of the two. When Division 1.1 requirements are controlling and the equivalence of the Division 1.3 is known, the HE equivalent weight of the Division 1.3 items may be added to the total explosive weight of 1.1 items to determine the NEW for Division 1.1 distance determinations.

e. When Class/Divisions 1.2 and 1.3 are located in the same site, determine the required distance for each separately. The two quantities do not need to be added together for QD purposes.

f. When Class/Divisions 1.1, 1.2, and 1.3 are located in the same site, determine the distances for the total quantity considered first as Division 1.1, next as Division 1.2, and finally as Division 1.3. The required distance is the greatest of the three. As permitted above by paragraphs 802d and 802e above, HE equivalence for Divisions 1.2 and 1.3 items may be used in NEW determinations for QD purposes.

g. The QD's for Class/Divisions 1.1, 1.2, or 1.3, individually or in combination, are not affected by the presence of Class/Division 1.4.

NOTE: Where testing has shown that 1.1 components installed on 1.3 items, e.g., Solid Rocket Motors (SRM) in operational configuration, in storage and will not initiate the 1.3, the QD is determined by the NEW of the 1.3.

804 INHABITED BUILDING DISTANCE

a. Inhabited Building Distance (IHBD) is the minimum allowable distance between an unrelated inhabited building and an explosives facility. IBHD's are also used between explosives facilities and administrative areas, adjacent operating lines with dissimilar hazards, and explosive locations and other nonexplosive exposures. IHBD's will also be provided between explosive facilities and Field Installation boundaries.

b. IHBD will also be applied to the following locations:

(1) Main power houses providing vital utilities to a critical operation/facility.

(2) Functions that could cause an immediate secondary hazard because of their failure to operate.

(804)

c. IHBD's in Table 8-1 provide a high degree of protection to frame or masonry buildings from structural damage and to their occupants from death or serious injury. They also provide reasonable protection to superficial parts as window frames, doors, porches, and chimneys. IHBD's do not provide protection against glass breakage or injury to personnel from such hazardous fragments.

805 PUBLIC TRAFFIC ROUTE DISTANCE

Public Traffic Route (PTR) distance is the minimum permitted between a public traffic route, within the installation for fragments and firebrand hazards. This is applied when the traffic route is within the boundaries and route access and use are controlled. These distances are 60 percent of the incremental IHBD.

806 INTRALINE DISTANCE

a. Intraline Distance (ID) is the minimum permitted between any two buildings consisting of one operating line. ID distances also are used for separating certain specified areas, buildings, and locations so arranged to permit performance of consecutive operations (part of the same operation) even though actual line operations are not involved. Administrative functions are not part of the consecutive operations and are to be at IHBD from the operating building/site. ID distances are expected to protect buildings from propagation of explosion due to blast effects, but not against the possibility of propagation due to fragments. Buildings separated by ID are vulnerable to substantial structural damage.

b. A service type magazine shall be located at ID, based on the quantity of explosives within the magazine, from the nearest operating building of the line it services. Service type magazines shall be separated from each other by a minimum of magazine distance.

c. ID distances may be barricaded or unbarricaded.

807 MAGAZINE DISTANCE

Magazine Distance is the minimum distance permitted between any two storage magazines. Distance required is determined by the construction (type) of magazine and also the type and quantity of explosives stored. Magazine Distance is expected to prevent propagation between magazines and provides a reasonable degree of protection against propagation of explosion due to fragments. It does not protect magazines from severe structural damage, except possibly for Earth-covered magazines.

808 MINIMUM FRAGMENT DISTANCES

a. Minimum fragment distances are to protect personnel in the open; firebrand distance minimums are to protect facilities. These distances will be applied to:

(1) Installation boundaries.

(2) Administration and housing areas.

(3) Athletic and other recreation areas except as described below.

(4) Main powerhouses providing vital utilities to a major portion of the installation.

(5) 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.

(6) Functions that, if momentarily put out of action, will cause an immediate secondary hazard by reason of their failure to function.

b. Examples when minimum fragment and firebrand distances need not be applied are:

(1) Recreation or training facilities if these facilities are for the exclusive use of personnel assigned to the potential explosion site (PES).

(2) Between facilities in an operating line, between operating lines, and between operating lines and storage locations that normally are separated by IHBD's to protect workers and ensure against interruption of production.

c. The minimum distance for protection from hazardous fragments will be that distance at which fragments, including debris from structural elements of the facility or process equipment, will not exceed a hazardous fragment density of one hazardous fragment per 600 square feet ($56m^2$). If this distance is not known, the following shall apply:

(1) For 100 lbs NEW (45 kg NEQ) or less of demolition explosives, thin-cased or low fragmentation explosive items, bulk high explosives, pyrotechnics, and in-process explosives of Class/Division 1.1, the minimum distance to exposure listed above will be 670 feet (204 m).

(2) For all types of Class/Division 1.1 in quantities of 101 to 30,000 lbs NEW (46 to 13,600 kg NEQ), the minimum distance will be 1250 feet (380m), unless it can be shown that fragments and debris from structural elements of the facility or process equipment will not present a hazard beyond the distance specified in Table 8-1. (Facilities sited at 1,235 or 1,245 feet in accordance with past standards will be considered to be in compliance with the 1,250-foot minimum requirement.)

809 FRAGMENT DISTANCE

a. The fragment distance for a particular explosive is based on the range to which a hazardous fragment density may be created by an explosion of the item involved. A hazardous fragment is one having an impact energy of 58 ft-lbs and a hazardous fragment density is constituted by at least one hazardous fragment impacting in an area of 600 square feet or less. Fragment distances do not indicate the maximum range to which fragments may be projected.

b. Fragment distance for 1.1 through 1.3 is indicated by a numerical figure in parentheses placed to the left of the division designators 1.1 through 1.3, such as (18) 1.1, (08) 1.2, (06) 1.3 when required. This number is used to indicate the fragment distance in hundreds of feet.

c. For items in Classes 1.1 and 1.3, a minimum distance number will be used where separation distances greater than specified for inhabited buildings by the applicable QD tables are necessary for specific hazards (projection of debris, fragments, or firebrands). These minimum fragment distances are to protect personnel in the open and will be applied to center boundaries, administrative and housing areas, athletic fields, and other recreation areas.

(1) If a minimum distance number is not shown for explosive items of Class 1.1 from which primary fragments would constitute a hazard, the minimum distance will be 1250 feet. For these items, the minimum distance or that required by the QD table will be used, whichever is greater.

(2) For bulk high explosives, propellant ingredients, pyrotechnics, other in-process materials, and explosive items of Class 1.1 from which primary fragments would not constitute a hazard, a minimum distance of 670 feet for NEW less than or equal to 100 lbs and 1250 feet for NEW of 101 to 30,000 lbs will be used unless it can be shown that debris from structural elements of buildings or process equipment will not present a hazard beyond the distances specified in Table 8-1, for the quantity involved.

(3) Rationale for using fragment distances less than 670- and 1250-foot requirements for Class 1.1 shall be included in all site plans and safety reviews. Where there are no existing test data to substantiate lesser distances, analogies to similar items or facilities, fragment dispersions from previous accident, or analytical modeling of the debris spread should be investigated (see Figure 8-1).

810 CLASS/DIVISION QUANTITY-DISTANCE TABLES

a. Class/Division 1.1 (Tables 8-1 through 8-3). 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.

(1) Inhabited Building and Public Traffic Route Distance — Separation distances required from standard earth-covered magazines and other types of PESs to inhabited buildings and public traffic routes are listed for various quantities of Class/Division 1.1 in Table 8-1. Specified separations from standard earth-covered magazines take into account reductions in blast over-pressure attributable to the earth cover of the magazines.

(2) Intraline Distance — Separation distances required between explosives and nonexplosive buildings and sites within an explosives operating line are listed for various quantities of Class/Division 1.1 in Table 8-2.

(3) Intermagazine Distance — Magazines for Class/Division 1.1 shall be separated one from another in accordance with DoD 6055.9.

(4) Public Traffic Route Distance — Public traffic route distances give consideration to the transient nature of the exposure in the same manner as for Class/Division 1.1.

(5) Intraline Distance — Intraline distances take account of the progressive nature of explosions involving these items (normally resulting from fire spread) and the ability to evacuate personnel from endangered areas before this progression involves large numbers of items. Exposed structures may be extensively damaged by projections and delayed propagation of explosion may occur due to ignition of combustibles by projections.

(6) Aboveground Magazine Distance — Aboveground magazine distance provides a high degree of protection against any propagation of explosion. There is some degree of risk, however, in delayed propagation when the Exposed Site (ES) contains combustible dunnage or packing materials that may be ignited by projected firebrands.

(810)

b. Class/Division 1.3 (Table 8-3)

Class/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 propagation shock waves or damaging blast overpressure beyond the magazine distance specified in Table 8-3. A severe hazard or spread of fire may result from tossing about of burning container materials, propellant, or other flaming debris.

Minimum Distance to Protect Against Expected Fragment Hazard	Hazard Class and Division	Expected Hazard
(XX)[1,2]	1.1	Mass-detonating with possible primary and secondary fragments
(18)	1.2	Nonmass-detonating with majority of primary fragments falling within indicated minimum distance
(12)	1.2	
(08)	1.2	
(04)	1.2	
(XX)[1,2]	1.3	Mass-fire with firebrands falling within minimum distance
NA	1.4	Moderate Fire

NOTES:

[1] See Paragraph 809c(3).
[2] Distance in hundreds of feet.

Figure 8-1. Classification System.

Table 8-1. Class/Division 1.1: Inhabited Building and Public Traffic Distance [2] (see Notes).

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
Col 1	Front Col 2 [3,9]	Side Col 3 [3,9]	Rear Col 4 [4,9]	Col 5 [5]	Front Col 6 [6,9]	Side Col 7 [6,9]	Rear Col 8 [7,9]	Col 9 [8]
1	500	250	250	1,250	300	150	150	750
2	500	250	250	1,250	300	150	150	750
5	500	250	250	1,250	300	150	150	750
10	500	250	250	1,250	300	150	150	750
20	500	250	250	1,250	300	150	150	750
30	500	250	250	1,250	300	150	150	750
40	500	250	250	1,250	300	150	150	750
50[1]	500	250	250	1,250	300	150	150	750
100	500	250	250	1,250	300	150	150	750
150	500	250	250	1,250	300	150	150	750
200	700	250	250	1,250	420	150	150	750
250	700	250	250	1,250	420	150	150	750
300	700	250	250	1,250	420	150	150	750
350	700	250	250	1,250	420	150	150	750
400	700	250	250	1,250	420	150	150	750
450	700	250	250	1,250	420	150	150	750
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

Table 8-1. Class/Division 1.1: Inhabited Building and Public Traffic Distance [2] (see Notes). (Continued)

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
Col 1	Front Col 2 [3,9]	Side Col 3 [3,9]	Rear Col 4 [4,9]	Col 5 [5]	Front Col 6 [6,9]	Side Col 7 [6,9]	Rear Col 8 [7,9]	Col 9 [8]
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	885
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
65,000	1,405	1,405	1,250	1,610	845	845	750	965
70,000	1,440	1,440	1,250	1,650	865	865	750	990
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
125,000	1,910	1,910	1,480	2,115	1,165	1,165	890	1,270

Table 8-1. Class/Division 1.1: Inhabited Building and Public Traffic Distance [2] (see Notes). (Continued)

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
Col 1	Front Col 2 [3,9]	Side Col 3 [3,9]	Rear Col 4 [4,9]	Col 5 [5]	Front Col 6 [6,9]	Side Col 7 [6,9]	Rear Col 8 [7,9]	Col 9 [8]
150,000	2,175	2,175	1,805	2,350	1,305	1,305	1.085	1,410
175,000	2,435	2,435	2,135	2,565	1,460	1,460	1,280	1,540
200,000	2,680	2,680	2,470	2,770	1,610	1,610	1,480	1,660
225,000	2,920	2,920	2,965	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

NOTES: Table 8-1

[1] The distance for 0 to 50 pounds may be used only when structures, blast mats, etc., can completely confine fragments and debris. Lesser distances may only be used if blast, fragments, and debris can be completely confined as with certain test firing barricades.

[2] See paragraph 808c(2) for application of 1250 ft. minimum inhabited building distance (fragment distance) for class 1.1 explosives. See also paragraph 805 for 60% reduction of fragment distance for Public Traffic Routes.

[3] Bases for table 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 lbs – Blast overpressure hazard. Computed by formula $d = 35W^{1/3}$.

100,000- 250,000 lbs – Blast overpressure hazard. Computed by formula $d = 0.3955W^{0.7227}$.

250,000-500,000 lbs – Blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

Table 8-1. Class/Division 1.1: Inhabited Building and Public Traffic Distance [2] (see Notes). (Continued)

[4] Bases for table distances:

1-100,000 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 $d = 0.004125W^{1.0898}$.

250,000-500,000 lbs - Blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

[5] Bases for table distances:

1-30,000 lbs – Fragments and debris hazard. Lesser distances permitted as follows: (a) bulk explosives with NEW to 100 lbs 670 ft; (b) Bare explosives in the open, distances computed by formula $d = 40W^{1/3}$.

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 $d = 2.42W^{0.577}$.

250,000-500,000 lbs – Blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

[6] Distances have same hazard bases and are equal to 60 percent of footnote 2 distances.

[7] Distances have same hazard bases and are equal to 60 percent of footnote 3 distances.

[8] Distances have same hazard bases and are equal to 60 percent of footnote 4 distances.

[9] Distances for NEW's 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 distances shown under other PES.

Table 8-2. Quantity-Distance – Intraline Separations.

Pounds of Explosives		Distance in Feet		Pounds of Explosives		Distance in Feet	
Over	Not Over	Bar.	Unbar.	Over	Not Over	Bar.	Unbar.
0	50[1]	30	60	35,000	40,000	310	620
50	100	40	80	40,000	45,000	320	640
100	200	50	100	45,000	50,000	330	660
200	300	60	120	50,000	60,000	340	680
300	400	65	130	55,000	65,000	350	700
400	500	70	140	60,000	70,000	360	720
500	600	75	150	65,000	75,000	370	740
600	700	80	160	70,000	80,000	380	760
700	800	85	170	75,000	85,000	390	780
800	900	85	175	80,000	90,000	395	790
900	1,000	90	180	85,000	95,000	405	810
1,000	1,500	105	210	90,000	100,000	410	820
1,500	2,000	115	230	95,000	125,000	420	840
2,000	3,000	130	260	100,000	150,000	450	900
3,000	4,000	145	290	125,000	175,000	480	960
4,000	5,000	155	310	150,000	200,000	505	1,010
5,000	6,000	165	330	175,000	225,000	525	1,055
6,000	7,000	170	340	200,000	250,000	545	1,090
7,000	8,000	180	360	225,000	275,000	565	1,135
8,000	9,000	185	370	250,000	300,000	585	1,170
9,000	10,000	195	390	275,000	325,000	600	1,200
10,000	15,000	225	450	300,000	350,000	620	1,240
15,000	20,000	245	490	325,000	375,000	635	1,270
20,000	25,000	265	530	350,000	400,000	650	1,300
25,000	30,000	280	560	375,000	450,000	665	1,330
30,000	35,000	295	590	400,000	500,000	715	1,430

[1] Lesser distances may be used when suppression shields/containers, structures, blast mats, etc., can completely contain fragments and debris. These distances will be approved by the Safety Office.

Table 8-3. Class 1.3 Quantity Distance.

		Distance in Feet		
Pounds (Over)	Pounds (Not Over)	Inhabited Building	Public Traffic Route	Intraline and Above-Ground Magazine
0	1,000	75	75	50
1,000	5,000	115	115	75
5,000	10,000	150	150	100
10,000	20,000	190	190	125
20,000	30,000	215	215	145
30,000	40,000	235	235	155
40,000	50,000	250	250	165
50,000	60,000	260	260	175
60,000	70,000	270	270	185
70,000	80,000	280	280	190
80,000	90,000	195	295	195
90,000	100,000	300	300	200
100,000	200,000	375	375	250
200,000	300,000	450	450	300
300,000	400,000	525	525	350
400,000	500,000	600	600	400
500,000	1,000,000	800	800	500

See Paragraph 810.

For determining distances in event special requirements exist for amounts over 1,000,000 lbs, the values given above will be extrapolated by means of cube-root scaling as follows: For IHB and PTR distances D = 8W 1/3, for aboveground magazines and intraline distances D = 5W 1/3.

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CHAPTER 9: TRANSPORTATION, MATERIALS HANDLING EQUIPMENT, AND SHIPMENT OF EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS

900 GENERAL TRANSPORTATION REQUIREMENTS

This chapter 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.

901 MOTOR VEHICLE SHIPMENT REGULATIONS

a. All motor vehicle shipments are governed by DOT and shall comply with State and municipal regulations.

b. 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 must be inspected and approved by a qualified explosive vehicle inspector.

c. Motor vehicles for explosives shipment, such as cargo type trucks and truck-tractor drawn semitrailer vans, are the preferred means of explosives transportation. Vehicles used for transporting explosives must meet the following requirements:

(1) Special precautions must be taken to avoid ignition of the material by the exhausts of vehicles.

(2) The lighting system shall be electric. Batteries and wiring shall be so located that they will not come into contact with containers of explosives.

(3) The interior of the cargo area shall have all exposed ferrous metal covered with nonsparking material when transporting scrap and bulk explosives. If the explosives consist of shipment packaged for shipment in accordance with DOT specifications, it will not be necessary to cover the ferrous metal. Where a top is required, it should be of noncombustible or flame-proof material. Whenever tarpaulins are used for covering explosives, they will be secured by means of rope or wire tiedowns. Nails will not be used to fasten protective tarpaulins.

(4) All trucks (NASA, Government, or commercial) destined for off-post shipment over public highways shall be equipped with one Class 10-BC rated portable fire extinguisher when transporting DOT Class 1, all Divisions, explosives.

(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.

(6) Vehicles will not be left unattended unless they are parked in a properly designated area. When an operator leaves a vehicle in a properly designated area, the brakes shall be set and wheels chocked.

(7) When transporting electro-explosive devices (EED's), full consideration must be given to the inherent hazards where vehicles are equipped with transmitters or other electromagnetic radiation sources.

d. Placarding of vehicles for off-site shipment shall comply with DOT Class 1 explosives requirements. EXPLOSIVES placards shall be displayed according to DOT CFR Title 49 172.504 general placarding requirements.

e. Placarding of vehicles that are not destined for off-site shipment requires the display of at least two fire symbol signs. This will enable installation fire department recognition in accordance with this regulation.

902 RAILROAD AND AIR 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, respectively.

903 ROCKET MOTORS IN A PROPULSIVE STATE OR WITH IGNITERS INSTALLED

Rocket motors m this category require a NASA-approved shipping permit. Permits will be issued by Code J, NASA Headquarters (see NMI 1152.61), "Transportation of Rocket Motors Containing Class B Explosives When in a Propulsive State or With Igniters Installed."

904 MATERIALS HANDLING EQUIPMENT FOR EXPLOSIVES

a. General.

(1) Specification, operation, and maintenance of materials handling equipments shall be in accordance with this standard and OSHA and NFPA regulations.

(2) Trucks with end-operating platforms or pedals shall be equipped with platform guards of heavy iron or heavy steel plate or materials of equal strength. The guards should be 18 inches high on the sides and should extend beyond the platform or pedal to protect the operator.

(3) Overhead guards must meet the requirements of ANSI Standard B 56.1 for forklift trucks of all types.

b. Battery-Powered Equipment.

(1) Battery-powered equipment and its use in hazardous locations shall comply with OSHA and NFPA standards. All equipment will be appropriately labeled for ready identification.

(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.

(3) Type EE and ES equipment shall not be used in Class I or Class II, Division I hazardous locations.

(4) Type EX equipment is the only equipment approved for use in specifically named Class I, Group D or Class II, Group G hazardous location (see NFPA 505).

(5) All equipment shall be provided with a fire extinguisher having a minimum rating of 5-BC.

905 GASOLINE, DIESEL-POWERED, AND LP-GAS-POWERED EQUIPMENT

a. Approved explosives handling gasoline, diesel-powered, and LP-gas-powered equipment can be used for all classes of explosives, providing the explosives are not located in a hazardous location as defined by NFPA and OSHA and if they meet the following precautionary measures and devices requirements:

(1) Equipped with backfire deflectors attached on the throat of the carburetor and must be of the oil-bath or screen type.

(2) A tight fitting fuel cap, properly vented.

(3) A flame arrester installed in the fill pipe.

(4) If required, a deflector plate shall be installed to prevent any overflow from the fuel tank from reaching the motor or the exhaust pipe.

(905)

b. All equipment shall be provided with a fire extinguisher having a minimum rating of 5-BC.

906 REFUELING PROCEDURES

a. Gasoline and diesel-powered equipment shall not be refueled inside warehouses but outside 20 feet from a building that is inert and 90 feet from an explosive facility.

b. During gasoline refueling, an electrically continuous path to ground shall be maintained between the tank being filled and the tank being emptied. The entire system shall be grounded before the refueling is begun. No smoking or open flame shall be allowed within 50 feet of the refueling operation. Motors of fork truck and/or the refueling truck must be turned off before refueling begins.

907 STORAGE OF GASOLINE, DIESEL-POWERED, OR LP-GAS-POWERED EQUIPMENT

a. 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.

b. A central storage located at an approved safe distance and at least 50 feet from buildings is preferred. Storage areas for LP-gas-powered equipment should have continuous mechanical ventilation from the floor level.

908 STORAGE OF BATTERY-POWERED EQUIPMENT

a. 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:

(1) Periods of idle storage shall not exceed 4 days.

(2) After each workday, MHE will be inspected for hot brakes, leaking oil, or fluid. If present, MHE will be removed from the building.

(3) Battery cables will not be disconnected in explosives storage locations due to the possible arcing when terminals separate.

(4) MHE will be packed and secured at the maximum distance from the explosives.

(5) MHE will not be stored in an operating building containing explosives because of the increased hazards of loose or exposed explosives.

909 OPERATING REQUIREMENTS

a. A distance of at least three truck lengths shall be maintained between trucks in operation.

b. Riders, lunch boxes, newspapers, extra clothing, etc., shall not be permitted on lift trucks at anytime.

c. When MHE is used as a personnel lift, approved safety pallets/work platforms must be used.

d. Trucks used outside after dark shall have red reflectors on the rear and be equipped with headlights front and rear.

e. Loads of tines of forklifts must not extend more than one-third of the height of the top tier of containers above the load backrest.

910 PREPARING EXPLOSIVES AND PYROTECHNICS FOR SHIPMENT

a. <u>Packaging Regulations</u>. The general regulations governing the marking, packing, and shipping of explosives are set forth in DOT regulations.

b. <u>Electrostatic Packaging Materials</u>. In packaging explosives and explosive items for shipment, NASA personnel will utilize all of the available technology and information to determine packaging materials that will minimize triboelectric and frictional charging with proper conductivity to permit a safe, slow distribution of generated charge. Correct use of these guidelines will almost eliminate the possibility of electrostatic discharge (ESD) in explosives packaging material.

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CHAPTER 10. EFFECTS OF EXPLOSIONS AND PERMISSIBLE EXPOSURES

1000 INTRODUCTION

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. As an alternative to using the Quantity-Distance (QD) tables in this document, reduced distances can be utilized if supported by testing/analyses of blast, fragment, and thermal exposure criteria in DoD 6055.9. These reduced distances will be approved by the Authority Having Jurisdiction (AHJ), Field Installation Safety Office and reviewed by the NASA Headquarters Safety Office.

1001 BLAST PRESSURE OUTPUT

a. Blast Wave Phenomena. The violent release of energy from a detonation in a gaseous medium gives rise to 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, P_{so}. 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 comprising 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.

(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.

(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 instantly is 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.

1002 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 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.

1003 EXPECTED EFFECTS-CLASS/DIVISION 1.1

a. Conventional Structures. Conventional structures are designed to withstand roof snow loads of 30 pounds per square foot (1.44 kPa) and wind loads of 100 miles per hour (161 km per hour). The loads equate to 0.2 pounds per square inch (psi). Airblast overpressure at Class/Division 1.1 barricaded intraline distance is 12 psi (82.7 kPa); at unbarricaded intraline distance, 3.5 psi (24 kPa); and at inhabited building distance (IHBD), 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 IHBD.

b. Earth-Covered Magazines. The earth-covered magazines separated one from another by the minimum distances required by DoD 6055.9, Table 9-5, 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.

c. Barricaded Open-Storage Modules. Barricaded open-storage modules provide a high degree of protection against propagation of explosion by blast and fragments. Items at K= 1.1 separations from a donor explosion will be covered with earth and unavailable for use until extensive uncovering operations and possibly maintenance are completed. Items at K=2.5 separations are expected to be readily accessible.

NOTE: K is a constant that is used to determine separation distance by the formula $d = KW^{1/3}$. The formula can be used to determine required distances between potential explosive sites (PES's) and exposed sites (ES's). See Notes for Tables 8-1 and 8-3.

1004 FRAGMENTS

a. General.

(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.

(2) Primary fragments are formed as a result of the shattering of the explosive container. The container may be the casing of the explosives, 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.

(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.

(4) A hazardous fragment is one having an impact energy of 58 ft-lb (79 joules) or greater.

1005 THERMAL HAZARD

a. 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 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.

b. Permissible Exposures. Personnel shall be provided protection that will limit thermal fluxes to 0.3 calorie per square centimeter per second 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 component concerned.

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APPENDIX A

GENERAL DEFINITIONS

For purposes of this standard, the following terms are defined:

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

Authority Having Jurisdiction (AHJ). Refers to the individual(s) at NASA Field Installations and Headquarters having the responsibility for "approving" a procedure or equipment at an installation and implementing the provisions of NHB 1700.1(V1).

Antistatic. Materials that exhibit a surface resistivity greater than 10^9 ohms per square, but less than 10^{14} ohms per square. This implies that the material does not exhibit triboelectric-charging propensities. This is unusual due to the topical treatment or volume impregnation of the material with a surfactant.

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

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

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 (room, cubicle, cell, work area, etc.) containing a single type of explosives activity that affords the required protection specified for appropriate hazard classification of the activity involved.

Blast. Brief and rapid movement of air or fluid away from a center of outward pressure, as in an explosion; the pressure accompanying this movement.

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

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

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.

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

Combustible Material. 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.

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

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

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

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 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. An approved documented variance that allows departure from a particular performance or design requirement, or baselined operational sequence for specified units and/or for a specific period of time.

Dielectric Strength. Ability of a material to withstand a given voltage without conducting electricity.

Dielectric Breakdown. When the dielectric strength of the material has been exceeded and current flows through the material.

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)T and is plotted in the same manner as a normal DTA curve.

Differential Thermal Analysis (DTA). A technique in which the temperature difference between a substance and a reference material is measured as a function of temperature 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.

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

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 arching 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.

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

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

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

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.

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.

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.

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 is transferred 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 property 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 term used to designate generally combustible materials or structures that have been treated or have surface coverings designed 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."

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 60° C and a vapor pressure not exceeding 280 kpa (41 psia) at 37.8° C. This is the definition as applied in this manual; it includes some materials defined as combustible liquids by the Department of Transportation (DOT).

Flash Point. Temperature at which an ignition source under specified conditions causes the material vapor to ignite.

Flame-Resistant. A word applied to combustible materials, such as clothing, that have been treated or coated to decrease their burning characteristics (e.g., fabrics that meet the requirements of MIL-C-43122).

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 an object to ground.

Grounding (Earthing). The process of connecting one or more conductive objects to the ground; a specific form of bonding.

> Note: The words "bonded" and "grounded" must be understood to 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 Fragment. A hazardous fragment is one having an impact energy of 58 ft-lb or greater.

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

High Explosive. An explosive (as denoted by its Class and Division, e.g., 1.1 through 1.x) 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 value of gas, heat, causing very high pressure and widespread shattering effect. The potential amount of gas, heat, and pressure shattering effect is indicated by its "Division," e.g., 1."1", 1."2", etc. Some authorities classify high explosives by their sensitivity to initiation as "primary" or "secondary" explosives. Primary being very sensitive to initiation and secondary as relatively insensitive.

High Explosive Equivalent or Explosive 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 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.

Holding Yard. A loading area for groups of rail cars, trucks or trailers used to store explosives and other dangerous materials for indefinite periods prior to storage or shipment.

Hot Work (Thermal). Any operation requiring the use of a flame-producing device, an electrically heated tool producing a temperature higher than 10° C, or a mechanical tool that can produce sparks or heat explosives or contaminate explosives, thereby providing an initiation stimulus.

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

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 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 shall be considered as inhabited buildings.

Inhabited Building Distance. Minimum allowable distance between an inhabited building and an explosive facility. Inhabited building distances are used between explosives facilities and administrative areas, operating lines with dissimilar hazards, explosive locations and other exposures, and explosive facilities and Installation boundaries.

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

Intraline Distance. 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 intraline distance required for the quantity of explosives contained in the service magazine.

Intraline Operations. Process accomplished within one operating line.

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

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

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

Low-Energy (EED). EED's containing energetic materials that are designed or manufactured to be initiated by 0.1 joule or less. For purposes of this document, the definition includes all devices assembled to a l.0-amp/1.0-Watt/no-fire criteria.

Lower Explosive Limit (LEL). Concentration of vapor or dust in air below which an explosion cannot occur.

Lower Flammable Limit (LFL). Concentration of a vapor or dust in air below which a burning reaction cannot be sustained.

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. 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.

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. 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.

Non-NASA Facility Personnel. Personnel of a contractor who does not have a continuing contract with NASA at the facility concerned.

Noncombustible. Not combustible, not burnable in the ordinary sense of the word.

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 an 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.

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.

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

Propellant, Liquid. Substances in fluid form (including cryogenics) used for propulsion or operating power for missiles, rockets and other related devices (see Table 7-1). For the purpose of this standard, liquid fuels and oxidizers are considered propellants even when stored and handled separately.

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. Any public street, road, or highway, navigable stream, or passenger railroad (includes roads on NASA Field Installations that are open to the public for thoroughfare).

Pyrotechnic Devices. Explosive device manufactured specifically for use as signals, illuminants, and like items.

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

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 propellant.

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

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

Solid Propellant. Explosives 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 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. The ohms per square units denote that the same ohms resistance value will be exhibited independent of the size of the square of surface material being measured.

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.

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.

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

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

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APPENDIX B

ACRONYMS

AHJ	Authority Having Jurisdiction
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
DoD	Department of Defense
DOT	Department of Transportation
DTA	Differential Thermal Analysis
EED	Electro-explosive Device
EMR	Electromagnetic Radiation
EOD	Explosives Ordnance Disposal
ES	Exposed Site
ESD	Electrostatic Discharge
FAE	Fuel-Air Explosive
HC	Hexachloroethane
HE	High Explosive
IAW	In Accordance With
ID	Intraline Distance
IHBD	Inhabited Building Distance
IHE	Insensitive High Explosives
IL	Intraline Distance
IMO	International Maritime Organization
JPL	Jet Propulsion Laboratory
km	Kilometer
kPa	Kilopascal
LOX	Liquid Oxygen
MCE	Maximum Credible Event
MHE	Materials Handing Equipment
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Administration
NMI	NASA Management Instruction
NEC	National Electric Code
NEQ	Net Explosive Quantity
NEW	Net Explosive Weight
NFPA	National Fire Protection Association
NHB	NASA Handbook
NIOSH	National Institute of Occupational Safety and Health
NSI	NASA Standard Initiator
OMI	Operations and Maintenance Instruction
OPF	Orbiter Processing Facility
OSHA	Occupational Safety and Health Administration
PCE	Protective Clothing and Equipment
PDR	Preliminary Design Review
PEL	Permissible Exposure Limit

PES	Potential Explosion Site
PETN	Pentaerythritol Tetranitrate
POL	Petroleum, Oil, Lubricant
PSI	Pounds Per Square Inch
PTR	Public Traffic Route
QD	Quantity Distance
RDX	Cyclonite
RPSF	Rotation, Processing and Surge Facility
S&A	Safe and Arm
SCBA	Self-Contained Breathing Apparatus
SCG	Storage Compatibility Group
SOP	Standard Operating Procedure
SRB	Solid Rocket Booster
TEA	Triethyl Aluminum
TNT	Trinitrotoluene
TOP	Technical Operating Procedure
TWA	Time Weighted Average
UL	Underwriters Laboratories
UNO	United Nations Organization
UV	Ultraviolet
WP	White Phosphorus

APPENDIX C

REFERENCE

Department of Transportation Regulations, "Shippers — General Requirements for Shipments and Packagings" (49 CFR 173), December 1991.

DoD Directive 6055.9, "DoD Explosives Safety Board," July 1984.

NASA Handbook (NHB) 1700.1(V1), "NASA Safety Policy and Requirements Document" (formerly the Basic Safety Manual).

NHB 1700.XX, "Shields, Operational for Explosives Operations, Criteria for Design and Tests for Acceptance."

NFPA No. 13, 30, 69, 70, 77, 78 (Latest Revision).

"Occupational Safety and Health Standards," 29 CFR 1910.109 and 1910.119.

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

"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.

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