# NFPA 422

Guide for

Aircraft Accident/Incident Response Assessment

2004 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 and acted on by NFPA at its May Association Technical Meeting held May 23–26, 2004, in Salt Lake City, UT. It was issued by the Standards Council on July 16, 2004, with an effective date of August 5, 2004, and supersedes all previous editions.

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## 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 has been revised to include only one, simpler form that can be used for all accidents/incidents. Several chapters have been added with information for the investigator.

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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/incidents involving fire.

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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.

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 is intended to provide the basis for a comprehensive emergency response analysis when completed.

**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, copies should be sent to the Technical Committee on Aircraft Rescue and Fire Fighting for entry into the NFPA database.

## 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 Publication.

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

NFPA 424, *Guide for Airport/Community Emergency Planning,* 2002 edition.

### 2.3 Other Publications. (Reserved)

## Chapter 3 Definitions

### 3.1 General.

The definitions contained in this chapter apply to the terms used in this guide. Where terms are not included, common usage of the terms applies.

### 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. (Reserved)

## 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 Federal Aviation Administration (FAA) can provide the location of the investigator in charge. For off-airport accidents/incidents, the local enforcement authority should be contacted.

## Chapter 5 Evidence Collected Using NFPA Aircraft Accident/Incident Report Form

### 5.1 Using the Report.

The instructions in this chapter provide information on how to complete the NFPA Aircraft Accident/Incident Report Form *(see Figure 5.1),* which is reproduced in this guide. The order of Chapter 5 corresponds directly to the numbered questions on the report. Each question is listed in bold type and is followed by instructions on answering the question.

## NFPA AIRCRAFT ACCIDENT/INCIDENT REPORT FORM

Report no. ________________ Date of report ________________

### I GENERAL

1. Aircraft data

(a) Type of aircraft ______________________ (b) Model no. ______________________

(c) Name of operator ______________________

❑ Passenger ❑ Cargo ❑ Combi ❑ General aviation ❑ Military

2. Location of emergency

Provide name of specific airport, if applicable, or city, nearest city, or nearest airport, stating distance factors and, where applicable, compass directions ______________________

3. Time factors

(a) Date of incident ______________________ (b) Local time ______________________

(c) How was aircraft entered?______________________ Time it took to enter ____________

4. Type of aircraft accident/incident (Check the appropriate items and elaborate on situation.)

(a) Fire in air; fire extinguished in flight ❑ Yes ❑ No Comments: ______________________

(b) Fire on the ground; no crash ❑ Yes ❑ No Comments: ______________________

(c) Fire — other (specify): ______________________

(d) Hazmat/dangerous goods incidents

Fuel spill ❑ Yes ❑ No Comments: ______________________

EMS response ❑ Yes ❑ No Comments: ______________________

Other response ❑ Yes ❑ No Comments: ______________________

### II FIRE FACTORS

1. General location of probable original ignition source (Describe evidence of ignition source.)

(a) Impact ❑ Yes ❑ No Comments: ______________________

(b) Power plants ❑ Yes ❑ No Comments: ______________________

(c) Aircraft electrical circuits ❑ Yes ❑ No Comments: ______________________

(d) Electrostatic sparks ❑ Yes ❑ No Comments: ______________________

(e) Other sources ❑ Yes ❑ No Comments: ______________________

**FIGURE 5.1 NFPA Aircraft Accident/Incident Report Form.**

2. Progress of the fire (as applicable)

(a) Describe the progress of the fire from ignition to extinguishment ______________________________

______________________________

______________________________

(b) Fire-fighting agents used

❑ Foam ________ L (gal) (solution)

❑ Dry chemical ________ kg (lb)

❑ Halogenated agent ________ kg (lb)

(c) Fire fighting carried out by ❑ Dedicated ARFF ❑ Other agency (explain) ______________________________

## III ACCIDENT/INCIDENT NOTIFICATION

1. How long after the accident/incident occurred was it discovered? ______________________________
2. Who discovered the accident/incident? ______________________________
3. Who dispatched the accident/incident response? ______________________________
4. How was the accident/incident alarm transmitted? ❑ Box ❑ Telephone ❑ Radio ❑ Observed

   Other ______________________________
5. Was the location of the accident/incident accurately described? ❑ Yes ❑ No
6. If not, indicate the reason and describe the effect on any related delay in the response of the ARFF ______________________________

   ______________________________
7. What were the conditions at the time of arrival of the ARFF (as applicable)? ______________________________

   ______________________________

## IV ACCIDENT/INCIDENT RESPONSE AND AGENT QUANTITIES

1. Time factors and agent quantities

   (a) If emergency pre-announced, from announcement to touchdown (impact): ________ minutes

   (b) If emergency not pre-announced, from accident/incident to alert of the ARFF services: ________ minutes

   (c) From alert to arrival of major vehicles: ________ minutes

   (d) From arrival of the ARFF to fire under control: ________ minutes; agent discharge ________ L (gal)

   (e) From arrival of the ARFF to rescue operations commencing: ________ minutes; agent discharge ________ L (gal)

   (f) From arrival of the ARFF to rescue operations terminated: ________ minutes; agent discharge ________ L (gal)

   (g) From arrival of the ARFF to extinguishment of the fire: ________ minutes; agent discharge ________ L (gal)

   (h) From extinguishment of fire to return to service: ________ minutes

   (i) List any factors that affected the response time of the ARFF ______________________________

   ______________________________

   (j) Weather conditions ______________________________
2. Who responded?

   (a) Dedicated ARFF ❑ Yes ❑ No

   Dedicated ARFF vehicle(s) ______________________________

   Dedicated ARFF water for foam ______________________________

   Dedicated ARFF complementary agents ______________________________

   Dedicated ARFF fire fighters ______________________________

   Dedicated ARFF incident commanders ______________________________

**FIGURE 5.1** ***Continued***

(b) Structural ❑ Yes ❑ No

Structural vehicle ______

Structural water ______

Structural fire fighters ______

Structural incident commanders ______

(c) Medical personnel ❑ Yes ❑ No

Vehicles ______

EMS ______

Doctors ______

Others (explain) ______

(d) Other agencies

Environmental (explain) ______

Wildlife (explain) ______

Police (explain) ______

**V REMARKS**

For questions regarding the form, call NFPA at (617) 984-7403.

Please send completed form to

NFPA Fire Investigations
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471
phone: (617) 770-3000
fax: (617) 984-7110
e-mail: investigations@nfpa.org

**FIGURE 5.1 *Continued***

## 5.2 General Section of Form.

**5.2.1 Aircraft Data.** The type of aircraft, the model number, and the name of the operator should be provided. Also, whether the aircraft is a passenger, cargo, combi, general aviation, or military aircraft should be indicated.

**5.2.2 Location of Emergency** The name of the specific airport, if applicable, or the name of the city, nearest city, or nearest airport should be provided, stating distance factors and, where applicable, compass directions (e.g., "1 mile northwest of Burbank Airport, Burbank, California").

**5.2.3 Time Factors.**

**(A)** Date of incident should be provided using the day/month/year format.

**(B)** Local time should be provided with hour and minutes.

**(C)** How the aircraft was entered and the time it took to enter it should be provided.

**5.2.4 Type of Aircraft Accident/Incident.** The basic types of accidents/incidents that involve the responsibilities of the aircraft fire investigator are specified in 5.2.4(A) through 5.2.4(D).

**(A) Fire in Flight; Fire Extinguished in Flight.** The probable cause of the fire should be determined, and the procedures used to extinguish the fire should be identified.

**(B) Fire on the Ground; No Crash.** The fire sequence should be examined carefully to determine whether it is possible to reduce the time needed to extinguish a fire, the time needed to detect a fire, and the time needed to isolate a fire.

**(C) Fire — Other.** The causal factor for aircraft accidents/incidents other than those specified in 5.2.4(A) and 5.2.4(B) should be determined, and the extinguishing procedures used and the extent to which they were successful should be identified. Can they be improved?

**(D) Hazmat/Dangerous Goods Incidents.** It is important to describe other emergencies that necessitate an ARFF response. Many times, prompt ARFF response prevents major aircraft damage and loss of life, and significant new response techniques are developed as a result.

## 5.3 Fire Factors Section of Form.

**5.3.1 General Location of Probable Original Ignition Source.** Ignition factors can be divided into five basic groups, as outlined in 5.3.1(A) through 5.3.1(E).

**(A) Impact.** The source of original ignition frequently is other than the aircraft itself. Ignition can result from a friction spark that occurs on impact or from power lines or the landing area lighting system. During investigations, a serious effort should be made to determine the probable cause of ignition. Each aircraft accident/incident that results in fire exhibits evidence of several ignition sources and usually more than one fire factor. The sources and factors of greatest concern are those that cause sustained fire progression. A close examination of the ground that runs from the aircraft back along the skid path and even beyond the point of initial ground contact is necessary to determine the point at which ignition occurred. This examination also helps determine whether fire was present prior to actual touchdown. Discoloration or charred material found in this area should be examined closely to attempt to determine the type of material burned and its possible location relative to the construction of the aircraft. Such material might consist of cabin furnishings, gear components, engine components, and so forth. Unlike structural buildings, where fire loads are somewhat static, the original ignition source in aircraft fires is not necessarily found in the areas where the most severe burning occurred. Information included in the report should describe the point of sustained ignition in relation to its position on or in the aircraft.

**(B) Power Plants.** In aircraft accidents/incidents where impact forces are extremely excessive, the aircraft power plants generally provide the initial ignition of aircraft fuel loads. For this reason, every attempt should be made to determine the damage to, as well as any movement of, the engines during and after initial impact. Ignition generally takes place when engines are torn loose, severing fuel and electrical power lines. This potential for ignition from aircraft power plants is especially true of the turbine engine, since it remains extremely hot internally and continues to rotate for a period of time after impact.

**(C) Aircraft Electrical Circuits.** The next most common fire ignition results when electrical lines are severed in a fuel vapor atmosphere. Every effort should be made to examine broken wires and circuit breaker panels to discover probable causes of ignition, keeping in mind that there probably was a source of flammable vapor or exposed combustibles in the area of the arcs, sparks, or heat if a fire was caused by such an ignition source. Examination of aircraft batteries also should be included in this investigation.

**(D) Electrostatic Sparks.** Electrostatic sparks often are the probable cause of the original ignition source, since the aircraft itself or portions of the aircraft that become separated during impact build up an electrostatic charge while moving through the air and might discharge this residual energy on contact with the ground.

**(E) Other Sources.** Other sources of ignition not covered by 5.3.1(A) through 5.3.1(D) should be investigated.

### 5.3.2 Progress of the Fire.

**(A) Describe the Progress of the Fire from Ignition to Extinguishment.** Once the point of sustained ignition is determined, a close examination of the burn pattern, together with a study of the aircraft construction, should provide a fairly clear picture of how the fire propagated prior to fire extinguishment. In many cases, the fire-fighting efforts themselves cause fire extension in unusual patterns. These patterns generally can be distinguished from normal fire progression by the presence of extinguishing agent residue in the burn deposit. Note that normal fire behavior causes upward extension of the fire more rapidly than it causes lateral extension. Most materials, when burned or heated, become subject to air currents, and a close examination of the burn area provides an indication of fire travel by the manner in which the charred material is curved.

**(B) Fire-Fighting Agents Used.** Most modern aircraft are equipped with bromotrifluoromethane (Halon 1301) systems, which discharge by remote control from the cockpit into the fire zone of each engine by selection. Some aircraft also discharge agent into baggage bins, but most do not. Other agents that might be used are carbon dioxide ($CO_2$), chlorobromomethane (CB or CBM), or bromochlorodifluoromethane (Halon 1211—BCF). The investigator should obtain all necessary details of the system from the fire-extinguishing equipment manufacturer.

**(C) Fire Fighting Carried Out By. (Reserved)**

### 5.4 Accident/Incident Notification Section of Form.

**5.4.1 How Long After the Accident/Incident Occurred Was It Discovered?** If there was uncontrolled ground fire, the investigator's job is made more difficult by destruction of possible evidence and the obscuration and masking of existing evidence. If the exact time of the accident/incident is not available, a close approximation later in the investigation helps significantly in determining burn times and the effect on evidence.

**5.4.2 Who Discovered the Accident/Incident?** The time lapse between the occurrence of an accident/incident and its discovery is a factor of some importance to the investigating team. Many aircraft accidents/incidents are discovered too late. The reasons for late discovery vary, for example, weather conditions, aircraft out of fuel, isolated areas, and loss of communication with the aircraft. The discovery of an accident/incident by notification by other aircraft or by survivors ultimately can be of great value to the investigator.

**5.4.3 Who Dispatched the Accident/Incident Response?** What agency ordered ARFF equipment to respond?

**5.4.4 How Was the Accident/Incident Alarm Transmitted?** It is important for the investigator to find out from reliable sources who initiated the alarm and how [e.g., box, telephone, radio, observed, other (specify)] it was transmitted. Many airports have a mutual aid agreement with local fire authorities whereby alarms are transmitted by a "hot line" connected directly to the fire department alarm station in the event that outside help is needed by the airport crash and rescue crew.

**5.4.5 Was the Location of the Accident/Incident Accurately Described?** If not, indicate the reason and describe the effects of any delay in fire and rescue service. The investigator should be informed of the accuracy or inaccuracy of the original description of the accident/incident location. In cases in which an inaccurate location was provided, valuable response time was lost. It is necessary to investigate the reason for the delay in the response.

**5.4.6 If the Accident/Incident Location Was Not Accurately Described, Indicate the Reason and Describe the Effect of Any Related Delay in the Response of the ARFF.** What were the consequences of erroneous response information?

**5.4.7 What Were the Conditions at the Time of Arrival of the ARFF?** The fire and evacuation conditions at the time of the arrival of the rescue units are highly significant in the final analysis of the accident/incident. These conditions can indicate the extent of fire, complete engulfment by fire, the presence of interior or exterior fires, types of odors, smoke, and the evacuation status of passengers. Were passengers evacuating or not evacuating, or was evacuation complete when rescue equipment arrived?

### 5.5 Accident/Incident Response and Agent Quantity Section of Form.

**5.5.1 Time Factors.** Time factors should be determined as precisely as possible from the records, flight crew, fire department, air traffic control tower, and Air Traffic Control (ATC), and so forth. After analysis, the investigator should be able to determine the effectiveness of each phase of the operation. Included in the analysis should be the response time of ARFF vehicles from alarm to arrival at the scene and the number of vehicles with very high frequency (VHF) communications. Also included should be response interference factors (e.g., weather, traffic, terrain) and factors that affected the response time of the ARFF vehicles, such as weather, distance from fire house, terrain, and access roads.

**5.5.2 Who Responded? (Reserved)**

### 5.6 Remarks Section of Form.

Included should be all conclusions drawn by the data collector after analysis of the detection and alarm system used and the time factors involved. If any time factors seem implausible, the data collector should request a simulation or rerun.

### 5.7 Distributing the Report.

Copies of each report should be sent to the appropriate government authorities involved in the investigation. When released by these authorities, reports should be sent to the following organizations:

(1) International Civil Aviation Organization, 1000 Sherbrooke Street, W, Montreal, Quebec, Canada H3A 2R2

(2) Fire Analysis Department, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, USA

(3) Other concerned qualified authorities such as the U.S. Air Force, U.S. Navy, U.S. Flight Safety Foundation, and so forth

# 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 these points:

(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 place to begin the investigation is to locate 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 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 indicates 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, indicates 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 FAA provides containers and toxicology analytical services for autopsy specimens, and 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 C 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.

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

| Material | Autoignition Temperature | |
|---|---|---|
| | °C | °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 | °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 |

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

| Material | Damage at Temperature Limit | Temperature Limit °C | °F |
|---|---|---|---|
| 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 |

**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.2.3 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 |

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

| Metal or Alloy | Melting Points °C | Melting Points °F |
|---|---|---|
| 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.

### Table B.6.2 Flammability Characteristics of Aviation Fuels

| Characteristic | Aviation Gasoline (AVGAS) | Kerosene-Grade Fuels (JET A, JP-5, JP-6/JET A-1) | Blends of Gasoli[ne and] Kerosene (JET B a[nd JP-4]) |
|---|---|---|---|
| Freezing point | –60°C (–76°F) | –40°C/–50°C (–40°F/–58°F) | –51°C (–60°F) |
| Vapor pressure | 38 to 48 kPa (5.5 to 7.0 lb/in.$^2$) | 0.7 kPa (0.1 lb/in.$^2$) | 14 to 21 kPa (2.0 to 3.0 lb/in.$^2$) |
| Flash point (by closed-cup method at sea level) | –46°C (–50°F) | 35°C to 63°C (95°F to 145°F) | –23°C to –1°C (–10°F to 30°F) |
| Flash point (by air saturation method) | –59°C to –65°C (–75°F to –85°F) | None | –51°C (–60°F) |
| Lower flammability limit | 1.4% | 0.6% | 0.8% |
| Upper flammability limit | 7.6% | 4.9% | 5.6% |
| Temperature range for flammable mixtures | –40°C to –1°C (–40°F to 30°F) | 35°C to 74°C (95°F to 165°F) | –23°C to 38°C (–10°F to 100°F) |
| Autoignition temperature | –476°C to 510°C (–825°F to 960°F) | 227°C to 246°C (440°F to 475°F) | 243°C to 249°C (470°F to 480°F) |
| Initial boiling point | 43°C (110°F) | 163°C (325°F) | 57°C (135°F) |
| End boiling point | 163°C (325°F) | 232°C (450°F) | 252°C (485°F) |
| Pool rate of flame spread* | 213 to 244 m/min (700 to 800 ft/min) | 30 m/min or less (100 ft/min or less) | 213 to 244 m/min (700 to 800 ft/min) |

Note: For further information, see NFPA 407, *Standard for Aircraft Fuel Servicing*.
*In mist form, rate of flame spread in all fuels is rapid.

**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.

## Annex C Informational References

### C.1 Referenced Publications.

The following documents or portions thereof are referenced within the annexes of this guide.

**C.1.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 402, *Guide for Aircraft Rescue and Fire Fighting Operations*, 2002 edition.

NFPA 407, *Standard for Aircraft Fuel Servicing*, 2001 edition.

**C.1.2 Other Publication.**

**C.1.2.1 ICAO Publication.** International Civil Aviation Organization, 999 University Street, Montreal, Quebec, Canada H3C 5H7.

ICAO DOC 6920-AN/855/4-1970, *Manual of Aircraft Accident Investigation*.

### C.2 Informational References.

The following documents or portions thereof are listed here as informational resources only. They are not directly referenced in this guide.

**C.2.1 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 2002 edition.

NFPA 1003, *Standard for Airport Fire Fighter Professional Qualifications*, 2000 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 2002 edition.

NFPA 1971, *Standard on Protective Ensemble for Structural Fire Fighting*, 2000 edition.

NFPA 1976, *Standard on Protective Ensemble for Proximity Fire Fighting*, 2000 edition.

### C.3 References for Extracts. (Reserved)

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