

# NFPA 485

## Standard for the Storage, Handling, Processing, and Use of Lithium Metal

1999 Edition



National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101  
An International Codes and Standards Organization

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## **NFPA 485**

### **Standard for the**

## **Storage, Handling, Processing, and Use of Lithium Metal**

### **1999 Edition**

This edition of NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 485 was approved as an American National Standard on August 13, 1999.

### **Origin and Development of NFPA 485**

The Committee on Combustible Metals and Metal Dusts began its work on developing a proposed standard on lithium at a Committee meeting in December 1990. The Committee reviewed drafts of the proposed standard and continued to revise the draft standard at Committee meetings held in June 1991, October 1991, March 1992, November 1992, March 1993, and November 1993.

The standard was submitted and adopted at the 1994 Annual Meeting in San Francisco, CA, May 16–18, 1994. The 1994 edition was the first edition of this standard.

The 1999 edition has relatively few major changes from the 1994 edition.

Numerous minor changes throughout the text of the standard and appendixes further clarify requirements. The scope of the document, as well as several definitions and requirements, have been rewritten to make it easier to comply with and enforce the standard.

**Technical Committee on Combustible Metals & Metal Dusts****Waldemar Seton, Chair**

SJO Consulting Engr, OR [SE]

**Roy E. Adams**, TIMET, NV [M]

Rep. Int'l Titanium Assn.

**Tom Christman**, Lockheed Martin Energy Systems, TN [U]**R. Thomas Currin**, Postin Products, Inc., NC [U]**Stephen C. Erickson**, The Dow Chemical Co., MI [M]**John A Gatchell**, Wah Chang, Albany, OR [M]**Ralph W. Hawk**, Chemetall Foote Mineral Co., NC [U]**Steven L. Klima**, Nexus Technical Services Corp., TN [SE]**Kevin Kreitman**, City of Albany Fire Dept., OR [E]**Kevin M. Laporte**, Uni-Wash/Polaris, MI [M]**Daniel J. Lazarz**, Babcock & Wilcox, VA [U]**John E. McConaghie**, Reade Mfg. Co., NJ [U]**Robert W. Nelson**, Pocasset, MA [SE]**David L. Oberholtzer**, Valimet, Inc., CA [M]

Rep. The Aluminum Assn.

**John Valiulis**, Factory Mutual Research Corp., MA [I]**Alternates****W. Anthony Major**, Silberline Mfg. Co., Inc., PA [M]

(Alt. to D. L. Oberholtzer)

**Larry J. Moore**, Factory Mutual Research Corp., [I]

(Alt. to J. Valiulis)

**Nonvoting****Thomas J. Matesic**, Reactive Metals & Alloys Corp., PA**Albert Muller**, Labanon, NJ

(Member Emeritus)

**Carl H. Rivkin**, NFPA Staff Liaison

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

**Committee Scope:** This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

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## NFPA 485

## Standard for the Storage, Handling, Processing, and Use of Lithium Metal

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NOTICE: An asterisk (\*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 8 and Appendix B.

### Chapter 1 General

#### 1-1 Scope.

**1-1.1** This standard shall apply to the storage, handling, processing, and use of solid or molten lithium.

**1-1.2\*** This standard shall also apply to those materials, including batteries and scrap, that exhibit the reactivity and burning characteristics of lithium metal as specified by the manufacturer.

**1-1.3** This standard shall not apply to the primary production of lithium.

**1-1.4\*** This standard shall not apply to the transportation of lithium.

**1-1.5** This standard shall not apply to those laboratories handling hazardous chemicals as defined in NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

**1-1.6\*** This standard shall not apply to pyrophoric materials such as finely divided solid forms of dry lithium or finely divided lithium dispersed in a flammable liquid.

**1-2 Applicability.** Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or adjacent property.

**1-3 Purpose.** The purpose of this standard is to minimize the occurrence of and resulting damage from fire and explosion hazards in the storage, handling, processing, and use of lithium and lithium alloys.

**1-4 Equivalency.** Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

**1-5 Definitions.** For the purpose of this standard, the following terms shall have the meanings given below.

**Approved.\*** Acceptable to the authority having jurisdiction.

**Authority Having Jurisdiction.\*** The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

**Dry Air.** Air with 2.2 grains of water per pound of air or less.

**Handling.** Any activity, including processing, that can expose the metal's surface to air or to any other substance capable of reacting with the metal under the conditions of the exposure.

**Labeled.** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

**Listed.\*** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

**Lithium.** Either pure metal or alloys having the generally recognized properties of lithium metal, including the burning characteristics of lithium.

**Noncombustible.\*** In the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

**Pyrophoric Material.\*** A substance capable of self-ignition on short exposure to air under ordinary atmospheric conditions.

**Shall.** Indicates a mandatory requirement.

**Should.** Indicates a recommendation or that which is advised but not required.

**Standard.** A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

### Chapter 2 General Precautions

**2-1\* Special Considerations.** Lithium shall be kept away from sources of moisture.

#### 2-2\* Handling, Processing, and Storage Areas for Lithium.

**2-2.1** Lithium shall be handled, processed, and stored only in accordance with the requirements of this standard.

**2-2.2** Lithium handling, processing, and storage areas shall have diamond markings on the exterior as specified in NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, to make emergency responders aware of the presence of water-reactive materials within the area. The diamond markings shall be at least 18 in. (45.72 cm)

on each side with appropriate size numbers and symbols as specified in NFPA 704.

### 2-3\* Lithium Fire Residue.

**2-3.1\*** Lithium fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

**2-3.2** Lithium fire residues shall be disposed of in accordance with federal, state, and local regulations.

**2-3.3** Containers of lithium fire residue shall be inspected and the results recorded monthly by individuals who are trained in the hazards of lithium and able to recognize potential problems associated with these containers.

## Chapter 3 Building Construction

### 3-1 General.

**3-1.1** This chapter shall be applied to buildings or portions of buildings that are dedicated to the handling or storage of solid or molten lithium.

**3-1.2\*** Buildings dedicated to the storage, handling, processing, or use of lithium shall be constructed of noncombustible materials.

*Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.*

**3-1.3** Buildings shall comply with applicable provisions of NFPA 101®, *Life Safety Code*®.

**3-1.4\*** Roof decks shall be watertight.

**3-1.5** Walls and ceilings shall be constructed with noncombustible insulation that has been tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

**3-1.6\*** In areas where solid lithium is stored, handled, or processed, floors shall be a solid surface, and shall be constructed with materials that are compatible and nonreactive with and capable of providing containment of the molten lithium resulting from fire.

**3-1.6.1** Where gratings are used or lithium is handled overhead, accessibility to the area below shall be restricted.

**3-1.7** Floor drains shall not be permitted.

**3-1.8** Where molten lithium is handled, dispensed, or stored, the handling area shall be provided with compatible and non-reactive containment. The containment shall provide for a volume of 110 percent of the maximum amount of material that is contained or could be spilled in the area. In areas where molten lithium is handled, wall-to-floor connections shall be sealed against the penetration of molten lithium.

**3-1.9** All electrical equipment and wiring shall comply with NFPA 70, *National Electrical Code*®.

### 3-2 Separation from Water.

**3-2.1\*** Water pipes or pipes that can contain water under normal use (e.g., domestic water, roof drains, waste pipes, etc.) shall not be permitted in areas containing lithium.

*Exception: Sprinkler system(s) deemed appropriate per 6-1.3 shall be permitted.*

**3-2.2** Portions of buildings where lithium is stored, handled, processed, or used shall be separated by watertight walls, ceilings, and door systems from adjacent areas not handling or storing lithium where water can be present. The floor shall be sloped away from the entrance to these areas, or other means shall be taken to prevent water from entering.

## Chapter 4 Handling or Processing of Solid or Molten Lithium

### 4-1 General Precautions.

**4-1.1** Lithium shall be handled only by trained personnel who are knowledgeable of the hazards associated with lithium.

**4-1.2** The number of persons in lithium-handling areas during operations shall be limited to those necessary for the operation.

**4-1.3** Access to lithium-handling areas by unauthorized personnel shall not be permitted.

**4-1.4** Lithium shall not be handled in the presence of incompatible materials. (*See also A-5-1.3.*)

**4-1.5** Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in lithium-processing areas.

**4-1.6\*** No open flames or electric or gas cutting, welding, or other spark-producing operations equipment shall be permitted in the section of the building where lithium is present unless approved hotwork procedures are followed by qualified personnel.

**4-1.7\*** The quantity of lithium permitted in processing areas shall be limited to that necessary for operations, but it shall not exceed the quantity required in one shift.

*Exception: Melting/casting operations shall be permitted to maintain more than one shift's supply of lithium in process vessels, or drums in which lithium would be melted, with appropriate protection, across one or more shifts.*

### 4-2 Solid Lithium Handling.

**4-2.1** Solid lithium shall be protected from moisture during handling by water-free mineral oil or by the use of dry air (air having a maximum of 2.2 grains of water per pound of air), argon, helium, or other protective methods.

*Exception: Lithium shall be permitted to be exposed to non-dry air when being transferred from clean, moisture-free, sealed metal portable containers dedicated to the handling of solid lithium to process vessels, when inert atmospheres for the lithium are not feasible and oil coating is inappropriate for the process. If left open for more than 15 minutes, the portable container shall be purged with a gas that is inert to lithium.*

**4-2.2\*** Only the amount of lithium needed for an individual task or procedure shall be removed from containers. Surplus lithium shall be returned to an approved container and resealed immediately in accordance with 4-2.1.



### 4-3 Molten Lithium Handling.

**4-3.1** Molten lithium shall be contained in closed systems that prevent its contact with air or reactive materials.

*Exception: As required for the process.*

**4-3.2** Molten lithium piping systems shall be designed in conformance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*. All pump seals and flange gaskets shall be made of compatible materials.

**4-3.3** Molten lithium systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials.

**4-3.4** Molten lithium shall be handled in a detached building or in portions of a building separated from other exposures by barrier walls so any fire can be dealt with as a lithium fire.

## Chapter 5 Storage of Solid or Molten Lithium

### 5-1 General Precautions.

**5-1.1\*** Lithium shall be permitted to be stored in shipping containers meeting the requirements of 49 *CFR* 100-199 or in clean, moisture-free, compatible and nonreactive metal sealed containers dedicated for the storage of lithium.

**5-1.2** Lithium shall not be stored in containers previously used for the storage of incompatible materials.

**5-1.3\*** Lithium shall not be stored in an area with incompatible materials.

**5-1.4** Lithium containers shall not be stored outside.

*Exception: Lithium fire residues shall be permitted to be stored outside where placed in a double-steel, overpack drum and inspected daily.*

### 5-2 Solid Lithium Storage.

**5-2.1** Solid lithium shall be stored only on the ground floor. There shall be no basement or depression below the lithium storage area into which water or molten metal shall be permitted to flow or fall during a fire.

**5-2.2** The solid lithium storage area shall be isolated from other areas so that water cannot enter by spray or drainage from automatic sprinkler systems or any other water source.

### 5-2.3 Container Storage Arrangement.

**5-2.3.1** Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

**5-2.3.2** Containers on pallets shall be permitted to be stored in racks not more than 15 ft (4.5 m) high.

**5-2.3.3** Containers on pallets and not stored in racks shall be stacked in a stable manner not to exceed three pallets high.

**5-2.3.4** Aisle widths shall be established and approved by the authority having jurisdiction to provide for access to and for the removal of materials during emergency situations.

**5-2.3.5** Idle pallet storage shall not be permitted in solid lithium storage areas.

**5-3 Molten Lithium Storage.** Molten lithium storage shall be in closed systems and in separate buildings or portions of buildings designed by competent designers solely for that purpose.

## Chapter 6 Fire Protection

### 6-1\* General Precautions.

**6-1.1** A fire protection plan shall be provided for all areas where lithium is processed, handled, used, and stored.

**6-1.2\*** Buildings or portions of buildings in which the only combustible hazard present is lithium shall not be permitted to be equipped with sprinkler protection.

**6-1.3\*** Buildings or portions of buildings that have combustible hazards in addition to lithium shall be evaluated for fire protection requirements with a process hazard analysis that is acceptable to the authority having jurisdiction. Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than lithium create a more severe fire hazard than the lithium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with lithium.

**6-1.4\*** As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the lithium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

**6-1.5** Prior to having lithium on site, the local fire department shall be notified of the presence of water-reactive materials, in particular lithium, on site, and shall be notified of the hazards of using water on lithium fires.

### 6-2 Extinguishing Agents and Application Techniques.

**6-2.1\*** Only listed, Class D, extinguishing agents or those tested and shown to be effective for extinguishing lithium fires shall be permitted. A supply of extinguishing agent for manual application shall be kept within easy reach of personnel working with lithium. The amount of extinguishing agent to be provided shall follow the listing agency's or manufacturer's recommendation.

**6-2.2** Extinguishing agents intended for manual application shall be kept in original, labeled factory containers. Container lids shall be kept in place to prevent extinguishing agent contamination and to keep agent moisture-free. Where large quantities of extinguishing agent are expected to be needed, a clean, dry shovel shall be provided with the container. Where small amounts are needed, a hand scoop shall be provided with each container.

**6-2.3\*** Portable or wheeled extinguishers listed for use on lithium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

**6-2.4\*** The following agents shall not be used as extinguishing agents on a lithium fire because of adverse reaction:

- (1) Water
- (2) Gaseous-based foams
- (3) Halon
- (4) Carbon dioxide

**6-2.5\*** An ABC dry chemical and a B:C dry chemical extinguisher shall not be used as a lithium fire extinguishing agent, but shall be permitted to be used on other classes of fires in the area where lithium is present.

**6-2.6\*** Fire extinguishing agent expellant gases shall be compatible with lithium.

### **6-3 Personal Protective Equipment for Fire Fighting.**

**6-3.1\*** Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a lithium fire.

**6-3.2\*** Additional eye protection shall be worn by personnel wearing SCBA protection to protect against the brighter than ambient light emitted during a lithium fire. Visual protection equivalent to a No. 6 welding lens shall be used.

### **6-4 Protective Equipment for Facility Personnel Performing Incipient-Stage Lithium Fire Fighting.**

**6-4.1** If incipient-stage lithium fires are to be fought, personal protective equipment shall be worn. Personal protective equipment shall include face shields, head protection, gloves, external clothing, and respiratory protection.

**6-4.1.1\*** Personnel who attempt to fight a lithium fire in its incipient stage shall, as a minimum, wear full face shields.

**6-4.1.2** Head protection shall consist of hard hats.

**6-4.1.3** Gloves shall conform with 7-2.3.

**6-4.1.4** If provided, external clothing shall conform with 7-2.5.

**6-4.1.5** Respiratory protection suitable for the hazards of lithium shall be provided.

**6-4.2** If incipient-stage lithium fires are to be fought, personal protective equipment shall be readily accessible and maintained in good condition in all areas where lithium is handled.

**6-4.3** A minimum of two sets of personal protective equipment shall be provided if incipient-stage lithium fires are to be fought.

### **6-5 Lithium Fire-Fighting Procedures.**

**6-5.1\*** While a lithium fire is being fought, every effort shall be made to avoid splattering the burning lithium.

**6-5.2\*** Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

## **Chapter 7 Personal Protective Equipment for Molten and Solid Lithium Handling Operations**

### **7-1\* Personal Protective Equipment for Solid Lithium Handling.**

**7-1.1** Eye protection shall be worn while handling solid lithium.

**7-1.2** Gloves shall be worn while handling solid lithium. Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

**7-1.3** Clothing worn while handling solid lithium shall have no exposed pockets or cuffs that could trap and carry lithium residues.

### **7-2\* Personal Protective Equipment for Handling Molten Lithium.**

**7-2.1** Personal protective equipment shall be worn and shall be compatible with the hazards of molten lithium.

**7-2.2** While handling molten lithium, safety glasses and full-face protection shall be worn, that is, face shields.

**7-2.3** Gloves shall be worn and shall be loose-fitting, easily removable, and compatible with the hazards of molten lithium.

**7-2.4** All clothing shall be loose-fitting, easily removable, flame-resistant, and compatible with the hazards of molten lithium.

**7-2.5\*** An external clothing layer shall be worn for protection from splash. The external clothing layer shall be impervious to body moisture.

**7-2.6** Protective footwear shall be appropriate for the hazards of molten lithium.

## **Chapter 8 Referenced Publications**

**8-1** The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix B.

**8-1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1996 edition.

NFPA 70, *National Electrical Code*®, 1999 edition.

NFPA 101®, *Life Safety Code*®, 1997 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 1996 edition.

### **8-1.2 Other Publications.**

**8-1.2.1 ASTM Publication.** American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1998.

**8-1.2.2 ANSI Publication.** American National Standards Institute, Inc., 11 West 42nd Street, 13th Floor, New York, NY 10036.

ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*, 1993 edition.

**8-1.2.3 U.S. Government Publication.** U.S. Government Printing Office, Washington, DC 20402.

*Code of Federal Regulations*, Title 49, Parts 100–199, 1998.

## Appendix A Explanatory Material

*Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.*

**A-1-1.2** Products or materials that have the characteristics of lithium should have a material safety data sheet (MSDS) that describes these burning characteristics. Refer to A-6-1, A-6-5.1, and A-6-5.2 for a general explanation of these characteristics, and consult with the manufacturer or technical personnel knowledgeable of the hazards associated with lithium.

**A-1-1.4** Regulations for the domestic shipment of dangerous goods (lithium and lithium alloy materials are so classified) are issued by the U.S. Department of Transportation (DOT) (49 *CFR* 100–199), which has specific responsibility for promulgating the regulations. These regulations are updated and published yearly by DOT.

International shipments are regulated by the United Nations, International Air Transport Association, International Maritime Organization, and other national agencies.

**A-1-1.6** Finely divided, dry lithium and finely divided lithium dispersed in a flammable liquid can exhibit pyrophoric properties and, therefore, do not act as combustible metals, as covered by this standard. Prior to handling these materials, the vendor of the lithium, lithium alloy, or lithium dispersion should be consulted for safe practices. These practices include the design of the facilities for storage and handling these materials, protective clothing requirements, training requirements, and general safety precautions.

Dry lithium and lithium alloy powders are pyrophoric in nature and water-reactive. Precautions are required because on exposure to air, the powders can ignite or explode.

Dispersions of lithium, possible with other alkali metals, in organic solvents, present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, the solvent presents the concerns of flammable or combustible liquids and vapors. In addition the MSDS provided by the supplier of the material, NFPA 30, *Flammable and Combustible Liquids Code*, and NFPA 77, *Recommended Practice on Static Electricity*, are applicable to address the problems of combustible liquids and vapors.

**A-1-5 Approved.** The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

**A-1-5 Authority Having Jurisdiction.** The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor depart-

ment, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

**A-1-5 Listed.** The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

**A-1-5 Noncombustible.** Materials reported as noncombustible, where tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750° C*, are considered noncombustible materials.

**A-1-5 Pyrophoric Material.** For further clarification of *pyrophoric*, refer to 49 *CFR* 173.124(b)(1).

**A-2-1** Lithium reacts with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction varies with conditions; therefore, the best approach is to take precautions to keep moisture away from lithium.

**A-2-2** Small facilities isolated from other facilities under the same ownership are ideal for handling and processing lithium. In the event of an uncontrolled lithium emergency, property damage would be considerably less.

**A-2-3** Lithium fire residue products can include metallic lithium, lithium nitride, lithium oxide, or lithium hydroxide, which can absorb moisture.

**A-2-3.1** Once a lithium fire is extinguished, lithium is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of lithium. Lithium fire residues can include other reactive components. These residues can react with each other and cause reignition. Containers of residues can be purged with argon gas or the residues can be coated with water-free mineral oil to reduce the potential for reaction. Under solid waste environmental regulations, these residues could be considered a hazardous waste, and subject to hazardous waste packaging, storage, notification and disposal regulations.

**A-3-1.2** Consideration should be given to automatic fire detection systems within these facilities to ensure life safety.

**A-3-1.4** The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintaining these roofs, especially in climates where heavy amounts of snow are expected.

**A-3-1.6** Nonslip surfaces should be provided due to the potential presence of mineral oil on the floor. Gratings should be used only where containment provisions have been provided below the area or where access can be restricted below the area.

**A-3-2.1** Laboratories, bathrooms, and other areas not dedicated to the processing of lithium can have water leaks. Consideration needs to be given to preventing water from such

leaks from entering the lithium processing areas, creating fire and explosion hazards.

**A-4-1.6** See NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*.

**A-4-1.7** When evaluating the amounts needed for process use, the risks and fire exposures should be evaluated with other processing requirements.

Lithium in containers staged for melting should be considered process vessels.

**A-4-2.2** Solid lithium is supplied in a variety of forms (e.g., ingots and ribbon), which are often individually protected in small cans or airtight foil pouches. If individual containers are not supplied and the containers are opened, lithium is exposed to surrounding air, causing slow reactions to take place. It is for this reason that once the container is opened, only that amount of lithium intended to be used should be removed.

**A-5-1.1** Lithium is shipped from lithium manufacturers in DOT- or HM 181-approved containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with lithium coated with mineral oil or packed under an argon cover. Containers used to store lithium under mineral oil for long-term storage (over three months) should be inverted to redistribute the mineral oil covering the lithium. Containers packed under an argon cover should be regularly checked to verify the integrity of the container seal. When lithium is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

**A-5-1.3** Lithium is known to be incompatible with the following materials: inorganic and organic acids; Halon 1211; Halon 2402; carbon tetrachloride; 1,1,1 trichloroethane; oxidizers such as nitric acid, chromic acid, phosphoric acid, or hypochlorous acid; and reducing acids such as sulfuric, hydrochloric, and sulfamic acid. Oxalic acid, phenol and organic acid mixtures, or compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of lithium. Refer to NFPA 491, *Guide to Hazardous Chemical Reactions*.

**A-6-1** Because of the unique nature of lithium fires, a comprehensive fire protection plan is necessary where lithium is processed, handled, used, or stored. This plan should include specific actions in the event of a lithium fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

This plan should pay special attention to the extreme hazards associated with lithium–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning lithium are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent lithium fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with lithium know its hazards. Such personnel will have the greatest chance to extinguish a lithium fire in its incipient stage. Training should include sufficient information to determine if extinguishment can be safely and effectively accomplished.

Lithium at room temperature in the presence of incompatible materials can reach the melting point and reach the autoignition temperature.

The degree of reaction and the amount of time to produce these effects vary with conditions surrounding the fire; temperature of the exposed lithium being the major factor. At low temperatures or temperatures within a few degrees of lithium's melting point, the reaction is slower with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting a lithium fire, it is very important that fire fighters be aware of the dangers of burning lithium. When molten lithium reacts with materials such as water or flammable or combustible liquids or gases, molten lithium can be ejected for a considerable distance. The severity of lithium reactions varies with a multitude of conditions.

Lithium in contact with moisture and air forms lithium hydroxide and lithium oxide, which will cause caustic burns without adequate personal protective equipment.

**A-6-1.2** The reaction of lithium, especially burning lithium, with water is extremely hazardous. Where combustible loading in areas used for lithium processing is determined by the authority having jurisdiction to require sprinkler protection, consideration should be given to the installation of preaction sprinkler systems to reduce the opportunity for accidental discharge.

**A-6-1.3** Where the presence of non–water reactive, combustible materials has been determined to require sprinkler protection, the quantities of lithium exposed to sprinkler action and the ability of workers to quickly secure the exposed lithium (e.g., place the lid back on the drum, reseal the container) also needs to be evaluated.

**A-6-1.4** If dry chemical extinguishing systems are used, see NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

**A-6-2.1** Several agents (e.g., copper powder, graphite-based agents and lith-x) have been tested on lithium fires and found to be successful with varying results. These agents all form a crust of varying durability over the fuel, but due to molten lithium's fluid properties, lithium tends to "burn-throughs." Copper powder formed the most durable crust of all these effective fire-fighting agents.

Low density agents were found to be difficult to apply in windy conditions, resulting in decreased effective range of extinguisher, reduced visibility, and larger amounts of agent needed.

Testing indicates that the amount of agent needed depends on several factors. Small-scale lithium fires require the use of an acceptable ratio of extinguishing agents. Larger fires can require dramatically larger ratios. The acceptable ratio varies, depending on the agent selected.

Lithium, with its low density, will float on solid or liquid. Extinguishing agents will tend to sink in molten lithium; therefore, as depth of fuel increases, the amount of agent needed will increase. Extended testing and evaluation of lithium fires indicates the amount of agent needed is not based on weight of agent per weight of fuel, but should be based on depth and surface area of involved fuel per weight of agent.

The lower the temperature of the lithium, the less heat will be required to be drawn from the lithium to reduce reactions, and therefore reduce the amount of agent needed.

**A-6-2.3** In cases where the weight of the lithium hazard is small and well defined, portable or wheeled extinguishers should be distributed so that at least one is located within 75 ft (22.7 m) of the hazard and additional extinguishers can be readily available.

The recommendation for use of wheeled extinguishers where large amounts of lithium are found is based on the following:

- (1) One or two individuals can deliver large amounts of agent in a relatively short period of time.
- (2) Being highly mobile, wheeled extinguishers can be situated to provide a more complete coverage of any facility.
- (3) Wheeled units protecting other areas that might not be affected in the emergency can be brought to the scene.

**A-6-2.4** The following extinguishing agents should not be used as lithium fire extinguishing agents.

(a) The application of water in any form on lithium releases considerable amounts of hydrogen gas, steam, and heat and is not recommended on lithium.

Tests have demonstrated that the effect of water on lithium fires is the formation of hydrogen gas. In some cases, hydrogen will burn and intensify the fire; in other cases, hydrogen results in rapid heat rise with an explosive-like effect.

The amount of hydrogen gas present in the vicinity of any lithium reaction is directly proportional to the degree of further reaction. If the environment surrounding the fire is such that the hydrogen gas is driven off or its concentration is reduced to a level below its lower explosive limit, the reaction is less intense.

(b) Past testing of the application of aqueous film-forming foam (AFFF) on burning lithium resulted in extreme reactions.

(c) Halon should not be used as a lithium fire extinguishing agent.

Halon, when applied to a lithium fire, exhibits an immediate reaction. One effect is that the reaction will track the agent stream, putting the fire fighter in increased danger.

(d) The application of CO<sub>2</sub> produces minimal reactions, yet the force of this agent can greatly spread burning lithium. Therefore, CO<sub>2</sub> is not recommended as a lithium fire extinguishing agent.

**A-6-2.5** Dry chemical agents should not be used on a lithium fire. Testing indicated that a B:C dry chemical was not an effective lithium fire-fighting agent although it exhibited the least amount of adverse reaction with lithium.

**A-6-2.6** Many common extinguishing agents and extinguisher expelling gases, when exposed to burning lithium, exhibit high reactivity. The degree of reactivity depends on a wide range of variables, such as temperature of the fire and other chemical compounds reacting with the lithium. For example, nitrogen commonly used to expel dry powder agent does not exhibit a high degree of reactivity until the temperature of the fire increases.

Testing has indicated that carbon dioxide and nitrogen, commonly used as extinguisher expellant gases, are reactive to lithium at higher temperatures. Argon gas, being nonreactive to lithium, can be used successfully as a substitute.

If lithium is involved in a multiclass fire and agents that are reactive to lithium (e.g., water, AFFF, and halon) are used, expect and prepare for the effects of the reaction. Use

unmanned delivery techniques and use whatever physical protection is available.

**A-6-3.1** Burning lithium will burn through material used in the construction of most fire fighter protective clothing. Some features (e.g., heavy quilted lining and aluminized outer shell) can reduce this risk. The SCBA face piece eye protection worn by fire fighters adequately protects against the impacts of a lithium fire with the exception of the intense light given off by burning lithium.

See NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*.

**A-6-3.2** Specific testing has indicated that white light levels emitted from burning lithium exceed recommended levels. Extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes.

A clip-on adapter over an SCBA face piece with a shaded glass lens equivalent to a No. 6 welding lens has been used very successfully to reduce such hazards. A darker lens tends to obstruct fire fighters' view to an unacceptable degree.

**A-6-4.1.1** Full face shields, preferably shaded shields, should be made readily available in areas where lithium fires are likely to occur. These shields will provide adequate protection against small incipient-stage lithium fires.

**A-6-5.1** One of the greatest dangers to fire fighters is the splattering effect of burning lithium. Molten lithium is very fluid and easily spread; therefore, extreme care needs to be taken when applying fire-fighting agent. The force used to deliver agent from an extinguisher can easily spread lithium particles; therefore, delivery technique is very important. Should direct agent application become hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

**A-6-5.2** Forming a crust over burning lithium reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since lithium tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If lithium surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the lithium. In the case of copper powder, a lithium-copper alloy is formed as heat is absorbed from the lithium. Once the crust is formed, the temperature of the lithium decreases and exothermic reactions are reduced. Extreme care should be taken to ensure the crust is not disturbed or broken until the temperature of the lithium is decreased to the point where resolidification occurs.

**A-7-1** Lithium in contact with moisture forms lithium hydroxide and lithium oxide, which will cause caustic burns. Lithium in contact with human skin will react with body moisture and cause thermal and caustic burns.

**A-7-2** Hazards involved with handling molten lithium are significantly greater than those of handling solid lithium due to enhanced reactivity, heat of reaction, and elevated temperatures.

**A-7-2.5** Fire risk is significantly reduced when the outer clothing layer is kept dry.

## Appendix B Referenced Publications

**B-1** The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 8. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

**B-1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1998 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1999 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 491, *Guide to Hazardous Chemical Reactions*, 1997 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1997 edition.

### B-1.2 Other Publications.

**B-1.2.1 ASTM Publication.** American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750° C*, 1998.

**B-1.2.2 U.S. Government Publication.** U.S. Government Printing Office, Washington, DC 20402.

Title 49, *Code of Federal Regulations*, Part 1200 (DOT and HM-181) and Parts 100–199.

### B-1.3 Informational Sources.

**B-1.3.1 National Safety Council Publication.** National Safety Council, 1121 Spring Lake Dr., Itasca, IL 60143-3201.

National Safety Council, Data Sheet 1-66, Lithium.

**B-1.3.2 New Mexico Engineering Research Institute Publication.** University of New Mexico, 901 University S.E., Albuquerque, NM 87106.

Moore, T. A., Stepetic, T. J., and Tapscott, R. E., Preliminary Environmental and Safety Evaluation of Large Scale Lithium Metal Fires, Naval Undersea Warfare Engineering Station, Keyport, Washington, March 1989.

Lee, M. E., Stepetic, T. J., Watson, J. D., and Moore, T. A., Lithium Fire Suppression Study, Phase 3 (Medium-Scale), Naval Undersea Warfare Engineering Station, Keyport, Washington, November 1989. (NMERI OC 90/10).

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