WARNING & PROTECTION DEVICES

WARNING DEVICES

Ammeters and voltmeters are designed to indicate AC and or DC current flow or voltage respectively. Coupled with good systems knowledge and expected indications, these instruments allow monitoring of electrical system performance.

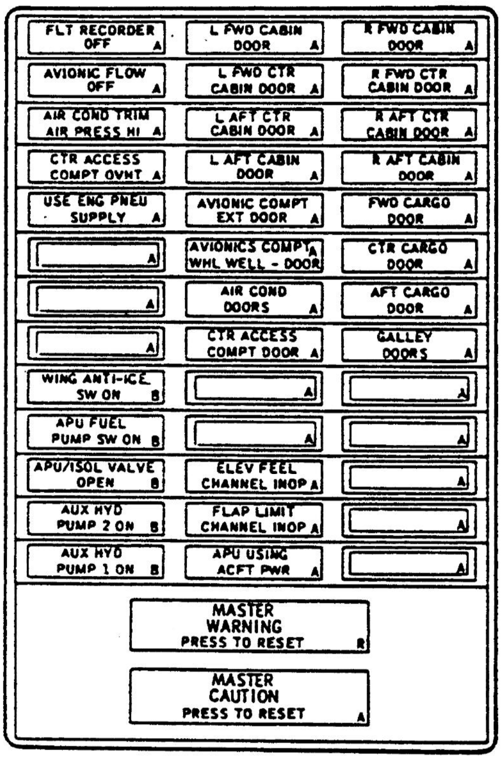
Indicating Lights referred to here, relate not only to the electrical system. The electrical system provides the capability to monitor other aircraft systems generator functions, undercarriage position, hydraulic system pressure, fuel pressure etc.

ANNUNCIATORS

Indicator flags, oscillating devices, small meters or lights indicating a normal or abnormal operating condition, are often referred to as annunciators. When a fault occurs and continues to exist for a finite period, an alert signal is then sent to an annunciator panel. In modern aircraft, annunciator panels are being replaced by computer screens, called EICAS (Engine Indication and Crew Alerting Systems) and ECAM (Electronic Centralized Aircraft Monitor Systems).

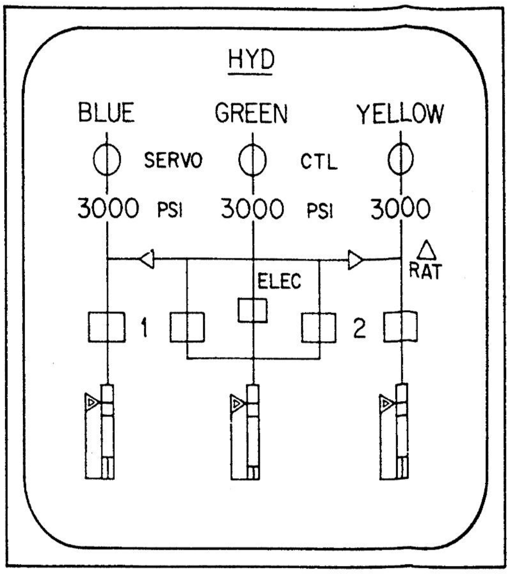
If the fault is potentially an 'unsafe condition' an aural warning and ***master warning*** light coloured red, will activate. If the fault is an 'abnormal condition', an aural and ***master caution*** light coloured amber will activate. Corresponding alerts are displayed on the EICAS.

Examples of annunciator light panels and electronic screens follow:



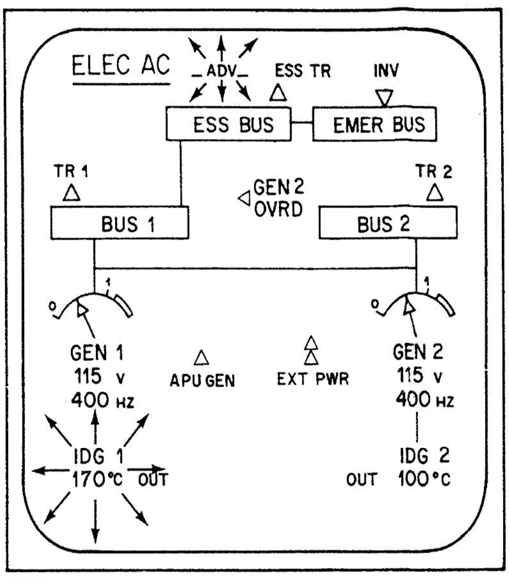
ANNUNCIATOR PANEL

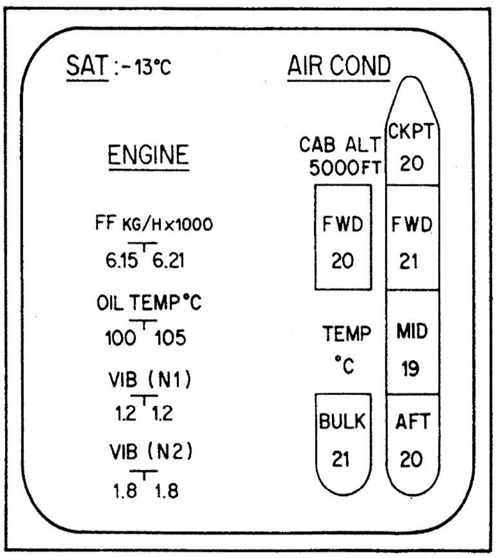
WARNING AND MONITORING SYSTEM, ECAM



COLOR CODE FOR SYSTEM DISPLAY

RED	Warning range for emergency condition
AMBER	Warning range for abnormal condition and flag "XX"
CYAN	All units (PSI, KG, etc.)
WHITE	Titles of system pages if called manually or by an advisory situation (in this last case the title is followed by "ADV" in white color).
GREEN	Numerical values or analog indications, when no warning threshold has been reached. Title of system pages (if not called manually or by an advisory situation).





A **Warning Indication** can also be presented by a circuit breaker. Circuit breakers are not always placed in the best visual position and when a warning type circuit breaker 'pops', the extension of the push button can be felt easily and it is usually coloured red to attract attention.

PROTECTION DEVICES

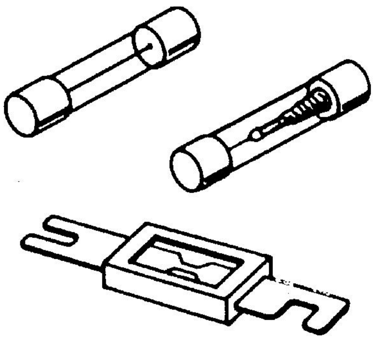
Fuses

Fuses are rated to allow a normal operating current flow to specific equipment. A fuse is a strip of metal having a very low melting point. It is placed in a circuit in series with the load so that all load current must flow through it. The metal strip is made of lead, lead and tin, or some other low-melting-temperature alloy.

When the current flowing through a fuse exceeds the capacity of the fuse, the metal strip melts and breaks the circuit creating an 'open circuit'.

Fuses are generally enclosed in glass or some other heat-resistant insulating material to prevent an arc from causing damage to other electric components.

Caution **:** *Fuses are often small and are awkward to handle. In a single pilot situation the pilot should use caution when replacing a fuse during flight.*



Circuit Breakers

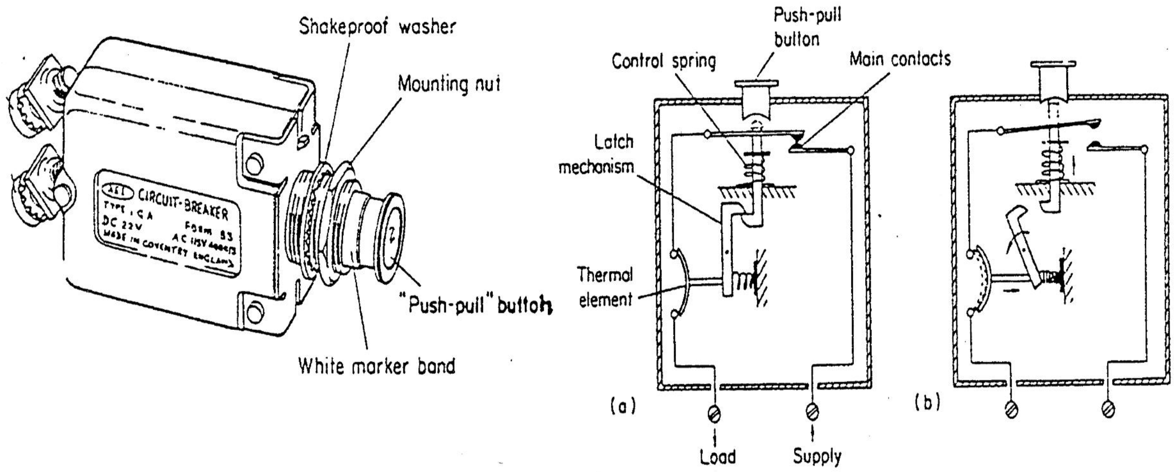
A circuit breaker will break the circuit if an excess current flows. Some circuit breakers sense an over current by measuring the heating effect using a bi-metallic device. If a circuit breaker 'pops', the pilot should wait at least two minutes to allow cooling before attempting to reset.

A circuit breaker serves a purpose similar to that of fuse and can usually be reset after a circuit fault is removed. An aircraft circuit breaker can be described as a manually operated switch which has an automatic tripping device. This tripping device breaks the circuit when the current reaches a pre-determined value. The switch-type circuit breakers serve as both a circuit breaker and a switch.

Magnetic circuit breakers operate using an electromagnet, which pulls on a small armature and trips the breaker when energized with an overload current.

When a magnetic circuit breaker has opened a circuit, it must be reset after the circuit fault has been removed. To do this the switch lever is moved to the FULL OFF position and then returned to the ON position. If there is still too much current flowing in the circuit and the overload still exists, the circuit breaker will trip again without damaging the circuit.

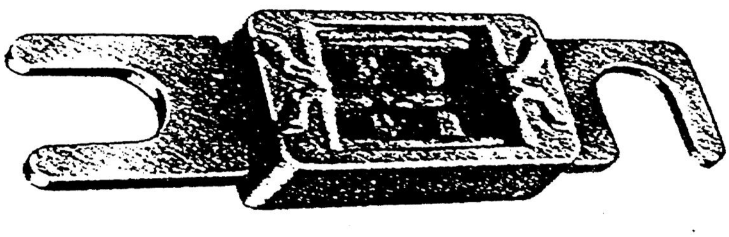
Caution: *Usually, the pilot is permitted to reset a circuit breaker only **once** during flight.*



Note; - All resettable circuit breakers should be designed to open the circuit regardless of the position of the operating control when an overload or circuit fault exists. Such circuit breakers are described as **tripfree**. Automatic-reset circuit breakers (device which reset themselves periodically), should not be used as circuit protectors.

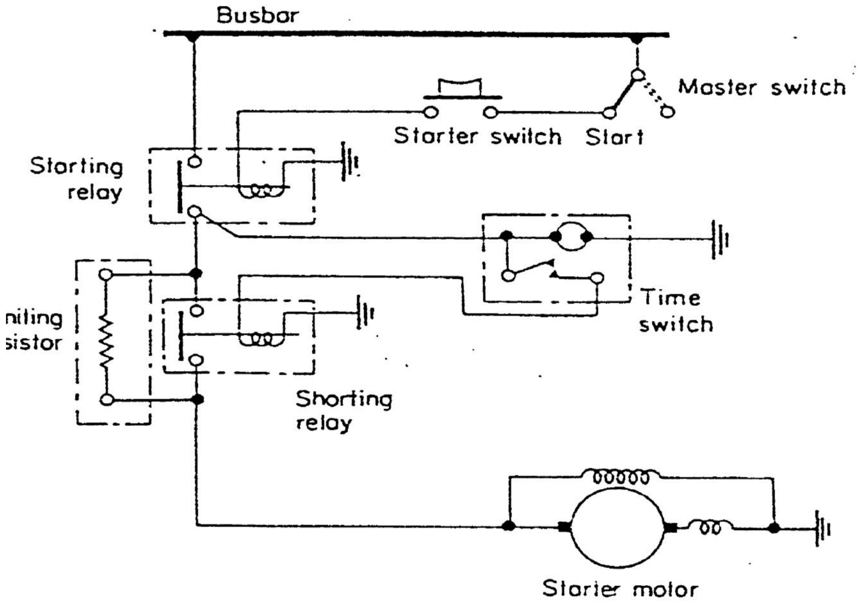
Current Limiters

A current limiter is a heavy duty resistive fuse device. Designed to restrict current flow for a considerable period (slow-blow) before breaking the circuit if the current remains excessive. When the circuit becomes overloaded, there is a short delay before the metal link melts and opens the circuit. This is because the link is made of copper, which has a higher melting point than the alloys used in fuses. The current limiter will carry more than its rated capacity and will also carry a heavy overload for a short time. It is designed to be used in heavy power circuits where loads may occur of such short duration that they will not damage the circuit or equipment. The capacity of a current limiter for any circuit is so selected that it will always interrupt the circuit before an overload has had time to cause damage.



Limiting Resistors

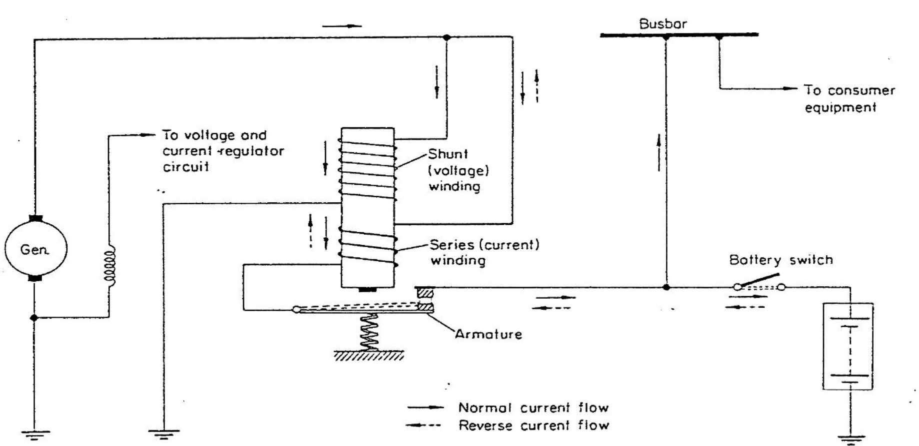
Limiting resistors provide current surge protection, particularly in DC circuits when a motor starts. The limiting resistor is switched in for only a few seconds to prevent a starting overload.



APPLICATION OF A LIMITING RESISTOR

Reverse Current Cut-out Relay (RCR)

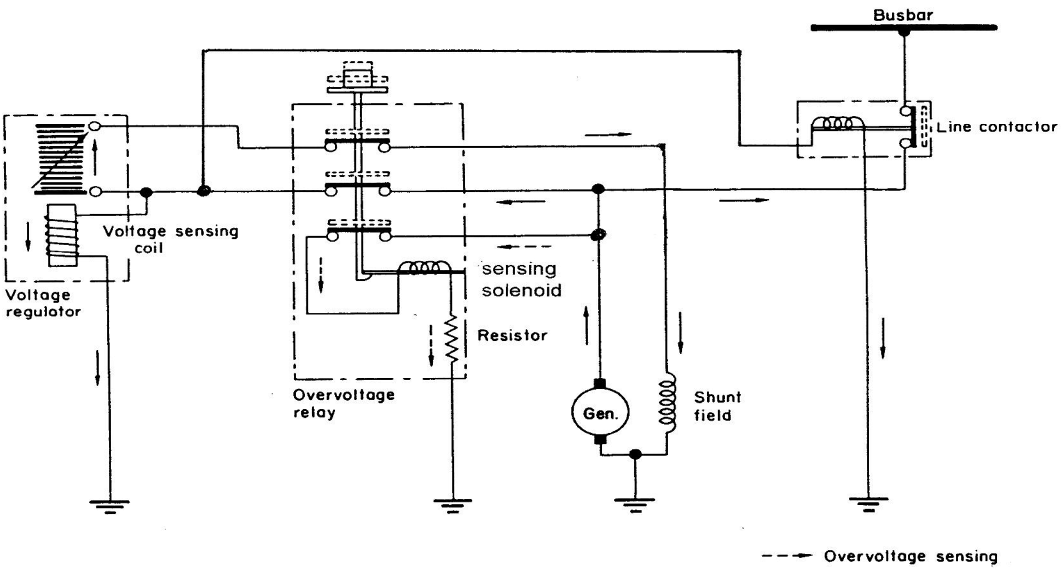
The reverse current relay is essentially an under voltage protection device and is common in most aircraft fitted with DC generators. It is not required in electrical systems powered by an alternator. When the output voltage of the generating unit becomes less than the battery voltage, perhaps due to a voltage regulator fault where it cannot sustain its preset value or a generator belt breaks, or the engine stops running, the reverse current relay will operate, opening the circuit. If the generator low voltage condition was allowed to exist for a significant period, the battery would tend to supply the generator, perhaps ‘motoring’ it and wasting this standby power source. The open circuit caused by the RCR will also cause the 'GEN FAIL' warning light to illuminate. In light aircraft an under voltage condition usually occurs just below 1500 RPM as the turning rate of the generator is insufficient. The RCR activates, the ‘GEN’ light comes on and the battery takes over and powers the bus.



THE RCR REDUCES THE RISK OF BATTERY WASTAGE.

Over-Voltage Protection

A fault with the voltage regulator or field excitation circuits could produce voltages well above the consumer equipment design voltage. This could damage the equipment, possibly cause a fire or cause the circuit breakers to open the circuit. In the diagram below, note the **sensing solenoid** in the over-voltage relay. If a high voltage was to occur, greater than its preset value, this solenoid is operated, disconnecting its armature from the spring loaded contact arm. The circuit is broken and the generating device is disconnected from the bus.

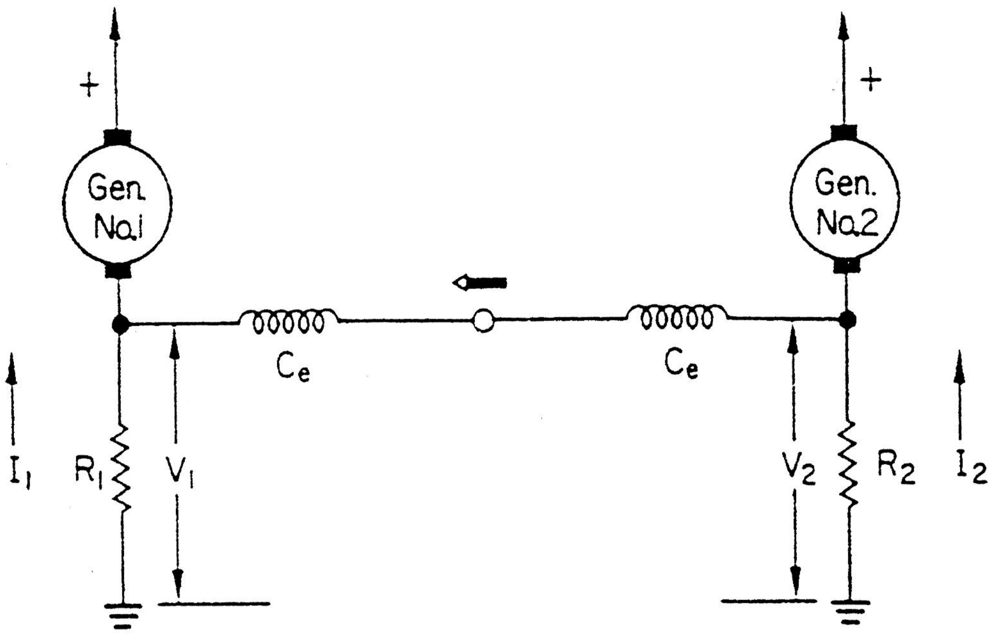


OVERVOLTAGE PROTECTION DC GENERATING SYSTEM

LOAD SHARING - DC SYSTEMS

The engine-driven DC generators on multi-engined aircraft should operate in parallel. In the event of an engine or generator failure, the remaining generators will continue to supply power without interruption. Parallel operation demands equal load sharing between generators, which means that their output voltages must be matched as closely as possible.

One method of ensuring equal voltage regulation on each generator is the use of a load equalizing circuit to control generator output by means of the voltage regulators.



DC LOAD SHARING

When both generators are providing the same output current, the loads are equal and the voltage measured at the sensing coil inputs is zero. This is the ideal load sharing situation.

A temporary imbalance can occur as equipment is switched on or off from one bus bar. This imbalance will cause current to flow in the equalising coils, the effect of which is to influence the voltage regulators to adjust generator outputs until the equalizing coil current is cancelled. This action restores the current balance (load sharing) between the generators.

FIRE AND SMOKE DETECTION

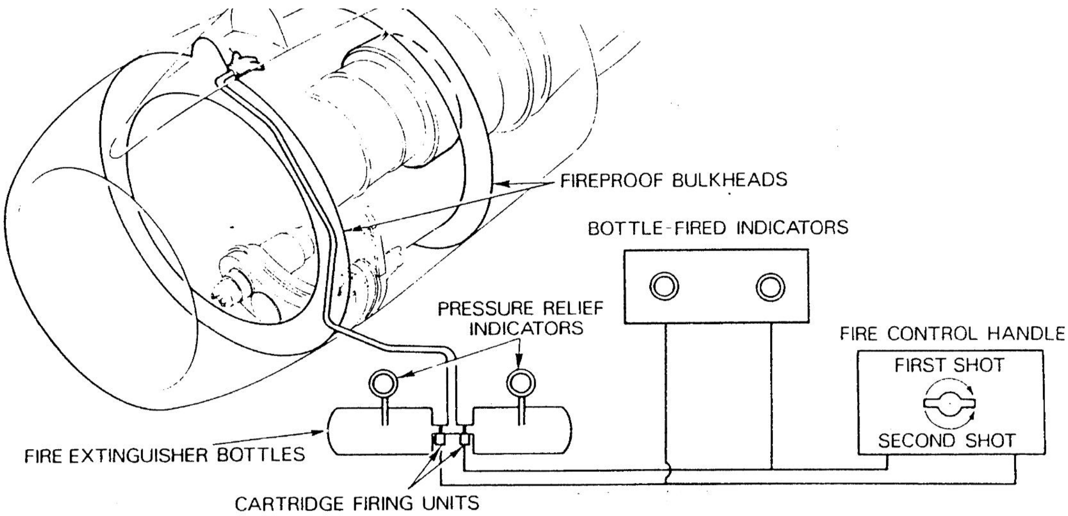
All aircraft except certain light aircraft are fitted with engine bay fire warning apparatus; in addition, all turbine engined aircraft and multi-engined aircraft powered by piston engines, are equipped with electrically-operated fire extinguishers that can be discharged into the potential fire zones of the engine bays. Warning of fire is given by warning lights and horns, which are connected to a series of flame and heat detectors installed in the engine bays. The discharge of the extinguishers is normally initiated by a manually operated switch, but in the event of the aircraft crash landing, all the extinguishers are discharged, as a precautionary measure, by the action of an inertia or impact switch.

TYPES OF DETECTORS

In the case of electrical systems the presence of a fire is signalled by a change in the electrical characteristics of the detector circuit, according to the type of detector, be it thermistor, thermocouple or electrical continuous element. In these cases, the change in temperature creates the signal which, through an amplifier, operates the warning indicator.

Both the thermocouple and thermistor detectors have properties making them ideally suited to this application. The thermocouple comprises two dissimilar metals which are joined together to form two junctions. As the temperature difference between two junctions increases, an E.M.F. is produced in the circuit and it is this E.M.F. that triggers the fire warning displays. The thermistor consists of a semi-conductor material whose resistance changes as temperature increases, with a corresponding change in the current flowing in the circuit. It is this change in the current that operates the warning indicators. A thermistor may be used as a single point detector or as a continuous element sensor.

Another form of continuous electrical element sensor, takes the form of a capacitive device, consisting of a tube containing a dielectric material with a conductor running through the centre. A control voltage is applied between the tube and the centre conductor. As the temperature increases, the properties of the dielectric change with a corresponding change in the value of capacitance. This change of capacitance is sensed by electronic circuits, when preset limits are exceeded a fire warning is generated.



FIRE EXTINGUISHING COMPLIMENTS FIRE DETECTION

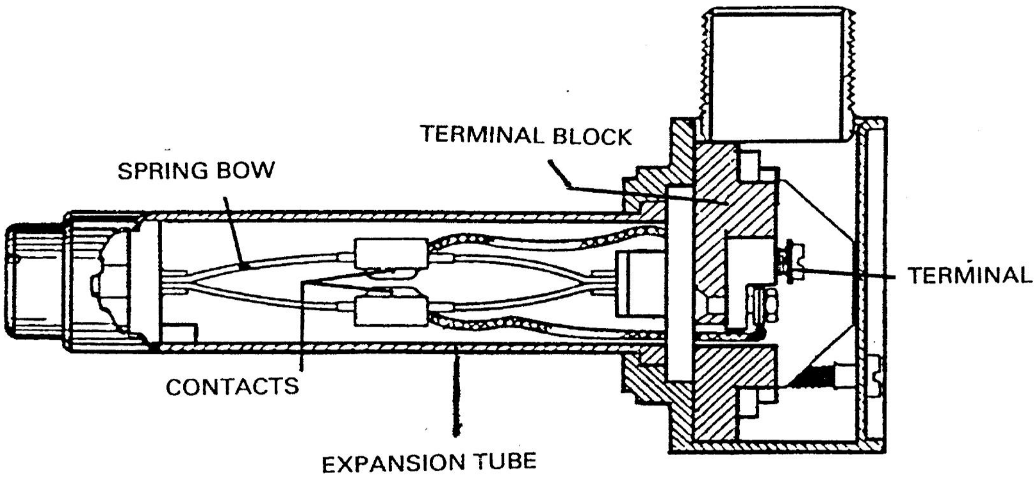
ENGINE OVERHEAT

Turbine overheat does not constitute a serious fire risk. Detection of an overheat condition however, is essential to enable the pilot to stop the engine before mechanical or material damage results.

A warning system of a similar type to the fire detection system, or thermocouples suitably positioned in the cooling airflow, may be used to detect excessive temperatures. Thermal switches positioned in the engine overboard air vents, such as the cooling air outlets, may also be included to give an additional warning.

One type of flame detector switch, consists of an expansion tube of alloy steel housing contacts, mounted on a special spring-bow assembly. At normal temperatures, the spring-bow assembly is under compression so that the springs are bowed and the contacts are open. When heat is applied, the steel tube expands to a greater extent than the spring-bow assembly; the compression is eased, the contacts close and so complete the circuit to the warning lamp.

A subsequent drop in temperature re-compresses the spring-bow assembly, opens the contacts and causes the warning lamp to go out. This switch is termed a resetting type flame
detector.



RESETTING TYPE FLAME DETECTOR

Smoke detectors are mounted in a tray which collects the air for sampling. The smoke detector consists of a photoelectric cell, a pilot lamp and a test lamp in a lightproof chamber. When smoke reduces light transmission to approximately 10% below that of clear air, light is reflected from the pilot lamp to the photoelectric cell, resulting in a smoke detection signal to the smoke detector amplifier.

The amplifier receives a signal from its detector when smoke is present and provides 28V DC to the fire protection module for relay logic and fire warning indicator operation.

NOTE: Cigarette smoke will actuate smoke detectors.

EMERGENCY LIGHTING

Small aircraft may have only two of three emergency lights. When no emergency system lights are fitted, portable or torch lights must be available. Large aircraft have as many as 80 emergency lights of various types throughout the aircraft. The types include exit, ceiling, doorway, egress path, overwing, crew service door (external) and in main doors, to illuminate inflated slides. Lights are powered by nickel-cadmium batteries either integral with a light assembly or from power packs through individual solid state units by the 28V DC essential bus whenever it is energized.

Lights should stay alight for 10 to 20 minutes with average condition, fully charged batteries. If the batteries have been flattened, it will take about 16 hours to *"fully"* recharge them.

Medium sized aircraft, with relatively simple electrical systems, often use inertia switches to illuminate emergency exits. On large aircraft, the emergency lights will come on when the essential DC bus de-energizes with the control switch ARMED. Essential DC bus is powered from the Transformer Rectifier Unit (TRU) and consequently when all engines stop and there is no power for the TRU's, the essential DC bus will de-energize, activating the lights.

EMERGENCY INSTRUMENTS

Light Aircraft

On small aircraft, the only electrical emergency or STANDBY instrument provided, is usually the Turn Indicator. For an aircraft to be airworthy for instrument flight, it must have a second attitude reference instrument powered by a separate and independent power source. In small aircraft, the primary attitude reference, is the Artificial Horizon (AH) which is powered by air (the vacuum system) and the Turn Indicator is powered by DC. The battery is of course the emergency power supply.

Heavy Aircraft

The standby attitude reference system provides a visual display of aircraft attitude. The system is in continuous operation during flight, but normally functions as an emergency backup system in the event of inertial navigation or power system failure. The system receives 28V DC from the battery bus. During emergency operation, the battery bus will be powered by the battery when the ESS DC BUS fails. More about complete systems later. This system consists of a standby attitude indicator and a static inverter.

The **standby attitude indicator** is usually a 26V AC, 3-phase vertical gyro. A power supply failure indicator monitors power to the gyro motor and causes a warning flag to appear if power is lost.

The **static inverter** accepts 28V DC power and converts it to the 115V, 400Hz AC, 3-phase power required by the standby attitude indicator. The inverter is a solid-state unit operating at all times from the BATTERY BUS. Large aircraft circuit diagnosis and systems are covered in Chapter 11.

> NOTE: With modern, very reliable electrical systems, there is a trend to use Liquid Crystal Displays, for main instrument screens and standby instruments.