NFPA® 422

Guide for Aircraft Accident/Incident Response Assessment

2010 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA® 422

Guide for

Aircraft Accident/Incident Response Assessment

2010 Edition

This edition of NFPA 422, *Guide for Aircraft Accident/Incident Response Assessment*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting. It was issued by the Standards Council on October 27, 2009, with an effective date of December 5, 2009, and supersedes all previous editions.

This edition of NFPA 422 was approved as an American National Standard on December 5, 2009.

Origin and Development of NFPA 422

Originally a manual, NFPA 422 was initially begun in 1963 and was submitted to the Association for adoption at the 1972 Annual Meeting. The document was revised in 1979 and 1984, and the 1989 edition was a reconfirmation of the 1984 edition.

The title for the 1994 edition was changed from *Manual for Aircraft Fire and Explosion Investigators* to *Guide for Aircraft Accident Response*. The document was completely revised to provide a framework for the accumulation of data relative to the effectiveness of aircraft accident/incident emergency response services in the application of principles found in the standards and guides developed by the Technical Committee on Aircraft Rescue and Fire Fighting.

This document is intended to assist the committee in collecting significant data that can be utilized to facilitate revisions to the NFPA aircraft rescue and fire-fighting documents.

The 1999 edition was a reconfirmation of the 1994 edition. Editorial changes were made to make the forms easier to use.

For the 2004 edition, the document was revised to include only one, simpler form that can be used for all accidents/incidents. Several chapters were added with information for the investigator.

In the 2010 edition of NFPA 422, the Aircraft Accident/Incident Report Form has been reformatted as a checklist, making it easier to fill out. The committee wanted to keep the report form as thorough as possible while still being simple and up-to-date. The committee is hoping that the redesigned form will increase the likelihood that it will be used and submitted, thus ensuring proper data collection and processing. The explanatory sections that accompany the form have been rewritten to reflect the form's revisions. In addition, the committee has made sure that the document follows the *Manual of Style for NFPA Technical Committee Documents* by making the appropriate corrections and updates.

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Marc S. Tonnacliff, U.S. Federal Aviation Administration, DC [E]
Rep. U.S. Federal Aviation Administration
Bernard Valois, Transport Canada Civil Aviation, Canada [E]
Joseph A. Wright, ARFF Technical Services, Inc., PA [SE]

Alternates

Abdulrahman A. Y. Alsaadi, Department of Civil Aviation, United Arab Emirates [U]
(Alt. to R. M. Radford)
Alan Black, Dallas/Fort Worth International Airport Board, TX [C]
(Alt. to C. Cinquemani)
Bradford Colton, American Pacific Corporation, NV [M]
(Alt. to F. B. Goodnight)
David Evans DeMaria, U.S. Federal Aviation Administration, DC [E]
(Alt. to M. S. Tonnacliff)
Robert J. Donahue, Massport Fire-Rescue, MA [L]
(Alt. to Massport Rep.)
Eric J. Gogley, U.S. Department of the Navy, CA [C]
(Alt. to R. A. Davidson)
George F. Hall, International Fire Associates Consulting, LLC, FL [C]
(Alt. to J. E. Podolske, Jr.)
Richard L. James, III, Hartsfield-Jackson Atlanta International Airport, GA [C]
(Alt. to P. S. Meyer)
Jason, McMillen, Emergency One, Inc., FL [M]
(Alt. to M. Manikkam)
James F. O'Regan, O'Regan Consulting/JRI, Inc., MA [M]
(Alt. to R. Colet)
Ron Parry, BAA plc, United Kingdom [C]
(Alt. to G. I. Moorshead)
Joseph L. Scheffey, Hughes Associates, Inc., MD [SE]
(Alt. to R. L. Darwin)
Nicholas M. Subbotin, U.S. Federal Aviation Administration, NJ [RT]
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(Alt. to G. Morinville)

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

Committee Scope: This Committee shall have primary responsibility for documents on aircraft rescue and fire-fighting services and equipment, for procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This Committee also shall have responsibility for documents on aircraft hand fire extinguishers and accident prevention and the saving of lives in future aircraft accidents involving fire.

Contents

NFPA 422

Guide for

Aircraft Accident/Incident Response Assessment

2010 Edition

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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.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in advisory sections of this document are given in Chapter 2 and those for extracts in the informational sections are given in Annex C. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text should be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1 Scope. This guide provides a framework for the collection of data that provide information on the effectiveness of aircraft accident/incident emergency response services.

1.2* Purpose. The purpose of this guide is to outline a format for a comprehensive emergency response analysis and to collect significant data that can be utilized to facilitate revisions to applicable NFPA documents.

1.2.1 Chapter 5 of this guide can be effectively used to record and critique airport emergency disaster exercises.

1.2.2 The purpose of Chapter 5 is also to provide the following:

(1) Information associated with an accident/incident that can be used to update and refine disaster plans for other airports and communities involved in aviation operations
(2) Data for the revision of NFPA 424, *Guide for Airport/Community Emergency Planning*

1.2.3 Both the positive and the negative consequences of the operation should be emphasized with the objective of improving life safety in future accidents/incidents.

1.3 Application. This guide applies the principles of those standards and guides developed by the Technical Committee on Aircraft Rescue and Fire Fighting.

1.4 Units. This guide uses metric units of measurement in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which falls outside of, but is recognized by, SI is used commonly in international fire protection.

1.4.1 If a measurement value provided in this guide is followed by an equivalent value in other units, the first stated value should be regarded as the recommendation. The equivalent value might be approximate.

1.4.2 SI units have been converted from U.S. customary values by multiplying the U.S. customary value by the conversion factor and rounding the result to the appropriate number of significant digits.

1.5 Report Form. This guide contains a report form that, when completed, is intended to provide the basis for a comprehensive emergency response analysis.

1.5.1 This report form can be photocopied from this guide if it is not available elsewhere.

1.5.2 The form should be completed by persons with knowledge of the pertinent subject matter.

1.5.3 No obtained information should be released to the news media or to any person unless permission has been obtained first from the chief of the official investigating team. The successful collection of information is related directly to its judicious treatment.

1.5.4 This form can be used by any persons or organizations for their internal use. However, when released, a copy should be sent to the Technical Committee on Aircraft Rescue and Fire Fighting.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

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

NFPA 424, *Guide for Airport/Community Emergency Planning*, 2008 edition.

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

2.4 References for Extracts in Advisory Sections.

NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, 2010 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* 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.

3.2.2 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

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

3.3 General Definitions.

3.3.1 Travel Time. The time interval that begins when a unit is en route to the emergency incident and ends when the unit arrives at the scene. [**1710**, 2010]

3.3.2 Turnout Time. The time interval that begins when the emergency response facilities (ERFs) and emergency response units (ERUs) notification process begins by either an audible alarm or visual annunciation or both and ends at the beginning point of travel time. [**1710**, 2010]

Chapter 4 Aircraft Accident/Incident Emergency Response Data

4.1 Fire Data. Reports on accidents/incidents that involve fires should include information on the origin of the fire, its propagation, and the type, quantity, and effectiveness of extinguishing agents and equipment. Methods for managing fires and fighting fires that follow crashes are of interest to the aircraft rescue and fire-fighting (ARFF) community. These facts can be used to identify trends and prescribe corrective action that enhances safety to life.

4.2 Emergency Exit Data. It should be noted whether egress from the aircraft was required and whether emergency exits were available. Where egress was obstructed, factors such as fire location and structural damage should be identified. This information should be developed as a result of interviewing flight crew, passengers, and witnesses.

4.3 Weather Data. It is important to record the weather conditions that existed at the time of the accident/incident.

4.4 ARFF-Relevant Data. Reports should indicate the type of fire-fighting equipment that was available and that was used, the response time and effectiveness of each responding vehicle, the quantity and type of extinguishing agents used, and an inventory of the remaining agent/water. It is critical to developing improvements for life safety that distinctions be made among total agent used, agent used for control of the fire, and, most important, agent quantity used for all life safety requirements. The level of experience and the degree of training of fire-fighting and rescue personnel should be reported. Reports should address identification of problems encountered with communications, command and control, and implementation of emergency plans.

4.5 Medical Data. Records should include medical findings that result from analysis of the accident/incident. This information should identify the effectiveness of medical triage and transportation of casualties.

4.6 In-Flight Fire Data. Complete information on in-flight fires is essential in order to improve and develop adequate fire-warning and fire-extinguishing systems. Comments on fire behavior, from discovery to extinguishment, should be included in the report. A complete, step-by-step description of the procedure used by the crew for extinguishing the fire should be recorded.

4.7* Responsibilities Regarding Data Collection. Investigation of an accident/incident by an authority having jurisdiction (AHJ) is normally limited to determination of the probable cause. The collection of vital data needed for improving ARFF effectiveness and efficiency generally is beyond the AHJ's investigational process.

4.7.1 To improve ARFF services, the data collector should identify the accident/incident, document the tactics and strategies employed, and determine the effectiveness of existing techniques. These efforts will serve to identify the requisite correctiveness actions that will improve the quality and efficiency of existing ARFF services.

4.7.2 Upon arrival, the data collector should immediately contact the accident/incident investigator in charge. For on-airport accidents/incidents, the airport authority or the AHJ can provide the location of the investigator in charge. For off-airport accidents/incidents, the local enforcement authority should be contacted.

Chapter 5 Data Collected Using NFPA Aircraft Accident/Incident Report Form

5.1 Using the Report Form. This chapter provides information on how to complete the NFPA Aircraft Accident/Incident Report Form, which is reproduced in Figure 5.1. The order of the sections in this chapter corresponds directly to the order of the sections on the report form. Sections 5.3 through 5.8 contain instructions for answering the questions in each section of the form.

5.2 Instructions for Using the Form. The report form can be used in either an electronic format, a feature to be added at a later time, or a nonelectronic format to complete the six categories of information.

5.2.1 Electronic Format. This format is reserved for future use.

5.2.2 Nonelectronic Format. After the form is filled out, it must be mailed or faxed to the current Chair for the Technical Committee on Aircraft Rescue and Fire Fighting.

5.3 General Information. This section of the form is designed to collect the general information regarding the accident/incident with respect to the airport three- or four-letter designator, who is the person filling out the form, and whether that person was on scene during the accident/incident. Other vital information collected in this section is who provided the ARFF services and who was the incident commander (IC) at the scene, if neither of them filled out the form.

5.4 Aircraft and Accident/Incident Characterization. This section of the form provides aircraft accident/incident information on type, aircraft involved, location, persons on board/injuries, cargo HAZMAT, wild/exotic/livestock animal(s), the use of evacuation slides, and first responders injured.

NFPA AIRCRAFT ACCIDENT/INCIDENT REPORT FORM

The NFPA Aircraft Accident/Incident Report Form is designed to collect data on aircraft accidents/incidents. This scientific and statistical information will provide empirical data to assist in the consensus standards-making process with the development of effective NFPA standards and guides. The ultimate goal is to continue to study the challenges faced by responders during significant aviation events and, to improve the effectiveness of ARFF operations and passenger safety during future accidents/incidents.

The questionnaire is divided into six categories of information:

General Information
Aircraft and Accident Incident Characterization
Time of Day and Weather Conditions
Incident Notification
Fire Factors
Response Characterization

In the future, the questionnaire might be available online through the NFPA 422 document web site. Until such time, it must be completed manually and submitted to the current Chair of the Technical Committee for Aircraft Rescue and Fire Fighting for data collection and use in further editions of this document.

GENERAL INFORMATION

(1) The airport three- or four-letter designator? ____________

(2) Your name, email address, and a contact phone number. ____________

____

(3) ARFF services are provided by:
- ❏ Municipal/county department
- ❏ Authority
- ❏ Hybrid authority and municipal department
- ❏ Private
- ❏ Other

(4) Were you on scene during the incident being reported?
- ❏ Yes
- ❏ No

(5) What was your position within the incident command organization?
- ❏ Incident command
- ❏ ARFF group supervisor
- ❏ Other

(6) If you were not on scene at the time of the accident, enter the name of the ARFF/Fire Service Incident Commander.

____

AIRCRAFT AND ACCIDENT/INCIDENT CHARACTERIZATION

(7) Select the best description of type of accident/incident.
- ❏ High impact
- ❏ Low impact
- ❏ Ground collision
- ❏ Runway excursion
- ❏ Runway overrun
- ❏ Runway undershot
- ❏ Other

 NFPA 422 (p. 1 of 7)

FIGURE 5.1 NFPA Aircraft Accident/Incident Report Form.

AIRCRAFT AND ACCIDENT/INCIDENT CHARACTERIZATION *(continued)*

(8) If ground collision is selected in question (7), please describe type of collision.
- ❏ Aircraft
- ❏ Ground vehicle
- ❏ Structure

(9) If "other" is selected in question (7) select the closest descriptor.
- ❏ Engine fire/indicator
- ❏ Flight deck problem
- ❏ Passenger deck problem
- ❏ Cargo fire/indicator
- ❏ Cargo hold problem
- ❏ APU fire/indicator
- ❏ Electrical problem
- ❏ Electrostatic sparks
- ❏ Landing gear/brakes/wheel well
- ❏ Fuel/hydraulic problem
- ❏ Control service problem
- ❏ Other

(10) Type/model and derivative of aircraft(s) involved in the incident/accident: ____

____

(11) The category of aircraft involved in the incident/accident:
- ❏ Commercial passenger
- ❏ Cargo
- ❏ COMBI
- ❏ General aviation
- ❏ Military
- ❏ Helicopter
- ❏ Experimental
- ❏ None

(12) Select the general location of the accident/incident:
- ❏ On-airport
- ❏ Off-airport

(13) If the accident/incident occurred *on-airport,* select the *location* where the aircraft came to rest:
- ❏ Runway
- ❏ CRFFAA
- ❏ Terminal
- ❏ Ramp
- ❏ Tower building
- ❏ Building
- ❏ Hangar
- ❏ Difficult environment
- ❏ Taxiway
- ❏ Between runways
- ❏ At or near a body of water
- ❏ Parking lot/garage
- ❏ Other

 NFPA 422 (p. 2 of 7)

FIGURE 5.1 ***Continued***

AIRCRAFT AND ACCIDENT/INCIDENT CHARACTERIZATION *(continued)*

(14) If the incident/accident occurred *off-airport,* select the *location* and *terrain* where the aircraft came to rest.

❑ Building
❑ Difficult environment
❑ Paved
❑ Unpaved
❑ Hard
❑ Soft
❑ Sandy
❑ Gravel
❑ Even
❑ Uneven
❑ Inclined
❑ Developed area populated
❑ Developed area unpopulated
❑ Rural area populated
❑ Rural area unpopulated
❑ At or near a body of water
❑ Parking lot/garage
❑ Other

(15) Were there injuries to people on the ground?

❑ Yes
❑ No
❑ Unknown

(16) How many passengers and crew were on the aircraft at the time of the accident? ____________________

(17) Was there any declared cargo HAZMAT onboard?

❑ Yes
❑ No
❑ Unknown

If yes, how did ARFF learn about it?

❑ ATC
❑ Flight crew
❑ Aircraft operator
❑ Airport management
❑ On-site discovery

Were ARFF personnel prepared?

❑ Yes
❑ No

(18) Were there any wild/exotic/livestock animal(s) on board?

❑ Yes
❑ No

Were there any handling concerns or problems?

❑ Yes
❑ No

If yes, please describe. ____

____

 NFPA 422 (p. 3 of 7)

FIGURE 5.1 ***Continued***

AIRCRAFT AND ACCIDENT/INCIDENT CHARACTERIZATION *(continued)*

(19) Were evacuation slides used?
- ❑ Yes
- ❑ No

If yes, how many slides were deployed from the aircraft?

❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9 ❑ 10 ❑ 11 ❑ 12 ❑ 13 ❑ 14 ❑ 15 ❑ 16

How many passengers/crew injuries were associated with the use of the slides? ______________________

How many first responders were injured with the use of the slides? ______________________

(20) How many first responders were injured other than previously listed? ______________________

TIME OF DAY AND WEATHER CONDITIONS

(21) What hour of the day did the event occur? Round up to the nearest half-hour if exact time is unknown. ____________

(22) What were the weather conditions at the time of the accident? Select all that apply.
- ❑ Clear
- ❑ Sunny
- ❑ Cloudy
- ❑ Unobscured
- ❑ No wind
- ❑ Normal winds
- ❑ High winds
- ❑ Cyclonic/tornadic activity
- ❑ Thunder storms
- ❑ Rain
- ❑ Heavy rain
- ❑ Freezing rain
- ❑ Heavy freezing precipitation
- ❑ Wet surface/terrain
- ❑ Soft surface/terrain
- ❑ Icy surface/terrain
- ❑ Snow/ice buildup
- ❑ Low visibility
- ❑ Fog
- ❑ Other

ACCIDENT/INCIDENT NOTIFICATION

(23) How was ARFF notified? ____

____

(24) Was there any advance notification?
- ❑ Yes
- ❑ No

If yes, how much advance notice was given? (minutes)

❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9 ❑ 10 ❑ 10+

 NFPA 422 (p. 4 of 7)

FIGURE 5.1 ***Continued***

ACCIDENT/INCIDENT NOTIFICATION *(continued)*

(25) How was the notification alarm transmitted?
- ❏ Ring down telephone
- ❏ Box
- ❏ Crew observation
- ❏ Electronic alert

(26) Were there any delays in transmitting the alert information?
- ❏ Yes
- ❏ No

If yes, describe the nature of the delayed notification. ______________________________

____

(27) Were there direct communications between the flight crew and the ARFF IC?
- ❏ Yes
- ❏ No

(28) Was a discrete emergency frequency (DEF) communication procedure used?
- ❏ Yes
- ❏ No
- ❏ Not available

If yes, at what point were communications established?
- ❏ Final approach
- ❏ In the air (unable to determine)
- ❏ On the ground

(a) Was the use of DEF useful?
- ❏ Yes
- ❏ No

(b) Any problem using DEF?
- ❏ Yes
- ❏ No

If yes, describe problem(s): ______________________________

____

FIRE FACTORS

(29) Was there a fuel leakage?
- ❏ Yes
- ❏ No

What was the approximate area of fuel on the ground? (m^2 or ft^2) ______________

(30) Was cargo HAZMAT a fire concern?
- ❏ Yes
- ❏ No

If yes, describe in what way. ______________________________

____

Did it affect fire-fighting conditions?
- ❏ Made condition catastrophic
- ❏ Made condition worse
- ❏ Had no effect
- ❏ Unable to determine

 NFPA 422 (p. 5 of 7)

FIGURE 5.1 ***Continued***

FIRE FACTORS *(continued)*

(31) Was there a post-impact fire?

❑ Yes
❑ No

In increments of 10 percent, what was the percentage of fuselage fire involvement upon your arrival on scene?

❑ 10 ❑ 20 ❑ 30 ❑ 40 ❑ 50 ❑ 60 ❑ 70 ❑ 80 ❑ 90 ❑ 100

Was there three-dimensional fire?

❑ Yes
❑ No

What was the approximate length of the fire area? (m^2 or ft^2) ____________________

What types of agents were used to suppress the fire?

❑ Purple K
❑ AFFF
❑ Halogenated agent
❑ Dry chemical
❑ Water
❑ Compressed air
❑ FEM 12

Was the wind a factor in your agent application?

❑ Yes
❑ No

What agent(s) were affected?

❑ Purple K
❑ AFFF
❑ Dry chemical
❑ Water
❑ CAF
❑ FEM 12

What quantity of primary agent was used to obtain initial knockdown of the fire?

❑ Liters
❑ U.S. gallons
❑ Kg
❑ Lb

Were agent refills needed?

❑ Yes
❑ No

Estimate total water used for the following:

(a) Initial fire knockdown

❑ Liters ____________________
❑ U.S. gallons ____________________

(b) Mop-up and maintaining protective layer

❑ Liters ____________________
❑ U.S. gallons ____________________

 NFPA 422 (p. 6 of 7)

FIGURE 5.1 ***Continued***

FIRE FACTORS *(continued)*

(32) Did an interior fire attack occur?
- ❑ Yes
- ❑ No

If yes, estimate how much water was used.
- ❑ Liters ____________________
- ❑ U.S. gallons ____________________

(33) Did an interior crew/passenger rescue occur?
- ❑ Yes
- ❑ No

RESPONSE CHARACTERIZATION

(34) How many ARFF apparatus were on the initial response?

❑ None ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9

(35) How many structural apparatus were dispatched on the initial response?

❑ None ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9

(36) What type of apparatus arrived first on scene?
- ❑ ARFF
- ❑ Structural
- ❑ Command
- ❑ Medic

(37) What was the number of ARFF personnel on the initial response?

❑ None ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9 ❑ 10 ❑ 11 ❑ 12 ❑ 13 ❑ 14 ❑ 15 ❑ 16 ❑ 17 ❑ 18 ❑ 19

(38) Was a mutual aid response involved at this incident?
- ❑ Yes
- ❑ No

What was the number of mutual aid/structural personnel on the initial response?

❑ None ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 ❑ 6 ❑ 7 ❑ 8 ❑ 9 ❑ 10 ❑ 11 ❑ 12 ❑ 13 ❑ 14 ❑ 15 ❑ 16 ❑ 17 ❑ 18 ❑ 19

(39) What was the time from alert to the arrival of the ARFF vehicle(s) to site? (in minutes and seconds) ______________

(40) What was the estimated time from the ARFF arrival to fire control/knockdown? (in minutes)

❑ 0.5 ❑ 1.0 ❑ 1.5 ❑ 2.0 ❑ 2.5 ❑ 3.0 ❑ 3.5 ❑ 4.0 ❑ 4.5 ❑ 5.0
❑ 5.5 ❑ 6.0 ❑ 6.5 ❑ 7.0 ❑ 7.5 ❑ 8.0 ❑ 8.5 ❑ 9.0 ❑ 9.5 ❑ 10.0

(41) What was the total time for the completion of incident operations? (in hours and minutes, e.g., 0:15) ______________

 NFPA 422 (p. 7 of 7)

FIGURE 5.1 ***Continued***

5.5 Time of Day and Weather Conditions. This section of the form asks for information regarding the time and weather conditions as they relate to the accident/incident.

5.6 Accident/Incident Notification Information. This section of the form requests information regarding the notification of the incident and specific facts about the alarm. This section also attempts to address direct communications between ARFF and the flight deck and the use of discrete emergency frequency (DEF) procedures.

5.7 Fire Factors. This section of the form provides descriptors for fire factors and conditions that were present that might have affected the response capabilities outside and inside the aircraft, such as a fuel spill or the presence of any HAZMAT on the aircraft. Specific characteristics of a post-impact fire are also elicited in this section as well as type and quantity of agent used to extinguish the fire. This section also asks whether there was an interior passenger rescue.

5.8 Response Characterization. This section of the form addresses the number and type of ARFF apparatus and ARFF personnel on the initial response. Other information collected in this section deals with factors relating to a mutual aid response as well as time stamps for the initial response (response time and turnout time), control/knockdown, and completion of the incident operations.

Chapter 6 Determining the Crash/Fire Sequence

6.1 General.

6.1.1 Determining the crash/fire sequence is accomplished primarily by the application of observation and logic to the physical evidence available.

6.1.2 Witness corroboration must always be thoroughly evaluated. In some investigations, witnesses have stated that they observed fire before the crash, when, in fact, fire occurred at impact. For this reason, the investigator must be very careful in correlating witness statements with the evidence revealed by examination of the wreckage.

6.1.3 Establishing that fire did occur in flight and determining its probable cause will result in action to correct future occurrences. Generally, in-flight fire can be distinguished from post-impact fire by the following:

(1) Parts subjected to an in-flight fire are burned more severely than parts subjected to ground fire.
(2) The smoke and soot pattern of an in-flight fire follows the airflow, and clear spaces occur downstream from rivets and skin splices.
(3) The smoke and soot pattern of a ground fire is sporadic (generally upward) and in different directions from the natural airflow of flight. Structural parts subjected to ground fire generally have twigs, leaves, and so forth outlined in the soot.
(4) In-flight fires are usually very hot, burn through metal parts, and leave less metal residue than ground fires. Analysis of the flow direction of molten metal deposits helps to distinguish in-flight fire from ground fire.
(5) Folds in the metal surfaces of the skin caused by impact can be carefully pulled apart. Indications of smoke and soot on the metal or paint inside the folds can be evidence of in-flight fire, while a clean surface inside the wrinkle with fire indication on the surrounding surfaces would indicate a possible post-crash fire.
(6) The inside surfaces of heating and ventilating systems that ingest outside air should be examined for evidence of smoke or soot.
(7) Soot and other residues from burning materials should be scraped from as many areas as possible and tagged and sent for chemical analysis. The analyses might show by-products of incendiary or explosive devices or by-products from fuel sources.

6.2 Methods of Determining the Crash/Fire Sequence.

6.2.1 Parts Not Subjected to Ground Fire.

6.2.1.1* The most logical way to begin the investigation is by locating parts not subjected to ground fire and examine them for evidence of in-flight fire. Evidence to look for is smoke, soot, heat, discoloration, charred sealant, and metal spray. Before considering such evidence as positive indication of in-flight fire, the investigator has to have knowledge of the normal appearance of such parts after extensive normal operation. Such normal deposits must be distinguished in order to correlate all the evidence.

6.2.1.2 Erroneous conclusions can be reached in the examination of heat discolorations because they are a relative function of both time and temperature. The same discoloration can result from exposure to a low temperature for a long period of time (normal operation) or from exposure to a high temperature for a short period of time (fire). The discoloration of titanium exposed to 316°C (600°F) for 260 minutes is the same as that resulting from exposure to 538°C (1000°F) for 15 minutes. This information applies to most other metals as well, within certain temperature ranges. If the metal has a known temperature point at which chemical change occurs (such as titanium), this point places a boundary on the temperatures reached. The higher normal operating temperatures of modern aircraft have dictated the increased use of stainless steel and titanium, both of which acquire a blue heat discoloration at these high normal operating temperatures. Investigators should check with the aircraft manufacturer and maintenance personnel of the airline involved when evaluating smoke and soot deposits and heat discoloration.

6.2.1.3 One method of determining whether a part has been subjected to ground fire is to note the location of the part in relation to the apparent ground fire area. Parts or molten metal droplets that are shed in flight can be found along the flight path. The source of such metal droplets might be traced to an aircraft component not listed in the manufacturer's specifications or to cargo. Other parts can be thrown completely clear of the fire area by the impact or by an explosion. Even parts found in the ground fire area can be free of ground fire damage. Frequently, parts are buried under a protective covering of dirt, both at the initial point of impact and at the point of rest. Sometimes the crash scene is just a hole in the ground from which the wreckage must be dug, in which case the ground fire was very small except for initial explosion, with the parts protected from ground fire by the dirt covering. If the crash site is swamp or water, the parts can be shrouded. Subsequent to ground fire fighting, the parts can be covered by foam or dry chemical or can be submerged below the level of unburned fuel. In some cases, parts can be trapped or enclosed in other parts that protect them from the ground fire.

6.2.1.4 The location in which a part is found might not be completely decisive in determining the crash/fire sequence, but close examination should provide additional information. The evidence to look for is the relation of the effects of the fire to the results of the physical disintegration. The existence of bright scratch marks, scuffs and smears in the soot, and discolored areas indicate that disintegration occurred after the soot and/or discoloration formed from in-flight fire. Soot in torn edges, as well as discoloration of torn edges and scratches, indicate that fire occurred after disintegration. Such soot and discoloration are not always true indications because residual heat remaining in a part thrown clear of impending ground fire area can be sufficient to discolor exposed surfaces; however, that is more apt to occur with parts of large mass.

6.2.1.5 In many accidents/incidents in which in-flight fire existed, metal spatter deposits are found on areas removed from the fire source area. These deposits can be analyzed to determine the content and possibly where the fire originated on the aircraft. The slipstreams from in-flight airflows or even compartmental airflows are strong enough to carry large masses of molten metal quite a distance and force them onto cold objects. Another indication of in-flight fire is the so-called aluminum "broomstraw" or "feathering" effect, common in in-flight fire investigations. Basically, when aluminum in a near-molten state is shock-loaded, such as in a crash impact, the material exhibits an extremely delaminated appearance resembling broomstraws or having feathered edges. This phenomenon occurs only under these circumstances and is thus positive evidence of an existing fire prior to impact or in-flight explosion.

6.2.1.6* Flame temperatures reached by fuel, oil, and hydraulic fluids in ambient air are normally in the range of 871°C to 1093°C (1600°F to 2000°F) due to the forced draft effect of airflow. Many internal areas of aircraft have "chimney" effects in flight.

6.2.1.7 The sources of fire frequently are localized at the point of greatest damage or at a point that indicates the greatest amount of heat. A broken or leaking fluid line resulting in fire can be located by careful inspection of the damage. Analysis of samples of ash or soot can indicate the source of fire. Such samples should be obtained before they are dissipated by wind or rain.

6.2.1.8 Soot patterns are formed as a result of soot drifting with the air stream until it strikes an object to which it can attach itself by means of the unburned oils it contains and by electrostatic attraction. One point to remember is that soot does not attach itself to surfaces that are heated over about 371°C (700°F). Therefore, areas that show the greatest intensity of fire might contain little or no soot.

6.2.1.9 Reconstructing the aircraft from the remaining parts might be necessary in order to detect a pattern. If, after reconstruction of the aircraft, a pattern in the direction of the in-flight airflow is detectable, an in-flight fire is indicated. Conversely, if there is no continuity of pattern across lines of failure, the patterns were formed after the aircraft disintegrated. The shapes of the patterns are affected by objects that shroud or block another part. The shrouded part shows the general outline of the object doing the shrouding. If a part is found with such an outline but the part that did the shrouding is not there, the pattern must have occurred before disintegration. Conversely, if both the outline and the shrouding part are found in relation but the shrouding part is not normally in this position on the airplane, the pattern was formed after disintegration.

6.2.2* Heat Intensity Investigations. Heat intensity is another means by which the crash/fire sequence can be determined. This method is becoming more prevalent as more higher heat–resistant materials are used in modern aircraft. The flame temperatures of post-crash fires in which combustibles like gasoline, JP-4, lubricating oil, and hydraulic fluids are being consumed in still air are normally in the range of 871°C to 1093°C (1600°F to 2000°F). The flame temperatures of in-flight fires are usually in excess of 1649°C (3000°F) due to the forced draft of the slipstream and/or compartment cooling airflow. The probable effect of the forced draft is to cause the fuel–air ratio to be more nearly stoichiometric. Therefore, when any parts that have a melting point in excess of 1093°C (2000°F), like stainless steel and titanium, show evidence of melting, the indication is that the fire occurred either in flight or in an oxygen-rich atmosphere. The indication is stronger if the part is found in an area in which investigation shows that the ground fire was not intense. The finding is not conclusive because a ground fire can exceed 1093°C (2000°F) due to strong ground winds, or peculiar piling of the wreckage can cause a chimney effect whereby the fire probably caused its own draft. In addition, materials that burn with an intense flame, like magnesium, can be present. Usually the area in which a flame temperature hot enough to melt stainless steel or titanium exists is very small and is the result of some localized jet effect, similar to a welder's torch.

6.2.3 Existence of Fire-Conducive Conditions.

6.2.3.1 Frequently a failure or condition that logically would produce fire is found before any evidence of in-flight fire is found. This circumstantial evidence should be proved or disproved by thorough investigation of possible evidence of in-flight fire in the wreckage.

6.2.3.2 Circumstantial evidence is extensive in variety. It can be a burn-through of the engine, disintegration of high-speed rotating parts, electrical shorting, and so forth. Electrical arcing damage can usually be differentiated from fire damage. Damage from electrical arcing is very localized in both metal removal and heating. Damage has an eroded appearance and possibly metal spatter similar to that produced in arc welding. The strands of copper wiring are fused together, and usually little beads are formed on the ends. Such fusing and beading do not occur from fire. The difference is probably due to the heating rate and intensity. Where subjected to internal heat such as from circuit overload, wiring insulation can expand away from the wire and be loose. Positions of circuit breakers should be noted. When heated externally, the heating rate is relatively slow, which permits a scale to form on the surface of the strands. This scale prevents fusing. In addition, the intensity of most fires, particularly those on the ground, is not sufficient [1093°C (2000°F)] to melt copper.

6.2.3.3* Caution should be taken in regard to any evidence that might indicate that an in-flight failure or fire occurred because a ground fire or the impact can produce similar evidence.

Chapter 7 Explosions

7.1 In-Flight Explosions. In-flight explosions can be indicated by widely scattered debris or missing sections of the wreckage. Debris patterns should be studied and analyzed with all available information pertaining to altitude, direction, air speed, attitude, cargo, and meteorological conditions. When available, witness interviews can be of great value. Extreme care should be taken that in-flight explosions are not misinterpreted as mechanical failure and vice versa. Visual inspection of separations caused by explosions can have a pattern of ripping and outward bending of the metal caused by overpressure. Separations caused by metal fatigue generally are ascertained by laboratory analysis. Separations resulting from adverse weather or loss of fastenings usually are more difficult to identify.

7.2 Explosive Decompressions. Breakups whose probable cause is explosive decompressions usually are initiated by a breech or fracture of a pressurized fuselage at altitude. Crashes of this type are difficult to investigate and can require a partial or complete reassembly of the wreckage. Pathological examination of bodies can reveal injuries associated with the severe turbulence. However, such examinations should be correlated carefully with the studies of the wreckage in order to separate ground impact effects from those occurring prior to the impact.

7.3 Pre-Impact Explosion. Care should be taken to separate evidence indicating pre-impact explosion from that indicating impact explosion. When available, witness accounts are extremely helpful. The location of debris in relation to the main wreckage should be analyzed. Pre-impact explosions, even if they occur immediately prior to impact, can scatter debris behind or beyond the impact area. Impact explosions are more likely to scatter wreckage around the crash site. Whenever possible, the entire fuel system should be analyzed. Integrity of couplings, proximity of hot engine parts, and energized electrical wires and components should be scrutinized. Meteorological conditions conducive to lightning activity should be noted.

7.4 Manufactured Explosives. Severe overpressures caused by manufactured explosives can cause remarkable distortion to an aircraft. These devices can be the result of terrorism, sabotage, murder, suicide, or a ground-to-air missile. In any event, an incident or attempted incident of this type constitutes a violation of local, state, and federal laws, and the appropriate authorities should be consulted early in the investigation to determine if any terrorist group has claimed responsibility for the accident/incident. The investigating team should be expanded to include qualified explosives technicians. Advance warning of the event might have occurred, which can be especially true in a hijacking. All communications tapes, especially the cockpit voice recorder, should be reviewed.

7.4.1 Site security is a primary concern. Only those persons who have experience in looking for this kind of evidence should be allowed to examine the wreckage. Close-up, medium-range, and overall single photographs should be taken to document the blast effect and components. Wreckage analysis is extremely important in these cases. Patterns and distribution should be analyzed to locate the point of origin of the detonation and the size of the device. A thorough search of the aircraft components adjacent to the point of detonation should be conducted to recover as many components of the device as possible. The search might be complicated by the fact that the structural parts in closest proximity to the explosive can be scattered the farthest and often are found on the fringe of the debris pattern.

7.4.2 Postmortem examinations of victims should be conducted to identify blast injuries. Examination should include full-body x-rays to locate embedded debris. Body photographs should include appropriate areas, properly composed and cleaned, to reveal wound detail. Knowing the exact location of the victims in the aircraft at the time of detonation is advantageous to the investigation.

7.4.2.1 In an accident/incident that possibly was caused by a manufactured explosive, the crash investigation evidence becomes part of a criminal investigation designed to establish motive and bring the perpetrator(s) to justice.

7.4.2.2 The utilization of an explosive device might be apparent early in the investigation.

Chapter 8 Hazardous Materials/Dangerous Goods

8.1 International Air Regulations. Due to an increase in air transportation of hazardous materials and dangerous goods, a proportionate probability of incidents involving these materials during air carrier operations exists. International air regulations are comprehensive regarding the packaging, handling, and stowing of such products. Accidents/incidents have been caused by either inadvertent or deliberate disregard of regulations.

8.2 Investigation Team. When escape of a hazardous substance is suspected in an accident/incident, the investigation team should be expanded as soon as possible to include a hazardous materials specialist. The contaminated area should be isolated until experts have rendered it safe. Many hazardous substances have properties that can cause severe injuries or death if proper protective equipment is not used.

8.3* Identification of Hazard. If hazardous materials or dangerous goods are suspected of being onboard the aircraft before manifests are known, access to the accident/incident scene should be limited to persons who are knowledgeable about the risks involved and who are properly protected. The investigation should first identify the substance, then establish its potential effect(s) in the accident/incident. The wreckage of the aircraft and the cargo should be analyzed. Freight manifests and shippers' and handlers' statements should be obtained, along with witness statements from first responders and emergency personnel. Special note should be made of unusual odors, coloration of smoke or flame, and fires that are particularly difficult to extinguish. Pathologists should be informed as soon as possible of the existence of hazardous materials or dangerous goods, so they can look for evidence to support the on-scene investigation. If such liaison is lacking, the autopsy reports can contain serious errors of omission or misinterpretation. The Federal Aviation Authority (FAA) provides containers and toxicology analytical services for autopsy specimens, and National Transportation Safety Board (NTSB) investigators can furnish the containers and their shipping cartons.

Chapter 9 Arson

9.1 Probability. Although the hijacking of airliners using flammable liquids has been attempted, arson has not been a significant problem in operating aircraft. Fires that occur for no apparent reason when the aircraft is unattended or tied down should be investigated for the possibility of arson. The local fire investigators who possess the necessary equipment, laboratory facilities, and expertise can perform an in-depth investigation.

9.2 Investigation Methods. The motives for arson are generally the same regardless of the object burned. Many of the methods used in motor vehicle fire investigation are appropriate in aircraft investigations. When someone with a knowledge of aircraft structure aids in the investigation, it is usually productive.

9.3 Local Agencies. Arson has increased in almost geometric proportions in recent years, resulting in a greater emphasis on the involvement and training of local fire and law enforcement agencies in fire investigation. The trend is toward multijurisdictional arson task forces. Great benefit can be obtained by close coordination between professional air crash investigators and professional fire investigators.

9.4 Investigation Results. The fire investigator should strive to determine the probable cause of the fire or explosion. Establishing whether the crash was fire-induced or crash-induced is extremely important. In either case, the investigator should try to determine the point of origin, the material first ignited, and the source of ignition. If possible, recommendations pertinent to crashworthiness and survivability should be made.

Chapter 10 Air Crash Investigator

10.1 General Process. The air crash investigation is a highly technical process involving many sciences. The involvement of fire or explosion in a crash further broadens the investigative procedures.

10.2 Background. Air crash investigation requires an extensive background in aviation on the part of the investigator. The advances in investigation techniques require total involvement by investigators in order to stay abreast.

Chapter 11 Aircraft Fire Reports

11.1 General Facts. It is important to report where the fire started, how it spread and was fed, what extinguishing agents were used, how effective they were, and whether the equipment malfunctioned. Methods of fighting fire following crashes and the making of forced entries into burning aircraft have been the subject of much research. All available facts on an aircraft fire should be reported because this leads to improved methods of saving lives.

11.2 Escape from Aircraft. The report should note whether escape from the burning plane was successful and whether emergency exits could or could not be used relative to the fire intensity and location. Information should be solicited from flight crew, passengers, and witnesses.

11.2.1 It is important to determine the weather conditions at the time of the fire, particularly wind direction and velocity.

11.2.2 Weather conditions, combined with the location and use of emergency exits, can determine cabin interior fire spread.

11.3 Fire-Fighting Response. Reports should indicate the type of ground fire-fighting equipment available and used, especially the response times and effectiveness of each responding vehicle, and the quantity and type of extinguishing agents used and remaining. The level of experience and degree of training of fire-fighting and rescue personnel also should be reported. The type of clothing worn by personnel involved and the degree of protection it provided is especially important. Reports should indicate any problems with communications, with command and control on the scene, and with any emergency plans.

11.4 Medical Report. A complete report should be made on the medical aspects of the accident/incident. The report should differentiate fire injuries from impact injuries and fire deaths from impact deaths. Pathological examinations should include toxicological analyses to identify all toxic products of combustion. The report also should describe fire extinguishment and victim care procedures.

11.5 Report on In-Flight Fire. What warned the flight crew that fire was in progress and how effective extinguishing attempts were should be determined. A complete step-by-step description of the procedure used by the crew for extinguishing the fire should be recorded and compared with the approved method listed in the applicable technical manual, flight manual, and flight attendant manual. Complete information on in-flight fire is essential in order to improve and develop adequate fire-warning and extinguishing systems. The voice recorder and the aircraft flight recorder are the most helpful to the investigator in gathering this important information.

11.6 Before Filling Out the Aircraft Fire Report.

11.6.1 The investigator should walk through the wreckage area first to size up the layout and distribution of wreckage, which gives a mental picture of the main line of distribution and is helpful for plotting and interpreting witness statements, breakup patterns, and so forth.

11.6.2 If the investigator arrives late on the scene, he or she should check with newspapers and other news media, since the media often have the first photographs of accident/incident sites. In the event that the wreckage has been disturbed or modified by weather, photographs, news reports, and television news tapes can be helpful. Great care should be taken to ensure that data concerning the position and condition of parts are reliable before plotting and analysis.

Annex A Explanatory Material

Annex A is not a part of the recommendations 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.1.2 The purpose of preparing these reports is not to define the process of investigating the probable cause of the accident/incident, but to identify the type of data that can be used to provide scientific and statistical information to assist in the consensus standards-making process and to prevent injury and loss of life in future accidents/incidents.

A.3.2.1 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor 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.4.7 In the United States, the National Transportation Safety Board (NTSB) identifies accidents/incidents by using the name of the nearest post office.

A.6.2.1.1 For example, the normal soot deposit in the aft fuselage of the military F-100 is made during ground operation. The negative pressure in the engine inlet duct is used to draw cooling air through the aft compartment from the annulus around the tail pipe, drawing some exhaust gases back into the compartment with the cooling air, leaving a normal deposit of soot on the interior of the aft fuselage.

A.6.2.1.6 For example, in the tail area aft of pressure bulkheads, the air tends to flow up the inside of the fin and out if there are passages through which it can flow or after fire has made such passage.

A.6.2.2 For example, burned-through oxygen lines probably would cause severe fire damage, as would solid-state oxygen canisters that would release large amounts of concentrated oxygen when heated by a fire. See Section 5.2 of NFPA 407, *Standard for Aircraft Fuel Servicing*, for spill prevention and control.

A.6.2.3.3 An example is a B-line connection. It is not uncommon to find in the wreckage numerous B-nuts, both steel and aluminum, that are only fingertight, thus indicating that an in-flight leak existed. Loose B-nuts can be caused by either mechanical damage or fire. Loosening by mechanical damage is usually evident by the mechanical condition of the connector and its attaching lines. Loosening by fire is probably due to annealing and relief of the stresses that constituted the torque. If a B-nut is more than a quarter of a turn loose, it is not the result of fire. A test (mock-up) to duplicate the circumstances might be required to confirm whether the looseness was fire induced or existed pre-fire.

A.8.3 Special attention should be given to radioactive substances carried in cargoes under restricted conditions. See Annex B of NFPA 402, *Guide for Aircraft Rescue and Fire-Fighting Operations*.

Annex B General Information for Aircraft Fire Investigations

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

B.1 Fire. The information in this annex can be of use to persons investigating the fire.

B.1.1 In most cases where there is evidence that a specific temperature has been attained, a time–temperature relationship exists, so it is not always possible to determine a precise temperature. A temperature of 816°C (1500°F) sustained for a few minutes can create the effect of fire that has burned at a lower temperature for a longer duration. There are sometimes specific points at which a temperature change occurs, in which case temperature ranges can be defined more closely. Laboratory analysis sometimes is needed, but investigators usually can trace or plot a fire pattern to a source point by studying the relative temperatures and the position of the burned or overheated area.

B.1.2 Fire resistance is not a property of a particular material but a characteristic of a particular system comprising material, oxidant, ignition source, and environmental conditions. For example, ordinary steel at room temperature is not ignitable with an ordinary match unless the steel is in the form of loosely packed steel wool. Such a distinction in the form of a material often is overlooked in the interpretation of fire data.

B.1.3 Most aluminum sheet and forging ingots used for aircraft components are from the 2000 and 7000 series. The 2000 series is an alloy that uses copper as the major alloy material (approximately 4 percent to 5 percent); the 7000 series uses zinc as its major alloy (approximately 5 percent to 6 percent). All alloys are approximately 95 percent aluminum, and most include very small percentages (in terms of chemical content) of other metals, such as titanium, silicon, manganese, and magnesium. The melting point of the sheet used generally is around 639°C (1180°F), but a few alloys can melt at temperatures as low as 527°C to 538°C (980°F to 1000°F). Very few forgings or castings melt at temperatures as low as 510°C (950°F). The letters used with aluminum series numbers designate temper and strain hardening. For example, 7075-T-6 contains 5.1 to 6.1 percent zinc plus small amounts of eight other elements, is solution heat-treated, and is artificially aged.

B.1.4 Certain types of heat treatment and strain hardening often change the basic characteristics of metal (e.g., from ductile to brittle), and these changes can cause alterations in appearance. Plating also tends to change characteristics.

B.1.5 When aluminum alloys are heated to the melting range, they wrinkle and pull apart, leaving bright cracks and fissures. If heated sufficiently to form droplets, they appear as little wrinkled bags. By comparison, iron alloys tend to burn when heated to the red range, forming oxides at the edges and in thin sections.

B.1.6 Fire damage to metal is manifested mainly in loss of strength. For example, 7075-T-6 alloy loses 10 percent of its strength when heated for 30 minutes at 204°C (400°F), for 10 minutes at 232°C (450°F), for 3 minutes at 288°C (550°F), or for 2 minutes at 316°C (600°F). Hardness tests can be used to determine the amount of temperature exposure, but an estimate of the length of exposure is necessary to determine the maximum temperature.

B.1.7 Titanium (Ti) changes color, from tan to light blue to dark blue to grey, as the temperature increases. It reacts strongly to gases when heated, and a scale begins to form at approximately 593°C (1100°F). This scale increases in thickness with time and turns bluish in color. At approximately 649°C to 816°C (1200°F to 1500°F), a grey or yellowish shade appears. At approximately 704°C (1300°F), an appreciable oxide scale forms, which flakes off. At approximately 882°C (1620°F), titanium undergoes an allotropic transformation (from alpha type to beta type), and the oxidation rate increases significantly.

B.1.7.1 Titanium fires in turbine engines have been a cause of concern for some time because they start quickly, are difficult to detect, and are nearly impossible to extinguish. Titanium fires can occur in the total absence of hydrocarbon or other fuel sources, a fact that, in itself, is evidence of a titanium fire.

B.1.7.2 The mechanism of titanium fires is complex. The scenario for a fire caused by titanium rotor blades might involve the following sequence:

(1) A titanium rotor blade rubs against the engine case and, because of the low thermal conductivity of titanium, the temperature of the blade increases rapidly.
(2) The titanium melts at about 1704°C (3100°F).
(3) The molten titanium absorbs oxygen to form titanium oxide (TiO_2), which boils, burns, and stabilizes at approximately 3093°C (5600°F).
(4) The TiO_2 continues to form and burn as long as an air supply is available.

B.1.7.3 Because molten titanium at very high temperatures melts through steel engine cases rapidly, engine design should avoid routing fuel and oil lines in the lower sector of the engine. It should be noted that steel melts at approximately 1704°C (3100°F).

B.1.8 Stainless steel changes color from tan to light blue to bright blue to black starting at 427°C to 482°C (800°F to 900°F). When examining stainless steel after heating, the investigator should check both sides. The lighter blue side is the side that was positioned opposite the heat source, and the heated area will be smaller in circumference.

B.1.9 Zinc chromate paint primers start to turn tan at 232°C (450°F) and turn brown at 260°C (500°F), dark brown at 316°C (600°F), and black at 371°C (700°F). Cadmium plating begins to discolor at 260°C (500°F). Glass cloth fuses at 649°C (1200°F). Silicone rubber blisters at 371°C (700°F). Neoprene rubber blisters at 260°C (500°F). Wire insulation is a good guide for determining lower temperature ranges if the material is known [e.g., nylon spaghetti melts at 121°C to 177°C (250°F to 350°F)].

B.1.10 Aircraft paints soften at 204°C (400°F), discolor at 316°C (600°F), blister at 427°C to 454°C (800°F to 850°F), and burn off completely at 482°C to 510°C (900°F to 950°F). Cutting through the paint with a sharp knife discloses the depth of overheating. Severe scorching blackens the surface without further darkening it. It is unusual to find the metal beneath paint damaged if the paint is not burned through completely. It is possible to char primer beneath heat-resisting aluminum paint without apparent surface burning.

B.2 Temperature Limits of Selected Materials.

B.2.1 The investigator should note carefully those materials that ignited, those that melted, and those that were damaged by heat.

B.2.2 Table B.2.2(a) lists the autoignition temperatures of several selected materials. Table B.2.2(b) is a list of materials and the temperatures at which damage or distortion occurs. The materials listed in both tables usually are found in private or commercial transport aircraft.

B.2.3 Table B.2.3 lists the melting points for metals and alloys currently used in aircraft. It is essential that the investigator be familiar with various aircraft metals and alloys and be well-informed regarding their purpose and their location in the aircraft.

Table B.2.2(a) Autoignition Temperatures of Selected Materials

Material	Autoignition Temperature °C	Autoignition Temperature °F
Canvas	96	204
Denatured alcohol	399	750
Glass matts	510	950
Hydraulic hose (Buna-N-Rubber)	510	950
Leather	454	850
Lubricating oil (MIL-1-7808)	421	790
Nylon-covered wire	538	1000
Plywood	482	900
Rubber–asbestos material	482	900
Rubber-covered wire	482	900
Styrene	490	914
Teflon	566	1050
Vinyl-covered wire	482	900

Table B.2.2(b) Temperature Limits for Selected Materials

Material	Damage at Temperature Limit	Temperature Limit °C	Temperature Limit °F
Cellulose (filled melamine)	Heat distortion	204	400
Enamel	Flakes	649–760	1200–1400
Glass	Softens	760–871	1400–1600
Glaze or electrical porcelain		1232	2250
Melamine-formaldehyde (filled)	Heat distortion	130–204	266–400
Methyl methacrylate	Heat distortion	99	210
Nylon (polyamide)	Heat distortion	149–182	300–360
Paper phenolic	Delamination and distortion	121	250
Paraffin wax	Melts	54	129
Plastic vinyl chloride	Heat distortion	85	185
Polystyrene	Distortion	99	210
Silicone rubber	Considerable softening at sustained service	218	425
Silver solders	Melt	629–789	1165–1450
Styrene elastomer	Distortion at sustained service	104	220
Zinc	Melts	419	786

Table B.2.3 Melting Points of Some Aircraft Metals and Alloys

Metal or Alloy	Melting Points	
	°C	°F
Aluminum alloys	660–677	1220–1250
Brass bearings	871–1093	1600–2000
Cadmium	321	609
Chromium	1889	3430
Copper	1083–1093	1981–2000
Iron	1539	2802
Lead	327	621
Magnesium alloys	650–677	1202–1250
Manganese	1243	2273
Mercury	–40	–40
Molybdenum	2627	4760
Nickel	1455	2651
Selenium	220	428
Silicon	1429	2605
Silver	960	1760
Stainless steel	1482	2700
Tin	232	449
Titanium	1704	3100
Tungsten	3410	6170
Vanadium	1732	3150

B.3 Electrical Wire. If electrical wire breaks when no current is flowing, the break will be clean and will display a typical cup-and-cone fracture with necking down. If current is flowing, it arcs when the wire breaks, causing little balls of oxidized metal to form on the tips of the wire strands. A fire external to the wiring bundle burns the outside first, and the conductor inside remains clean and bright, except where the insulation has burned through. Wires that are burned due to excess current burn from the inside out, and the conductor will be dark and oxidized, perhaps without damage to the outer cover. The tin coating on copper wire diffuses into the copper at temperatures above its melting point of 232°C (449°F) and becomes rough or even disappears. On-scene examination should be only for general observation and possible conclusions. Detailed laboratory examination should be performed to confirm the mechanism of the wire faults and failures. Additionally, chemical analysis of wire breaks can reveal the presence of combustibles during the failure.

B.4 Evaluation of Light Bulbs. Examination of any surviving light bulbs helps in determining whether electrical power was on in a particular system at the time of impact. The filaments of small bulbs indicate whether the bulb was illuminated at impact when the bulb was shock-loaded. If a filament is hot at impact, it will stretch and distort substantially. If the filament is cold at impact, it will break but not distort or stretch from its original shape and pattern. If the glass shatters and the filament is exposed, it still will provide the information but will oxidize and discolor quickly. This examination is valuable in determining the system's operational status at impact, provided failure lights and warning light bulbs survive any subsequent fire in the area. See ICAO DOC 6920-AN/855/4, *Manual of Aircraft Accident Investigation,* Part III, 7.3, "Electrical Systems," for further information on fire origin.

B.5 Soot Residue. All hydrocarbon fuels used in aircraft leave a similar soot residue, except when instantaneous combustion or explosion occurs. In that case, no sooting is left, so tests might not be successful in identifying or differentiating between hydrocarbon fuels and various other hydrocarbon liquids that are found about aircraft. Cleaning fluids, oils, and so forth, can leave similar residues. Soot does not deposit or adhere to surfaces that are above 371°C (700°F).

B.6 Flammability Characteristics of Aviation Fuels.

B.6.1 The three basic types of aviation fuels are as follows:

(1) Aviation gasoline (AVGAS)
(2) Kerosene-grade fuels (JET A, JET A-1, JP-5, JP-6, and JP-8)
(3) Blends of gasoline and kerosene (JET B, JP-4)

B.6.2 The flammability characteristics of the three basic fuel types are provided in Table B.6.2. A comparison is included in B.6.3 through B.6.5 to focus attention on their differences.

B.6.3 In order to burn, all petroleum fuels need to be vaporized and mixed with air in specified proportions. AVGAS has a strong tendency to vaporize, and, as a result, the air over the surface of the liquid always is mixed with a considerable quantity of vapor. In a closed tank, so much fuel vapor is given off by AVGAS that the fuel–air mixture can be too rich to burn. When any fuel is in contact with air, it continues to evaporate until the air is saturated.

B.6.4 Kerosene-grade fuel ordinarily has a low tendency to vaporize, and, in a closed tank, the fuel vapor and air mixture can be too lean to burn. However, kerosene-grade fuels can be ignited by heating them above their flash point. It also is possible to ignite such fuels without heating the bulk of the fuel to flash point. Such ignition can be achieved by wicking the fuel on an absorbent material that can be heated locally (a hot spot) until the fuel ignites. The hot spot on the wick furnishes sufficient vapor to sustain the flame. Such conditions can occur accidentally during crash and post-crash conditions.

B.6.5 Fuels that contain a blend of AVGAS and kerosene retain most of the worst fire characteristics of both fuels *(see Table B.6.2).* The vapor mixture in a closed tank normally is neither too rich nor too lean. Flammability limits include a wide temperature range, autoignition temperature is low, and flame spread is almost as fast as when AVGAS is used.

B.7 Hydraulic Fluids. When heated, some hydraulic fluids vaporize into a white mist that is acrid and causes choking. When burned, the residue is first dark-colored and viscous; then it changes to a dark-charred material, and a white, fluffy deposit appears after prolonged heat. When burned, hydraulic fluids produce a yellowish flame with white smoke. If Skydrol® (a trade-name hydraulic fluid commonly used in aircraft) is heated and a piece of aluminum is placed in it, an acetylene-type odor is evident. Skydrol 500 has a flash point of approximately 227°C (440°F), and autoignition occurs at approximately 496°C (925°F). In mist form, Skydrol 500 can ignite at room temperature.

B.8 Aging of Fluids. The aging of fluids, such as oil and hydraulic fluid, is caused by an increase in their acidity over time. Increased acidity tends to lower the flash point, but the problem is considered negligible, since a complete fluid change by volume is performed on the average aircraft at least four times per year. The flash points provided in Table B.6.2 are based on standard sea level pressure; lower pressures reduce the flash point and increase volatility. Fuels cannot burn unless in the vapor state, and the mixture ratio determines whether a fuel can burn. Skydrol and other ester-based fluids also possess these same properties.