

NFPA[®] 460

Standard for Aircraft Rescue and Firefighting Services at Airports

2024 Edition



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NFPA® 460

Standard for

Aircraft Rescue and Firefighting Services at Airports

2024 Edition

This edition of NFPA 460, *Standard for Aircraft Rescue and Firefighting Services at Airports*, was prepared by the Technical Committee on Aircraft Rescue and Firefighting. It was issued by the Standards Council on October 7, 2022, with an effective date of October 27, 2022.

This edition of NFPA 460 was approved as an American National Standard on October 27, 2022.

Origin and Development of NFPA 460

This first edition of NFPA 460, *Standard for Aircraft Rescue and Firefighting Services at Airports*, is a consolidation of NFPA 403, NFPA 405, and NFPA 412, as part of a document consolidation plan that was approved during the April 2019 Standards Council meeting. This plan affects all documents in the Emergency Response and Responder Safety (ERRS) project.

Many of the revisions made for this edition are related to the consolidation of the legacy documents NFPA 403, NFPA 405, and NFPA 412 into NFPA 460. The technical committee has revised several definitions for clarification and to reflect current use and practices, as well as provided guidance and clarification on the positioning of aircraft rescue and firefighting (ARFF) vehicles at air shows. The technical committee also has revised the recurrent training requirements to be better aligned with initial training requirements and to ensure individuals are able to demonstrate their skills.

The technical committee has revised the portion of NFPA 460 that was previously NFPA 412, in order to clarify the nature of the testing. There had been confusion regarding previous editions of NFPA 412 where it had been perceived as a foam testing standard, when in fact it was testing the foam production capabilities of ARFF apparatus built to NFPA 414 (now NFPA 1900). The purpose of the test results being measured as part of the NFPA 412 content in NFPA 460 is to ensure that the ARFF vehicle is operating as designed with regard to the production of foam.

Another change for this first edition of NFPA 460 includes replacing the term *halogenated agents* with *clean agents* to reflect current use and practice.

For more information about the ERRS consolidation project, see nfpa.org/errs.

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Robert C. Mathis, *Chair*

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John W. McDonald, *Secretary*

US General Services Administration, MD [U]

Rep. US General Services Administration

Gerard G. Back, JENSEN HUGHES, MD [SE]

Keith W. Bagot, US Federal Aviation Administration, NJ [RT]

Rep. US Federal Aviation Administration

Gary David Barthram, Heathrow Airport Fire Service, United Kingdom [U]

Ralph B. Colet, JRI Inc., CA [M]

Howard “Ted” Costa, City of Gloucester, MA [SE]

Matthew Dandona, UL LLC, IL [RT]

Hanh Deniston, Metropolitan Washington Airports Authority, VA [L]

Rep. International Association of Fire Fighters

Michael Flores, Los Angeles Fire Department, CA [U]

Neil Gray, United Kingdom Civil Aviation Authority, United Kingdom [E]

Edward M. Hawthorne, DFW Dynamics, TX [U]

Rep. American Petroleum Institute

Denny J. Heitman, US Department of the Air Force, IL [E]

Elizabeth A. Hendel, Beacon Occupation Health and Safety Services, AZ [SE]

Rene Herron, Capella University, FL [SE]

Ronald E. Jones, E-One, Inc., FL [M]

Ronald J. Krusleski, Houston Fire Department ARFF, TX [SE]

Rep. Aircraft Rescue & Fire Fighting Working Group, Inc.

David Scott Lanter, Blue Grass Airport, KY [C]

Rep. Airports Council International-North America

Stephen Listerman, Cincinnati/Northern Kentucky International Airport Fire Department, OH [E]

James Lonergan, American Pacific Corporation (AMPAC), PA [M]

Rep. Fire Equipment Manufacturers' Association

John Anderson Maddox, Lakeland Fire Department, FL [U]

William K. Major, Buffalo Niagara International Airport Fire Department, NY [L]

Paul Martel, Canadian Forces Fire Marshal, Canada [E]

Graydon L. Matheson, King County Sheriff's Office-ARFF Division, WA [U]

John E. McLoughlin, American Airlines, FL [SE]

Greg Palmer, North Carolina Office of the State Fire Marshal, NC [E]

Danny M. Pierce, ARFF Solutions, CA [SE]

Paul W. Powell, Rosenbauer America, TX [M]

Rep. Fire Apparatus Manufacturers Association

Eric Keoki Rhode, Commander Navy Installations, DC [E]

Jason Shively, Oshkosh Corporation, WI [M]

Darrell Sooter, The Boeing Company, SC [M]

Marc S. Tonnacliff, US Federal Aviation Administration, DC [E]

Rep. US Federal Aviation Administration

Adam Uhler, Akron Brass Company, OH [M]

Alternates

Daniel Buckingham, US General Services Administration, DC [U]
(Alt. to John W. McDonald)

Joshua Curell, Rural Metro Sikorsky, FL [U]
(Voting Alt.)

Ray Dabbelt, Cincinnati/Northern Kentucky International Airport Fire Department, OH [E]
(Alt. to Stephen Listerman)

Christopher P. James, UL LLC, NC [RT]
(Alt. to Matthew Dandona)

Duane F. Kann, Rosenbauer, MN [M]
(Alt. to Paul W. Powell)

Kevin Matlock, US Air Force, FL [E]
(Alt. to Denny J. Heitman)

Paul Joseph Nye, Allison Park, PA [L]
(Alt. to Hanh Deniston)

Sarah Marie Peck, Akron Brass, TX [M]
(Alt. to Adam Uhler)

Frederick Poirier, Canadian Forces Fire Marshal Office, Canada [E]
(Alt. to Paul Martel)

James Price, US Department of Transportation, GA [E]
(Alt. to Marc S. Tonnacliff)

Joseph L. Scheffey, JENSEN HUGHES, MD [SE]
(Alt. to Gerard G. Back)

Steven Schwartz, Oshkosh Corporation, WI [M]
(Alt. to Jason Shively)

Oscar L. Scott, Los Angeles Fire Department, CA [U]
(Alt. to Michael Flores)

Leroy Stephens, E-One, FL [M]
(Alt. to Ronald E. Jones)

Ronald J. Tocci, Dallas Fire-Rescue Department, TX [SE]
(Alt. to Ronald J. Krusleski)

Jonathan Torres, FAA William J. Hughes Technical Center, NJ [RT]
(Alt. to Keith W. Bagot)

Nonvoting

Francois Villard, Fire Safety Security Crisis Management Training, Switzerland [SE]

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Committee Scope: This Committee shall have primary responsibility for aircraft rescue and firefighting (ARFF) documents used by organizations providing ARFF services for operational procedures; training; foam testing and application; specialized equipment; and planning for aircraft emergencies.

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NFPA 460**Standard for****Aircraft Rescue and Firefighting Services at Airports**

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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 Annex A.

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Information on referenced and extracted publications can be found in Chapter 2 and Annex H.

Chapter 1 Administration

1.1 Scope. This standard contains the minimum requirements for aircraft rescue and firefighting (ARFF) services at airports and the required performance criteria by which an authority having jurisdiction over ARFF maintains proficiency and effective ARFF at airports, and establishes test procedures for evaluating the foam firefighting equipment installed on ARFF vehicles designed in accordance with Chapters 1 through 6 of NFPA 1900.

1.1.1 Requirements for other airport fire protection services are not covered in this document.

1.2 Purpose. This standard is prepared for the use and guidance of those charged with providing and maintaining aircraft rescue and firefighting services at airports and establishes the basis for a recurring training program that focuses on measurable performance criteria.

1.2.1 The tests specified in this standard provide procedures for the evaluation of foam firefighting equipment in the field to determine compliance with Chapters 1 through 6 of NFPA 1900.

1.3* Application. This standard can be applied as follows:

- (1) Chapters 1 through 3, 4 through 10, and Annexes A through E and G constitute the 2022 edition of NFPA 403.
- (2) Chapters 1 through 3, 11 through 26, and Annexes A and G constitute the 2022 edition of NFPA 405.
- (3) Chapters 1 through 3, 27 through 29, and Annexes A, F, and G constitute the 2022 edition of NFPA 412.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2022 edition.
NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 2019 edition.

NFPA 1900, *Standard for Aircraft Rescue and Firefighting Vehicles, Automotive Fire Apparatus, Wildland Fire Apparatus, and Automotive Ambulances*, 2024 edition.

NFPA 2500, *Standard for Operations and Training for Technical Search and Rescue Incidents and Life Safety Rope and Equipment for Emergency Services*, 2022 edition.

2.3 Other Publications.

2.3.1 ICAO Publications. International Civil Aviation Organization, 999 Robert-Bourassa Boulevard, Montréal, Quebec H3C 5H7, Canada.

Annex 19 to the Convention on International Civil Aviation, International Standards and Recommended Practices, *Safety Management*, amended first edition, July 2016.

2.3.2 Military Specifications. Department of Defense Single Stock Point, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 1911-5094.

US Military Specification MIL-F-24835, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate, for Fresh and Sea Water*.

2.3.3 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2021 edition.

NFPA 2500, *Standard for Operations and Training for Technical Search and Rescue Incidents and Life Safety Rope and Equipment for Emergency Services*, 2022 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Shall. Indicates a mandatory requirement.

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

3.2.5 Standard. An NFPA standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrases "standards development process" or "standards development activities," the term "standards" includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

3.3.1* Aerobic Box. The Federal Aviation Administration (FAA) defines the aerobic box as the airspace at an air show where participating aircraft are authorized to perform aerobic maneuvers appropriate to their category (CAT).

3.3.2 Air Boss. The individual who has the primary responsibility for air show operations on the active taxiways, runways, and the surrounding air show demonstration area.

3.3.3 Air Show Waiver. An official document issued by the FAA that authorizes certain operations of aircraft to deviate from a regulation but under conditions that ensure an equivalent level of safety.

3.3.4 Air Traffic Control. A service established to provide air and ground traffic control for airports.

3.3.5 Aircraft Accident. An occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and until all such persons have disembarked and in which any person suffers death or serious injury or in which the aircraft receives substantial damage.

3.3.6* Aircraft Firefighting. The control or extinguishment of fire adjacent to or involving an aircraft following ground accidents or incidents.

3.3.7* Aircraft Incident. An occurrence, other than an accident, associated with the operation of an aircraft, that affects or could affect continued safe operation if not corrected.

3.3.8* Aircraft Rescue. Action taken to save or set free persons involved in an aircraft accident/incident by safeguarding the integrity of the aircraft fuselage from an external/internal fire, to support self-evacuation, and to undertake the removal of injured and trapped persons.

3.3.9 Aircraft Showline Categories.

3.3.9.1 Category I Showline. A Category I showline must be not less than 1500 ft from the primary spectator area (minimum showline distances are measured from the crowd line to the center of the aircraft closest to any spectator area). Reciprocating engine-powered aircraft with a speed of 245 knots indicated air speed (KIAS) or higher in straight and level flight at 75 percent power at standard temperature and pressure (15°C at sea level) shall not perform aerobic maneuvers closer than the Category I showline. Turbine engine-powered aircraft with a speed of 245 KIAS or higher in straight and level flight at 85 percent power at standard temperature and pressure shall not perform aerobatics closer than the Category I showline.

3.3.9.2 Category II Showline. A Category II showline must be not less than 1000 ft from the primary spectator area. Reciprocating engine-powered aircraft with a speed of more than 156 KIAS and less than 245 KIAS in straight and level flight at 75 percent power at standard temperature and pressure shall not perform aerobic maneuvers closer than the Category II showline. Turbine engine-powered aircraft with a speed higher than 156 KIAS and less than 245 KIAS in straight and level flight at 85 percent power at standard temperature and pressure shall not perform aerobatics closer than the Category II showline.

3.3.9.3 Category III Showline. A Category III showline must be not less than 500 ft from the primary spectator area. Reciprocating engine-powered aircraft with a speed of 156 KIAS or less in straight and level flight at 75 percent power at standard temperature and pressure shall not perform aerobic maneuvers closer than the Category III showline. Turbine engine-powered aircraft with a speed higher than 156 KIAS or less in straight and level flight at 85 percent power at standard temperature and pressure shall not perform aerobatics closer than the Category III showline.

3.3.10 Airport Fire Chief. The individual normally having operational control over the airport's rescue and firefighting personnel and equipment, or a designated appointee.

3.3.11 Airport Fire Department Personnel. Personnel under the operational jurisdiction of the chief of the airport fire department assigned to aircraft rescue and firefighting.

3.3.12 Airport Manager. The individual having managerial responsibility for the operation and safety of an airport. The manager can have administrative control over aircraft rescue and firefighting services but normally does not exercise authority over operational fire and rescue matters.

3.3.13 Area Classifications.

3.3.13.1 Critical Rescue and Firefighting Access Area (CRFFAA). The rectangular area that surrounds a runway within which aircraft movements can be expected to occur on airports

and whose width extends 500 ft (150 m) from each side of the runway centerline and whose length is 3300 ft (1000 m) beyond each runway threshold. (See Figure A.3.3.13.3.)

3.3.13.2 Movement Area. That part of an airport to be used for the takeoff, landing, and taxiing of aircraft, and the apron(s), unless otherwise specified.

3.3.13.3* Rapid Response Area (RRA). A rectangle that includes the runway and the surrounding area extending to a width of 500 ft (150 m) outward from each side of the runway centerline and to a length of 1650 ft (500 m) beyond each runway end, but not beyond the airport property line. (See Figure A.3.3.13.3.)

3.3.14 ARFF Personnel. Personnel actively engaged in the pursuit of rescue and firefighting at the scene of an airport incident.

3.3.15 Fixed Base Operator (FBO). An enterprise based on an airport that provides storage, maintenance, or service for aircraft operators.

3.3.16 Flight Service Station (FSS). An air traffic facility that briefs pilots, processes and monitors flight plans, and provides in-flight advisories.

3.3.17 Foam. An aggregation of small bubbles used to form an air-excluding, vapor-suppressing blanket over the surface of a flammable liquid fuel.

3.3.17.1* Alcohol-Resistant Foam Concentrate. A concentrate used for fighting fires on water-soluble materials and other fuels destructive to regular, AFFF, or FFFP foams, as well as for fires involving hydrocarbons. [11, 2021]

3.3.17.2* Aqueous Film-Forming Foam (AFFF) Concentrate. A concentrate based on fluorinated surfactants plus foam stabilizers to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors and usually diluted with water.

3.3.17.3* Film-Forming Fluoroprotein Foam Concentrate (FFFP). A protein-foam concentrate that uses fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. [11, 2021]

3.3.17.4 Fluorine-Free Synthetic Foam. A synthetic foam concentrate containing no fluorochemicals for suppressing hydrocarbon fuel vapors.

3.3.17.4.1 Fluorine-Free Synthetic Foam (FFSF). Foam concentrate based on a mixture of hydrocarbon surface active agents that are fluorine free.

3.3.17.5 Fluoroprotein (FP) Foam. A protein-based foam concentrate, with added fluorochemical surfactants, that forms a foam showing a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel.

3.3.17.5.1* Fluoroprotein Foam Concentrate (FP). A concentrate very similar to protein-foam concentrate but with a synthetic fluorinated surfactant additive. [11, 2021]

3.3.17.6 Protein (P) Foam. A protein-based foam concentrate that is stabilized with metal salts to make a fire-resistant foam blanket.

3.3.17.7* Protein Foam Concentrate (P). Concentrate consisting primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against

freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and to otherwise ensure readiness for use under emergency conditions. [11, 2021]

3.3.18* Foam Concentrate. A concentrated liquid foaming agent as received from the manufacturer. [11, 2021]

3.3.19 Foam Drainage Time (Quarter Life). The time in minutes that it takes for 25 percent of the total liquid contained in the foam sample to drain from the foam.

3.3.20 Foam Expansion. The ratio between the volume of foam produced and the volume of solution used in its production.

3.3.21 Foam Pattern. The ground area over which foam is distributed during the discharge of a foam-making device.

3.3.22 Foam Solution. The solution that results when foam concentrate and water are mixed in designated proportions prior to aerating to form foam.

3.3.23 Foam Stability. The degree to which a foam resists spontaneous collapse or degradation caused by external influences such as heat or chemical action.

3.3.24 Fuselage. The main body of an aircraft.

3.3.25 International Civil Aviation Organization (ICAO). An international body charged with matters dealing with the development, coordination, and preservation of international civil aviation.

3.3.26 Knowledge. What the individual must know or understand in order to carry out a role and subsequent tasks to the standard required.

3.3.27 Mutual Aid. A written intergovernmental agreement between agencies, jurisdictions, or both, that they assist one another on request by furnishing personnel, equipment, expertise, or a combination in a specified manner.

3.3.28 Personal Protective Equipment (PPE). Multiple elements of compliant protective clothing, and equipment that when worn together provide protection from some, but not all, risks of emergency incident operations.

3.3.29 Response Time. The total period of time measured from the time of an alarm until the first ARFF vehicle arrives at the scene of an aircraft accident/incident and is in position to apply agent.

3.3.30 Safety Management System. A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures. [ICAO: Annex 19]

3.3.31 Size-Up. A mental process of evaluating the influencing factors at an incident prior to committing resources to a course of action. [2500, 2022]

3.3.32 Skills. Behaviors or actions that require practice in order to be performed satisfactorily. The skills or abilities can be manual, social, interpersonal, or intellectual.

3.3.33 Table-Top Training. A workshop style of training involving a realistic emergency scenario and requiring problem-solving participation by personnel responsible for management and support at emergencies.

3.3.34 Testing.

3.3.34.1 Input-Based Testing. Testing the foam solution by measuring the flow rate or volume of concentrate, or suitable substitute for concentrate, and comparing this flow rate or volume to the flow rate or volume of water used, then using those two numbers to calculate the proportions of concentrate and water in the foam solution.

3.3.34.2 Output-Based Testing. Testing the foam solution by collecting a sample of the solution after aerating and dispensing it, and using instruments and calculations to determine the sample's proportions of concentrate and water in the foam solution.

Chapter 4 Organization of Aircraft Rescue and Firefighting (ARFF) Services (NFPA 403)

4.1 Administration.

4.1.1 Scope. Chapters 4 through 10 contain the minimum requirements for aircraft rescue and firefighting (ARFF) services at airports. Requirements for other airport fire protection services are not covered in this document.

4.1.2 Purpose.

4.1.2.1 Chapters 4 through 10 are prepared for the use and guidance of those charged with providing and maintaining aircraft rescue and firefighting services at airports.

4.1.2.2 The principal objective of a rescue and firefighting service is to save lives.

4.1.2.2.1 The preparation for dealing with an aircraft accident/incident occurring at, or in the immediate vicinity of, an airport is of primary importance because it is within this location that the greatest opportunity to save lives exists.

4.1.2.2.2 The need for extinguishing a fire can occur either immediately following an aircraft accident/incident, or at any time during rescue operations, and must be assumed at all times.

4.1.2.3 The most important factors bearing on effective rescue in a survivable aircraft accident are the training received, the effectiveness of the equipment, and the speed with which personnel and equipment designated for rescue and firefighting purposes can be put to use.

4.1.3 Equivalency.

4.1.3.1 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.

4.1.3.2 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

4.1.3.3 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

4.2 Administrative Responsibilities.

4.2.1 The airport management shall be responsible for the provisions of ARFF services on the airport.

4.2.2 Mutual aid shall be prearranged between such services on airports and any off-airport fire or rescue agencies serving the environs of the airport.

4.3* Emergency Preparedness. The airport shall develop a risk management plan for fire emergency scene strategy.

4.3.1 Airports shall prepare and maintain in current status an airport/community emergency plan.

4.3.1.1 The plan shall assign specific duties and responsibilities and include all airport and community resources necessary to cope with a major aircraft emergency and other potential emergencies requiring ARFF resources.

4.3.2* Airport/community emergency plans shall be tested at least every 3 years in the form of a full-scale exercise.

4.3.2.1 In addition, airport management and resources (including mutual aid resources) shall participate in annual tabletop exercises that encompass their duties and responsibilities depicted in the emergency plan.

4.4 Categorizing Airports for ARFF Services.

4.4.1 The authority having jurisdiction shall determine the level of protection based on the largest aircraft scheduled into the airport.

4.4.2 Airports shall be categorized for ARFF services in accordance with Table 4.4.2. (*See Annex B.*)

Table 4.4.2 Airport Category by Overall Length and Width of Aircraft

Airport Category US			Overall Length of Aircraft Up to but Not Including		Maximum Exterior Width Up to but Not Including	
			ft	m	ft	m
1	A*	1	30	9	6.6	2
2	A*	2	39	12	6.6	2
3	A*	3	59	18	9.8	3
4	A	4	78	24	13.0	4
5	A	5	90	28	13.0	4
6	B	6	126	39	16.4	5
7	C	7	160	49	16.4	5
8	D	8	200	61	23.0	7
9	E	9	250	76	23.0	7
10	E	10	295	90	25.0	8

Notes:

(1) Airport categories are used in the calculations to eliminate the need for calculating specific quantities of extinguishing agents for each type of aircraft.

(2) Although only water is normally necessary for interior handline attack, logistically and tactically it should be discharged as foam and is therefore included in the quantities of water necessary for foam production in Table 5.3.1(a) and Table 5.3.1(b).

*It is FAA Category A if the airport has scheduled service with aircraft that have more than nine passenger seats.

4.4.3* The airport category for a given aircraft shall be based on the overall length of the aircraft or the fuselage width.

4.4.3.1 If, after selecting the category appropriate to the aircraft's overall length, the aircraft's fuselage width is greater than the maximum width given in Table 4.4.2, then the category for that aircraft shall be the next one higher.

Chapter 5 Extinguishing Agents (NFPA 403)

5.1 Primary Agents.

5.1.1* One or more of the following types of primary agents shall be used for aircraft firefighting involving hydrocarbon fuels:

- (1) Aqueous film-forming foams (AFFF)
- (2) Fluoroprotein foam (FP) or film-forming fluoroprotein foam (FFFP)
- (3) Protein foam (P)
- (4) Fluorine-free synthetic foam

5.1.2* All foam concentrates shall be listed.

5.1.2.1 Any primary agent used at the minimum quantities and discharge rates in Table 5.3.1(a) and Table 5.3.1(b) shall meet the applicable fire extinguishment and burnback performance requirements of the performance tests specified.

5.2 Complementary Agents. Each required ARFF vehicle responding shall carry either one or both of the following categories of complementary agents:

- (1)* Potassium-based dry chemical
- (2)* Clean agent

5.3 Quantity of Agents.

5.3.1 The minimum amounts of water for foam production and the minimum amounts of complementary agents necessary

shall be as specified in Table 5.3.1(a) or Table 5.3.1(b), based on the system of categorizing airports listed in Table 4.4.2.

5.3.2 Sufficient foam concentrate shall be provided on each vehicle to proportion, at the prescribed percentage of foam concentrate to water, into double the quantity of water specified in Table 5.3.1(a) or Table 5.3.1(b) at the maximum tolerance specified in this standard.

5.3.3* Each airport shall conduct and document a needs analysis to determine a minimum 100 percent water for foam generation for each initial responding ARFF vehicle within the critical rescue and firefighting access area and ensure that local arrangements fulfill that capability.

5.4* Compatibility of Agents. Chemical compatibility shall be ensured between foam and complementary agents where used simultaneously or consecutively.

5.5* Combustible Metal Agents.

5.5.1 Extinguishing agents for combustible metal fires shall be provided in portable fire extinguishers that are rated for Class D fires in accordance with 5.2.4 of NFPA 10.

5.5.2 At least one nominal 20 lb (9.1 kg) extinguisher shall be carried on each vehicle specified in Table 6.1.1.

5.6 Agent Discharge Capabilities.

5.6.1 The discharge capabilities of extinguishing agents shall not be less than the rates specified in Table 5.3.1(a) or Table 5.3.1(b) of this standard and Table 4.2.1.2(c) and Table 4.2.1.2(d) of NFPA 1900.

5.6.2 Other than at Category 1 and Category 2 airports, where the handline nozzles can be used, the discharge rates for foam shall be met using only the ARFF vehicle turret(s).

Table 5.3.1(a) Extinguishing Agents, Discharge, and Response Capability in US Customary Units

Airport Category	Response Phases	Response Capability (sec)	MIL-F-24835 and ICAO C		ICAO B		ICAO A		Complementary Agents ^a	
			Required Water (gal)	Discharge Capability (m)	Required Water (US gal)	Discharge Capability (gpm)	Required Water (US gal)	Discharge Capability (gpm)	Quantity (lb)	Discharge (lb/sec)
1	Q1 ^b	180 ^b	120	120	160	160	180	180	100	5
	Q2 ^c		0		0		0			
	Q3 ^d		0		0		0			
TOTAL			120		160		180			
2	Q1 ^b	180 ^b	157	157	213	213	236	236	200	5
	Q2 ^c	210 ^c	43		57		64			
	Q3 ^d		0		0		0			
TOTAL			200		270		300			
3	Q1 ^b	180 ^b	285	285	392	392	438	438	300	5
	Q2 ^c	210 ^c	85		118		132			
	Q3 ^d	240 ^{d,e}	300	60	300	60	300	60		
TOTAL			670		810		870			
4	Q1 ^b	180 ^b	468	468	646	646	715	715	300	5
	Q2 ^c	210 ^c	272		374		415			
	Q3 ^d	240 ^{d,e}	600	60	600	60	600	60		
TOTAL			1,340		1,620		1,730			
5	Q1 ^b	180 ^b	863	863	1,194	1,194	1,331	1,331	450	5
	Q2 ^c	210 ^c	647		896		999			
	Q3 ^d	240 ^{d,e}	1,250	125	1,250	125	1,250	125		
TOTAL			2,760		3,340		3,580			
6	Q1 ^b	180 ^b	1,245	1,245	1,725	1,725	1,920	1,920	450	5
	Q2 ^c	210 ^c	1,245		1,725		1,920			
	Q3 ^d	240 ^{d,e}	1,250	125	1,250	125	1,250	125		
TOTAL			3,740		4,700		5,090			
7	Q1 ^b	180 ^b	1,585	1,585	2,192	2,192	2,437	2,437	450	5
	Q2 ^c	210 ^c	2,045		2,828		3,143			
	Q3 ^d	240 ^{d,e}	1,250	125	1,250	125	1,250	125		
TOTAL			4,880		6,270		6,830			
8	Q1 ^b	180 ^b	2,095	2,095	2,901	2,901	3,222	3,222	900	10
	Q2 ^c	210 ^c	3,185		4,409		4,898			
	Q3 ^d	240 ^{d,e}	2,500	250	2,500	250	2,500	250		
TOTAL			7,780		9,810		10,620			
9	Q1 ^b	180 ^b	2,619	2,619	3,626	3,626	4,030	4,030	900	10
	Q2 ^c	210 ^c	4,451		6,164		6,850			
	Q3 ^{d,f}	240 ^{d,e}	2,500	250	2,500	250	2,500	250		
TOTAL			9,570		12,290		13,380			
10	Q1 ^b	180 ^b	3,195	3,195	4,424	4,424	4,915	4,915	900	10
	Q2 ^c	210 ^c	6,069		8,405		9,338			
	Q3 ^d	240 ^{d,e}	5,000	500	5,000	500	5,000	500		
TOTAL			14,260		17,830		19,250			

^aThe minimum quantity is based on ISO qualified potassium bicarbonate. Powder can be substituted by a listed agent exceeding the performance of potassium bicarbonate.

^bQuantity of water for foam production for initial control of the pool fire.

^cQuantity of water for foam production to continue control or fully extinguish the pool fire.

^dWater available for interior firefighting.

^eThe 240-second requirement begins after arrival of the first ARFF apparatus.

^fFor multiple passenger deck aircraft within this category, the Q3 discharge capability should be increased to 375 gpm (1420 L/min) and required water increased to 3750 gal (14,195 L).

Table 5.3.1(b) Extinguishing Agents, Discharge, and Response Capability in SI Units

Airport Category	Response Phases	Response Capability (sec)	MIL-F-24385 and ICAO C		ICAO B		ICAO A		Complementary Agents ^a	
			Required Water (L)	Discharge Capability (L/min)	Required Water (L)	Discharge Capability (L/min)	Required Water (L)	Discharge Capability (L/min)	Quantity (kg)	Discharge (kg/sec)
1	Q1 ^b	180 ^b	450	450	600	600	700	700	45	2.25
	Q2 ^c		0		0		0			
	Q3 ^d		0		0		0			
TOTAL			450		600		700			
2	Q1 ^b	180 ^b	591	591	787	787	906	906	90	2.25
	Q2 ^c	210 ^c	159		213		244			
	Q3 ^d		0		0		0			
TOTAL			750		1,000		1,150			
3	Q1 ^b	180 ^b	1,077	1,077	1,500	1,500	1,692	1,692	135	2.25
	Q2 ^c	210 ^c	323		450		508			
	Q3 ^d	240 ^{d,e}	1,100	110	1,100	110	1,100	110		
TOTAL			2,500		3,050		3,300			
4	Q1 ^b	180 ^b	1,772	1,772	2,468	2,468	2,722	2,722	135	2.25
	Q2 ^c	210 ^c	1,028		1,432		1,578			
	Q3 ^d	240 ^{d,e}	2,250	225	2,250	225	2,250	225		
TOTAL			5,050		6,150		6,550			
5	Q1 ^b	180 ^b	3,257	3,257	4,514	4,514	5,029	5,029	205	2.25
	Q2 ^c	210 ^c	2,443		3,386		3,771			
	Q3 ^d	240 ^{d,e}	4,750	475	4,750	475	4,750	475		
TOTAL			10,450		12,650		13,550			
6	Q1 ^b	180 ^b	4,700	4,700	6,525	6,525	7,250	7,250	205	2.25
	Q2 ^c	210 ^c	4,700		6,525		7,250			
	Q3 ^d	240 ^{d,e}	4,750	475	4,750	475	4,750	475		
TOTAL			14,150		17,800		19,250			
7	Q1 ^b	180 ^b	5,983	5,983	8,297	8,297	9,214	9,214	205	2.25
	Q2 ^c	210 ^c	7,717		10,703		11,886			
	Q3 ^d	240 ^{d,e}	4,750	475	4,750	475	4,750	475		
TOTAL			18,450		23,750		25,850			
8	Q1 ^b	180 ^b	7,937	7,937	10,992	10,992	12,202	12,202	410	4.5
	Q2 ^c	210 ^c	12,063		16,708		18,548			
	Q3 ^d	240 ^{d,e}	9,450	945	9,450	945	9,450	945		
TOTAL			29,450		37,150		40,200			
9	Q1 ^b	180 ^b	9,907	9,907	13,722	13,722	15,259	15,259	410	4.5
	Q2 ^c	210 ^c	16,843		23,328		25,941			
	Q3 ^{d,f}	240 ^{d,e}	9,450	945	9,450	945	9,450	945		
TOTAL			36,200		46,500		50,650			
10	Q1 ^b	180 ^b	12,103	12,103	16,759	16,759	18,603	18,603	410	4.5
	Q2 ^c	210 ^c	22,997		31,841		35,347			
	Q3 ^d	240 ^{d,e}	18,900	1,890	18,900	1,890	18,900	1,890		
TOTAL			54,000		67,500		72,850			

^aThe minimum quantity is based on ISO qualified potassium bicarbonate. Powder can be substituted by a listed agent exceeding the performance of potassium bicarbonate.

^bQuantity of water for foam production for initial control of the pool fire.

^cQuantity of water for foam production to continue control or fully extinguish the pool fire.

^dWater available for interior firefighting.

^eThe 240-second requirement begins after arrival of the first ARFF apparatus.

^fFor multiple passenger deck aircraft within this category, the Q3 discharge capability should be increased to 375 gpm (1420 L/min) and required water increased to 3750 gal (14,195 L).

Chapter 6 Aircraft Rescue and Firefighting (ARFF) Vehicles (NFPA 403)

6.1 Rescue and Firefighting Vehicles.

6.1.1* The minimum number of ARFF vehicles provided at each airport shall be as specified in Table 6.1.1.

Table 6.1.1 Minimum Number of ARFF Vehicles

Airport Category	Number of Vehicles
1	1
2	1
3	1
4	1
5	2
6	2
7	2
8	3
9	4
10	4

6.1.2* Vehicles with sufficient collective capacities shall be constructed to comply with the provisions of Chapters 1 through 6 of NFPA 1900 and Table 5.3.1(a) or Table 5.3.1(b).

6.1.3 Consideration shall be given to the provision of an additional vehicle or vehicles in order that minimum requirements are maintained during periods when a vehicle is out of service.

6.1.4 All foam-producing ARFF vehicles shall be tested annually in accordance with Chapters 27 through 29.

6.1.5 The equipment delivering the complementary agent shall be tested annually by the discharging agent to ensure functionality.

6.2* Tools and Equipment.

6.2.1 Tools and equipment to effectively support ARFF services shall be available at the incident or accident scene within the required response time.

Chapter 7 Airport Emergency Communications (NFPA 403)

7.1 Communications and Alarms.

7.1.1 Airport ARFF services communications shall have a capability that is consistent with the airport's operational needs.

7.1.2 The operational communications system shall provide a primary and, where necessary, an alternate means for direct communication between the following, as applicable (*see Annex C*):

- (1) Alerting authority such as the air traffic control tower or flight service station, airport manager, fixed-base operator, or airline office and the airport ARFF service
- (2) Air traffic control tower or flight service station and ARFF vehicles en route to an aircraft emergency or at the accident or incident site
- (3) Fire department alarm room and ARFF vehicles at the accident or incident site
- (4) Airport ARFF services and applicable mutual aid organizations located on or off the airport
- (5) ARFF vehicles

- (6) Responding vehicles and an aircraft in a situation of emergency using an established discreet VHF frequency

7.1.3 To ensure that the communications system is operational under a variety of airport emergency conditions, provisions shall be made for an emergency standby power source or alternate backup communications system.

7.1.4 A preventive maintenance program shall be carried on to keep all communications equipment in a fully serviceable condition.

7.1.5 The functional performance of all communications systems shall be tested at intervals not exceeding 24 hours.

Chapter 8 ARFF Personnel, Protective Clothing, and Equipment (NFPA 403)

8.1 Personnel.

8.1.1 A person shall be appointed to direct the airport ARFF services.

8.1.1.1 The responsibilities of this person shall include overall administrative supervision of the organization, effective training of personnel, and operational control of emergencies involving aircraft within the airport jurisdiction.

8.1.2* During flight operations and 15 minutes prior and 15 minutes following, ARFF personnel shall be readily available to staff the rescue and firefighting vehicles and to perform firefighting and rescue operations.

8.1.2.1 Staffing levels shall be as follows:

- (1) Established through a task resource analysis based on the needs and demands of the airport
- (2) Not be lower than the values specified in Table 8.1.2.1 for the minimum total number of ARFF-trained personnel responding to an initial alarm, based on the minimum response times in Chapter 9 and extinguishing agent discharge rates and quantities required in Chapter 5

8.1.2.2 A task and resource analysis shall be performed to determine additional staffing requirements.

8.1.2.2.1 This analysis shall be documented.

8.1.2.2.2 Under no circumstances shall the minimum required staffing be less than those values appearing in Table 8.1.2.1. (*See Annex D.*)

Table 8.1.2.1 Minimum Required ARFF Personnel at Airports

Airport Category	ARFF Personnel
1	2
2	2
3	2
4	3
5	6
6	9
7	9
8	12
9	15
10	15

Note: See also Annex D.

8.1.3 Responding units shall include personnel trained and equipped for cabin interior firefighting.

8.1.3.1 The responding units and personnel shall demonstrate the ability to apply extinguishing agent to the interior of the aircraft within 4 minutes of arrival at the accident/incident location by the first arriving ARFF unit.

8.1.4 All ARFF personnel shall meet the requirements of NFPA 1003.

8.1.4.1 All ARFF personnel shall undertake recurrent training meeting the requirements of Chapters 11 through 26. (*See Annex E.*)

8.1.5 All ARFF and other authorized personnel shall be given suitable uniforms or identifying insignia to prevent any misunderstanding as to their right to be in the fire area or the aircraft movement area of an airport during an emergency.

8.1.6 Wherever possible, at international airports, the incident commander (IC) shall have a reasonable command of the English language to facilitate communication with the flight crew.

8.2 Protective Clothing.

8.2.1* A complete set of approved personal protective clothing and equipment shall be provided, maintained, and readily available for use by each person required to perform duties in the hot and warm operational zones.

8.2.2* All personnel engaged in operations within the immediate emergency area of an aircraft accident shall wear approved personal protective clothing and equipment commensurate with their level of involvement.

8.2.2.1 Personnel in 8.2.2 shall not remove any portion of personal protective clothing and equipment until in a declared safe area or as directed to do so by the IC or his or her representative.

Chapter 9 Airport Fire Station Location and Response Capability (NFPA 403)

9.1 Siting and Response.

9.1.1* ARFF vehicles shall be garaged at one or more strategic locations as needed to meet required response times.

9.1.2* Emergency equipment shall have immediate and direct access to critical aircraft movement areas and the capability of reaching all points within the rapid response area (RRA) in the time specified.

9.1.2.1 Therefore, the location of the airport fire station(s) shall be based on minimizing response time to aircraft accidents and incidents and other required response areas.

9.1.3* Response Time.

9.1.3.1* The response time of the first-arriving ARFF vehicle to reach any point on the operational runway and begin agent application shall be within 3 minutes of the time of the alarm.

9.1.3.2* The response time of the first-arriving ARFF vehicle to reach any point remaining within the on-airport portion of the RRA with improved surface conditions shall be within 4 minutes from the time of the alarm.

9.1.3.3* The response time of the first-arriving ARFF vehicle to reach any passenger boarding areas with improved surface conditions shall be within 4 minutes from the time of the alarm.

9.1.3.4 All response times shall be in optimum visibility and surface conditions.

9.1.3.5 Additional ARFF vehicles necessary to achieve the agent discharge rate shall arrive in accordance with the times specified in Table 5.3.1 (a) or Table 5.3.1 (b).

9.1.4 Airport ARFF services shall develop/implement a plan for responding to an accident/incident involving any aircraft within the aircraft movement area beyond or outside the runway and RRA.

Chapter 10 Special Events (NFPA 403)

10.1* Airport-Based Air Shows.

10.1.1 Prior to the air show, ARFF personnel shall meet with the air show operations officer, air show air boss, and appropriate air traffic control personnel to review areas of responsibility.

10.1.1.1 All participating agencies shall either participate in a pre-event tabletop emergency response exercise or be available to conduct an emergency response drill prior to the air show.

10.1.1.2 The planning meeting shall include, at a minimum, the following:

- (1) Written or graphic illustration of the aerobatic box to be reviewed during the pre-air show safety briefing
- (2) Review of procedures and methods to establish the standard radio communications and runway/taxiway clearances required during the air show
- (3) Review of pre-fire plans for participating aircraft and a discussion about emergency extraction, canopy release, fuel shutoff, master on/off switch, and aircraft lift points
- (4) Hands-on training, if available

10.1.2* ARFF vehicles and crew shall be prepositioned during the period of the air show waiver in such a way that ARFF personnel can respond to an accident or incident and deploy firefighting agents within 60 seconds to anywhere within the aerobatic box in optimum conditions of visibility and surface conditions.

10.1.3 During the period of the air show waiver, responding crew shall have personal protective equipment (PPE) donned and will be ready to respond.

10.1.4 Vehicle engines shall be running throughout the entire active flying portion of the air show.

10.1.5* ARFF vehicles assigned to an air show shall not be positioned behind the crowd line.

10.1.5.1 Friends and family shall not be located in the area of ARFF vehicle positions.

10.1.5.2 Folding chairs or any other obstructions shall not be positioned in front of prepositioned ARFF vehicles.

10.1.6* Public air shows expected to include jet or turbine performances, or any air show in which the length of the aerobatic box exceeds 8,000 ft or the width of the aerobatic box exceeds 2,000 ft, ARFF vehicles and crash fire rescue (CFR) personnel shall be deployed to the right and left of the air

show/open house crowd area with unimpeded access to the area in which air show flight operations are conducted.

10.1.7* An ARFF vehicle shall be positioned at or near show center.

10.1.7.1 All deployed vehicles shall be positioned so that they have an unobstructed line of sight on the whole airfield, specifically, the aerobatic box in which the majority of the air show flight operations are conducted.

10.1.8 Prefire plans for specific aircraft shall be made available.

10.1.8.1 A written or graphic illustration of the aerobatic box shall be presented to performers and emergency response personnel during the pre-air show safety briefing.

10.1.8.2 In consultation with the air show operations officer and the air show air boss, firefighters shall either participate in a pre-event tabletop emergency response exercise or be available to conduct an emergency response drill on the practice/rehearsal day of the air show (typically a Friday for a Saturday/Sunday event).

10.1.9 Hands on training, if available, shall be provided.

10.1.9.1* Prior to the beginning of air show flight operations, at least one firefighter from each ARFF vehicle deployed in support of the show shall make themselves available to meet with the pilot-in-command of each aircraft participating in the air show or open house to discuss emergency extraction, canopy release, fuel shutoff, master switch on/off switch and aircraft lift points.

10.1.10* Prior to the air show and not later than the first safety briefing on the rehearsal or practice day of the air show (typically Friday at most shows), firefighters shall meet with the air show operations officer, the air show air boss, and appropriate air traffic control personnel to discuss procedures and methods to establish the standard radio communications and runway/taxiway clearances required for ARFF personnel to respond to an incident or accident during the air show.

10.1.11 To ensure clear lines of communications, the incident commander shall consider positioning himself or herself or a liaison with the air boss throughout the air show.

10.2 ARFF Vehicle Positioning at Air Shows.

10.2.1 ARFF vehicles and crew shall be pre-positioned to allow ARFF personnel to respond to an accident or incident within 60 seconds to any point within the aerobatic box.

10.2.2 During the period of the air show waiver, responding crew shall have PPE prepared and teams ready to respond.

10.2.3 All deployed vehicles shall be positioned so that they have an unobstructed line of sight on the whole airfield, specifically, the aerobatic box in which the majority of the air show flight operations are conducted.

10.2.4 ARFF vehicles assigned to an air show shall not be positioned behind the crowd line.

10.2.5 For public air shows in which the length of the aerobatic box exceeds 8,000 ft or the width of the aerobatic box exceeds 2,000 ft, ARFF vehicles and personnel shall be deployed to the right and left of the air show/open house crowd area with unimpeded access to the area in which the air show flight operations are conducted.

10.2.6 To ensure clear lines of communication, the incident commander shall consider positioning a liaison with the air boss throughout the air show.

Chapter 11 General Requirements (NFPA 405)

11.1 Administration.

11.1.1 Scope. Chapters 11 through 26 contain the required performance criteria by which an authority having jurisdiction over aircraft rescue and firefighting (ARFF) maintains proficiency and effective ARFF at airports.

11.1.2 Purpose. Chapters 11 through 26 are intended for the use of those charged with maintaining ARFF services at airports and establishes the basis for a recurring training program that focuses on measurable performance criteria.

11.1.2.1 Chapters 11 through 26 address the development of productive and coordinated aircraft rescue and fire control operations with a goal of reducing risk for participants and the environment.

11.1.2.2 Results of evaluations conducted in accordance with the requirements of Chapters 11 through 26 shall be recorded and maintained by the authority having jurisdiction.

11.1.2.3 Continuous broad-based training is fundamental to maintaining proficient ARFF services at airports.

11.1.2.4 ARFF personnel at airports shall meet the requirements of NFPA 1003 prior to assignment and thereafter receive necessary recurring training that will enable them to consistently meet the requirements of Chapters 11 through 26 relative to each individual's role and tasks.

11.1.3 Application.

11.1.3.1 The provisions of Chapters 11 through 26 are considered fundamental to maintaining levels of professional competence of ARFF services at airports.

11.1.3.2 Chapters 11 through 26 are intended to be adopted as a model for the development of a proficient in-service training program for ARFF personnel at airports.

11.1.3.3 The authority having jurisdiction has the responsibility to ensure that ARFF personnel receive initial training in relation to each individual's role and expected tasks to enable them to perform competently. It is recognized that recurring proficiency training assists in the maintenance of competence through practice of initial skills and reinforcement of knowledge.

11.2 General.

11.2.1 Each evaluation of skills and knowledge required by Chapters 11 through 26 shall be conducted at regular intervals of at least once every twelve (12) consecutive calendar months by a designated qualified evaluator(s) appointed by the authority having jurisdiction.

11.2.2 All evaluations shall be performed as follows:

- (1) As determined by the authority having jurisdiction
- (2) So as to meet each objective in its entirety

11.3 Evaluation Criteria. The authority having jurisdiction shall establish the evaluation criteria for each objective or task

to be evaluated in accordance with Chapters 11 through 26 to ensure competency for each person assigned ARFF duties.

11.3.1 Where actual operation is not possible, evaluation of skills and knowledge shall be carried out by simulations.

11.3.2 Those simulated exercises shall be structured to involve the organization and achievement of specific task(s), to include team coordination, explanations, and illustrations that seek to reproduce a real-life situation.

11.3.3 Whenever any of the following terms — *rules, regulations, procedures, supplies, apparatus, and equipment* — are referred to in Chapters 11 through 26, it shall be implied that they are the terms of the authority having jurisdiction.

11.4* Record Keeping. Records sections, including “general” individual training records, shall be maintained for each ARFF employee and include the following:

- (1) Name of the individual
- (2) Date of training
- (3) Subject covered, course methodology, and training materials utilized
- (4) Climate conditions and time of day
- (5) Duration of training
- (6) Instructor comments
- (7) Performance evaluation
- (8) Name of instructor
- (9) Signature of student

Chapter 12 Airport Familiarization (NFPA 405)

12.1 Scope. This chapter identifies the knowledge and skills necessary to maintain proficiency in airport familiarization.

12.2 Competency.

12.2.1 ARFF personnel shall demonstrate a thorough knowledge of their airport and its immediate surrounding area under all operating conditions, which is fundamental in achieving a rapid response by ARFF personnel and equipment to the critical rescue and firefighting access area (CRFFAA), with special emphasis to prevent runway incursions.

12.2.2 The program shall train ARFF personnel during both daytime and nighttime hours and include airport-specific training.

12.3 Criteria. ARFF personnel, given a map of the airport and vicinity, shall be able to perform all of the following:

- (1) Identify all runways, taxiways, and access roads, their designations and associated aircraft travel direction, and road restrictions
- (2) Describe the airfield lighting system (i.e., center line, edge and threshold lights, and so on)
- (3) Describe airfield pavement marking and signing systems, including standard colors used in markings and signs
- (4) Identify the limits of the runway safety areas on the airport, including engineered materials arresting systems (EMAS), as applicable
- (5) Identify the various aircraft navigational aids and associated critical areas located on the airport
- (6) Describe airport rules and regulations for operating and accessing on the airport’s movement and nonmovement areas, including communicating with the air traffic control tower (ATCT)

- (7) Identify key terrain features, installations, and potential hazards on the airport
- (8) Identify the probable direction of fuel travel in a simulated leak in the fuel distribution system
- (9) Identify the location of all emergency fuel shutoff(s) and describe the process by which these shutoffs stop the flow of fuel within the system
- (10) Identify hazardous materials locations stored or used on the airport
- (11) Identify aircraft ramps/parking areas and related support facilities
- (12) Identify frangible gate locations, predesignated staging areas, and controlled access points
- (13) Identify water supply locations
- (14) Identify fuel storage and distribution locations
- (15) Identify roadways that cannot be utilized by ARFF apparatus due to road restrictions such as length, height, weight, etc.

12.4 Scenarios. Given a simulated incident or accident scenario, a radio, and a destination on the airport, ARFF personnel shall demonstrate competency in performing the following:

- (1) Communicate with the air traffic control (ATC) on appropriate frequency
- (2) Obtain all necessary clearances
- (3) Select the shortest and safest response route to arrive at the designated point within specified times required by the authority having jurisdiction
- (4) Communicate directly by radio with a flight crew regarding the aircraft emergency situation
- (5) Identify and interpret light-gun signals used by the air traffic control tower (ATCT)

12.5 Airport Markings. ARFF personnel, given a diagram of the aircraft movement area, shall identify the following airport markings:

- (1) Color of runway markings
- (2) Color of taxiway markings
- (3) Hold position markings
- (4) Displaced thresholds
- (5) Aiming point/landing zone bars
- (6) Apron ground markings
- (7) Other painted surface markings
- (8) Any additional markings applicable to the airport

12.6 Lighting. ARFF personnel shall demonstrate a knowledge of the following:

- (1) Runway centerline and edge lighting
- (2) Taxiway centerline and edge lighting
- (3) Runway threshold lights
- (4) Runway end identifier lights
- (5) Obstruction lighting
- (6) Visual slope indicator lights
- (7) Runway guard lights
- (8) Stop bars
- (9) Runway status lights
- (10) Surface Movement Guidance Control System (SMGCS)
- (11) Any additional lighting applicable to the airport

12.7 Signage. ARFF personnel shall identify the following signage systems for the airport:

- (1) Runway distance remaining signs
- (2) Directional signs
- (3) Runway signs

- (4) Taxiway signs
- (5) Any additional signage applicable to the airport

12.8 Airport Traffic Vehicle. Given a map of the airport, ARFF personnel shall identify all motor vehicle traffic routes and the traffic flow system of the airport, including vehicle parking and storage areas.

Chapter 13 Aircraft Familiarization (NFPA 405)

13.1 Scope. This chapter identifies the knowledge and skills necessary to maintain proficiency in aircraft familiarization.

13.2* Competency. ARFF personnel shall demonstrate a thorough knowledge of all types of aircraft utilizing the airport.

13.3 Criteria. ARFF personnel shall possess the following knowledge:

- (1) Identify the various types and models of aircraft, including the approximate number of passengers each is designed to carry
- (2) Identify the categories of aircraft propulsion systems and their associated hazards
- (3) Identify major aircraft structural components using the correct terms and nomenclature
- (4) Describe materials used in aircraft construction and their effects on fire and rescue operations
- (5) Demonstrate the correct use of an aircraft familiarization chart by identifying and describing important aircraft components
- (6) Locate, identify, and have a working knowledge of the aircraft systems and components for aircraft typically operating at the airport
- (7) Estimated typical crew and passenger capacity
- (8) Correct location and operation of normal entry door(s), emergency exit openings, evacuation slides, and cargo compartment doors
- (9) Exits that have evacuation slides and the evacuation slide deployment that will be inhibited when accessed from the aircraft exterior
- (10) Location of aircraft propulsion and auxiliary power units (APU), including normal and emergency shutdown procedures for each
- (11) Type, location, and isolation of batteries found on aircraft and their associated hazards
- (12) Crew compartment locations and access
- (13) Fuel used, location of fuel tanks, fuel line locations, and capacity of fuel tanks for a given aircraft
- (14) Hydraulic reservoirs and hydraulic accumulators
- (15) Oxygen cylinders and oxygen generators
- (16) Brake and wheel systems
- (17) Ground ventilations and outflow valve(s)
- (18) Flight data recorder and cockpit voice recorder
- (19) Various onboard fire protection warning and extinguishment systems
- (20) Flight interphone system
- (21) Access panels
- (22)* Any hazards unique to a particular aircraft, such as ram air turbines (RAT) or air-driven generators (ADG)
- (23) Any hazards associated with military aircraft, such as ejection seats, armament, exotic metals, composite materials, and specialized fuels

Chapter 14 ARFF Personnel Safety and Safety Management (NFPA 405)

14.1* Scope. This chapter identifies the knowledge and skills necessary to ensure safety as it relates to ARFF personnel and safety management.

14.2 Competency. To reduce the risk associated with ARFF operations, ARFF personnel shall have in-depth knowledge of the exposure to the hazards associated with their occupation through training and testing of their knowledge and skills.

14.3 Criteria. ARFF personnel shall demonstrate the knowledge to describe the following:

- (1) Hazards associated with aircraft rescue and firefighting
- (2) Hazards to personnel posed by aircraft and aircraft systems
- (3) Common fireground accidents
- (4) Causes of injuries in specific incidents
- (5) Correct lifting and equipment-handling techniques
- (6) Slip, trip, and fall hazards
- (7) Dangers associated with cutting or striking stationary or moving objects
- (8) Overexertion, on-scene personnel rehabilitation, and other physiological factors
- (9) Use of issued and approved protective clothing and equipment
- (10) The limitations of protective clothing and equipment, and the proper safety precautions to take while wearing personal protective equipment (PPE) — specifically while operating power and hand tools
- (11) The purpose, components, operation, and limitations of self-contained breathing apparatus (SCBA), including the following:
 - (a) The inspection process for an SCBA
 - (b) Changing the air supply cylinder of a team member with an exhausted air supply cylinder
 - (c) The proper donning and doffing of the SCBA
- (12) Mounting, dismounting, and riding various types of apparatus
- (13) Basic driving skills and distractions associated with vehicle operations
- (14) Behavioral health and wellness programs
- (15) Methods of protection against other potentially infectious material
- (16) Water rescue operations
- (17) Use of tools and equipment

Chapter 15 Personal Protective Equipment (NFPA 405)

15.1 Scope. This chapter identifies the knowledge and skills necessary to identify, maintain, and utilize personal protective equipment (PPE).

15.2 Competency. ARFF personnel shall demonstrate their knowledge of PPE.

15.3 Criteria. ARFF personnel shall be able to demonstrate the wearing, daily inspection, care, maintenance, and purpose of the following protective clothing and equipment:

- (1) Boots
- (2) Gloves
- (3) Turnout coat
- (4) Turnout pants

- (5) Helmet
- (6) Eye protection
- (7) SCBA
- (8) Other issued respiratory protection
- (9) Protective hoods
- (10) Specialized clothing as required for a specific hazard
- (11) Hearing protection

15.4 Breathing Apparatus. ARFF personnel shall be able to demonstrate the various components and their purpose relative to their assigned breathing apparatus, including the following:

- (1) Physiology of respiration, including the following:
 - (a) Respiratory system
 - (b) Need for respiratory protection
- (2) Types of breathing apparatus assigned and available for use by ARFF personnel
- (3) Breathing apparatus procedures, including the following:
 - (a) Donning and doffing procedures
 - (b) Safety precautions and emergency procedures
 - (c) Decontamination/cleaning methods and procedures
 - (d) Inspection, care, and maintenance of all SCBA components
 - (e) Breathing apparatus control procedures
 - (f) Cylinder removal and replacement
 - (g) Cylinder recharging
 - (h) Daily inspection checklist
 - (i) Emergency procedures to be taken when the following situations occur:
 - i. Cylinder low-air alarm activation
 - ii. Cylinder air supply is exhausted
 - iii. Breathing regulator malfunction
 - iv. Face piece damage
 - v. Low-pressure hose damage
 - vi. High-pressure hose damage
 - (j) Identification of the location and the proper mounting, donning and doffing of the vehicle seat-mounted breathing apparatus, where provided

Chapter 16 Aircraft Cargo Hazards (NFPA 405)

16.1* Scope. This chapter identifies the knowledge, skills, and procedures necessary to identify and mitigate cargo hazards during emergencies.

16.2 Competency. ARFF personnel shall demonstrate familiarity with the level of personal protection required for dealing with specific incidents.

16.3 Criteria. ARFF personnel shall demonstrate the following:

- (1) Comprehensive knowledge of the airport's dangerous goods response plan
- (2) Use of reference materials to identify dangerous goods and determine the applicable action to manage the incident
- (3) Procedures for the identification, risk assessment, isolation, rescue, and evacuation requirements for a given dangerous goods incident

- (4) Correct utilization of PPE and monitoring devices as they relate to the airport's dangerous goods response plan

16.4 Decontamination. ARFF personnel shall, for a given dangerous goods incident, identify the decontamination procedures required for personnel, equipment, and the incident site.

Chapter 17 Emergency Communications Systems (NFPA 405)

17.1 Scope. This chapter identifies the knowledge and skills necessary to identify and operate airport communications systems accessible for fire department use.

17.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills pertaining to the use and required maintenance of communications systems used by the airport fire department.

17.3 Criteria. ARFF personnel shall be able to maintain and demonstrate a proficiency in the following:

- (1) Knowledge of and ability to operate all radio systems and frequencies using prescribed procedures, discipline, and protocol to communicate with the following entities/agencies as applicable:
 - (a) Control tower or Common Traffic Advisory Frequency (CTAF)
 - (b) Airport administrative offices
 - (c) Airlines
 - (d) Fixed-base operators
 - (e) Mutual aid agencies
 - (f) Airport service vehicles
 - (g) Airport fire service vehicles
- (2) Emergency notification and reporting procedures
- (3) Knowledge of phonetic alphabet and standard airport communications terminology
- (4) Knowledge of and ability to operate all fire department, ground control, mutual aid, and airport radio frequencies using prescribed procedures, discipline, and protocol
- (5) Ability to initiate and operate all communications features contained in the fire department alarm room, its emergency vehicles, and any vehicle dedicated for use as a communications or command unit
- (6) Ability to communicate with flight deck personnel by means of an aircraft's interphone system, by control tower relay, by direct radio contact, and by use of standard international ground-to-aircraft hand signals
- (7) Knowledge of location of the aircraft interphone system jack located on each aircraft type using the airport
- (8) Ability to locate, for purposes of emergency use, vital telephone numbers so that calls can be directed to individuals and agencies as required
- (9) Working knowledge of alternate means of communications; the location and use of special equipment such as cellular and hardwired field phones, power megaphones, and flashlights for hand signaling; and the ability to interpret light signals from the control tower

Chapter 18 ARFF Vehicles and Equipment (NFPA 405)

18.1 Scope. This chapter identifies the knowledge and skills to be demonstrated by designated ARFF personnel who are required to operate ARFF vehicles and special equipment under all operating conditions.

18.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills pertaining to the use of required ARFF vehicles and equipment used by the airport fire department.

18.3 Criteria. ARFF personnel shall be able to describe the equipment and its location on each ARFF vehicle at the airport.

18.4 Tools and Equipment.

18.4.1 ARFF personnel shall be able to describe the individual tools and equipment on each ARFF vehicle on the airport.

18.4.2 The description shall include the equipment's designed use, required maintenance, storage procedures, and a demonstration of its use.

18.5 Vehicle Inspection and Maintenance. ARFF personnel shall be able to demonstrate their knowledge and skills relative to routine inspection and maintenance of vehicles in accordance with fire department policy and manufacturers' specifications and maintenance manuals.

18.6 Operation of Equipment and Devices. ARFF personnel shall be able to demonstrate the knowledge and skills to operate the following systems when assigned to an emergency vehicle:

- (1) Communications equipment
- (2) Pump operation
- (3) Proportioning system
- (4) Turret(s)
- (5) Vehicle-mounted elevated devices, where provided, such as extendable turret (ET) systems
- (6) Skin-penetrating tools, where provided
- (7) Various nozzles — types and applications
- (8) Lighting systems — for accident site
- (9) Vision enhancement systems utilized during low visibility
- (10) Rescue tools
- (11) Ladders
- (12) Ventilation equipment
- (13) Complementary agent system, inspection, operation, and reservicing
- (14) Systems for reservicing of firefighting agent
- (15) Backup systems for the production and application of firefighting agent, where applicable

18.7 ARFF Vehicle Operation. Designated ARFF personnel shall have the knowledge and skills to operate the assigned vehicle(s) under the following conditions:

- (1) While responding to an incident/accident
- (2) While operating and maneuvering at an emergency scene
- (3) With its agent tanks fully loaded, semiloading, and unloaded
- (4) In all climatic conditions experienced at the airport
- (5) Within certain limits while negotiating high-speed tight turns and high-speed braking
- (6) In an environment that has no signage
- (7) In various conditions of lighting
- (8) In off-road conditions

- (9) While discharging firefighting agent on the move or at a static position through the turret(s) and under truck nozzles, as applicable

Chapter 19 Extinguishing Agents (NFPA 405)

19.1 Scope. This chapter identifies the knowledge and skills required for ARFF personnel relative to the correct agent selection and application technique of extinguishing agents to be used on fires involving aircraft.

19.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills pertaining to the selection and use of extinguishing agents used by the airport fire department.

19.3 Criteria. Given all the extinguishing agents used at the airport, ARFF personnel shall be able to describe the choice and application of extinguishing agents.

19.4 Selection and Application. ARFF personnel shall be able to describe and demonstrate the agent selection and application technique of extinguishing agents for the following types of fires:

- (1) Aviation fuels
- (2) Interior aircraft combustibles
- (3) Combustible metals
- (4) Energized electrical equipment
- (5) Composite materials
- (6) Engine
- (7) Cargo
- (8) Wheel
- (9) Avionics bay
- (10) Auxiliary power unit (APU)
- (11) Different battery types

19.5 Descriptions of Effects. Given all the extinguishing agents used at the airport, ARFF personnel shall be able to describe the positive and negative effects of agent application when the following conditions exist:

- (1) Wind
- (2) Rain
- (3) Freezing weather
- (4) Extreme heat
- (5) Use of more than one agent (i.e., compatibility)
- (6) Fuel-soaked surfaces
- (7) Flowing fuel
- (8) Pressurized fuel
- (9) Confined spaces
- (10) Uneven terrain

19.6 Description of Environmental Effects.

19.6.1 ARFF personnel shall know where to find the safety data sheets (SDS) for all extinguishing agents in use at their airport.

19.6.2 ARFF personnel shall be able to demonstrate knowledge of the required local, state, and federal procedures in order to minimize the impact of these agents on the environment.

Chapter 20 Emergency Aircraft Evacuation Assistance (NFPA 405)

20.1 Scope. This chapter identifies the comprehensive knowledge and skills necessary in emergency aircraft evacuation procedures for all types of aircraft using the airport.

20.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills pertaining to emergency aircraft evacuation systems and devices.

20.3 Criteria. ARFF personnel shall be able to demonstrate knowledge of the following emergency evacuation systems and devices:

- (1) Aircraft emergency exits
- (2) Aircraft evacuation slides
- (3) Military aircraft evacuation and ejection systems and canopy ejection systems, where applicable
- (4) Aircraft interior access vehicle
- (5) Cut-in/forcible entry areas to specifically include the hazards associated with cutting, forcing, prying, or piercing the skin of an aircraft
- (6) Exterior access equipment
- (7)* Passenger and crew seat restraint systems
- (8) Crew seat operation
- (9) Cockpit ingress/egress
- (10) Aircraft ballistic air bags
- (11) Ballistic parachute systems

Chapter 21 Rescue and Firefighting Operations (NFPA 405)

21.1* Scope. This chapter identifies the knowledge and skills necessary during an emergency involving aircraft.

21.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills pertaining to the rescue and firefighting operations at airports.

21.3 Criteria. ARFF personnel shall be able to describe how each of the following items affects an emergency response:

- (1) Nature of the emergency
- (2) Type of aircraft
- (3) Number of passengers and crew
- (4) Amount of fuel on board
- (5) Expected runway and airport traffic patterns for aircraft
- (6) Location of the incident/accident and response time
- (7) Type and location of cargo
- (8) Wind direction and velocity
- (9) Weather conditions and terrain
- (10) ARFF vehicle status
- (11) Time of day or night

21.4 Emergency Alerts. ARFF personnel shall be able to identify the types of emergency alerts that occur on the airport and the actions of the fire department required for each type.

21.5 Vehicle Routes. Given multiple locations on and off the airport, ARFF personnel shall be able to describe the response routes, alternate routes, and problems or hazards that they present.

21.6 Size-Up Procedures. Given any accident situation, ARFF personnel shall describe how the correct “size-up” (risk assessment) procedures are carried out.

21.7 Factors Affecting Fire Attack. Given a fire situation, ARFF personnel shall describe how the following factors affect the fire attack:

- (1) Wind
- (2) Terrain
- (3) Wreckage
- (4) Survivors
- (5) Hazardous areas

21.8 Response Considerations. ARFF personnel shall be able to define the following factors in regard to an aircraft fire and their relationships as exposures:

- (1) Survivors
- (2) Other aircraft
- (3) Structures
- (4) Unaffected parts of the involved aircraft

21.9 Tactical Considerations. ARFF personnel shall be able to define and prioritize the following tactical fire suppression considerations:

- (1) Rescue
- (2) Exposure protection
- (3) Fire confinement
- (4) Ventilation
- (5) Interior attack
- (6) Fire extinguishment
- (7) Overhaul
- (8) Environmental impact

21.10 ARFF Vehicle Positioning. Given a scenario, ARFF personnel shall explain the positioning of ARFF vehicles to assist in a given strategy with respect to the following factors:

- (1) Ground slope
- (2) Wind direction
- (3) Movement of other vehicles
- (4) Applicable use of turrets and handlines

21.11 Agent Application. ARFF personnel shall be able to describe the factors, including agent selection and application techniques, that affect extinguishing agent application pertinent to water or agent conservation.

21.12 Ventilation Considerations. ARFF personnel shall be able to identify the following ventilation factors as they relate to an aircraft fire:

- (1) Backdraft considerations
- (2) Flashover considerations
- (3) Ventilation locations
- (4) Methods of ventilation

21.13 Structural Apparatus. ARFF personnel shall be able to define the role of structural apparatus that respond to aircraft emergencies.

21.14 Extinguishing Agent Resupply. ARFF personnel shall be able to explain extinguishing agent resupply procedures established by the airport fire department.

21.15 Fire Department Supply and Resupply. ARFF personnel shall be able to identify fire department supply and resupply sources on and adjacent to the airport.

21.16 Other Aircraft Accident Considerations. ARFF personnel shall be able to explain other aircraft accident operation policy procedures established by their fire department as they relate to the following:

- (1) Biological hazards or hazardous materials considerations
- (2) Site security
- (3) Evidence preservation with emphasis on site photographs and documentation
- (4) Relocation of human and fragmented remains
- (5) Movement of wreckage and preservation of accident evidence to include the marking or diagramming of wreckage moved from its original post-accident location
- (6) Mass casualty, including the following:
 - (a) Casualty collection point
 - (b) Treatment area
 - (c) Transportation
 - (d) Routing

Chapter 22 Recurrent Live Fire Training (NFPA 405)

22.1 Scope. This chapter identifies the knowledge and skills to be demonstrated by designated ARFF personnel required for live fire recurrent training.

22.2 Competency. ARFF personnel shall demonstrate the knowledge and operational skills necessary to extinguish a live aircraft fire.

22.3 Criteria. Given extinguishing agents, ARFF personnel shall choose the appropriate extinguishing agent to extinguish a live aircraft fire.

22.4* Live Spill Fire Training. The live spill fire training in 22.4.1 through 22.4.3 shall use hydrocarbon fuel, propane, or a combination of both.

22.4.1* When conducting live spill fire training, ARFF personnel shall utilize the minimum burn area based on the airport category.

22.4.2 ARFF personnel shall extinguish an aircraft fuel spill fire utilizing the appropriately sized burn area, given PPE, an assignment, and an ARFF vehicle handline flowing an appropriate extinguishing agent, so that the agent is applied using the proper techniques and the fire is completely extinguished.

22.4.3 ARFF personnel shall extinguish an aircraft fuel spill fire utilizing the appropriately sized burn area, given PPE, an assignment, and an ARFF vehicle turret flowing an appropriate extinguishing agent, so that the agent is applied using the proper techniques and the fire is completely extinguished.

22.5* Live Fire Training.

22.5.1 The live fire training in 22.5.2 shall use hydrocarbon fuel, propane, or a combination of both.

22.5.2 ARFF personnel shall attack a fire while operating as a member of a team, given a team, approved PPE, an assignment, a firefighting vehicle hand line or vehicle turret, and an extinguishing agent.

22.5.3 ARFF personnel shall ensure access is gained into the fire area, effective agent application practices are used, the fire is approached, attack techniques facilitate suppression given the level of the fire, hidden fires are located and controlled, and hazards are avoided or managed.

22.5.4 ARFF personnel shall demonstrate the ability to bring a fire under control in three of the following seven fire scenarios:

- (1) Interior fire
- (2) Auxiliary power unit (APU) fire
- (3) Engine fire
- (4) Wheel well/brake fire
- (5) Electronics and electrical (E and E) compartment fire
- (6) Three-dimensional aircraft running fuel fire
- (7) Aircraft incident/accident debris fire

22.6 Extendable Turret (ET) Live Fire Training.

22.6.1 ARFF personnel shall attack a fire while operating as a member of a team, given a team, an assignment, an ARFF vehicle boom-mounted turret flowing the approved minimum required flow, a piercing tip, and procedures for agent application, so that the chosen agent is applied according to procedures for agent application.

22.6.2 ARFF personnel shall ensure the fire is extinguished as required by the AHJ in three of the following six fire scenarios:

- (1) Interior fire
- (2) Auxiliary power unit (APU) fire
- (3) Engine fire
- (4) Wheel wheel/brake fire
- (5) Baggage or cargo hold fire
- (6) Three-dimensional aircraft running fuel fire

Chapter 23 Airport Emergency Plan (NFPA 405)

23.1* Scope. ARFF personnel shall understand their duties and responsibilities as defined in the airport emergency plan (AEP).

23.2 Competency. ARFF personnel shall be able to identify and describe each type of emergency listed in the plan, including alert procedures, that requires a response from the fire department.

23.3 Criteria. Given the AEP, ARFF personnel shall demonstrate the proper knowledge to respond to accidents and incidents in the airport in accordance with the AEP.

23.4 Incident Command. For each emergency involving the fire department, ARFF personnel shall provide descriptions or identify the following:

- (1) Describe the chain of command and command authority at incidents both on and off the airport
- (2) Identify the functional areas of the Incident Command System (ICS) and their responsibilities in the National Incident Management System (NIMS)
- (3) Describe the procedures for the change of command during any phase of the emergency
- (4) Identify and describe other agencies involved in the unified command system, including the role, responsibility, and authority of each individual agency
- (5) Describe, in general, various ARFF personnel duties and responsibilities under the plan
- (6) Describe the incident management structure in use at the airport and how this interfaces with external mutual aid organizations
- (7) Describe differences in offensive and defensive in ARFF operations

Chapter 24 Emergency Medical Services (EMS) (NFPA 405)

- 24.1 Scope.** ARFF personnel shall maintain EMS training based on the requirements of the authority having jurisdiction.
- 24.2 Competency.** ARFF personnel shall be certified by the appropriate authority for the level of training attained.
- 24.3 Criteria.** ARFF personnel shall maintain proficiency through certification and recurrent requirements.

Chapter 25 Administration and Standards (NFPA 405)

- 25.1 Scope.** This chapter identifies general administrative requirements and responsibilities.
- 25.2 Competency.** ARFF personnel shall be familiar with basic administrative requirements and responsibilities.
- 25.3 Criteria.** ARFF personnel shall demonstrate a comprehensive knowledge of the following:
- (1) Airport and fire department standard operating procedures/guidelines
 - (2) Local instructions and regulations
 - (3) Individual responsibilities as they relate to the maintenance and operational effectiveness of ARFF
 - (4) Record-keeping requirements, including personnel records related to professional competency
 - (5) Organizational structure
 - (6) Occupational health and safety regulations
 - (7) Emergency planning, including personnel roles and responsibilities structured within the plan

Chapter 26 Water Rescue Operations (NFPA 405)

- 26.1* Scope.** This chapter identifies the knowledge and skills required by ARFF personnel in maintaining levels of competency required in water rescue operations.
- 26.2 Competency.** Because saving lives is the first priority in aircraft rescue and firefighting, ARFF personnel shall possess knowledge of water safety and be highly skilled in water rescue operations for all airports with the need for potential water rescue operations.
- 26.3 Criteria.** Any member of the organization who might be expected to perform functions as the operator of a watercraft shall be provided training to meet Section 21.4 of NFPA 2500.

Chapter 27 Aircraft Rescue and Firefighting Vehicle Foam Production Performance Testing (NFPA 412)

- 27.1 Administrative**
- 27.1.1 Scope.** Chapters 27 through 29 establish test procedures for evaluating the foam firefighting equipment installed on aircraft rescue and firefighting vehicles designed in accordance with Chapters 1 through 6 of NFPA 1900.
- 27.1.2 Purpose.** The tests specified in Chapters 27 through 29 provide procedures for the evaluation of foam firefighting equipment in the field to determine compliance with Chapters 1 through 6 of NFPA 1900 and this standard.
- 27.2 Foam System Performance Tests.**
- 27.2.1** In addition to manufacturers’ performance testing, ARFF vehicles shall be tested on a schedule set by the AHJ to meet the following criteria:
- (1) Expansion ratio
 - (2) Drainage 25 percent
 - (3) Proportioning

Chapter 28 Performance Criteria (NFPA 412)

- 28.1 Expansion Ratio and Drainage Time Requirements.** Foams shall be tested as specified in 29.3.2 and 29.3.3 of this standard and meet at least the performance requirements specified in Table 28.1.
- 28.1.1** The foam system shall be tested as specified in 29.3.2 and 29.3.3 of this standard and meet the performance requirements specified in Table 28.1.
- 28.2 Foam Solution Concentration.**
- 28.2.1*** For nominal 6 percent concentrates, the concentration shall be between 5.5 percent and 7.0 percent for turret and ground sweep nozzles and between 5.5 percent and 8.0 percent for hand line and undertruck nozzles.
- 28.2.2** For nominal 3 percent concentrates, the concentration shall be between 2.8 percent and 3.5 percent for turret and ground sweep nozzles and between 2.8 percent and 4.0 percent for hand line and undertruck nozzles.
- 28.2.3** For nominal 1 percent concentrates, the concentration shall be between 1.0 percent and 1.3 percent for all nozzles.

Table 28.1 Foam Quality Requirements

Foam Agents	Minimum Expansion Ratio	Minimum Solution 25% Drainage Time (min)	
		Test Method A	Test Method B
AFFF/FFFP/Fluorine-free air-aspirated	5:1	3	2.25
AFFF/FFFP/Fluorine-free non-air-aspirated	3:1	1	0.75
Protein	8:1	N/A	10
Fluoroprotein	6:1	N/A	10

Chapter 29 Test Methods and Calculations (NFPA 412)

29.1 Preparation for Testing. ARFF vehicles shall be inspected by a qualified technician familiar with the vehicle's extinguishment systems prior to conducting a foam test.

29.1.1 This pre-test inspection shall ensure that the vehicle's water and foam components are functioning as designed.

29.1.2 Items for inspection shall include the following:

- (1) Verify water discharge rates of each device (-0 to $+10\%$) are in accordance with Chapters 4 through 6 of NFPA 1900.
- (2) Verify vehicle pump operating pressure is in accordance with the OEM recommendations.
- (3) Verify pressure relief valve settings are in accordance with the OEM recommendations.
- (4)* Inspect the foam tank of each vehicle for the presence of crystallization, gelling, or sediment.
- (5)* For output-based testing, obtain a sample of foam concentrate from the vehicle concentrate tank to form the baseline for concentration analysis and to determine whether the agent concentrate in the vehicle has been contaminated.
- (6) Flush the piping system.
- (7) If so equipped, inspect the eductor for any blockage.
- (8) Inspect the foam metering device.
- (9) Inspect water and foam electric or pneumatic components for correct operation.
- (10) Inspect the manual foam metering valve or override for correct positioning.

29.2 Foam Solution Concentration Determination.

29.2.1* Foam solution concentration shall be determined using one of the following methods as described in 29.2.2, 29.2.3, or 29.2.4.

29.2.1.1 All equipment used to determine percent concentrate shall be calibrated per the manufacturer's recommendation.

29.2.1.2 When testing foam concentration from vehicles, the lowest flow rate outlet shall be tested first.

29.2.1.3 One calibrated handheld refractometer or one calibrated handheld conductivity meter suitable for the foam solution being tested shall be used for the methods described in 29.2.2 or 29.2.3.

29.2.1.4 The testing device shall meet the following minimum performance requirements:

- (1) Visual refractometer, as follows:
 - (a) Range: 0.0 to 10.0 Brix
 - (b) Resolution: 0.01% Brix
 - (c) Precision: $\pm 0.1\%$ Brix
 - (d) Temperature compensation range: 10°C to 30°C (50°F to 86°F)
- (2) Digital refractometer, as follows:
 - (a) Range: 0.0 to 60.0 Brix
 - (b) Resolution: 0.1 Brix
 - (c) Precision: ± 0.1 Brix
 - (d) Temperature compensation range: 0°C to 50°C (32°F to 122°F)
- (3) Conductivity meter, as follows:
 - (a) Range: 0.00 μS to 199.9 mS

- (b) Resolution: 0.01 μS to 0.1 mS
- (c) Accuracy: $\pm 1\%$ FS
- (d) Temperature accuracy: $\pm 0.5^{\circ}\text{C}$ (0.9°F)

29.2.2* Method A (Output-Based Testing Using a Refractometer or Conductivity Meter). A calibration curve shall be prepared using the apparatus and procedure in 29.2.2.1 and 29.2.2.2.

29.2.2.1 Apparatus. In preparing the calibration curve, the following apparatus shall be used:

- (1) Three 3.381 fl oz (100 mL) graduates
- (2) One measuring pipette [0.338 fl oz (10 mL capacity)]
- (3) One 3.381 fl oz (100 mL) beaker
- (4) One 16.907 fl oz (500 mL) beaker

29.2.2.2 Procedure.

29.2.2.2.1* Using a "zero" reading or simply a sample of the water being used and foam concentrate from the tanks of the vehicle to be tested, the following three standard solutions shall be made up by pipe fitting into three beakers, each roughly 3.381 fl oz (100 mL) in size:

- (1) The nominal concentration of the foam concentrate to water in height
- (2) One-third more than the nominal concentration of the foam concentrate to water in height
- (3) One-third less than the nominal concentration of the foam concentrate to water in height

29.2.2.2.2* The graduated cylinders shall then be filled to the 3.381 fl oz (100 mL) mark with water.

29.2.2.2.2.1 After thoroughly mixing, a refractive index or conductivity reading shall be taken of each standard solution.

29.2.2.2.2.2 A plot shall be made of the scale reading against the known foam solution concentrates and serve as a calibration curve for this particular series of foam tests.

29.2.2.3* Test Sample Concentration.

29.2.2.3.1 Portions of solution drained during the drainage test described in 29.3.2.2 shall be used as a source of test sample for the concentration determination.

29.2.2.3.2 Refractive index or conductivity readings of the test sample shall be compared to the calibration curve, and the corresponding foam solution concentration read from the graph.

29.2.3 Method B (Output-Based Testing Using a Refractometer Only). A calculation shall be made using the apparatus and procedure described in 29.2.3.1 and 29.2.3.2.

29.2.3.1* Apparatus. The concentration determination shall be made using the following apparatus:

- (1) Three clean plastic or glass containers
- (2) One dropper or pipette
- (3) A refractometer with a scale capable of reading the complete refractive index for the samples

29.2.3.2 Procedure. Using water and foam concentrate from the tanks of the vehicle to be tested, sample concentrations shall be determined as follows:

- (1) Obtain a foam concentrate sample in a clean container and label "foam concentrate."

- (2) Obtain a water sample from the truck water tank or pump water discharge in a second clean container and label "water."
- (3) Allow foam solution to discharge from a hoseline or turret for at least 30 seconds. Obtain a foam solution sample from the discharge device in a third clean container and label "foam solution." The portions of drained solution obtained during the drainage test described in 29.3.3.2 can be used for the "foam solution" sample.
- (4) Take a refractive index reading for the water sample. Record the reading as R_w .
- (5) Clean the instrument.
- (6) Repeat step 29.2.3.2(4) with foam concentrate. Record the reading as R_c .
- (7) Clean the instrument.
- (8) Repeat step 29.2.3.2(4) with foam solution. Record the reading as R_s .

29.2.3.3 Test Sample Concentration. Determining the foam concentration of the foam solution sample shall be done by calculating the following formula using the readings obtained in the steps given in 29.2.3.2(4), 29.2.3.2(6), and 29.2.3.2(8):

[29.2.3.3]

$$\% \text{ foam solution concentration} = \frac{R_s - R_w}{R_c - R_w} \times 100$$

29.2.4* Method C (Input-Based Testing). A determination of the flow rates shall be made possible using the procedure and apparatus in 29.2.4.1 through 29.2.4.3.

29.2.4.1 Apparatus. A device shall be used to measure the flow rate for the concentrate or the concentrate substitute.

29.2.4.1.1 A test sheet shall be compiled for each vehicle with measured water flow rates for each discharge, and the corresponding operational settings for the vehicle, as needed, in order to provide a known water flow rate from the water pump during each test.

29.2.4.1.2 A concentrate substitute shall be used instead of actual concentrate.

29.2.4.2 Procedure.

29.2.4.2.1 The foam concentration tank shall be closed off or the tank emptied and filled with substitute.

29.2.4.2.1.1 An alternative substitute shall flow in such a manner that the flow rates for the concentrate substitute can be read during testing.

29.2.4.2.2 Using the vehicle's operational settings for producing foam, the operator shall test each discharge once flow rates have stabilized.

29.2.4.2.3 The flow rates for each discharge shall then be noted, together with any operational readings that could impact the water flow rates, such as water flow, concentrate flow, water pressure, or rpm.

29.2.4.2.4 After completing the testing, the concentrate supply pipes, piping, and tank shall be drained for any concentrate substitute in order to prevent dilution of the concentrate in the concentrate tank.

29.2.4.3 Concentration. The foam solution concentrate shall be determined using this formula:

[29.2.4.3]

$$\frac{\text{Surrogate (in lieu of foam) flow rate or volume} \times 100}{\text{Solution flow rate or volume}} = \% \text{ foam solution concentration}$$

29.3 Foam Expansion and Drainage Determination.

29.3.1 General Requirements.

29.3.1.1 Tests shall be conducted with the temperature of the water or foam solution in the range of 60°F to 80°F (16°C to 27°C).

29.3.1.2 The following corrections shall be applied to protective foams:

- (1) *Expansion ratio.* If the solution temperature is higher than 70°F (21°C), no correction applies. If the temperature is lower than 70°F (21°C), add 0.1 unit of expansion for each 3°F (1.7°C) below 70°F (21°C).
- (2) *Drainage time.* If the solution temperature is higher than 70°F (21°C), add 0.1 minute for each 3°F (1.7°C) above 70°F (21°C). If the solution temperature is lower than 70°F (21°C), subtract 0.1 minute for each 3°F (1.7°C) below 70°F (21°C).

29.3.1.3 Foam samples selected for analysis shall be representative of the foam produced by the nozzle as it would be applied to the fire hazard.

29.3.1.4 This selection shall be accomplished by placing a foam sample collector in the center of the ground pattern as determined in the nozzle pattern test.

29.3.1.5 Apparatus. The expansion and drainage determinations shall be made using the following apparatus, in addition to the specific apparatus required for Method A or Method B:

- (1) Stopwatch
- (2) Scale/balance
- (3) Straightedge

29.3.2 Test Method A.

29.3.2.1 Foam Sampling Apparatus.

29.3.2.1.1 The foam sample collector shall be constructed as specified in Figure 29.3.2.1.1.

29.3.2.1.2 The foam sample shall be collected in a standard 33.814 fl oz (1000 mL) capacity graduated cylinder.

29.3.2.1.2.1 The cylinder shall be cut off at the 33.814 fl oz (1000 mL) mark to ensure a fixed volume of foam as a sample.

29.3.2.1.2.2 The cylinder shall be marked in 0.338 fl oz (10 mL) graduations below the 3.381 fl oz (100 mL) mark.

29.3.2.2 Test Procedure.

29.3.2.2.1 The empty weight of the foam sample container shall be recorded to the nearest gram on a scale/balance having a maximum capacity sufficient to weigh the foam sample container and the foam sample.

29.3.2.2.1.1 The foam sample collector shall then be located in the center of the discharge pattern determined in Section 29.5.

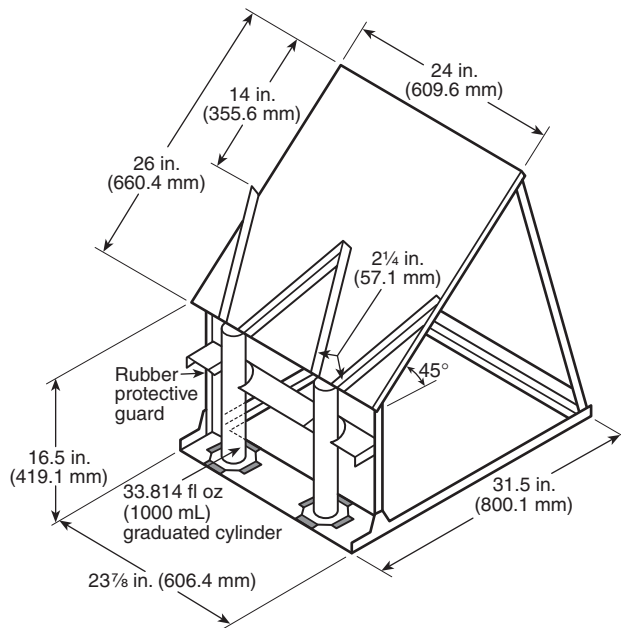


FIGURE 29.3.2.1.1 Foam Sample Collector, Method A.

29.3.2.2.1.2 The foam sample container shall be positioned at the bottom of the foam collector so that the foam hitting the collector flows into the container.

29.3.2.2.1.3 The foam nozzle shall flow for a minimum of 30 seconds prior to being aimed at the foam sample collector.

29.3.2.2.1.4 The foam nozzle shall be aimed so that the foam deflects off the side of the foam collector and then moved so as to discharge foam onto the foam sample collector.

29.3.2.2.1.5 As soon as the foam sample container has been completely filled with foam, the discharge nozzle shall be shut off and the timing of the 25 percent drainage started.

29.3.2.2.2 The foam sample container shall be removed from the base of the foam collector, excess foam struck off the top of the foam container using a straightedge, and any remaining foam wiped from the outside surface of the container.

29.3.2.2.3* The container shall then be placed on a level surface at a convenient height.

29.3.2.2.3.1 At 30-second intervals, the level of accumulated solution in the bottom of the cylinder shall be noted and recorded.

29.3.2.2.3.2 The drainage shall be recorded until the liquid level reaches 3.212 fl oz (95 mL) for non-aspirated nozzles, 2.029 fl oz (60 mL) for air-aspirated nozzles.

29.3.2.2.4 The container shall then be placed on the scale/balance.

29.3.2.2.4.1 The total weight of the foam sample and container shall be determined to the nearest gram.

29.3.2.2.4.2 The weight of the foam sample in the container shall be determined by subtracting the weight of the empty container from the weight of the container filled with the foam.

29.3.2.2.4.3 The weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in fluid ounces (milliliters).

29.3.2.2.4.4 The 25 percent drainage time shall then be interpolated from the drainage data collected in 29.3.2.2.3.1 and 29.3.2.2.3.2.

29.3.2.2.5 Samples of the foam shall be weighed to the nearest gram.

29.3.2.2.6 The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion} = \frac{33.814 \text{ fl oz (1000 mL)}}{(\text{full weight}) - (\text{empty weight in grams})} \quad [29.3.2.2.6]$$

29.3.3 Test Method B.

29.3.3.1 Foam Sampling Apparatus.

29.3.3.1.1 The object shall be to obtain a sample of foam that is typical of that to be applied to the burning fuel surface under anticipated fire conditions.

29.3.3.1.1.1 The foam collector shall be constructed as specified in Figure 29.3.3.1.1.1.

29.3.3.1.2 The foam sample shall be collected in a cylindrical 54.102 fl oz (1600 mL) container.

29.3.3.1.2.1 The foam sample container shall be constructed as specified in Figure 29.3.3.1.2.1.

29.3.3.1.3 Foam drainage shall be recorded using a 3.381 fl oz (100 mL) graduated beaker for foams with expected expansion ratios above 5:1, and an 8.454 fl oz (250 mL) graduated cylinder for foams with expected expansion ratios of 5:1 or below.

29.3.3.1.4 The weight of the appropriate empty graduated cylinder shall be recorded before the test.

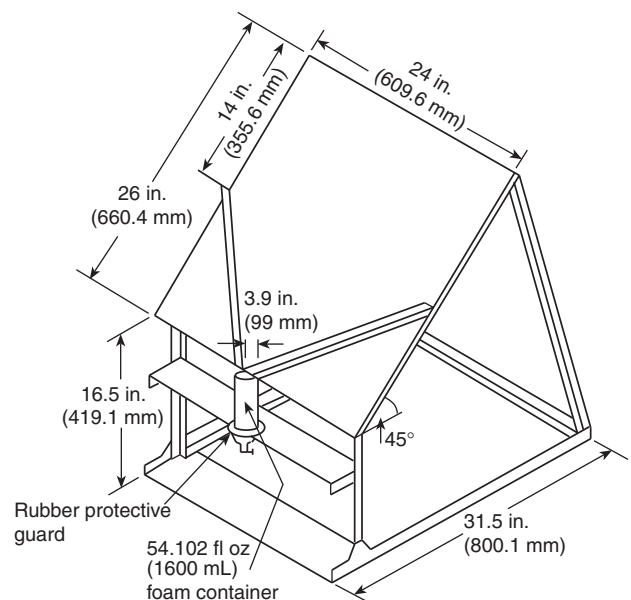


FIGURE 29.3.3.1.1.1 Foam Sample Collector, Method B.

29.3.3.2 Test Procedure.

29.3.3.2.1 The empty weight of the foam sample container shall be recorded to the nearest gram on a scale/balance having a maximum capacity sufficient to weigh the foam sample container, on a suitable support, and the foam sample.

29.3.3.2.1.1 The foam sample collector shall then be located in the center of the discharge pattern determined in Section 29.5 of this standard.

29.3.3.2.1.2 The foam sample container shall be positioned at the bottom of the foam collector so that the foam hitting the collector will flow into the container.

29.3.3.2.1.3 The foam nozzle shall be aimed so that the foam deflects off the side of the foam collector, adjusted to its normal operating pressure, and then moved so as to discharge foam onto the foam sample collector.

29.3.3.2.1.4 As soon as the foam sample container has been completely filled with foam, the discharge nozzle shall be shut off and the timing of the 25 percent drainage started.

29.3.3.2.2 The foam sample container shall be removed from the base of the foam collector, excess foam struck off the top of the foam container using a straightedge, and any remaining foam wiped from the outside surface of the container.

29.3.3.2.2.1 The container shall then be placed on the scale/balance.

29.3.3.2.2.2 The total weight of the foam sample and container shall be determined to the nearest gram.

29.3.3.2.2.3 The weight of the foam sample in the container shall be determined by subtracting the weight of the empty container from the weight of the container filled with the foam.

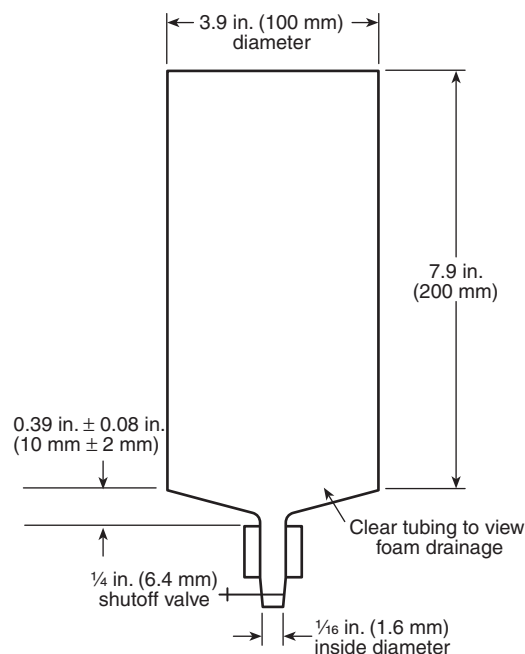


FIGURE 29.3.3.1.2.1 54.102 fl oz (1600 mL) Foam Sample Container.

29.3.3.2.2.4 The weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in milliliters.

29.3.3.2.3 The foam sample container shall then be placed on a suitable support and a graduated cylinder placed below the drain spout.

29.3.3.2.3.1 At 30-second intervals as the foam breaks down, the accumulated foam solution in the bottom of the container shall be drawn off into a 3.381 fl oz (100mL) graduated cylinder and the amount recorded.

29.3.3.2.3.2 The drainage shall be recorded until the liquid level reaches 5.072 fl oz (150 mL) for non-aspirated nozzles, 3.212 fl oz (95 mL) for air-aspirated nozzles.

29.3.3.2.4 The foam sample container complete with any remaining foam shall then be weighed to the nearest gram.

29.3.3.2.4.1 The graduated cylinder used to record the drainage and the collected foam shall then be weighed in the same manner.

29.3.3.2.4.2 The net weight of the foam sample shall be determined by adding the weights in 29.3.3.2.4 and 29.3.3.2.4.1 together and subtracting the weight of the empty foam sample container and the empty graduated cylinder.

29.3.3.2.4.3 The net weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in milliliters.

29.3.3.2.5* The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion} = \frac{54.102 \text{ fl oz (1600 mL)}}{\text{net weight of foam sample in grams}} \quad [29.3.3.2.5]$$

29.4 Ground Sweep and Hand Line Nozzle Pattern Tests.

29.4.1 Ground sweep nozzles and hand line foam nozzles shall be discharged onto a paved surface for a period of 30 seconds, for pattern testing, as shown in Table 4.1.1.2 of NFPA 1900.

29.4.2 Ground sweep nozzles shall be discharged from their fixed positions.

29.4.3 Hand line nozzles shall be held at their normal working height and tilted upward to form a 30-degree angle with the horizontal.

29.4.4 Markers shall be set out to denote the outline of the effective foam pattern and plotted, as described for the turret test in 29.5.3.

29.4.5 Patterns from both the straight stream and the fully dispersed nozzle settings shall be established, measured, and recorded.

29.5 Turret Ground Pattern Test.

29.5.1 Pattern testing shall only be required for vehicle prototype testing by the vehicle manufacturer, as shown in Table 4.1.1.2 of NFPA 1900.

29.5.1.1 Prior to the start of the test, the following conditions shall be met:

- (1) The water tank shall be full.
- (2) The foam concentrate tank shall be full with the type of foam concentrate to be used during actual emergencies.
- (3) The proportioner shall be set for normal firefighting operation.

29.5.1.2 For premixed systems, the tank shall be full with the premixed solution in the correct proportion for normal firefighting operations.

29.5.2* Discharge tests shall be conducted to establish the firefighting foam discharge patterns produced and the maximum range attainable by the turret nozzle.

29.5.2.1 The test shall be conducted under wind conditions of 5 mph (8 km/h) or less.

29.5.2.2 To determine maximum discharge range, the turret nozzles shall be tilted upward to form a 30-degree angle with the horizontal.

29.5.3 Foam shall be discharged onto a paved surface for a period of 30 seconds at the specified pressure, in both the straight stream and fully dispersed nozzle settings.

29.5.3.1 Immediately after foam discharge has stopped, markers shall be placed around the outside perimeter to preserve the identity of the foam pattern as it fell on the ground.

29.5.3.2 For purposes of defining the edge of the pattern, any foam less than ½ in. (12.7 mm) in depth shall be disregarded.

29.5.3.3 Distances between markers shall be plotted on graph paper.

29.5.3.4 For each nozzle setting, the following shall be shown:

- (1) The vertical axis shows the reach.
- (2) The horizontal axis shows the pattern width.

29.5.3.5 The distance from the nozzle to the end of the effective foam pattern shall be measured and plotted on the graph paper.

29.6 Report of Test Results.

29.6.1* All test reports shall include a statement of the operating conditions, such as pressures, temperatures, wind velocities, and direction in relation to vehicle position, and a full description of the materials and equipment used.

Annex A Explanatory Material

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

A.1.3 Application. Any AHJs incorporating NFPA 403, NFPA 405, NFPA 412, or any combination of the three, can replace those references with chapters and still reference similar content. For example, if an AHJ incorporated the 2018 edition of NFPA 403 (i.e., in accordance with the 2018 edition of NFPA 403), and they wish to update to the latest information, they can do so by incorporating Chapters 1 through 3, 4 through 10, and Annexes A through E of the 2024 edition of NFPA 460 (i.e., in accordance with Chapters 1 through 3, 4

through 9, and Annexes A through E of the 2024 edition of NFPA 460).

A.3.2.1 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 or 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.3.2.2 Authority Having Jurisdiction (AHJ). The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA standards in a broad manner because 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 department, 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.3.3.1 Aerobic Box. The aerobic box is the area in which air show flight operations are conducted. The boundaries, dimensions, and parameters of the aerobic box are clearly and specifically defined as part of the application that air show organizers submit to the AHJ to receive authorization to conduct an air show.

A.3.3.6 Aircraft Firefighting. Aircraft firefighting does not include the control or extinguishment of airborne fires in aircraft.

A.3.3.7 Aircraft Incident. An incident does not result in serious injury to persons or substantial damage to the aircraft.

A.3.3.8 Aircraft Rescue. Rescue and firefighting personnel, to the extent possible, will assist in evacuation of the aircraft using normal and emergency means of egress. Additionally, rescue and firefighting personnel will, by whatever means necessary and to the extent possible, enter the aircraft and provide all possible assistance in the evacuation of the occupants.

A.3.3.13.3 Rapid Response Area (RRA). Approximately 85 percent of the accidents as historically recorded in the CRFFAA occurred within the boundary of the RRA. Response time to the on-airport portion of the RRA should meet the times specified in 9.1.3. (See Figure A.3.3.13.3.)

A.3.3.17.1 Alcohol-Resistant Foam Concentrate. Some alcohol-resistant foams might be capable of forming a vapor-suppressing aqueous film on the surface of hydrocarbon fuels.

A.3.3.17.2 Aqueous Film-Forming Foam Concentrate (AFFF). The foam formed acts as a barrier both to exclude air or oxygen and to develop an aqueous film on the fuel surface that

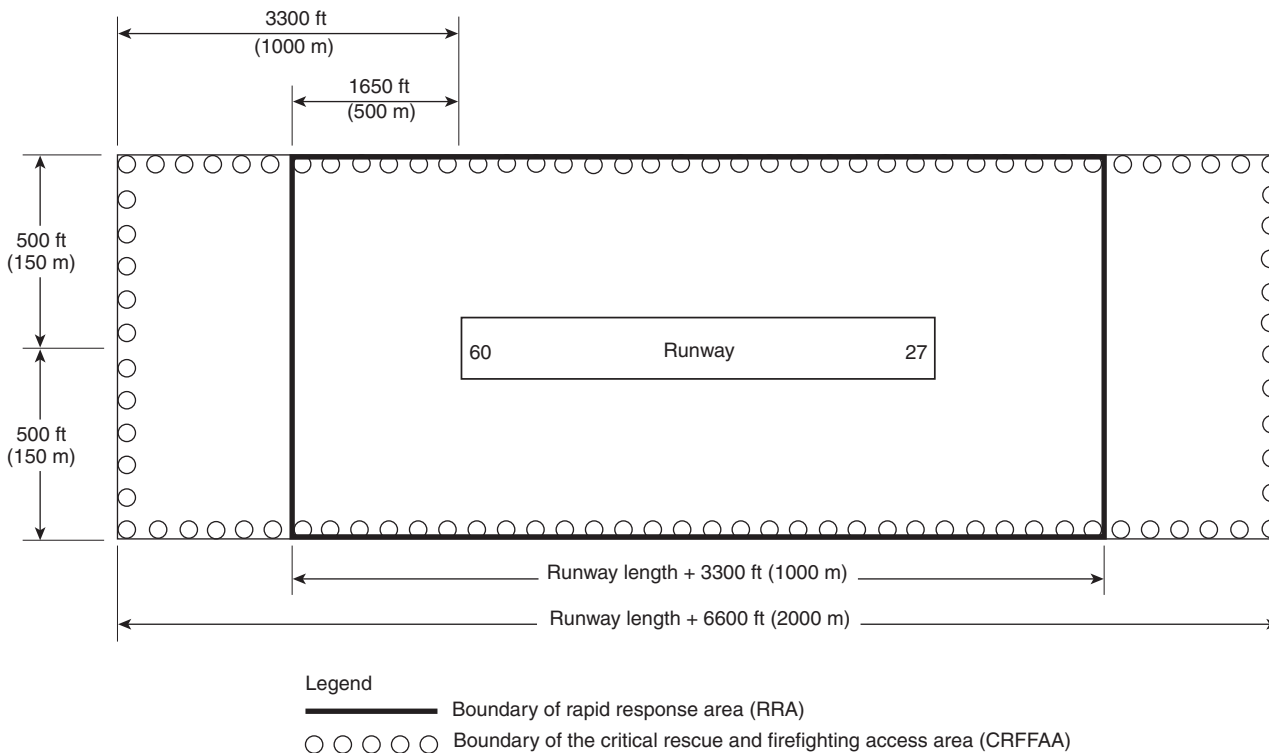


FIGURE A.3.3.13.3 Response and Access Areas.

is capable of suppressing the evolution of fuel vapors. The foam produced with AFFF concentrate is dry chemical compatible and thus is suitable for combined use with dry chemicals. [11, 2021]

A.3.3.17.3 Film-Forming Fluoroprotein Foam Concentrate (FFFP). In addition to an air-excluding foam blanket, this concentrate also can deposit a vaporization-preventing film on the surface of a liquid fuel. It is diluted with water to form 3 percent to 6 percent solutions depending on the type. This concentrate is compatible with certain dry chemicals. [11, 2021]

A.3.3.17.5.1 Fluoroprotein Foam Concentrate. This type of foam utilizes a protein base plus stabilizing additives and inhibitors to protect against freezing, corrosion, and bacterial decomposition, and it also resists fuel pickup. The foam is usually diluted with water to form a 3 percent or 6 percent solution and is dry chemical compatible. [11, 2021]

A.3.3.17.7 Protein Foam Concentrate. These concentrates are diluted with water to form 3 percent to 6 percent solutions depending on the type. They are compatible with certain dry chemicals. [11, 2021]

A.3.3.18 Foam Concentrate. For the purpose of this document, "foam concentrate" and "concentrate" are used interchangeably. [11, 2021]

A.4.3 The risk management plan should be based on an offensive and defensive policy. Strategic decisions establish the basic positioning of resources and the types of functions they will be assigned to perform at the scene of a fire or emergency incident. The level of risk to which members are exposed is driven by the strategy; offensive strategy places members in interior

positions where they are likely to have direct contact with the fire, while defensive strategy removes members from interior positions and high-risk activities. The attack plan is based on the overall strategy and drives the tactical assignments that are given to individual or groups of companies/crews and the specific functions they are expected to perform. Risk identification, evaluation, and management concepts should be incorporated into each stage of the command process.

A.4.3.2 Information on airport/community emergency plans and full-scale exercises is provided in NFPA 440.

A.4.4.3 See Table A.4.4.3, which shows aircraft types and their measurements by category.

A.5.1.1 Foams used for control and extinguishment of aircraft fires involving fuel spills are produced by incorporation of air into a solution of foam concentrate and water. Their characteristics, as indicated by expansion and drainage rate, are influenced by the amount of mechanical agitation to which the water, foam concentrate, and air are subjected. They extinguish fire by physically separating the fuel vapors from the heat and oxygen necessary for combustion, spreading over the surface of the fuel to effectively suppress vaporization and secure an extinguished area by protecting it from reignition. Foam, being essentially water, cools the surface of the fuel and any metal surfaces in the fuel. The solution drainage from some foams forms an aqueous film on most aviation fuels. It is advantageous for a foam blanket to reseal if disrupted, and essential that either the foam has good thermal and mechanical stability or that provision is made to renew the foam blanket from time to time during a lengthy rescue operation.

Table A.4.4.3 Aircraft Data

Aircraft Type	Width		Length	
	ft	m	ft	m
Aerospatiale–British Aerospace Concorde	83.67	25.50	203.67	62.08
Airbus				
A-318	111.87	34.10	103.10	31.44
A-319	111.87	34.10	111.0	33.84
A-300	147.08	44.83	177.3	54.05
A-310	144	43.89	153.1	46.66
A-320	111.25	33.91	123.3	37.57
A-321	111.25	34.10	146	44.51
A-330-200	197.83	60.30	192.9	58.82
A-330-300	197.83	60.30	208.9	63.69
A-340-300	197.83	60.30	208.9	63.69
A-340-500	208.16	63.45	222.8	67.93
A-340-600	208.16	63.45	247.2	75.36
A-350-800	212.43	64.75	198.6	60.54
A-350-900	212.43	64.75	219.4	66.89
A-350-1000	211.61	64.50	242.3	73.88
A-380	261.64	79.75	238.58	72.72
Antonov An-22	211	64.31	167	50.90
Antonov An-225	290	88.39	275.58	84.00
ATR 72	88.58	27.00	89.08	27.15
Beechcraft 1900	54.5	16.61	57.83	17.63
Beechcraft King Air 350	57.92	17.65	46.67	14.23
Boeing 727	108	32.92	153.17	46.69
Boeing 737-300	94.67	28.86	119.5	36.42
Boeing 737-600	112.7	34.30	102.6	31.20
Boeing 737-700	112.7	34.30	110.4	33.60
Boeing 737-800	112.7	34.30	129.6	39.50
Boeing 737-900 ER	112.7	34.30	138.2	42.10
Boeing 747-400	211	64.31	231.75	70.64
Boeing 757	124.67	38.00	155.25	47.32
Boeing 767-200 ER	156.1	47.60	159.2	48.50
Boeing 767-300 ER	156.08	47.57	180.25	54.94
Boeing 767-400 ER	170.4	51.90	201.40	61.30
Boeing 777-200	199.11	60.90	209.1	63.70
Boeing 777-300	199.11	60.90	242.4	73.90
Boeing 787-8	197	60.00	186	57.00
Boeing 787-9	197	60.00	206	63.00
Boeing DC 10-40	165.25	50.37	180.5	55.02
Boeing MD-11	169.25	51.59	200.67	61.16
Boeing MD-88	107.67	32.82	147.75	45.03
Casa CN-235	84.5	25.76	70	21.34
Cessna Citation 5	53.42	16.28	48.67	14.83
DeHavilland Dash 5	85	25.91	73	22.25
Grumman Gulfstream 4	77.67	23.67	88.25	26.90
Ilyushin IL-86	158.5	48.31	191.75	58.45
Lockheed L-1011-500	164.25	50.06	164.17	50.04
Short 360	74.83	22.81	70.83	21.59
Tupolev Tu-154	123.17	37.54	157.17	47.91

Foam liquid concentrates of different types or from different manufacturers should not be mixed unless it is first established that they are compatible. Protein and fluoroprotein foam concentrates, in particular, are generally not compatible with AFFF concentrates and should not be mixed, although foams generated separately from these concentrates are compatible and can be applied simultaneously to a fire. All foams used as primary agents are available for use at 3 percent and 6 percent concentrations, usually in either fresh- or saltwater, and some are for use at other concentrations such as 1 percent or 5 percent.

Foam can be produced in a number of ways. The method of foam production selected should be carefully weighed, considering the techniques best suited for the equipment concerned, the rates and patterns of discharge desired, and the manpower needed to properly utilize the foam capabilities of the vehicles. The principal methods of foam production are given in Chapters 27 through 29.

The quality of water used in making foam can affect the foam performance. Locally available water might require adjustment of the proportioning device to achieve optimum foam quality. No corrosion inhibitors, freezing point depressants, or any other additives should be used in the water supply without prior consultation and approval of the foam concentrate manufacturer.

CAUTION: Converting aircraft crash firefighting and rescue vehicles to use a type of foam concentrate other than that for which they were initially designed should not be accomplished without consultation with the equipment manufacturer and without a thorough flushing of the agent and the complete foam delivery system. Particular attention should be given to ensuring that the system component materials are suitable for the particular concentrate being substituted and that, where necessary, the proportioning equipment is recalibrated and reset.

CAUTION: Any salvageable aircraft that comes in contact with foam agents during firefighting or fuel spill-securing operations should be thoroughly flushed with freshwater as soon as practicable. Both the foam manufacturer and the airframe manufacturer should be contacted for any additional requirements that might be associated with specific foam agents or aircraft components.

A.5.1.2 Acceptable standards for foam concentrates vary from country to country. In the US, the AHJ is the US FAA, which requires foam concentrates be aqueous film-forming foam agents meeting all of the criteria of the US Military Specification MIL-F-24835, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate, for Fresh and Sea Water*. Freshwater or seawater can be used for the fire test. Concentrates that successfully pass this testing appear on the Qualified Products List (QPL-24385-28). This US military specification standard contains a variety of physical property requirements that allow these concentrates to be interchangeable and still function properly if the proportioning system is not operating at the proper rate. This is in comparison to ICAO requirements, which do not require a specific surfactant type. Foam concentrates that have passed the ICAO Level A, B, or C performance tests will have varying viscosities affecting proportioning and nozzle type (aspirating or nonaspirating) and are not considered interchangeable. The ICAO and US military specification standards contain performance tests that are specific to the requirements for airport hazards, and concentrates should be

tested by an authorized body to conduct and certify compliance. Certification documentation from the foam concentrate manufacturer should be made available to the AHJ. Chapters 27 through 29 contain additional foam quality and drainage time requirements along with the test methods for these properties.

A.5.2(1) A number of chemical compounds are offered on a proprietary basis that are referred to as dry chemical fire extinguishing agents. Historically, sodium bicarbonate-based compounds were initially so described, but in recent years, a number of other chemicals have been tested and potassium bicarbonate-based powders have proven most effective as a means of quickly extinguishing flammable liquid fires when applied with a proper technique and at an adequate rate. Potassium bicarbonate has good flooding characteristics and can penetrate to otherwise inaccessible areas. Dry chemicals, as currently used in aircraft rescue and firefighting, can be used to extinguish three-dimensional liquid fuel or running fires where foam is present on the ground.

A.5.2(2) “Clean agent” extinguishing agents are hydrocarbons in which one or more hydrogen atoms have been replaced by atoms from the halogen series — fluorine, chlorine, bromine, or iodine. This substitution confers not only nonflammability but flame extinguishment properties to many of the resulting compounds. Clean agents are used both in portable fire extinguishers and in extinguishing systems. The three halogen elements commonly found in extinguishing agents are fluorine (F), chlorine (Cl), and bromine (Br).

Extinguishing mechanisms vary for “clean agent” extinguishing agents. The primary extinguishing mechanism for Halon 1211 acted by chemically interrupting the continuing combination of the fuel radicals with oxygen in the flame chain reactions. This process is known as *chain breaking*. Clean agents that have replaced Halon 1211 primarily act by increasing the heat capacity of the air within the fire zone. This results in a cooling of the fire by removing heat that the reaction needs to sustain the flame.

The discharge of clean agents can create hazards to personnel such as dizziness, impaired coordination, reduced visibility, and exposure to toxic decomposition products. In any proposed use of clean agents where there is a possibility that people might be trapped in or enter into atmospheres made hazardous, suitable safeguards should be provided to ensure prompt evacuation of, and to prevent entry into, such atmospheres and also to provide means for prompt rescue of any trapped personnel. Breathing apparatus should be worn.

Clean agents leave no agent residue and are the preferred agent for aircraft tire fires, engine fires, interior aircraft fires, electrical component fires, and flightline vehicle or equipment engine fires. Due to its ozone-depleting properties, production of new Halon 1211 stopped in 1994 and discharge of agent for training was no longer allowed. In June 1995, the FAA certified HCFC Blend B as an acceptable alternate agent to Halon 1211 for ARFF, FAA Cert-Alert 95-03. Like Halon 1211, HCFC Blend B is a clean extinguishing agent effective on Class A, B, and C hazards. It does not leave a residue after application, and therefore minimal or no collateral damage occurs from the agent itself to equipment and other assets in the area where it is employed.

A.5.3.3 Firefighting vehicles meeting the requirements of 5.3.2 carry a sufficient quantity of foam concentrate for one

refill; therefore, rapid water resupply is of prime importance. The reserve water supply can be maintained in tankers or structural equipment. Hydrants can be considered if they are adequately located. Mutual aid services can be considered for this purpose if they are capable of responding in the critical time required to maintain the fire attack.

A.5.4 It is important that the compatibility of the foam and dry chemical agents be established if they are to be used together. Halon 1211 is compatible with all foams.

A.5.5 A variety of metals burn when heated to high temperatures by friction or exposure to external heat; others burn from contact with moisture or in reaction with other materials. Because accidental fires can occur during the transportation of these materials, it is important to understand the nature of the various fires and hazards involved. The most common combustible metals used in aircraft are magnesium and titanium.

The hazards involved in the control or complete extinguishment of combustible metal fires include extremely high temperatures, steam explosions, hydrogen explosions, toxic products of combustion, explosive reaction with some common extinguishing agents, breakdown of some extinguishing agents with the liberation of combustible gases or toxic products of combustion, and dangerous radiation in the case of certain nuclear materials. Some agents displace oxygen, especially in confined spaces. Therefore, extinguishing agents and methods for their specific application should be selected with care. Some combustible metal fires should not be approached without suitable self-contained breathing apparatus and protective clothing, even if the fire is small. Other combustible metal fires can be readily approached with minimum protection.

Numerous agents have been developed to extinguish combustible metal (Class D) fires, but a given agent does not necessarily control or extinguish all metal fires. Although some agents are valuable in working with several metals, other agents are useful in combating only one type of metal fire. Despite their use in industry, some of these agents provide only partial control and cannot be classified as actual extinguishing agents. Certain agents that are suitable for other classes of fires should be avoided in the case of combustible metal fires, because violent reactions can result (e.g., water on sodium, vaporizing liquids on magnesium fires).

Certain types of combustible metal extinguishing agents have been in use for years, and their success in handling metal fires has led to the terms *approved extinguishing powder* and *dry powder*. These designations have appeared in codes and other publications where it was not possible to employ the proprietary names of the powders. These terms have been accepted in describing extinguishing agents for metal fires and should not be confused with the name *dry chemical*, which normally applies to an agent suitable for use on flammable liquid (Class B) and live electrical equipment (Class C) fires.

A.6.1.1 It is desirable to have more than one vehicle available to facilitate attacking aircraft fires from more than one point or quarter, as an aid to expedite rescue, to reduce the potential seriousness of vehicle breakdown, and to minimize the out of service consequences when a vehicle is in need of routine maintenance or repairs. Having at least two firefighting vehicles available is particularly important when dealing with transport-type aircraft, due to the need to rapidly cover any burning fuel spill to protect the aircraft and its occupants from radiated heat during the evacuation and rescue period, and to

maintain the secure area around the fuselage to permit the safe evacuation and rescue of the occupants.

A.6.1.2 The capacity of each vehicle with regard to firefighting, rescue equipment, and staffing should be compatible with the desired performance characteristics established for vehicles in the various categories specified in Chapters 1 through 6 of NFPA 1900. It is particularly important that the vehicle not be overloaded so as to reduce the required acceleration, top speed, or vehicle flotation below the acceptable minimums set forth in Chapters 1 through 6 of NFPA 1900.

The off-pavement performance capability of each ARFF vehicle should be established by tests at each airport during the various weather and terrain conditions experienced at that airport to establish, prior to an actual emergency, the capabilities and limitations of the vehicle for off-pavement response to accident or incident locations. In addition, periodic tests should be conducted to ensure that the performance requirements of the vehicle are as originally designed and that the skill levels of the driver/operator remain high.

Where climatic or geographic conditions exist that considerably reduce the effectiveness of conventional wheeled vehicles, it is often necessary to carry extinguishing agents in a specialized vehicle suitable for traveling the airport terrain, such as a tracked, amphibious, air-cushioned, or high-mobility wheeled vehicle. Where these difficult operational conditions exist, experts should be consulted to develop a vehicle specification that matches the vehicle's performance capabilities to the unique conditions present at the airport.

Overall vehicle dimensions should be within practical limits with regard to local highway practices, width of gates and height and weight limitations of tunnels and bridges, and other local considerations.

Simplicity of vehicle operation with emphasis on operation of the extinguishing agent discharge devices is extremely important due to the time restrictions imposed for successful ARFF operations and the need to keep the firefighting crew to the minimum required for safe and efficient operations. Successful control of the fire in the practical critical area (PCA) is essential using the minimum amount of agent necessary to secure the objective. To control an aircraft fire, it is necessary to apply extinguishing agents at a rate higher than the fire is capable of destroying the control effort. Hand hose lines are usually not adequate for fire involving larger types of aircraft due to their limited discharge rate and are used primarily for protection of rescue parties, maintaining control of the fire in the PCA, and combating fires in aircraft interiors. For these reasons, turrets are needed to rapidly knock down the fire and secure the evacuation routes.

Improvements in vehicle and equipment design over recent years have increased the firefighting efficiency of these units and have outdated older rescue and firefighting vehicles. Before procuring any used vehicle for an ARFF service, the possible savings in initial cost should be carefully weighed against the lower maintenance cost, the reduced manpower requirements, and the greater firefighting efficiency that can be expected from new vehicles and equipment built in accordance with Chapters 1 through 6 of NFPA 1900. Secondhand vehicles might have been subjected to abusive service, components might have been overstressed, and repair parts might be impossible to obtain. Foam firefighting equipment purchased

for this service should be tested in accordance with Chapters 27 through 29.

Specialized vehicles might be needed to allow firefighters to safely reach elevations that are above the efficient range of ground ladders and the normal range of ARFF vehicles. Firefighters should have the ability to access any level of the aircraft to effectively perform their mission with an aircraft interior access vehicle as described in Chapter 5 of NFPA 1900.

All essential vehicles should be provided with two-way radio communications with air traffic control (ATC) or the airport controlling facility, for example, air-radio, flight service station, and so forth.

At least one elevated boom and where specified, a cabin skin penetration device, should be provided at airports of Category 6 through 9; Category 10 should have two.

A.6.2 A comprehensive and up-to-date list of tools is provided in Chapters 1 through 6 of NFPA 1900. Consideration should be given to the addition of a vehicle termed as a *rescue truck* for the purpose of carrying a wide range of rescue equipment suited for conditions and aircraft utilizing the Category 7 or larger airports.

A.8.1.2 The personnel required for the initial alarm is based on the information in Table A.8.1.2.

Table A.8.1.2 ARFF Personnel Based on Airport Category

Airport Category	ARFF Personnel
1–3	2 ARFF trained personnel
4	3 ARFF trained personnel including an Incident Commander
5	6 ARFF personnel including an IC and 2 trained personnel for rapid intervention
6–10	The minimum total number of trained personnel responding should be based on the equivalent of 3 per ARFF vehicle. Additionally, an IC and 2 trained personnel for rapid intervention should be provided.

A.8.2.1 Personal protective clothing and equipment should meet the requirements of NFPA 1981 and NFPA 1975.

Canadian references for personal protective equipment are as follows:

- (1) Firefighter protective clothing: CAN/CGSB-155.1, *Firefighters' Protective Clothing for Protection Against Heat and Flame*, April 1998
- (2) Firefighter protective boots: CAN/BNQ 1923-410, *Fire Fighting — Protective Helmets*

U.K. references for personal protective equipment are as follows:

- (1) Helmets for firefighting in buildings and other structures with full-face visor: BS EN 443, *Helmets for fire fighting in buildings and other structures*
- (2) Tunic/overtrousers (i.e., turnout gear): BS EN 469, *Protective clothing for firefighters — Performance requirements for protective clothing for firefighting*
- (3) Gloves: BS EN 659, *Protective gloves for firefighters*

- (4) Footwear (i.e., safety footwear): BS EN ISO 20345, *Personal protective equipment. Safety footwear*, (including footwear for firefighters)
- (5) Conspicuous clothing: BS EN ISO 20471, *High-visibility clothing — Test methods and requirements*
- (6) Flash hoods: BS EN 13911, *Protective clothing for firefighters — Requirements and test methods for fire hoods for firefighters*

Guidance and proximity of protective clothing can be found in FAAC150/5210-14B, *Airport Rescue Firefighting Equipment, Tools and Clothing*.

Fire entry suits are not recommended for civil airport application. Rapid fire control afforded by present firefighting equipment and short times for survival without fire control make the fire entry suit unnecessary and inappropriate.

A.8.2.2 Tests have shown that many toxic gases are produced when aircraft cabin interior finish materials are burned or charred. These gases include carbon monoxide, hydrogen chloride, chlorine, hydrogen cyanide and other cyanogen components, and carbonyl chloride (phosgene). A principal cause of difficulty lies in the fact that the supply of breathing air is greatly reduced by combustion of these cabin finish materials. It is, therefore, necessary that ARFF personnel who enter or operate in the vicinity of an aircraft during the fire sequence be equipped with self-contained breathing equipment. Helmets or hoods should be designed to accommodate the SCBA facepiece without interference; most existing proximity hoods do not have this provision.

A.9.1.1 Factors that influence response time include the following:

- (1) Means of notification of the ARFF force
- (2) Completeness of the information in the activation message
- (3) Location of the fire station
- (4) Acceleration, top speed, on-road handling, and off-road mobility characteristics of the vehicles
- (5) Degree of preparatory training
- (6) Provision of emergency access roads
- (7) Climatic conditions
- (8) ARFF personnel expeditious response to vehicles in the fire station
- (9) 45 and 90 degree turns

Fire house garage doors should be wide enough to provide adequate clearance to permit drivers to easily back into the garage without damaging either the vehicle or the garage.

The minimum size of the firehouse garage door(s) for a major firefighting vehicle should be at least 18 ft (5.5 m) wide by 18 ft (5.5 m) high.

A.9.1.2 The geographical center of an airport might not be the best location for siting the airport fire station. Locating the airport fire station for structural firefighting utility should be of secondary importance. Before selecting the actual location, time trials should be run to determine the optimum location that would ensure the quickest response to all potential accident sites. Also, an evaluation should be placed on present and future usage of the airport movement areas to ensure proper selection of the fire station site. [See Figure A.9.1.2(a) and Figure A.9.1.2(b).]

Care should be taken to ensure that access to or from the airport fire station cannot and will not be blocked by taxiing or parked aircraft or vehicular traffic.

Airport fire stations located close to taxiways and runways or adjacent to flight patterns should have soundproof training rooms, living quarters, and an alarm room. The high noise level of turbine engines can cause damage to hearing; accordingly, at airports handling turbine-powered aircraft, firefighters on duty outside of soundproofed areas should be provided with aural protection. Where high noise levels are encountered, it might be necessary to supplement audible signals with visual signals, such as flashing lights, to alert firefighters.

Where airport response plans call for response outside the airport fences, suitable exits should be provided around the perimeter of the airport for ARFF vehicles. Particular attention should be given to the provision of ready access to the rapid response area (RRA) and critical rescue and firefighting access area (CRFFAA). The CRFFAA is the rectangular area surrounding any given runway. Its width extends 500 ft (150 m) outward from each side of the runway centerline, and its length is 3300 ft (1000 m) beyond each runway end. This is the area where accidents historically have occurred. [See Figure A.9.1.2(b).]

A.9.1.3 Two or more airport fire stations should be strategically located on the airport where a centrally located fire station cannot meet the response criteria given in 9.1.3.

When creating the response roadways from the firehouse to the incident area(s), the airport designer should consider the information in Table A.9.1.3(a) and Table A.9.1.3(b) when sizing the radius of curves. ARFF vehicles accelerate much faster than over-the-road vehicles and are very capable of obtaining higher speeds in a very short distance. The total response time from the time of alarm to the time ARFF vehicles arrive on scene and begin agent application is the cumulative time for notification, reflex time for ARFF personnel to don protective clothing and start ARFF vehicles, and the actual travel time to the accident/incident location.

A.9.1.3.1 The operational objective of the first-responding ARFF vehicle should be to reach any point on the operational runway and begin agent application within 2 minutes of the time of the alarm, in optimum visibility and surface conditions.

A.9.1.3.2 The operational objective of the first-arriving ARFF vehicle to reach any point remaining within the on-airport portion of the RRA should be within 3 minutes from the time of the alarm, in optimum visibility and surface conditions.

A.9.1.3.3 The operational objective of the first-arriving ARFF vehicle to reach any passenger boarding areas should be within 3 minutes from the time of alarm, in optimum visibility and surface conditions.

A.10.1 ARFF Response at Public Air Shows. Air shows are aviation events that are often conducted at civilian and military airfields. The unique nature of air show flying requires a non-standard level of preparedness. A heightened level of ARFF preparedness and response is required for the non-standard environment in which air shows are conducted and the non-standard manner in which those aircraft are often flown.

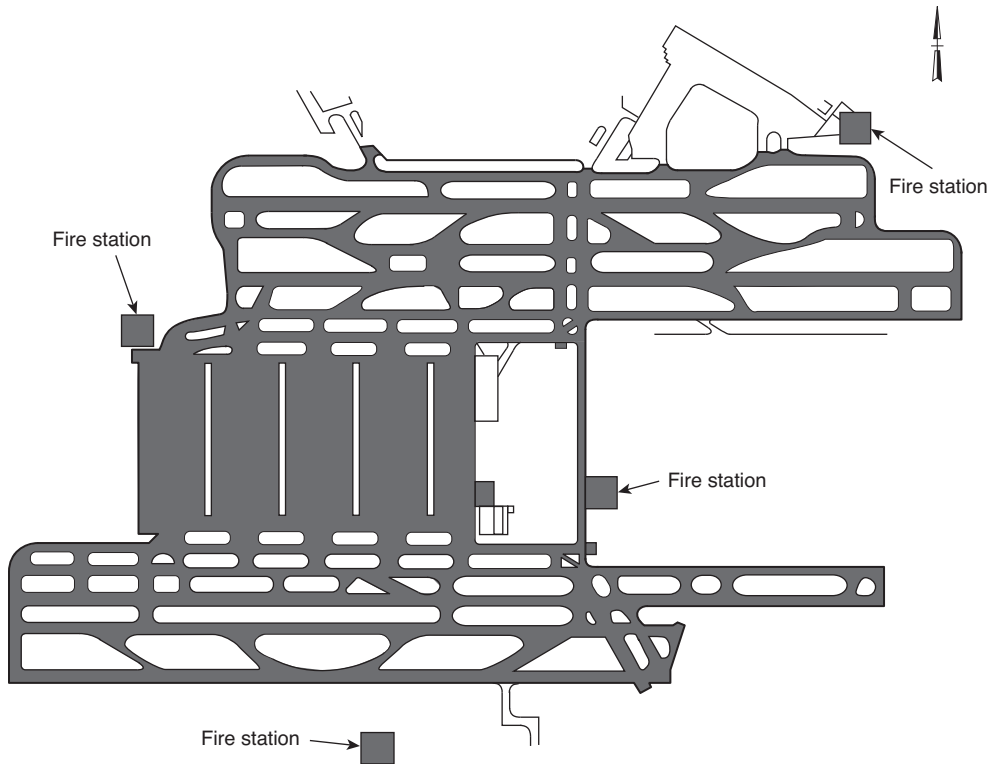


FIGURE A.9.1.2(a) Example of Category 9 Airport Fire Station Locations.

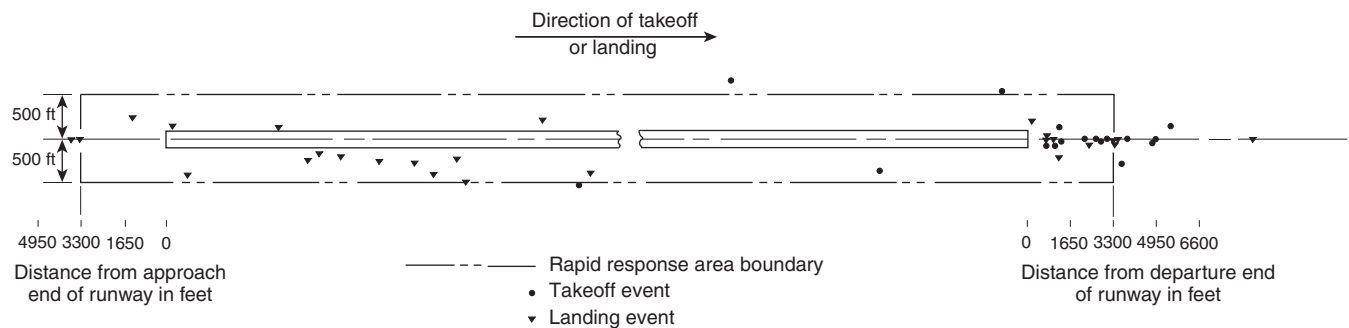


FIGURE A.9.1.2(b) Historical Data Regarding Location of Accidents During Landing and Takeoff.

Table A.9.1.3(a) Vehicle Speed over Distance from a Standing Start

Distance Traveled from a Standing Start of the Vehicle		Speed of Vehicle at the Given Distance					
		Vehicle Water Tank Capacity 60 gal to 528 gal (227 L to 1999 L)		Vehicle Water Tank Capacity >528 gal to 1585 gal (>1999 L to 6000 L)		Vehicle Water Tank Capacity >1585 gal (>6000 L)	
		mph	kph	mph	kph	mph	kph
100	30.5	18	29.0	20	32.2	18	29.0
250	76.2	25	40.2	30	48.3	25	40.2
500	152.4	30	48.3	40	64.4	30	48.3
750	228.6	40	64.4	45	72.4	40	64.4
1000	304.8	45	72.4	50	80.5	45	72.4

Table A.9.1.3(b) Minimum Radius of a Curve Based on Speed

Speed		Minimum Radius of a Curve with a 0.04 Superelevation (Almost Flat)*	
mph	kph	ft	m
20	32.2	130	39.6
30	48.3	302	92.0
40	64.4	573	174.6
50	80.5	955	291.1
55	88.5	1432	436.5
60	96.6	1637	498.9

*Values were extracted from “A Policy on Geometric Design of Highways and Streets,” American Association of State Highway and Transportation Officials, 2011 edition.

A.10.1.2 Historically, when an accident or incident occurs during a public air show, the aircraft wreckage comes to rest within the aerobatic box. By positioning ARFF vehicles at each end of the crowd area and one at the show center, our response time will improve and can save lives.

A.10.1.5 It is recommended that ARFF vehicles be tactically prepositioned to provide the shortest and most direct routes to the show center.

A.10.1.6 In such cases, it is recommended that one of the two vehicles be a small, rapid-intervention-type vehicle. It is also recommended that there never be fewer than two vehicles deployed and ready to respond to an incident or accident.

A.10.1.7 The vehicle positioned at the show center should be a small, rapid-intervention-type vehicle.

A.10.1.9.1 If the firefighters are different on subsequent days of the event, at least one firefighter should make himself or herself available to each pilot and other firefighters to re-brief the emergency response information.

A.10.1.10 These procedures and methods will be developed with the goal of allowing firefighters to respond to an incident or accident without being delayed by procedural or communications issues.

A.11.4 Acceptable training records include paper or electronic training records.

A.13.2 It is specifically recommended that in addition to scheduled commercial aircraft, personnel should consider becoming familiar with general aviation and business class aircraft that could make an emergency landing at your airport.

A.13.3(22) Some examples are military aircraft with armament, canopy jettison systems, ejection seats, general aviation aircraft with ballistic chutes, and wildland firefighting aircraft.

A.14.1 The concept of safety management system (SMS) is becoming a worldwide aviation industry standard. It is recognized by the Joint Planning and Development Office (JPDO), International Civil Aviation Organization (ICAO), European Aviation Safety Agency (EASA), Civil Aviation Authority (CAA), and product and service providers as the next step in the evolution of safety in aviation. Safety management systems are also becoming the standard for the management of safety beyond aviation.

A.16.1 The term *mitigate* as it is used in this context means to lessen in severity, that is, emergency response personnel are expected to perform duties, as they relate to aircraft cargo hazards, only to the extent to which they are trained, equipped, and qualified. Utilizing an outside response or professional firm to perform activities beyond the capabilities of the on-airport response might be necessary.

A.20.3(7) Aircraft seatbelt airbags and other protective airbags continue to be an emerging safety technology. Not unlike automotive airbags, these safety devices are a self-contained, self-powered system and can be typically found under each equipped passenger seat. They are typically comprised of an electronics module, battery, high-pressure compressed gas cylinder, and firing system with a high-velocity squib and inflator. Upon detection of a sudden deceleration event by the electronics module, the squib is fired into the compressed gas cylinder, which inflates the airbag(s). Seat belts that contain an airbag can be visually identified as being thicker than normal seat belts.

ARFF personnel are reminded to use extreme caution when dealing with any airbag system — especially those that are undeployed, particularly if the seat is damaged or partially separated from the airframe.

The authority having jurisdiction is encouraged to engage airlines and aircraft manufacturers for specific safety information related to these systems.

A.21.1 Rescue and firefighting operations involve a multitude of tasks, many of which occur simultaneously. All of these tasks need to be considered in “sizing up” an emergency.

A.22.4 Federal, state, or local restrictions might prohibit or restrict the use of hydrocarbon-based fires for training. In these circumstances, the authority having jurisdiction could substitute a live fire trainer utilizing either propane or a combination system of propane and hydrocarbon fuels.

A.22.4.1 The fuel-spill burn area provides ARFF personnel with a realistic scenario to practice responding to, gaining control of, and extinguishing a ground-based, aviation fuel-spill fire typical of ramp service mishaps and aircraft accidents. Government authorities such as the FAA or ICAO can provide minimum sizes and requirements for burn areas.

A.22.5 ARFF personnel should be able to demonstrate proficiency in the use of all extinguishing agents required to meet the airport index. It is recognized that most airports operate under constraints that do not allow all ARFF personnel to discharge all primary and complementary agents annually. The authority having jurisdiction should consider a live fire training process for firefighter proficiency with locally available extinguishing agents.

A.23.1 ARFF personnel are key members of a team organized to deal with airport emergencies.

A.26.1 Personnel who can be called upon to effect rescue from an aircraft that has crashed and/or ditched in water have to have a sound understanding of seamanship and water safety if the rescue of the aircraft’s occupants is to succeed.

A.28.2.1 The amount of foam concentrate in the solution fed to the foam maker plays an important part, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the

concentration meets the required level, even if the foam meets the minimum expansion and drainage time values at other levels of concentration.

A.29.1.2(4) The presence of contaminants inside a vehicle's foam tank could affect the performance of a vehicle's foam proportioner system. If crystallization, gelling, or sediment are found, it is recommended to remove the contaminants in accordance with guidance provided by the foam concentrate manufacturer prior to conducting testing. See FAA CertAlert No. 16-09, *Particles in Aqueous Film Forming Foam (AFFF) Tanks on Aircraft Rescue Fire Fighting (ARFF) Vehicles and AFFF Storage Tanks*, for additional information.

A.29.1.2(5) To ensure that the foam concentrate from the vehicle tank(s) has not been contaminated, a foam concentrate sample from the foam tank(s) should be compared to a new sample of the same type and brand.

If different foam concentrate products or concentrates from different manufacturers are mixed, they might stratify inside the vehicle's foam tank.

Any significant difference indicates possible water contamination of the foam concentrate in the vehicle. The methods used for concentrate comparison should be as described in Section 29.2.

A.29.2.1 The conductivity method is not recommended where seawater is used for making foam solution.

When the conductivity method is used and samples are to be stored and analyzed at some time other than during testing, clean glass containers should be used to store the samples.

Storage of solution in other types of containers (metal, low-density polyethylene) might affect the conductivity reading over a period of time. Care should be taken that conductivity measurements are made when the water and foam solution are at the same temperature. Small differences in temperature might substantially change conductivity measurements.

The recommended meter automatically compensates for different temperatures. If other meters are used, the instructions for the conductivity meter calibration and temperature compensation should be carefully followed.

A.29.2.2 A refractometer is used to measure the refractive index of the foam solution samples. This method is not particularly accurate for AFFF or alcohol-resistant AFFF because they typically exhibit very low refractive index readings. Therefore, the conductivity method might be preferred where those products are used. See Figure A.29.2.2(a), Figure A.29.2.2(b), Figure A.29.2.2(c), and Figure A.29.2.2(d).

Figure A.29.2.2(a) gives an example of a visual refractometer. The index of refraction is measured by placing a few drops of the solution to be tested on the prism of a refractometer, closing the cover plate, and holding this type of refractometer up to a light source to take a reading where the dark field intersects the numbered scale.

Figure A.29.2.2(b) shows the view through the eyepiece of a visual refractometer, measuring a 6 percent AFFF solution. The dark section intersects the scale at 1.7, and this value is recorded as the reading for a 6 percent concentration.

The following are the minimum specifications to assist operators in selecting a visual refractometer:

- (1) Range: 0.0 to 10.0 Brix
- (2) Resolution: 0.01% Brix
- (3) Precision: $\pm 0.1\%$ Brix
- (4) Temperature compensation range: 10°C to 30°C (50°F to 86°F)

Figure A.29.2.2(c) is an example of a digital refractometer. The index of refraction is measured by placing a few drops of the solution to be tested in the prism, following the user instructions of the device for calibration and cleaning requirements.

The following are the minimum specifications to assist operators in selecting a digital refractometer:

- (1) Range: 0.0 to 60.0 Brix
- (2) Resolution: 0.1 Brix
- (3) Precision: ± 0.1 Brix
- (4) Temperature compensation range: 0°C to 50°C (32°F to 122°F)

Figure A.29.2.2(d) is one style of conductivity meter. This device can be used to measure the electrical conductivity of a solution. These devices are typically easy to use and have repeatable results, by following the user instructions of the device for calibration and cleaning requirements.

The following are the minimum specifications to assist operators in selecting a conductivity meter:

- (1) Range: 0.00 μ S to 199.9 mS
- (2) Resolution: 0.01 μ S to 0.1 mS
- (3) Accuracy: $\pm 1\%$ FS
- (4) Temperature accuracy: $\pm 0.5^\circ\text{C}$ (0.9°F)

A.29.2.2.2.1 Care should be taken to compensate for concentrate density using a calibrated scale.

A.29.2.2.2.2 Method A procedures are used to provide a reference line on which the reading of the solution tested is plotted to determine its exact concentration. Figure A.29.2.2.2(a) shows a typical graph using 6 percent AFFF solution, and Figure A.29.2.2.2(b) shows a typical graph using a 6 percent FFFP solution.



FIGURE A.29.2.2(a) Visual Refractometer.

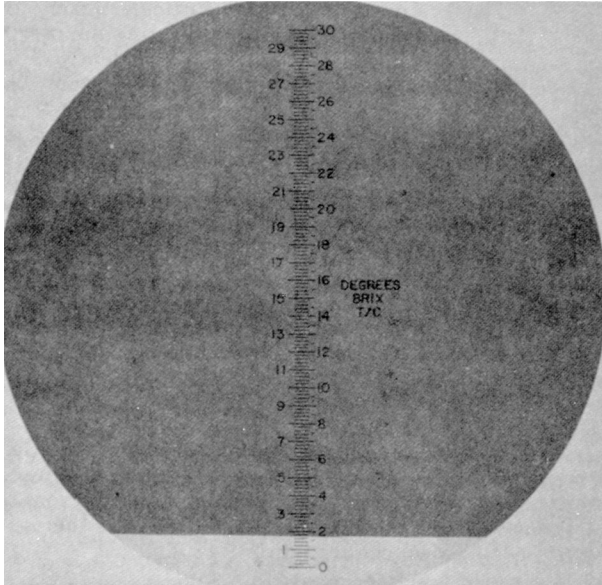


FIGURE A.29.2.2(b) Illustrating the Field of View by Looking into the Refractometer.



FIGURE A.29.2.2(c) Digital Refractometer.

A.29.2.2.3 Because of the high sensitivity of the conductivity meter, it is necessary to collect a larger sample of drainage before making the determination. This will allow for the variation in conductivity of the drained liquid caused by small changes in the chemical composition of AFFF solution as it drains over a period of time.

The equipment used to determine concentration should enable the user to accurately measure whether the foam solution produced by proportioning equipment is within the tolerance specified in 28.2.1 and 28.2.2. Conductivity meters should have an automatic temperature compensation feature and should measure a conductivity range of 0–199.9 $\mu\text{S}/\text{cm}$ in a low scale, and 0–199.9 mS/cm in a high scale.



FIGURE A.29.2.2(d) Conductivity Meter.

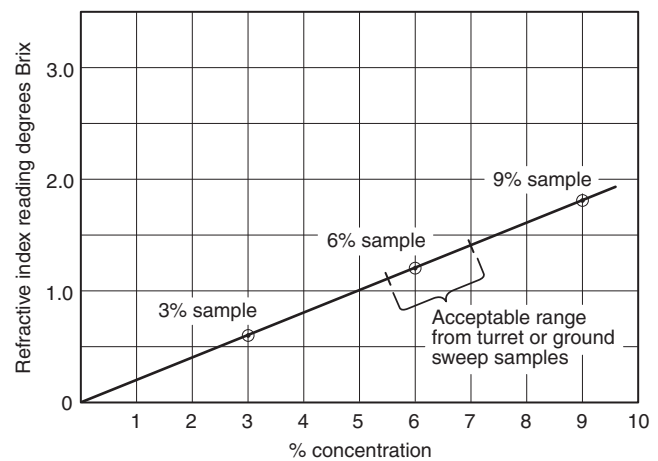


FIGURE A.29.2.2.2(a) Typical Graph Using AFFF (6%).

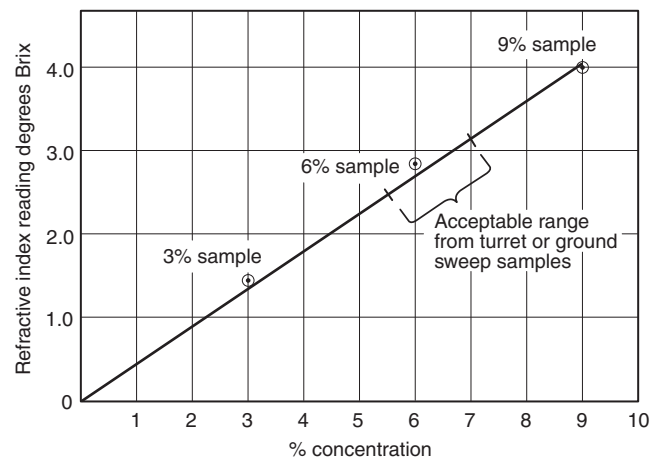


FIGURE A.29.2.2.2(b) Typical Graph Using FFFP (6%).

A.29.2.3.1 However, low-range refractometers (e.g., 0–10 Brix) might not be able to provide a 100 percent concentration reading of the foam concentrate when using Method B. This is particularly true when using 1 percent and 3 percent foam concentrates.

A.29.2.4 Since foam is not discharged during input-based testing, Test Method C can only be used to test and determine the foam solution concentration. The use of this method should be established by the AHJ.

The use of a surrogate liquid instead of foam solution might be permitted for the purpose of determining the discharge pattern and maximum range.

A.29.3.2.2.3 The following equation is an example calculation of drainage time. The net weight of the foam sample in the foam container is assumed to be 200 g. Since 1 g of foam solution occupies approximately 0.034 fl oz (1 mL), the total volume of foam solution contained in the given foam sample is 6.763 fl oz (200 mL):

$$\text{25\% drainage volume} = \frac{\text{volume of solution}}{4} = \frac{200 \text{ mL}}{4} = 50 \text{ mL} \quad [\text{A.29.3.2.2.3a}]$$

The time versus solution volume data are recorded as shown in Table A.29.3.2.2.3.

It is seen that the 25 percent volume of 1.691 fl oz (50 mL) lies within the 2- to 3-minute period. The increment to be added to the lower value of 2 minutes is found by interpolation of the data:

$$\frac{50 \text{ mL (25\% volume)} - 40 \text{ mL (2-min volume)}}{60 \text{ mL (3-min volume)} - 40 \text{ mL (2-min volume)}} = \frac{10}{20} = 0.5 \quad [\text{A.29.3.2.2.3b}]$$

Therefore, the 25 percent drainage time is found by adding 0.5 minute to 2.0 minutes, giving a final value of 2.5 minutes, or 2 minutes 30 seconds.

A.29.3.3.2.5 The following equation shows the calculation of expansion. The net weight of the foam sample (*see Table 28.1*) is assumed to be 200 g; therefore, the volume of foam solution contained in the 54.102 fl oz (1600 mL) foam sample is 6.763 fl oz (200 mL).

Table A.29.3.2.2.3 Drainage Time

Time (min:sec)	Assumed Drained Solution Volume	
	fl oz	mL
0:00	0	0
0:30	0.338	10
1:00	0.676	20
1:30	1.014	30
2:00	1.353	40
2:30	1.691	50
3:00	2.029	60

[A.29.3.3.2.5]

$$\text{Expansion} = \frac{\text{volume of foam}}{\text{volume of solution}} = \frac{1600}{200} = 8$$

A.29.5.2 Pattern testing should only be required for vehicle prototype testing by the vehicle manufacturer. Section 6.3 of NFPA 1900 can be used as a reference for pattern testing.

See Figure A.29.5.2.

A.29.6.1 Figure A.29.6.1(a) and Figure A.29.6.1(b) show forms for use in reporting and graphing test results.

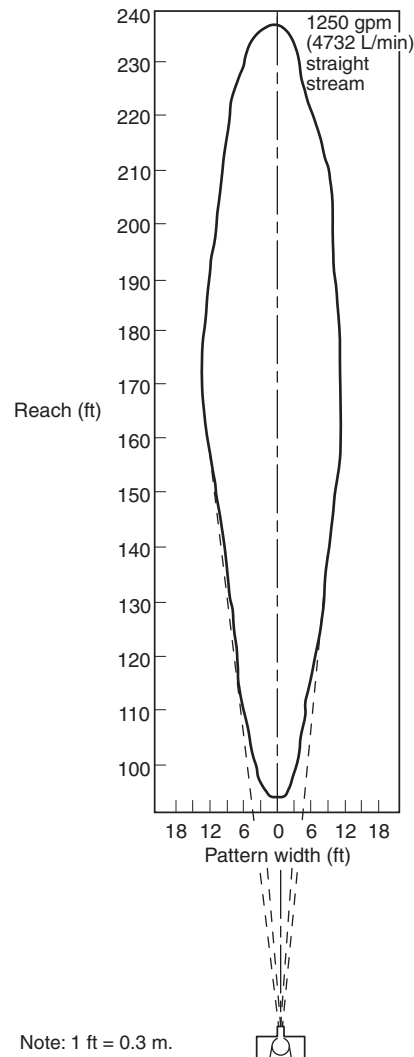


FIGURE A.29.5.2 Typical Foam Discharge Pattern.

FOAM PHYSICAL PROPERTY TESTS WORKSHEET (in accordance with NFPA 460)

Date: _____

Test number: _____

Location: _____

Test subject: _____

Vehicle: _____

Type foam liquid concentrate: _____

Foam maker: _____ Pattern setting: _____

Operating pressure: _____ psi at pump, nozzle

Flow: _____ gpm

Air temperature: _____ °F (°C) Water temperature: _____ °F (°C)

Wind: _____ mph

Direction relative to pattern axis: _____

Gross weight of full foam container*: _____ grams

Weight of empty container: _____ grams

Net weight of foam sample: _____ grams

*Foam container must have the dimensions as specified in NFPA 460.

$$\begin{aligned}\text{Foam expansion} &= \frac{\text{Volume of foam container}}{\text{Net weight of foam sample}} \\ &= \frac{\text{_____ mL}}{\text{_____ grams (from above)}} = \text{_____}\end{aligned}$$

$$\begin{aligned}25\% \text{ volume} &= \frac{\text{Net weight of foam sample}}{4} \\ &= \frac{\text{_____ grams (from above)}}{4} = \text{_____ mL}\end{aligned}$$

FIGURE A.29.6.1(a) Example of a Worksheet for Reporting Results of Foam Physical Properties Test.

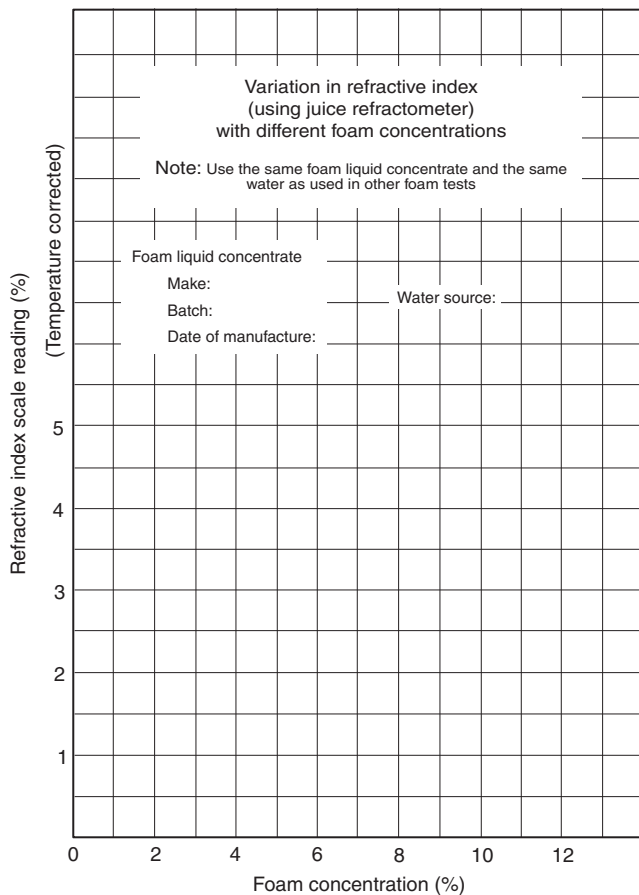


FIGURE A.29.6.1(b) Example of a Worksheet for Graphing Results of Foam Physical Properties Test.

Annex B Basis of Agent Quantities (NFPA 403)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Background. This standard's goals and requirements are to assure the survivability of ambulatory occupants and the ability of ARFF responders to perform interior fire attack, potential rescue of non-ambulatory survivors, and recovery of victims. The quantity of agent defined in this standard provides enough agent to protect the aircraft fuselage, control the fire endangering escaping occupants, establish a safe area for continued operations, perform final extinguishment, and prevent re-ignition.

B.2 Area Concept. The first meeting of the Rescue and Fire-Fighting Panel (RFFP-I) was convened by the International Civil Aviation Organization (ICAO) in Montreal, Canada, from March 10 to March 20, 1970.

At that time, the method contained in Annex 14, Attachment C (5th edition), for the determination of the level of protection (agent quantities and number of vehicles) to be provided at airports for fixed wing aircraft was based on the fuel load and passenger capacity of the aircraft. As a result of correspondence exchanged among the Panel members, there was general agreement that a new or revised method for specifying the quantity of extinguishing agents and rescue equipment to be provided was needed.

The Panel unanimously agreed that the concept for determining the level of protection should be the "critical area." This was an area to be protected in any post-accident situation that would permit the safe evacuation of the aircraft occupants. The purpose of the critical area concept was not to define fire attack procedures. Instead, it was to serve as the basis for calculating the quantities of extinguishing agents necessary to achieve protection within an acceptable period of time.

Based on the logic that passenger capacity was related to length, the Panel also unanimously agreed that the critical area should be a rectangle having as one dimension the length of the fuselage. However, a wide division of opinion existed as to what width should be used. The RFFP-I report documents five proposed means of defining the width of the critical area.

It was finally agreed that no single system could be used to express the area to be protected for all sizes of aircraft. In the end, the Panel agreed that the critical area should be a rectangle, having as one dimension the overall length of the aircraft, and as the other dimension the overall length of the aircraft for aircraft with wing spans of less than 100 ft (30 m) and should be 100 ft (30 m) for aircraft with wing spans of 100 ft (30 m) or more. A standard fuselage width of 20 ft (6 m) was assumed. Using this approach, the aircraft in service at that time were grouped into a series of eight categories. Beginning with category one, each successive category represented a logical progression in aircraft length (Hewes 1970, p. 2-1).

The concept of using graduated aircraft categories as a means of assessing fire protection needs has survived to the present time with only minor revisions to reflect changes in the operating aircraft fleet. This general concept has been adopted worldwide by both consensus standard-writing organizations and national regulatory authorities.

By correspondence following RFFP-I, the members agreed that the use of the area concept for determining the level of firefighting agents and equipment needed to combat an aircraft accident fire was based on the following facts:

- (1) The quantity of agent necessary to control or cover the fire area could be relatively accurately determined.
- (2) The rate of application of the agents to control the fire in the most effective time period could also be determined.

Hence, when RFFP-II convened in 1972, the Panel confirmed the critical area concept where one dimension of the area would be the length of the aircraft. However, there was no consensus as to length of the other side. In addition, the Panel concluded that there was a need to distinguish between the *theoretical critical area* within which it might be necessary to control a fire and a *practical critical area* that was representative of actual aircraft accident conditions. Although the Panel had not agreed on the dimensions, it did agree that the theoretical critical area should be defined as covered in B.2.1.

B.2.1 Theoretical Critical Area (TCA) — Definition. The theoretical area adjacent to an aircraft in which fire must be controlled for the purpose of ensuring temporary fuselage integrity and providing an escape area for its occupants.

The RFFP-II had the benefit of large test fire experiments conducted by a member country aimed at estimating the size of the theoretical critical fire area (Geyer 1972). This study paid particular attention to the width on each side of the fuselage that would have to be secured to protect the aircraft's skin from melting under severe fire conditions. On the basis of the data

presented in this report, the Panel agreed that the TCA should be a rectangle having as one dimension the overall length of the aircraft, and the other dimension determined by the following:

- (1) For aircraft with an overall length of less than 65 ft (20 m): 40 ft (12 m) plus the width of the fuselage
- (2) For aircraft with an overall length of 65 ft (20 m) or more: 100 ft (30 m) plus the width of the fuselage (Harley 1972, p. 3-1f)

The TCA serves only as a means for categorizing aircraft in terms of the magnitude of the potential fire hazard in which they might become involved. It is not intended to represent the average, maximum, or minimum spill fire size associated with a particular aircraft. The original formula for the maximum theoretical critical area, as presented in the RFFP-II report, was given as follows (Harley 1972, p. 3-16):

$$A_T = L \times (30 + w) \quad \text{where } L > 20 \text{ m} \quad [\text{B.2.1a}]$$

or

$$A_T = L \times (100 + w) \quad \text{where } L > 65 \text{ ft, and} \\ A_T = L \times (12 + w) \quad \text{where } L < 20 \text{ m} \quad [\text{B.2.1b}]$$

or

$$A_T = L \times (40 + w) \quad \text{where } L < 65 \text{ ft} \quad [\text{B.2.1c}]$$

where:

A_T = theoretical critical area (TCA)

L = overall length of the aircraft

w = width of the aircraft fuselage

The data analyzed by RFFP-II in its effort to respond to the issue of TCA versus practical critical area (PCA) appeared to indicate that the PCA was approximately two-thirds of the TCA. This had been verified by a study conducted by one of the member countries of actual spill fire sizes and aircraft accidents (Ansart 1970). Another analysis of ARFF operations had not included the study of the PCA as compared to the TCA (Harley 1972, p. 1-1). However, that study did compare the actual amount of water used for foam at those accidents with the amounts recommended by RFFP-I. It was found that out of 106 accidents for which this information was available, in 99 cases, or 93 percent, the amounts recommended by the Panel were in excess of those required in the actual aircraft accident. In light of the findings, the Panel decided to use two-thirds of the TCA as the PCA (Harley 1972, p. 3-3). (See Figure B.2.1 for a graphic display of this concept.) The formula for the PCA developed by RFFP-II for fixed-wing aircraft can be expressed as follows:

$$\text{PCA} = (0.67) \times (\text{TCA}) \quad [\text{B.2.1d}]$$

B.3 Control Time. After defining the critical area to be protected and developing a system of fire protection category

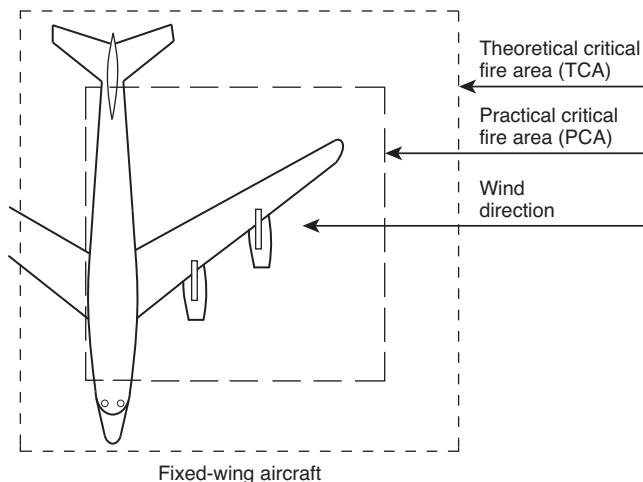


FIGURE B.2.1 Theoretical Critical Fire Area (TCA) Relative to Practical Critical Fire Area (PCA).

ries, RFFP-I turned its attention to the issues of discharge rates and the extinguishing agents to be applied to the critical area. The Panel concluded that fire control time and fire extinguishment time within the critical area should be considered individually and defined as follows:

- (1) *Control time:* The time required from the arrival of the first firefighting vehicle to the time the initial intensity of the fire is reduced by 90 percent.
- (2) *Extinguishment time:* The time required from arrival of the first firefighting vehicle to the time the fire is completely extinguished (Hewes 1970, p. 2-2).

RFFP-II confirmed these definitions, and based on an analysis of accident data furnished by member countries, it considered that the equipment and techniques to be used should be capable of controlling the fire in the PCA in 1 minute (Harley 1972, p. 3-4). This concept has not only survived to the present time, but it has, with minor revisions from time to time to update changes in the operating aircraft fleet, been adopted worldwide by both consensus standards-making organizations and national regulatory authorities.

RFFP-II was unable to identify a recommended time period for the extinguishment time. This was due to the numerous variables involved at each aircraft accident, such as the size of the aircraft, area of fire, and three-dimensional fires (Harley 1972, p. 3-4).

B.4 Discharge Time. At RFFP-I, the Panel agreed that discharge rates should be designed to achieve the lowest possible fire control time that is consistent with the objective of preventing the fire from melting through the fuselage or causing an explosion of the fuel tanks. The Panel also agreed that the equipment and techniques to be used should be capable of controlling the fire in the critical area in 1 minute and of extinguishing the fire within another minute. Using available fire extinguishment test data based on protein foam, the Panel concluded that for a single agent attack, an application rate of 0.2 US gpm/ft² (8.2 L/min/m²) for 2 minutes would be sufficient to meet the fire control and fire extinguishment time requirements. The Panel also agreed that when dual agent attack techniques were used (foam and dry chemical, CO₂, or a

halocarbon), a reduced application rate could be used. A minimum of 0.15 US gpm/ft² (6.1 L/min/m²) was recommended.

Based on the consideration that the lighter construction of small aircraft increased their vulnerability to fire penetration, the Panel also recommended that the same discharge rates be used for small aircraft.

All of the discussions and recommendations at RFFP-I were based on the performance of protein foam only. The Panel's report recognized the existence of both fluoroprotein and aqueous film-forming foams and indicated that some member countries were starting to use them. However, the Panel generally agreed that there was insufficient documentation of performance upon which to base recommendations. The report also indicated a general understanding among Panel members that the suitability of other agents and their relationship with protein foam would be considered later (Hewes 1970, p. 2-2).

At RFFP-II, the Panel confirmed the application rate for protein foam recommended by RFFP-I and agreed that an application rate of 0.13 US gpm/ft² (5.3 L/min/m²) for aqueous film-forming foam was suitable. The Panel could not agree on a suitable recommendation for fluoroprotein due to the wide variety of foams. However, it did recognize them as useful aircraft fuel firefighting foams and left the application rate to the authority having jurisdiction, to be based on test data for the individual foams (Harley 1972, p. 3-4f).

B.5 Quantities of Agent to Be Provided. By multiplying the TCA corresponding to the upper limit of the airport category times the recommended protein foam application rate, times a factor of 2 for the recommended discharge time, RFFP-I produced a table of recommended water quantities for foam production. The table also included recommended weights for complementary agents and the recommended discharge rates for both single and dual agent attack for eight airport categories (Hewes 1970, p. 2-17).

At RFFP-II, the Panel agreed that when determining the amounts of extinguishing agents to be provided, the amounts required to control and to extinguish a fire should be determined separately. The quantities were named and defined in B.5.1 and B.5.2.

B.5.1 Quantity Q_1 — Definition. The quantity required to obtain a 1-minute control time in the PCA.

The formula for the water required for control (Q_1) in the PCA can be expressed as follows:

[B.5.1]

$$Q_1 = \text{PCA} \times R \times T$$

where:

PCA = practical critical area

R = rate of application for the specific foam

T = time of application

B.5.2 Quantity Q_2 — Definition. The quantity required for continued control of the fire after the first minute or for complete extinguishment of the fire or for both.

The Panel concluded that the amount of water required for Q_2 could not be calculated exactly, as it depended on a number

of variables. Those variables considered of primary importance by the Panel were the following:

- (1) Maximum gross weight
- (2) Maximum passenger capacity
- (3) Maximum fuel load
- (4) Previous experience (analysis of aircraft rescue and fire-fighting operations)

These factors were used by RFFP-II to generate Q_2 values for each airport category where $Q_2 = f \times Q_1$. The values of f ranged from 3 percent for Category 1 airports through 170 percent for Category 8 airports (Harley 1972, p. 3-16ff).

B.6 Application Rates and Amounts. The basic concepts developed by the ICAO RFFPs are still considered valid. However, the variables previously mentioned that are used to develop the f factor for Q_2 have been refined over time and are now expressed as follows:

- (1) *Aircraft Size.* Aircraft size reflects the potential level of risk. This risk factor is a composite of the passenger load, the potential internal fire load, flammable liquid fuel capacity, and the fuselage length and width. Careful consideration of all these factors allows the identification of a meaningful operational objective — that is, the area to be rendered fire free (controlled or extinguished).
- (2) *Relative Effectiveness of Agent Selected.* This variable is accounted for by the specific application rate identified for each of the common generic foam concentrate types.
- (3) *Time Required to Achieve PCA Fire Control.* Information from reliable large-scale fire tests, empirical data from a wide variety of sources, and field experience worldwide indicate that 1 minute is both a reasonable and a necessary operational objective.
- (4) *Time Required to Maintain the Controlled Area Fire Free or to Extinguish the Fire.* This time is an operational objective that provides a safety factor for the initial fire attack on the PCA while waiting for the arrival of backup support or to complete extinguishment of remaining fires outside the PCA.

The quantity of water for foam production required for 1-minute fire control of the PCA is still referred to as Q_1 . However, data collected in the ensuing years has permitted specifying the required application rates for three generic foam types needed to extinguish fire in 1 ft² or 1 m² of the PCA as follows:

- (1) AFFF = 0.13 gpm/ft² or 5.5 L/min/m²
- (2) FP = 0.18 gpm/ft² or 7.5 L/min/m²
- (3) PF = 0.20 gpm/ft² or 8.2 L/min/m²

These application rates were based primarily on full-scale studies conducted by Geyer (1972) using both high volatility JP4 fuel and lower volatility fuel such as JP5 and Jet A. Over the years, NFPA 403 expanded the use of the FP application rate to other surfactants, such as FFFP and FFSF foams, which could meet ICAO B level foam tests. The fourth edition, 2014 of the ICAO *Airport Services Manual, Part 1, Rescue and Fire Fighting*, introduced a more difficult performance test — Level C. The intent of the new ICAO Level C foam performance test was an attempt to match test parameters to those in MIL-F-24835, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate, for Fresh and Sea Water*, while keeping the test in line with the ICAO Level A and B test procedures. During the development process, under sponsorship from the CAA, 27 foams from eight manufacturers were tested by CNPP (CNPP-Vernon,

2008). The result is a test that is rigorous, but in certain aspects does not quite match to the performance of the Mil-Spec foams, which are required to contain film-forming fluorinated surfactants. Fire test differences relate to pan size, fuel (gasoline versus Jet A), manual versus fixed foam application, and the allowance of 99 percent control versus full extinguishment at 1 minute. However, it has been shown that few foams have the ability to pass ICAO C, reflecting the difficulty of this test procedure. There has been limited full-scale testing of ICAO C foams, but tests to date have reflected extinguishments on Jet A within 1 minute at the ICAO application rate of 0.092 gpm/ft² (3.75 L/min/m²). The 0.13 gpm/ft² (5.5 L/min/m²) application rate requirement for AFFF meeting Mil-Spec in NFPA 403 is 40 percent higher. ICAO Level C foams will have a safety margin when used at the 0.13 gpm/ft² (5.5 L/min/m²) application rate. It was concluded, for purposes of this standard, that ICAO Level C foam application rates could be set as equivalent to Mil-Spec foam.

When considering the ICAO C foams, the committee also considered the classification designations used in Chapters 4 through 10 for application rates. Historically, these related to the constituents of the foam, (e.g., protein fluoroprotein, and fluorinated surfactants) used in AFFF. There was a desire by the committee to eliminate the designation of foams by constituents, and use a performance-based approach. The ICAO Levels A, B, and C provide such an approach. Foams are evaluated based on fire performance, not physical or chemical attributes. This allows future modifications of foam formulations (e.g., for environmental improvement) without changing the fire performance criteria.

It was recognized that there are some limitations to this approach that users of ICAO C should be aware of. The intent of the MIL-F-24835 standard is to create AFFF foam concentrates that have similar physical properties and will be interchangeable between various manufacturers. The Mil-Spec also requires fire performance tests of the foam concentrate proportioned incorrectly, either too low or too high. It is noted that the ICAO tests are primarily fire performance tests and foams between manufacturers are not considered interchangeable. There are no requirements for testing of incorrectly proportioned foam. Airports adopting ICAO foam concentrates should evaluate equipment requirements any time a switch to a new manufacturer of foam concentrates is considered.

Therefore, starting with the 2018 edition of NFPA 403, the following application rates by test standard are used:

- (1) MIL-F-24835 and ICAO Level C = 0.13 gpm/ft² or 5.5 L/min/m²
- (2) ICAO Level B = 0.18 gpm/ft² or 7.5 L/min/m²
- (3) ICAO Level A = 0.20 gpm/ft² or 8.2 L/min/m²

UL 162, *Standard for Foam Equipment and Liquid Concentrates* and EN 1568, *Specification for Low Expansion Foam Concentrates for Surface Application to Water-Immiscible Liquids*, have been recognized in past revisions of NFPA 403. In the move toward classification by performance testing, these referenced test standards were deleted since they were not developed with a focus of aircraft rescue and firefighting applications.

Over time the changes in aircraft size factor have required revisions to the values of both Q_1 and Q_2 and the introduction of a third component, Q_3 , which make up the total quantity of water (Q) required for the production of foam.

For example, Q_1 changes as a function of the accepted foam application rates and the size of the operational aircraft common to the various airport categories. And, because Q_2 is a function of Q_1 , it too is impacted by changes in aircraft size and requires revision from time to time to accurately reflect the changes in the operational aircraft fleet.

The operational significance of the components making up Q is substantial in that Q relates to both the specific quantities of fire suppression agents required to control fire in the PCA and to the requirement that the specified quantity of agent be applied to the PCA within a time frame of 1 minute. In turn, Q_2 relates to the need to have sufficient fire suppression agents available to maintain conditions that do not pose a threat to life in the PCA until such time as rescue operations are completed. The secondary role of Q_2 is to extinguish all fires in and peripheral to the PCA.

The development of the requirement for these two quantities of water is based on exterior aircraft fuel spill fire control parameters. Information from actual incidents in recent years has shown that with increased aircraft crash worthiness, water for interior firefighting operations is also necessary. This quantity of water, called Q_3 , is based on the need for handlines to be used for interior firefighting. Hence, the total quantity of water (Q) is now defined as follows:

[B.6]

$$Q = Q_1 + Q_2 + Q_3$$

where:

Q_1 = water requirement for control of PCA

Q_2 = water requirement to maintain control or extinguish the remaining fire or both

Q_3 = water requirement for interior firefighting

(See Figure B.6.)

B.6.1 The method for calculating the values for each component of Q is presented here:

[B.6.1]

$$Q_1 = \text{PCA} \times R \times T$$

where:

PCA = (0.67) × TCA, TCA = $L \times (K + W)$, and

L = length of aircraft

W = width of fuselage

R = application rate of selected agent

T = time of application (1 minute)

K = values shown in Table B.6.1

(See Table B.6.1.)

B.6.2 The current values of Q_2 as a percentage of Q have been determined to be as shown in Table B.6.2.

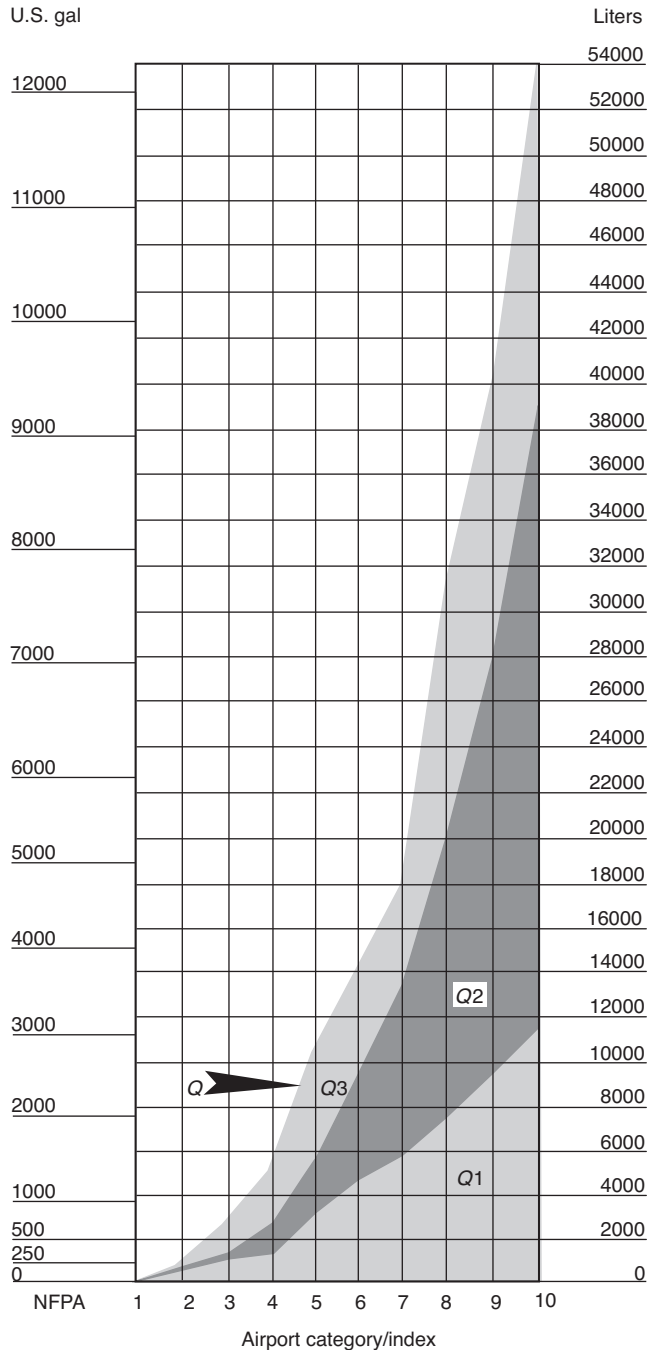


FIGURE B.6 Comparison of Water by Volume of Q_1 , Q_2 , Q_3 , and Q for Producing Foam Solution Using AFFF.

B.6.3 The values of Q_3 are based on accepted water flow requirements for the type of firefighting operations to be experienced when combating an interior aircraft fire. They are determined as shown in Table B.6.3.

In December 2000, ICAO RFFP-9 met. It was agreed that to accomplish a timely interior fire suppression, all necessary equipment and personnel should be in place and the suppression activity should be in action within 5 minutes of notification

Table B.6.1 K Factors

Feet	
K	= 39 where L = less than 39 = 46 where L = 39 up to but not including 59 = 56 where L = 59 up to but not including 78 = 98 where L = 78 and over
Meters	
K	= 12 where L = less than 12 = 14 where L = 12 up to but not including 18 = 17 where L = 18 up to but not including 24 = 30 where L = 24 and over

Table B.6.2 Q_2 as a Percent of Q_1

Airport Category	$Q_2\%$ Q_1	Airport Category	$Q_2\%$ Q_1
1	0	6	100
2	27	7	129
3	30	8	152
4	58	9	170
5	75	10	190

Table B.6.3 Quantity of Water for Handlines

Airport Category	Q_3 Equals (US gal)
1	0
2	0
3	60 gpm $\times$ 5 min = 300 gal
4	60 gpm $\times$ 10 min = 600 gal
5	125 gpm $\times$ 10 min = 1250 gal
6	125 gpm $\times$ 10 min = 1250 gal
7	125 gpm $\times$ 10 min = 1250 gal
8	250 gpm $\times$ 10 min = 2500 gal
9	250 gpm $\times$ 10 min = 2500 gal
10	500 gpm $\times$ 10 min = 5000 gal

of the accident event. This requirement places a premium on the need to have sufficient personnel and equipment to perform this task in the first responders group.

B.6.4 Sample Calculation Using Airport Category 4 and AFFF Foam.

$$TCA = L \times (K + W)$$

$$= 77.8 \times (56 + 12.9) = 5360 \text{ ft}^2$$

$$PCA = \frac{2}{3} \times TCA = \frac{2}{3} \times 5360 \text{ ft}^2 = 3573 \text{ ft}^2$$

$$Q_1 = 0.13 \text{ gpm/ft}^2 \times 3573 \text{ ft}^2 \times 1 = 464 \text{ gal}$$

$$Q_2 = 58\% \times Q_1 = 0.58 \times 464 = 269 \text{ gal}$$

$$Q_3 = 600 \text{ gal}$$

now

$$Q = Q_1 + Q_2 + Q_3$$

$$= 464 + 269 + 600 = 1333 \text{ gal}$$

rounded up to 1340 gal

This quantity is shown in Table 5.3.1(a).

The example is given to illustrate the logic and the factors used to arrive at the quantity of water for foam production required for an airport Category 4.

B.7 Updated Review of TCA/PCA. A recent pair of studies performed by the US Federal Aviation Administration (FAA) demonstrated that the PCA/TCA concept is still valid. The reports are: DOT/FAA/AR/11-29, *A Technical Review of Methodologies for Calculating Firefighting Agent Quantities Needed to Combat Aircraft Crash Fires*, US Department of Transportation, Federal Aviation Administration, April 2012; and DOT/FAA/AR/11-27, *Analysis of Suppression Effects on Aviation Fuel Fires Around an Aircraft*, US Department of Transportation, Federal Aviation Administration, November 2011. These analyses addressed various factors in assessing current ARFF agent requirements. These factors included the historical development of the existing methods and the recent fire-related loss history. The recent loss history includes the effectiveness of the ARFF response. A fire hazard analysis was performed for threats to occupants in an aircraft and those who have escaped the aircraft. The NFPA 403 methodology was found to be acceptable and appropriate for establishing agent quantities.

Annex C Operational Communications System (NFPA 403)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Considerations for Communication Systems. At those locations where the primary alerting authority (such as a control tower) is not operational during all the hours that the airport is open to aircraft traffic, a secondary alerting authority should be designated and trained. Appropriate communications and alarm control devices should be available at the secondary alerting authority's operating location and be operational during all times that the primary alerting authority is not available.

At those locations where a city or town or county off-airport fire department furnishes the airport rescue and firefighting (ARFF) personnel, and the alerting/dispatching of those personnel for airport emergencies is handled by an emergency direct-line telephone between the airport alerting authority and the off-airport alarm room, the airport fire station alarm(s) should ring upon activation of the direct emergency line. If possible, this type of "third party" dispatching of airport firefighting and rescue services should be avoided.

Because the majority of the calls for ARFF services are initiated by or first received by air traffic controllers, the airport fire department alarm room and the control tower, the flight service station, or other air traffic control point should be linked by two-way radio and direct-line telephone to enhance the response time of the fire and rescue crews.

The emergency direct-line telephone should not pass through any intermediate automated switchboard or operator that could subject the alert calls to delays.

The tone of the emergency telephone bell (or buzzer) should be distinctly different from all other communications signaling devices within hearing of personnel in the alarm room, on the apparatus floor, or in living quarters as applicable.

Protection against delays due to telephone bell or buzzer failure should be provided by use of redundant warning lights

activated by the same input signal as the telephone ringer. The lights should be strategically located throughout the alarm room, the apparatus floor, and living space as dictated by the fire station design and the normal activities of the fire and rescue service personnel.

The fire station alarm should be linked to the emergency telephone so that a call on the emergency telephone circuit simultaneously actuates the audible alarm throughout the fire station.

Consideration should be given to having the alarm circuitry open the vehicle bay doors in the fire station upon sounding the alarm. However, some climatic conditions can make this impractical, or noise when doors are opened can interfere with hearing the dispatch.

The notification of all units designated to respond to an aircraft emergency on a large airport should be done through the use of a "conference" circuit that allows simultaneous notification. This "conference" circuit should include, as appropriate, the following units or offices:

- (1) Control tower, flight service station, or other control point
- (2) Rescue and firefighting
- (3) Airport police
- (4) Airport management
- (5) Airline station manager(s), as appropriate
- (6) Military units (joint-use airports)
- (7) Other authorities on or off the airport as required by the airport's emergency plan

At airports with several air carriers, the notification of the appropriate station manager might be accomplished more effectively by the use of individual paging devices.

Fire stations where personnel are normally present for duty but might be preoccupied with housekeeping or training duties should be equipped with a public address system. This is particularly important in fire stations where the alarm room, training room, and living quarters are physically separated from the apparatus floor. Such a system should significantly enhance response time and firefighter effectiveness by providing vital details of the emergency to each firefighter during response, such as location of accident or incident site, type of aircraft, number of persons involved, aircraft fuel load, and preferred vehicle routing, and so forth.

At airports with a main fire station and one or more substations, an interconnected public address system should be provided.

At airports employing dual function personnel or auxiliary firefighters, an audible alarm should be installed in all areas where auxiliary firefighting personnel are employed to notify them of any emergency recall for fire and rescue duties. It should be a distinctly different sound and loud enough to be clearly heard above the normal noise level.

At airports equipped with ground-to-air radio, the person authorized to receive in-flight emergency messages should be provided with a device for actuating these alarms.

Alarm actuating stations should be provided near hangars, shops, fueling stations, and aircraft parking areas.

Individual paging devices, although potentially more expensive, can be used. This method has the advantage of notifying those persons with assigned rescue firefighting duties.

A reliable voice communications capability should be available between the ARFF service and any off-airport organizations expected to participate in the airport/community mutual aid plan.

Each emergency response vehicle on an airport should be equipped with two-way voice radio communication between the alerting authority, all other ARFF vehicles, and the designated command post.

On airports with a control tower, the communications channel between vehicles and the tower should be on the assigned standard ground control frequency, or as designated in the Airport Emergency Plan Letter of Agreement between airport management, the control tower, and/or flight service station.

On airports without a control tower but with another means of ground-to-air communications, the ARFF vehicles should be equipped to communicate on a frequency common with the control point.

Where practicable, the two-way radio capability on the ARFF service vehicle(s) should not be tied into public service frequencies (city, county, or airport maintenance). This independent communications network will help ensure interruption-free communication in an emergency situation.

On-scene commanders (OSCs) should have a communication capability while outside or remote from their vehicle communications systems. Portable radios can be used by the OSC for direct contact with the airport fire services and air traffic control services.

A reliable form of communication should be provided between the aircraft commander, the OSC, ARFF services, and the airport alerting authority to preclude unnecessary aircraft emergency evacuation or misunderstandings.

Additionally, direct communications can be established between the flight deck and the incident commander (IC) or ARFF personnel by use of the discrete emergency frequencies (DEF) and deck to ground lines. Normally this communication capability results from the use of a flight service headset that is plugged into a wheel well or nose interphone jack (this can be coded red on some aircraft).

The ARFF service alarm room should be designed and operated in such a manner that an alarm can be received, evaluated, and acted on with a minimum of activity or consultation.

For an alarm room to serve its intended function, provisions should be made to ensure that all personnel assigned to alarm room duties are trained in communication equipment operations, proper communication procedures, and local emergency plan implementation procedures.

Annex D Task and Resource Analysis Model (NFPA 403)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 General. The most appropriate approach to accurately determine the necessary levels of staffing in airports was developed by reviewing and combining several task analysis methodologies from airport regulators and fire departments. The

recommended Task and Resource Analysis model for this approach is described in this annex.

D.2 Scope. This annex describes the stages that must be followed by an airport operator in performing a Task and Resource Analysis in order to justify the minimum number of qualified personnel required for an airport rescue and firefighting service (ARFF) to respond effectively to an aircraft incident/accident. If an airport operator requires the ARFF to attend to structural incidents/accidents in addition to aircraft incidents/accidents, the possibility of being unable to meet required response times must be considered.

D.3 Purpose. The Task and Resource Analysis uses a risk-based approach and focuses on possible worst-case scenarios. This allows it to identify the minimum number of personnel required to perform identified tasks in real time before external services are needed at the incident/accident site to effectively support the ARFF services.

The Task and Resource Analysis also should include the types of aircraft using the aerodrome and the need for personnel to use breathing apparatus, handlines, ladders, and other ARFF equipment provided at the aerodrome.

D.4 Preliminary Information. The airport operator should first establish the minimum number of ARFF vehicles required for delivering the extinguishing agents at the required discharge rate for the specified airport category.

D.5 Task and Resource Analysis/Risk Assessment. A Task and Resource Analysis should consist primarily of a qualitative analysis of the rescue and firefighting service (RFFS) response to a realistic, worst-case aircraft accident scenario. The purpose of this analysis is to review the current and future staffing levels of the RFFS deployed at the aerodrome. The analysis should be supported by a quantitative risk assessment to estimate risk reduction. This risk assessment could be related to risk reduction to passengers and aircrew as a result of deploying additional personnel. One of the most important elements of the assessment is determining the impact of any critical paths that were identified by the qualitative analysis.

D.6 Qualitative Analysis. A Task and Resource Analysis and a Workload Assessment are used to examine the effectiveness of the current staffing level and determine the level of improvement that would result from additional staffing. A worst-case accident scenario should be analyzed to assess the relative effectiveness of at least two levels of RFFS staffing: minimum level and optimum level.

D.7 Quantified Risk Assessment. Generally, the quantified risk assessment will be used to support the conclusions of the qualitative analysis by examining the risks to passengers and aircrew from aircraft accidents at the airport. This risk assessment allows the employment of additional RFFS staff to be evaluated in terms of reducing the risk of passenger and aircrew lives lost and expressed in monetary terms. This value can be compared with the cost of employing additional personnel. However, this comparison is of little, if any, value in determining minimum levels of personnel.

D.8 Task and Resource Analysis. The basic contents of an analysis are as follows:

- (1) Description of aerodrome, including the number of runways.
- (2) RFFS category (AIP).

- (3) Response criteria, such as area, number of fire stations, times.
- (4) Rate of movements — that is, remission factor.
- (5) Hours of operation.
- (6) Current structure and establishment.
- (7) Level of staffing.
- (8) Level of supervision.
- (9) RFFS competence in terms of training and facilities.
- (10) Extraneous duties such as domestic and first aid response.
- (11) Alarm system.
- (12) ARFF vehicles and extinguishing agents.
- (13) Specialized equipment such as fast-rescue craft, hovercraft, water carrier, hose line.
- (14) Role responsibilities at medical facilities.
- (15) Predetermined attendees: local police, firefighters, and EMTs.
- (16) Worst-Case Accident Scenario Analysis/Workload Assessment. (This analysis should include personnel mobilization, deployment at the scene, scene management, firefighting, suppression/extinguishment, complementary media, post-fire security, personal protective equipment (PPE), rescue team(s), aircraft evacuation, and media replenishment. Note: This analysis/assessment should identify any conflicts between the current and proposed workloads.)
- (17) Appraisal of existing RFFS provision.
- (18) Future requirements, aerodrome development and expansion.
- (19) Enclosures such as maps, event trees, and so forth.
- (20) Airport certification manual, aerodrome manual, and so forth.

The preceding list is not exhaustive and should only act as a guide.

D.9 Stage 1. The airport operator must understand the goals and objectives of the ARFF staff services and the tasks that personnel are required to perform.

Example:

Goal: To maintain a dedicated ARFF staff of qualified and experienced fire and rescue personnel with specialized equipment to make an immediate response to an aircraft incident/accident in an airport or its immediate vicinity.

Objective: To save lives.

Tasks:

- (1) Meet the required response time.
- (2) Extinguish an external fire.
- (3) Protect exit routes.
- (4) Assist in passenger and aircrew self-evacuation.
- (5) Extinguish an internal fire.
- (6) Rescue trapped personnel.

The preceding list is not exhaustive and should only act as a guide.

D.10 Stage 2. The airport operator must identify a selection of representative realistic accidents that could occur at the airport. This selection can be identified by analyzing statistics of previous accidents at airports and data from both international and national sources.

(Note: All accidents/incidents are to involve fire to represent worst-case scenarios.)

Example:

- (1) Internal aircraft fire
- (2) Aircraft engine failure with a fire
- (3) Aircraft aborts and overruns with fire
- (4) Aircraft into aircraft with fire
- (5) Aircraft into terminal building(s) with a fire

D.11 Stage 3. The airport operator must identify the types of aircraft commonly used at the airport. This stage is important because the type of aircraft and its configuration have a direct impact on the resources required in meeting Stage 1. For ease of analysis, it might be necessary to group the types in relation to common aircraft configuration.

Example:

- (1) Long, wide-bodied aircraft with multiple passenger decks and multiple aisles
- (2) Long, narrow-bodied aircraft with single aisle, high passenger density
- (3) Short, narrow-bodied aircraft with single aisle, high passenger density and restricted over-wing exits

A representative aircraft from this example can then be chosen as one of the following:

- (1) Boeing 747
- (2) Boeing 757
- (3) Boeing 737

D.12 Stage 4. Every airport is unique in that the airport location, runway and taxiway configuration, aircraft movements, airport infrastructure and boundary, and so forth, could present specific additional risks to the airport operator.

For the worst-case accident scenario to be modeled, a major factor to consider is the worst-case location for the most likely accident type that could occur.

The worst-case location should be confirmed by a facilitator using a team of experienced fire service personnel who have knowledge of the airport and the worst-case locations in which an aircraft accident could occur.

The role of the facilitator is to assist the team in reaching agreement on the worst-case locations and, by using a scoring system, to rank order these locations.

The team must determine their reasons for identifying the worst-case locations. Each team member gives each location a weighted number. The numbers for each location can then be added up to correspond to each identified location.

Example:

The team could have identified that the following factors contributed to a worst-case location:

- (1) Travel time
- (2) Route to the accident site — that is, hard or soft ground
- (3) Terrain
- (4) Crossing active runways
- (5) Aircraft congestion
- (6) Surface conditions
- (7) Communications
- (8) Supplementary water supplies
- (9) Adverse weather conditions
- (10) Additional lighting