Introduction to Aircraft Systems

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Aircraft emergency system/應急系統

- Introduction
- Warning systems
- Fire detection and suppression
- Emergency power source
- Explosion suppression
- Emergency oxygen
- Passenger evacuation & Crew escape
- Crash recorder
- Emergency landing

Evacuation of the US airways flight 1549 as it floats on the Hudson River. Jan 15, 2009.

Introduction

Introduction

- Despite the best efforts of designers, constructors and operators, there will always be the risk of failure or accident that impairs the continuing safe operation of the aircraft.
- Under such circumstances there is the possibility of damage to the aircraft, and the risk of injury and death:
  - Crews & passengers
  - Public members on the ground
- Emergency systems are designed to predict certain failures or accidents.
  - If the statistical probability of the occurrence of failures/accidents is sufficiently high, aircraft will incorporate emergency systems to improve the survivability of the aircraft and its crew.

Introduction

- The **integrity level** of emergency system must be high:
  - it is the final method of survival for aircraft, crew and passengers.
- The emergency system should **be separated** from other aircraft systems:
  - failures are not propagated to them (i.e., emergency system)
- It requires:
  - Separated source of power
  - Alternative methods of operation
  - Clear emergency warning indications

Warning systems

Warning systems

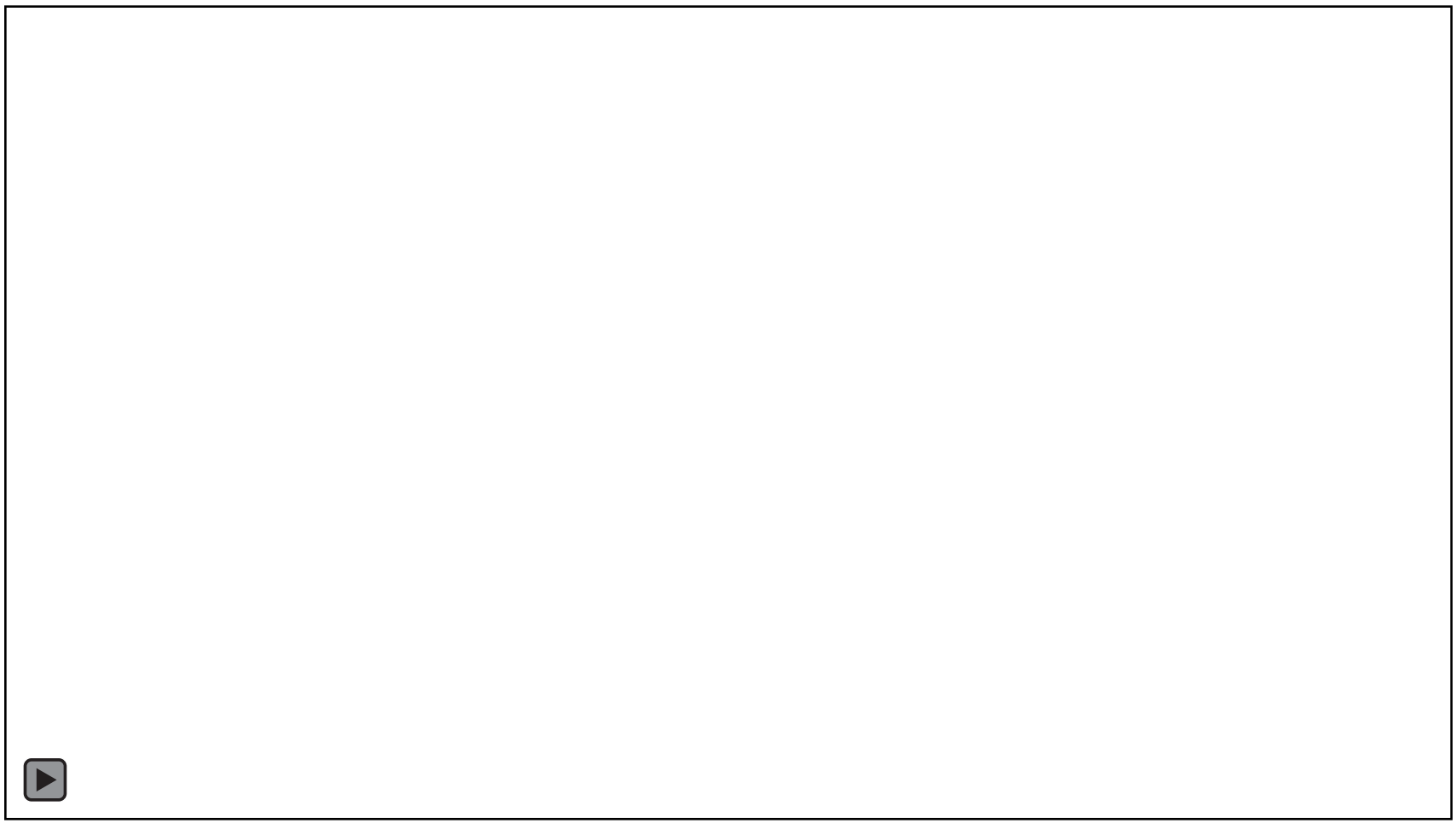
- In modern aircraft, the flight and propulsion systems are automatically controlled.
  - Any detected malfunctions should be sent to the crew for decision making.
- In the past, warnings were presented as individual warning lights
  - The lights were sited on the cockpit panels near to the controls
- Philosophy of color usage:
  - Red: failures and need corrective action
  - Amber: cautions with less need for immediate response
  - Blue and green: for advisory or status indication

Warning systems

Warning systems

- The attention of the crew to the warning can be achieved by:
  - incorporating a flashing lamp or attention-getter in the direct vision of the pilot;
  - using audible tones in the cockpit or on the crew headsets.

- Bells, buzzers, electronic warbles and tones are in use on many aircraft today.
- A hierarchy of tones is required to ensure unambiguous attention getting in circumstances where a number of warnings arise together



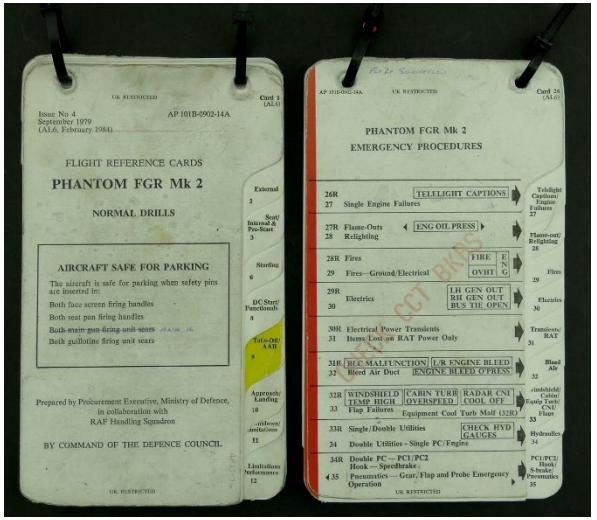
https://www.youtube.com/watch?v=9i2tmlZ509c

Warning systems

- A typical sequence of events for an immediate attention warning:
  - System warning is detected by a sensor or control unit;
  - The signal is sent to the central warning panel;
  - The attention getters flash, and audible tones are illuminated
  - The pilot presses the attention getter to stop the flashing and audible tones
  - The pilot reads the caption and takes the necessary actions

Flight reference card and multi-function displays

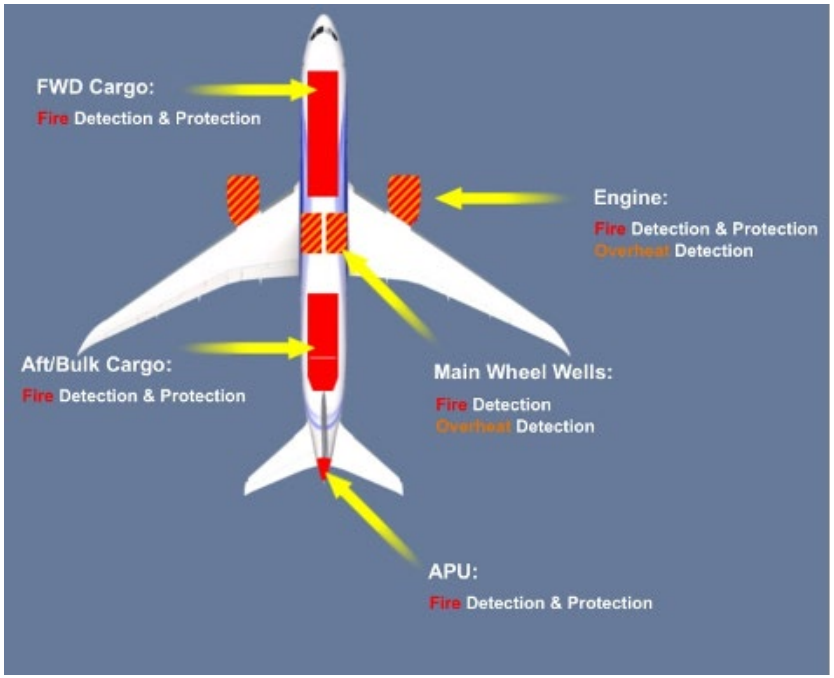
- To ensure the pilot takes the correction action, a set of flight reference cards is carried. The pilot read the caption rapidly to perform the correct action.
- The modern aircraft tends to using the multi-function displays (MFD) to show the warning messages.
  - It can also tell the pilot the action to take.
  - The electronic flight reference can be used to replace the flight reference card



Fire detection and suppression

Fire detection and suppression

- The occurrence of a fire in an aircraft can damage the structure
- Most likely location of fire is related to engine
- Apart from efforts to prevent the fire, detection is still necessary in case of accident
- Fire detection systems are often installed in bays where the engine and APU are located: to detect the temperature

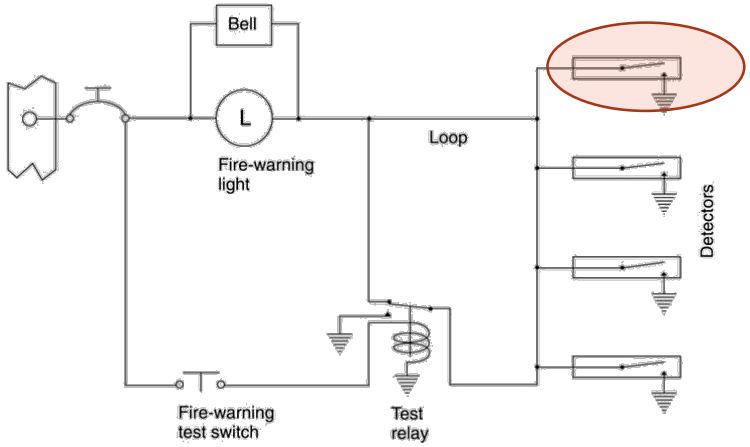


Fire detection and suppression

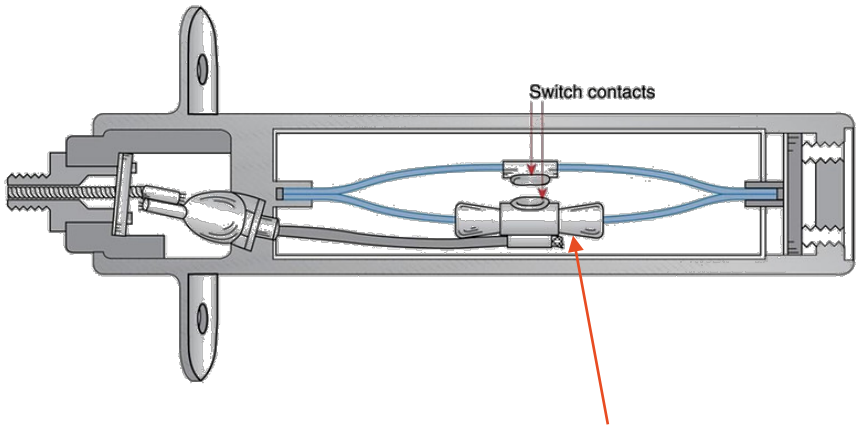
- The fire detection technologies include:
  - Thermal switch system
  - Thermocouple
  - Optical detection method
  - Pneumatic thermal fire detection
  - Thermistor type continuous-loop
    - Fenwall system
    - Kidde Continuous-Loop System

Thermal switch system

- Many older aircraft still operating have some type of thermal switch system or thermocouple system.
- These thermal switches are heat-sensitive units that complete electrical circuits at a certain temperature.
- A thermal switch system has one or more lights energized by the aircraft power system and thermal switches that control the light(s).

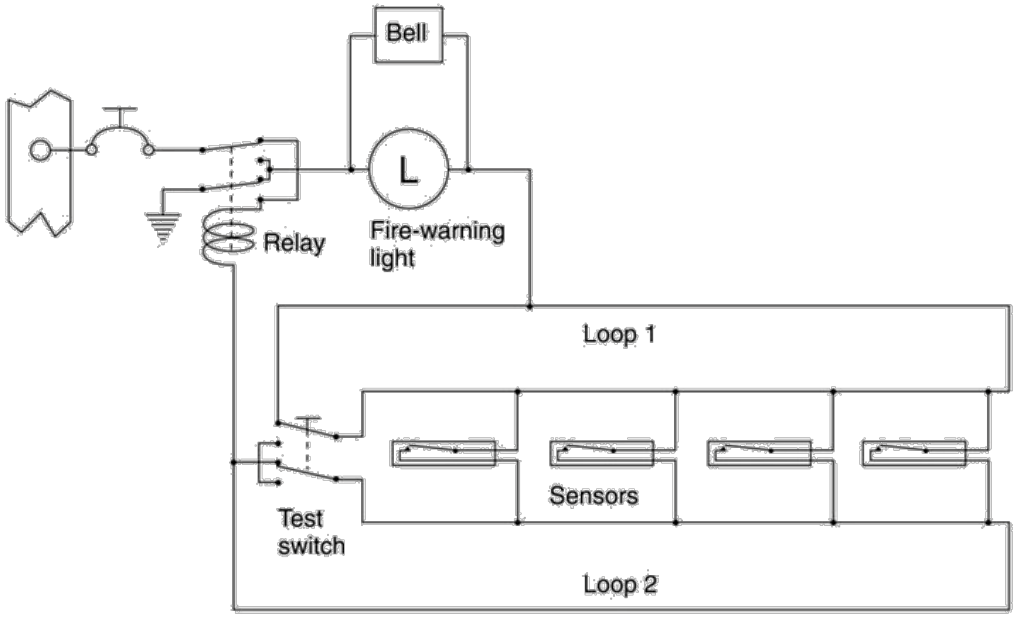


Single-loop thermal switch fire detection



Contacts are actuated by differential expansion of the metals

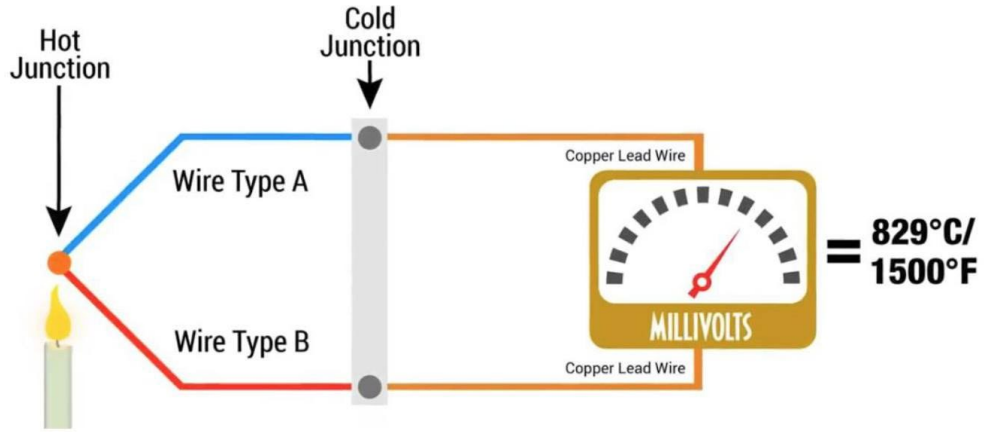
Thermal switch system



In some systems, two circuit loops are used to prevent the false indication of fire. These systems tend to be more robust as they are withstand some false alarm such as short to the ground.

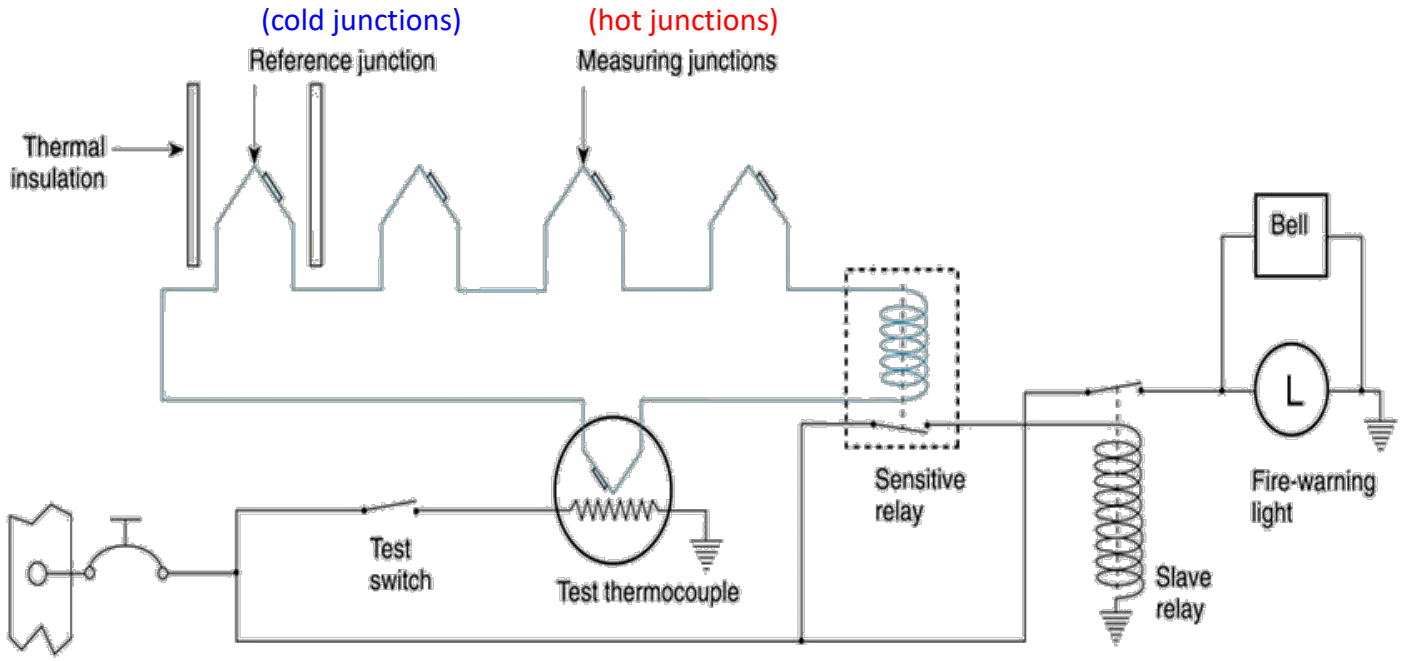
Thermocouple type detector

- Thermocouple consists of two different metals, which can generate (small) current if there is temperature difference



In aircraft, various thermocouples are placed in the possible fire zones, and they are connected to the fire detection circuits.

Thermocouple type detector

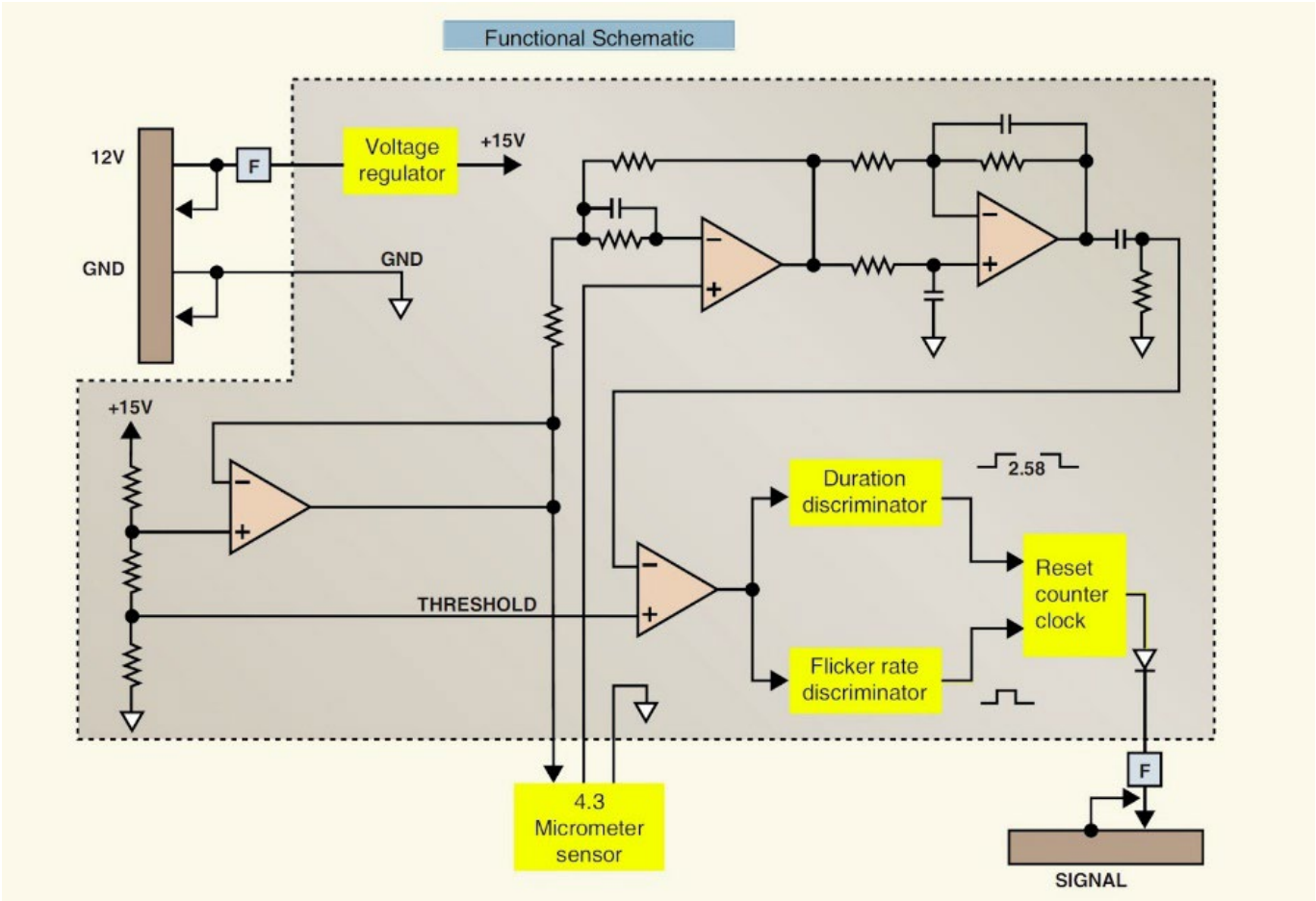


- If there is a fire, the measuring junction is heated more rapidly than the reference junction, generating a voltage.
- The voltage is higher than the threshold, the sensitive relay is active. The slave relay is closed so that the alarming circuit is completed.

Optical fire detection systems

- Optical fire detection systems are also referred to as “flame detectors”. They are used to detect the hydrocarbon flames.
- Infrared optical fire protection:
  - They are mainly used in light turboprop aircraft and helicopter engines

- Radiation emitted by the fire crosses the airspace between the fire and the detector and impinges on the detector and window.
- The window allows a broad spectrum of radiation to pass into the detector where it impinges on sensing device filter.
- The filter allows only radiation in a tight waveband to pass on to the sensing device.
- The radiation striking the sensing device raises its temperature, causing small thermoelectric voltages
- These voltages are fed to an amplifier connected to various analytical electronic processing circuits


Functional Schematic
12V
GND
F
Voltage regulator
+15V
GND
+15V
THRESHOLD
Duration discriminator
2.58
Reset counter clock
Flicker rate discriminator
4.3 Micrometer sensor
F
SIGNAL

Pneumatic thermal fire detection

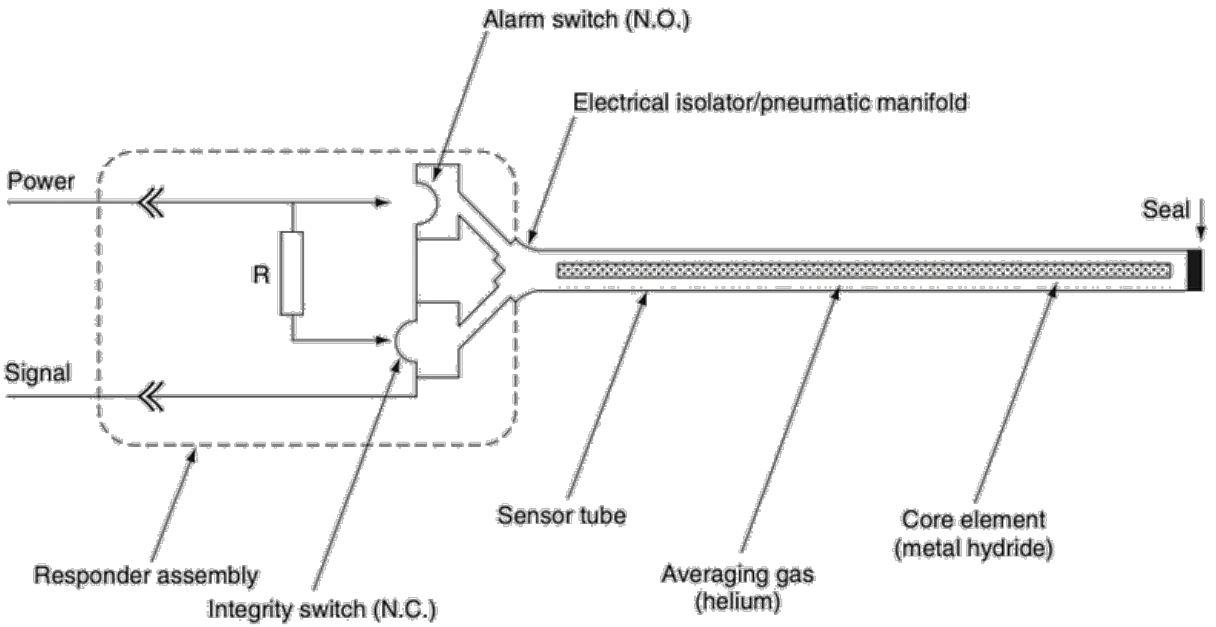
- Pneumatic detectors are based on the principles of gas laws.
- For the given volume, we have:

$$p \propto T$$

- The sensing element consists of a closed helium-filled tube connected at one end to a responder assembly.

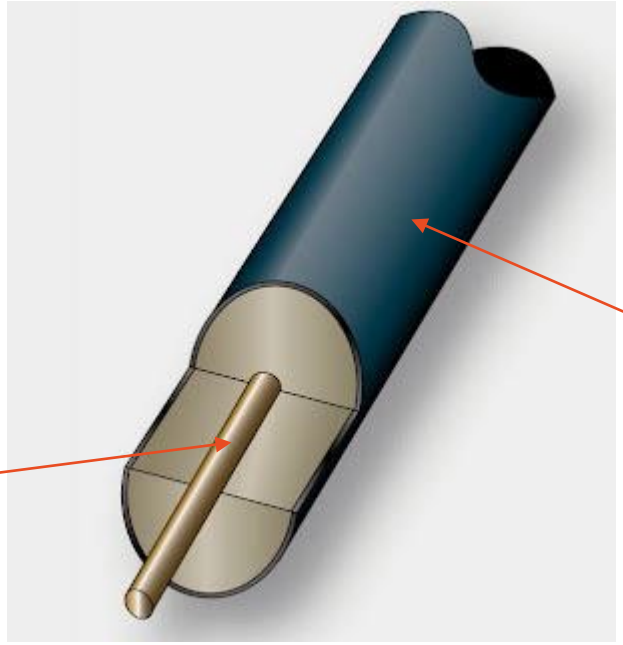
Pneumatic thermal fire detection

- 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.
- The pneumatic detector integrity pressure switch opens and triggers the fault alarm if the pneumatic detector losses pressure



Thermistor type: Fenwal continuous-loop system

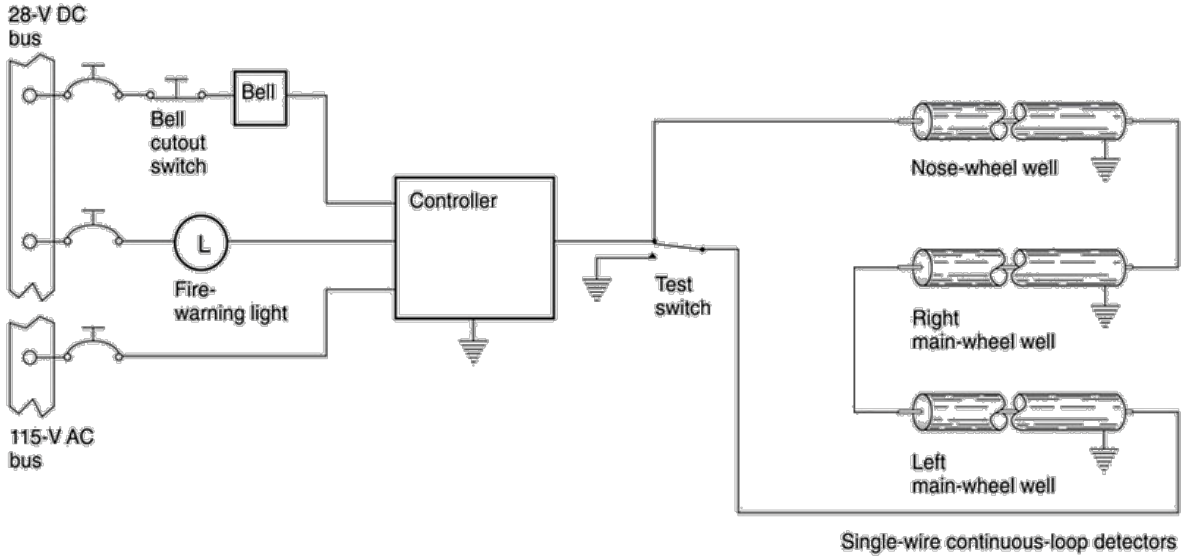
- The sensing element is made of a slender inconel/鉻鎳鐵合金 tube:
  - packed with thermally cover and a conductor.
- The sensing elements are connected in series to a control unit, which impresses a small voltage on the sensing elements.



Fenwal probe

Thermistor type: Fenwal continuous-loop system

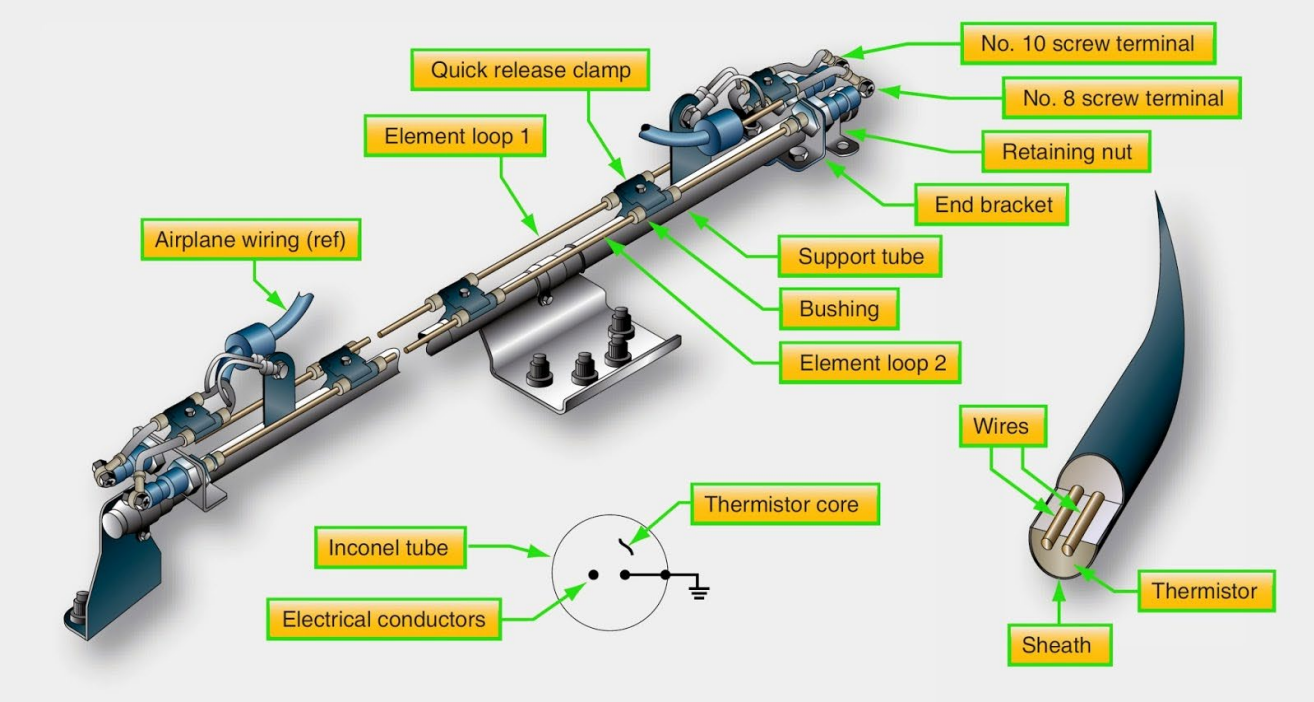
- When an overheat occurs at any point within the sensing element, the resistance drops sharply, causing current to flow between the outer cover and the center conductor.
- This current flow is sensed by the control unit, which produces a signal to actuate the output relay.



Schematic of the Fenwal fire detection system

Thermistor type: Kidde continuous-loop system

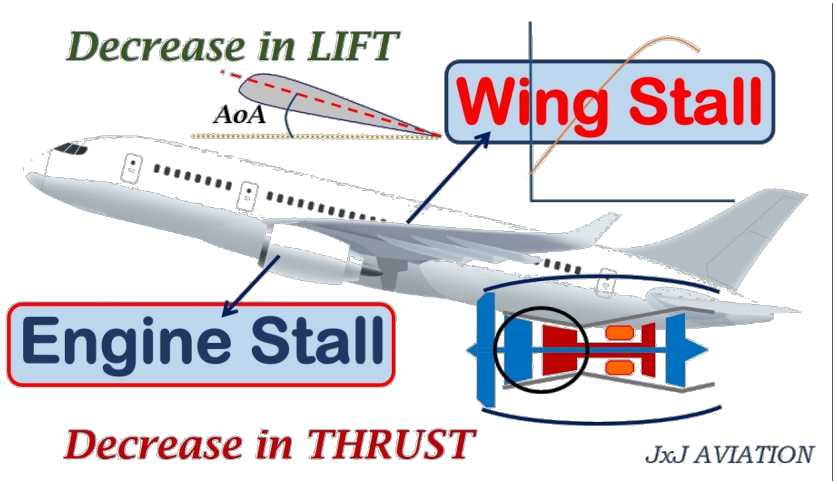
- In the Kidde continuous-loop system, two wires are imbedded in an inconel tube filled with a thermistor core material.
- Two electrical conductors go through the length of the core.
  - One conductor has a ground connection to the tube
  - The other conductor connects to the fire detection control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

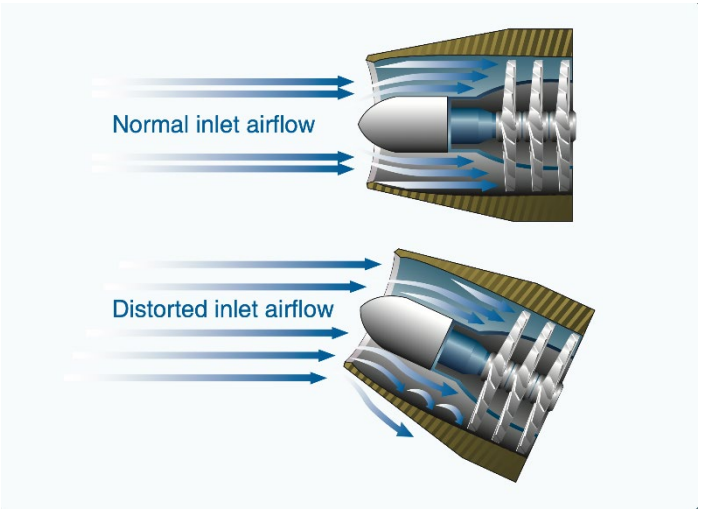


Emergency power sources

Emergency power sources

- Redundancy is necessary for modern commercial aircraft to achieve continued safe operation in case of single or multiple failures
  - It is achieved as high levels as independent systems
- For an aircraft at high angle of attack, it may experience stall.
  - Disturbance of engine intake air flow can cause engine flame out
  - This can cause total loss of engine generated power





Emergency power sources

- Emergency power can be provided by different methods, including:
  - Emergency power unit (EPU)
  - Electro-hydraulic pump
  - Ram air turbine (RAT)

Emergency power unit (EPU)

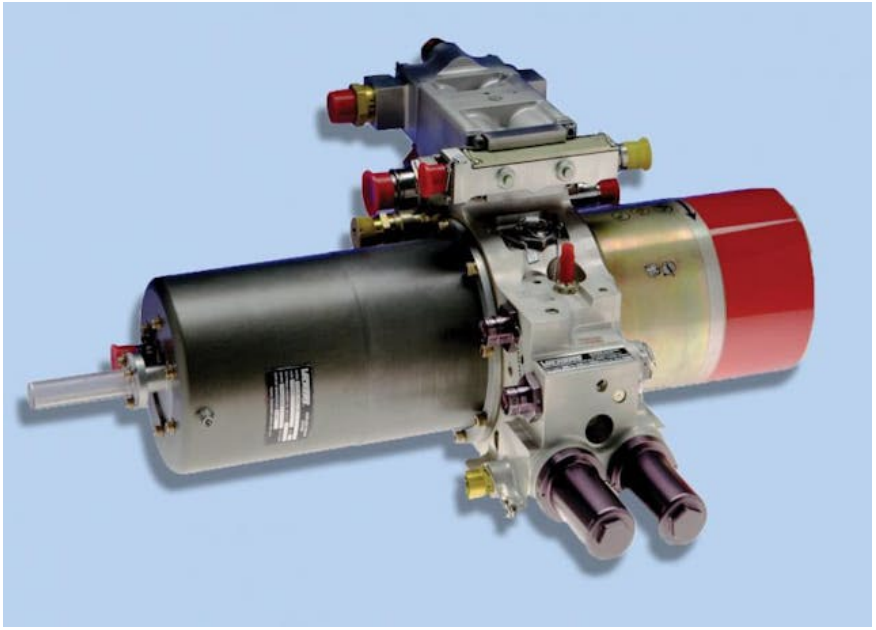
- EPU consists of a turbine which can be rotated by the released energy from fuels such as hydrazine/聯氨.
  - Hydrazine is stored in a sealed tank and isolated from the turbine by a shut-off valve, which is opened in emergency conditions.
- The turbine rotation can drive an aircraft gearbox to enable the hydraulic pump and generator to be energised.

An infographic shows the emergency power unit systems in an F-16 fighter jet

Electro-hydraulic pump

- An electro-hydraulic pump is used to provide hydraulic power for aircraft
- An manual or automatic operation can be used to initiate a one-shot or thermal battery to drive a hydraulic pump
- It is used for a short duration to recover the aircraft and start the engines.

The electro pump is used to start the hydraulic systems

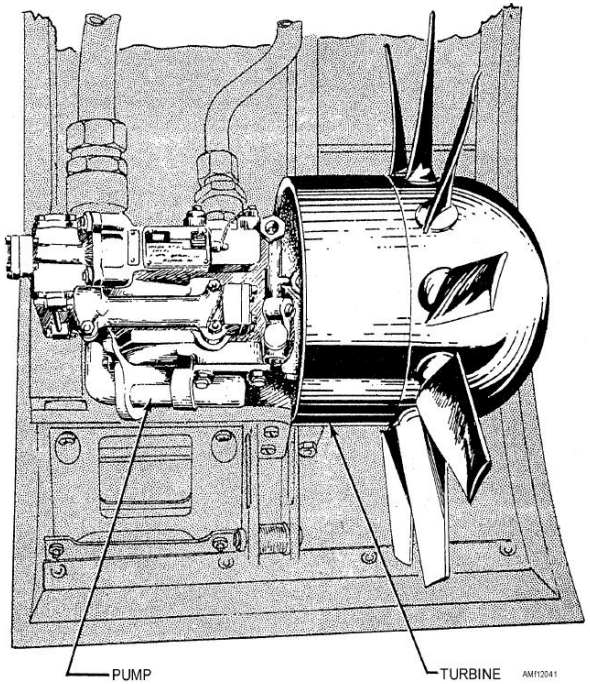


Example: IDS Tornado emergency power system

- The Interdictor/strike (IDS) Tornado emergency power system provides hydraulic power for double engine flame-out, double generator failure.
  - A single shot battery is activated by an explosive device.
  - It can also drive a fuel pump to provide power up to 13 minutes.

Ram air turbine

- Ram air turbine (RAT) does not require a source of power.
  - It may be called an air driven generator (ADG) on some aircraft
- It works due to the forward movement of the aircraft.
- The multi-bladed unit drops from a stowed position in the aircraft and provides electric power.



Ram air turbine

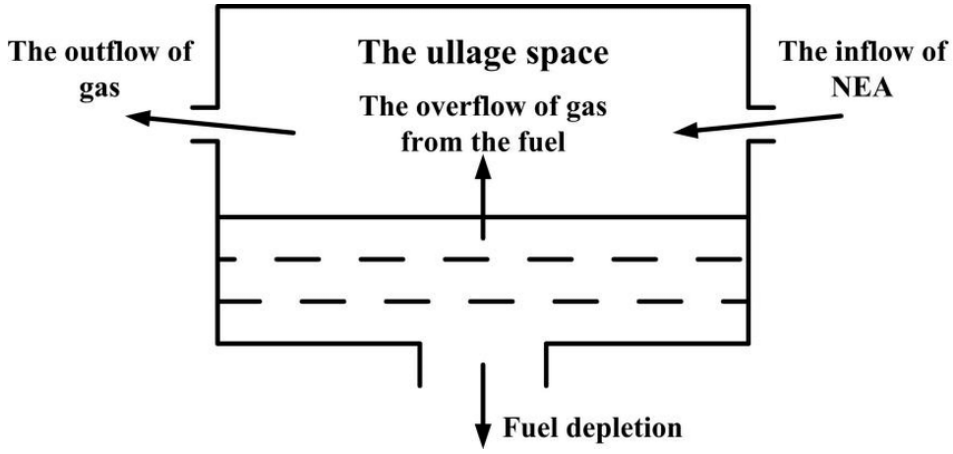
RAT on a Republic F-105 Thunderchief fighter-bomber

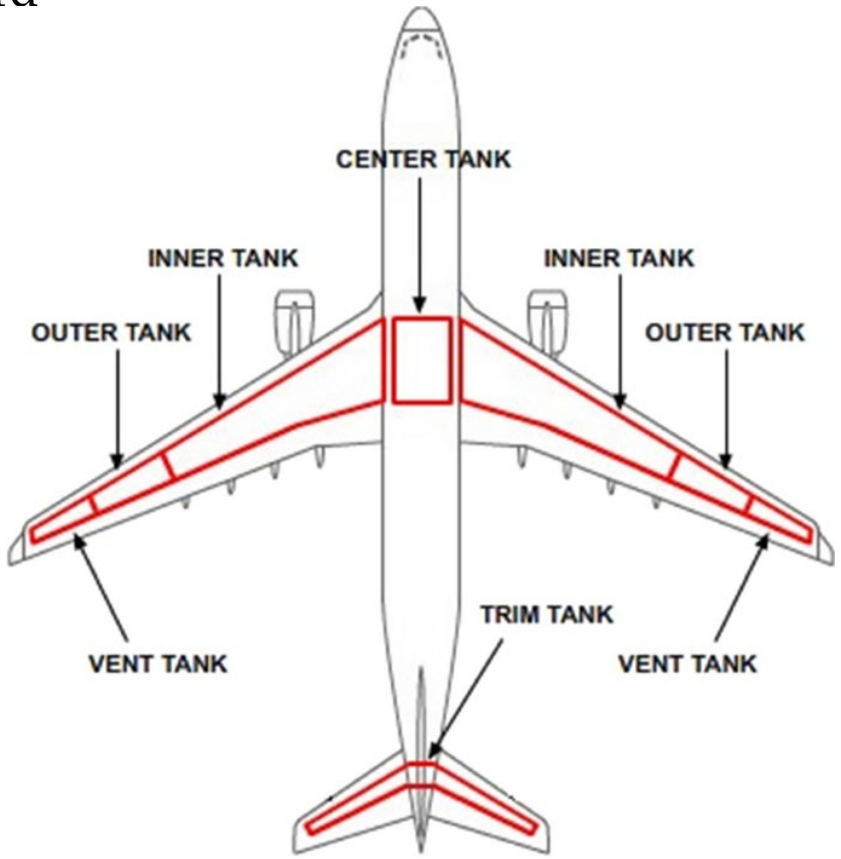
Convair F-102 Delta Dagger. The yellow circle highlights a ram air turbine with five blades

Explosion suppression

Explosion suppression

- Ullage: the volume above the surface of fuel in tanks
  - It is a mixture of fuel vapour and air
  - It is considered as an explosion hazard





Explosion suppression

- Possible causes of explosion:
  - Lightning strike
  - External fire
  - Fire after refuelling
  - Fire in heated tanks, etc.

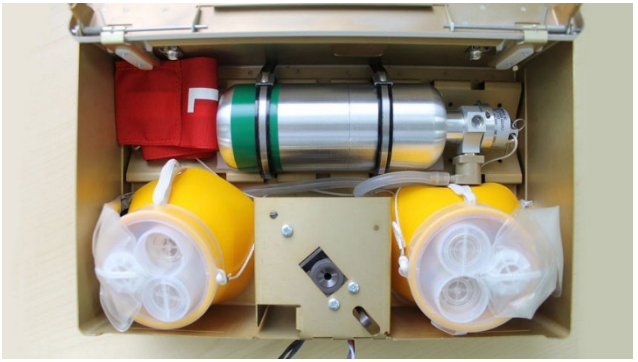
- Electrical components are installed in fuel tanks:
  - Fuel gauge probes
  - Density measurement probes
  - Level sensors
  - Transfer pumps
  - Boost pumps

- Methods of reducing the risk of explosions include filling the ullage space with reticulated foam or with nitrogen gas
- The nitrogen gas is provided either from an external source or an On Board Inert Gas Generation System (OBIGGS)

Emergency oxygen

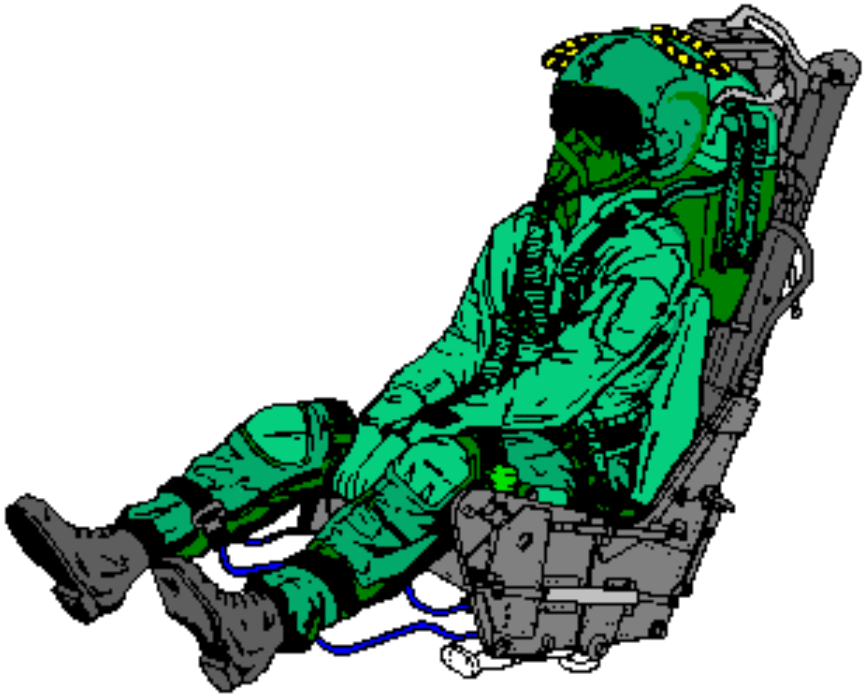
Emergency oxygen

- For aircraft operated above 10,000 ft, the cabin should be pressurized to an altitude condition that is safe and comfortable for crew and passengers
- In case of pressurization failure, oxygen should be provided
  - Aircrew is provided with face masks that can get oxygen from a pressurized bottle.
  - Face masks for passengers are normally stowed in the racks above the seats
- Meanwhile, the aircraft should descent to a height where oxygen concentration in the air is sufficient



Emergency oxygen

- If the normal oxygen supply fails, the crew can change over the oxygen bottle carried on their ejection seats
- This can supply oxygen for a short duration, but it is sufficient for returning to a base



Passenger evacuation and crew escape

Passenger evacuation

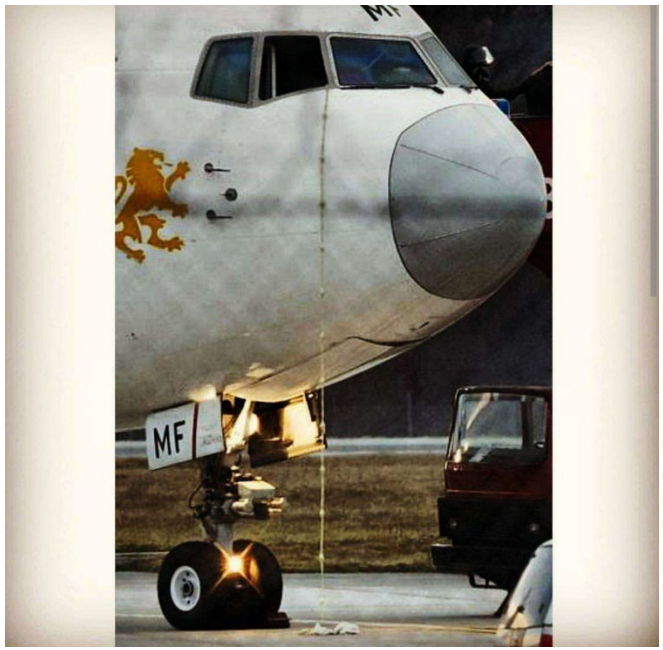
- Commercial aircrafts and military transports must provide evacuation means for passengers in certain situations
- Emergency exit doors are provide:
  - Doors are fitted with escape chutes so that passengers can slide to the ground
  - The chutes can inflate rapidly on command
  - Doors are designed with sufficient width and open outwards
  - All doors and exits are identified with illuminated signs

Passenger evacuation

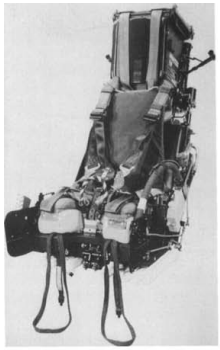
- The escape slides are:
  - Situated on bottom of half door
  - Carbon fibre pressure cap
  - Light weight & sizeable
  - Door open while armed to realise slide
- Speed of inflation:
  - 1960s: 25 seconds
  - 2015: 6 seconds

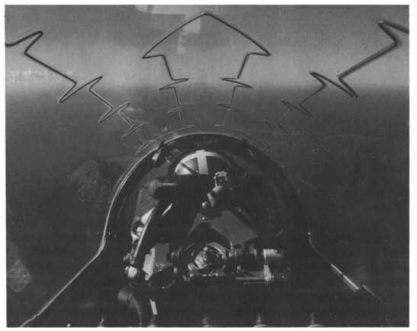
Crew escape

- The crew of commercial aircraft can escape through passenger emergency exit or by an escape rope



- Military crews in combat aircraft are provided with ejection seats



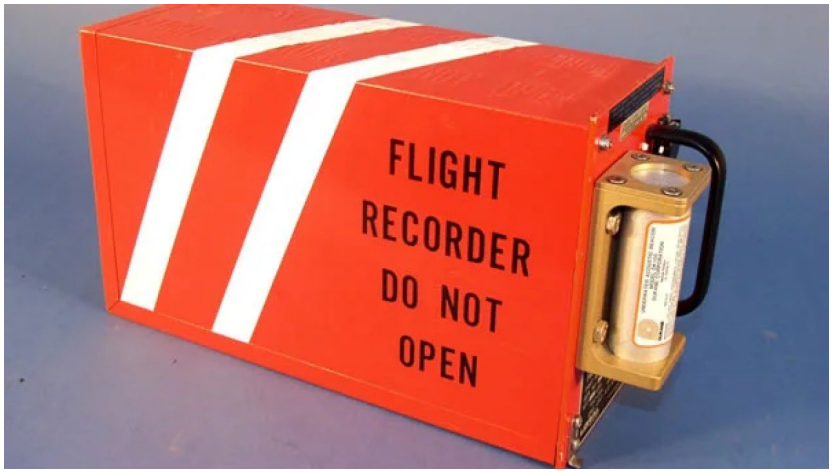


(British Aerospace)

Crash recorder

Crash recorder

- It is mandatory to carry a recorder in commercial aircraft
  - For military aircraft, it is also necessary if it flies in civilian airspace
- The recorder, which is also called the accident data recorder, flight recorder, or black box recorder, is used to record the flight data and voice.
- The flight data & voice recordings are not a system of reducing flight injuries
  - However, they are useful for better understanding of the aircraft accident.



It also contains a radio and sonar locator to guide recue crews to its location

Crash recorder

- It is connected to the aircraft systems to record the flight critical parameters and information about the aircraft
  - Control column
  - Flight control surface position
  - Engine speed
  - Pressure, temperature, altitude, airspeed
  - Crew conservation, etc.

- Recorded time: > 25 minutes
- Fire resistance: > 30 minutes for 1100°C
- Water pressure resistance: 7000 m
- Operation after crash: 30 minutes

Emergency landing

Emergency landing

- Emergency landing happens as response to an emergency:
  - involving an imminent or ongoing threat to safe
  - other sudden need such as medical emergency
- There are several different types of emergency landing:
  - **Forced landing**: the aircraft is forced to make landing due to technical problems. The task should be finished as soon as possible
  - **Precautionary landing**: a planned landing at a location where the information is limited. This is often related to the medical or police emergency.
  - **Ditching**: the same a forced landing. But it is only on the water.
  - **Crash landing**: the aircraft lands when it receives significant structural damage.

Emergency landing: suggested controller actions

- Best principle embedded the ASSIST principle could be follow:
  - A(Acknowledge): acknowledge the situation; ask for number of persons on broad and if there are any dangerous goods
  - S (Separate): separate the aircraft as necessary and prioritise it for landing.
  - S (Silence): silence the non-urgent calls and use separate frequency where possible
  - I (Inform): inform the airport emergency fir rescue services (RFFS) and all concerned parties according to the local procedures
  - S (Support): support the flight by provide any information requested and necessary such as next suitable aerodrome, runway length, etc.
  - T (Time): provide time for crew to access and deal with the emergency, don't pressure with non urgent matters

Emergency landing: military aircraft

- For military aircraft, in case of emergency landing or aborted take-off, it is necessary to provide an alternative to onboard systems to stop the aircraft
  - Arrestor wire engaging on a wire across the runway
  - A barrier net cross the runway

Arrestor cables

Barrier net

Summary

Summary

- Different emergency systems in an aircraft are introduced.
- The features of the emergency systems can vary with aircraft design, though the philosophy could be unchanged.