

# Chapter 9

# Engine Fire Protection Systems

## Introduction

Because fire is one of the most dangerous threats to an aircraft, the potential fire zones of all multiengine aircraft currently produced are protected by a fixed fire protection system. A “fire zone” is an area or region of an aircraft designated by the manufacturer to require fire detection and/or fire extinguishing equipment and a high degree of inherent fire resistance. The term “fixed” describes a permanently installed system in contrast to any type of portable fire extinguishing equipment, such as a hand-held fire extinguisher.

In accordance with Title 14 of the Code of Federal Regulations (14 CFR) parts 23 and 25, engine fire protection systems are mandatory on: multiengine turbine-powered aircraft, multiengine reciprocating engine-powered aircraft incorporating turbochargers, aircraft with engine(s) located where they are not readily visible from the flight deck, all commuter and transport category aircraft, and the auxiliary power unit (APU) compartment of any aircraft incorporating an APU. Fire protection systems are not mandatory for many single and twin reciprocating engine general aviation (GA) aircraft.

Several general failures or hazards can result in overheat conditions or fires peculiar to turbine engine aircraft because of their operating characteristics. The two major types of turbine failure can be classified as 1) thermodynamic and 2) mechanical.

Thermodynamic causes upset the proportion of air used to cool combustion temperatures to the levels that the turbine materials can tolerate. When the cooling cycle is upset, turbine blades can melt, causing a sudden loss of thrust. The rapid buildup of ice on inlet screens or inlet guide vanes can result in severe overheating, causing the turbine blades to melt or to be severed and thrown outward. Such failure can result in a severed tail cone and possible penetration of the aircraft structure, tanks, or equipment near the turbine wheel. In general, most thermodynamic failures are caused by ice, excess air bleed or leakage, or faulty controls that permit compressor stall or excess fuel.

Mechanical failures, such as fractured or thrown blades, can also lead to overheat conditions or fires. Thrown blades can puncture the tail cone, creating an overheat condition. Failure of forward stages of multi-stage turbines is usually

much more severe. Penetration of the turbine case by failed blades is a possible fire hazard, as is the penetration of lines and components containing flammable fluids.

A high flow of fuel through an improperly adjusted fuel nozzle can cause burn-through of the tail cone in some engines. Engine fires can be caused by burning fluid that occasionally runs out through the exhaust pipe.

## Components

A complete fire protection system includes both a fire detection and a fire extinguishing system. To detect fires or overheat conditions, detectors are placed in the various zones to be monitored. Fires are detected in aircraft by using one or more of the following: overheat detectors, rate-of-temperature-rise detectors, and flame detectors. In addition to these methods, other types of detectors are used in aircraft fire protection systems but are not used to detect engine fires. For example, smoke detectors are better suited to monitor areas such as baggage compartments or lavatories, where materials burn slowly or smolder. Other types of detectors in this category include carbon monoxide detectors.

Fire protection systems on current-production aircraft do not rely on observation by crewmembers as a primary method of fire detection. An ideal fire detector system includes as many of the following features as possible:

1. A system that does not cause false warnings under any flight or ground condition.
2. Rapid indication of a fire and accurate location of the fire.
3. Accurate indication that a fire is out.
4. Indication that a fire has reignited.
5. Continuous indication for duration of a fire.
6. Means for electrically testing the detector system from the aircraft flight deck.
7. Detectors that resist damage from exposure to oil, water, vibration, extreme temperatures, or handling.
8. Detectors that are light in weight and easily adaptable to any mounting position.
9. Detector circuitry that operates directly from the aircraft power system without inverters.
10. Minimum electrical current requirements when not indicating a fire.

11. Each detector system should turn on a flight deck light, indicating the location of the fire, and have an audible alarm system.
12. A separate detector system for each engine.

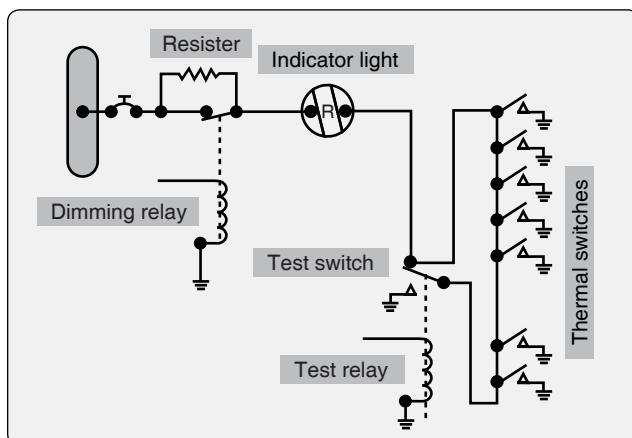
## Engine Fire Detection Systems

Several different types of fire detection systems are installed in aircraft to detect engine fires. Two common types used are spot detectors and continuously loop systems. Spot detector systems use individual sensors to monitor a fire zone. Examples of spot detector systems are the thermal switch system, the thermocouple system, the optical fire detection system, and the pneumatic-based thermal fire detection system. Continuous loop systems are typically installed on transport type aircraft and provide more complete fire detection coverage by using several loop-type sensors.

### Thermal Switch System

A number of detectors or sensing devices are available. Many older model aircraft still operating have some type of thermal switch system or thermocouple system. A thermal switch system has one or more lights energized by the aircraft power system and thermal switches that control operation of the light(s). These thermal switches are heat-sensitive units that complete electrical circuits at a certain temperature. They are connected in parallel with each other, but in series with the indicator lights [Figure 9-1]. If the temperature rises above a set value in any one section of the circuit, the thermal switch closes, completing the light circuit to indicate a fire or overheat condition.

No set number of thermal switches is required; the exact number usually is determined by the aircraft manufacturer. On some installations, all the thermal detectors are connected to one light; others may have a separate thermal switch for each indicator light.



**Figure 9-1.** Thermal switch fire circuit.

Some warning lights are push-to-test lights. The bulb is tested by pushing it in to check an auxiliary test circuit. The circuit shown in *Figure 9-1* includes a test relay. With the relay contact in the position shown, there are two possible paths for current flow from the switches to the light. This is an additional safety feature. Energizing the test relay completes a series circuit and checks all the wiring and the light bulb.

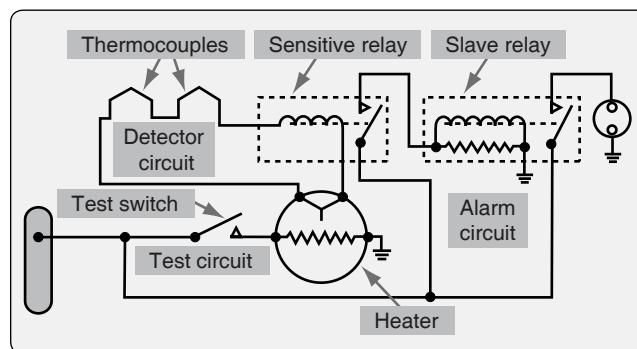
Also included in the circuit shown in *Figure 9-1* is a dimming relay. By energizing the dimming relay, the circuit is altered to include a resistor in series with the light. In some installations, several circuits are wired through the dimming relay, and all the warning lights may be dimmed at the same time.

### Thermocouple Systems

The thermocouple fire warning system operates on an entirely different principle than the thermal switch system. A thermocouple depends on the rate of temperature rise and does not give a warning when an engine slowly overheats or a short circuit develops. The system consists of a relay box, warning lights, and thermocouples. The wiring system of these units may be divided into the following circuits: (1) the detector circuit, (2) the alarm circuit, and (3) the test circuit. These circuits are shown in *Figure 9-2*.

The relay box contains two relays, the sensitive relay and the slave relay, and the thermal test unit. Such a box may contain from one to eight identical circuits, depending on the number of potential fire zones. The relays control the warning lights. In turn, the thermocouples control the operation of the relays. The circuit consists of several thermocouples in series with each other and with the sensitive relay.

Thermocouple leads are made from a variety of metals, depending on the maximum temperature to which they are exposed. Iron and constantan, or copper and constantan, are common for CHT measurement. Chromel and alumel are used for turbine EGT thermocouples. The point where these metals are joined and exposed to the heat of a fire is called a hot junction. There is also a reference junction enclosed in a dead air space between two insulation blocks.



**Figure 9-2.** Thermocouple fire warning circuit.

A metal cage surrounds the thermocouple to give mechanical protection without hindering the free movement of air to the hot junction. Thermocouple leads are designed for a specific installation and may not be altered, if they are altered they will no longer be calibrated specific probe and instrument combination.

If the temperature rises rapidly, the thermocouple produces a voltage because of the temperature difference between the reference junction and the hot junction. If both junctions are heated at the same rate, no voltage results. In the engine compartment, there is a normal, gradual rise in temperature from engine operation; because it is gradual, both junctions heat at the same rate and no warning signal is given.

If there is a fire, however, the hot junction heats more rapidly than the reference junction. The reference junction is also commonly referred to as the cold junction. The ensuing voltage causes a current to flow within the detector circuit. Any time the current is greater than 4 milliamperes (0.004 ampere), the sensitive relay closes. This completes a circuit from the aircraft power system to the coil of the slave relay. The slave relay then closes and completes the circuit to the warning light to give a visual fire warning.

The total number of thermocouples used in individual detector circuits depends on the size of the fire zones and the total circuit resistance, which usually does not exceed 5 ohms. As shown in *Figure 9-2*, the circuit has two resistors. The resistor connected across the slave relay terminals absorbs the coil's self-induced voltage to prevent arcing across the points of the sensitive relay. The contacts of the sensitive relay are so fragile that they burn or weld if arcing is permitted.

When the sensitive relay opens, the circuit to the slave relay is interrupted and the magnetic field around its coil collapses. When this happens, the coil gets a voltage through self-induction, but with the resistor across the coil terminals, there is a path for any current flow as a result of this voltage. Thus, arcing at the sensitive relay contacts is eliminated.

### ***Optical Fire Detection Systems***

Optical sensors, often referred to as "flame detectors," are designed to alarm when they detect the presence of prominent, specific radiation emissions from hydrocarbon flames. The two types of optical sensors available are infrared (IR) and ultraviolet, based on the specific emission wave lengths they are designed to detect.

#### ***Infrared Optical Fire Protection***

IR-based optical flame detectors are used primarily on light turboprop aircraft and helicopter engines. These sensors have proven to be very dependable and economical for the

relatively benign environments of these applications.

#### ***Principle of Operation***

Radiation emitted by the fire crosses the airspace between the fire and the detector and impinges on the detector front face and window. The window allows a broad spectrum of radiation to pass into the detector where it impinges on the face of the sensing device filter. The filter allows only radiation in a tight waveband centered around 4.3 micrometers in the IR to pass on to the radiation-sensitive surface of the sensing device. The radiation striking the sensing device minutely raises its temperature causing small thermoelectric voltages to be generated. These voltages are fed to an amplifier whose output is connected to various analytical electronic processing circuits. The processing electronics is tailored exactly to the time signature of all known hydrocarbon flame sources and ignores false alarm sources, such as incandescent lights and sunlight. Alarm sensitivity level is accurately controlled by a digital circuit. A typical warning system is illustrated in *Figure 9-3*.

#### ***Pneumatic Thermal Fire Detection***

Pneumatic detectors are based on the principles of gas laws. The sensing element consists of a closed helium-filled tube connected at one end to a responder assembly. As the element is heated, the gas pressure inside the tube increases until the alarm threshold is reached. At this point, an internal switch closes and reports an alarm to the flight deck. The pneumatic detector integrity pressure switch opens and triggers the fault alarm if the pneumatic detector loses pressure, as in the case of a leak.

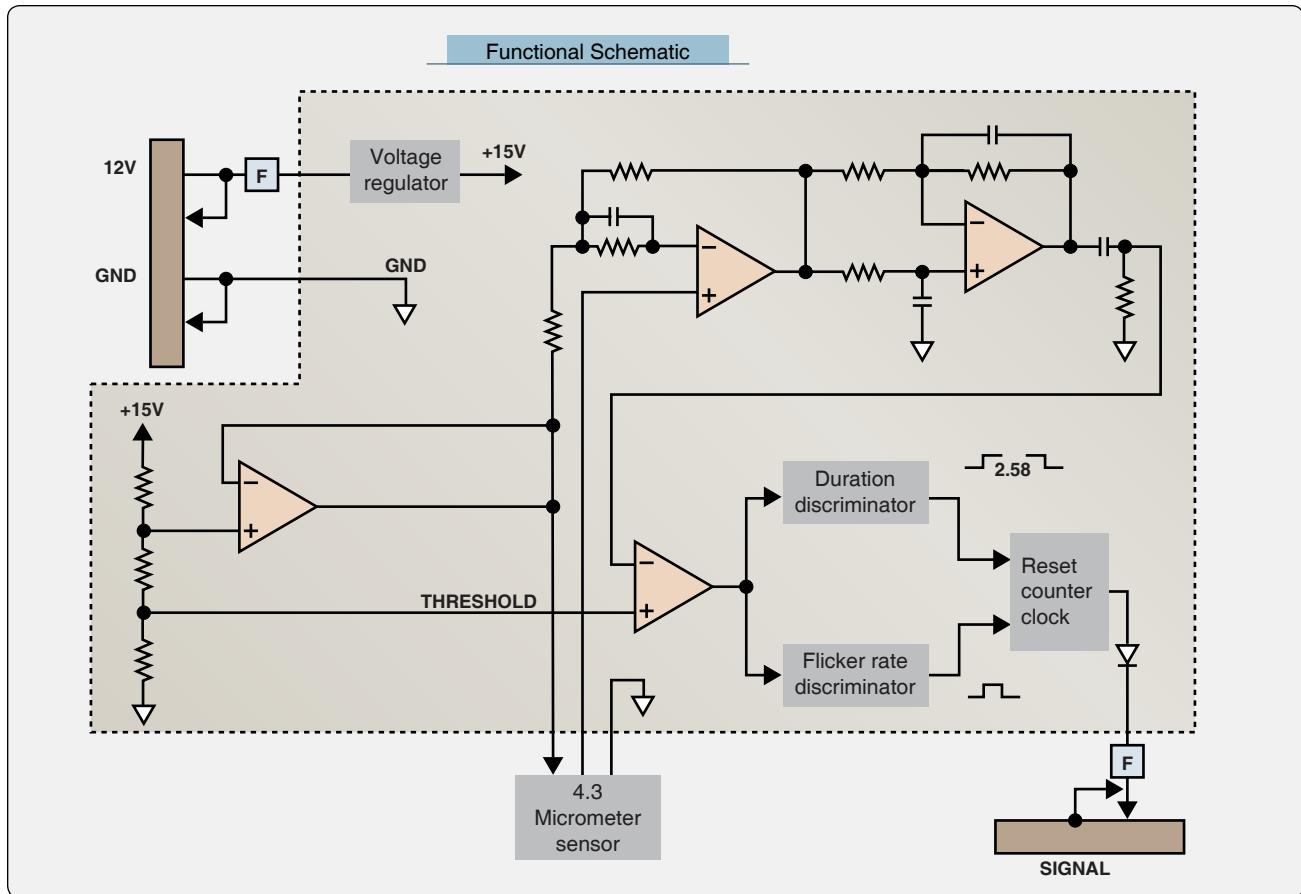
#### ***Continuous-Loop Detector Systems***

Large commercial aircraft almost exclusively use continuous thermal sensing elements for powerplant protection, since these systems offer superior detection performance and coverage, and they have the proven ruggedness to survive in the harsh environment of modern turbofan engines.

A continuous-loop detector, or sensing system, permits more complete coverage of a fire hazard area than any of the spot-type temperature detectors. Continuous-loop systems are versions of the thermal switch system. They are overheat systems, heat-sensitive units that complete electrical circuits at a certain temperature. There is no rate-of-heat-rise sensitivity in a continuous-loop system. Two widely used types of continuous-loop systems are the Kidde and the Fenwal systems. This text briefly discusses the Fenwal system, while the Kidde system is discussed more in-depth.

#### ***Fenwal Continuous-Loop System***

The Fenwal system uses a slender inconel tube packed with thermally sensitive eutectic salt and a nickel wire center

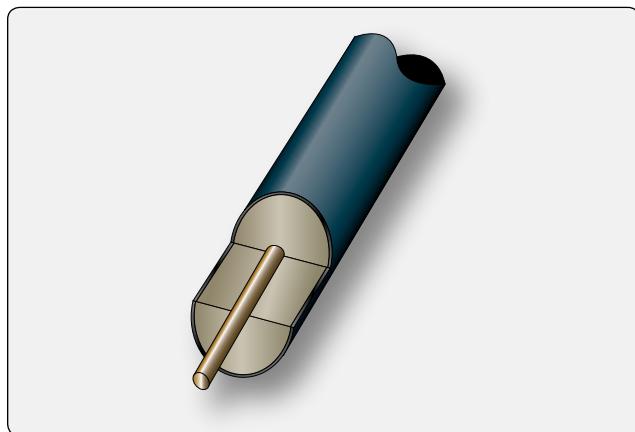


**Figure 9-3.** Optical fire detection system circuit.

conductor. [Figure 9-4] Lengths of these sensing elements are connected in series to a control unit. The elements may be of equal or varying length and of the same or different temperature settings. The control unit, operating directly from the power source, impresses a small voltage on the sensing elements. When an overheat condition occurs at any point along the element length, the resistance of the eutectic salt within the sensing element drops sharply, causing current to flow between the outer sheath and the center conductor. This

current flow is sensed by the control unit, which produces a signal to actuate the output relay.

When the fire has been extinguished or the critical temperature lowered, the Fenwal system automatically returns to standby alert, ready to detect any subsequent fire or overheat condition. The Fenwal system may be wired to employ a “loop” circuit. In this case, should an open circuit occur, the system still signals fire or overheat. If multiple open circuits occur, only that section between breaks becomes inoperative.

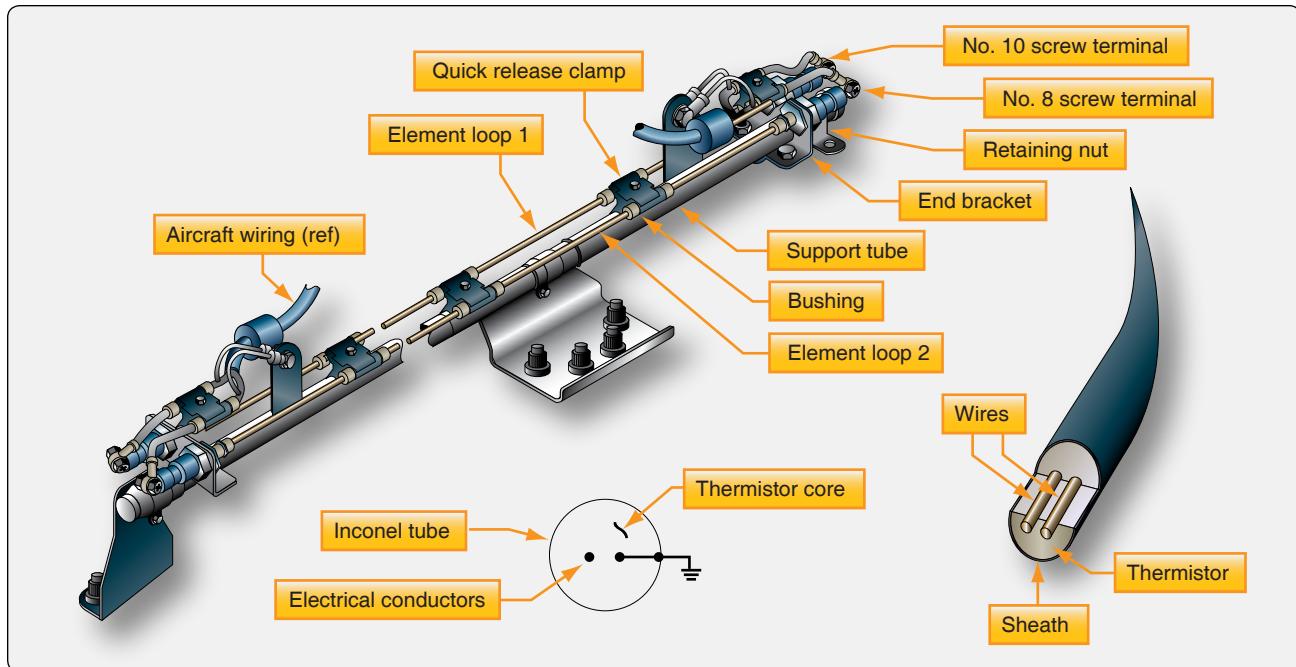


**Figure 9-4.** Fenwal sensing element.

#### Kidde Continuous-Loop System

In the Kidde continuous-loop system, two wires are imbedded in an inconel tube filled with a thermistor core material. [Figure 9-5] Two electrical conductors go through the length of the core. One conductor has a ground connection to the tube and the other conductor connects to the fire detection control unit.

As the temperature of the core increases, electrical resistance to ground decreases. The fire detection control unit monitors this resistance. If the resistance decreases to the overheat set point, an overheat indication occurs in the flight deck. Typically, a 10-second time delay is incorporated for the



**Figure 9-5.** Kidde continuous-loop system.

overheat indication. If the resistance decreases more to the fire set point, a fire warning occurs. When the fire or overheat condition is gone, the resistance of the core material increases to the reset point and the flight deck indications go away.

The rate of change of resistance identifies an electrical short or a fire. The resistance decreases more quickly with an electrical short than with a fire. In addition to fire and overheat detection, the Kidde continuous-loop system can supply nacelle temperature data to the aircraft condition monitoring function of the Aircraft In-Flight Monitoring System (AIMS).

#### Sensing Element

The sensing element consists, essentially, of an infinite number of unit thermistors electrically in parallel along its length. The resistance of the sensing element is a function of the length heated, as well as the temperature-heating of less than the full length of element, which requires that portion to be heated to a higher temperature to achieve the same total resistance change. As a result, the system responds not to a fixed alarm temperature but to the sum of the resistances (in parallel) that reflects a nonarithmetic “average.” The sensing element may be routed close to nonhazardous hot spots that may have a normal temperature well above the overall alarm temperature, without danger of causing a false alarm. This feature permits the alarm point to be set close to the maximum general ambient temperature, giving greater sensitivity to a general overheat or fire without being subject to false alarms from localized nonhazardous hot spots.

#### Combination Fire & Overheat Warning

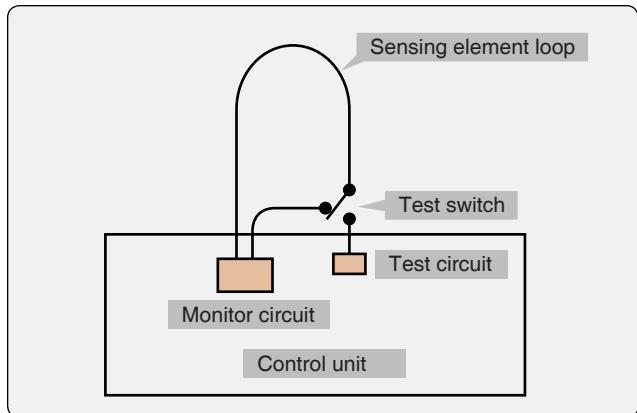
The analog signal from the thermistor sensing element permits the control circuits to be arranged to give a two-level response from the same sensing element loop. The first is an overheat warning at a temperature level below the fire warning, indicating a general engine compartment temperature rise, which could be caused by leakage of hot bleed air or combustion gas into the engine compartment. It could be an early warning of fire and would alert the crew to appropriate action to reduce the engine compartment temperature. The second-level response would be at a level above that attainable by the leaking hot gas and would be the fire warning.

#### Temperature Trend Indication

The analog signal produced by the sensing element loop as its temperature changes can readily be converted to signals suitable for meter or cathode ray tube (CRT) display to indicate engine bay temperature increases from normal. A comparison of the readings from each loop system also provides a check on the condition of the fire detection system, because the two loops should normally read alike.

#### System Test

The integrity of the continuous-loop fire detection system may be tested by actuating a test switch in the flight deck, which switches one end of the sensing element loop from its control circuit to a test circuit, built into the control unit, that simulates the sensing element resistance change due to fire. [Figure 9-6] If the sensing element loop is unbroken, the resistance detected “seen” by the control circuit is now



**Figure 9-6.** Continuous-loop fire detection system test circuit.

that of the simulated fire and so the alarm is signaled. This demonstrates, in addition to the continuity of the sensing element loop, the integrity of the alarm indicator circuit and the proper functioning of the control circuits. The thermistor properties of the sensing element remain unchanged for the life of the element (no chemical or physical changes take place on heating), so that it functions properly as long as it is electrically connected to the control unit.

#### Fault Indication

Provision can be made in the control unit to send a fault signal to activate a fault indicator whenever the short discriminator circuit detects a short in the sensing element loop. While this is a requirement in 14 CFR for transport category aircraft because such a short disables the fire detection system, it is offered as an option for other aircraft types in which it may not be a requirement.

#### Dual-Loop Systems

Dual-loop systems are, in essence, two complete basic fire detection systems with their output signals connected so that both must signal to result in a fire warning. This arrangement, called "AND" logic, results in greatly increased reliability against false fire warnings from any cause. Should one of the two loops be found inoperative at the preflight integrity test, a flight deck selector switch disconnects that loop and allows the signal from the other loop alone to activate the fire warning. Since the single operative loop meets all fire detector requirements, the aircraft can be safely dispatched, and maintenance deferred to a more convenient time. However, should one of the two loops become inoperative in flight and a fire subsequently occur, the fire signaling loop activates a flight deck fault signal that alerts the flight crew to select single-loop operation to confirm the possible occurrence of fire.

#### Automatic Self-Interrogation

Dual-loop systems automatically perform the loop switching and decision-making function required of the flight crew upon appearance of the fault indication in the flight deck. Automatic self-interrogation eliminates the fault indication and assures the immediate appearance of the fire indication should fire occur while at least one loop of the dual-loop system is operative. Should the control circuit from a single loop signal "fire," the self-interrogation circuit automatically tests the functioning of the other loop. If it tests operative, the circuit suppresses the fire signal (because the operative loop would have signaled if a fire existed). If, however, the other loop tests inoperative, the circuit outputs a fire signal. The interrogation and decision takes place in milliseconds, so that no delay occurs if a fire actually exists.

#### Support Tube-Mounted Sensing Elements

When you want to mount the sensing elements on the engine, and in some cases, on the aircraft structure, the support tube-mounted element solves the problem of providing sufficient element support points, and greatly facilitates the removal and reinstallation of the sensing elements for engine or system maintenance.

Most modern installations use the support tube concept of mounting sensing elements for better maintainability as well as increased reliability. The sensing element is attached to a prebent stainless steel tube by closely spaced clamps and bushings, where it is supported from vibration damage and protected from pinching and excessive bending. The support tube-mounted elements can be furnished with either single- or dual-sensing elements.

Being prebent to the designed configuration assures its installation in the aircraft precisely in its designed location, where it has the necessary clearance to be free from the possibility of the elements chafing against engine or aircraft structure. The assembly requires only a few attachment points, and removal for engine maintenance is quick and easy. Should the assembly require repair or maintenance, it is easily replaced with another assembly, leaving the repair for the shop. A damaged sensing element is easily replaced in the assembly. The assembly is rugged, easy to handle, and unlikely to suffer damage during handling for installation or removal.

#### Fire Detection Control Unit (Fire Detection Card)

The control unit for the simplest type of system typically contains the necessary electronic resistance monitoring and alarm output circuits, housed in a hermetically sealed aluminum case and filled with a mounting bracket and circular electrical connector. For more sophisticated systems, control modules may be employed that contain removable

control cards having circuitry for individual hazard areas, and/or unique functions. In the most advanced applications, the detection system circuitry controls all aircraft fire protection functions, including fire detection and extinguishing for engines, APUs, cargo bays, and bleed air systems.

### Fire Zones

The powerplant installation has several designated fire zones: (1) the engine power section; (2) the engine accessory section; (3) except for reciprocating engines, any complete powerplant compartment in which no isolation is provided between the engine power section and the engine accessory section; (4) any APU compartment; (5) any fuel-burning heater and other combustion equipment installation; (6) the compressor and accessory sections of turbine engines; and (7) combustor, turbine, and tailpipe sections of turbine engine installations that contain lines or components carrying flammable fluids or gases. *Figure 9-7* shows fire protection for a large turbo fan engine.

In addition to the engine and nacelle area zones, other areas on multiengine aircraft are provided with fire detection and protection systems. These areas include baggage compartments, lavatories, APU, combustion heater installations, and other hazardous areas. Discussion of fire protection for these areas is not included in this section, which is limited to engine fire protection.

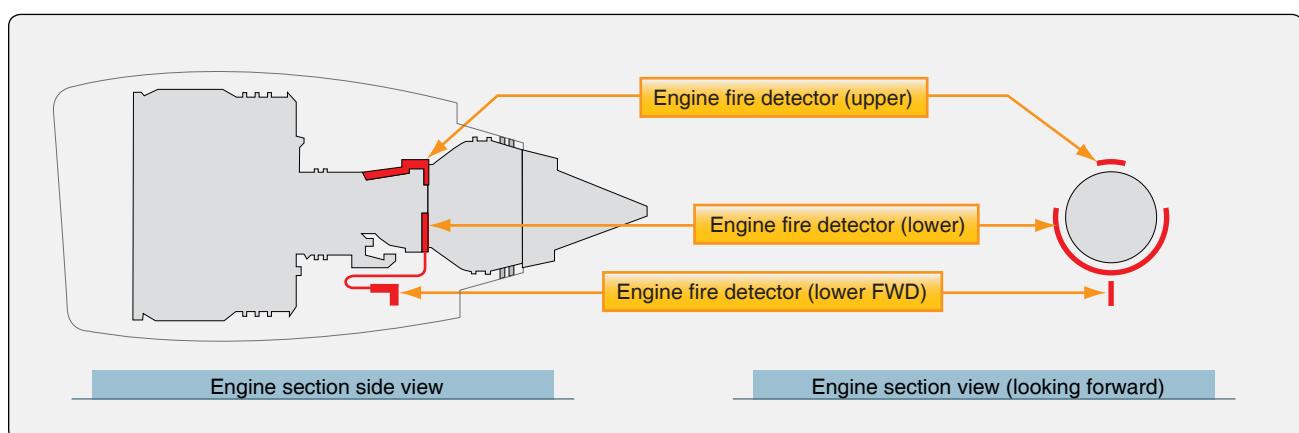
### Engine Fire Extinguishing System

Commuter aircraft certificated under 14 CFR part 23 are required to have, at a minimum, a one-shot fire extinguishing system. All transport category aircraft certificated under 14 CFR part 25 are required to have two discharges, each of which produces adequate agent concentration. An individual one-shot system may be used for APUs, fuel burning heaters, and other combustion equipment. For each “other” designated fire zone, two discharges (two-shot system) must be provided, each of which produces adequate agent concentration. *[Figure 9-8]*

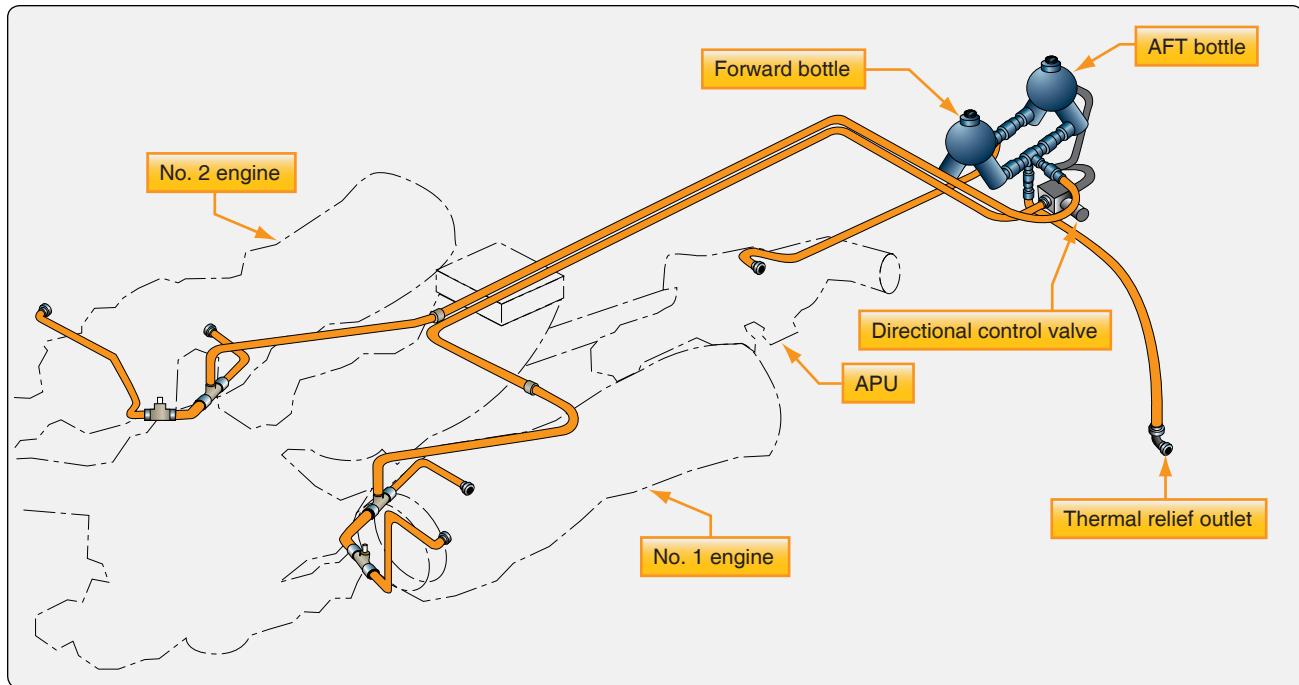
### Fire Extinguishing Agents

The fixed fire extinguisher systems used in most engine fire protection systems are designed to dilute the atmosphere with an inert agent that does not support combustion. Many systems use perforated tubing or discharge nozzles to distribute the extinguishing agent. High rate of discharge (HRD) systems use open-end tubes to deliver a quantity of extinguishing agent in 1 to 2 seconds. The most common extinguishing agent still used today is Halon 1301 because of its effective firefighting capability and relatively low toxicity (U.L. classification Group 61). Noncorrosive, Halon 1301 does not affect the material it contacts and requires no clean-up when discharged. Halon 1301 is the current extinguishing agent for commercial aircraft, but a replacement is under development. Because Halon 1301 depletes the ozone layer only recycled Halon 1301 is currently available. Halon 1301 is used until a suitable replacement is developed. Some military aircraft use HCL-125, which the Federal Aviation Administration (FAA) is testing for use in commercial aircraft.

Carbon dioxide ( $\text{CO}_2$ ) is an effective extinguishing agent. It is most often used in fire extinguishers that are available on the ramp to fight fires on the exterior of the aircraft, such as engine or APU fires.  $\text{CO}_2$  has been used for many years to extinguish flammable fluid fires and fires involving electrical equipment. It is noncombustible and does not react with most substances. It provides its own pressure for discharge from the storage vessel, except in extremely cold climates where a booster charge of nitrogen may be added to winterize the system. Normally,  $\text{CO}_2$  is a gas, but it is easily liquefied by compression and cooling. After liquefaction,  $\text{CO}_2$  remains in a closed container as both liquid and gas. When  $\text{CO}_2$  is then discharged to the atmosphere, most of the liquid expands to gas. Heat absorbed by the gas during vaporization cools the remaining liquid to  $-110^{\circ}\text{F}$ , and it becomes a finely divided white solid, dry ice snow.



**Figure 9-7.** Large turbofan engine fire zones.



**Figure 9-8.** Typical fire extinguishing system.

### Turbine Engine Ground Fire Protection

On many aircraft, means are usually provided for rapid access to the compressor, tailpipe, or burner compartments. Many aircraft systems are equipped with spring-loaded or pop-out access doors in the skin of the various compartments. Internal engine tailpipe fires that take place during engine shutdown or false starts can be blown out by motoring the engine with the starter. A running engine can be accelerated to rated speed to achieve the same result. If such a fire persists, a fire extinguishing agent can be directed into the tailpipe. It should be remembered that excessive use of CO<sub>2</sub>, or other agents that have a cooling effect, can shrink the turbine housing on the turbine and cause the engine to disintegrate.

### Containers

Fire extinguisher containers (HRD bottles) store a liquid halogenated extinguishing agent and pressurized gas (typically nitrogen) normally manufactured from stainless steel. Depending upon design considerations, alternate materials are available including titanium. Containers are also available in a wide range of capacities and are produced under Department of Transportation (DOT) specifications or exemptions. Most aircraft containers are spherical in design, which provides the lightest weight possible. However, cylindrical shapes are available where space limitations are a factor. Each container incorporates a temperature/pressure sensitive safety relief diaphragm that prevents container pressure from exceeding container test pressure in the event of exposure to excessive temperatures. [Figure 9-9]

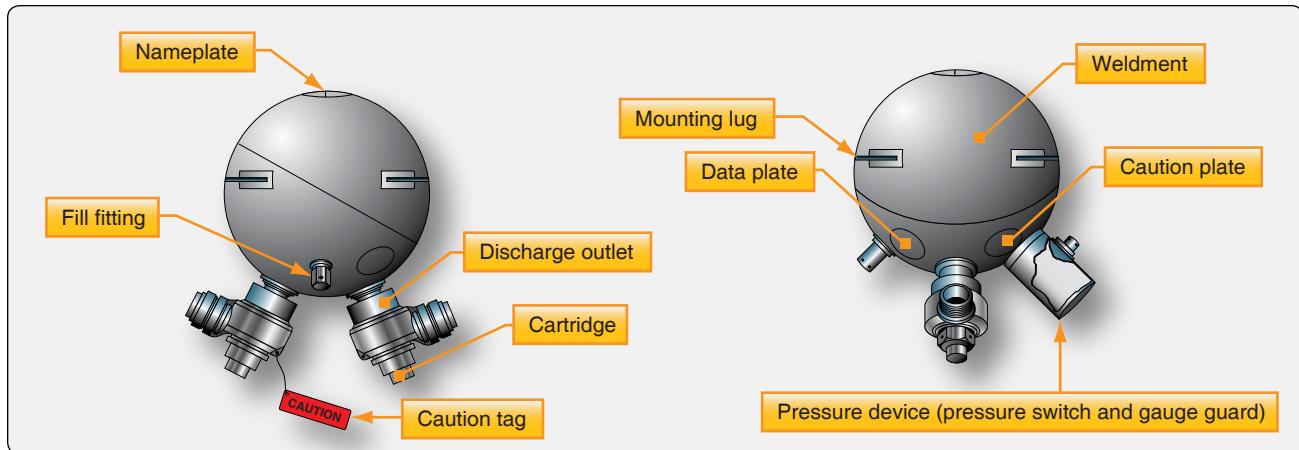
### Discharge Valves

Discharge valves are installed on the containers. A cartridge (squib) and frangible disc type valve are installed in the outlet of the discharge valve assembly. Special assemblies having solenoid-operated or manually-operated seat type valves are also available. Two types of cartridge disc-release techniques are used. Standard release type uses a slug driven by explosive energy to rupture a segmented closure disc. For high temperature or hermetically sealed units, a direct explosive impact type cartridge is used, which applies fragmentation impact to rupture a prestressed corrosion-resistant steel diaphragm. Most containers use conventional metallic gasket seals that facilitate refurbishment following discharge. [Figure 9-10]

### Pressure Indication

A wide range of diagnostics are utilized to verify the fire extinguisher agent charge status. A simple visually indicated gauge is available, typically a vibration-resistant helical bourdon-type indicator. [see Figure 9-9]

A combination gauge switch visually indicates actual container pressure and also provides an electrical signal if container pressure is lost, precluding the need for discharge indicators. A ground checkable diaphragm-type low-pressure switch is commonly used on hermetically sealed containers. The Kidde system also has a temperature compensated pressure switch that tracks the container pressure variations with temperatures by using a hermetically sealed reference chamber.



**Figure 9-9.** Fire extinguisher containers (HRD bottles).



**Figure 9-10.** Discharge valve (left) and cartridge (squib) (right).

### Two-Way Check Valve

A complete line of two-way check valves is available, manufactured from either lightweight aluminum or steel. These valves are required in a two-shot system to prevent the agent in a reserve container from backing up into the previous emptied main container. Valves are supplied with either MS-33514 or MS-33656 fitting configurations.

### Discharge Indicators

Discharge indicators provide immediate visual evidence of container discharge on fire extinguishing systems. Two kinds of indicators can be furnished: thermal and discharge. Both types are designed for aircraft and skin mounting. [Figure 9-11]

#### Thermal Discharge Indicator (Red Disc)

The thermal discharge indicator is connected to the fire container relief fitting and ejects a red disc to show when container contents have dumped overboard due to excessive heat. The agent discharges through the opening created when the disc blows out. This gives the flight and maintenance crews an indication that the fire extinguisher container needs

to be replaced before the next flight.

#### Yellow Disc Discharge Indicator

If the flight crew activates the fire extinguisher system, a yellow disc is ejected from the skin of the aircraft fuselage. This is an indication for the maintenance crew that the fire extinguishing system was activated by the flight crew, and that the fire extinguishing container needs to be replaced before the next flight.

### Fire Switch

Fire switches are typically installed on the center overhead panel or center console in the flight deck. [Figure 9-12] When the fire switch is activated, the following happens: the engine stops because the fuel control shuts off, the engine is isolated from the aircraft systems, and the fire extinguishing system is activated. Some aircraft use fire switches that need to be pulled and turned to activate the system, while others use a push-type switch with a guard. To prevent accidental activation of the fire switch, a lock is installed that releases the fire switch only when a fire has been detected. This lock can be manually released by the flight crew if the fire detection



Figure 9-11. Discharge indicators.



Figure 9-12. Engine fire switches.

system malfunctions. [Figure 9-13]

### Warning Systems

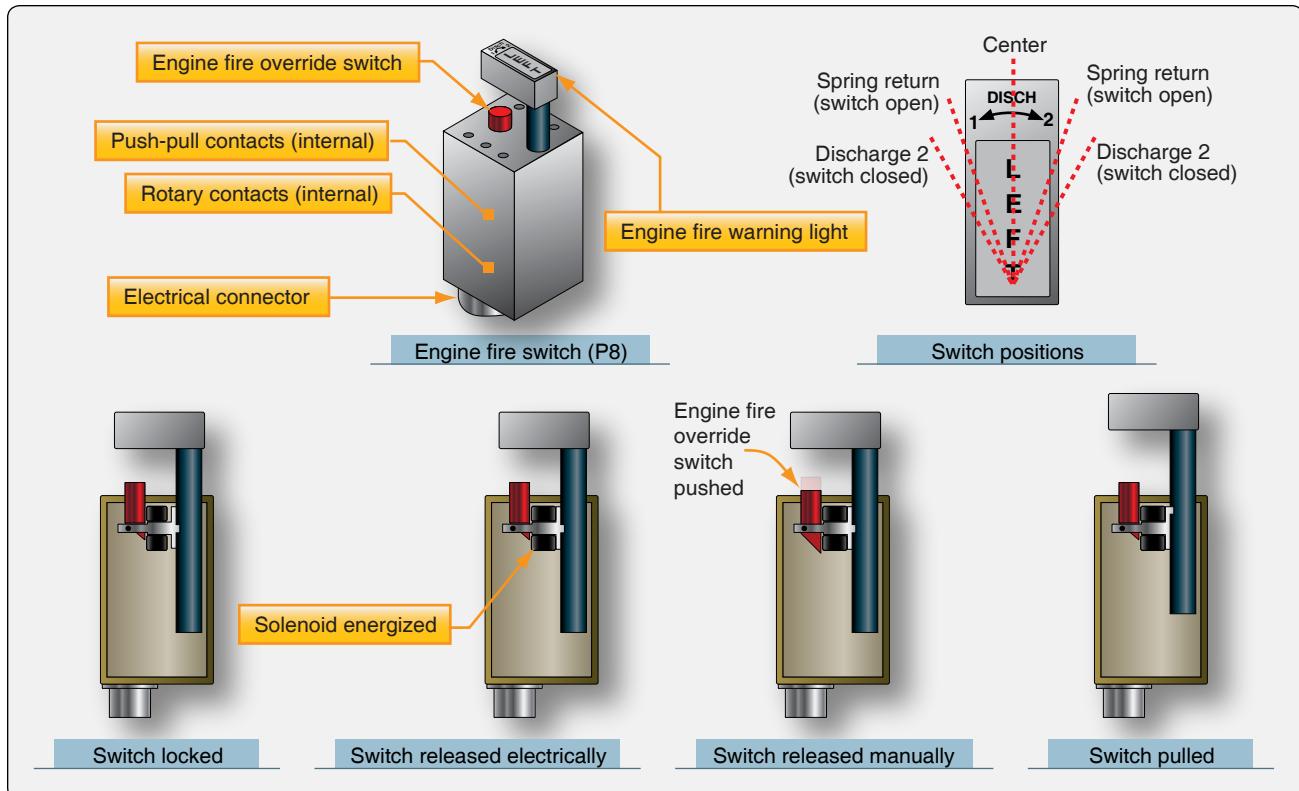
Visible and audible warning systems are installed in the flight deck to alert the flight crew. A horn sounds and one or several warning lights illuminate to alert the flight crew that an engine fire has been detected. These indications stop when the fire is extinguished.

## Fire Detection System Maintenance

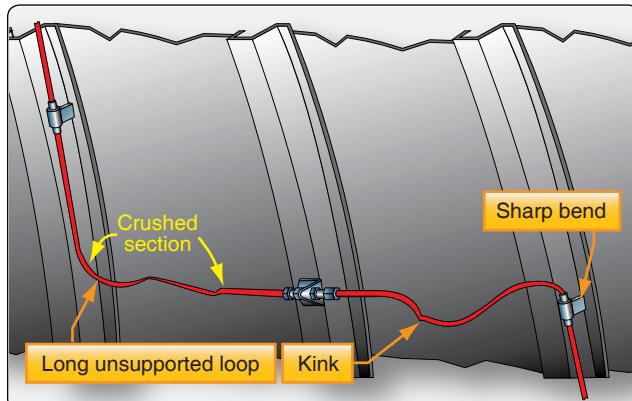
Fire detector sensing elements are located in many high-activity areas around aircraft engines. Their location, together with their small size, increases the chance of damage to the sensing elements during maintenance. An inspection and maintenance program for all types of continuous-loop systems should include the following visual checks. These procedures are examples and should not be used to replace the applicable manufacturer's instructions.

Sensing elements of a continuous-loop system should be inspected for the following:

1. Cracked or broken sections caused by crushing or squeezing between inspection plates, cowl panels, or engine components.
2. Abrasion caused by rubbing of the element on cowling, accessories, or structural members.
3. Pieces of safety wire or other metal particles that may short the spot-detector terminals.
4. Condition of rubber grommets in mounting clamps, which may be softened from exposure to oils or hardened from excessive heat.
5. Dents and kinks in sensing element sections. Limits on the element diameter, acceptable dents and kinks, and degree of smoothness of tubing contour are specified by the manufacturer. No attempt should be made to straighten any acceptable dent or kink, since stresses may be set up that could cause tubing failure. (See illustration of kinked tubing in *Figure 9-14*.)
6. Nuts at the end of the sensing elements [*Figure 9-15*] should be inspected for tightness and the presence of a safety wire. Loose nuts should be retorqued to the value specified by the manufacturer's instructions. Some types of sensing element connection joints require the use of copper crush gaskets, which should be replaced any time a connection is separated.
7. If shielded flexible leads are used, they should be inspected for fraying of the outer braid. The braided sheath is composed of many fine metal strands woven into a protective covering surrounding the inner insulated wire. Continuous bending of the cable or rough treatment can break these fine wires, especially those near the connectors.
8. Sensing element routing and clamping should be inspected carefully. [*Figure 9-14*] Long, unsupported sections may permit excessive vibration that can cause breakage. The distance between clamps on straight runs, usually about 8–10 inches, is specified by the manufacturer. At end connectors, the first support clamp is usually located about four to six inches from



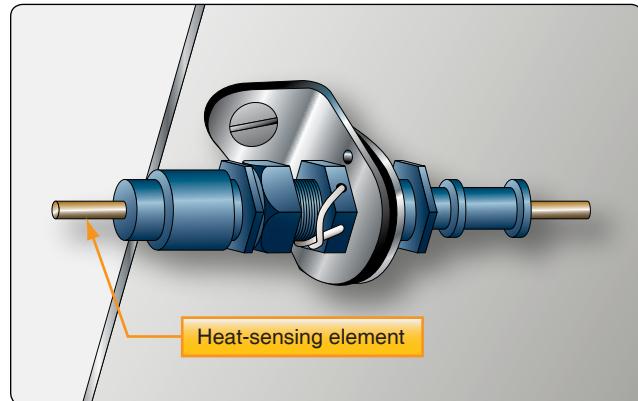
**Figure 9-13.** Engine fire switch operation.



**Figure 9-14.** Sensing element defects.

the end connector fittings. In most cases, a straight run of one inch is maintained from all connectors before a bend is started, and an optimum bend radius of three inches is normally applied.

9. Interference between a cowl brace and a sensing element can cause rubbing. [Figure 9-16] This interference may cause wear and short the sensing element.
10. Grommets should be installed on the sensing element so that both ends are centered on its clamp. The split end of the grommet should face the outside of the nearest bend. Clamps and grommets should fit the element snugly. [Figure 9-17]

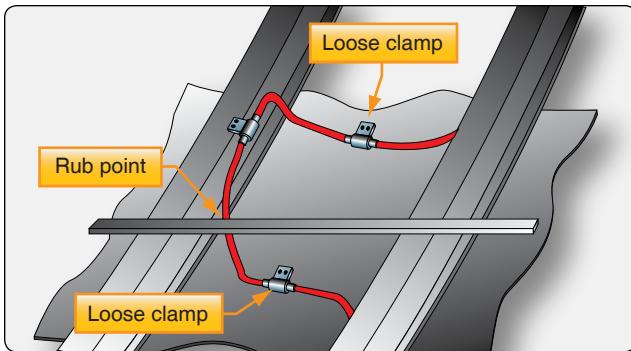


**Figure 9-15.** Connector joint fitting attached to the structure.

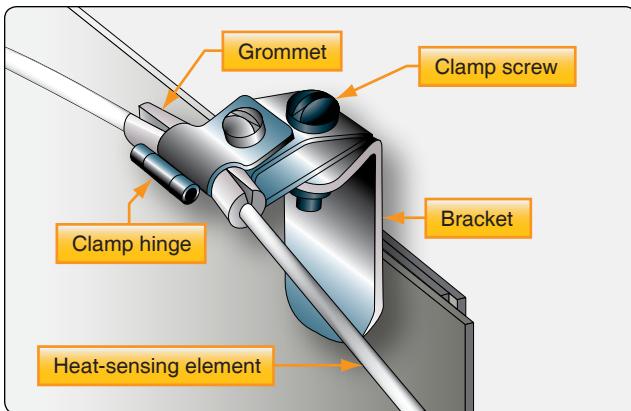
## Fire Detection System Troubleshooting

The following troubleshooting procedures represent the most common difficulties encountered in engine fire detection systems:

1. Intermittent alarms are most often caused by an intermittent short in the detector system wiring. Such shorts may be caused by a loose wire that occasionally touches a nearby terminal, a frayed wire brushing against a structure, or a sensing element rubbing against a structural member long enough to wear through the insulation. Intermittent faults often can be located by moving wires to re-create the short.



**Figure 9-16.** Rubbing interference.



**Figure 9-17.** Inspection of fire detector loop clamp.

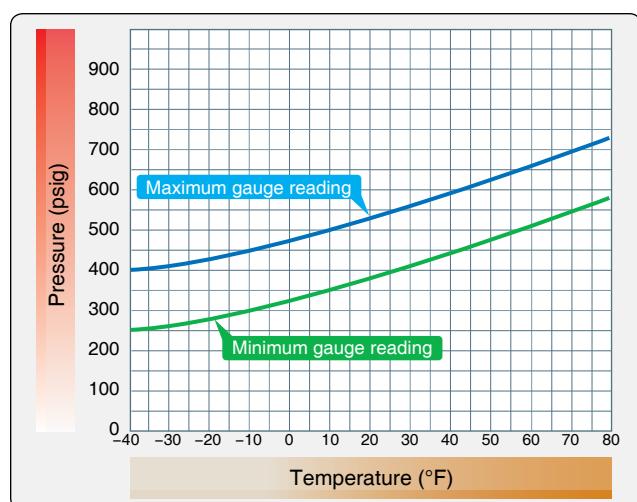
2. Fire alarms and warning lights can occur when no engine fire or overheat condition exists. Such false alarms can be most easily located by disconnecting the engine sensing loop connections from the control unit. If the false alarm ceases when the engine sensing loop is disconnected, the fault is in the disconnected sensing loop, which should be examined for areas that have been bent into contact with hot parts of the engine. If no bent element can be found, the shorted section can be located by isolating the connecting elements consecutively around the entire loop.
3. Kinks and sharp bends in the sensing element can cause an internal wire to short intermittently to the outer tubing. The fault can be located by checking the sensing element with an ohm meter while tapping the element in the suspected areas to produce the short.
4. Moisture in the detection system seldom causes a false fire alarm. If, however, moisture does cause an alarm, the warning persists until the contamination is removed or boils away, and the resistance of the loop returns to its normal value.
5. Failure to obtain an alarm signal when the test switch is actuated may be caused by a defective test switch or control unit, the lack of electrical power, inoperative

indicator light, or an opening in the sensing element or connecting wiring. When the test switch fails to provide an alarm, the continuity of a two-wire sensing loop can be determined by opening the loop and measuring the resistance. In a single-wire, continuous-loop system, the center conductor should be grounded.

## Fire Extinguisher System Maintenance Practices

Regular maintenance of fire extinguisher systems typically includes such items as the inspection and servicing of fire extinguisher bottles (containers), removal and reinstallation of cartridge and discharge valves, testing of discharge tubing for leakage, and electrical wiring continuity tests. The following paragraphs contain details of some of the most typical maintenance procedures.

Fire extinguisher containers are checked periodically to determine that the pressure is between the prescribed minimum and maximum limits. Changes of pressure with ambient temperatures must also fall within prescribed limits. The graph shown in *Figure 9-18* is typical of the pressure temperature curve graphs that provide maximum and minimum gauge readings. If the pressure does not fall within the graph limits, the extinguisher container is replaced. The service life of fire extinguisher discharge cartridges is calculated from the manufacturer's date stamp, which is usually placed on the face of the cartridge. The cartridge service life recommended by the manufacturer is usually in terms of years. Cartridges are available with a service life of 5 years or more. To determine the unexpired service life of a discharge cartridge, it is usually necessary to remove the electrical leads and discharge line from the plug body, which can then be removed from the extinguisher container.



**Figure 9-18.** Fire extinguisher container pressure-temperature chart.

Be careful when replacing cartridge and discharge valves. Most new extinguisher containers are supplied with their cartridge and discharge valve disassembled. Before installation on the aircraft, properly assemble the cartridge in the discharge valve and connect the valve to the container, usually by means of a swivel nut that tightens against a packing ring gasket. [Figure 9-19]

If a cartridge is removed from a discharge valve for any reason, it should not be used in another discharge valve assembly, since the distance the contact point protrudes may vary with each unit. Thus, continuity might not exist if a used plug that had been indented with a long contact point were installed in a discharge valve with a shorter contact point.

The preceding material in this chapter is general in nature, addressing the principles involved and general procedures to be followed. When actually performing maintenance, always refer to the applicable maintenance manuals and other related publications pertaining to a particular aircraft.

### **Boeing 777 Aircraft Fire Detection & Extinguishing System**

The following section discusses the fire detection and extinguishing system of the B777 aircraft. The information is included only for familiarization purposes.

Each engine has two fire detection loops: loop 1 and loop 2. A fire detection card in the system card file monitors the loops for fires, overheat conditions, and faults. There is a fire detection card for each engine.

#### **Overheat Detection**

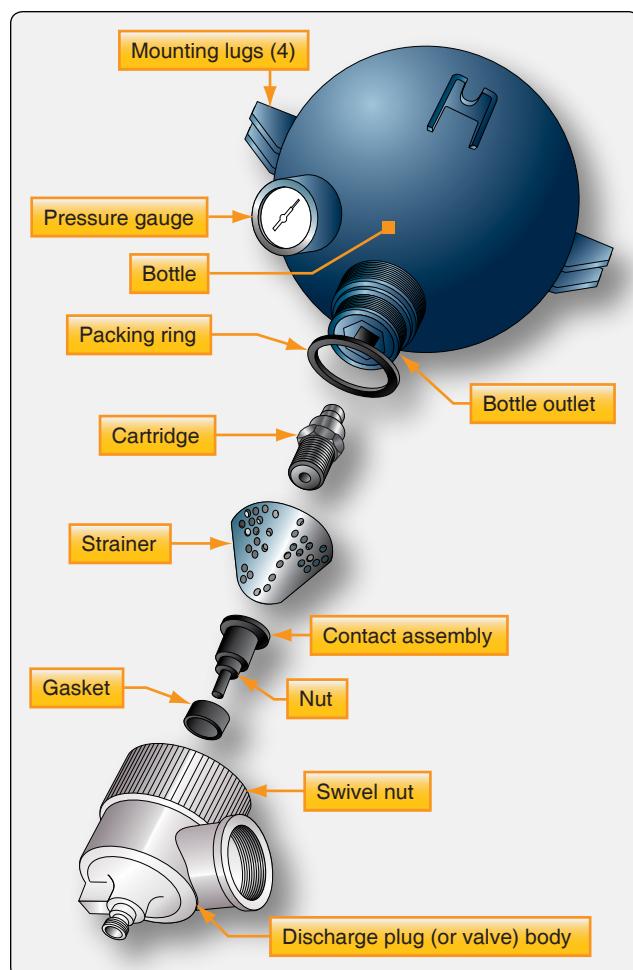
If the fire detection loops detect an overheat condition, the fire detection card sends a signal to the AIMS and to the warning electronics unit. The following indications occur in the flight deck:

- The master caution lights come on.
- The caution aural operates.
- An engine overheat caution message shows.

#### **Fire Detection**

If an engine fire occurs, the fire detection card sends a signal to the AIMS and to the warning electronics unit, and a warning message illuminates. The following indications occur in the flight deck:

- The master warning lights come on.
- The fire warning aural operates.
- An engine fire warning message shows.
- The engine fire warning light comes on.



**Figure 9-19. Components of fire extinguisher container.**

- The fuel control switch fire warning light comes on.

#### **Nacelle Temperature Recording**

The fire detection card measures the average temperature of the loops. This data goes to the AIMS through the system's ARINC 629 buses and is recorded by the aircraft condition monitoring function.

#### **Continuous Fault Monitoring**

The fire detection card monitors the two loops and their wiring for defects. In normal (dual loop) operation, both loops must have a fire or overheat condition to cause the flight deck indications.

If a failure occurs in a loop, the fire detection card sends the data to the AIMS. A status message shows, and the system changes to single-loop operation. In this mode, fire/overheat indications occur when one loop is defective and the other has a fire or overheat condition.

## Single/Dual Loop Operation

The fire detection card monitors the loops for faults. In normal (dual loop) operation, both loops must have a fire or overheat condition to cause the flight deck indications. If one detection loop fails, the card sends data about the failure to the AIMS, and a status message shows. The card changes to single-loop operation, if necessary. If both detection loops fail, an advisory message and status messages are displayed, and the fire detection system does not operate.

## System Test

Built-in test equipment (BITE) performs a test of the engine fire detection system for these conditions:

- When the system first gets power.
- After a power interrupt.
- Every 5 minutes of operation. [Figures 9-20 and 9-21]

## Boeing 777 Fire Extinguisher System

### Fire Extinguisher Containers

The B777 aircraft has two fire extinguishing bottles that contain Halon fire extinguishing agent pressurized with nitrogen. The engine fire switches in the flight deck are pulled and rotated to release the Halon. Halon from each bottle can be discharged to the right or left engine. Engine indicating and crew alerting system (EICAS) messages, status messages,

and indicator lights show when the bottle pressure is low. The two engine fire extinguishing bottles are located behind the right sidewall lining of the forward cargo compartment, aft of the cargo door. [Figure 9-22]

The two engine fire extinguishing bottles are identical. Each bottle has these following components:

- A safety relief and fill port,
- A handle for removal and installation,
- A pressure switch,
- Two discharge assemblies,
- An identification plate, and
- Four mounting lugs. [Figures 9-23, 9-24, 9-25]

The bottles contain Halon fire extinguishing agent pressurized with nitrogen. If the pressure in the bottle becomes too high, the safety relief and fill port opens so that the bottle does not explode. The discharge assembly has an explosive squib. An electric current from the fire extinguishing circuit fires the squib. This releases the Halon through the discharge port. The pressure switch gives flight deck indications when bottle pressure decreases. The switch monitors the pressure inside the bottle and is normally open. When the pressure decreases because of a leak or bottle discharge, the switch closes an indicating circuit.

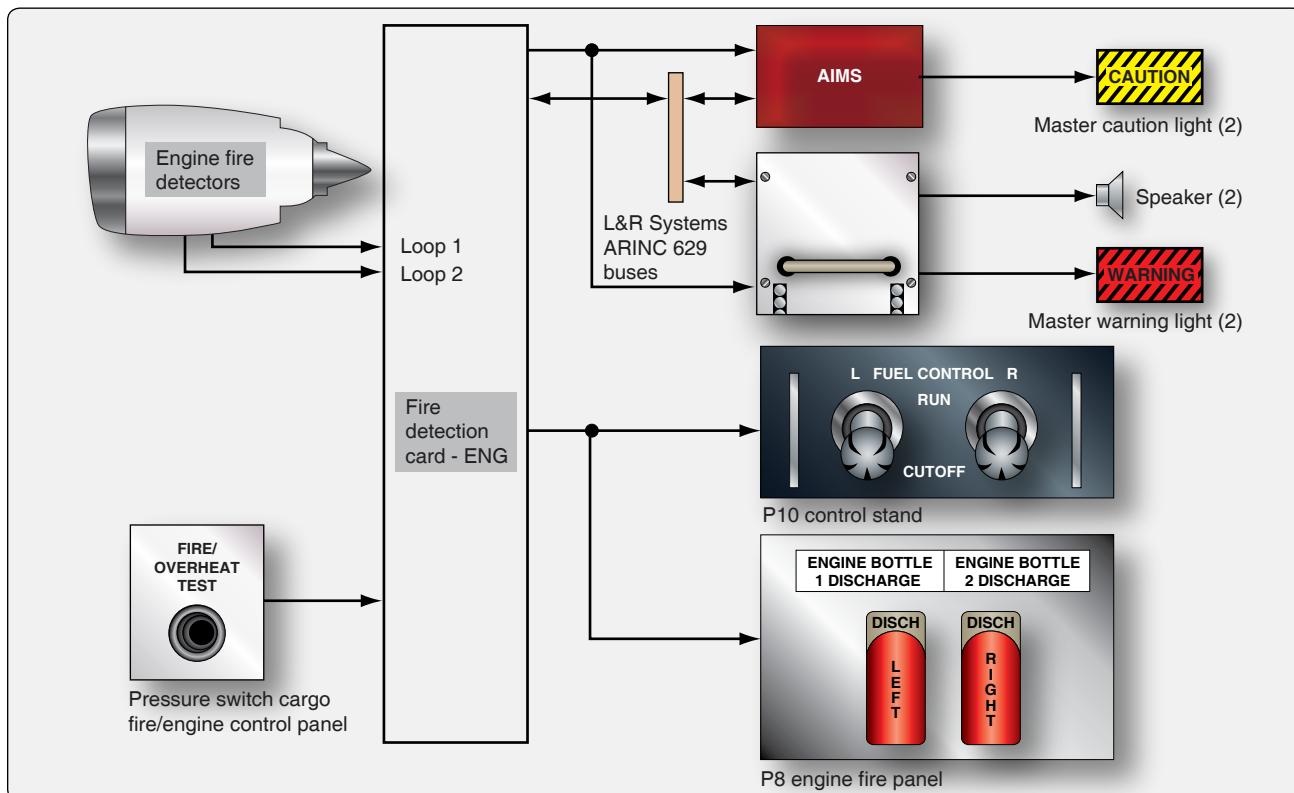
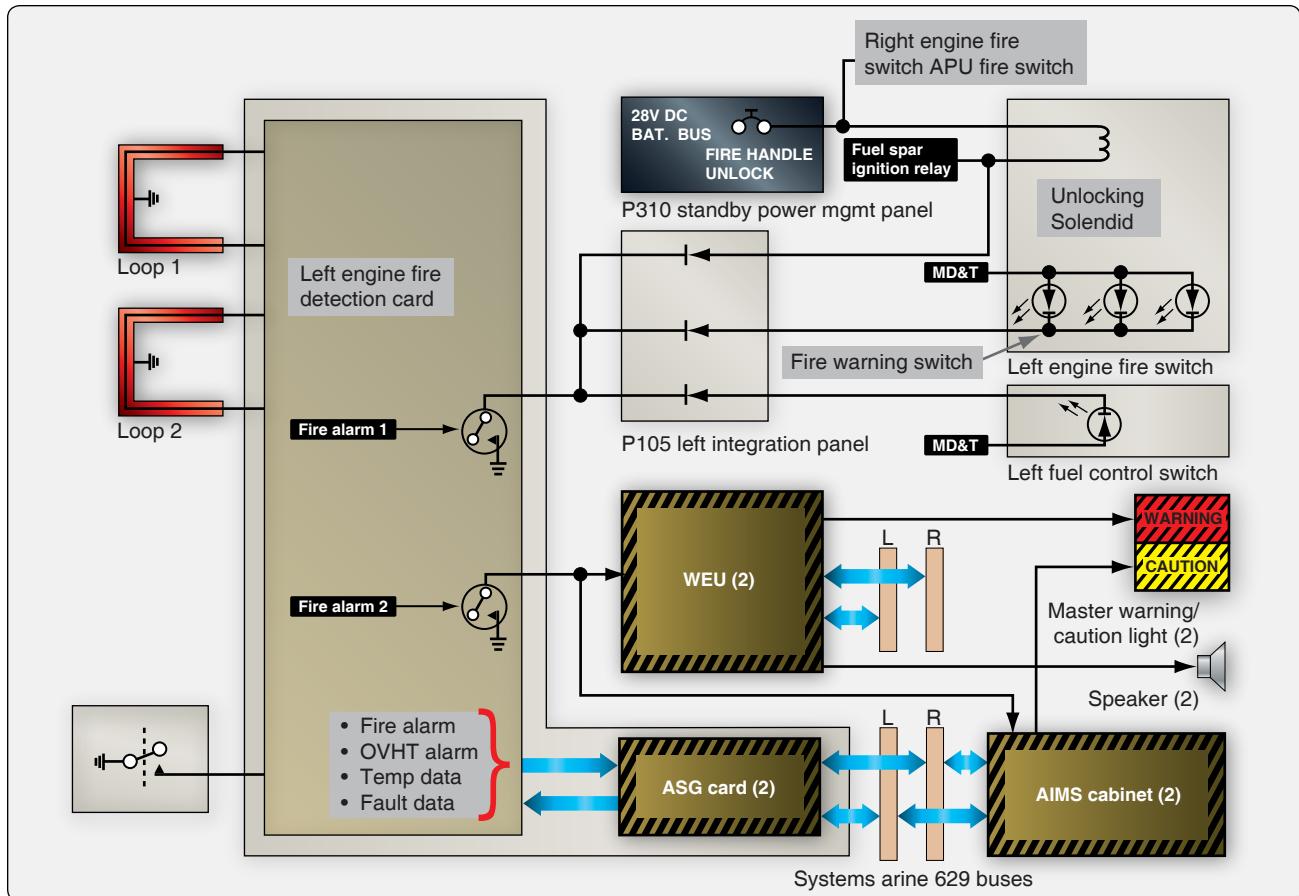
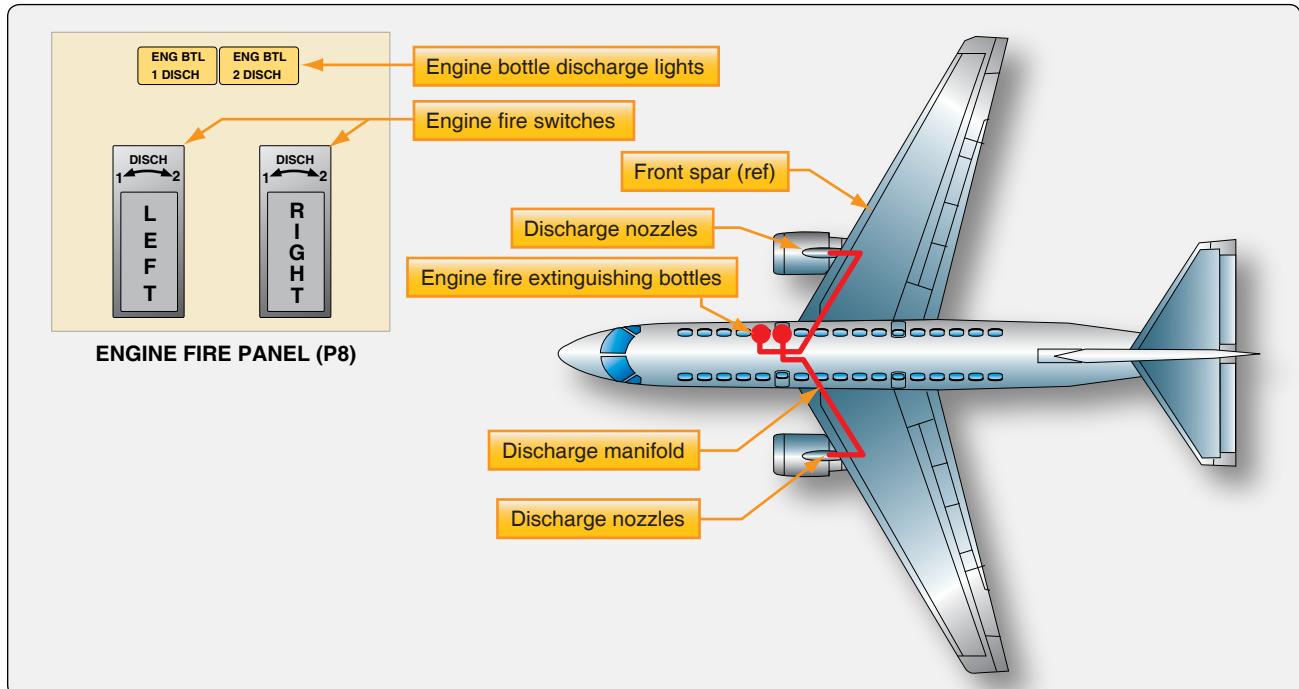


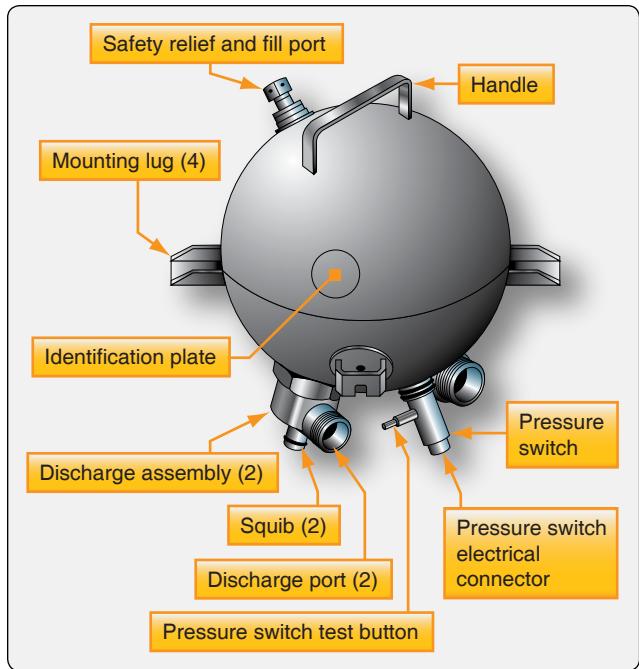
Figure 9-20. Engine fire detection system.



**Figure 9-21.** Engine fire detection system functional description.



**Figure 9-22.** Boeing 777 fire extinguisher container location.



**Figure 9-23.** Fire extinguishing bottle.

### Squib

The squib is installed in the discharge assembly at the bottom of the fire container. A fire container has two squibs, one for each engine. The squib is an electrically operated explosive device. When the squib is activated, it fires a slug through the breakable disc, and nitrogen pressure inside the bottle pushes the Halon through the discharge port. The squib fires when the fire switch is pulled and turned to the DISCH 1 or DISCH 2 position. [Figure 9-22]

### Engine Fire Switches

The engine fire panel is in the flight deck on the P8 aisle stand. The engine fire panel has a fire switch for each engine and a discharge light for each fire bottle. [Figure 9-26]

The engine fire switch has four functions:

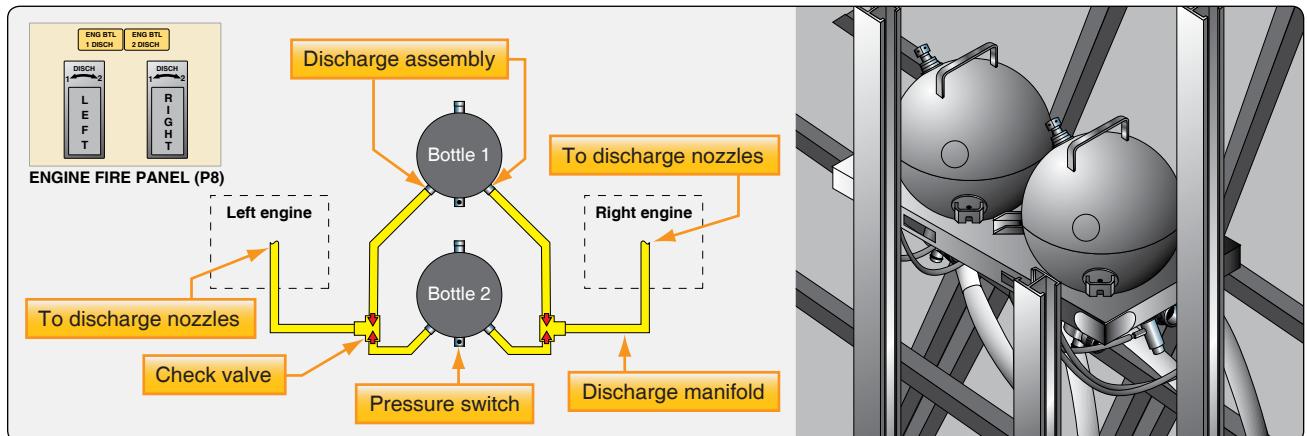
- Gives an indication of an engine fire,
- Stops the engine,
- Isolates the engine from the aircraft systems, and
- Controls the engine fire extinguishing system.

The fire switch assembly incorporates a solenoid that locks the fire switch so that the flight crew cannot pull it accidentally. If an engine has a fire, the fire warning light comes on and the solenoid energizes to release the switch. When the solenoid is energized, the fire switch can be pulled.

When the fire detection system malfunctions or the solenoid is defective, and the flight crew wants to extinguish an engine fire, someone must push the fire override switch. The fire override switch allows the fire switch to be pulled when the solenoid is not energized. When the fire switch is pulled, the push-pull switch contacts operate electrical circuits that stop the engine and isolate it from the aircraft systems. With the switch pulled, it can be rotated to left or right to a mechanical stop at the discharge position. The rotary switch contacts close and operate the fire extinguishing system.

When the fire switch is pulled, the switch isolates the following aircraft systems from the engine:

- Closes the fuel spar valve.
- Deenergizes the engine fuel metering unit (FMU) cutoff solenoid.
- Closes the engine hydraulic pump shutoff valve.
- Depressurizes the engine driven hydraulic pump valve.
- Closes the pressure regulator and shutoff valve.
- Removes power from thrust reverser isolation valve.
- Trips the generator field.
- Trips the backup generator field. [Figure 9-27]



**Figure 9-24.** Location of fire extinguishing bottles.

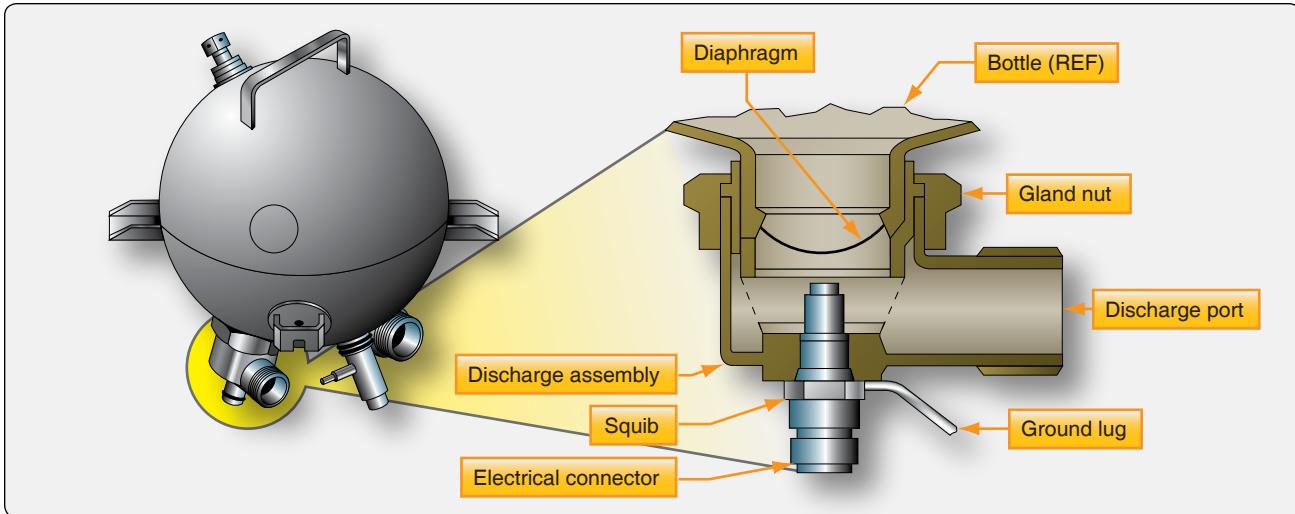


Figure 9-25. Squib or cartridge.

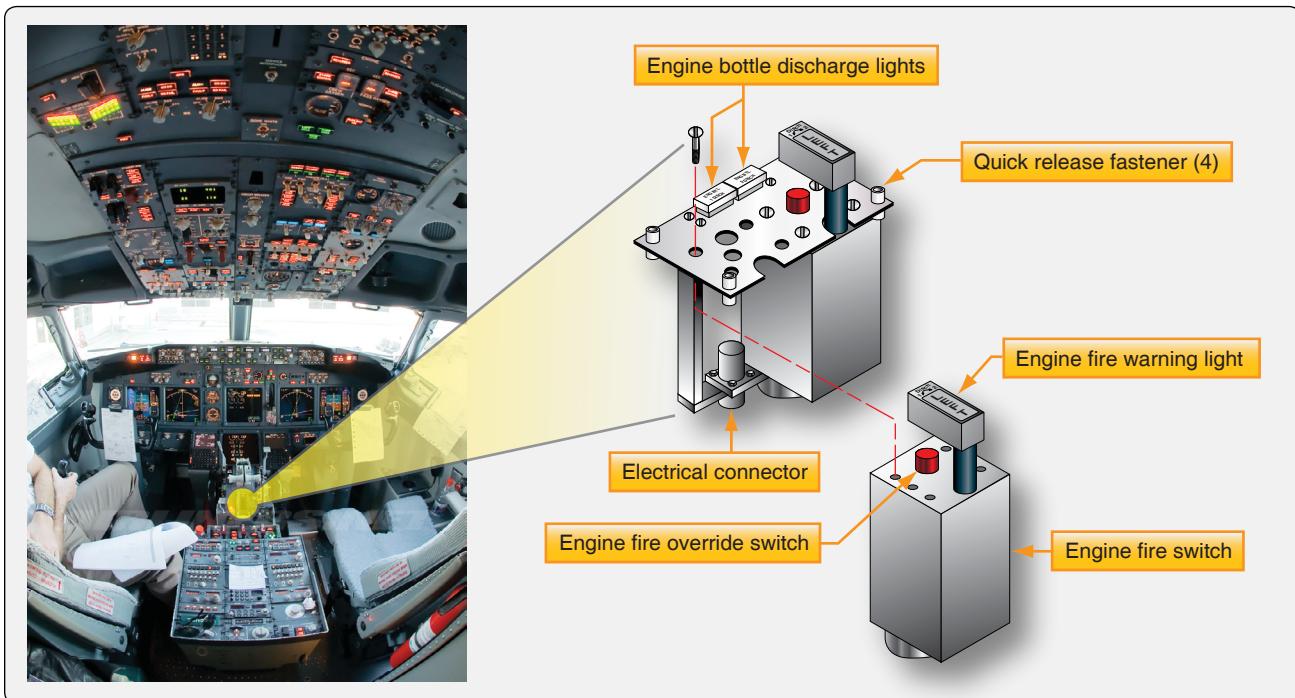


Figure 9-26. Fire switch.

### Engine Fire Operation

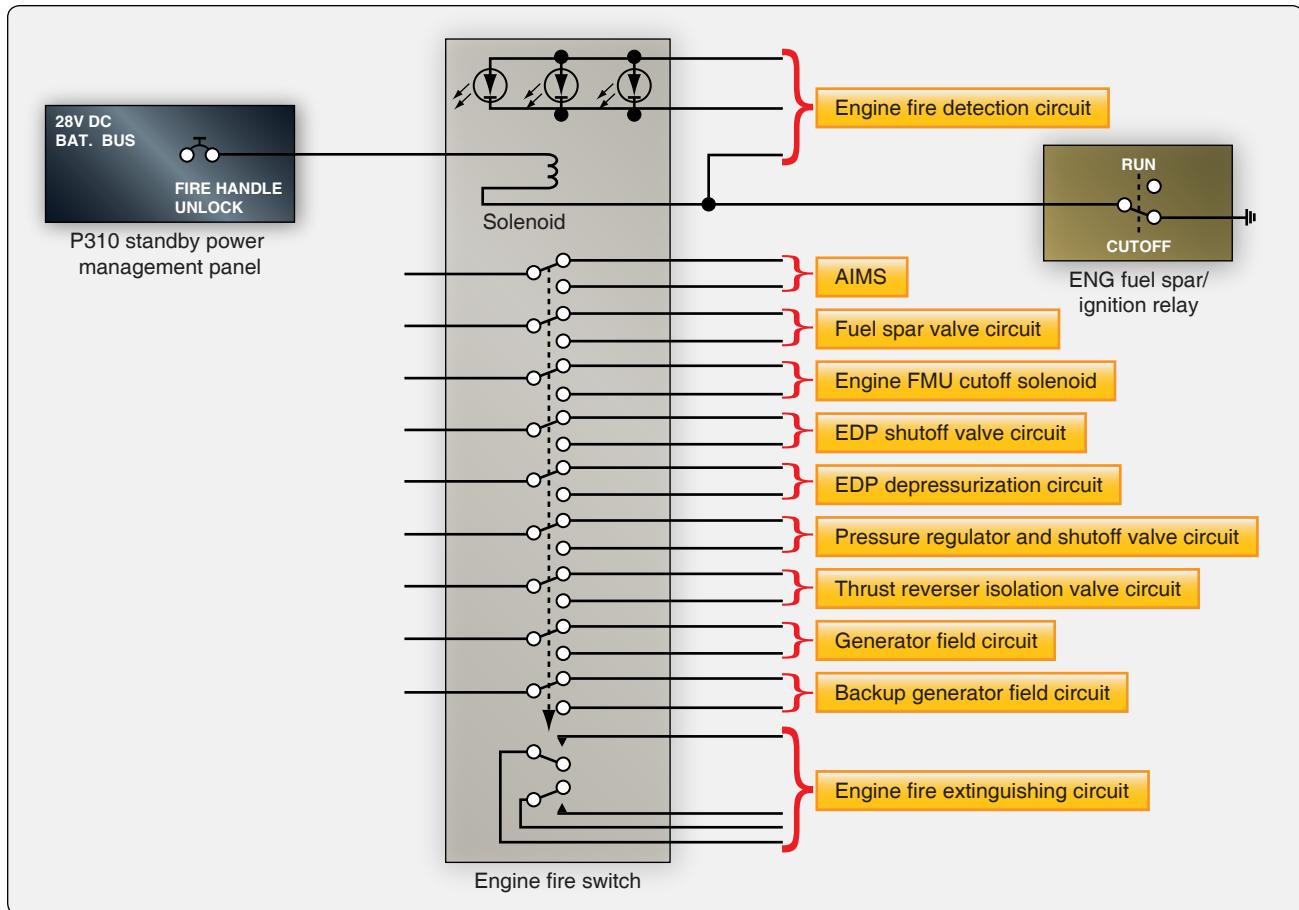
If an engine has a fire, the engine fire detection system gives a fire warning in the flight deck. The engine fire warning lights come on to identify which fire switch to use to extinguish the fire. The solenoid in the fire switch energizes and releases the switch so that the fire switch can be pulled. If the solenoid does not energize, push the fire override switch to release the fire switch manually. When the fire switch is pulled, it stops the engine, and the fire switch isolates the engine from the aircraft systems.

If the fire warnings do not go away when the switch is pulled,

position the switch to the DISCH 1 or DISCH 2 position, and hold the switch against the stop for one second. This fires the squib in the fire extinguisher container and releases the fire extinguishing agent into the engine nacelle. Ensure that the engine bottle discharge light comes on. If the first bottle does not extinguish the fire, the switch must be placed to the other DISCH position. This fires the squib for the other bottle.

### APU Fire Detection & Extinguishing System

The APU fire protection system is similar in design to engine fire protection systems, but there are some differences. The APU is often operated with no personnel in the flight



**Figure 9-27.** Engine fire switch circuit.

deck and; the APU fire protection system can operate in an unattended mode on the ground with the engines not running. If there is an APU fire in the unattended mode, the fire extinguisher discharges automatically. The APU operates in the attended mode when at least one engine is running. If there is an APU fire in this mode, the crew discharges the bottle manually. Fire switches are located on the cargo fire/engine control panel and the service and APU shutdown panel located outside the aircraft on the nose landing gear. [Figure 9-28]

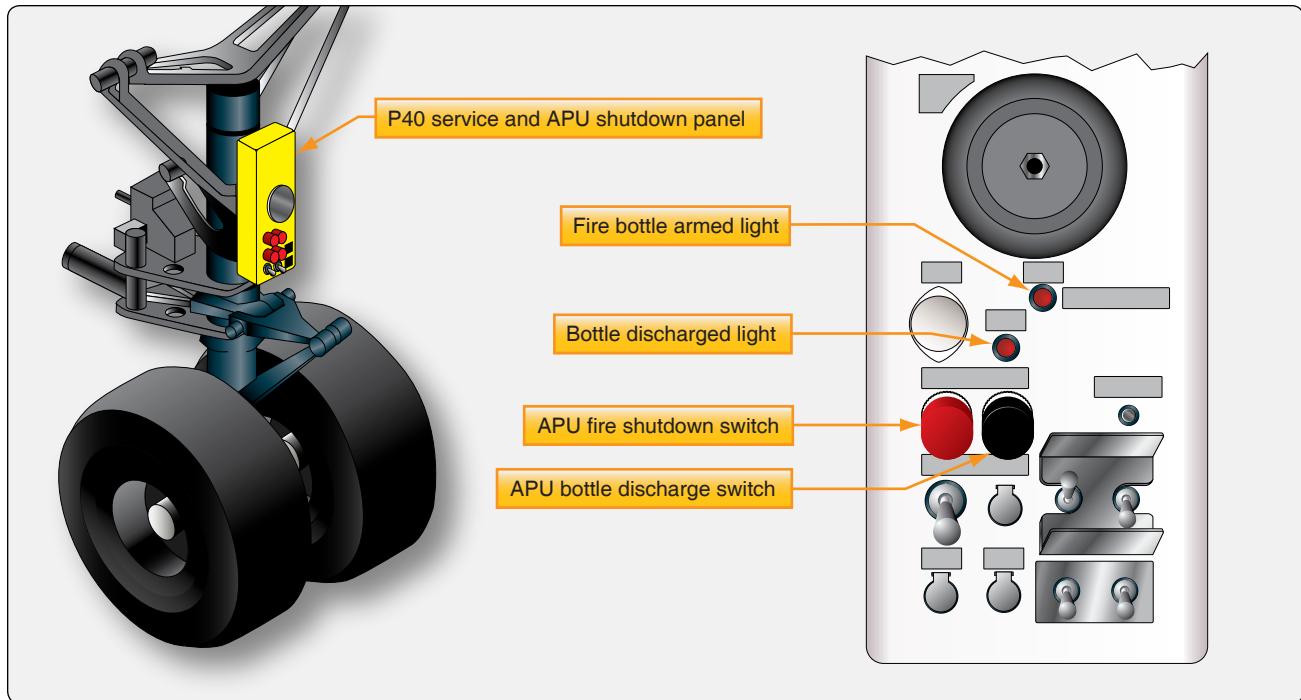
### APU Fire Warning

If there is an APU fire, the APU fire detection system gives fire warnings and automatically stops the APU. The APU fire warning light comes on to identify the correct fire switch to use to extinguish the fire. The fire switch solenoid releases the switch so that it can be pulled up. If the APU is running, it stops when the fire switch is pulled. The fire switch isolates the APU from the aircraft systems.

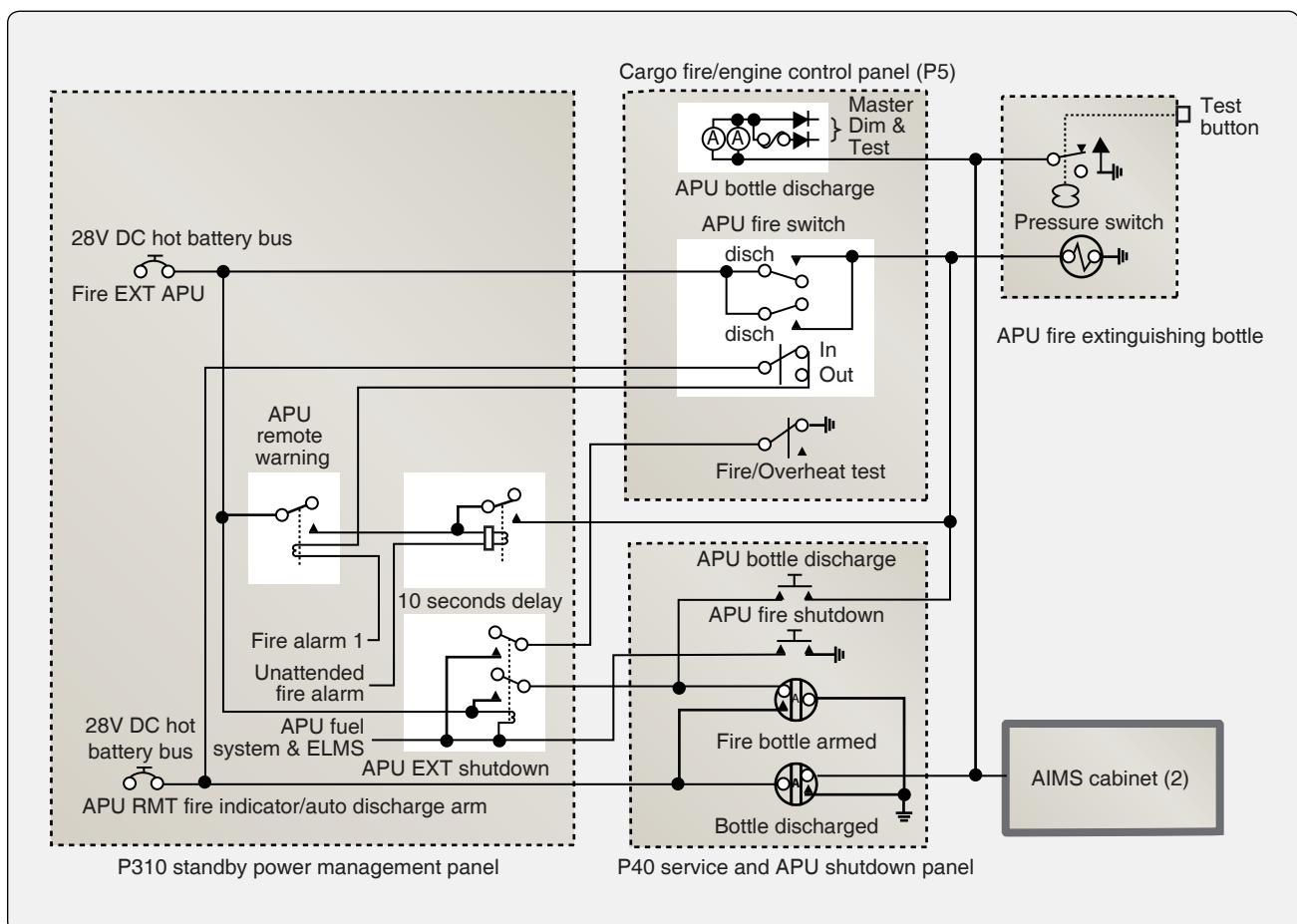
### Fire Bottle Discharge

If the fire warnings do not go away with the switch out, put the switch to the left or right DISCH position. Hold the

switch against the discharge stop for one second. This fires the bottle squib and releases the fire extinguishing agent into the APU compartment. Verify that the APU bottle discharge light comes on. [Figure 9-29]



**Figure 9-28.** P40 service and APU shutdown panel.



**Figure 9-29.** APU fire extinguishing circuit.