5 Fire Protection (ATA 26)

5.1 Definition

Those fixed and portable units and components which detect and indicate fire or smoke and store and distribute fire extinguishing agent to all protected areas of the aircraft; including bottles, valves, tubing, etc. (**ATA 100**)

5.2 Detection Fundamentals

Fire detection comprises that part of the fire protection system, which is used to sense and indicate the presence of overheat, smoke, or fire (**ATA 100**).

There are various **ways in detecting a fire**, including:

- **direct observation** by cockpit and cabin crew (optical indication, sensing of heat or smell)
- **overheat detector**
- **smoke detector**
- rate-of-temperature-rise detector
- inspection by video camera
- fiberoptic detectors
- thermal imaging devices
- radiation sensing devices
- ultraviolet aircraft fire detection system
- detection of combustion gases like CO or CO_2

Designated **fire zones** must be equipped with fire detection and extinguishing equipment. Designated fire zones are (**JAR-25**, **FAR Part 25**):

- power plant compartment (section 1181)
- auxiliary power unit (APU) compartment (section A1181)
- combustion heater chamber (section 859)

Fire detection and extinguishing equipment is required for cargo compartments according to the **cargo compartment classification** (section 857, **JAR-25**, **FAR Part 25**):

- *Class A* compartments are accessible in flight. A fire in the compartment would be easily discovered by a crew member while at his station.
- *Class B* compartments provide access in flight to enable a crew member to use a hand fire extinguisher. The compartments are equipped with a smoke or fire detector.

- *Class C* compartments are equipped with a smoke or fire detector and a built-in fire extinguishing system.
- *Class D* compartments are able to confine a fire completely without the safety of the aircraft being endangered.

Lavatories must be equipped with a smoke detector system, and lavatories must be equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper, or waste, located within the lavatory (section 854, **JAR-25**, **FAR Part 25**).

Other areas equipped with fire detectors may include the avionic compartment or the landing gear bay.

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fire detector
├───>overheat detector
│     ├───>point detector
│     │     ├───>thermal switch
│     │     │     ├──>spot detector
│     │     │     └──>bimetallic thermostat
│     │     └────>thermocouple
│     └───>continuous-loop detector
│           ├───>electric
│           │     ├──>averaging
│           │     └──>discrete
│           └───>pneumatic
├───>smoke detector
│     ├───>ionization type
│     └───>photoelectric type
└───>...
```

Figure 5.1 Roadmap to the most widely used detection devices

Fire detectors are generally either *overheat detectors* or *smoke detectors*. From the beginnings until today, these and other **fire-detection devices** for aircraft have been developed by only a few US companies: *Walter Kidde*, *Fenwal*, and *Systron-Donner*. Their component designs will be presented here (**Hillman 2001**). The roadmap to the following discussion of the most widely used detection devices is presented in Figure 5.1.

5.3 Overheat Detection

In the 1940s overheat detection coverage in the engine nacelle was done with *thermal switches* or *thermocouples*. Several of these switches were positioned in parallel at different places around the engine. A fire alarm was activated if one of the switches was triggered.

However, it was recognized that these **point detectors** were very limited with regard to area of coverage. The placement of the point detector therefore became the most critical factor in how successful the detection system would be.

In the early and mid 1950s **continuous-loop detectors** were introduced in the aircraft industry. This technology became the most popular detection approach for aircraft engines and has remained so to this day. Distinguished are *electric* continuous-loop detectors and *pneumatic* continuous-loop detectors. Electric continuous-loop detectors are of either *averaging type* or the *discrete type* (Figure 5.2).

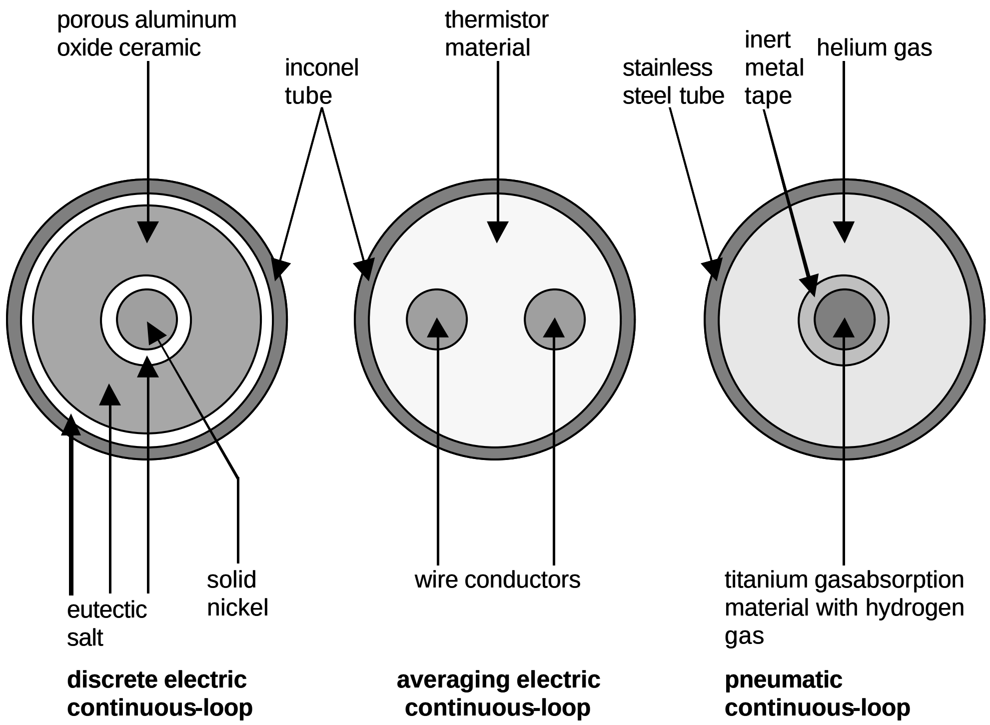

Figure 5.2 Cross section of continuous-loop detectors

Some versions of electric continuous-loop detectors dependent on the amount of element heated to reach their alarm threshold level. These have been termed **averaging electrical continuous-loop detectors**. Their alarm threshold averages the temperature over its entire length. These detectors monitor either changing electrical *resistance* alone or *resistance and capacitance* in conjunction. Electrical continuous sensing elements have one or two internal wire conductors embedded in a ceramic-like thermistor material contained in a metallic outer tube. As the surrounding temperature increases, the resistance between the inner conductor and the outer tube conductor decreases while the capacitance increases. When two internal wire conductors are embedded in the sensing element, the resistance change between these two wires is typically measured. When the resistance between the internal conductor and the external sensing element tube drops to some predetermined level (and/or the capacitance increases) corresponding to the desired alarm temperature, a monitoring *control unit* issues a hazard signal. When the hazard condition is eliminated and the temperature returns to normal, the resistance increases and the capacitance decreases, thereby canceling the alarm. Multiple trip resistance / capacitance settings can be used when multiple thresholds are pursued to indicate fire versus overheat.

Shortly after the first averaging-type detection systems, **discrete electrical continuous-loop detectors** were introduced (Figure 5.3). To achieve its alarm threshold, the discrete system utilizes sensing elements that are essentially independent of the length of element heated. These systems employ a sensing element which, as in the electrical averaging systems, has either one or two internal wire conductors embedded in a ceramic-like core material surrounded by a metallic outer tube. The ceramic core is impregnated with eutectic salt. The salt melts at its eutectic melt temperature, even when only a very short length of element is heated. When this occurs, the electrical resistance between the inner conductor and the outer tube very rapidly breaks down (also, the capacitance increases), and a monitoring control unit signals a fire or overheat, depending on which is appropriate for the intended application. The characteristics of the discrete type are paramount for reliable early warning of small, discrete overheat events, such as bleed air duct failures. By its nature, the discrete type cannot provide multiple alarm thresholds or any kind of analog temperature trend information.

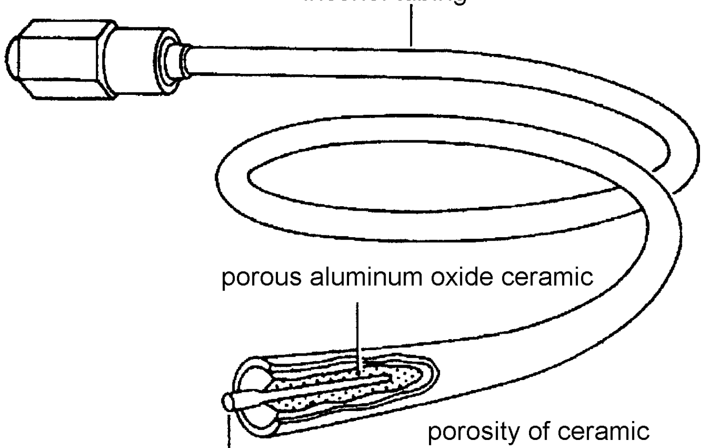

Figure 5.3 Discrete electric continuous-loop detector (A321, pneumatic system, leak detection)

Pneumatic-based **continuous-loop detectors** rely on increasing gas pressure to achieve the alarm threshold. These sensing elements have a hydrogen-charged core surrounded by helium gas, contained in a metallic outer tube. As the surrounding temperature increases, the helium gas pressure increases, closing a pressure switch and thereby issuing an alarm. As the temperature returns to normal, the pressure decreases and the alarm is canceled. If a localized high temperature event is present, the hydrogen core also outgasses its hydrogen gas, increasing the internal pressure and closing the pressure switch. As the sensing element cools, the hydrogen absorbs back into the core so that the internal pressure decreases, removing the alarm output. A leak in the detector can be discovered with an integrity switch opening due to a loss of pressure (Figure 5.4).

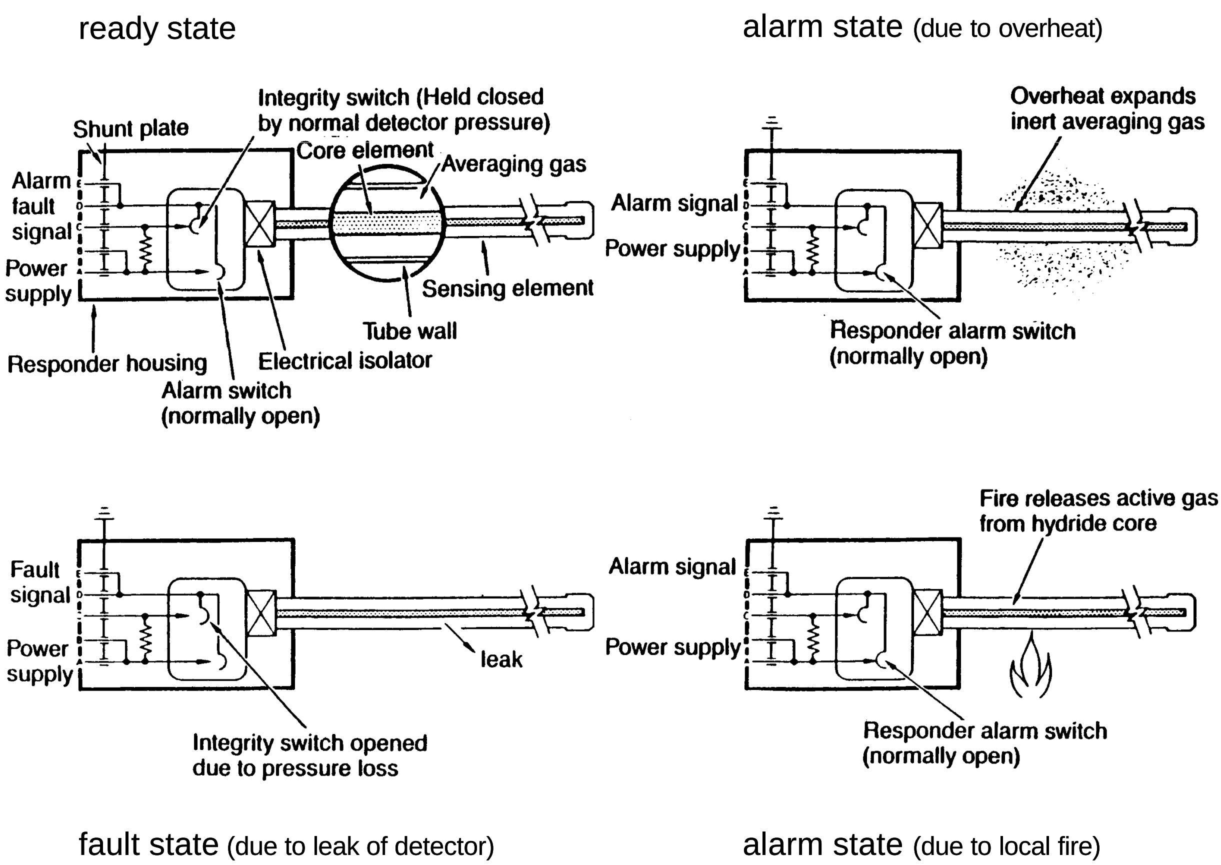

Figure 5.4 Principle of pneumatic continuous-loop detector (A321)

Overheat detection may be applied in the areas of the *engine*, *auxiliary power unit* (APU), *bleed air ducts*, and the *landing gear bay*.

5.4 Smoke Detection

Smoke detection systems are the primary means of fire detection used in cargo compartments. This has not changed much over the last 50 years. While solid state electronics and new optics and new processing algorithms have been introduced, the basic mechanism that these detectors operate under has remained the same. There are two basic designs of smoke detectors: *ionization* and *photoelectric*.

Ionization-type smoke detectors monitor ionized combustion byproducts as they pass through a charged electrical field. Photoelectric detectors measure light attenuation, reflection, refraction, and/or absorption of certain wavebands. Ionization smoke detectors have been used from the early years. The typical approach was to use a radioactive isotope as the source to charge the combustion products (Figure 5.5). However, this source may also charge everything else, including dust and fine water droplets and can make ionization type-detectors unreliable. Ionization-type smoke detectors have been used by the commercial aviation community primarily in lavatories and cargo compartments.

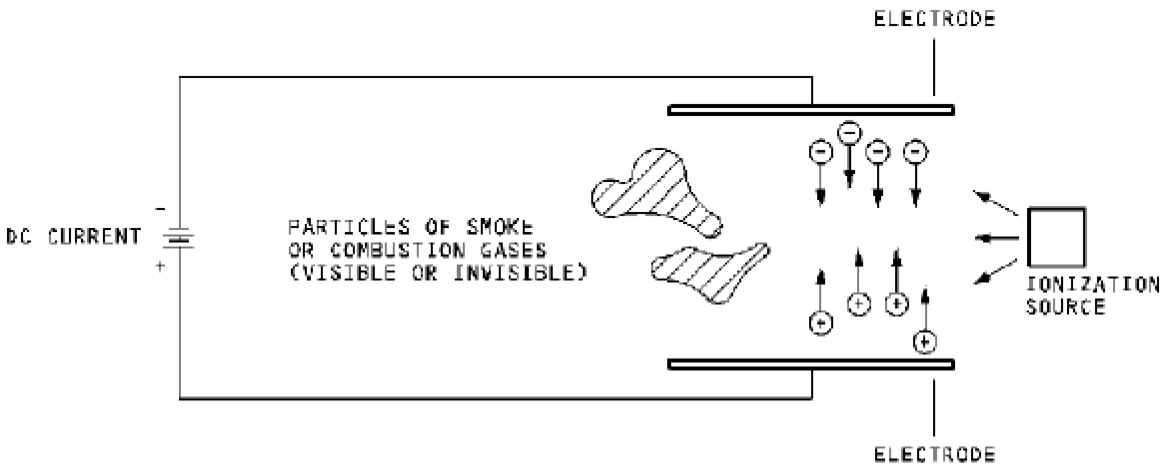

Figure 5.5 Principle of ionization type smoke detector (A321)

Photoelectric-type smoke detectors have become the industry standard. This is not to imply that photoelectric-based detectors have been free from false alarms. These detectors, too, have been quite troublesome over the years. Most cargo compartment applications use aerospace-quality photoelectric-type smoke detectors that rely on scattered or reflected light radiation caused by a particulate matter between a radiation-emitting source and a detector device. Solid state photoelectric smoke detectors use a long-life light-emitting diode (LED) as the source of light.

Smoke detectors still have many limitations. Their operational success depends highly on their placement with respect to where a fire event is. But there are also **problems with other detectors**. Since one cannot count on a visual line of sight of a cargo bay fire, future cargo-detection technologies cannot rely on the use of video camera or thermal imaging devices. Deep-seated fires and/or fires inside LD3 containers will still be hidden. This makes standalone thermal-based systems impractical. While combustion gases, such as CO or CO_2, could be monitored, these gases may be introduced from sources other than fires.

Smoke detection can be applied in the *cargo compartment*, *lavatories*, *galleys*, and *avionic compartments.*

5.5 Extinguishing Fundamentals

Fire extinguishing includes that part of the fire protection system using fixed or portable systems used to extinguish a fire (**ATA 100**).

A **fire classification** includes three types of fire relevant to aircraft application:

- *Class A*:
  Fires involving ordinary combustible solid materials, such as wood, paper, rubber and many plastics
- *Class B*:
  Fires involving flammable liquids, oils, greases, paints, lacquers and flammable gases
- *Class C*:
  Fires involving energized electrical equipment.

Each of these types of fires requires its own suitable **type of extinguisher**:

- *Water* extinguishers are used on Class A fires only. Water must never be used on Class C fires and can be counterproductive on Class B fires.
- *CO_2* extinguishers are specifically used to combat Class C fires. A hand-held CO_2 extinguisher includes a megaphone-shaped nozzle that permits discharge of the CO_2 close to the fire. Be aware that excessive use of CO_2 extinguishers robs a closed area of oxygen. In an aircraft, this could affect passengers.
- *Dry chemical* fire extinguishers can be used on Class A, B, or C fires. Use of such an extinguisher on the flight deck could lead to temporary severe visibility restrictions. In addition, because the agent is nonconductive, it may interfere with electrical contacts of surrounding equipment.
- *Halon* has almost exclusively been in use in portable aircraft fire extinguishers.

In the *late 1940s* time frame, the very effective halogenated hydrocarbon (later termed *halon*) fire extinguishing agents were introduced. The primary agents used for fixed fire extinguishing systems were methylbromide (Halon 1001) and bromochloromethane (Halon 1011). **Halon 1011** eventually displaced Halon 1001 for engine extinguishing systems primarily because of lower toxicity and corrosion.

The halons introduced in the *early 1950s* were less toxic than Halon 1011. Over the next 30 years, the higher vapor pressure bromotrifluoromethane (Halon 1301) essentially displaced most of the Halon 1011. Because of the high vapor pressure of **Halon 1301**, the use of elaborate spray nozzles and spray bars was no longer required. The new Halon 1301 extinguisher systems were designed to discharge at a very high rate. This concept was called the *high rate discharge* (HRD) concept. The high rate discharge systems utilized halon pressurized to 600 psig (40 bar).

Hand-held dibromoflouromethane (**Halon 1211**) and/or water extinguishers have been the approved approach for accessible fire fighting.

In *recent years*, due to international agreement on banning the production and use of ozone-depleting substances, including all the halons, the need for **alternate extinguishing agents** to the halons has arisen. However, the use of halons is still permitted for essential applications, such as aircraft, until a "suitable" replacement agent can be developed, approved, and certified for aircraft use. Until that time comes, existing stocks of halon, recovered from decommissioned fire protection systems, are sufficient to support many years of aircraft production and use. Upon review of alternative agents, it is evident that there is no clear winner with respect to a replacement for Halon 1301 in fire suppression systems that will use similar hardware and architecture. Each candidate has at least one characteristic that makes it inferior to Halon 1301.

5.6 Engine and APU Extinguishing

First step: **the engine is shut down** and combustible fluid entry (jet fuel, hydraulic fluid, and engine oil) into the engine compartment is stopped. This is necessary for the engine extinguisher to be effective. If the engine were not shut off, the fire would probably just relight after the extinguishing agent dissipated. Because of this practice, only multiengine aircraft utilize extinguishing systems.

Second step: **the extinguishing agent flows from a pressure vessel** through rigid pipes and is sprayed in the engine-protected zones.

Third step: If after some time (30 s) the fire warning still remains on, **extinguishing agent from a second pressure vessel** (if still available for that engine) **may be used** for further fire extinguishing.

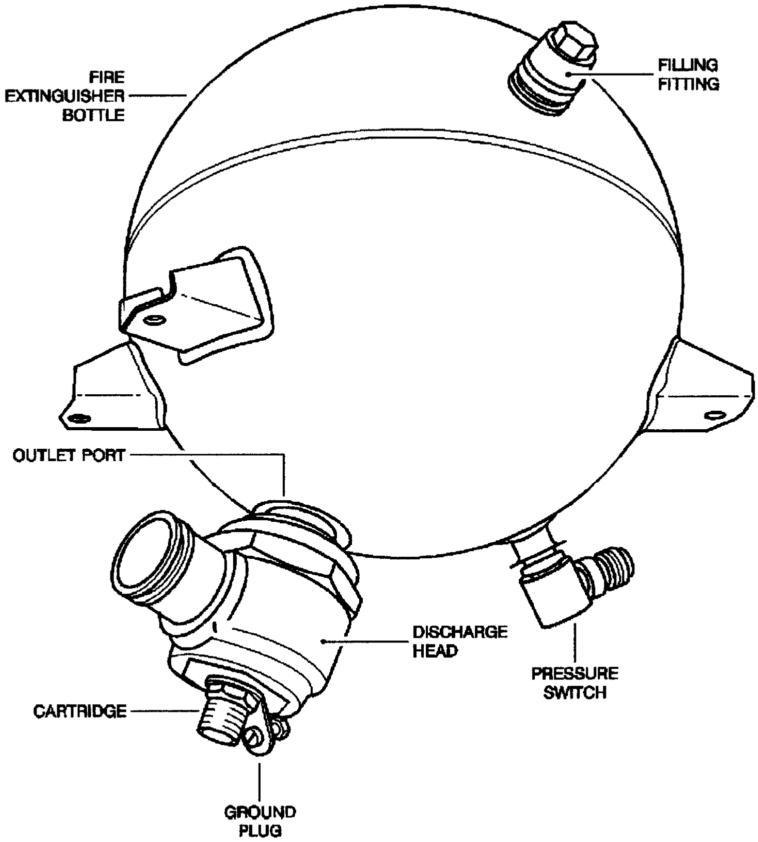

Figure 5.6 Fire extinguishing bottle (A321)

The extinguishing agent is stored in high-pressure vessels commonly called *bottles*. A **spherical-shaped pressure vessel** design represents the most weight- and volume-efficient geometrical configuration for containing the greatest amount of agent. It is also the optimum shape with respect to stress levels in the vessel's material. The spherical pressure vessel is the most popular design (Figure 5.6). Other details of the design are stated in section 1199 of **JAR-25** and **FAR Part 25**.

APU fire extinguishing is technically similar to engine fire extinguishing, but the APU may only be equipped with one bottle.

5.7 Cargo Extinguishing and Inerting

Cargo compartments have traditionally been protected with hand-held fire extinguishers if the compartment was accessible and with a fixed Halon 1301 fire extinguishing/inerting system if the compartment was not accessible.

Like engine extinguishing systems, a cargo compartment suppression system is required to provide an initial peak volumetric agent concentration to "knock-down" the fire. Since complete fire extinction cannot be assured, a cargo suppression system is required to maintain a lower concentration for some extended period of time. The compartment is thus inerted to prevent the fire from reigniting or growing. The typical time period for keeping the compartment inert against flaming combustion is 60 minutes. In case of *extended range twin-engine operations* (ETOPS), inerting periods are much higher.

A typical cargo fire suppression system will consist of two fire extinguishers connected to single or multiple cargo compartments by distribution plumbing. The “knock-down” or *high rate discharge* (HRD) extinguisher provides the initial high volumetric concentration, and the second *low rate discharge* (LRD) extinguisher provides the metered lower inerting concentration.

5.8 Passenger Compartment Extinguishing

Fires that could occur in an aircraft cockpit or cabin are Class A, B, and C. The number of hand-held fire extinguishers to be carried in an aircraft is determined by section 851 of the certification regulations (**JAR-25**, **FAR Part 25**).

For airplanes with a passenger capacity of 20 or more, each lavatory must be equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper, or waste, located within the lavatory. The extinguisher must be designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle (section 854 **JAR-25**, **FAR Part 25**).

5.9 Example: Airbus A321

For each engine, two fire *extinguisher bottles* contain fire extinguishing agent. The fire extinguisher bottles are connected to the *extinguishing lines*. The lines are routed in the pylon, leading to the *outlet nozzles* around the engine. The agent from the second bottle can be used if, after application of the first bottle, the fire warning remains on. The fire extinguisher bottles are controlled from the cockpit by pressing the DISCH (discharge) button. This supplies 28 V dc to two *filaments* in the *cartridge* on the bottle (see Figure 5.7). The filaments ignite 400 mg of explosive powder, which in turn causes rupture of the *frangible disc* in the cartridge and frees the agent with a high discharge rate.

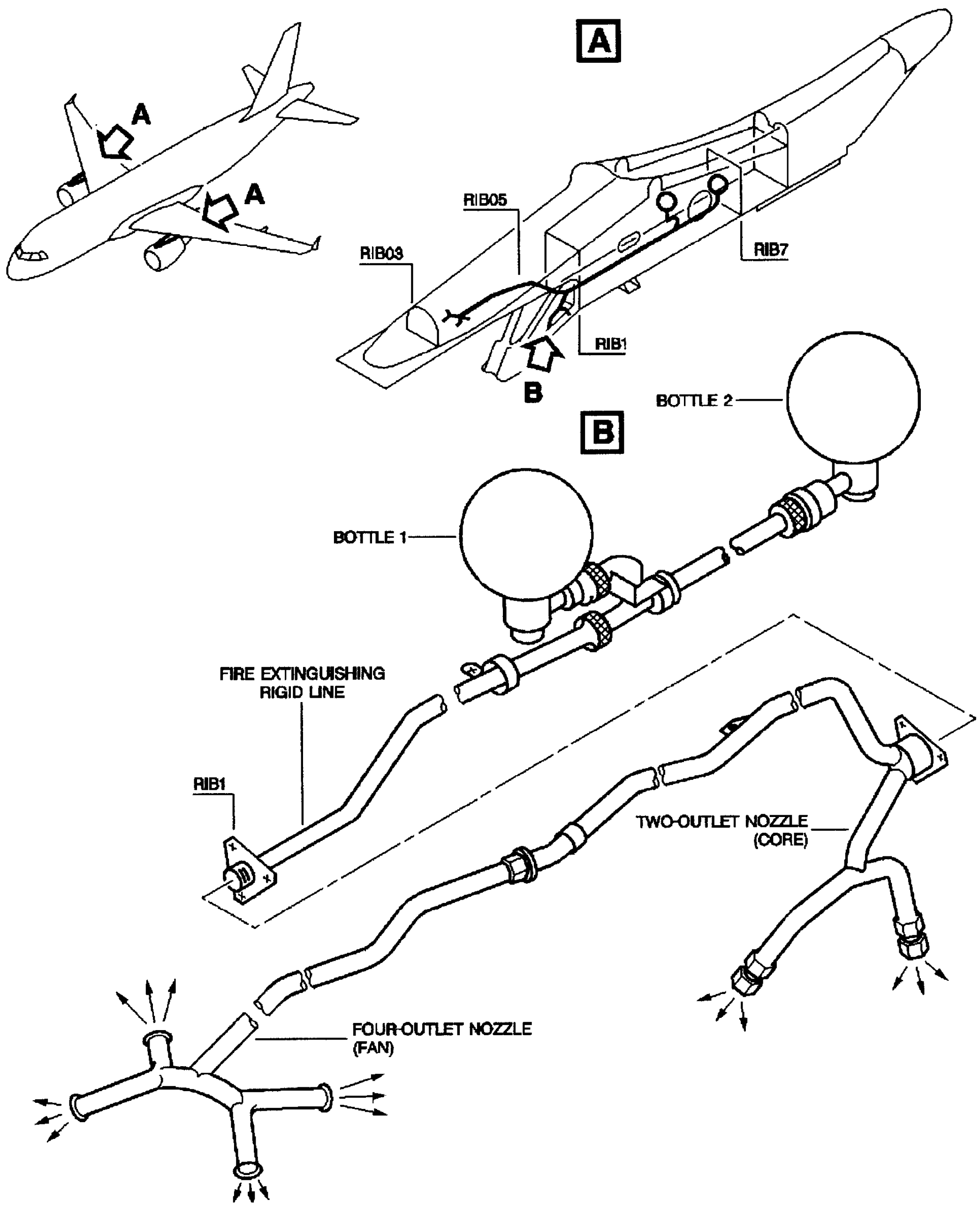

Figure 5.7 A321 engine fire extinguishing distribution system