CHAPTER 9

ENGINE FIRE PROTECTION SYSTEMS

GENERAL

Because fire is one of the most dangerous threats to an aircraft, the potential fire zones of all multi-engine 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 CO_2 fire extinguisher.

RECIPROCATING ENGINE FIRE PROTECTION SYSTEMS

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 reciprocating engine aircraft by 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 not used to detect engine fires. For example, smoke detectors are better suited to monitor areas such as baggage compartments, 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 crew members as a primary method of fire detection. An ideal fire detector system will include as many as possible of the following features:

(1) A system which will 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 re-ignited.
(5) Continuous indication for duration of a fire.
(6) Means for electrically testing the detector system from the aircraft cockpit.
(7) Detectors which resist damage from exposure to oil, water, vibration, extreme temperatures, or handling.
(8) Detectors which are light in weight and easily adaptable to any mounting position.
(9) Detector circuitry which 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 cockpit light, indicating the location of the fire and have an audible alarm system.
(12) A separate detector system for each engine.

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 will close, 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; on others there may be one thermal switch for each indicator light.

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.

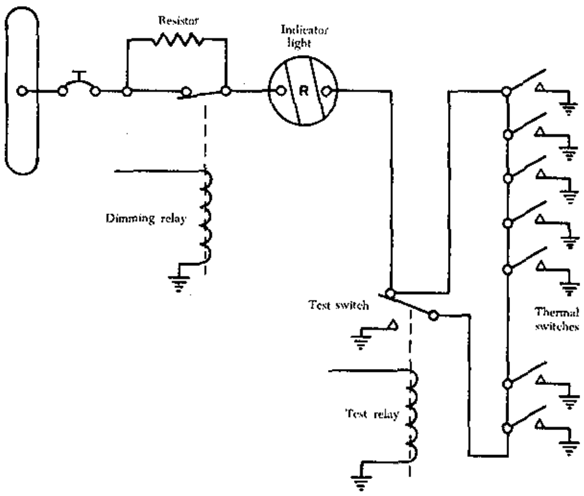

FIGURE 9–1. Thermal switch fire circuit.

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 will 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

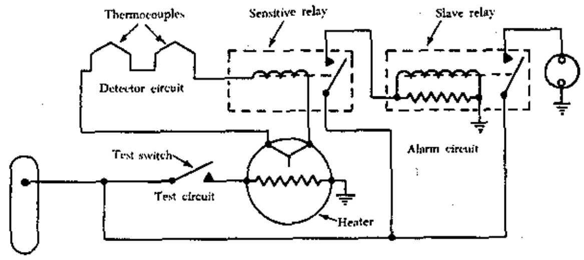

FIGURE 9–2. Thermocouple fire warning circuit.

relays. The circuit consists of several thermocouples in series with each other and with the sensitive relay.

The thermocouple is constructed of two dissimilar metals such as chromel and constantan. The point where these metals are joined and will be 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 will result. 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 will heat 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 will close. This will complete a circuit from the aircraft power system to the coil of the slave relay. The slave relay will then close and complete 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 will 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.

Continuous-Loop Detector Systems

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.

In the Kidde continuous-loop system (figure 9–3), two wires are imbedded in a special ceramic core within an Inconel tube.

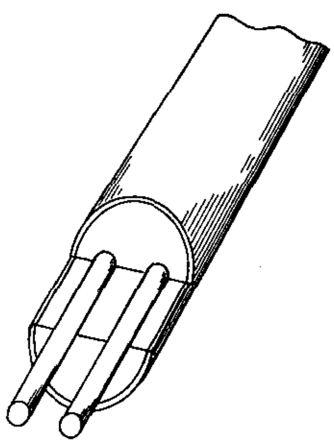

FIGURE 9–3. Kidde sensing element.

One of the two wires in the Kidde sensing system is welded to the case at each end and acts as an internal ground. The second wire is a hot lead (above ground potential) that provides a current signal when the ceramic core material changes its resistance with a change in temperature.

Another continuous-loop system, the Fenwall system (figure 9–4), uses a single wire surrounded by a continuous string of ceramic beads in an Inconel tube.

The beads in the Fenwal detector are wetted with a eutectic salt, which possesses the characteristic of suddenly lowering its electrical resistance as the sensing element reaches its alarm temperature. In

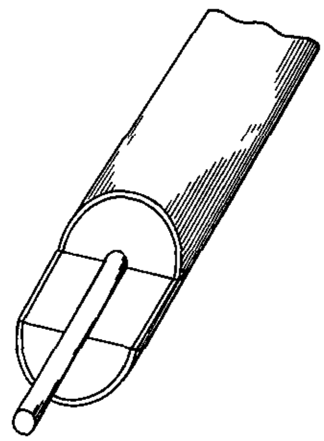

FIGURE 9–4. Fenwal sensing element.

both the Kidde and the Fenwal systems, the resistance of the ceramic or eutectic salt core material prevents electrical current from flowing at normal temperatures. In case of a fire or overheat condition, the core resistance drops and current flows between the signal wire and ground, energizing the alarm system.

The Kidde sensing elements are connected to a relay control unit. This unit constantly measures the total resistance of the full sensing loop. The system senses the average temperature, as well as any single hot spot.

The Fenwal system uses a magnetic amplifier control unit. This system is nonaveraging but will sound an alarm when any portion of its sensing element reaches the alarm temperature.

Both systems continuously monitor temperatures in the engine compartments, and both will automatically reset following a fire or overheat alarm after the overheat condition is removed or the fire extinguished.

Spot Detector Systems

Spot detector systems operate on a different principle from the continuous loop. Each detector unit (figure 9–5) consists of a bimetallic thermoswitch. Most spot detectors are dual-terminal thermoswitches, electrically above ground potential.

Fenwal spot detectors are wired in parallel between two complete loops of wiring, as illustrated in figure 9–6. Thus, the system can withstand one fault, either an electrical open circuit or a short to ground, without sounding a false fire warning. A double fault must exist before a false fire warning can occur. In case of a fire or overheat condition, the spot-detector switch closes and completes a circuit to sound an alarm.

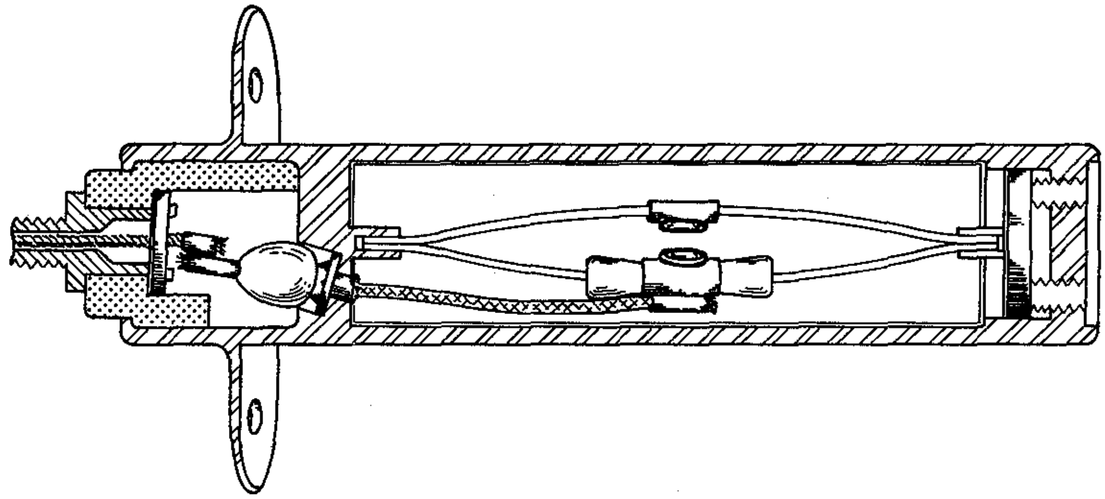

FIGURE 9–5. Fenwal spot detector.

The Fenwal spot-detector system operates without a control unit. When an overheat condition or a fire causes the switch in a detector to close, the alarm bell sounds and a warning light for the affected area is lighted.

FIRE ZONES

Engine fire detectors are located according to fire zones. Each engine and nacelle area usually is divided into three zones similar to the zoned nacelle shown in figure 9–7. Zone I identifies the engine power section area forward of the cowl flap trailing edges and inner ring baffles. Zone II identifies the engine accessory section area between the inner ring baffles and the firewall, and zone III identifies the nacelle area aft of the firewall.

In addition to the engine and nacelle area zones, other areas on multi-engine aircraft are provided with fire detection and protection systems. These areas include baggage compartments, auxiliary powerplant installations, 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.

FIRE EXTINGUISHING AGENTS

The fixed fire extinguisher systems used in most reciprocating engine fire protection systems are designed to dilute the atmosphere with an inert agent that will not support combustion. Many systems use perforated tubing or discharge nozzles to distribute the extinguishing agent. More recently developed HRD (high rate of discharge) systems use open-end tubes to deliver a quantity of extinguishing agent in from 1 to 2 seconds.

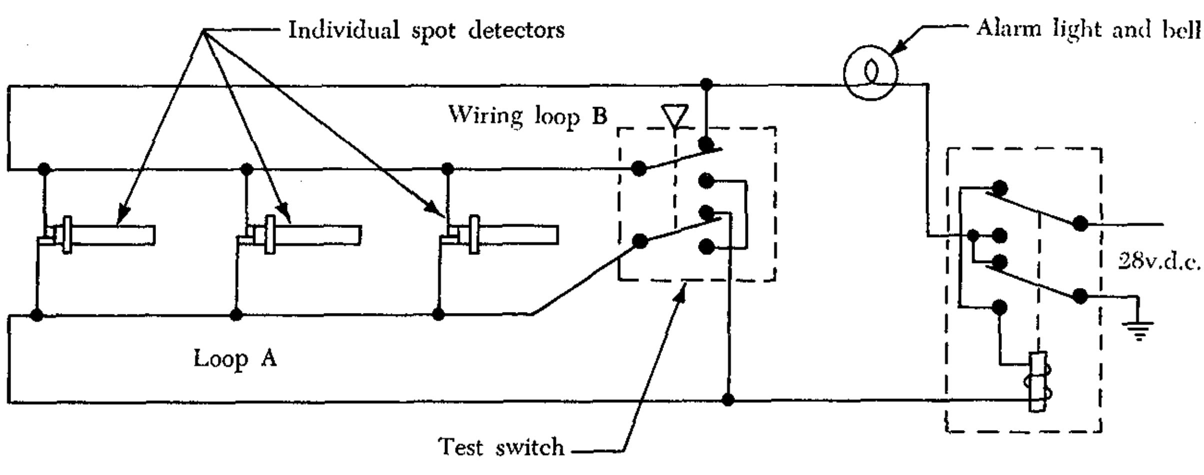

FIGURE 9–6. Fenwal spot-detector circuit.

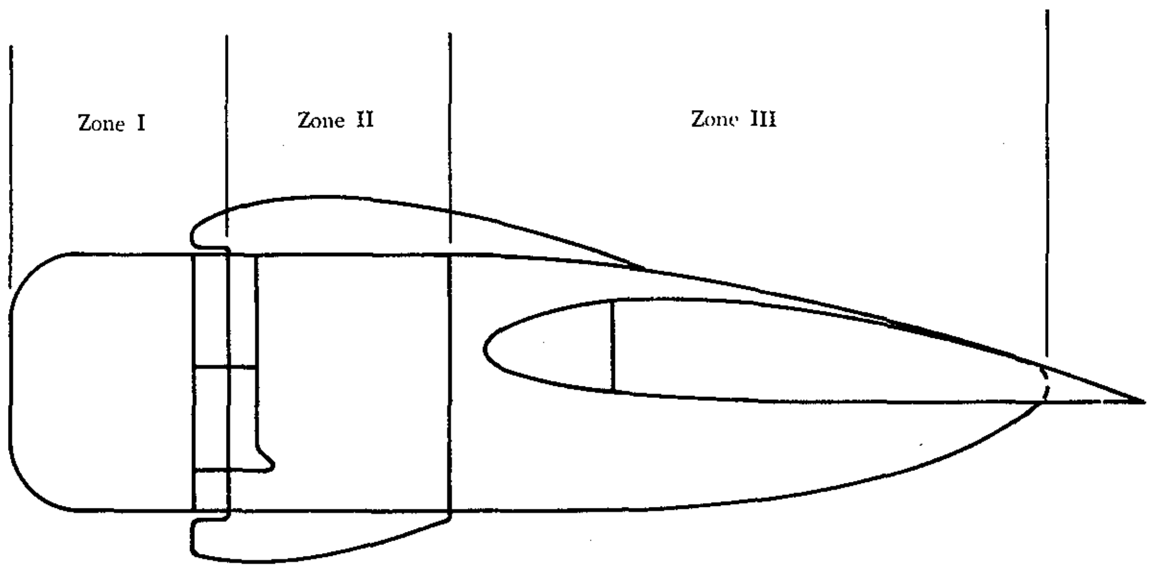

FIGURE 9–7. Fire zone areas.

Carbon Dioxide (CO_2). UL toxicity rating of 5a, especially recommended for use on class B and C fires. Extinguishes flame by dissipating oxygen in the immediate area. From a standpoint of toxicity and corrosion hazards, carbon dioxide is the safest agent to use. It was for many years the most widely used agent. If handled improperly, it can cause mental confusion and suffocation. Because of its variation in vapor pressure with temperature, it is necessary to store CO_2 in stronger containers than are required for most other agents.

Halogenated Hydrocarbons (commonly called Freon).

Methyl bromide (Halon 1001). Chemical formula–CH_3Br–a liquified gas, with a UL toxicity rating of 2. Methyl bromide is a more effective extinguishing agent than CO_2 from a standpoint of weight. It is also more toxic than CO_2 and cannot be used in areas where harmful concentrations can enter personnel compartments. A warning agent, such as colored smoke, is mixed with methyl bromide, which will seriously corrode aluminum alloy, magnesium or zinc.

Chlorobromomethane (Halon 1011). Chemical formula–CH_2ClBr.–is a liquefied gas, with a UL toxicity rating of 3. Commonly referred to as "CB", chlorobromomethane is more toxic than CO_2. It is corrosive to aluminum, magnesium, steel and brass. It is not recommended for aircraft use.

Carbon tetrachloride (Halon 104). Chemical formula–CCl_4–a liquid with a UL toxicity rating of 3. It is poisonous and toxic. Hydrochloric acid vapor, chlorine and phosgene gas are produced whenever "carbon tet" is used on ordinary fires. The amount of phosgene gas is increased whenever "carbon tet" is brought in direct contact with hot metal, certain chemicals, or continuing electrical arcs. It is no longer approved for any fire extinguishing use.

Dibromodifluoromethane (Halon 1201). Chemical formula–CBr_2F_2–a liquified gas with a UL toxicity rating of 4. This agent is noncorrosive to aluminum, brass, and steel, and it is more toxic than CO_2. It is one of the more effective fire extinguishing agents available, but is not recommended for aircraft use.

Bromochlorodifluoromethane (Halon 1211). Chemical formula–$CBrClF_2$–liquified gas with a UL toxicity rating of 5. It is colorless, noncorrosive and evaporates rapidly leaving no residue whatever. It does not freeze or cause cold burns and will not harm fabrics, metals, or other materials it contacts. Halon 1211 acts rapidly on fires by producing a heavy blanketing mist that eliminates air from the fire source, but more important interferes chemically with the combustion process. It has outstanding properties in preventing reflash after the fire has been extinguished.

Bromotrifluoromethane (Halon 1301). Chemical formula–CF_3Br–is a liquefied gas with a UL toxicity rating of 6. It has all the characteristics of Halon 1211. The significant difference between the two is: Halon 1211 throws a spray similar to CO_2 while Halon 1301 has a vapor spray that is more difficult to direct.

Halon 1211 and Halon 1301 are widely used in HRD (high rate of discharge) fire extinguishing systems installed in turboprop and turbojet powered aircraft.

UNDERWRITERS' LABORATORIES' CLASSIFICATION OF COMPARATIVE LIFE HAZARD OF FIRE EXTINGUISHING AGENTS

Group	*Definition*	*Examples*
6 (least toxic)	Gases or vapors which in concentrations up to at least 20% by volume for durations of exposure of the order of 2 hours do not appear to produce injury.	Bromotrifluoromethane (Halon 1301)
5a	Gases or vapors much less toxic than Group 4 but more toxic than Group 6.	Carbon Dioxide
4	Gases or vapors which in concentrations of the order of 2 to 2½% for durations of exposure of the order of 2 hours are lethal or produce serious injury.	Dibromodifluoromethane (Halon 1202)
3	Gases or vapors which in concentrations of the order of 2 to 2½% for durations of exposure of the order of 1 hour are lethal or produce serious injury.	Bromochloromethane (Halon 1011), Carbon tetrachloride (Halon 104)
2	Gases or vapors which in concentrations of the order of ½ to 1% for durations of exposure of the order of ½ hour are lethal or produce serious injury.	Methyl bromide (Halon 1001)

TABLE 9–1. UL Toxicity Table.

Reciprocating Engine CO_2 Fire Extinguisher Systems

CO_2 is one of the earliest types of engine fire extinguisher systems for reciprocating engine transport aircraft and is still used on many older aircraft.

The fire extinguisher system is designed around a CO_2 cylinder (figure 9–8) and a remote control valve assembly in the cockpit. The cylinder stores the flame-smothering carbon dioxide under the pressure required to distribute the extinguishing agent to the engines. The gas is distributed through tubing from the CO_2 cylinder valve to the control valve assembly in the cockpit, and then to the engines via tubing installed in the fuselage and wing tunnels. The tubing terminates in perforated loops that encircle the engines (figure 9–9).

To operate the CO_2 fire extinguisher system, the selector valve must be set for the engine that is on fire. A pull on a T-shaped control handle located adjacent to the engine selector valve actuates the release lever in the CO_2 cylinder valve. The compressed liquid in the CO_2 cylinder flows in one rapid burst to the outlets in the distribution line (figure 9–9) of the affected engine. Contact with the air converts the liquid into gas and "snow," which smothers the flame.

A more sophisticated type of CO_2 fire protection system is used on many four-engine aircraft. This system is capable of delivering CO_2 twice to any one of the four engines. Fire warning systems are

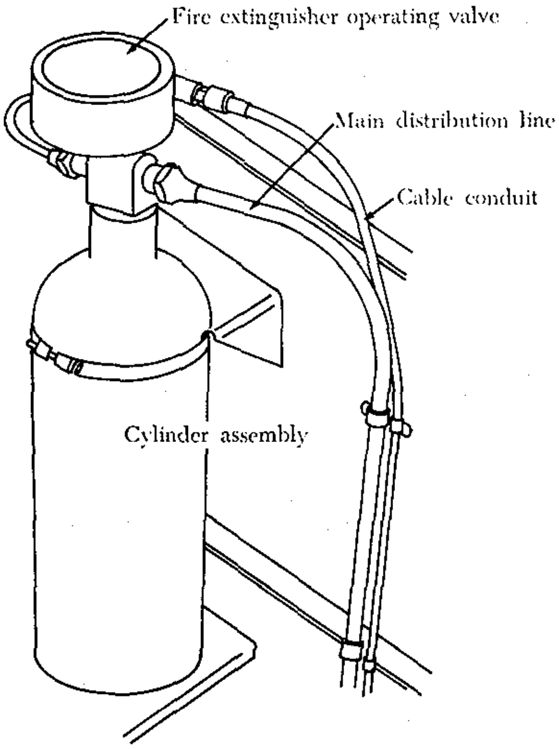

FIGURE 9–8. CO_2 cylinder installation.

installed at all fire hazardous locations of the aircraft to provide an alarm in case of fire.

The various warning systems operate fire warning lights on the cockpit fire control panels and also energize a cockpit warning bell.

One such CO_2 system consists of six cylinders, mounted three to a row in each side of the nose wheel well. Flood valves are installed on each CO_2 bottle. The flood valves of each row are interconnected. The valves on the two aft bottles, in each bank of three, are designed to be opened mechanically by a cable connected to discharge control handles on the main fire control panel in the cockpit. In case of discharge by mechanical means, the forward bottle flood valve in each bank is operated by the released CO_2 pressure from the two aft bottles through the interconnecting lines. The flood valve on the forward bottle of each bank contains a solenoid. The valve is designed to be operated electrically by energizing the solenoid when a button on the control panel is depressed. In case of a discharge by electrical means, the valves on the two aft bottles of each bank are operated by the released CO_2 pressure from the forward bottle through the interconnector lines.

Each bank of CO_2 bottles has a red thermosafety-discharge indicator disk set to rupture at or above a pressure of 2,650 p.s.i. Discharge overboard will occur at temperatures above 74° C. Each bank of bottles also has a yellow system-discharge indicator disk. Mounted adjacent to the red disk, the yellow disks indicate which bank of bottles has been emptied by a normal discharge.

This type of CO_2 fire protection system includes a fire warning system. It is a continuous-loop, low-impedance, automatic resetting type for the engine and nacelle areas.

A single fire detector circuit is provided for each engine and nacelle area. Each complete circuit consists of a control unit, sensing elements, a test relay, a fire warning signal light, and a fire warning signal circuit relay. Associated equipment, such as flexible connector assemblies, wire, grommets, mounting brackets, and mounting clamps, is used in various quantities, depending on individual installation requirements. For example, on a four-engine aircraft, four warning light assemblies, one for each engine and nacelle area, give corresponding warning indications when an alarm is initiated by a respective engine fire warning circuit. Warning light assemblies in the CO_2 manual release handles are connected to all four engine fire detector circuits, along with a fire warning bell with its guarded cutoff switch and indicating light.

The insulated wire of the detector circuit runs from the control unit in the radio compartment to the test relay. The wire is then routed through the nacelle and engine sections and back to the test relay, where it is joined to itself to form a loop.

Each control unit contains tubes or transistors, transformers, resistors, capacitors, and a potentiometer. It also contains an integrated circuit which introduces a time delay that desensitizes the warning system to short-duration transient signals that otherwise would cause momentary false alarms. When a fire or overheat condition exists in an engine or nacelle area, the resistance of the sensing loop decreases below a preset value determined by the setting of the control unit potentiometer, which is in the bias circuit of the control unit detector and amplifier circuit. The output of this circuit energizes the fire warning bell and fire warning light.

TURBINE ENGINE FIRE PROTECTION SYSTEMS

Several general failures or hazards can result in overheat conditions or fires peculiar to turbine engine aircraft because of their operating charac

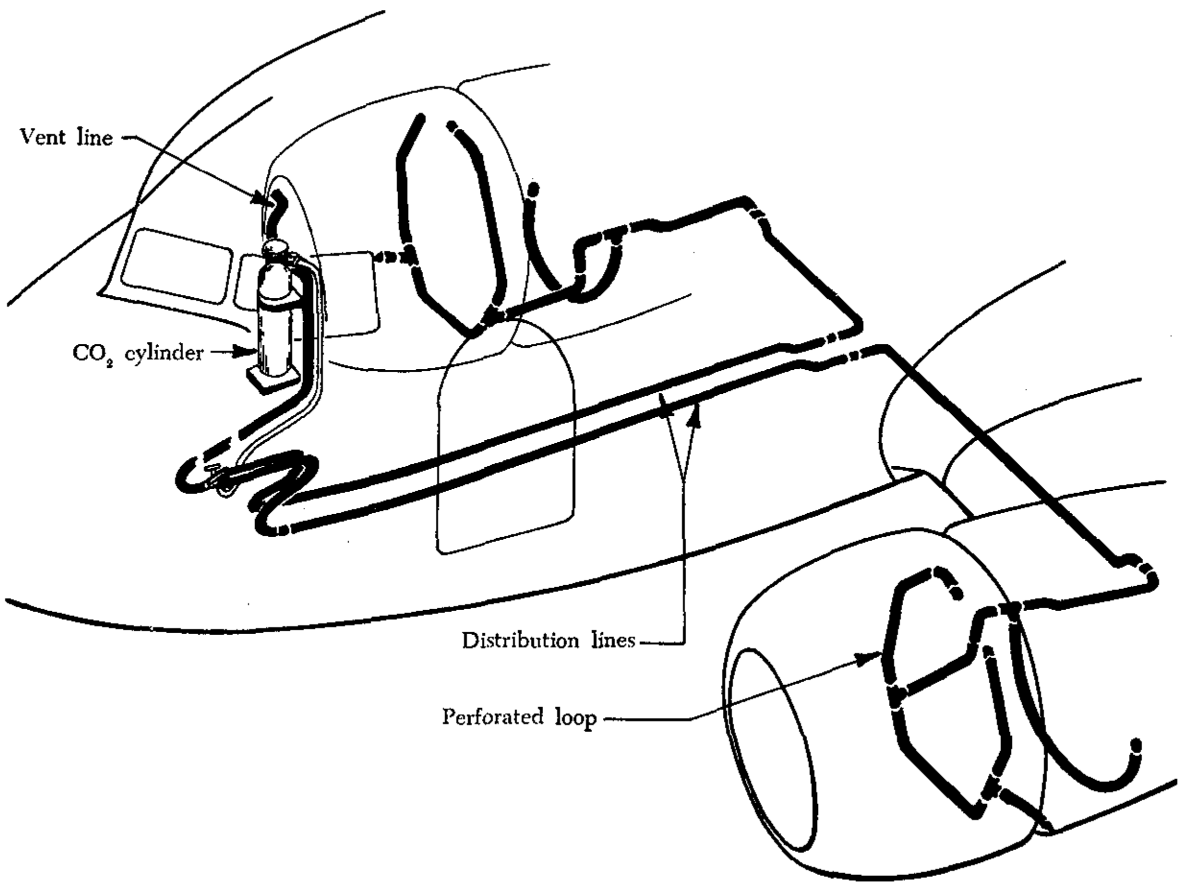

FIGURE 9–9. CO_2 fire extinguisher system on a twin-engine transport aircraft.

teristics. The two major types of turbine failure can be classified as either thermodynamic or mechanical.

Thermodynamic causes are those which upset the proportion of air used to cool combustion temperatures to the levels which the turbine metals 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 overtemperature, causing the turbine blades to melt or to be severed and thrown outward. Such failures 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 which 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 usually is 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.

Turbine Engine Fire Zones

Because turbine engine installations differ markedly from reciprocating engines, the fire zone system used for most reciprocating engines cannot be used.

A possible fire zone in a turbine engine installation is any area in which an ignition source, together with combustibles, combustible fluid line leakage, or combustible mixtures, may exist. The following engine compartments usually are protected:

(1) Engine power section, which includes the

burner, turbine, and tailpipe.

(2) Engine compressor and accessory section, which includes the compressor and all the engine accessories.

(3) Complete powerplant compartments, in which no isolation exists between the engine power section and the accessory section.

Turbine Engine Fire Extinguishing Agents

The fire extinguishing agents used in reciprocating engine fire protection systems are also used in turbine engine systems. The effectiveness of the various agents is influenced by the type of turbine engine fire protection system used, whether it is an HRD (high-rate-of-discharge) system rather than a conventional system, or whether the method of distribution is nozzle, spray ring, or open-end outlet. The choice of agent is also influenced by the airflow conditions through the engine.

Types of Fire or Overheat Detectors

The following list of detection methods includes those most commonly used in turbine engine fire protection systems. The complete aircraft fire protection system of most large turbine engine aircraft will 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) Fiber-optic detectors.
(8) Observation of crew or passengers.

The three types of detectors most commonly used for fast detection of fires are the rate-of-rise, radiation sensing, and overheat detectors.

Turbine Engine Ground Fire Protection

The problem of ground fires has increased in seriousness with the increased size of turbine engine aircraft. For this reason, a central ground connection to the aircraft's fire extinguishing system has been provided on some aircraft. Such systems provide a more effective means of extinguishing ground fires and eliminate the necessity of removing and re-charging the aircraft-installed fire extinguisher cylinders. These systems usually include means for operating the entire system from one place, such as the cockpit or at the location of the fire extinguishing agent supply on the ground.

On aircraft not equipped with a central ground connection to the aircraft fire extinguishing system, means are usually provided for rapid access to the compressor, tailpipe, or burner compartments. Thus, 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. If the engine is running, it 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_2 or other agents that have a cooling effect can shrink the turbine housing on the turbine and cause the engine to disintegrate.

TYPICAL MULTI-ENGINE FIRE PROTECTION SYSTEM

A turbine engine fire protection system for a large multi-engine turbojet aircraft is described in detail in the following paragraphs. This system is typical of most turbojet transport aircraft and includes components and systems typically encountered on all such aircraft. It is emphasized that the maintenance procedures and installation details of each particular type of aircraft are a function of a specific aircraft configuration.

The engine fire protection system of most large turbine engine aircraft consists of two subsystems: a fire detection system and a fire extinguishing system. These two subsystems provide fire protection not only to the engine and nacelle areas but also to such areas as the baggage compartments, wheel wells, etc. Only the engine fire protection system is included in this discussion.

Each turbine engine installed in a pod and pylon configuration contains an automatic heat-sensing fire detection circuit. This circuit consists of a heat-sensing unit, a control unit, a relay, and warning devices. The warning devices normally include a warning light in the cockpit for each circuit and a common alarm bell used with all such circuits.

The heat-sensing unit of each circuit is a continuous loop routed around the areas to be protected. These areas are the burner and tailpipe areas. Also included in most turbine engine aircraft fire extinguishing systems are the compressor and accessory areas, which in some installations may be protected by a separate fire protection circuit. Figure 9–10 illustrates the typical routing of a continuous-loop fire detection circuit in an engine pod and pylon. A typical continuous loop is made up of sensing

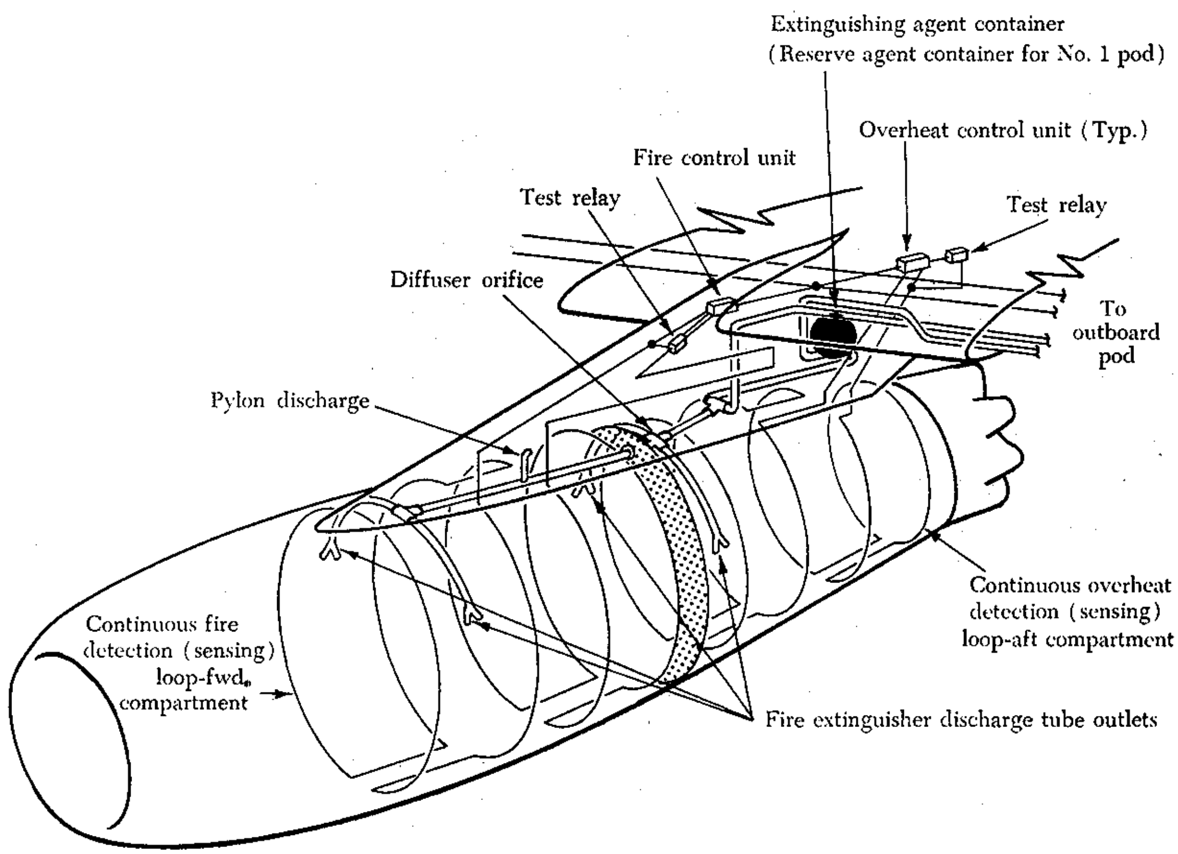

FIGURE 9–10. Typical pod and pylon fire protection installation.

elements joined to each other by moistureproof connectors, which are attached to the aircraft structure. In most installations, the loop is supported by attachments or clamps every 10 to 12 inches of its length. Too great a distance between supports may permit vibration or chafing of the unsupported section and become a source of false alarms.

In a typical turbine engine fire detection system, a separate control unit is provided for each sensing circuit. The control unit contains an amplifier, usually a transistorized or magnetic amplifier, which produces an output when a predetermined input current flow is detected from the sensing loop. Each control unit also contains a test relay, which is used to simulate a fire or overheat condition to test the circuit.

The output of the control unit amplifier is used to energize a warning relay, often called a fire relay. Usually located near the control units, these fire relays, when energized, complete the circuit to the appropriate warning devices.

The warning devices for engine and nacelle fires and overheat conditions are located in the cockpit. A fire warning light for each engine usually is located in a special fire switch handle on the instrument panel, light shield, or fire control panel. These fire switches are sometimes referred to as fire-pull T-handles. As illustrated in figure 9–11, the T-handle contains the fire detection warning light. In some models of this fire-pull switch, pulling the T-handle exposes a previously inaccessible extinguishing agent switch and also actuates microswitches that energize the emergency fuel shutoff valve and other pertinent shutoff valves.

Turbine Engine Fire Extinguisher System

The fire extinguishing portion of a complete fire protection system typically includes a cylinder or container of an extinguishing agent for each engine and nacelle area. One type of installation provides for a container in each of the pylons on multi-engine aircraft. This type of system uses an extinguishing agent container similar to the type shown in figure 9–12. This type of container is equipped with two discharge valves that are operated by electrically discharged cartridges. These two valves

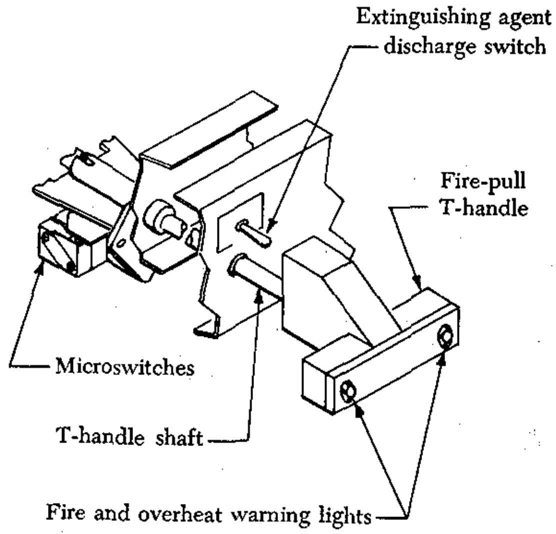

FIGURE 9–11. Fire-pull T-handle switch.

are the main and the reserve controls that release and route the agent to the pod and pylon in which the container is located or to the other engine on the same wing. This type of two-shot, crossfeed configuration permits the release of a second charge of fire extinguishing agent to the same engine if another fire breaks out, without providing two containers for each engine area.

Another type of four-engine installation uses two independent fire extinguisher systems. The two engines on one side of the aircraft are equipped with two fire extinguisher containers (figure 9–13), but they are located together in the inboard pylon. A pressure gage, a discharge plug, and a safety discharge connection are provided for each container. The discharge plug is sealed with a breakable disk combined with an explosive charge that is electrically detonated to discharge the contents of the bottle. The safety discharge connection is capped at the inboard side of the strut with a red indicating disk. If the temperature rises beyond a predetermined safe value, the disk will rupture, dumping the agent overboard.

The manifold connecting the two containers of the dual installation (figure 9–13) includes a double check valve and a T-fitting from which tubing connects to the discharge indicator. This indicator is capped at the inboard side of the strut with a yellow disk, which is blown out when the manifold

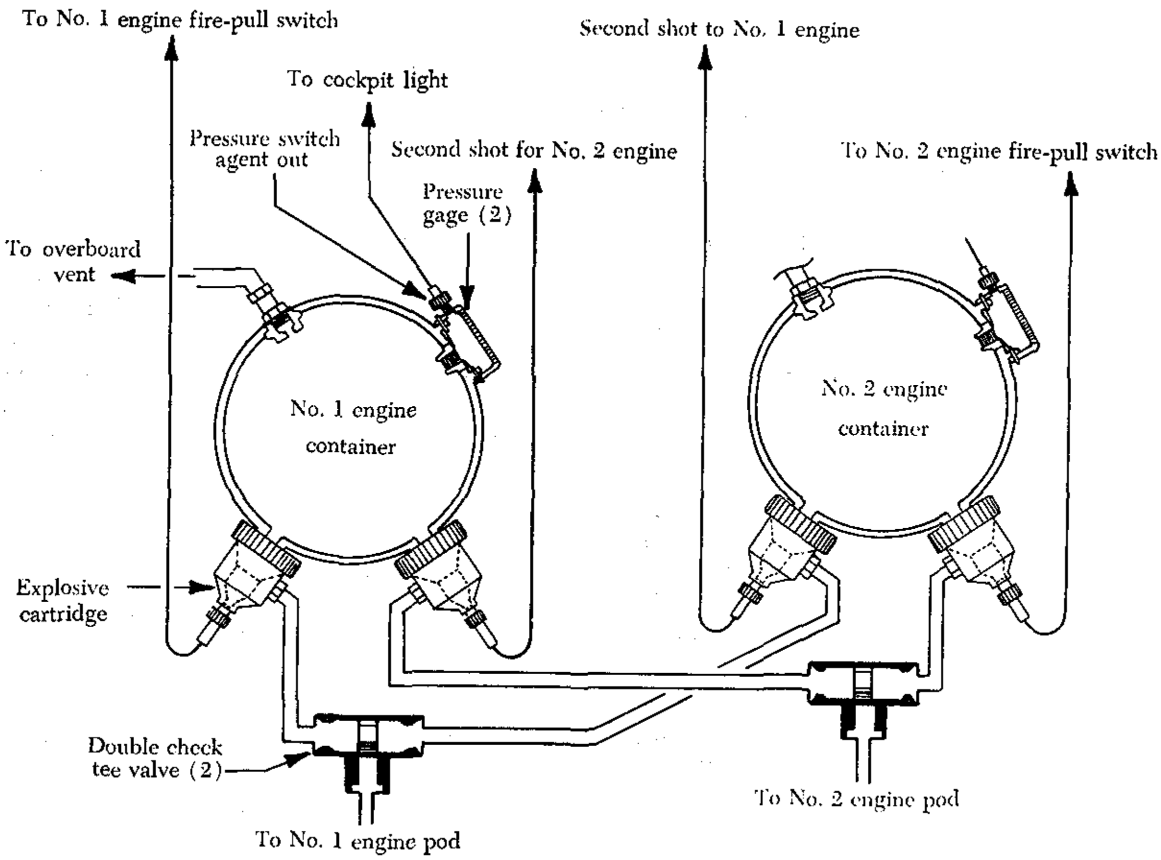

FIGURE 9–12. Fire extinguisher system for a multi-engine aircraft.

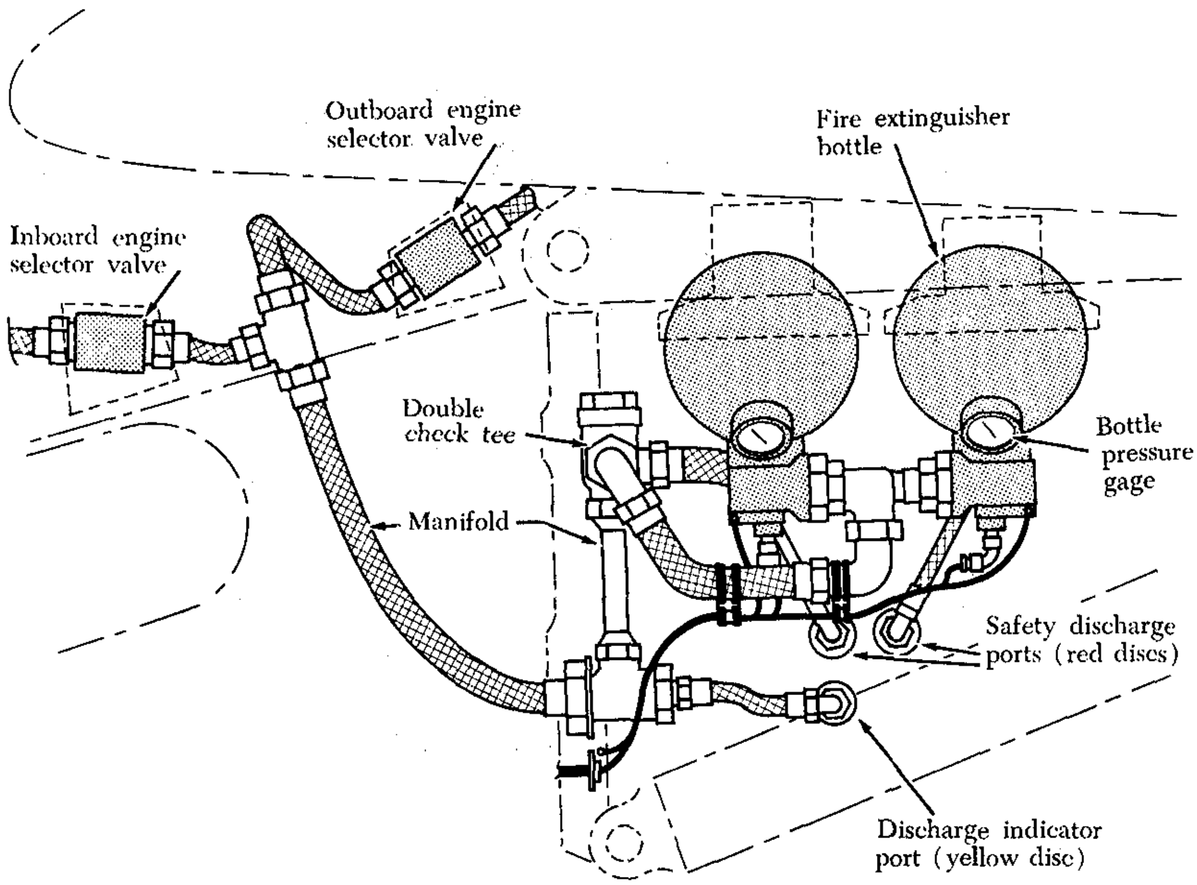

FIGURE 9–13. Dual container installation and fittings.

is pressurized from either container. The discharge line has two branches (figure 9–13), a short line to the inboard engine and a long one extending along the wing leading edge to the outboard engine. Both of the branches terminate in a T-fitting near the forward engine mount.

Discharge tube configuration may vary with the type and size of turbine engine installations. In figure 9–14, a semicircular discharge tube with Y-outlet terminations encircles the top forward area of both the forward and aft engine compartments. Diffuser orifices are spaced along the diffuser tubes. A pylon discharge tube is incorporated in the inlet line to discharge the fire extinguishing agent into the pylon area.

Another type of fire extinguisher discharge configuration is shown in figure 9–15. The inlet discharge line terminates in a discharge nozzle, which is a T-fitting near the forward engine mount. The T-fitting contains diffuser holes that allow the fire extinguishing agent to be released along the top of the engine and travel downward along both sides of the engine.

When any section of the continuous-loop circuit is exposed to an overheat condition or fire, the detector warning lights in the cockpit illuminate and the fire warning bell sounds. The warning light may be located in the fire-pull T-handle, or in some installations the fire switch may incorporate the associated fire warning light for a particular engine under a translucent plastic cover, as shown in figure 9–16. In this system, a transfer switch is provided for the left and right fire extinguisher system. Each transfer switch has two positions: "TRANS" and "NORMAL." If a fire occurs in the No. 4 engine, the warning light in the No. 4 fire switch will illuminate; and with the transfer switch in the "NORMAL" position, the No. 4 fire switch is pulled and the No. 4 pushbutton discharge switch located directly under the fire switch will be accessible. Activating the discharge switch will discharge a container of fire extinguishing agent into the No. 4 engine area.

If more than one shot of the agent is required, the transfer switch is placed in the "TRANS" position so that the second container can be discharged

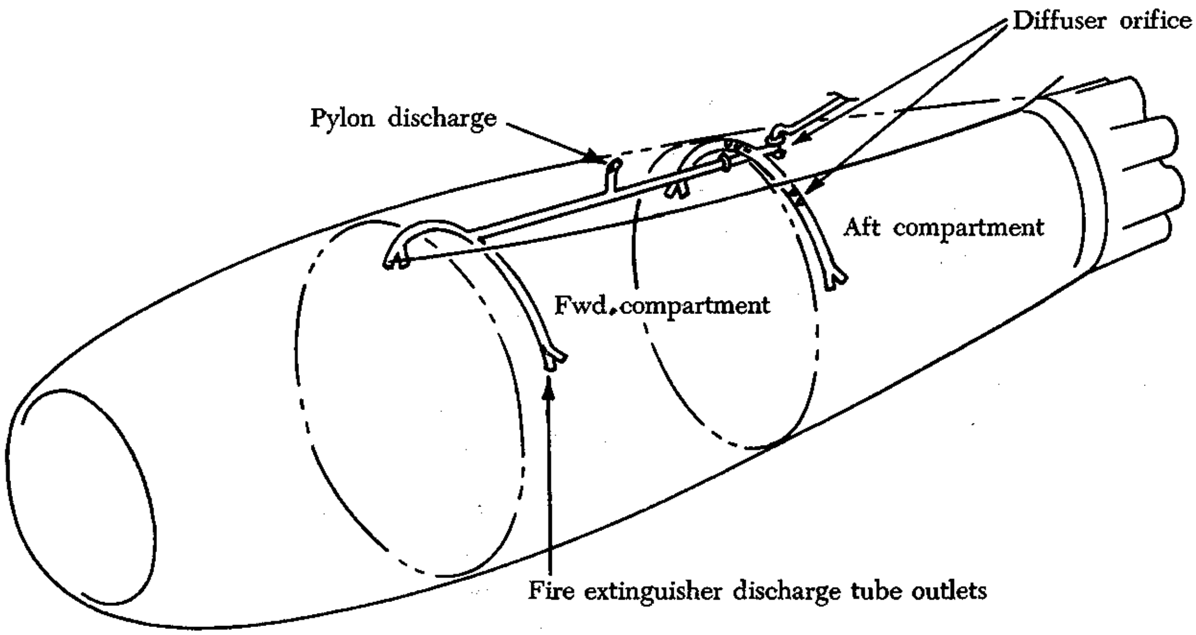

FIGURE 9–14. Fire extinguisher discharge tubes.

into the same engine.

An alarm bell control permits any one of the engine fire detection circuits to energize the common alarm bell. After the alarm bell sounds, it can be silenced by activating the bell cutout switch (figure 9–16). The bell can still respond to a fire signal from any of the other circuits.

Most fire protection systems for turbine engine aircraft also include a test switch and circuitry that permit the entire detection system to be tested at one time. The test switch is located in the center of the panel in figure 9–16.

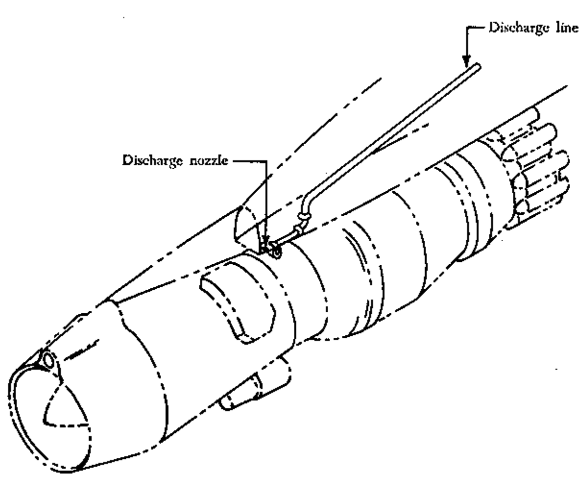

FIGURE 9–15. Fire extinguisher discharge nozzle location.

FIRE DETECTION SYSTEM MAINTENANCE PRACTICES

Fire detector sensing elements are located in many high-activity areas around aircraft engines. Their location, together with their small size, increases the change of damage to the sensing elements during maintenance. The installation of the sensing elements inside the aircraft cowl panels provides some measure of protection not afforded elements attached directly to the engine. On the other hand, the removal and re-installation of cowl panels can easily cause abrasion or structural defects to the sensing elements. 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 which may short the spot-detector terminals.
(4) Condition of rubber grommets in mounting clamps, which may be softened from expo-

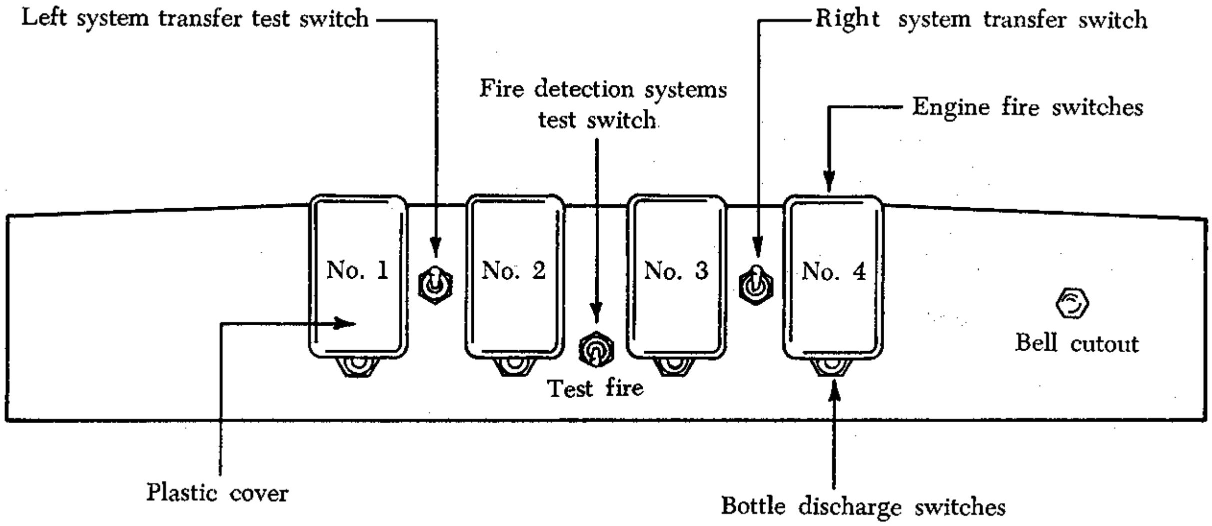

FIGURE 9–16. Fire detection system and fire switches.

sure 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. (See illustration of kinked tubing in figure 9–17.)

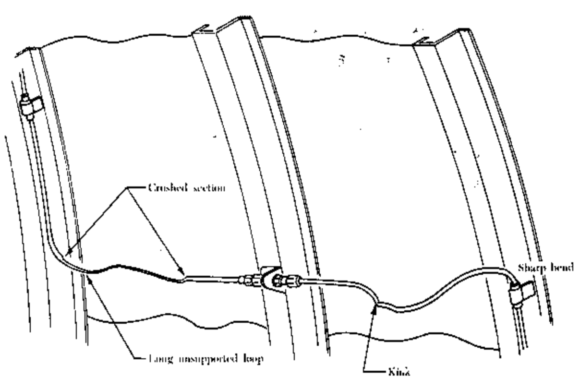

FIGURE 9–17. Sensing element defects.

(6) Nuts at the end of the sensing elements (figure 9–18) should be inspected for tightness and 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. These 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 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 9–19). Long, unsupported sections may permit excessive vibration that can cause breakage. The distance between clamps on straight runs, usually about 8 to 10 in., is specified by each manufacturer. At end connectors, the first support clamp usually is located about 4 to 6 in. from the end connector fittings. In

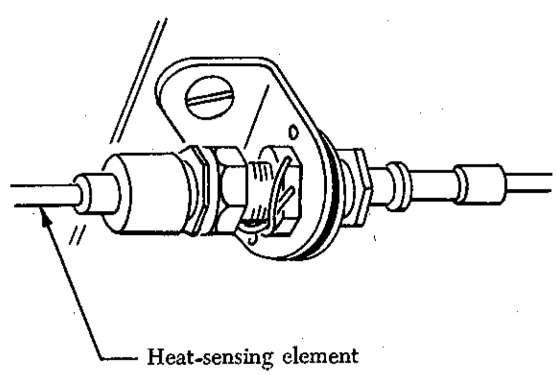

FIGURE 9–18. Connector joint fitting attached to structure.

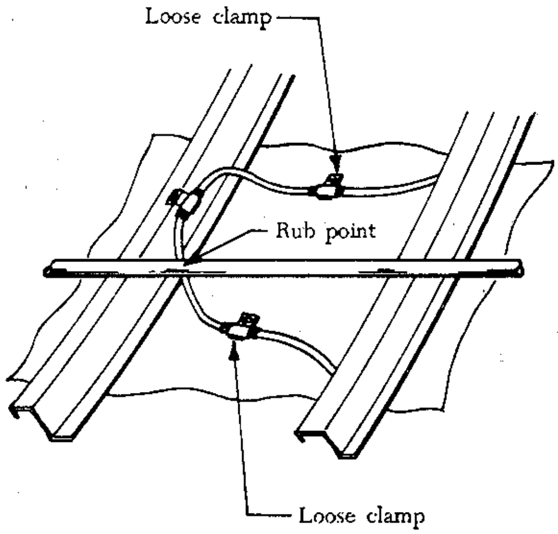

FIGURE 9–19. Rubbing interference.

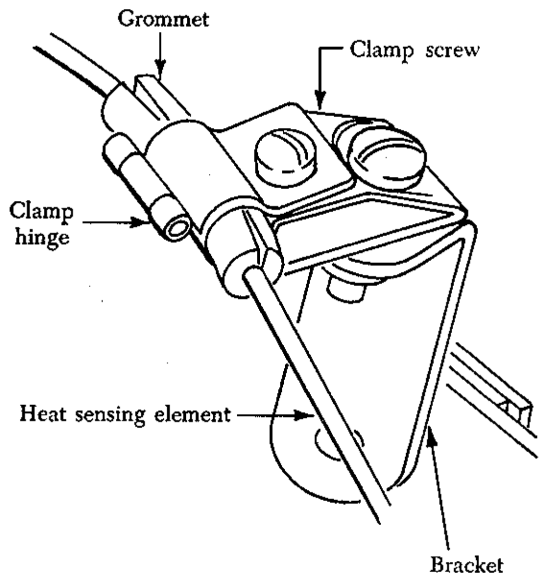

FIGURE 9–20. Typical fire detector loop clamp.

most cases, a straight run of 1 in. is maintained from all connectors before a bend is started, and an optimum bend radius of 3 in. normally is adhered to.

(9) Interference between a cowl brace and a sensing element can cause rubbing (figure 9–19). 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 (figure 9–20) should fit the element snugly.

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.

(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 which 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 a megger 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 will persist 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 re-installation 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 9–21 is typical of the pressure-temperature curve graphs that provide maximum and minimum gage 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 hours below a predetermined temperature limit. Cartridges are available with a service life of approximately 5,000 hours. 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. On one type fire extinguisher container, the date can be seen without removing the plug body. Refer to figure 9–22 for location of the components of a typical extinguisher container.

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, as illustrated in figure 9–22.

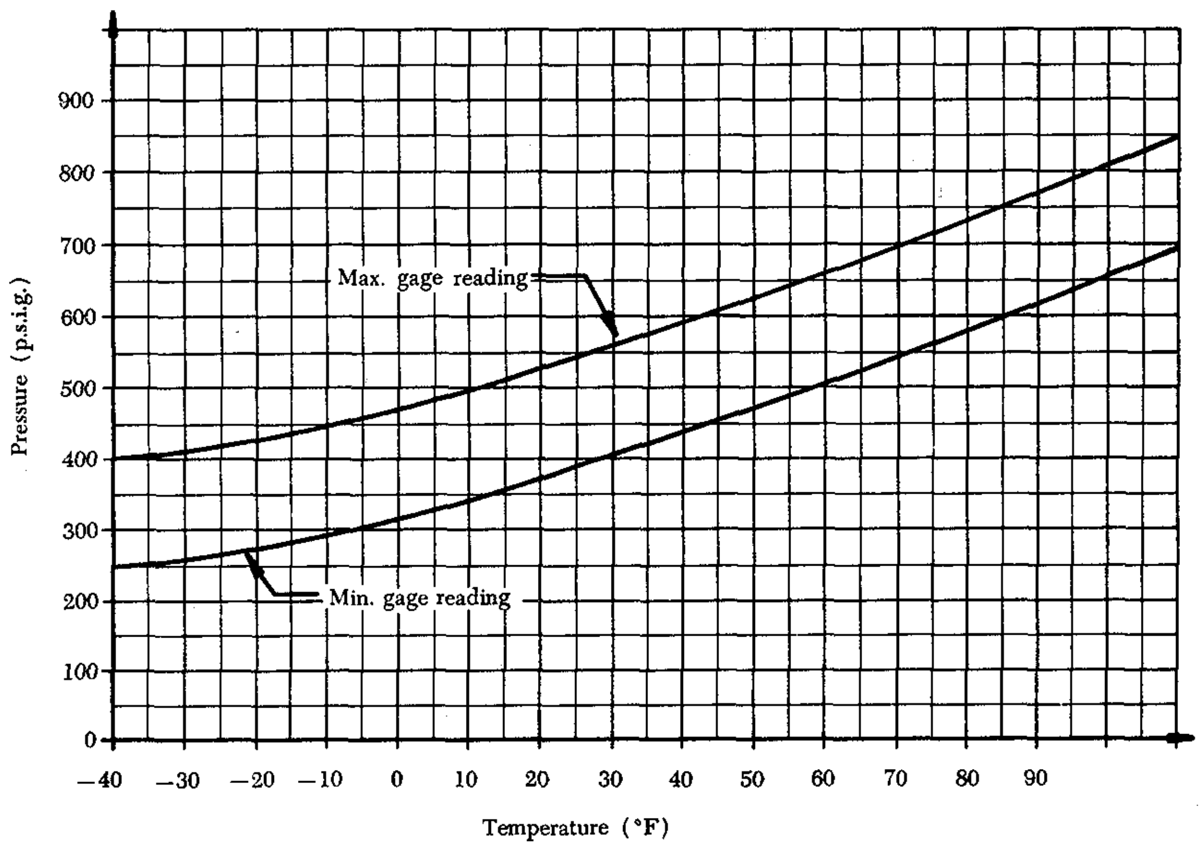

FIGURE 9–21. Fire extinguisher container pressure-temperature curve.

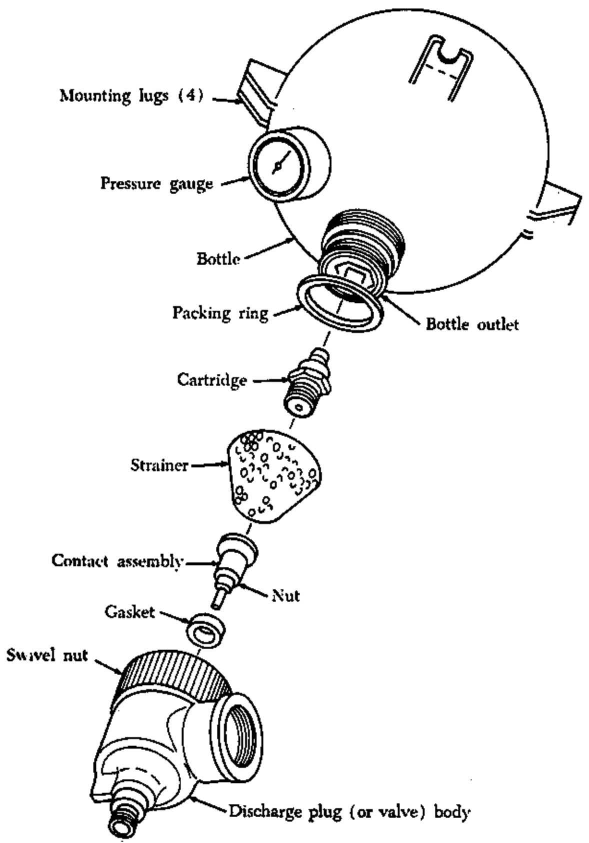

FIGURE 9–22. Components of a typical fire extinguisher container.

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.

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.***

TURBOJET AIRCRAFT FIRE PROTECTION SYSTEM (SABERLINER)

This description of the fire protection system installed in the Saberliner is included for familiarization purposes.

A high-rate-of-discharge fixed fire-extinguishing system is provided for each engine pod. Fire detector elements are located at strategic points within each pod as illustrated in figure 9–23. Two pressurized extinguishing-agent containers provide bromotrifluoromethane. This can be directed from either container to either engine pod as required. The discharge lines from each container meet at a double-check "T" valve to make a single discharge line. The one-way check valve prevents one container from discharging into the other container line and, thereby, possibly depleting the contents of one container into the other.

The system is controlled from the cockpit by the use of manual handles plus an electrical selector switch. Two discharge indicator disks, mounted externally on the fuselage, indicate either manual discharge of the containers, or automatic discharge overboard due to a thermal condition. A pressure gage, mounted on each container, and visible from the main wheel well, indicates pressure in the container.

A discharge valve is attached to the bottom of each container. The cartridge in the extinguisher No. 1 or extinguisher No. 2 discharge valve, figure 9–24, is ignited by 28-volt dc power when a "FIRE PULL" handle is pulled and the fire-extinguisher

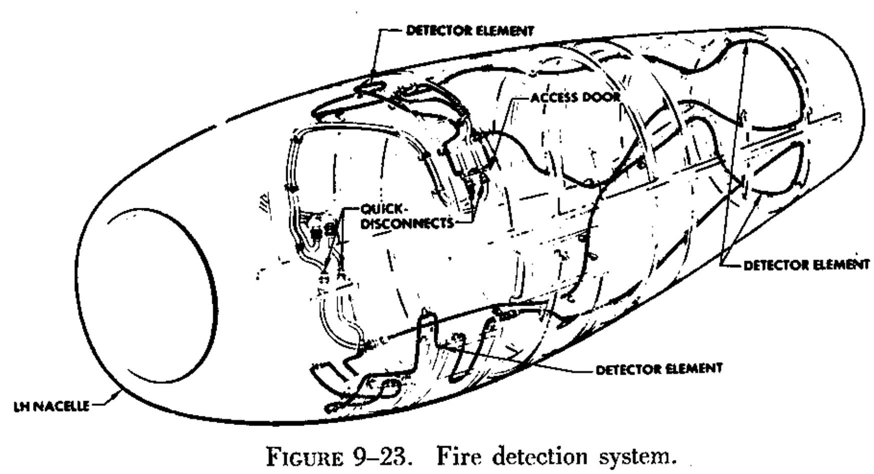

FIGURE 9–23. Fire detection system.

selector is actuated to either EXT No. 1 or EXT No. 2. A direction valve then routes the extinguishing agent to the proper engine, according to which "FIRE PULL" handle is pulled. When a cartridge is fired, the contents of one container are discharged by nitrogen pressure and forced through delivery lines and nozzles into the forward compartment of the selected engine pod.

Operation of System

Mechanically interconnected "FIRE PULL" handles, one for each engine are on the fire-extinguisher control panel, on the windshield bow. During a fire or overheat condition, indicated by a warning light in the respective "FIRE PULL" handle, immediately pull handle aft. When the right hand "FIRE PULL" handle is pulled, the emergency bleed-air shutoff valve closes and the extinguisher system direction valve is energized to allow the extinguishing agent to be routed to the right-hand engine. In addition, the dc generator is taken off the line. When the "FIRE PULL" handle is returned to its original position, those items previously turned off, except the dc generator, are reinstated, unless the engine master switch is turned off. If the second "FIRE PULL" handle is pulled, the first handle automatically retracts to its original position.

Selector Switch

The fire-extinguisher selector switch, is mounted in the center of the extinguisher control panel and powered by the dc essential bus and has three positions: EXT No. 1, EXT No. 2, and a center, unmarked, "OFF" position. When the selector switch is momentarily positioned to either EXT No. 1 or EXT No. 2 and has been armed by pulling the "FIRE PULL" handle, the extinguishing agent from one container is discharged to the engine pod selected by the handle. After the initial container has been expended, the fire-extinguisher selector switch may, if necessary, be momentarily positioned to the other extinguisher to discharge the second container.

Direction Valve

Downstream from the double-check "T" valve, the line connects to a direction valve. (Figure 9–24.) The valve has two exit ports: a normally open port connected with the left engine pod fire-extinguishing discharge line, and a normally closed port connected with the discharge line to the right engine pod. When the right-hand engine "FIRE PULL" handle is pulled, an electrical circuit is completed to the direction valve, energizing the solenoid. The fire-extinguishing agent discharge is then directed to the right-hand engine pod.

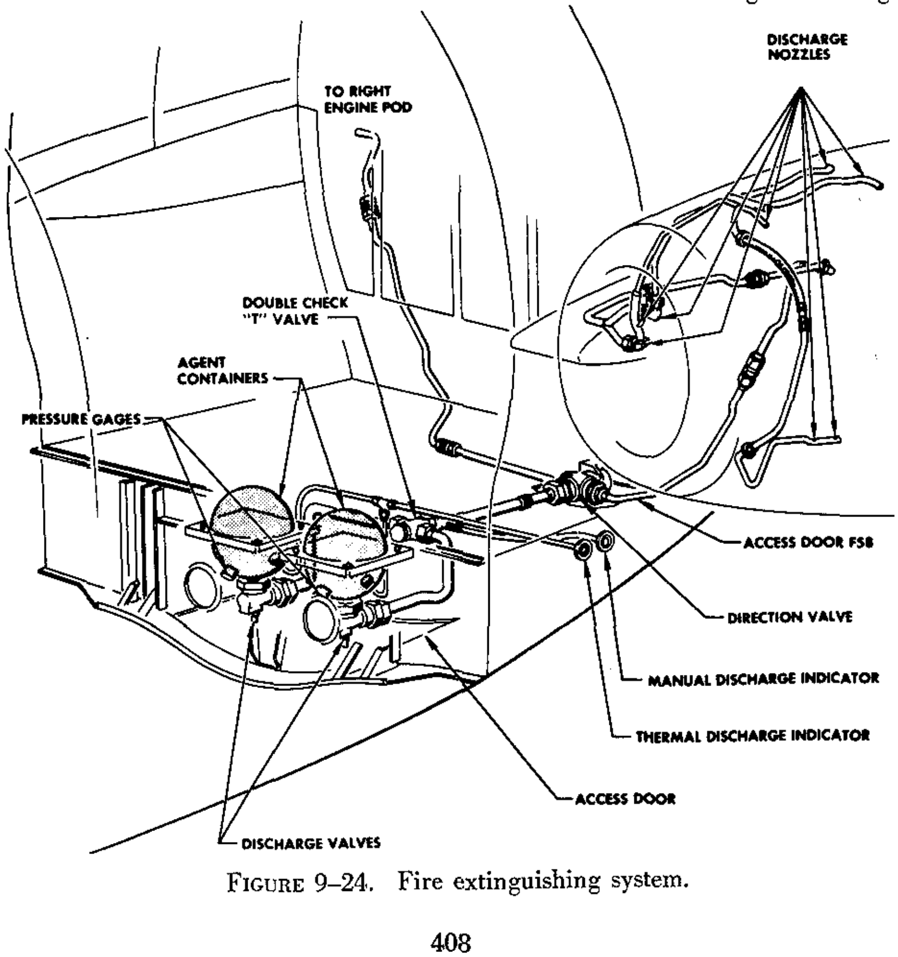

FIGURE 9–24. Fire extinguishing system.

Agent Containers

Two containers for the fire-extinguisher system are installed aft of the main wheel well area between fuselage stations 298 and 307. Each container has a gage which indicates the pressure in the container. A discharge valve containing a cartridge is mounted on the lower part of each container. The cartridge, when fired, discharges the container contents into the ducting toward the engine pods. A fitting is provided in each container to accommodate lines to the thermal discharge indicators installed in the fuselage exterior.

Indicators

Two fire-extinguishing system discharge indicating disks are mounted on the left side of the fuselage, aft of the wing. The yellow disk in the aft discharge indicator is connected by a $\frac{1}{4}$-inch line to the fire extinguisher discharge line between the double-check "T" valve and the direction valve. When either container is discharged, a limited flow will be directed to the yellow disk, blowing it out. A check of the container pressure gages will show whether one or both containers have been discharged.

The red disk in the forward discharge indicator is connected by a $\frac{1}{4}$-inch line to both containers. When the containers have been overheated excessively, the internal pressure will cause the fusible safety outlet plug to discharge. The agent flow will be directed to the red disk, blowing it out. A check of the container pressure gages will show whether one or both containers were discharged.