

Fire Protection Systems

Because fire is one of the most dangerous threats to an aircraft, the potential fire zones of modern multiengine aircraft are protected by a fixed fire protection system. A fire zone is an area, or region, of an aircraft designed 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 Halon or water fire extinguisher. A complete fire protection system on modern aircraft, and on many older aircraft, includes a fire detection system and a fire extinguishing system. Typical zones on aircraft that have a fixed fire detection and/or fire extinguisher system are:

1. Engines and auxiliary power unit (APU)
2. Cargo and baggage compartments
3. Lavatories on transport aircraft
4. Electronic bays
5. Wheel wells
6. Bleed air ducts



To detect fires or overheat conditions, detectors are placed in the various zones to be monitored. Fires are detected in reciprocating engine and small turboprop aircraft using one or more of the following:

1. Overheat detectors
2. Rate-of-temperature-rise detectors
3. Flame detectors
4. Observation by crewmembers

In addition to these methods, other types of detectors are used in aircraft fire protection systems but are seldom used to detect engine fires. For example, smoke detectors are better suited to monitor areas where materials burn slowly or smolder, such as cargo and baggage compartments. Other types of detectors in this category include carbon monoxide detectors and chemical sampling equipment capable of detecting combustible mixtures that can lead to accumulations of explosive gases.

The complete aircraft fire protection systems of most large turbine-engine aircraft incorporate several of these different detection methods.

1. Rate-of-temperature-rise detectors
2. Radiation sensing detectors
3. Smoke detectors
4. Overheat detectors
5. Carbon monoxide detectors
6. Combustible mixture detectors
7. Optical detectors
8. Observation of crew or passengers

The types of detectors most commonly used for fast detection of fires are the rate-of-rise, optical sensor, pneumatic loop, and electric resistance systems.

Classes of Fires

The following classes of fires that are likely to occur onboard aircraft, as defined in the U.S. National Fire Protection Association (NFPA) Standard 10, Standard for Portable Fire Extinguishers, 2007 Edition, are:

1. Class A—fires involving ordinary combustible materials, such as wood, cloth, paper, rubber, and plastics.
2. Class B—fires involving flammable liquids, petroleum oils, greases, tars, oil-based paints, lacquers, solvents, alcohols, and flammable gases.

3. Class C—fires involving energized electrical equipment in which the use of an extinguishing media that is electrically nonconductive is important.
4. Class D—fires involving combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

Requirements for Overheat and Fire Protection Systems

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

1. No 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 re-ignited.
5. Continuous indication for duration of a fire.
6. Means for electrically testing the detector system from the aircraft cockpit.
7. Resists damage from exposure to oil, water, vibration, extreme temperatures, or handling.
8. Light in weight and easily adaptable to any mounting position.
9. Circuitry that operates directly from the aircraft power system without inverters.
10. Minimum electrical current requirements when not indicating a fire.
11. Cockpit light that illuminates, indicating the location of the fire, and with an audible alarm system.
12. A separate detector system for each engine.

Fire Detection/Overheat Systems

A fire detection system should signal the presence of a fire. Units of the system are installed in locations where there are greater possibilities of a fire. Three detector system types in common use are the thermal switch, thermocouple, and the continuous loop.

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 17-1] 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 is usually determined by the aircraft manufacturer. On some installations, all the thermal detectors are connected to one light; on others, there may be one thermal switch for each indicator light.

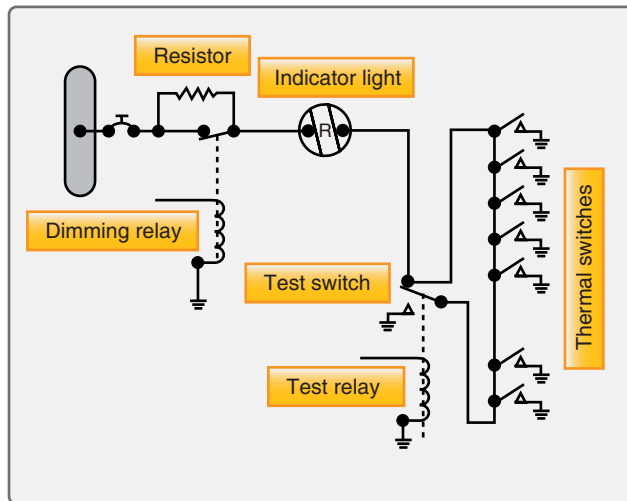


Figure 17-1. Thermal switch fire circuit.

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 17-1* 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 17-1* 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 System

The thermocouple fire warning system operates on an entirely different principle from 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. Detector circuit

2. Alarm circuit
3. Test circuit

These circuits are shown in *Figure 17-2*. 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.

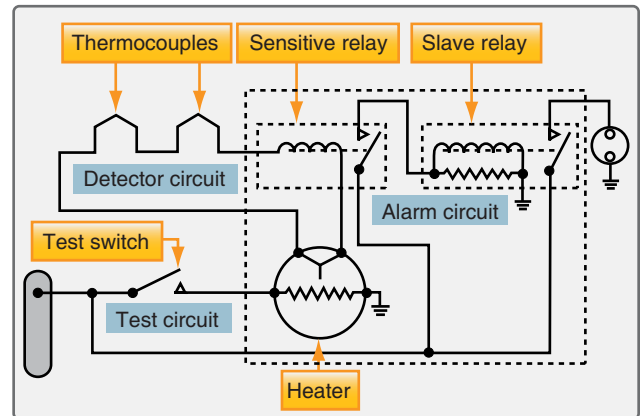


Figure 17-2. Thermocouple fire warning circuit.

The thermocouple is constructed of two dissimilar metals, such as chromel and constantan. The point at which 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. A metal cage surrounds the thermocouple to give mechanical protection without hindering the free movement of air to the hot junction. 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 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 17-2*, 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. The coil then 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, eliminating arcing at the sensitive relay contacts.

Continuous-Loop Systems

Transport aircraft almost exclusively use continuous thermal sensing elements for powerplant and wheel well protection. 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. Two widely used types of continuous-loop systems are the thermistor type detectors, such as the Kidde and the Fenwal systems, and the pneumatic pressure detector, such as the Lingberg system. (Lindberg system is also known as Systron-Donner and, more recently, Meggitt Safety Systems.)

Fenwal System

The Fenwal system uses a slender Inconel tube packed with thermally sensitive eutectic salt and a nickel wire center conductor. [*Figure 17-3*] 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

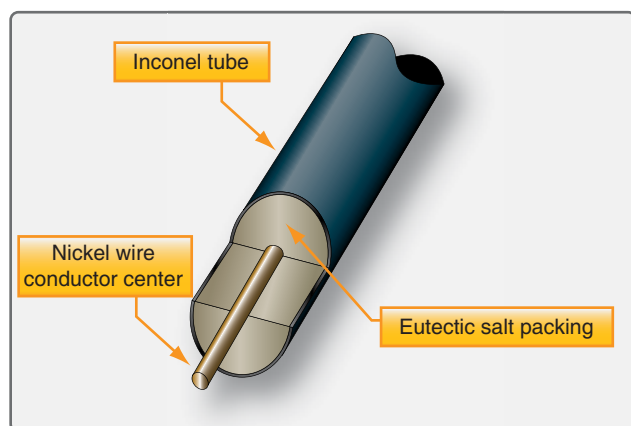


Figure 17-3. *Fenwal sensing element.*

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 and activate the alarms. When the fire has been extinguished or the critical temperature lowered below the set point, 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.

Kidde System

In the Kidde continuous-loop system, two wires are imbedded in an inconel tube filled with a thermistor core material. [*Figure 17-4*] 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 the 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 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 disappear. 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 some aircraft, in addition to fire and overheat detection, the Kidde continuous-loop system can supply nacelle temperature data to the airplane condition monitoring function of the aircraft in-flight monitoring system (AIMS).

Sensing Element

The resistance of a sensor varies inversely as it is heated; as sensor temperature is increased, its resistance decreases. Each sensor is composed of two wires embedded in thermistor material that is encased in a heavy wall inconel tube for high strength at elevated temperatures. The electrical connectors at each end of the sensor are ceramic insulated. The inconel tubes are shrouded in a perforated stainless steel tube and supported by Teflon-impregnated asbestos bushings at intervals. The shroud protects the sensor from breakage due to vibration, abrasion against airplane structure, and damage from maintenance activity.

The resistance of a sensor also varies inversely with its length, the increments of length being resistances in parallel. The heating of a short length of sensor out of a given length

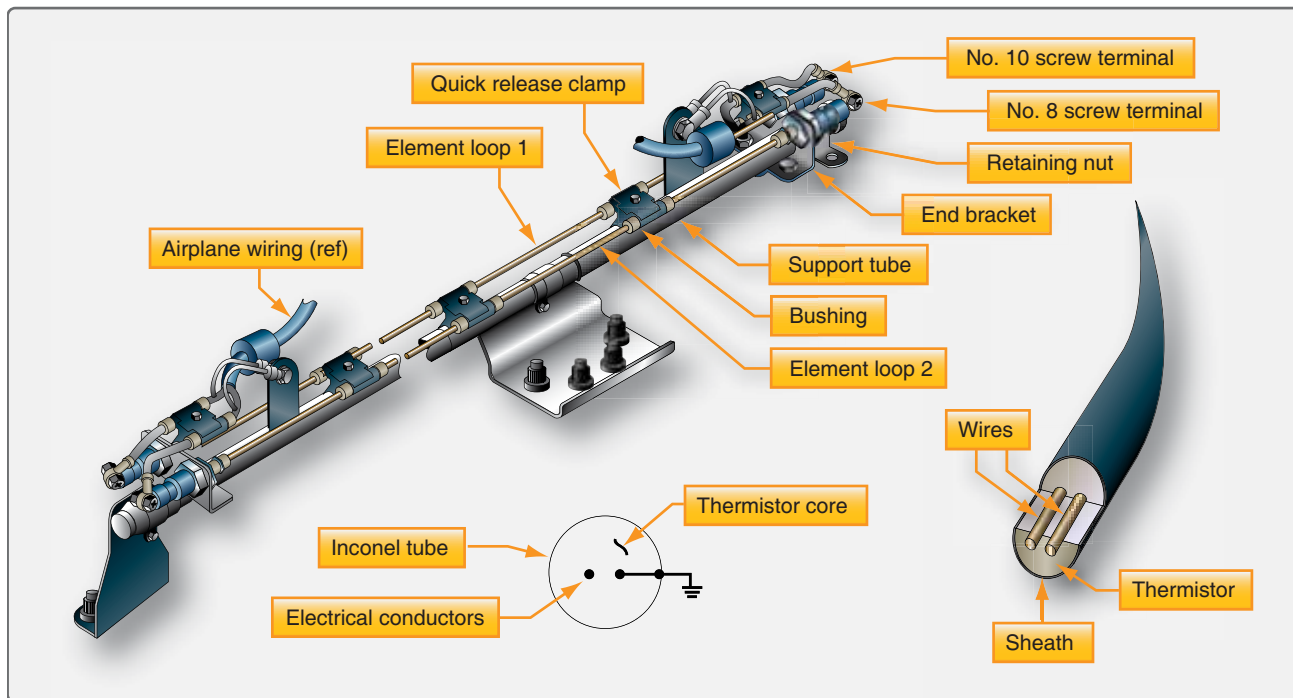


Figure 17-4. Kidde continuous-loop system.

requires that the short length be heated above the temperature alarm point so the total resistance of the sensor decreases to the alarm point. This characteristic permits integration of all temperatures throughout the length of the installation rather than sensing only the highest local temperature. The two wires encased within the thermistic material of each inconel tube form a variable resistance network between themselves, between the detector wire and the inconel tube, and between each adjacent incremental length of sensor. These variable resistance networks are monitored by the application of 28 volts direct current (DC) to the detector wire from the detector control unit.

Combination Fire and 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, such as would be caused by leakage of hot bleed air or combustion gas into the engine compartment. It could also be an early warning of fire and would alert the crew to appropriate action to reduce the engine compartment temperature. The second-level response is at a level above that attainable by a leaking hot gas and is the fire warning.

Temperature Trend Indication

The analog signal produced by the sensing element loop as its temperature changes is converted to signals suitable for flight deck 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 that switches one end of the sensing element loop from its control circuit to a test circuit built into the control unit, which simulates the sensing element resistance change due to fire. [Figure 17-5] If the sensing element loop is unbroken, the resistance detected by the control circuit is that of the simulated fire, and the alarm is activated. The test demonstrates, in addition to the continuity of the sensing

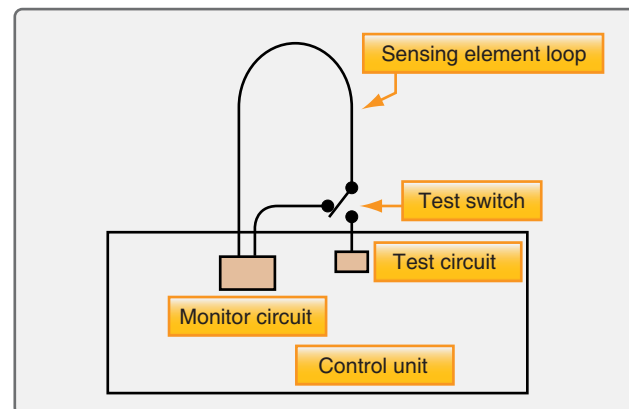


Figure 17-5. Continuously loop fire detection system test circuit.

element loop, the integrity of the alarm indicator circuit and the proper functioning of the control circuits. The thermistic properties of the sensing element remain unchanged for the life of the element (no irreversible changes take place when heated); the element functions properly as long as it is electrically connected to the control unit.

Fault Indication

Provision is made in the control unit to output a fault signal which activates a fault indicator whenever the short discriminator circuit detects a short in the sensing element loop. This is a requirement for transport category aircraft because such a short disables the fire detection system.

Dual-Loop Systems

Dual-loop systems are 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 cockpit 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 cockpit 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 cockpit, a function called automatic self-interrogation. 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

For those installations where it is desired 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, should its removal for engine maintenance be necessary, it is quickly and easily accomplished. Should the assembly require repair or maintenance, it is easily replaced with another assembly, leaving the repair for the shop. Should a sensing element be damaged, it is easily replaced in the assembly.

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 fitted with a mounting bracket and electrical connector. For more sophisticated systems, control modules are employed that contain removable control cards with 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.

Pressure Type Sensor Responder Systems

Some smaller turboprop aircraft are outfitted with pneumatic single point detectors. The design of these detectors is 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 cockpit. Continuous fault monitoring is included. This type of sensor is designed as a single-sensor detection system and does not require a control unit.

Pneumatic Continuous-Loop Systems

The pneumatic continuous-loop systems are also known by their manufacturers' names Lindberg, Systron-Donner, and Meggitt Safety Systems. These systems are used for

engine fire detection of transport type aircraft and have the same function as the Kidde system; however, they work on a different principle. They are typically used in a dual-loop design to increase reliability of the system.

The pneumatic detector has two sensing functions. It responds to an overall average temperature threshold and to a localized discrete temperature increase caused by impinging flame or hot gasses. Both the average and discrete temperature are factory set and are not field adjustable. [Figure 17-6]

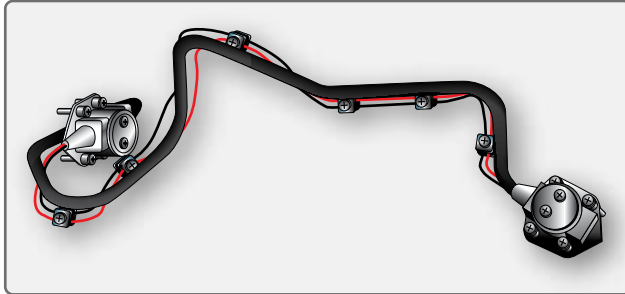


Figure 17-6. *Pneumatic dual fire/overheat detector assembly.*

Averaging Function

The fire/overheat detector serves as a fixed-volume device filled with helium gas. The helium gas pressure inside the detector increases in proportion to the absolute temperature and operates a pressure diaphragm that closes an electrical contact, actuating the alarm circuit. The pressure diaphragm within the responder assembly serves as one side of the electrical alarm contact and is the only moving part in the detector. The alarm switch is preset at an average temperature. Typical temperature ranges for average temperature settings are 200 °F (93 °C) to 850 °F (454 °C).

Discrete Function

The fire/overheat detector's sensor tube also contains a hydrogen-filled core material. [Figure 17-7] Large quantities of hydrogen gas are released from the detector core whenever a small section of the tube is heated to the preset discrete temperature or higher. The core outgassing increases the pressure inside the detector and actuates the alarm switch. Both the averaging and discrete functions are reversible. When the sensor tube is cooled, the average gas pressure is lowered and the discrete hydrogen gas returns to the core material. The reduction of internal pressure allows the alarm switch to return to its normal position, opening the electrical alarm circuit.

Figure 17-8 shows a typical aircraft fire detection system in which a control module monitors two loops of up to four pneumatic detectors each, connected in parallel. The control module responds directly to an alarm condition and continuously monitors the wiring and integrity of each loop. The normally open alarm switch closes upon an overheat or fire condition, causing a short circuit between terminals A and C. During normal operation, a resistance value is maintained across the terminals by a normally closed integrity switch. Loss of sensor gas pressure opens the integrity switch, creating an open circuit across the terminals of the faulted detector. In addition to the pressure-activated alarm switch, there is a second integrity switch in the detector that is held closed by the averaging gas pressure at all temperatures down to -65 °F (-54 °C). If the detector should develop a leak, the loss of gas pressure would allow the integrity switch to open and signal a lack of detector integrity. The system then does not operate during test.

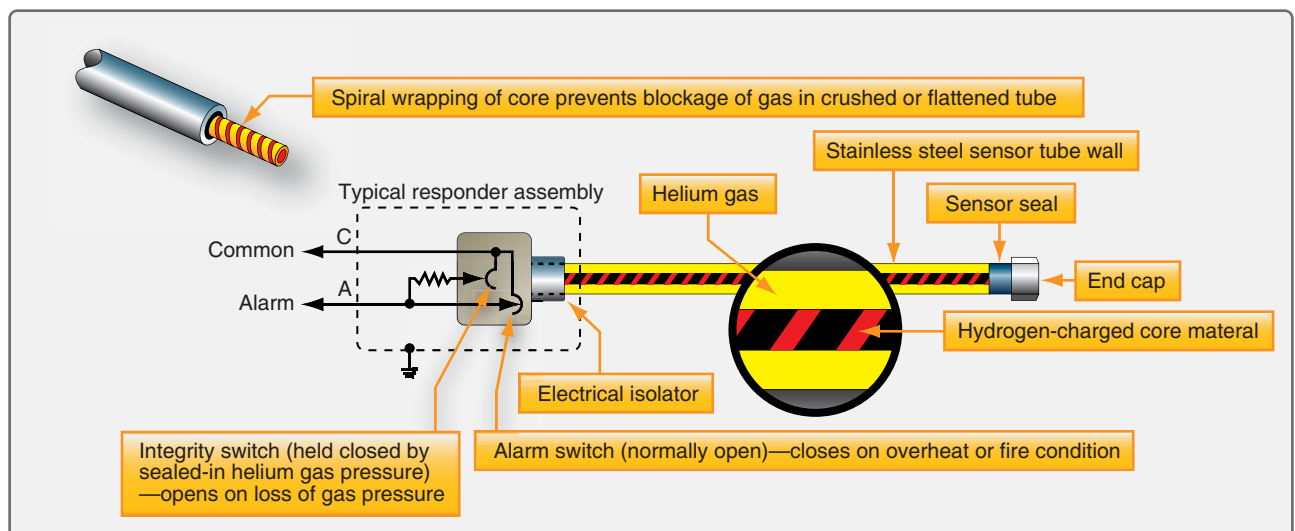


Figure 17-7. *Pneumatic pressure loop detector system.*

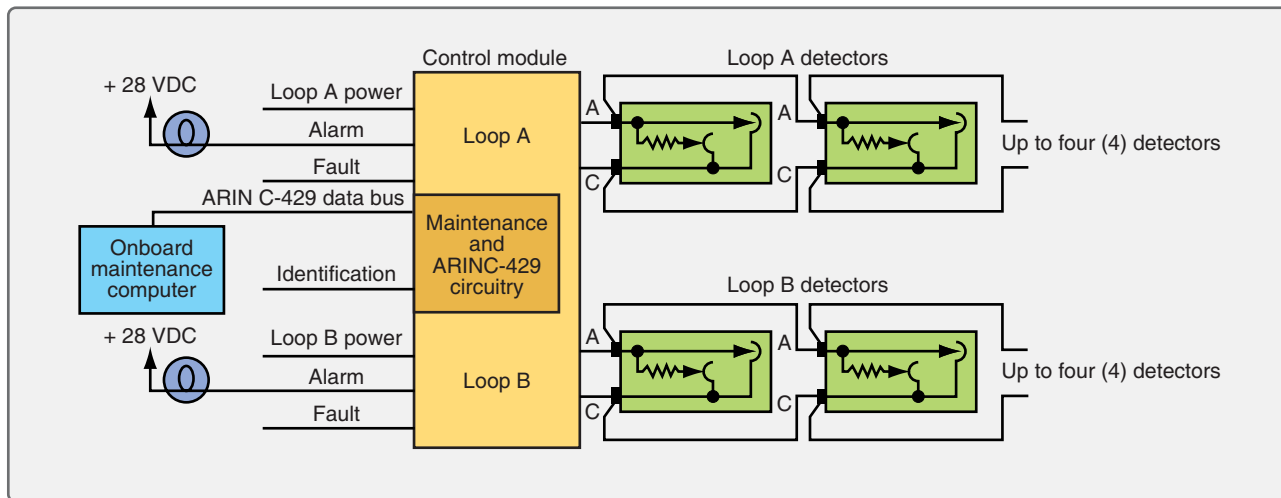


Figure 17-8. Aircraft detection system control module.

Fire Zones

Powerplant compartments are classified into zones based on the airflow through them.

1. Class A zone—area of heavy airflow past regular arrangements of similarly shaped obstructions. The power section of a reciprocating engine is usually of this type.
2. Class B zone—area of heavy airflow past aerodynamically clean obstructions. Included in this type are heat exchanger ducts, exhaust manifold shrouds, and areas where the inside of the enclosing cowl or other closure is smooth, free of pockets, and adequately drained so leaking flammables cannot puddle. Turbine engine compartments may be considered in this class if engine surfaces are aerodynamically clean and all airframe structural formers are covered by a fireproof liner to produce an aerodynamically clean enclosure surface.
3. Class C zone—area of relatively low airflow. An engine accessory compartment separated from the power section is an example of this type of zone.
4. Class D zone—area of very little or no airflow. These include wing compartments and wheel wells where little ventilation is provided.
5. Class X zone—area of heavy airflow and of unusual construction, making uniform distribution of the extinguishing agent very difficult. Areas containing deeply recessed spaces and pockets between large structural formers are of this type. Tests indicate agent requirements to be double those for Class A zones.

Smoke, Flame, and Carbon Monoxide Detection Systems

Smoke Detectors

A smoke detection system monitors the lavatories and cargo baggage compartments for the presence of smoke, which is indicative of a fire condition. Smoke detection instruments that collect air for sampling are mounted in the compartments in strategic locations. A smoke detection system is used where the type of fire anticipated is expected to generate a substantial amount of smoke before temperature changes are sufficient to actuate a heat detection system. Two common types used are light refraction and ionization.

Light Refraction Type

The light refraction type of smoke detector contains a photoelectric cell that detects light refracted by smoke particles. Smoke particles refract the light to the photoelectric cell and, when it senses enough of this light, it creates an electrical current that sets off a light.

Ionization Type

Some aircraft use an ionization type smoke detector. The system generates an alarm signal (both horn and indicator) by detecting a change in ion density due to smoke in the cabin. The system is connected to the 28 volt DC electrical power supplied from the aircraft. Alarm output and sensor sensitive checks are performed simply with the test switch on the control panel.

Flame Detectors

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 (UV), based on the specific emission wavelengths that they are designed to detect. 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 these applications.

When radiation emitted by the fire crosses the airspace between the fire and the detector, it impinges on the detector front face and window. The window allows a broad spectrum of radiation to pass into the detector where it strikes the sensing device filter. The filter allows only radiation in a tight waveband centered on 4.3 micrometers in the IR band 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 are 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. [Figure 17-9]

Carbon Monoxide Detectors

Carbon monoxide is a colorless, odorless gas that is a byproduct of incomplete combustion. Its presence in the

breathing air of human beings can be deadly. To ensure crew and passenger safety, carbon monoxide detectors are used in aircraft cabins and cockpits. They are most often found on reciprocating engine aircraft with exhaust shroud heaters and on aircraft equipped with a combustion heater. Turbine bleed air, when used for heating the cabin, is tapped off of the engine upstream of the combustion chamber. Therefore, no threat of carbon monoxide presence is posed.

Carbon monoxide gas is found in varying degrees in all smoke and fumes of burning carbonaceous substances. Exceedingly small amounts of the gas are dangerous if inhaled. A concentration of as little as 2 parts in 10,000 may produce headache, mental dullness, and physical lethargy within a few hours. Prolonged exposure or higher concentrations may cause death.

There are several types of carbon monoxide detectors. Electronic detectors are common. Some are panel mounted and others are portable. Chemical color-change types are also common. These are mostly portable. Some are simple buttons, cards, or badges that have a chemical applied to the surface. Normally, the color of the chemical is tan. In the presence of carbon monoxide, the chemical darkens to grey or even black. The transition time required to change color is inversely related to the concentration of CO present. At 50 parts per million, the indication is apparent within 15 to 30 minutes. A concentration of 100 parts per million changes the color of the chemical in as little as 2–5 minutes. As concentration increases or duration of exposure is prolonged, the color evolves from grey to dark grey to black.

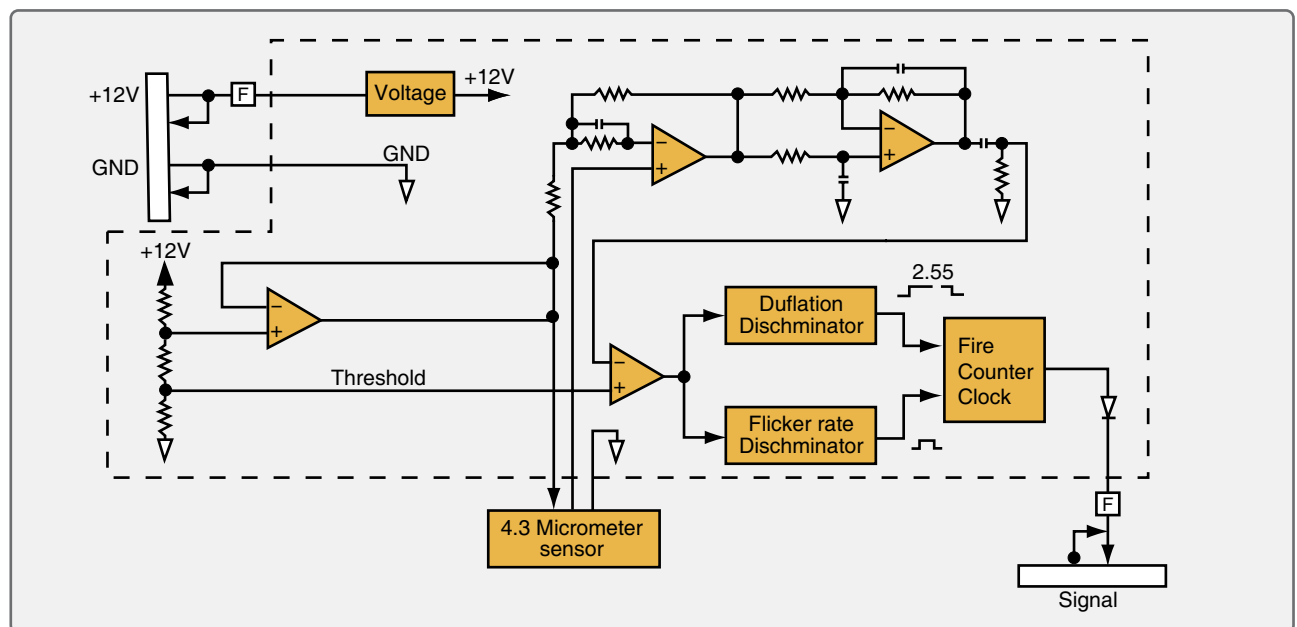


Figure 17-9. Infrared (IR) based optical flame detector.

Extinguishing Agents and Portable Fire Extinguishers

There must be at least one hand held, portable fire extinguisher for use in the pilot compartment that is located within easy access of the pilot while seated. There must be at least one hand held fire extinguisher located conveniently in the passenger compartment of each airplane accommodating more than 6 and less than 30 passengers. Each extinguisher for use in a personnel compartment must be designed to minimize the hazard of toxic gas concentrations. The number of portable, hand held fire extinguishers for transport aircraft is shown in *Figure 17-10*.

Passenger capacity	No. of extinguishers
7 through 30	1
31 through 60	2
61 through 200	3
201 through 300	4
301 through 400	5
401 through 500	6
501 through 600	7
601 through 700	8

Figure 17-10. *Hand held fire extinguisher requirement for transport aircraft.*

Halogenated Hydrocarbons

For over 45 years, halogenated hydrocarbons (Halon) have been practically the only fire extinguishing agents used in civil transport aircraft. However, Halon is an ozone depleting and global warming chemical, and its production has been banned by international agreement. Although Halon usage has been banned in some parts of the world, aviation has been granted an exemption because of its unique operational and fire safety requirements. Halon has been the fire extinguishing agent of choice in civil aviation because it is extremely effective on a per unit weight basis over a wide range of aircraft environmental conditions. It is a clean agent (no residue), electrically nonconducting, and has relatively low toxicity.

Two types of Halons are employed in aviation: Halon 1301(CBrF₃) a total flooding agent, and Halon 1211 (CBrClF₂) a streaming agent. Class A, B, or C fires are appropriately controlled with Halons. However, do not use Halons on a class D fire. Halon agents may react vigorously with the burning metal.

NOTE: While Halons are still in service and are appropriate agents for these classes of fires, the production of these ozone depleting agents has been restricted. Although not required, consider replacing Halon extinguishers with Halon replacement extinguishers when discharged. Halon replacement agents found to be compliant to date include the halocarbons HCFC Blend B, HFC-227ea, and HFC-236fa.

Inert Cold Gases

Carbon dioxide (CO₂) 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. CO₂ 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, CO₂ is a gas, but it is easily liquefied by compression and cooling. After liquification, CO₂ remains in a closed container as both liquid and gas. When CO₂ 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 °F, and it becomes a finely divided white solid, dry ice snow.

Carbon dioxide is about 1½ times as heavy as air, which gives it the ability to replace air above burning surfaces and maintain a smothering atmosphere. CO₂ is effective as an extinguishing agent primarily because it dilutes the air and reduces the oxygen content so that combustion is no longer supported. Under certain conditions, some cooling effect is also realized. CO₂ is considered only mildly toxic, but it can cause unconsciousness and death by suffocation if the victim is allowed to breathe CO₂ in fire extinguishing concentrations for 20 to 30 minutes. CO₂ is not effective as an extinguishing agent on fires involving chemicals containing their own oxygen supply, such as cellulose nitrate (used in some aircraft paints). Also, fires involving magnesium and titanium cannot be extinguished by CO₂.

Dry Powders

Class A, B, or C fires can be controlled by dry chemical extinguishing agents. The only all purpose (Class A, B, C rating) dry chemical powder extinguishers contain mono-ammonium phosphate. All other dry chemical powders have a Class B, C U.S – UL fire rating only. Dry powder chemical extinguishers best control class A, B, and C fire but their use is limited due to residual residue and clean up after deployment.

Water

Class A type fires are best controlled with water by cooling the material below its ignition temperature and soaking the material to prevent re-ignition.

Cockpit and Cabin Interiors

All materials used in the cockpit and cabin must conform to strict standards to prevent fire. In case of a fire, several types of portable fire extinguishers are available to fight the fire. The most common types are Halon 1211 and water.

Extinguisher Types

Portable fire extinguishers are used to extinguish fires in the cabin or flight deck. *Figure 17-11* shows a Halon fire extinguisher used in a general aviation aircraft. The Halon extinguishers are used on electrical and flammable liquid fires. Some transport aircraft also use water fire extinguisher for use on non-electrical fires.

The following is a list of extinguishing agents and the type (class) fires for which each is appropriate.

1. Water—class A. Water cools the material below its ignition temperature and soaks it to prevent reignition.
2. Carbon dioxide—class B or C. CO₂ acts as a blanketing agent. NOTE: CO₂ is not recommended for hand-held extinguishers for internal aircraft use.
3. Dry chemicals—class A, B, or C. Dry chemicals are the best control agents for these types of fires.
4. Halons—only class A, B, or C.
5. Halocarbon clean agents—only class A, B, or C.
6. Specialized dry powder—class D. (Follow the recommendations of the extinguisher's manufacturer because of the possible chemical reaction between the burning metal and the extinguishing agent.)

The following hand-held extinguishers are unsuitable as cabin or cockpit equipment.

- CO₂
- Dry chemicals (due to the potential for corrosion damage to electronic equipment, the possibility of visual obscuration if the agent were discharged into the flight deck area, and the cleanup problems from their use)
- Specialized dry powder (it is suitable for use in ground operations)

Installed Fire Extinguishing Systems

Transport aircraft have fixed fire extinguishing systems installed in:

1. Turbine engine compartments
2. APU compartments
3. Cargo and baggage compartments
4. Lavatories

CO₂ Fire Extinguishing Systems

Older aircraft with reciprocating engines used CO₂ as an extinguishing agent, but all newer aircraft designs with turbine engines use Halon or equivalent extinguishing agent, such as halocarbon clean agents.

Halogenated Hydrocarbons Fire Extinguishing Systems

The fixed fire extinguisher systems used in most engine fire and cargo compartment 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.



Figure 17-11. Portable fire extinguisher.

The most common extinguishing agent still used today is Halon 1301 because of its effective firefighting capability and relatively low toxicity (UL classification Group 6). Noncorrosive Halon 1301 does not affect the material it contacts and requires no cleanup when discharged. Halon 1301 is the current extinguishing agent for commercial aircraft but a replacement is under development. Halon 1301 cannot be produced anymore because it depletes the ozone layer. Halon 1301 will be used until a suitable replacement is developed. Some military aircraft use HCL-125 and the Federal Aviation Administration (FAA) is testing HCL-125 for use in commercial aircraft.

Containers

Fire extinguisher containers (HRD bottles) store a liquid halogenated extinguishing agent and pressurized gas (typically nitrogen). They are 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. They 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. [Figures 17-12 and 17-13]



Figure 17-12. Built-in non-portable fire extinguisher containers (HRD bottles) on an airliner.

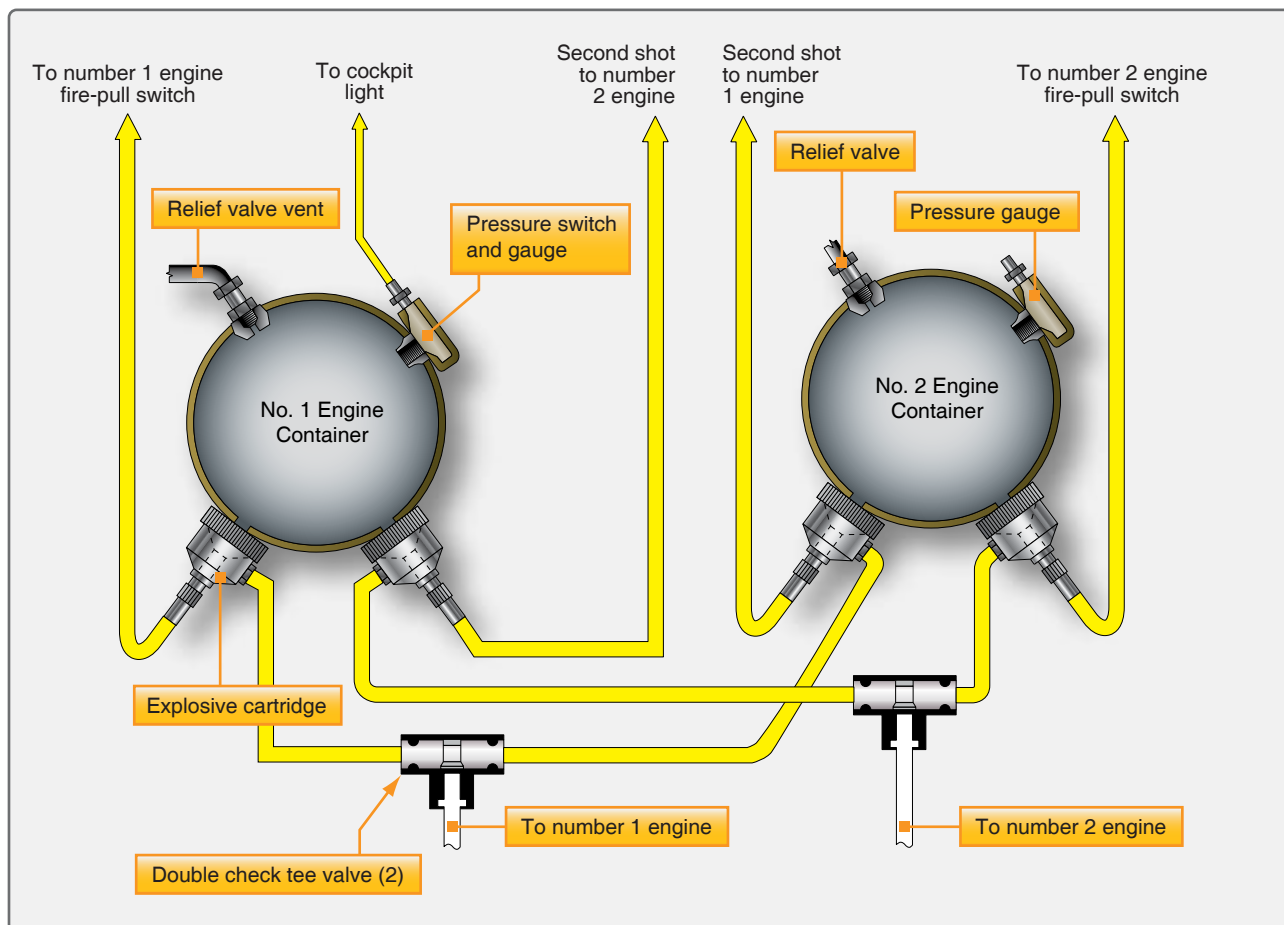


Figure 17-13. Diagram of fire extinguisher containers (HRD bottles).

Discharge Valves

Discharge valves are installed on the containers. A cartridge (squib) and frangible disk-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 disk-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 that applies fragmentation impact to rupture a prestressed corrosion resistant steel diaphragm. Most containers use conventional metallic gasket seals that facilitate refurbishment following discharge. [Figure 17-14]

Pressure Indication

A wide range of diagnostics is utilized to verify the fire extinguisher agent charge status. A simple visual indication gauge is available, typically a helical bourdon-type indicator that is vibration resistant. [Figure 17-13] 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 has a temperature compensated pressure switch that tracks the container pressure variations with temperatures by using a hermetically sealed reference chamber.

Two-Way Check Valve

Two-way check valves are required in a two-shot system to prevent the extinguisher agent from 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 17-15]



Figure 17-15. Discharge indicators.

Thermal Discharge Indicator (Red Disk)

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



Figure 17-14. Discharge valve (left) and cartridge, or squib (right).

Yellow Disk Discharge Indicator

If the flight crew activates the fire extinguisher system, a yellow disk 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 the fire extinguishing container needs to be replaced before next flight.

Fire Switch

The engine and APU fire switches are typically installed on the center overhead panel or center console in the flight deck. [Figure 17-16] When an engine 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 system malfunctions. [Figure 17-17]



Figure 17-16. Engine and APU fire switches on the cockpit center overhead panel.

1. The detection system must provide a visual indication to the flight crew within 1 minute after the start of a fire.

Cargo Fire Detection

Transport aircraft need to have the following provisions for each cargo or baggage compartment:

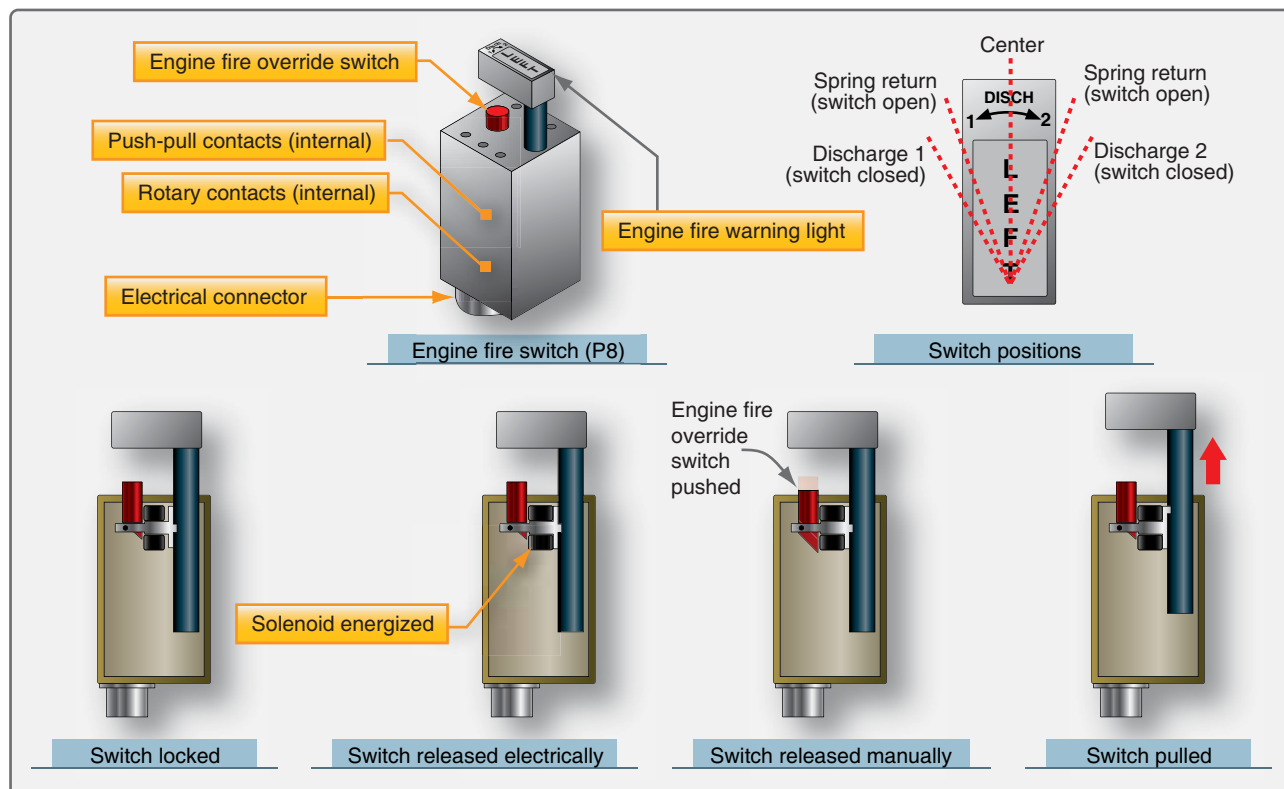


Figure 17-17. Engine fire switch operation.

2. The system must be capable of detecting a fire at a temperature significantly below that at which the structural integrity of the airplane is substantially decreased.
3. There must be means to allow the crew to check, in flight, the functioning of each fire detector circuit.

Cargo Compartment Classification

Class A

A Class A cargo or baggage compartment, is one in which the presence of a fire would be easily discovered by a crewmember while at his or her station and each part of the compartment is easily accessible in flight.

Class B

A Class B cargo, or baggage compartment, is one in which there is sufficient access in flight to enable a crewmember to effectively reach any part of the compartment with the contents of a hand fire extinguisher. When the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent enters any compartment occupied by the crew or passengers. There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.

Class C

A Class C cargo, or baggage compartment, is one not meeting the requirements for either a Class A or B compartment but in which:

1. There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.
2. There is an approved built-in fire extinguishing or suppression system controllable from the cockpit.

3. There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by the crew or passengers.
4. There are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.

Class E

Class E cargo compartment is one on airplanes used only for the carriage of cargo and in which:

1. There is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station.
2. The controls for shutting off the ventilating airflow to, or within, the compartment are accessible to the flight crew in the crew compartment.
3. There are means to exclude hazardous quantities of smoke, flames, or noxious gases from the flight crew compartment.
4. The required crew emergency exits are accessible under any cargo loading condition.

Cargo and Baggage Compartment Fire Detection and Extinguisher System

The cargo compartment smoke detection system gives warnings in the flight deck if there is smoke in a cargo compartment. [Figure 17-18] Each compartment is equipped with a smoke detector. The smoke detectors monitor air in the cargo compartments for smoke. The fans bring air from the cargo compartment into the smoke detector. Before the air goes in the smoke detector, in-line water separators remove condensation and heaters increase the air temperature. [Figure 17-19]



Figure 17-18. Cargo fire detection warning.

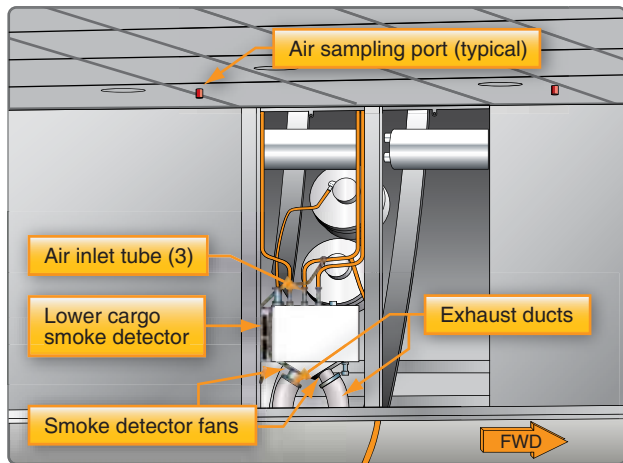


Figure 17-19. *Smoke detector installation.*

Smoke Detector System

The optical smoke detector consists of source light emitting diodes (LEDs), intensity monitor photodiodes, and scatter detector photodiodes. Inside the smoke detection chamber, air flows between a source (LED) and a scatter detector photodiode. Usually, only a small amount of light from the LED gets to the scatter detector. If the air has smoke in it, the smoke particles reflect more light on the scatter detector. This causes an alarm signal. The intensity monitor photodiode makes sure that the source LED is on and keeps the output of the source LED constant. This configuration also finds contamination of the LED and photodiodes. A defective diode, or contamination, causes the detector to change to the other set of diodes. The detector sends a fault message.

The smoke detector has multiple sampling ports. The fans draw air from the sampling ports through a water separator and a heater unit to the smoke detector. [Figure 17-20]

Cargo Compartment Extinguishing System

The cargo compartment extinguishing system is activated by the flight crew if the smoke detectors detect smoke in the cargo compartment. Some aircraft are outfitted with two

types of fire extinguisher containers. The first system is the dump system that releases the extinguishing agent directly when the cargo fire discharge switch is activated. This action extinguishes the fire.

The second system is the metered system. After a time delay, the metered bottles discharge slowly and at a controlled rate through the filter regulator. Halon from the metered bottles replaces the extinguishing agent leakage. This keeps the correct concentration of extinguishing agent in the cargo compartment to keep the fire extinguished for 180 minutes.

The fire extinguishing bottles contain Halon 1301 or equivalent fire extinguishing agent pressurized with nitrogen. Tubing connects the bottles to discharge nozzles in the cargo compartment ceilings.

The extinguishing bottles are outfitted with squibs. The squib is an electrically operated explosive device. It is adjacent to a bottle diaphragm that can break. The diaphragm normally seals the pressurized bottle. When the cargo discharge switch is activated, the squib fires and the explosion breaks the diaphragm. Nitrogen pressure inside the bottle pushes the Halon through the discharge port into the cargo compartment. When the bottle discharges, a pressure switch is activated that sends an indication to the flight deck that a bottle has been discharged. Flow control valves are incorporated if the bottles can be discharged in multiple compartments. The flow control valves direct the extinguishing agent to the selected cargo compartment. [Figure 17-21]

The following indications occur in the cockpit if there is smoke in a cargo compartment:

- Master warning lights come on.
- Fire warning aural operates.
- A cargo fire warning message shows.
- Cargo fire warning light comes on.

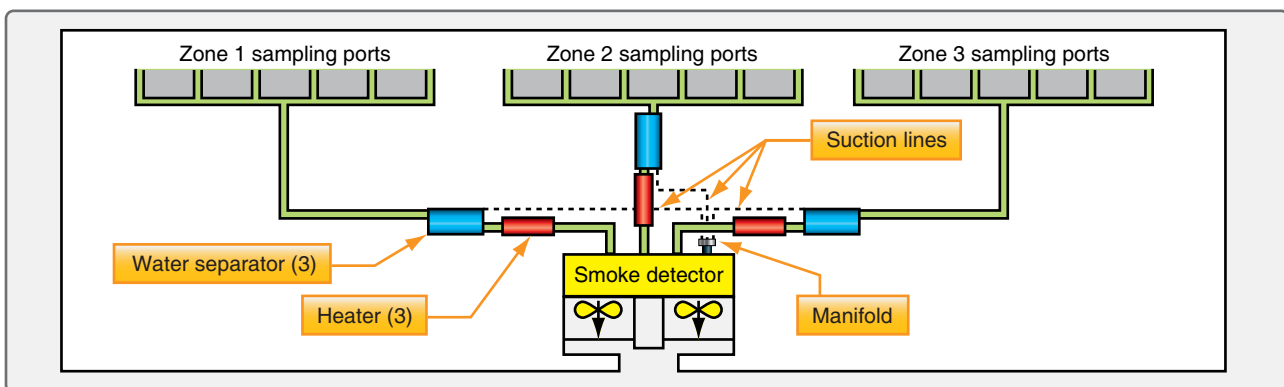


Figure 17-20. *Smoke detector system.*

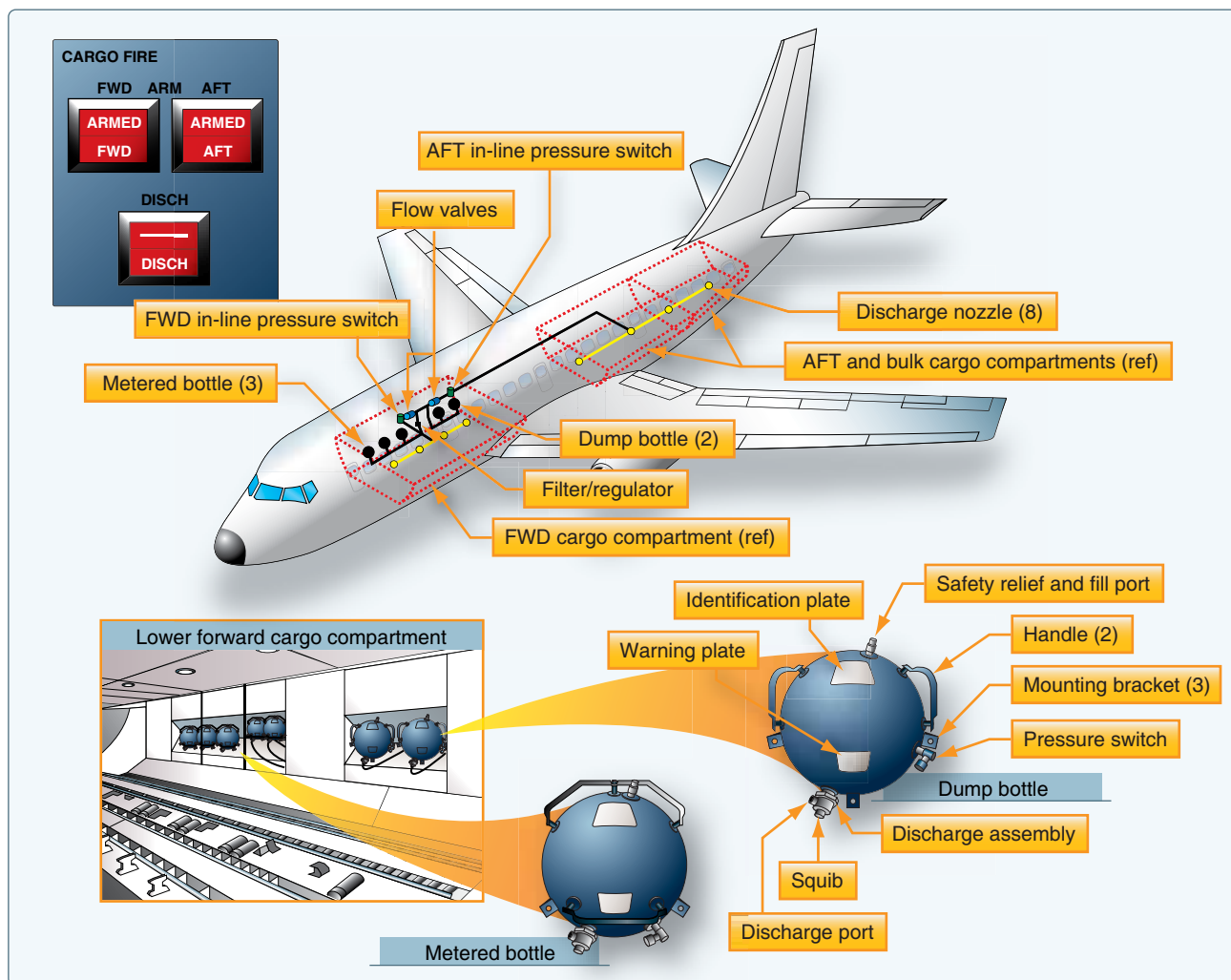


Figure 17-21. Cargo and baggage compartment extinguishing system.

The master warning lights and fire warning aural are prevented from operating during part of the takeoff operation.

Lavatory Smoke Detectors

Airplanes that have a passenger capacity of 20 or more are equipped with a smoke detector system that monitors the lavatories for smoke. Smoke indications provide a warning light in the cockpit or provide a warning light or audible warning at the lavatory and at flight attendant stations that would be readily detected by a flight attendant. Each lavatory must have a built-in fire extinguisher that discharges automatically. The smoke detector is located in the ceiling of the lavatory. [Figure 17-22]

Lavatory Smoke Detector System

Refer to Figure 17-23. The lavatory smoke detector is powered by the 28-volt DC left/right main DC bus. If there is smoke in the sensing chamber of the smoke detector, the alarm LED (red) comes on. The timing circuit makes an intermittent ground. The warning horn and lavatory call

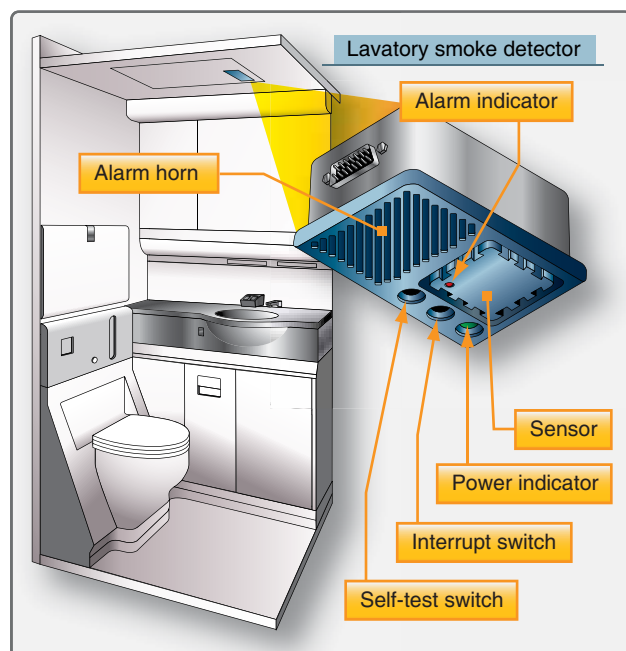


Figure 17-22. Lavatory smoke detector.

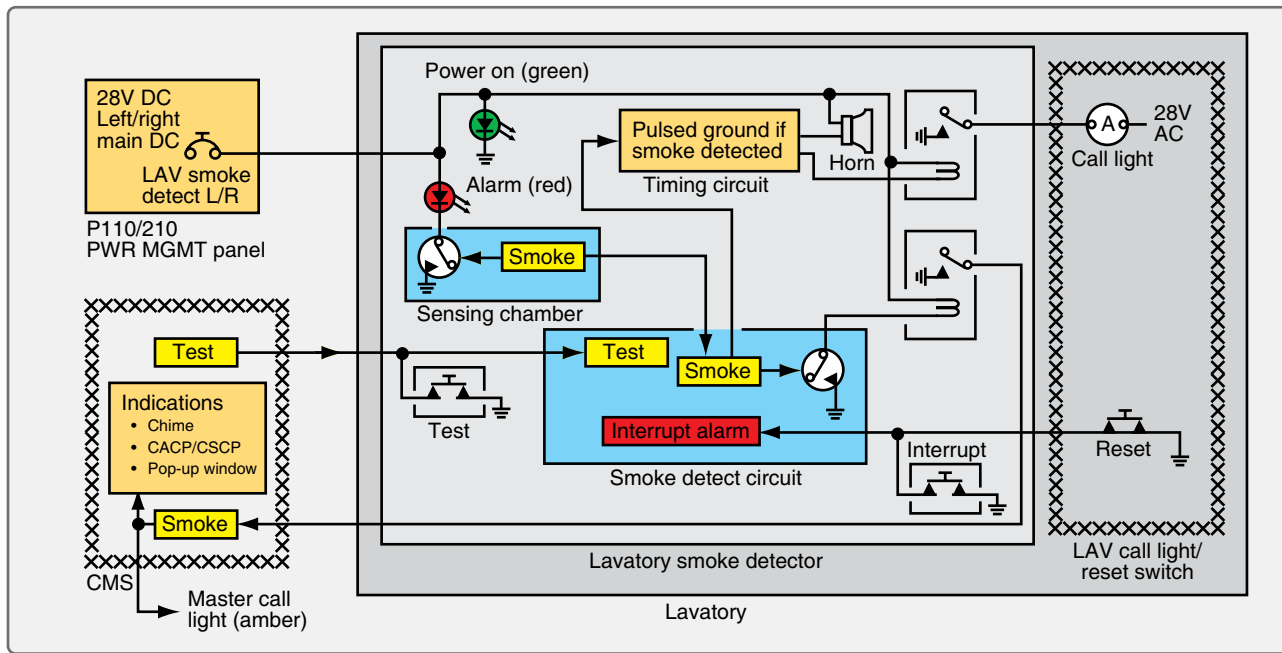


Figure 17-23. Lavatory smoke detector diagram.

light operate intermittently. The smoke detection circuit makes a ground for the relay. The energized relay makes a ground signal for the overhead electronics unit (OEU) in the central monitoring systems (CMS). This interface gives these indications: lavatory master call light flashes, cabin system control panel (CSCP) and cabin area control panel (CACP) pop-up window shows, and the lavatory call chime operates. Push the lavatory call reset switch or the smoke detector interrupt switch to cancel the smoke indications. If there is still smoke in the lavatory, the alarm LED (red) stays on. All smoke indications go away automatically when the smoke is gone.

Lavatory Fire Extinguisher System

The lavatory compartment is outfitted with a fire extinguisher bottle to extinguish fires in the waste compartment. The fire extinguisher is a bottle with two nozzles. The bottle contains pressurized Halon 1301 or equivalent fire extinguishing agent. When the temperature in the waste compartment reaches approximately 170 °F, the solder that seals the nozzles melt and the Halon is discharged. Weighing the bottle is often the only way to determine if the bottle is empty or full. [Figure 17-24]

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



Figure 17-24. Lavatory fire extinguishing bottle.

systems should include the following visual checks. Note: 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 cowl, 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 that 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 manufacturers. No attempt should be made to straighten any acceptable dent or kink, since stresses may be set up that could cause tubing failure. [Figure 17-25]

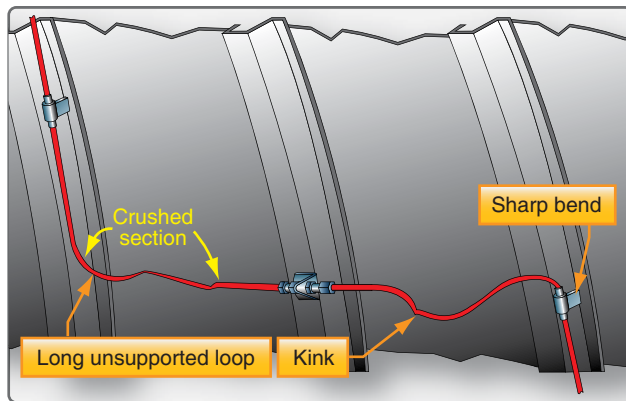


Figure 17-25. Sensing element defects.

6. Nuts at the end of the sensing elements should be inspected for tightness and safety wire. [Figure 17-26] 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. These should be replaced any time a connection is separated.

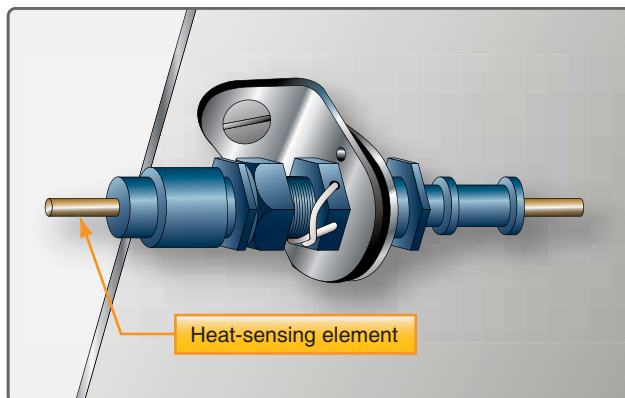


Figure 17-26. Connector joint fitting attached to the structure.

7. If shielded flexible leads are used, they should be inspected for fraying of the outer braid. The braided sheath is made up 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 17-27] Long, unsupported sections may permit excessive vibration that can cause breakage. The distance between clamps on straight runs, usually about 8 to 10 inches, is specified by each manufacturer. At end connectors, the first support clamp usually is located about 4 to 6 inches from 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 3 inches is normally adhered to.

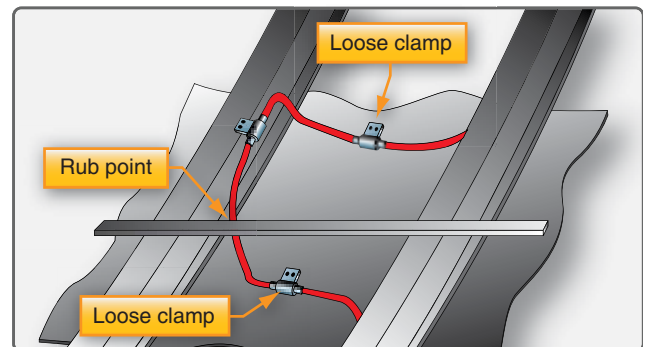


Figure 17-27. Rubbing interference.

9. Interference between a cowl brace and a sensing element can cause rubbing. 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 17-28]

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

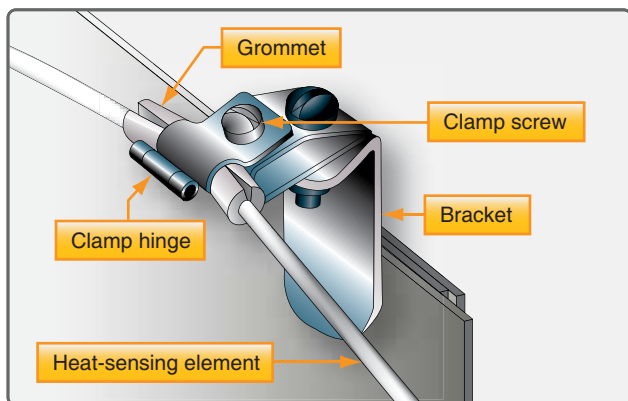


Figure 17-28. Inspection of fire detector loop clamp.

through the insulation. Intermittent faults often can be located by moving wires to recreate the short.

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

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.

Container Pressure Check

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 17-29* 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.

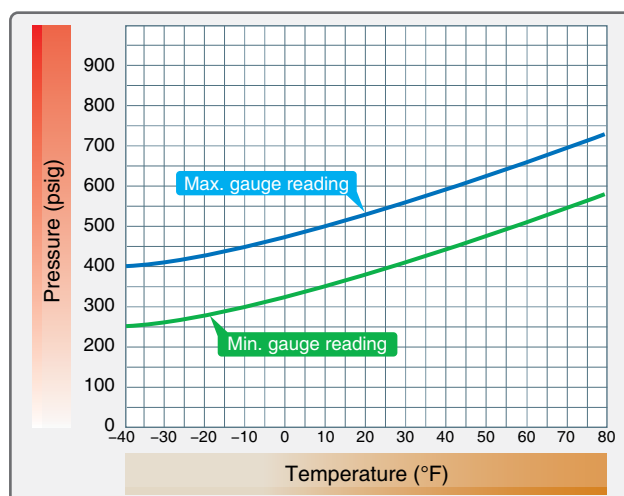


Figure 17-29. Fire extinguisher container pressure-temperature chart.

Discharge Cartridges

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.

Agent Containers

Care must be taken in the replacement of cartridge and discharge valves. Most new extinguisher containers are supplied with their cartridge and discharge valve disassembled. Before installation on the aircraft, the cartridge must be assembled properly in the discharge valve and the valve connected to the container, usually by means of a swivel nut that tightens against a packing ring gasket. [Figure 17-30]

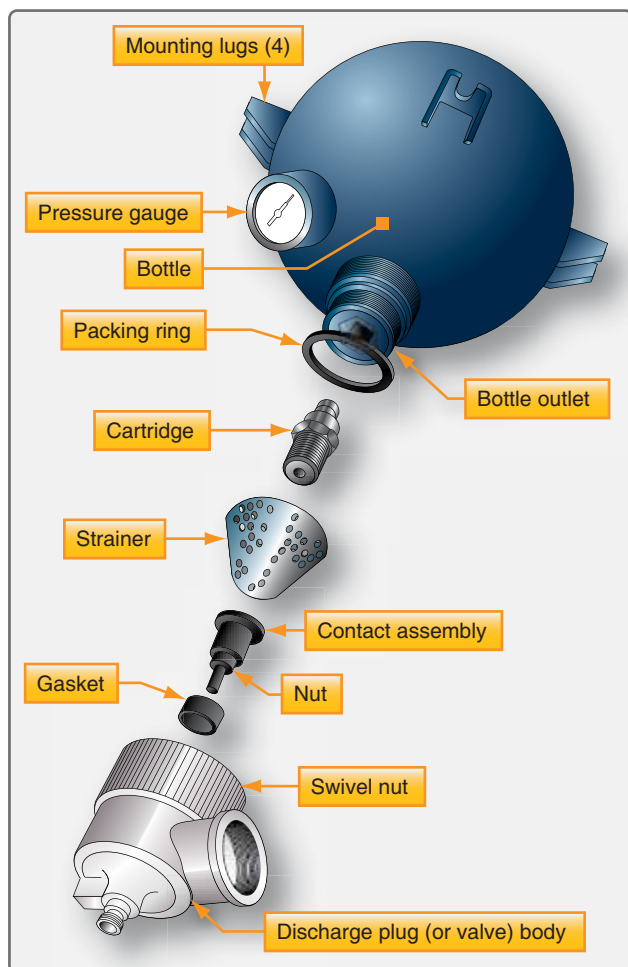


Figure 17-30. *Components of fire extinguisher container.*

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.

Note: The preceding material in this chapter has been largely of a general nature dealing with 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.

Fire Prevention

Leaking fuel, hydraulic, deicing, or lubricating fluids can be sources of fire in an aircraft. This condition should be noted and corrective action taken when inspecting aircraft systems. Minute pressure leaks of these fluids are particularly dangerous for they quickly produce an explosive atmospheric condition. Carefully inspect fuel tank installations for signs of external leaks. With integral fuel tanks, the external evidence may occur at some distance from where the fuel is actually escaping. Many hydraulic fluids are flammable and should not be permitted to accumulate in the structure. Sound-proofing and lagging materials may become highly flammable if soaked with oil of any kind. Any leakage or spillage of flammable fluid in the vicinity of combustion heaters is a serious fire risk, particularly if any vapor is drawn into the heater and passes over the hot combustion chamber.

Oxygen system equipment must be kept absolutely free from traces of oil or grease, since these substances spontaneously ignite when in contact with oxygen under pressure. Oxygen servicing cylinders should be clearly marked so they cannot be mistaken for cylinders containing air or nitrogen, as explosions have resulted from this error during maintenance operations.

