FIRE INVESTIGATION

1. INTRODUCTION.

Fire frequently destroys or consumes clues that could readily disclose the accident cause; for example ruptured or chafed-through fuel lines may be the origin of the fire and the cause of the accident and then subsequently be consumed by the fire. Fire that is a result, rather than a cause, of an accident also hampers the investigator by destruction or damage of evidence. With a thorough knowledge of fire science, fire behavior, and the vehicle and aircraft systems, the investigator will be able to determine the origin of the fire, its ignition source, the reason for the fire, and the category of fire. Remember, a fire investigation is a systematic search of the accident scene for information about a fire. Its primary purpose is to reconstruct the events that led to the fire – to seek out the cause of the fire.

Warning here too?

Safety of the investigator is paramount to a successful investigation. Follow proper precautions to protect those exposed to hazardous materials at the crash site. Many materials used in building vehicles and aircraft have safe and stable composites that when acted on by extreme heat become unstable and can release harmful vapors, smoke, fumes, , and particles not visible to the naked eye. Included in hazards for the investigator are the blood borne pathogens that may be contaminated with communicable diseases. For these reasons respirators and chemical and/or biological personal protective equipment (PPE) may be required. Always err on the side of caution by ensuring PPE is worn when investigating accidents that contain the above hazardous materials. See appendix P for more information.

2. DEFINITIONS.

a. Auto-ignition temperature – the temperature at which a material will ignite on its own without any outside source of ignition.

b. Combustibles (Ordinary) – sources of fuel for a fire that include flammable materials such as wood, paper, cloth, metal, rubber, plastic, and glass.

c. Combustible liquid – liquid having a flash point at or above 100º F.

d. Deflagration – subsonic gaseous combustion resulting in intense heat and light and possibly a low level shock wave. Deflagration is a very rapid burning that produces intense heat. It can occur when a combustible gas (such as propane from a barbecue grill) becomes mixed with air in particular proportions and is then ignited. The type of explosion gives an indication of the amount of gases involved or the explosive limit of the gases. For example, a large volume of gases creates longer burning fire with a small explosion and a characteristic whoosh sound. In addition to sound, where the explosion takes place can be significant. Some gases are lighter than air, hence an explosion that occurs in the bottom half of a structure might eliminate certain ignition sources.

e. Detonation – a supersonic combustion process occurring in a confined or open space characterized by a shock wave preceding the flame front.

f. Diffusion flame or open flame – rapid oxidation reaction with production of heat and light. A gas flame or candle flame is termed an open flame, as is the initial fireball during an aircraft impact.

g. Eutectic Melting – the lowest temperature at which aluminum alloy will melt. At this temperature, a phenomenon called “broom straw effect” occurs if the aluminum is highly stressed.

h. Explosion – detonation within a confined space resulting in a rapid buildup of pressure and rupture of the confining vessel.

i. Fire – rapid oxidation or other fuel reaction producing heat and light.

j. Fire Resistant – the ability of a material or structure to withstand the effects of fire over time.

k. Flame Resistant – material is considered flame resistant when it does not continue to burn when the ignition source is removed.

l. Flammable liquid – liquid that has a flash point below 100º F and a vapor pressure not exceeding 40 pounds per square inch absolute (psia) at 100º F. Fuel (JP-4, -5, -8, MOGAS), hydraulic fluid, engine oil, and skydrol are examples of flammable liquids.

m. Flammability limits – generally expressed as the upper explosive limit (UEL) and lower explosive limit (LEL). These describe the highest and lowest concentrations of a fuel in air by volume in percent, which will sustain combustion. A fuel-air mixture below the LEL is too lean to burn and a mixture above the UEL is too rich too burn. These limits do not play a role in a post crash fire but are significant in in-flight fire. For there to be an in-flight fire, the aircraft must be in a temperature/altitude condition where the fuel-air mixture can exist. Normally, this is between altitudes of 13,000 and 20,000 feet MSL. Below 13,000 feet MSL, there is too much oxygen and too little vapors for an in-flight fire and above 20,000 feet MSL, there are too many vapors and not enough oxygen for an in-flight fire.

n. Flashover – the situation where an area or its contents are heated to above its auto-ignition temperature, but does not ignite due a lack of oxygen. When oxygen is added, the area and its contents ignite simultaneously, sometimes with explosive force.

o. Flash point – the lowest temperature at which a material will produce a flammable vapor. It is a measure of the volatility of the material.

p. Ground fire – fire which spreads over a wide area (or several separate areas) and normally exists as puddles of burning, uncontained fuels spilled from fuel tanks and lines damaged in the crash. Also known as post-crash fire.

q. Impact fire – fires whose explosion-like fireball is a direct result of high energy (steep and fast i.e., stall/spin) crashes that atomize fuel into a fine, fast, hot-burning mist.

r. In-flight fire – fire that existed before the aircraft impacted the ground.

s. Post-crash fire – same as ground fire.

t. Production of explosive gases – explosive gases are produced during the second stage of a fire. That is, as the temperature of the fire rises toward 800° to 1000° F and the available supply of oxygen is lowered, incomplete burning produces smoke and gases. The hazard here is that these gases are not vented and they become heated above their ignition temperature. These gases are capable of igniting with explosive force when a new air supply is suddenly introduced. This sudden ignition of hot, unburned gases is termed backdraft.

u. Stoichiometric - Every chemical reaction has its characteristic proportions. Stoichiometry is the branch of chemistry and chemical engineering that deals with the quantities of substances that enter into, and are produced by, chemical reactions.

v. Volatility - is the evaporation capability of a given substance. The greater the tendency of substance to vaporize, the more volatile it is.

3. FIRE SCIENCE AND FIRE BEHAVIOR.

Fire investigation requires both knowledge of fire science and fire behavior. To have a fire there must be fuel, oxygen, and heat (See Figure O-1 below - The Fire Triangle).

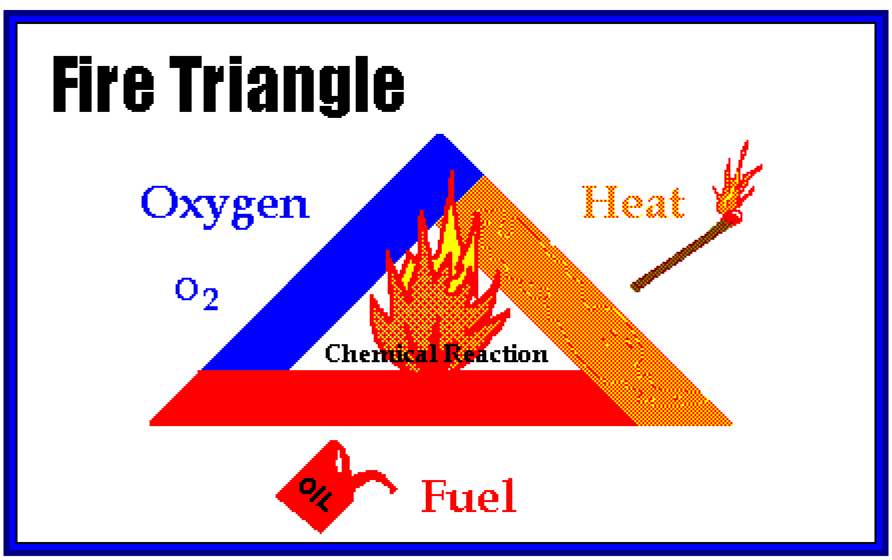


FIGURE 1. The Fire Triangle.

The heat must be of sufficient intensity to cause the fuel (liquid, or solid) to vaporize and then ignite the vapors. The three elements of the fire triangle may be independently varied with ignition occurring under certain conditions. A change in one element may affect the other two elements. A stronger ignition source (heat) may lower the amount of oxygen required (lower oxygen concentration) and/or reduce the amount of fuel vapors necessary at ignition. Increasing the amount of oxygen available may lower the energy necessary for ignition (heat) and/or decrease the amount of fuel vapors needed. For sustained burning, the fire itself must produce enough heat to vaporize more fuel, creating a chain reaction. Additionally, the more oxygen added to the fire, the faster and hotter it burns. An external aircraft in-flight fire will burn at temperatures greater than 3000º F due to the slipstream of air. A post-crash fire will normally burn at 2000º F in still air.

a. By-products of Combustion.

(1) Flame – burning fuel vapor along with hot fuel particles.

(2) Gases – invisible products of complete or incomplete burning. These include acrolein, ammonia, carbon monoxide, hydrogen bromide, hydrogen cyanide, hydrogen chloride, hydrogen sulfide, sulfur dioxide, and nitrogen dioxide.

(3) Smoke – smoke is a combination of gases, air, and suspended particles that are the products of incomplete combustion.

(4) Heat – generated by the chemical reaction called burning. Heat always flows from a higher temperature to a lower temperature, never from a lower temperature to a higher temperature without an outside force being applied. Fires generate heat, which is necessary to sustain fire. Excess heat is then transferred to surrounding objects, which may ignite, explode, or decompose. Heat transfer is accomplished by three methods – conduction, convection, and radiation.

b. Methods of Heat Transfer – An understanding of how heat travels, allows the investigator to start the investigation with where the fire was extinguished and backtrack along avenues of heat travel to the origin of the fire.

(1) Convection – heat transfer through the movement of gases. The gases may be the direct product of fires, the results of chemical reaction, or additional gases brought to the fire by the movement of air and heated at the fire surfaces by conduction. Convection determines the general direction of the spread of the fire. Convection causes fires to rise as heat rises and to move in the direction of the prevailing air currents.

(2) Conduction – the transfer of heat through direct contact of two materials. Heat a metal pipe and touch a second pipe, the second pipe will also get hot. This often accounts for a fire spreading from one area to another, even when a wall separates each area.

(3) Radiation – radiation is defined as the electromagnetic wave transfer of heat to a solid. Waves travel in all directions from the fire and may be reflected off a surface, as well as be absorbed by it. Absorbed heat may raise the temperature beyond the material's combustion point, and then a fire erupts. Heat may also be conducted through a vessel to its contents, which will then expand and may explode.

c. Heat Intensity. Heat intensity is another possible means by which the investigator can determine the crash/fire sequence. The flame temperature of a post-crash fire, in which combustibles like gasoline, JP-4, lubricating oils, and hydraulic fluids are being consumed, are normally in the range of 1600º to 2000º F. The flame temperatures of an in-flight fire may be in excess of 3000º F due to the forced draft of the slipstream. The effect of the forced draft causes the fuel/air ratio to be a nearly stoichiometric mixture. Therefore, when parts having a melting point in excess of 2000ºF, like stainless steel and titanium, show evidence of melting, it is a strong indication the fire occurred in flight. The indication of an in-flight fire is even stronger if the part is found in an area in which it appears that the ground fire was not intense. But remember, it is possible for ground fires to exceed 2000ºF. Strong ground winds may provide a forced draft, or peculiar piling of the wreckage may produce a “chimney effect” and the fire will make its own draft. Also, materials like magnesium may be present which burn with an intense flame. Usually, the areas in which a flame temperature is hot enough to melt stainless steel and titanium are very small and are the result of some localized jet effect, similar to that made by a welding torch.

d. Soot Patterns. A soot pattern is formed as a result of the soot drifting with the air stream. Soot can attach itself to an object by means of the unburned oils it contains and by electrostatic attraction. Remember that soot will not attach itself to surfaces that are over approximately 700º F. Any object that tends to shroud or block off another part will affect the shape of the pattern. The blocked part will show the general outline of the object that provides the blocking effect. If a part is found with such an outline, but the part that did the blocking is not there, the pattern must have occurred before impact. However, if both the outlined and blocking part are to be related but the blocking part is not normally in this position in the aircraft, the pattern was formed after impact; for example, the finding of a clean surface when unfolding a sooted piece of metal.

e. Heat Patterns and Ignition Characteristics of Flammable Materials and Liquids. A heat pattern consists of the deterioration and discoloration of the objects in the affected area. In order to detect the pattern, an investigator must know the effects of heat on various materials. The degree of these effects is a function of time at temperature. The time of exposure must be considered in cases of a sustained fire. Usually, a knowledge of the effects of heat on materials will enable the investigator to determine the relative deterioration and from this, the heat pattern. Listed below are heat and ignition characteristics on some flammable materials and liquids.

(1) Magnesium – Magnesium chips and thin sections burn more readily than thick sections and require an intense fire to ignite. It turns molten at 1050° F to 1200° F and may ignite. It burns with an intense white flame, is a good source of re-ignition for other flammable materials and liquids, and typically cannot be extinguished with the usual aircraft fire-extinguishing agents. Magnesium fires are self-sustaining and the oxide deposits vary between white and black. Magnesium is used in bearing supports and frames, and housings and other engine and landing gear components.

(2) Pure Aluminum – Aluminum fires are not self-sustaining, pure aluminum melts at 1175° F.

(3) Aluminum Alloys – Aluminum alloys melt at 1200° F and ignite at 1250° F. They are used in compressor casings, seals, fittings, aircraft skin, and honeycomb construction.

(4) Titanium – Titanium chips and thin sections burn more readily than thick sections. It melts at 3100° F, ignites at 2500° F and high speed rubbing between titanium parts may cause ignition. It burns smoothly with little sparking and requires a high concentration of oxygen to continue burning. It discolors from tan to light blue to dark blue to gray with increasing temperature. Titanium has a high affinity for gases when heated and a scale will begin to form at 1100° F. This scale (crust or flaking) increases in thickness with time at temperature. Titanium is used in compressor blades, cases, supports, and other engine and landing gear parts.

(5) Steel – Steel melts at 2700° F and ignites at 2750° F. It begins to discolor at 800° F to 900° F and turns tan to light blue to dark blue to black. Low and medium carbon steels are used in compressor rotor discs and turbine casings. Stainless steel is used in inlet guide vanes, cases, supports, and other engine and landing gear parts.

(6) Zinc Chromate – turns tan at 450° F, brown at 500° F, dark brown at 600° F, and blackens at 700° F.

(7) Copper – melts at 2000° F. Copper is used in bearing cages and wiring.

(8) Brass – melts at 1600° F to 2000° F. Brass is used in bearings and bushings.

(9) Lead – melts at 625° F.

(10) Rubber – Neoprene rubber blisters at 500° F and silicone rubber blisters at 700° F. Rubber is used in seals, clamp liners, gaskets, and fuel hoses.

(11) Petroleum Products (Flammable Liquids) – Generally require temperatures over 800° F for ignition. High airflow (slipstream) reduces likelihood of ignition but produces more damage when fire does occur. Skydrol will sustain a fire at temperatures of 425° F or greater. Flame temperatures of post-crash fires in which fuel is being burned in still air are generally in the range of 1600° 2000°F. Listed below are the flammability characteristics of some aircraft fuels and oils:

(a) JP-4 has a flashpoint of 0° F and an ignition temperature of 470°-480° F.

(b) JP-5 (Kerosene or Jet-A) – has a flashpoint of 105°-150° F and an ignition temperature of 440° – 475° F.

(c) JP-8 has a flashpoint of 115° F and an ignition temperature of 435° F.

(d) Jet A/A-1 has a flashpoint of 105° – 140° F and an ignition temperature of 435° – 484° F.

(e) MIL-H-5606 has a flashpoint of 220° F and an ignition temperature of 400° F.

(f) MIL-H-83282 has a flashpoint of 425° F, an ignition temperature of 680° F, and is fire resistant.

(g) Skydrol has a flashpoint of 360° F, an ignition temperature of 925° F, and is fire resistant.

(h) Hydraulic Fluid (Petroleum Based) has a flashpoint of 195^{O} F and an ignition temperature of 437^{O} F.

(i) Hydraulic Fluid (Synthetic) has a flashpoint of 320^{O} F and an ignition temperature of 945^{O} F.

(j) Engine Oil has a flashpoint of 437^{O} F and an ignition temperature of 440^{O} – 480^{O} F.

(k) Kerosene has a flashpoint of 95^{O} – 145^{O} F and an ignition temperature of 440^{O} – 480^{O} F.

(12) Composites. In today's aircraft and vehicles, carbon fiber and fiberglass are the principal composites. Fiberglass will melt at 1200^{O} F, but the reaction of a carbon fiber composite is dependent upon the resin that is used in the construction of the material. The carbon will decompose no farther with exposure to fire but the resin will melt, destroying the integrity of the structure. The melting temperature of the resin varies with the each resin, but they will normally burn out at 1100^{O} For below.

NOTE 1*: Parts with large mass may retain sufficient heat to discolor the edges of the fracture surfaces.*

NOTE 2*: Additional heat affects (discoloration) of metals are listed in Figure R-2.*

NOTE 3*: Additional temperature ranges and melting points of different metals are listed in Figure R-3.*

f. Smoke Stain Analysis. Smoke travels in a consistent pattern that is based on what the structure allows it to do. Smoke will travel upwards and at a slight slant (depending on air currents) away from the fire source. It will therefore stain ceilings (inside of the aircraft and vehicle) unless those ceilings are involved with direct flame contact. The smoke, once its vertical travel is halted, will move horizontally seeking to continue upward. If the horizontal and vertical movements are stopped, the smoke begins to "pile up" in one corner; when this happens the smoke is forced downward in an identifiable pattern known as mushrooming. Mushrooming looks like fingers on a hand splayed in a downward direction.

g. Smoke Color Analysis. The color of smoke is of help in determining what is burning. The earlier the smoke color is observed, the more meaning it has. Smoke colors and their meanings are at paragraph f above.

h. Burn Pattern Analysis. Each object involved in a fire is affected in a more or less unique way by heat and flames. The type of damage done and the rate and intensity of burning depends on such factors as the material, shape, surface area, and exterior finish of the object. These factors, and the fire itself, determine the patterns of damage that remain on the object after the fire is extinguished.

(1) Characteristic Burn Patterns--

(a) Ordinary Combustibles. When these products burn they leave a V shaped pattern on walls and floors. The width of the V shape is dependent on the speed of burning of the combustible.

(b) Flammable Liquids. These liquids form pools and hence their burn pattern is oval and irregular in shape.

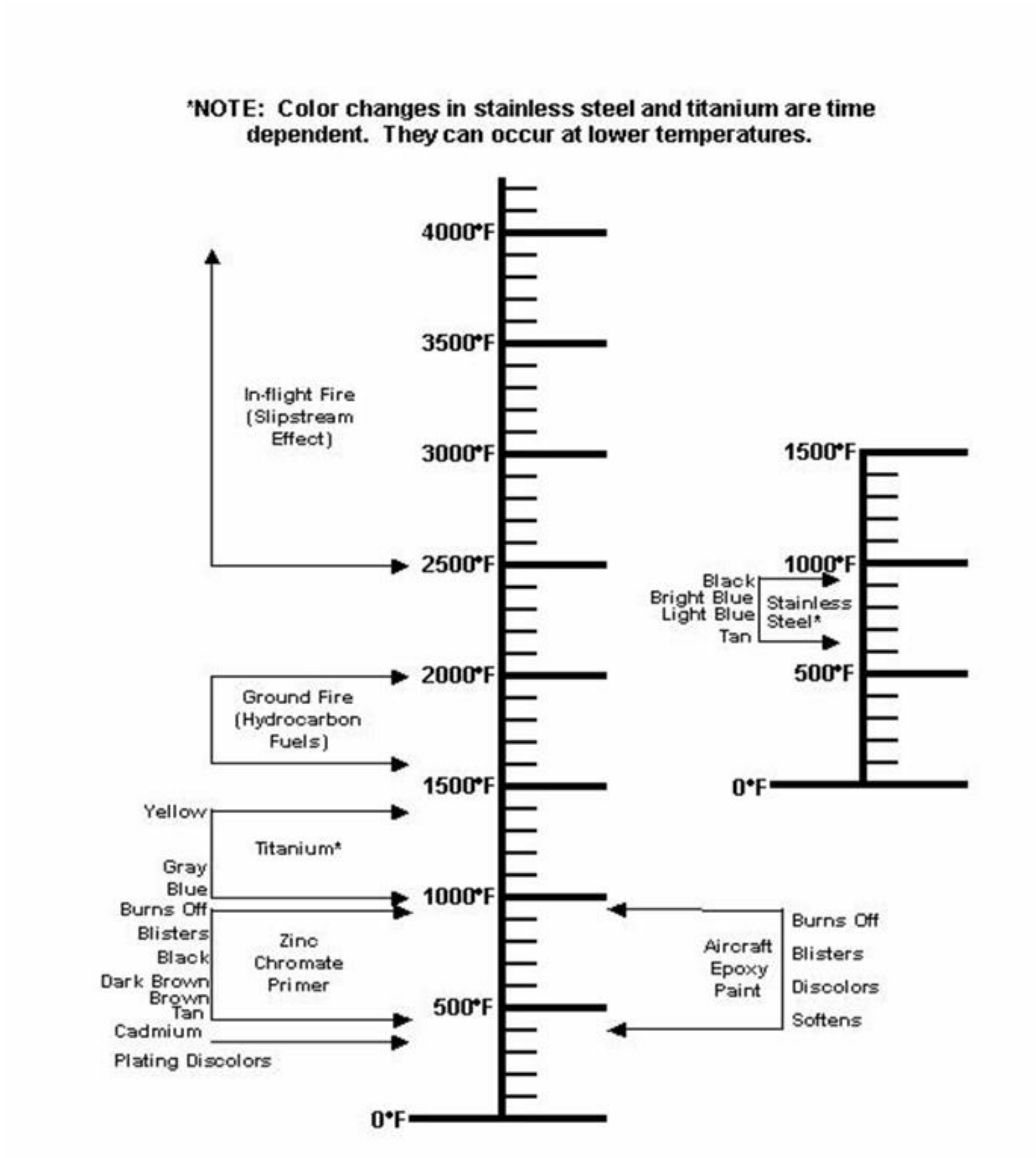


Figure O-2. Useful Temperature Ranges

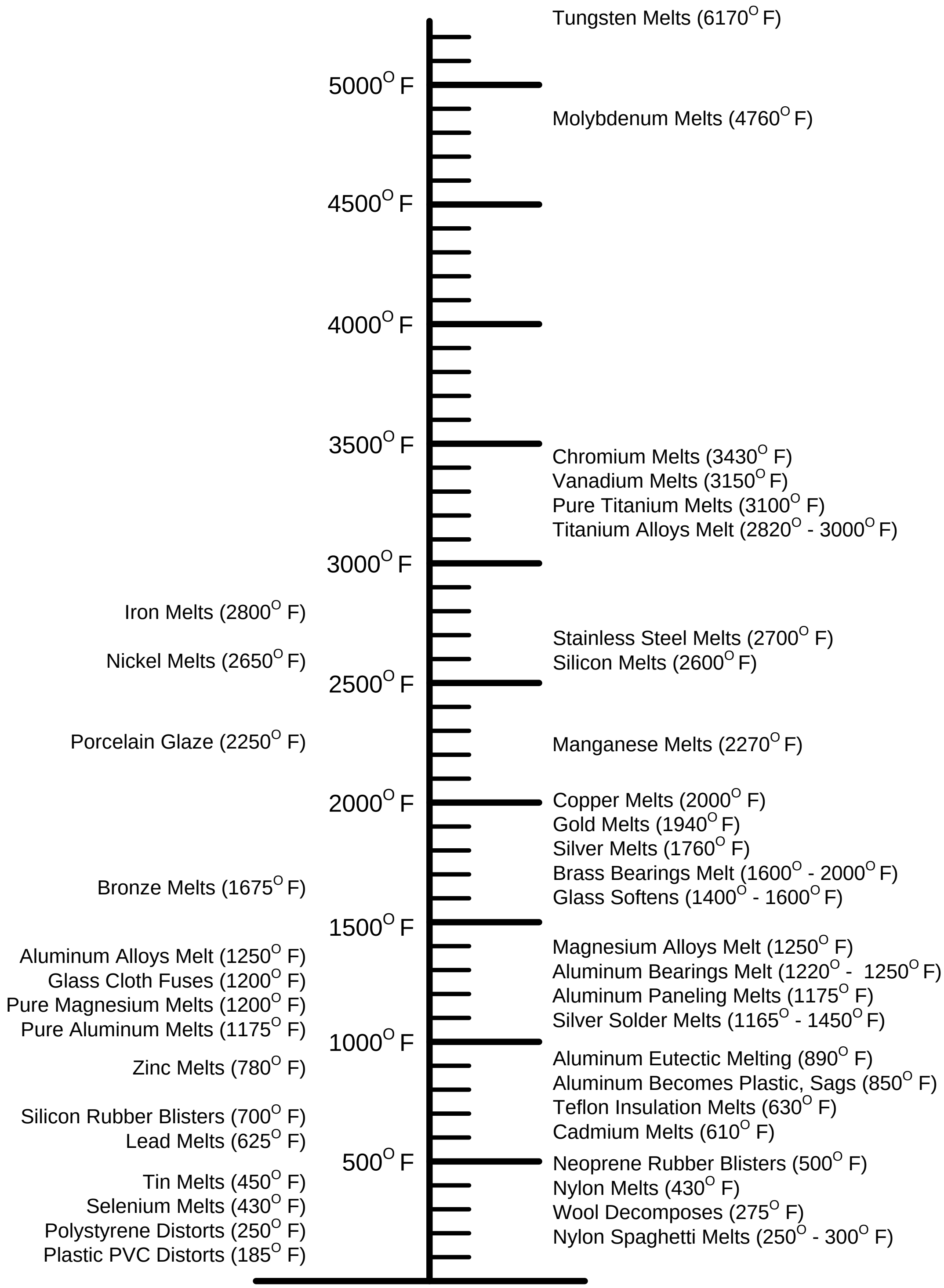
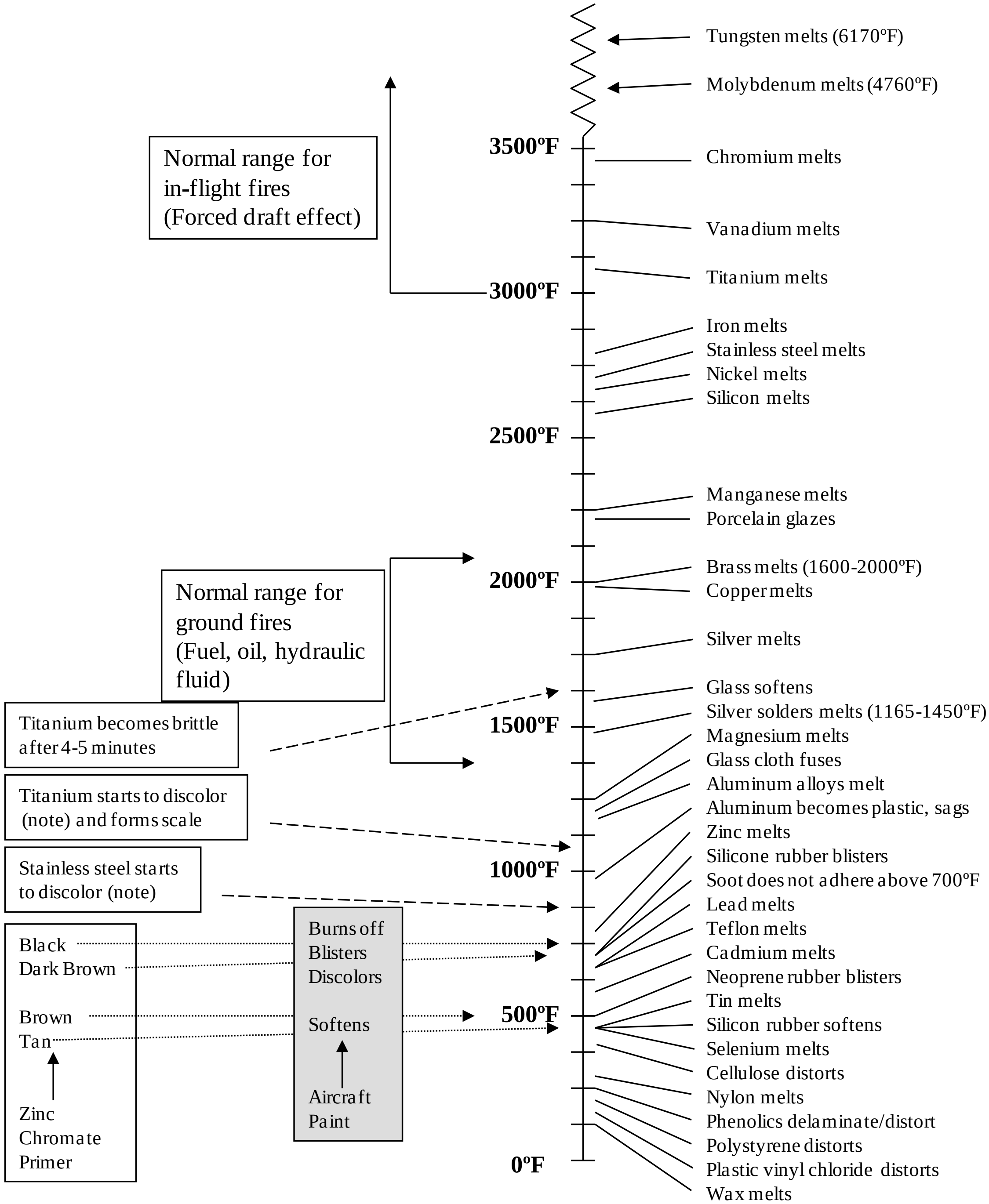


Figure O-3. Melting Points of Aircraft Materials

Melting Point Reference Chart For Investigators



Reference: Aircraft Fire Investigator's Manual, National Fire Protection Association

Note: With increasing temperature and time at temperature titanium will discolor from tan, to light blue, to dark blue, to gray. Stainless steel will discolor from tan, to light blue, to bright blue, to black. The same discoloration can be achieved by exposure to a low temperature for a long period of time as can result from a high temperature imposed over a short period of time.

4. THE FIRE INVESTIGATION.

The four primary objectives in a fire investigation are:

a. Determining the Point of Origin: This is the exact location where the fire started. This may be a specific point or it may be an area as is the case with flammable liquid spills. This is important in determining how the fire started.

b. Determining the Heat Source (Source of Ignition): The heat source is the source of heat energy that started the fire. Typical heat sources are-

(1) Engine hot section parts. This is a source of ignition on all aircraft, ground vehicles, and other pieces of equipment equipped with a gas or diesel powered engine.

(2) Hot engine exhausts. This is a source of ignition on all aircraft, ground vehicles, and other pieces of equipment equipped with a gas or diesel powered engine.

(3) Electrical arcing. This is extremely possible in military intelligence gathering aircraft such as the RC-12 series and the RC-7B. The RC-7B has 1000 pounds of wiring to operate the on-board systems. Be sure to check if Kapton wiring is used on the aircraft.

(4) Overheated equipment. This is extremely possible in military intelligence gathering aircraft such as the RC-12 series and the RC-7B. Both types of aircraft have systems on-board requiring large quantities of electricity to operate and a separate cooling system. If the cooling system becomes inoperable during flight, overheating of the equipment may occur.

(5) Bleed air systems. Heat ducts on the aircraft may become extremely hot and become a source of ignition.

(6) Static discharge. Static electricity is generated by the contact and then separation of dissimilar materials. As the aircraft flies, it generates static electricity. If the electrical potential difference is great enough, a static discharge may occur in the form of electrical arcing. If the energy level of the arcing is great enough and occurs in the vicinity of flammable vapors, such as fuel vapors, a fire may be the result.

(7) Lightning. Lightning will normally strike an external element of the aircraft, such as a prop or the wingtip. It travels through the aircraft and exits through the tail or some other aft external part. If the aircraft is properly bonded and the bond is maintained, nothing usually happens. If the bond is not maintained and the electrical charge passes in the vicinity of flammable vapors such as fuel vapors, a fire may occur.

(8) Hot brakes or wheels. Hot brakes or wheels can generate enough heat to ignite a high velocity spray of hydraulic fluid.

(9) Heaters.

(10) Auxiliary power units.

(11) In-flight galleys/ovens.

(12) Open flames.

(13) Smoking materials.

(14) Friction sparks. Friction sparking occurs when a metal is rubbed against another material. The spark is dependent upon the metal involved. Sparking from steel, magnesium, and titanium will ignite fuel vapors.

(15) Hazardous cargo. Determine what type, if any, hazardous cargo was aboard the vehicle or aircraft. These include flammable liquids and solids, oxidizers, spontaneously combustible materials, and materials that are dangerous when wet.

NOTE: *There must be a heat source at the point of origin; if there is not, something is definitely wrong and further investigation is required.*

c. Determining the Reason for Fire: The circumstance or set of circumstances by which the heat source and the combustible fuel came together at the point of origin.

d. Determining the Category of Fire:

(1) Natural – Takes place without human action or intervention.

(2) Accidental – One that results from either an unsafe act or unsafe condition.

(3) Arson – A fire that is started deliberately and maliciously, with the intent to cause damage to property.

NOTE: *The fire investigation should be conducted to determine the objectives in the order they are listed.*

e. Aircraft Fire Investigation.

(1) Examine the ground around the aircraft. A fire resulting from impact with the ground will often leave imprints of twigs, grasses, or leaves in the soot pattern on the burned wreckage. Also, look for the burn pattern around the main wreckage. A large oval or irregular shaped pattern indicates a flammable liquid (normally fuel) fire.

(2) Examine the wreckage. A ground fire will have smoke, heat and soot patterns that will normally go upwards but may vary slightly due to surface winds. Look for pieces of folded metals and unfold sooty looking or clean surfaces indicating in-flight or ground fires (see Figure R-4). Locate all aircraft parts, those that separated in-flight and after impact. If these parts show evidence of fire burn, soot, and heat patterns, the fire more than likely occurred in-flight. Additionally, locate any buried parts. Buried parts normally will not be exposed to the post crash fire, but if it shows evidence of burning, then the air craft was on fire prior to impact.

(a) Examine the exterior of the aircraft. In many post-crash and in-flight fires, the engine exhaust is a prime ignition source. Examine the area around the engine exhaust and inside the cowlings for evidence of burning. The inside of the cowlings are normally discolored due to the heat of the engine. Look for molten pieces of metal and the orientation of the heat, soot, and burn patterns. Examine rivet holes. Most metal failures occur along lines of rivets. If the rivets were exposed to fire prior to impact, the rivet holes should be clean. Look for shadowing. Sometimes one part will protect another from the post crash fire. If the protected part shows evidence of burning, this is an indication of an in-flight fire.

(b) Examine the interior of the aircraft. When examining the interior of the aircraft, look for mushrooming along the walls and ceiling indicating there was a fire in the cabin or cockpit. Examine the windows, if anything remains. A cabin or cockpit fire would be indicated by soot, smoke, or burning on the inside of the window. Additionally, if the remains of the glass or plastic show no evidence of being exposed to the slipstream airflow in flight, then the glass or plastic melted and/or burned as a result of the post crash fire.

(3) In-flight fire versus post-crash fire. In-flight fires, other than electrical, are usually the result of some failure or condition that releases combustible fluids or vapors. The fluid or vapor may drift or flow a considerable distance and be widespread before reaching an ignition source. Once ignited, it will flashback to the source of the combustible and produce a reasonably concentrated fire similar to an electrical fire. The spread of flame, soot, heat, and consequently fire damage is greatly influenced by the airflow in the region of the fire. The usual influence of the airflow is to confine the fire to a shape of a cone with an apex of the cone at the combustible source and expanding in the direction of the airflow. Confining the effects of the fire results in outlines or patterns of soot and heat. The patterns formed in flight will not be the same as those formed on the ground. The direction of the soot and heat patterns is controlled by the direction of the airflow across the parts. In flight, this is usually from front to rear. When the aircraft is at rest, the direction of the airflow across the parts will be changed. The smoke and flame will rise vertically, or be blown in the direction of the surface wind. Additionally, the impact of the aircraft will cause the parts to be in random orientation. The impact or continued ground fire may open up fuel cells or other combustible material containers and provide a broader source of combustibles. A fire that has limits beyond the surfaces of the aircraft will produce a pattern that cannot be detected. It may be necessary to reconstruct the aircraft from the remaining parts in order to detect a fire pattern. If, following the reconstruction of the aircraft, there is a detectable pattern in the direction of the in-flight airflow, an in-flight fire is indicated. Conversely, if there is no continuity of pattern across lines of failure, the patterns were formed after the impact. Listed below are some additional tips and hints to assist the investigator in determining if the fire occurred in-flight.

(a) In-flight fires leave less metal residue than ground fires because molten metal is deposited downstream of the fire.

(b) Look for in-flight fire evidence on parts not subjected to the ground fire.

(c) Burn and soot patterns uniformly across and into folds of crumpled metal indicates in-flight fire.

(d) Parts or molten metal droplets may be found along the flight path.

(4) Additional Aircraft Fire Investigation Tips.

(a) Some parts or components may have been moved prior to the arrival of the investigator.

(b) Secondary fires may obscure or mask other fire evidence.

(c) Water or dirt may protect parts from ground fire.

(d) Halon fire extinguishing agents may react with hot components.

(e) Soot and discoloration patterns may be from normal operations. JP-8 burns hotter and dirtier than JP-4 and it leaves a soot trail on top of the wings.

(f) Bright scratch marks, scuffs, and smears in the soot and heat pattern indicates damage occurred after the soot and discoloration.

(g) Soot in torn edges or fracture surfaces indicates that fire occurred after impact.

(h) Explosions can occur with little or no soot or thermal evidence.

(i) Rain, snow, and fire fighting operations may affect soot pattern evidence.

(j) Discoloration of torn edges and scratches may be due to residual heat in large mass parts.

(k) Molten metal will not deposit on objects with a greater melting temperature of the molten metal.

(l) Molten metal may be deposited by gravity, airflow, blast wave, or relative motion or a combination of these.

(m) Gas released from pressurized containers will give strange burn patterns. Nitrogen will tend to suppress the fire while high-pressure oxygen will increase the temperature and rate of burning.

(n) Rupture discs or thermal plugs on pressurized containers (landing gear tires) may give pressure and temperature information.

(o) Oxygen release may result in severe burning often resulting in a white ash deposit.

(p) Normal fire behavior results in upward extension more rapidly than lateral extension.

(q) Witnesses may give a different account of the same event. Do not presuppose until several eyewitnesses' statements support a conclusion. Making a witness statement matrix will assist the investigator in comparing witness information.

(r) A breaking spar can sound like an explosion.

(s) Fuel and hydraulic fluid spray/mist may look like smoke.

(t) Fire and smoke emissions, either internal or external to the aircraft are important in identifying location, color, intensity, and time of emissions.

(u) Determine if survivors and/or eyewitnesses had time to discuss the accident before they are interviewed. Be sure to qualify your witness, one man's pop maybe another man's crack. Have eyewitnesses retrace their actions and have them show their location in reference to the accident site and what they said they saw or heard.

(v) Impact or fire may loosen nuts. If more than ¼ turn is required to tighten a nut, then the fire did not cause the accident.

(w) Electrical arcing damage will be localized, have an eroded appearance, and possible metal splatter. Strands of copper wiring may fuse together and little beads may form on the end of the strands.

(x) Aluminum, near the molten state and shock loaded, will "broomstraw" or "feather," (eutectic melting). The end of the molten aluminum piece will look like a broken piece of wood. See figure O-4.

FIGURE O-4. Aluminum that is near the molten state and is shock-loaded will "Broomstraw."

(y) If the fire warning lights can be located and anything remains of the component, send it off for light bulb analysis to determine if a fire warning light illuminated in flight.

(z) If aircraft was equipped with cockpit voice recorder (CVR), determine if crew had discussed any type of fire. If not equipped with CVR, contact the air traffic control facility that last had contact with the aircraft to determine if the crew had declared an emergency, and the nature of that emergency.

(5) Completion of DA Form 2397-12: Upon completion of a thorough and in-depth fire investigation, the investigator should be able to easily complete DA Form 2397-12. The form will indicate when the fire started, indications of the fire, origin of the fire, source of ignition, the combustible materials that were the principal fuel for the fire, if the fire suppression and detection

systems operated as designed or were even activated, and the extent of fire damage to the aircraft. Additionally, the history of flight and analysis paragraphs on DA Form 2397-3 should also state this same information.

f. Ground Vehicle Fire Investigation:

(1) Examine the ground around the vehicle. Preservation of evidence such as tread marks, foot prints and containers in the area may be important if arson is discovered. If the ground has been involved, compare wind direction at the time of the fire with the burn pattern on the ground. Fire extending from a vehicle to the ground will fan out and leave a wide burn pattern on the grass. If the fire started accidentally in the grass, a heat source must be present.

(2) Examine the exterior of the vehicle.

(a) Upper half of the vehicle – Examine blistered and peeled paint. This may give evidence of a low burn point, even if the fire was confined to the interior of the vehicle. At the same time check all upper areas for sagging. The area with the most pronounced sagging would be located over the hottest part of the fire-usually the point of origin.

(b) Lower half of the vehicle – Examine the gas tank filler tube and cap. If the gas cap is found and it has distorted locking flanges and the filler tube has matching damage, then the gas tank probably exploded. An examination of vehicle appendages should be conducted to determine if the serviceability of tires, hubcaps, etc. is consistent with the age of the vehicle. If the fire start point is below the vehicle, the area beneath the vehicle should be sampled for flammable liquids.

(3) Examine the interior of the vehicle.

(a) Driver/Crew Compartment. Study all materials to include windows, seat springs and upholstery to determine where damage is most severe. It is important to correlate available data. This allows you to determine the area of heaviest burning. Checking seat springs for elasticity gives an indication of the proximity of the fire to the seat.

(b) Engine Compartment. If a disconnected line is suspected to be the culprit, then deposits of soot can be found around the connectors and inside the line. If distributor points are fused, the heat source may be electricity. If the battery is dead, a massive short may have occurred. No matter what the source, the engine compartment contains very little flammable material. For this reason, a fire in the engine compartment will usually burn itself out if the hood is closed. If the hood is open and the wind is blowing the fire against the windshield, then the windshield can break or melt.

(4) Completion of DA Form 285. There are no specific blocks to check for fire when completing DA Form 285. The history and analysis paragraphs are the only areas where fire is discussed. These paragraphs should be written so the reader knows that the investigator determined the origin of the fire, source of ignition, the reason for the fire and the type of fire. The investigator should also state if the fire was a cause of the mishap or a result of the mishap.

5. CONCLUSION

A fire investigation is not an easy task and often clues are deceptive. The investigator must correlate all significant data to determine the origin of the fire, the source of ignition, the reason for the fire, and the type of fire. Never base your conclusions on one piece of evidence. Most smoking holes contain false clues. Test your hypothesis and support your conclusions with all possible independent evidence sources. Remember, there is help available. Start with the local fire department and use all available professional fire assistance.