Before going into its operational and constructional detail, we first review relevant fundamental voltage generating Principle

PRINCIPLE

A generator is a machine that converts mechanical energy into electrical energy and the principle of Generator is magnetic induction, this principle can be summarised as:

Whenever a conductor is moved within a magnetic field in such a way that the conductor cuts across magnetic lines of flux, voltage is generated in the conductor.

The amount of voltage generated depends on:

- The strength of the magneticfield
- The angle at which the conductor cuts the magneticfield
- The speed at which the conductor ismoved
- The length of the conductor within the magneticfield
- The polarity of the voltage depends on the direction of the magnetic lines of flux and the direction of movement of the conductor

Direction of the current in generator :

For,
Conventional CurrentFlow --- Fleming's Right-hand Rule ElectronCurrent Flow --- Fleming's Left-handRule

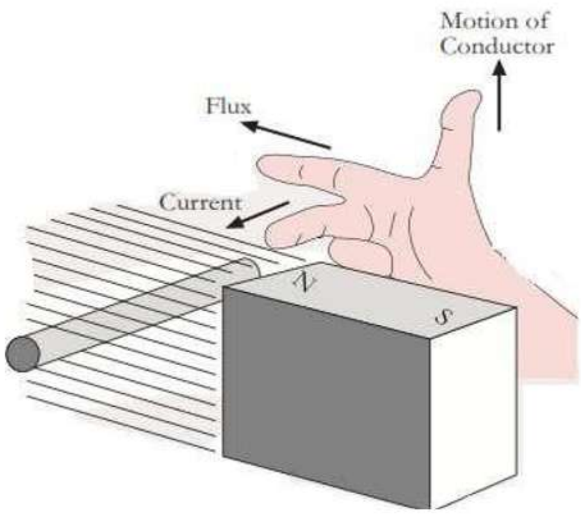


Figure 3 : Fleming's Right-hand Rule

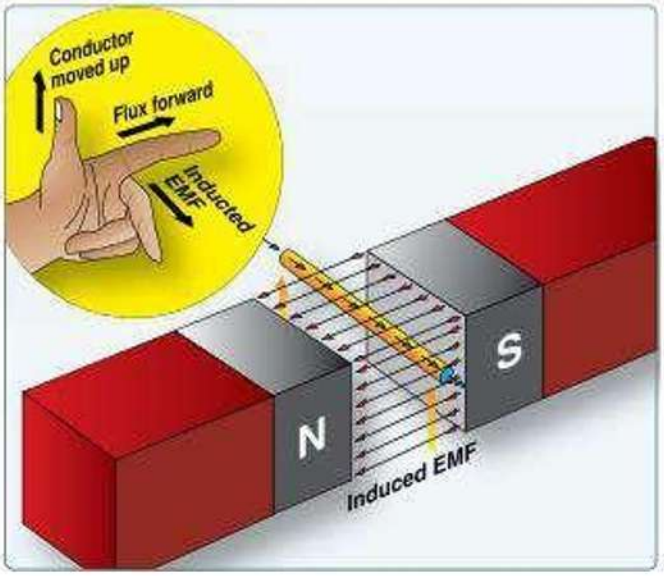


Figure 4 : Fleming's Left-hand Rule

Either rule is applied depending upon the current type (Conventional or Electron) by using the thumb and first two fingers of the left hand or Right hand arranged perpendicular to each other as in figure-3 or figure-4. If the thumb is pointed in the direction of conductor movement; the forefinger in the direction of magnetic flux from north to south; then the middle finger points in the direction of current flow in an external circuit to which the voltage isapplied.

SIMPLE GENERATOR

The simplest generator is an ac generator. A simple generator, figure-5 and 6 consists of a wire loop positioned so that it can rotate in a stationary magnetic field and as it does will produce an induced emf in the loop. Sliding contacts, usually called brushes, connect the loop to an external circuit load in order to pick up or use the induced emf.

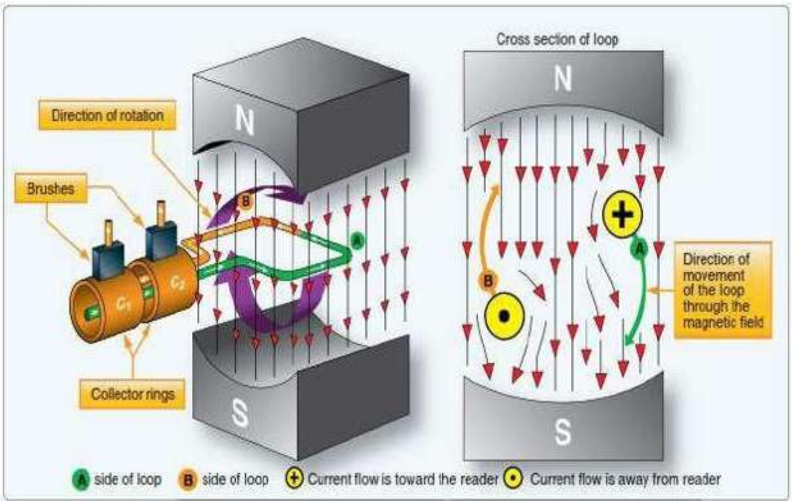


Figure 5 : Simple Generator

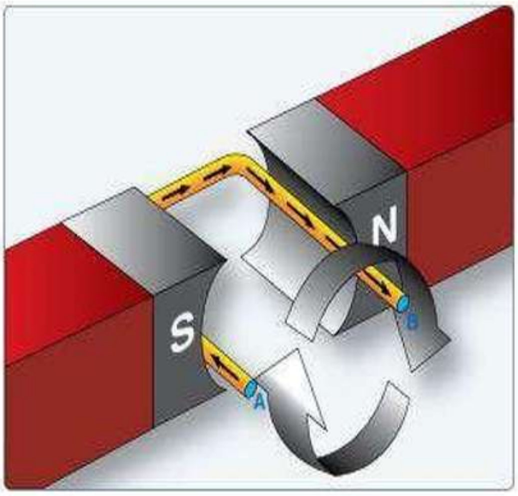
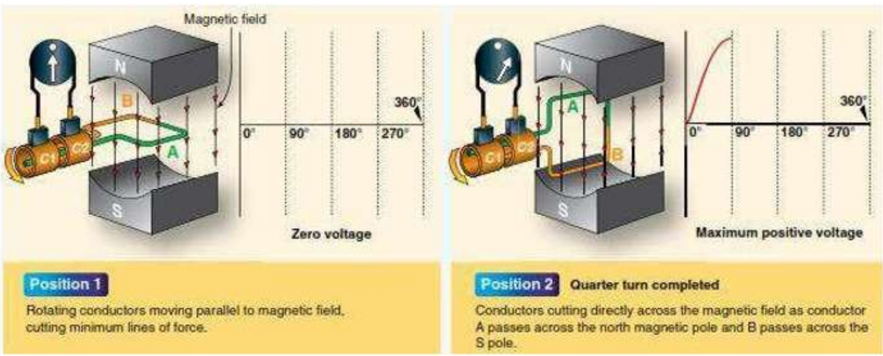


Figure 6 : Voltage Induced in a Loop POSITION 1

The conductor A moves parallel to the lines of force. Since it cuts no lines of force, the induced voltage is zero. As the conductor advances from position 1 to position 2, the induced voltage gradually



increases.

Figure 7 :

POSITION 2

The conductor is now moving in a direction perpendicular to the flux and cuts a maximum number of lines of force; therefore, a maximum voltage is induced. As the conductor moves beyond position 2, it cuts a decreasing amount of flux, and the induced voltage decreases. (Figure 7)

POSITION 3

At this point, the conductor has made half a revolution and again moves parallel to the lines of force, and no voltage is induced in the conductor. As the A conductor passes position 3, the direction of induced voltage now reverses since the A conductor is moving downward, cutting flux in the opposite direction. As the A conductor moves across the South Pole, the induced voltage gradually increases in a negative direction until it reaches position
4. (Figure 8)

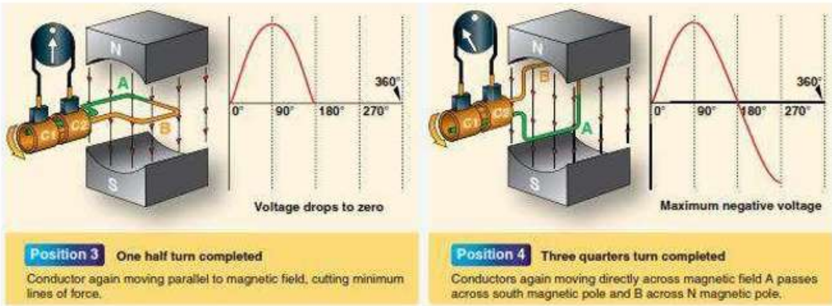


Figure 8 :

POSITION 4

Like position 2, the conductor is again moving perpendicular to the flux and generates a maximum negative voltage. From position 4 to position 5, the inducedvoltage gradually decreases

until the voltage is zero, and the conductor and wave are ready to start another cycle. (Figure 8)

POSITION 5

The curve shown at position 5 is called a sine wave. It represents the polarity and the magnitude of the instantaneous values of the voltages generated. The horizontal baseline is divided into degrees, or time, and the vertical distance above or below the baseline represents the value of voltage at each particular point in the rotation of the loop. (Figure9)

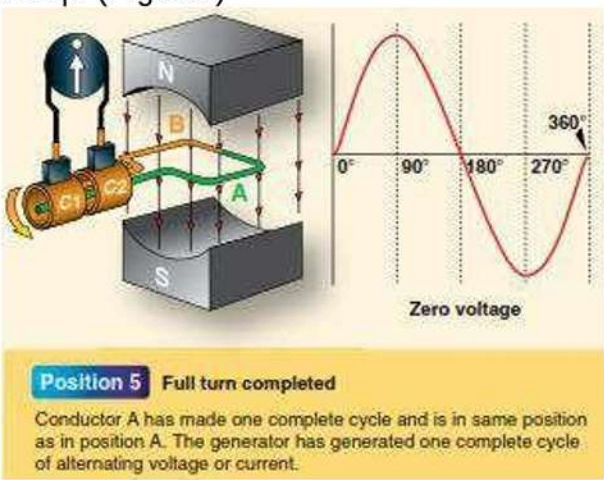


Figure 9 :

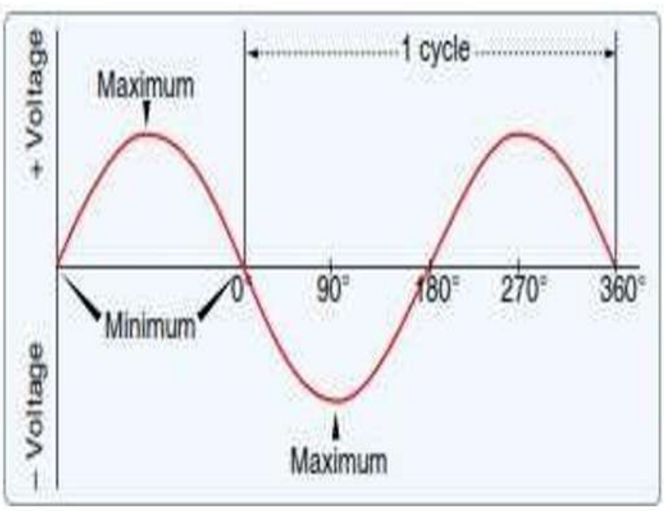


Figure 10 : O/P of ElementaryGenerator

Principle shows that voltage is induced in the armature of a generator throughout the entire 360° rotation of the conductor. The armature is the rotating portion of a DC generator. As shown, the voltage being induced is AC. (Figure 10). Since the conductor loop is constantly rotating, some means must be provided to connect this loop of wire to the electrical loads. As shown in Figure 9, slip rings and brushes can be used to transfer the electrical energy from the rotating loop to the stationary aircraft loads. The slip rings are connected to the loop and rotate; the brushes are stationary and allow a current path to the electrical loads. The slip rings are typically a copper material and the brushes are a soft carbon substance. It is important to remember that the voltage being produced by this basic generator is AC, and AC voltage is supplied to the slip rings. Since the goal is to supply DC loads,some

SIMPLE DC GENERATOR

CONSTRUCTION

The major parts, or assemblies, of a DC generator are, a field frame, a rotating armature, and a brush assembly. The parts of a typical aircraft generator are shown in Figure 11.

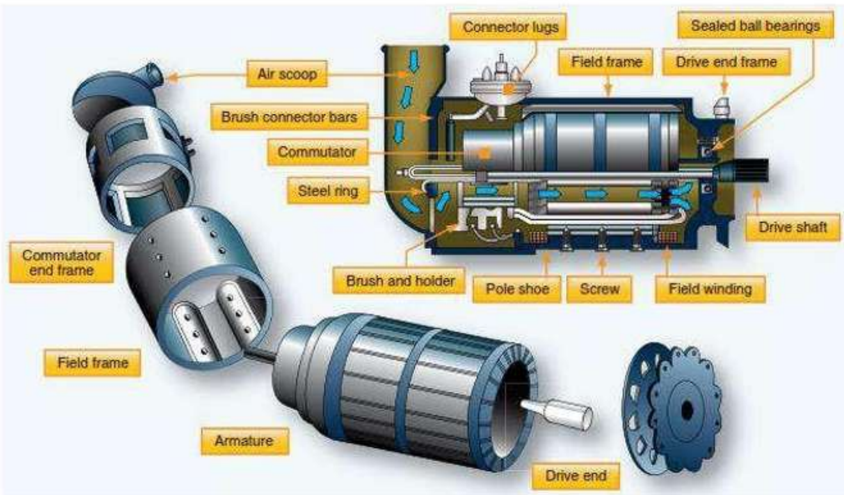


Figure 11 : Typical 24 Volt Aircraft Generator FIELD FRAME

The frame has two functions: to hold the windings neededto produce a magnetic field, and to act as a mechanical support for the other parts of the generator. The actual electromagnet conductor is wrapped around pieces of laminated metal called field poles. The poles are typically bolted to the inside of the frame and laminated to reduce eddy current losses and serve the same purpose as the iron core of an electromagnet; they concentrate the lines of force produced by the field coils. The field coils are made up of many turns of insulated wire and are usually wound on a form that fits over the iron core of the pole to which it is securely fastened. (Figure12)

Figure 12 : Generator Field Frame

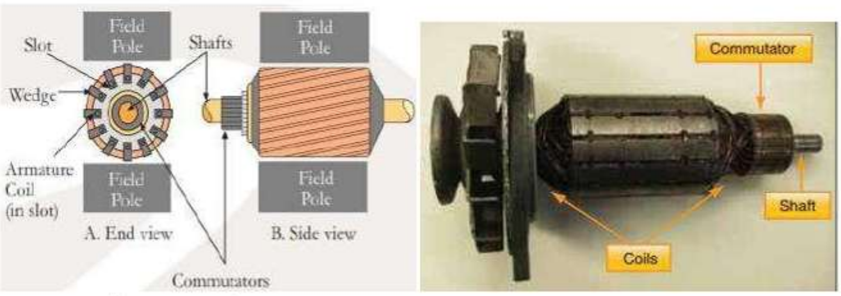
A DC current is fed t o t he field coils to produce an electromagnetic field. This current is typically obtained from an external source that provides voltage and current regulation for the generator system.

ARMATURE

The armature assembly of a generator consists of two primary elements: the wire coils (called windings) wound around an iron core and the commutator assembly. The armature windings are evenly spaced around the armature and mounted on a steel shaft. The armature rotates inside the magnetic field produced by the field coils. The core of the armature acts as an iron conductor in the magnetic field and, for this reason, is laminated to prevent the circulation of eddy currents. A typical armature assembly is shown in Figure13.

COMMUTATORS

Figure 14 and 15, shows a cross-sectional view of a typical commutator. The commutator is located at the end of an armature and consists of copper segments divided by a thin insulator. The insulator is often made from the mineral mica. The brushes ride on the surface of the commutator forming the electrical contact between the armature coils and the external circuit. A flexible, braided copper conductor, commonly called a pigtail, connects each brush to the external circuit. The brushes are free to slide up and down in their holders in order to follow any irregularities in the surface of the commutator. The constant making and breaking of electrical connections between the brushes and the commutator segments, along with the friction between the commutator and the brush, causes brushes to wear out and



need regular attention or replacement.

Figure 13 : A Drum-type Armature

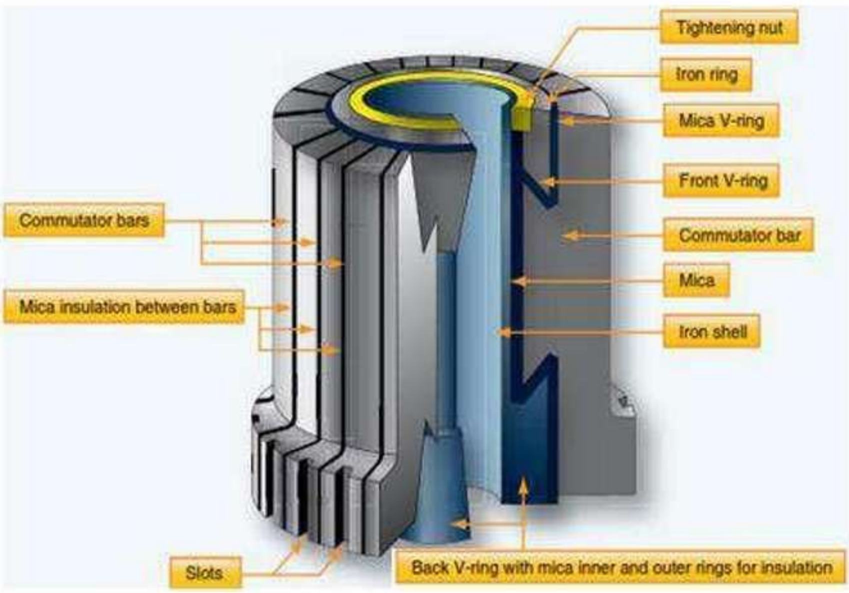


Figure 14 : Typical DC Generator Commutator

Figure 15: Commutator with Portion Removed to Show Construction

For these reasons, the material commonly used for brushes is high-grade carbon. The carbon must be soft enough to prevent

undue wear of the commutator and yet hard enough to provide reasonable brush life. Since the contact resistance of carbon is fairly high, the brush must be quite large to provide a current path for the armature windings. The commutator surface is highly polished to reduce friction as much as possible. Oil or grease must never be used on a commutator, and extreme care must be used when cleaning it to avoid marring or scratching the surface.

CARBON BRUSHES

A pair of carbon brushes picks off the output current from the rotating armature. (Figure 16)

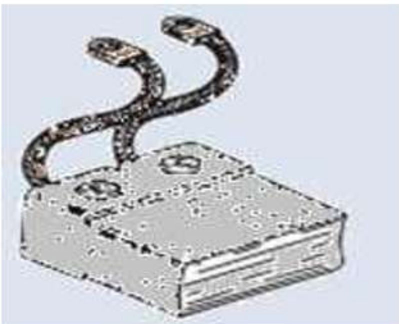


Figure 16 : Carbon Brush GENERATOR CONTROL SYSTEMS

Most generator control systems perform a number of functions related to the regulation, sensing, and protection of t he DC generation system. Light aircraft typically require a less complex generator control system than larger multiengine aircraft. Some of the functions listed below are not found on light aircraft.

Voltage Regulation The most basic of the GCU functions is that of voltage regulation. Regulation of any kind requires the regulation unit to take a sample of a generator output and compare that sample to a known reference. If the generator's output voltage falls outside of the set limits, then the regulation unit must provide an adjustment to the generator field current. Adjusting field current controls generator output.

OVERVOLTAGE PROTECTION

The overvoltage protection system compares the sampled voltage to a reference voltage. The overvoltage protection circuit is used to open the relay that controls the field excitation current. It is typically found on more complex generator control systems.

PARALLEL GENERATOR OPERATIONS

On multiengine aircraft, a paralleling feature must be employed to ensure all generators operate within limits. In general, paralleling systems compare the voltages between two or more generators and adjust the voltage regulation circuit accordingly.

OVER EXCITATION PROTECTION

When one generator in a paralleled system fails, one of the generators can become overexcited and tends to carry more than its share of the load, if not all of the loads. Basically, this condition causes the generator to produce too much current. If this condition is sensed, the overexcited generator must be brought back within limits, or damage occurs. The over excitation circuit often works in conjunction with the overvoltage circuit to control thegenerator.

DIFFERENTIAL VOLTAGE

This function of a control system is designed to ensure all generator voltage values are within a close tolerance before being connected to the load bus. If the output is not within the specified tolerance, then the generator contactor is not allowed to connect the generator to the load bus.

REVERSE CURRENT SENSING

If the generator cannot maintain the required voltage level, it eventually begins to draw current instead of providing it. This situation occurs, for example, if a generator fails. When

GENERATOR CONTROLS FOR HIGH OUTPUT GENERATORS

Most modern high output generators are found on turbine powered corporate-type aircraft. These small business jets and turboprop aircraft employ a generator and starter combined into one unit. This unit is referred to as a starter generator. A starter-generator has the advantage of combining two units into one housing, Savings pace and weight. Since the starter-generator performs two tasks, engine starting and generation of electrical power, the control system for this unit is relativelycomplex.

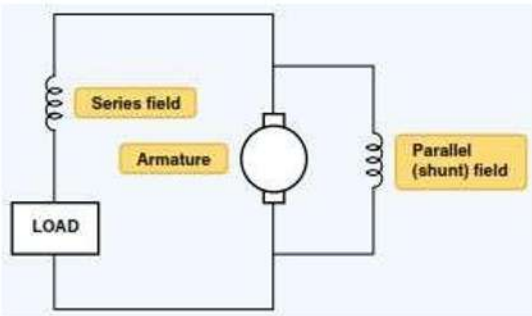


Figure 17 : Starter Generator

A simple explanation of a starter-generator shows that the unit contains two sets of field windings. One field is used to start the engine and one set for the generation of electrical power. Figure 17 above. During the start function, the GCU must energize the series field and the armature causes the unit to act like a motor. During the generating mode, the GCU must disconnect the series field, energize the parallel field, and control the current produced by the armature. At this time, the starter generator acts like a typical generator. Of course, the GCU must perform all the functions described earlier to control voltage and protect the system. These functions include voltage regulation,reverse current sensing, differential voltage, over excitation protection, overvoltage protection, and parallel generator operations.

A typical GCU is shown in Figure 18.

Figure 18 : Generator Control Unit (GCU)

In general, modern GCUs for high-output generators employ solid-state electronic circuits to sense the operations of the generator or starter-generator. The circuitry then controls a series of relays and/or solenoids to connect and disconnect the unit to various distribution busses. One unit found in almost all voltage regulation circuitry is the zener diode. The zener diode is a voltage sensitive device that is used to monitor system voltage. The zener diode, connected in conjunction to the GCU circuitry, then controls the field current, which in turn controls the generator output.

GENERATOR CONTROLS FOR LOW OUTPUT GENERATORS

A typical generator control circuit for low-output generators modifies current flow to the generator field to control generator output power. As flight variables and electrical loads change, the GCU must monitor the electrical system and make the appropriate adjustments to ensure proper system voltage and current. The typical generator control is referred to as a voltage regulator or a GCU. Since most low-output generators are found on older aircraft, the control systems for these systemsare electromechanical devices. (Solid-state units are found on more modern aircraft that employ DC alternators and not DC generators.) The two most common types of voltage regulator are the carbon pile regulator and the three-unit regulator. Each of these units controls field current using a type of variable resistor. Controlling field current then controls generator output. A simplified generator control circuit is shown in Figure18.

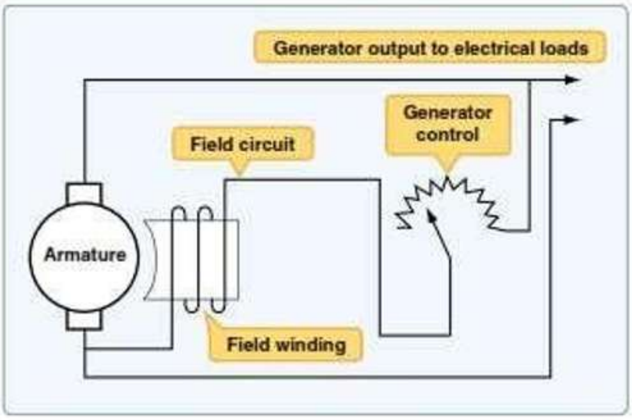


Figure 18 : Voltage Regulator for Low-Output Generator CARBON PILE REGULATORS

The carbon pile regulator controls DC generator output by sending the field current through a stack of carbon disks (the carbon pile). The carbon disks are in series with the generator field. If the resistance of the disks increases, the field current decreases and the generator output goes down. If the resistance of the disks decreases, the field current increases and generator output goes up. As seen in Figure-19, a voltage coil is installed in parallel with the generator output leads. The voltage coil acts like an electromagnet that increases or decrease strength as generator output voltage changes. The magnetism of the voltage coil controls the pressure on the carbon stack. The pressure on the carbon stack controls the resistance of the carbon; the resistance of the carbon controls field current and the field current controls generator output. Carbon pile regulators require regular maintenance to ensure accurate voltage regulation; therefore, most have been replaced on aircraft with more modernsystems.

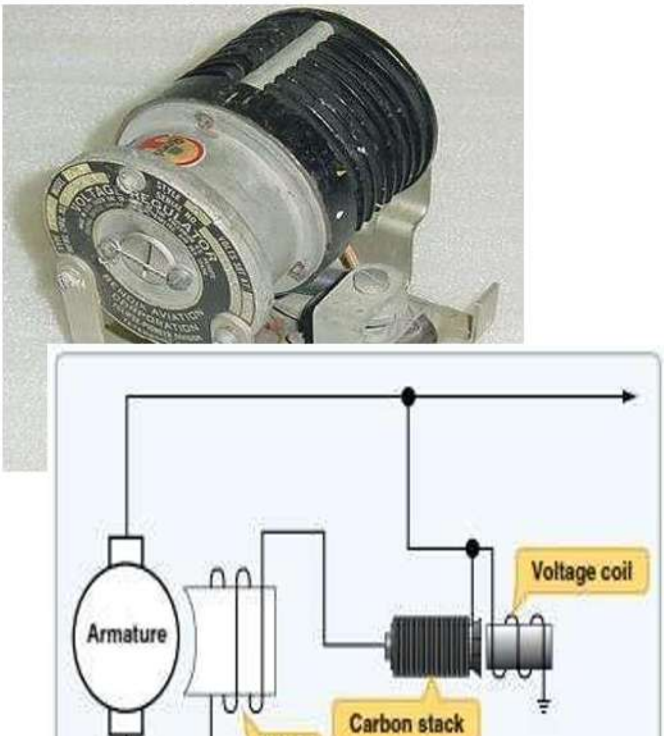


Figure 19 : Carbon Pile Voltage Regulator Circuit with Typical Carbon Pile Voltage Regulator

THREE-UNIT REGULATORS

The three-unit regulator used with DC generator systems is made of three distinct units. Each of these units performs a specific function vital to correct the electrical system operation. A typical three-unit regulator consists of three relays mounted in a single housing. Each of the three relays monitors generator outputs and opens or closes the relay contact points according to system needs. A typical three

unit regulator is shown in Figure 20.

Figure-20, The three relays found on this regulator are used to regulate voltage, limit current, and prevent reversecurrent flow

VOLTAGE REGULATOR SECTION

The voltage regulator section of the three-unit regulator is used to control generator output voltage. The voltage regulator monitor output and control the generator field current as needed. If the regulator senses that system voltage is too high, the relay points open and the current in the field circuit must travel through a resistor. This resistor lowers field current and therefore lowers generator output. Remember, generator output goes down whenever generator field current goes down. As seen in Figure 21,thevoltagecoilisconnectedinparallelwiththegenerator output, and it therefore measures the voltage of the system. Ifvoltage gets beyond a predetermined limit, the voltage coil becomes a strong magnet and opens the contact points.

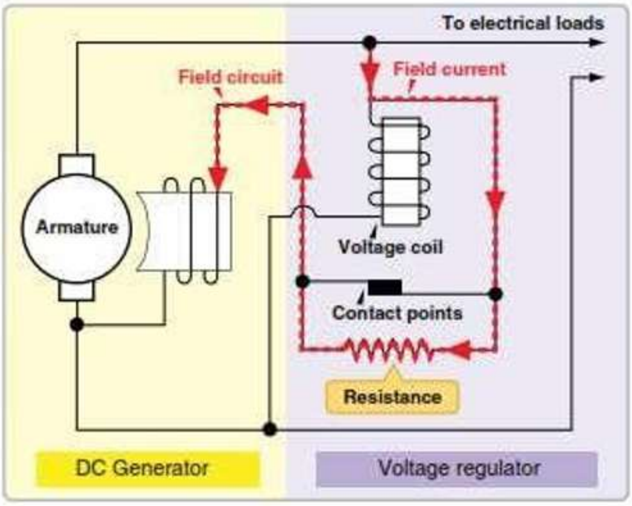


Figure 21 : Voltage Regulator

If the contact points are open, field current must travel through a resistor and therefore field current goes down. The dotted arrow shows the current flow through the voltage regulator when the relay points are open. Since this voltage regulator has only two positions (points open and points closed), the unit must constantly be in adjustment to maintain accurate voltage control. During normal system operation, the points are opening and closing at regular intervals. The points are in effect vibrating. This type of regulator is sometimes referred to as a vibrating type regulator. As the points vibrate, the field current raises and lowers and the field magnetism averages to a level that maintains the correct generator output voltage. If the system requires more generator output, the points remain closed longer and vice versa.

CURRENT LIMITER SECTION

The current limiter section of the three-unit regulator is designed to limit generator output current. This unit contains a relay with a coil wired in series with respect to the generator output. As seen in Figure-22, all the generator output current must travel through the current coil of the relay. This creates a relay that is sensitive to the current output of the generator. That is, if generator output current increases, the relay points open and vice versa. The dotted line shows the current flow to the generator field when the current limiter points are open. It should be noted that, unlike the voltage regulator relay, the current limiter is typically closed during normal flight. Only during extreme current loads must the current limiter points open; at that time, field current is lowered and generator output is kept withinlimits.

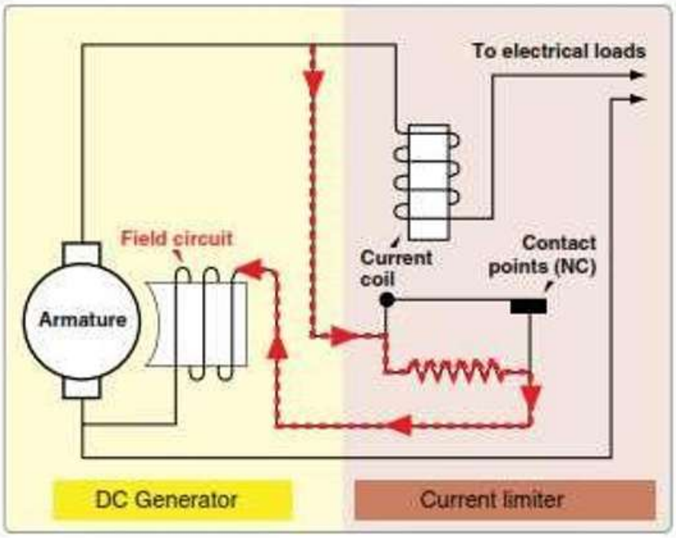


Figure 22 : Current Limiter REVERSE-CURRENT RELAY RELAY

The third unit of a three-unit regulator is used to prevent current from leaving the battery and feeding the generator. This type of current flow would discharge the battery and is opposite of normal operation. It can be thought of as a reverse current situation and is known as reverse current relay. The simple reverse current relay shown in Figure-23, contains both a voltage coil and a current coil. The voltage coil is wired in parallel to the generator output and is energized any time the generator output reaches its operationalvoltage.

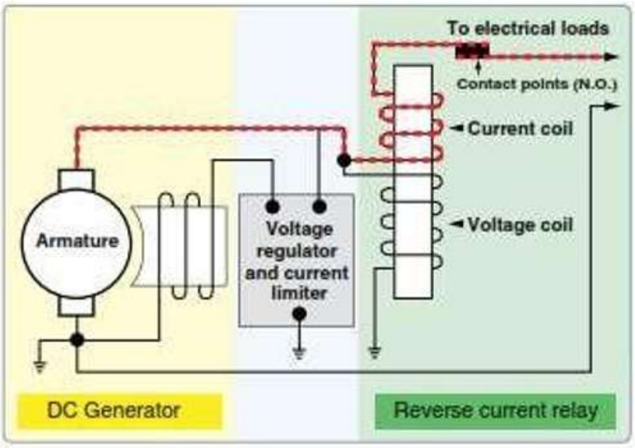


Figure 23 : Reverse - CurrentRelay

As the voltage coil is energized, the contact points close and the current is then allowed to flow to the aircraft electrical loads, as shown by the dotted lines. The diagram shows the reverse current relay in its normal operating position; the points are closed and current is flowing from the generator to the aircraft electrical loads. As current flows to the loads, the current coil is energized and the points remain closed. If there is no generator output due to a system failure, the contact points open because magnetism in the relay is lost. With the contact points open, the generator is automatically disconnected from the aircraft electricalsystem, which prevents reverse flow from the load bus to the generator. A typical three-unit regulator for aircraft generators is shown in Figure 24.

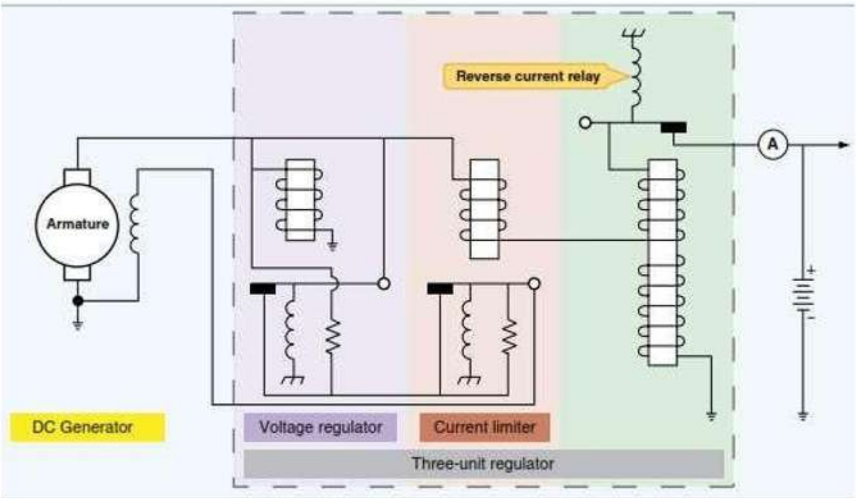


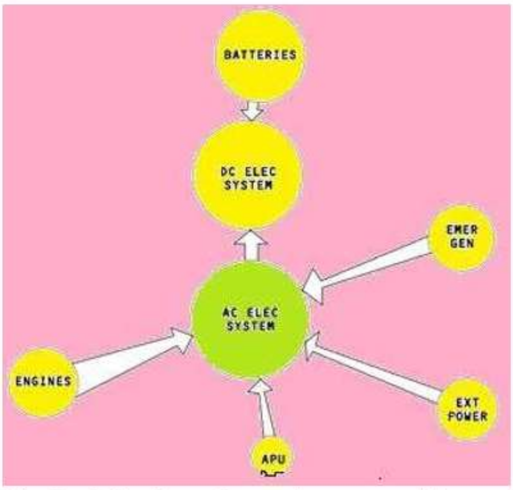
Figure 24 : Three-Unit Regulator for Variable Speed Generators

As seen in Figure-24, above all three units of the regulator work together to control generator output. The regulator monitors generator output and controls power to the aircraft loads as needed for flight variables. Note that the vibrating regulator just described was simplified for explanation purposes. A typical vibrating regulator found on an aircraft would probably be more complex.

AC POWER SYSTEMS

The AC electrical system can be supplied by the Engine generators, the APU generator or an External power source. The DC electrical system is supplied from the AC electrical system or from the batteries as a back up source. An Emergency Generator,

driven by the Blue Hydraulic System pressurized by the Ram Air Turbine in emergency configuration,



can supply part of the AC and DC electrical systems in case of loss of normal supply.

Figure 25 : Power Distribution

Figure 26 : Invertor

Since certain electrical systems operate only on AC, many aircraft employ a completely AC electrical system, as well as a DC system. The typical AC system would include an AC alternator (generator), a regulating system for that alternator, AC power distribution busses, and related fuses and wiring. Note that when referring to AC systems, the terms "alternator" and "generator" are often used interchangeably. AC power systems are becoming more popular on modern aircraft. Light aircraft tend to operate most electrical systems using DC, therefore the DC battery can easily act as a back up power source. Some modern light aircraft also employ a small AC system. In this case, the light aircraft probably uses an AC inverter to produce the AC needed for this system. Inverters are commonly used when only a small amount of AC is required for certain systems. Inverters may also be used as a backup AC power source on aircraft that employ an AC alternator. Figure-26, shows a typical inverter that might be found on modern aircraft. A modern inverter is a solid-state device that converts DC power into AC power. The electronic circuitry within an inverter is quite complex; however, for an aircraft technician's purposes, the inverter is simply a device that uses DC power, then feeds power to an AC distribution bus. Many inverters supply both 26-volt AC, as well as 115-volt AC. The aircraft canbe

ALTERNATORS

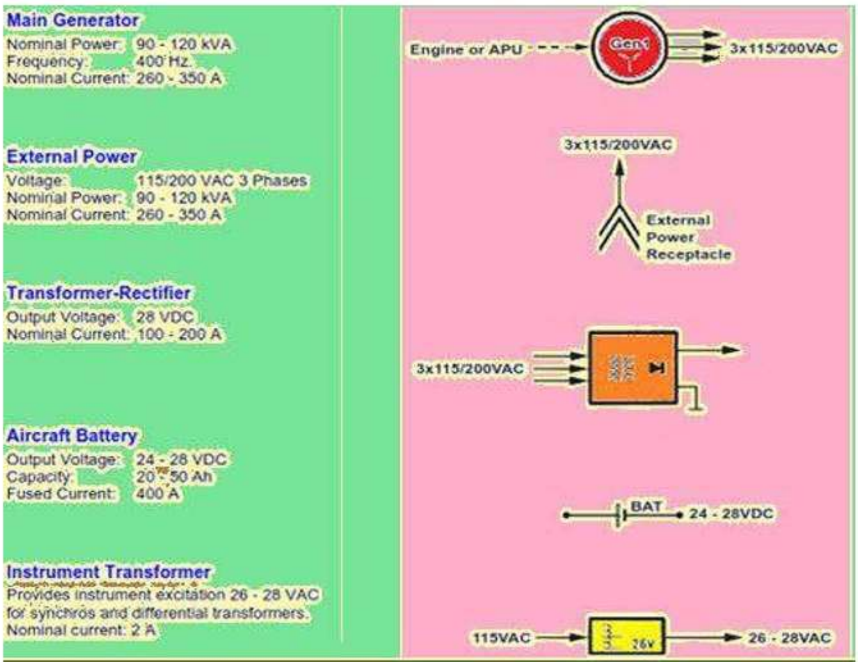


Figure 27 : Power Sources

designed to use either voltage or both simultaneously. If both voltages are used, the power must be distributed on separate 26- and 115-volt AC busses.

SIMPLE ALTERNATORS

Most of the electrical power used in modern, large transport aircraft, as well as in domestic applications, is Alternating Current (AC or ac). As a result, the AC Generator is the most important means of producing electrical power. They are generally called Alternators and vary in size depending upon the power load requirement. The typical aircraft ac system generates a sine wave of a given voltage, typically 115 V and 26 V, and in most case, of a constant frequency. The majority of aircraft that use ac as the primary power source use a 3-phase system, i.e. the generatorproducesthree(3)sinewavesthatareat120degree with respect to each other. Many of the terms and principles covered in this chapter should be familiar to you from earlier chapters as they are th same as those covered in the chapter on dc generators. However, before we go on any further, we need to revisit 3-phase ac to look at how practical systems are connected.

THREE PHASE ALTERNATOR CONNECTION

There are two (2) ways of connecting the three output windings of a 3-phase alternator-Delta wound and star or 'Y' wound.

1. Star or 'Y' Wound 3-Phase ACAlternator

With this type of alternator, each of the three windings are connected together at a common or neutral point as illustrated in figure 28, below :

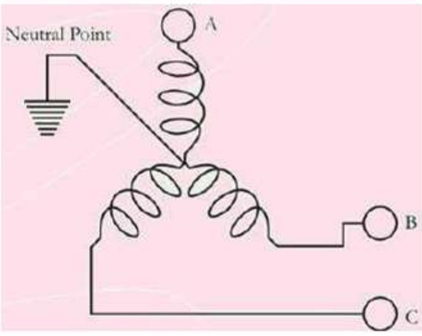


Figure 28 : Star or 'Y' Wound Alternator

As shown in figure 28, the other three ends of the windings are brought out as its output leads, each of which is now across two of the windings in series.

However, the output voltage will never be twice that of one windings as thevoltagesare with respect toeach other. It will instead be 1.73 times that of the single winding. Aircraft alternators produce 115 V ac from each winding at a frequency of 400Hz. Therefore, the output across outputs A to B or B to C is approximately 199 V ac. Since the windings are in series between two of the output leads, the output current is the same as the phasecurrent.

2. Delta WoundAlternator

With the Delta wound alternator, both ends of each winding can be connected to the ends of the other windings to form a Delta connection shown in figure 29, below.

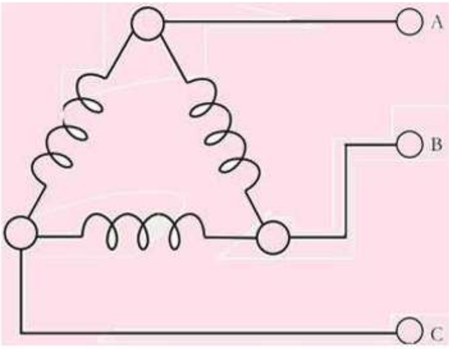


Figure 30 : Delta Connected 3-Phase Alternator

It this construction, an output lead is brought from each junction so that the output voltage will always be the same as the phase voltage. As shown in figure 30, there are two coils in series across or in parallel with each of the phase windings. Since the current in each of the windings is 120 degree out of phase with that in the other windings, the output current is also 1.73 times that of the current in the phasewinding.

BASIC AC GENERATORS

Regardless of size, all electrical generators, whether dc or ac, depend upon the principle of magnetic induction. An emf is induced in a coil as a result of:

1. A coil cutting through a magneticfield.
2. A magnetic field cutting through acoil.

As long as there is relative motion between a conductor and a magnetic field, a voltage will be induced in the conductor. That part of a generator that produces the magnetic field is called the field and that part in which the voltage is induced is called the armature. For relative motion to take place between the conductor and the magnetic field, all generators must have two mechanical parts, a rotor and a stator. The rotor is the part that rotates; the stator is the part that remains stationary. In a dc generator, the armature is always the rotor, but with alternators, the armature may be either the rotor orstator.

ROTATING-ARMATURE ALTERNATORS

The rotating-armature alternator is similar in construction to the dc generator in that the armature rotates in a stationary magnetic field as shown in figure31.

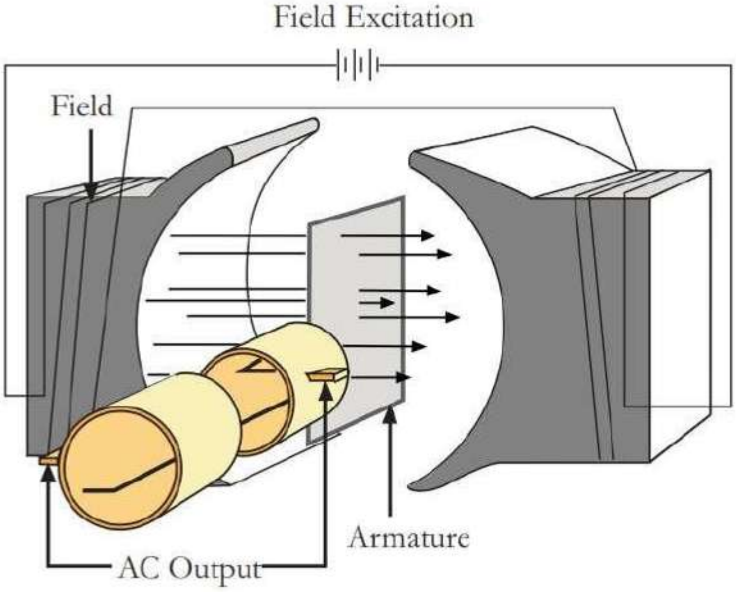
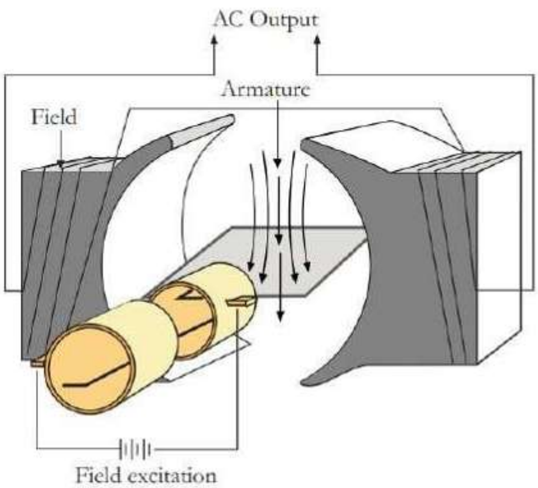


Figure 31 : Simple Rotating Armature Alternator

In the DC generator, the emf generated in the armature windings is converted from ac to dc by means of the commutator. In the alternator, the generated ac is brought to the load unchanged by using slip rings. The rotating armature is only found in alternators of low power rating and generally is not used to supply electric power in large quantities. A major disadvantage of a rotating armature it that it requires slip rings and brushes to conduct the current from the armature to the load. The armature, brushes, and slip rings are difficult to insulate, and arc-overs and short circuits can result at high voltages. For this reason, high-voltage alternators are usually of the rotating-fieldtype.

ROTATING-FIELD ALTERNATORS

The rotating-field alternator has a stationary armature winding and a rotating-field winding as shown in figure 32. The advantage of having a stationary armature winding is that the generated voltage can be connected directly to the load and since the voltage applied to the rotating field is low voltage dc, the problem of high voltage arc-over at the slip rings does not exist. The stationary armature, or stator, of this alternator type holds the windings that are cut by the rotating magnetic field. The voltage generated in the armature as a result of this cutting action is the ac power that willbe applied to the load. The stators of all rotating-field alternators are basically the same. The stator consists of a laminated iron core



with the armature windings embedded in this core, as shown in figure-33; which is secured to the statorframe.

Figure 32 : Simple Rotating Field Alternator

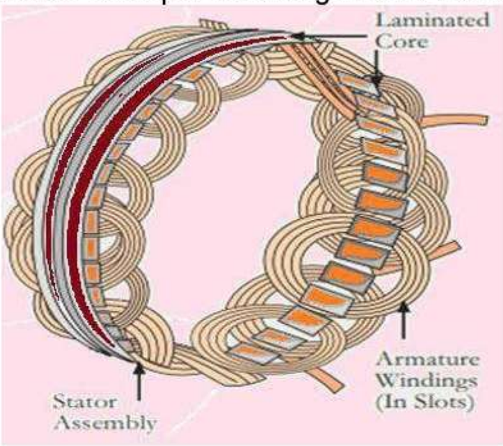


Figure 33 : Stationary Armature Windings ALTERNATOR COMPONENTS AND THEIR FUNCTION

A typical rotating-field ac generator consists of an alternator and a smaller dc generator built into a single unit. The output of the alternator section supplies alternating voltage to the load. The only purpose for the dc exciter generator is to supply the direct current required to maintain the alternator field. This dc generator is referred to as the Exciter. A typical alternator is shown in the figure 34; while the bottom view of this figure is in figure35.

The exciter is a dc, shunt-wound, self-excited generator and the exciter shunt field (2) creates an area of intense magnetic flux between its poles. When the exciter armature (3) is rotated in the exciter-field flux, voltage is induced in the exciter armature windings. The output from the exciter commutator (4) is connected through brushes and slip rings (5) to the alternator field. Since this is direct current already converted by the exciter commutator, the current always flows in one direction through the alternator field (6). Therefore, a fixed polarity magnetic field is maintainedatalltimesinthealternatorfieldwindings.Whenthe alternator field is rotated, its magnetic flux is passed through and across the alternator armature windings (7). In some alternators, the exciter is supplied directly off the aircraft's batteries but as this can drag the battery voltage down considerably, is only used for smalleralternators.

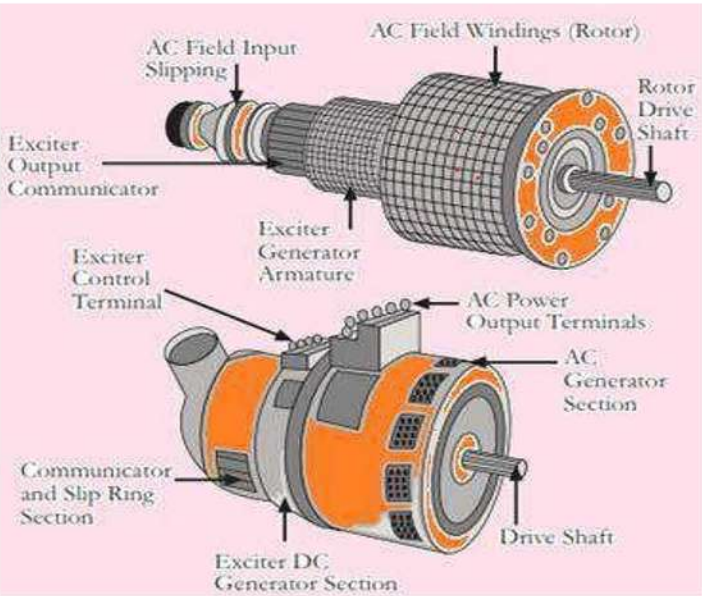


Figure 34 : Typical AC Generator

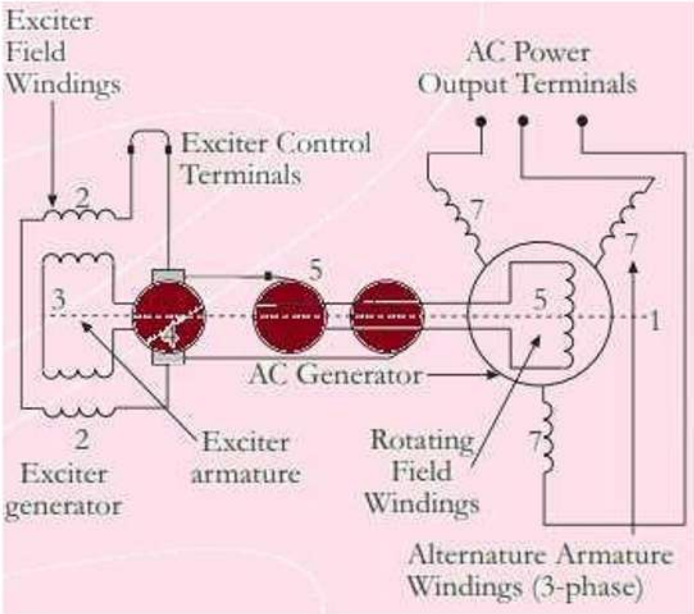


Figure 35 : Bottom View, Alternator Schematic

ALTERNATOR ROTORS

There are two types of rotors used in rotating-field alternators-The turbine-driven Rotor and Salient-pole rotors. Figure 36, shows the construction of these two rotors. The salient-pole rotor shown in Figure -36, is used in low-speed alternators and often consists of several separately wound pole pieces, bolted to the frame of the rotor. If we could compare the physical size of the two types of rotors with the same electrical characteristics, we would see that the salient-pole rotor would have a greater diameter.

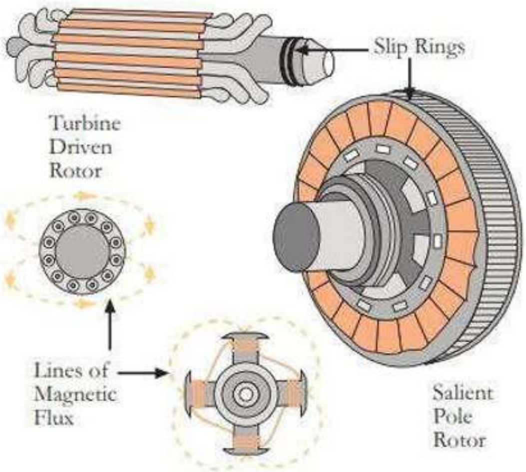
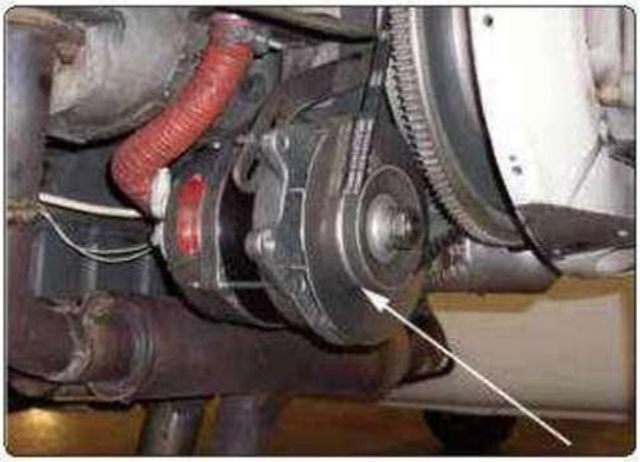


Figure 36 : Typical Rotor Construction

At the same number of revolutions per minute, it has a greater centrifugal force than the turbine-driven rotor. To reduce this force to a safe level so that the windings will not be thrown out of the machine, the salient pole is used in low-speed designs, usually with a Constant Speed Drive (CSD) unit to keep the speed constant.

DC ALTERNATORS

DC alternators and their related controls are found on modern, light, piston-engine aircraft. The alternator is mounted in the engine compartment driven by a v-belt, or drive gear mechanism, which receives power from the aircraft engine. (Figure 37) The control system of a DC alternator is used to automatically regulate alternator output power and ensure the correct system voltage for various flight parameters. DC alternators contain two major components: the armature winding and the field winding. The field winding (which produces a magnetic field) rotates inside the armature and, using the process of electromagnetic induction,the armature produces a voltage. This voltage produced by the armature is fed to the aircraft electrical bus and produces a current to power the electrical loads. Figure 38, shows a basic diagram of a typicalalternator.



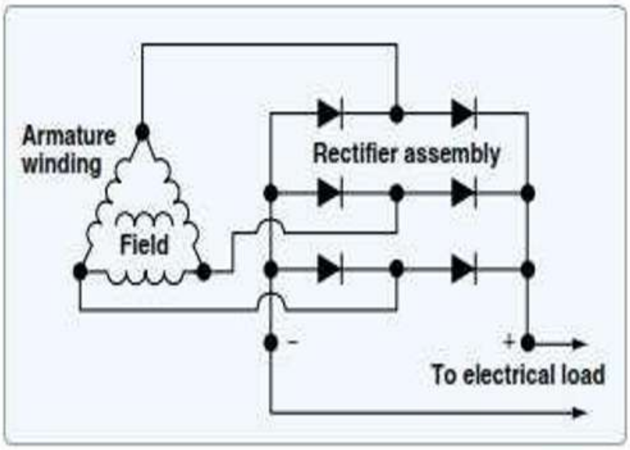


Figure 37 : DC Alternator Installation

Figure 38 : Diagram of a Typical Alternator

The armature used in DC alternators actually contains three coils of wire. Each coil receives current as the magnetic field rotates inside the armature. The resulting output voltage consists of three distinct AC sine waves, as shown in Figure 39. The armature winding is known as a three- phase armature, named after the three different voltage waveformsproduced.

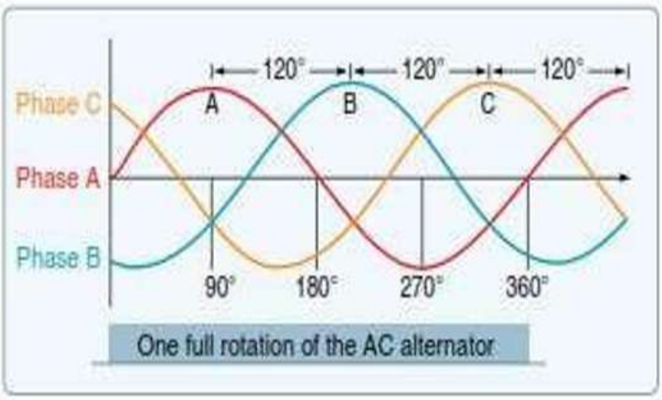


Figure 39 : Sine Waves.

Figure 40 shows the two common methods used to connect the three phase armature windings: the delta winding and the Y winding. For all practical purposes, the two windings produce the same results in aircraft DC alternators. Since the three-phase voltage produced by the alternators armature is AC, it is not compatible with typical DC electrical loads and must be rectified (changed to DC). Therefore, the armature output current is sent through a rectifier assembly that changes the three-phase AC to DC (Figure-41). Each phase of the three-phase armature overlaps when rectified, and the output becomes a relatively smooth ripple DC (Figure 41).

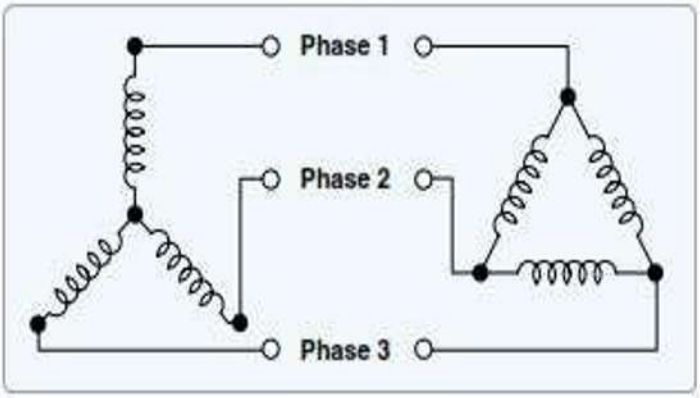


Figure :40 :Three-phase armature windings : Y on the left and delta winding on the right

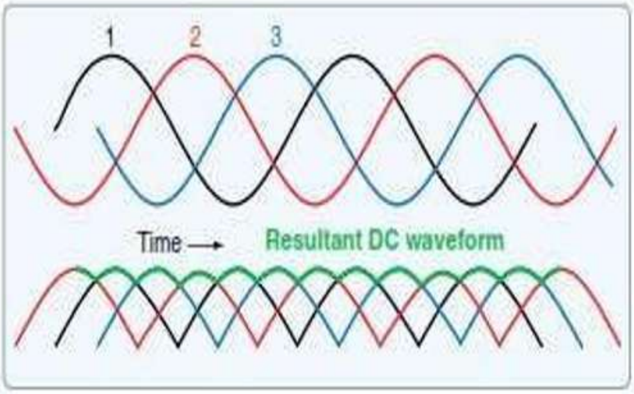


Figure 41 : Relatively Smooth Ripple DC

The invention of the diode has made the development of the alternator possible. The rectifier assembly is comprised of six diodes. This rectifier assembly replaces the commutator and brushes found on DC generators and help to make the alternator more efficient. Figure 42, shows the inside of a typical alternator; the armature assembly is located on the outer edges of the alternator and the diodes are mounted to the case. The field winding, shown in Figure-43, is mounted to a rotor shaft so it can spin inside of the armature assembly.

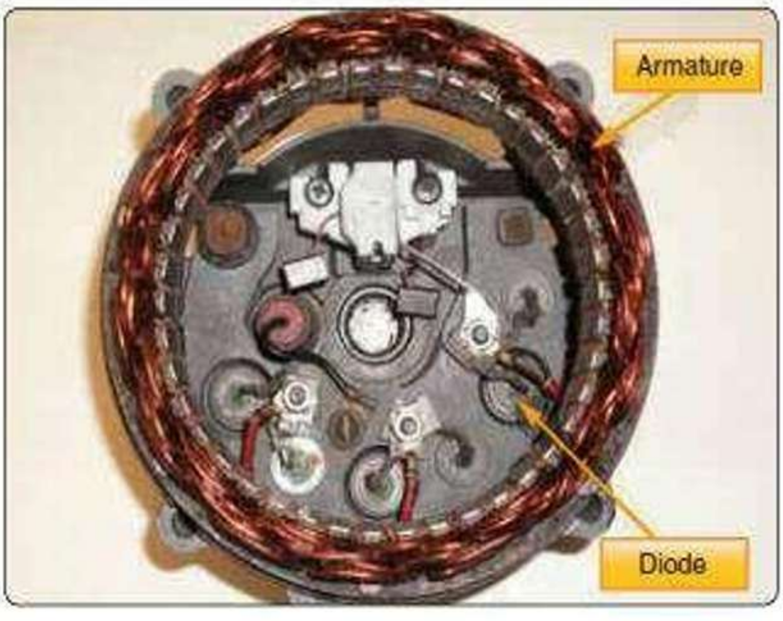


Figure 42 : Diode Assembly

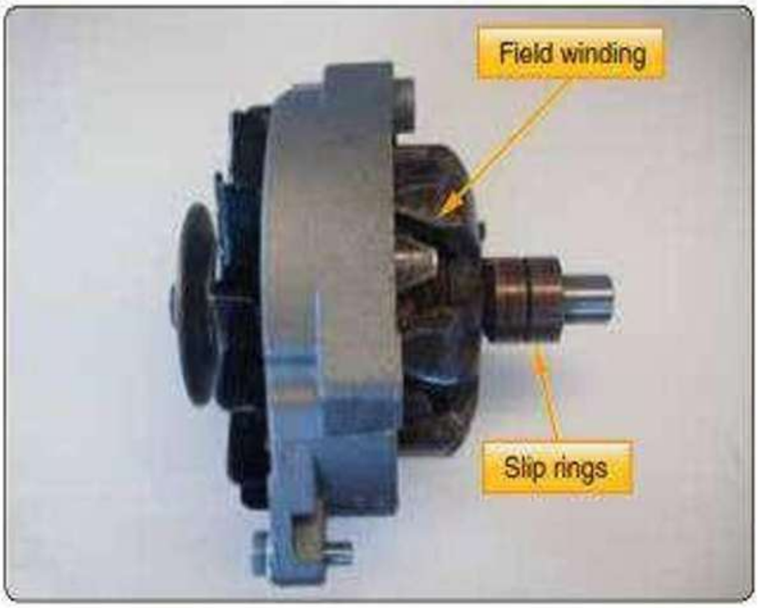


Figure 43 : Alternator Field Winding

The field winding must receive current from an aircraft battery in order to produce an electromagnet. Since the field rotates, a set of brushes must be used to send power to the rotating field. Two slip rings are mounted to the rotor and connect the field winding to electrical contacts called brushes. Since the brushes carry relatively low current, the brushes of an alternator are typically smaller than those found inside a DC generator. Figure-44, DC alternator brushes last longer and require less maintenance than those found in a DCgenerator.

Figure 44 : Alternator Brushes

The alternator case holds the alternator components inside a compact housing that mounts to the engine. Aircraft alternators either produce a nominal 14-volt output or a 26-volt output. The physical size of the alternator is typically a function of the alternator's amperage output. Common alternators for light aircraft range in output form 60–120amps.

DC ALTERNATOR VOLTAGE REGULATORS

Voltage regulators for DC alternators are similar to those found on DC generators. The general concepts are the same in that adjusting alternator field current controls alternator output. Regulators for most DC alternators are either the vibrating-relay type or solid-state regulators, which are found on most modern aircraft. Vibrating-relay regulators are similar to those discussed in the section on generator regulators. As the points of the relay open, the field current is lowered and alternator output is lowered and vice versa. Solid-State Regulators Solid-state regulators for modern light aircraft are often referred to as alternator control units(ACUs).Theseunitscontainnomovingpartsandare generally considered to be more reliable and provide better system regulation than vibrating-type regulators. Solid-state regulators rely on transistor circuitry to control alternator field current and alternator output.

The regulator monitors alternator output voltage/current and controls alternator field current accordingly. Solid state regulator typically provides additional protection circuitry not found in vibrating-type regulators. Protection may include over- or under- voltage protection, over current protection, as well as monitoring the alternator for internal defects, such as a defective diode. In many cases, the ACU also provides a warning indication to the pilot if a system malfunction occurs. A key component of any solid-state voltage regulator is known as the zener diode. Figure- 45, shows the schematic diagram symbol of a zener diode, as well as one installed in an ACU. The operation of a zener diode is similar to a common diode in that the zener only permits current flow in one direction. This is true until the voltage applied to the zener reaches a certain level. At that predetermined voltage level, the zener then permits current flow with either polarity. This is known as the breakdown or zener voltage.

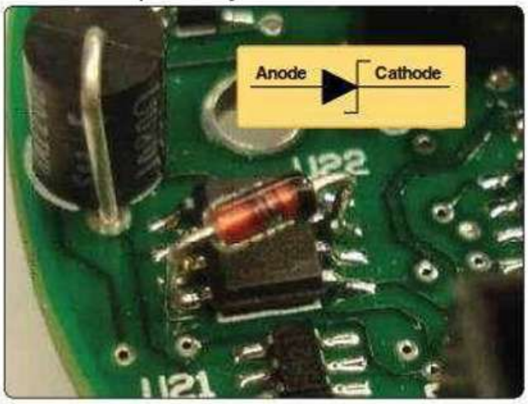
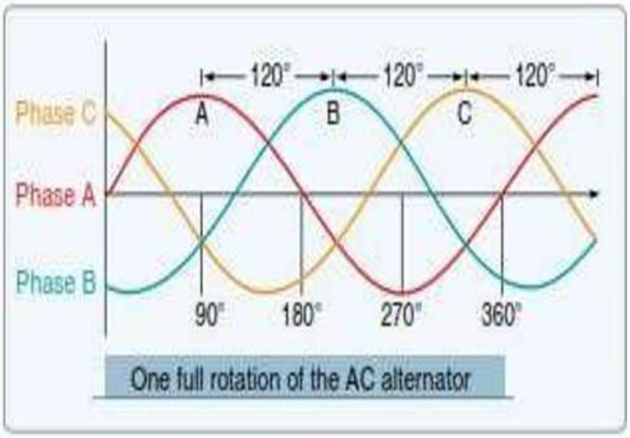


Figure 45 : Zener Diode

As an ACU monitors alternator output, the zener diode is connected to system voltage. When the alternator output reaches the specific zener voltage, the diode controls a transistor in the circuit, which in turn controls the alternator field current. This is a simplified explanation of the complete circuitry of an ACU. [Figure 9-73] However, it is easy to see how the zener diode and transistor circuit are used in place of an electromechanical vibrating-type regulator. The use of solid-state components creates a more accurate regulator that requires very little maintenance. The solid relay in a -state ACU is, therefore, the control unit of choice for modern aircraft with DCalternators.

AC ALTERNATORS

AC alternators are found only on aircraft that use a large amount of electrical power. Virtually all transport category aircraft, such as the Boeing 757 or the Airbus A-380, employ one AC alternator



driven by each engine. These aircraft also have an auxiliary AC alternator driven by the auxiliary power unit. In most cases, transport category aircraft also have at least one more AC backup power source, such as an AC inverter or a small AC alternator driven by a ram-air turbine (RAT). AC alternators produce a three-phase AC output. For each revolution of the alternator, the unit produces three separate voltages. The sine waves for these voltages are separated by 120°. [Figure-46,] This wave pattern is similar to those produced internally by a DC alternator; however, in this case, the AC alternator does not rectify the voltage and the output of the unit is AC. The modern AC alternator does not utilize brushes or slip rings and is often referred to as a brushless AC alternator. This brushless design is extremely reliable and requires very little maintenance. In a brushless alternator, energy to or from the alternator's rotor is transferred using magnetic energy. In other words, energy from the stator to the rotor is transferred using magnetic flux energy and the processof electromagnetic induction. A typical large aircraft AC alternator is shown in Figure 47.

Figure46

Figure47

As seen in Figure 48, the brushless alternator actually contains three generators: the Exciter generator (armature and permanent magnet field), the Pilot exciter generator (armature and fields windings), and the main AC alternator armature winding and field winding. The need f or brushes is eliminated by using a combination of these three distinct generators. The exciter is a small AC generator with a stationary field made of a permanent magnet and two electromagnets. The exciter armature is three phase and mounted on the rotor shaft. The exciter armature output is rectified and sent to the pilot exciter field and the main generator field. The pilot exciter field is mounted on the rotor shaft and is connected in series with the main generator field. The pilot exciter armature is mounted on the stationary part of the assembly. The AC output of the pilot exciter armature is supplied to the generator control circuitry where it is rectified, regulated, and then sent to the exciter field windings. The current sent to the exciter field provides the voltage regulation for the main AC alternator. If greater AC alternator output is needed, there is more current sent to the exciter field and vice versa. In short, the exciter permanent magnet and armature starts the generation process, and the output of the exciter armature is rectified and sent to the pilot exciter field. The pilot exciter field creates a magnetic field and induces power in the pilot exciter armature through electromagnetic induction. The output of the pilot exciter armature is sent to the main alternator control unit and then sent back to the exciter field. As the rotor continues to turn, the main AC alternator field generates power into the main AC alternator armature, also using electromagnetic induction. The output of the main AC armature is three-phase AC and used to power the various electricalloads.

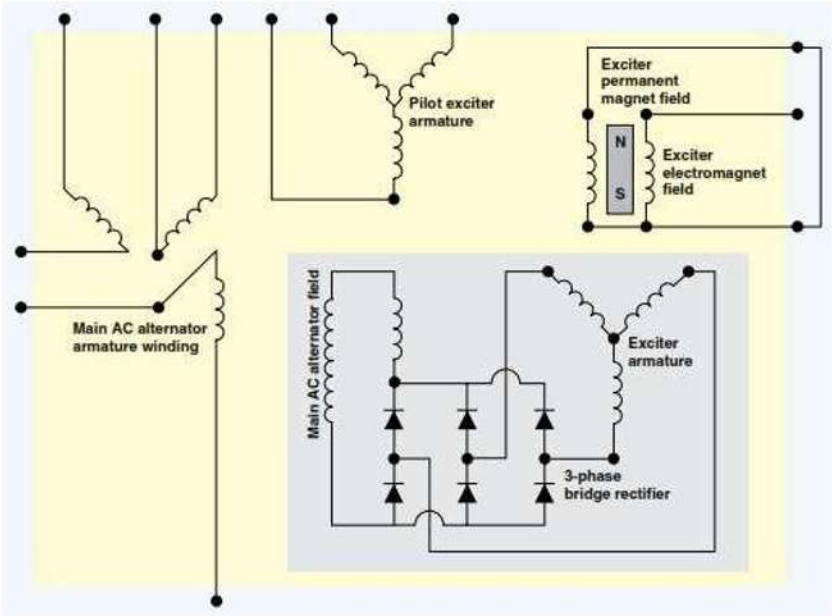


Figure 48

Some alternators are cooled by circulating oil through the internal components of the alternator. The oil used for cooling is supplied from the constant speed drive assembly and often cooled by an external oil cooler assembly. Located in the flange connecting the generator and drive assemblies, ports make oil flow between the constant speed drive and the generator possible. This oil level is critical and typically checked on a routine basis.

BRUSHLESS GENERATOR

The generator is a conventional 3 co- axial component brushless generator which consists of a Permanent Magnet Generator (PMG), a rotating diode pilot exciter, the generator itself. The generator is driven at a constant speed and is cooled by air or oil spraying. Rotation of the permanent magnet generator rotor induces an alternating current (ac) voltage in the 3-phase windings of the permanent magnet generator stator. This ac voltage is supplied through a connector on the IDG housing and aircraft wiring to the GCU where it is rectified into direct current (dc) voltage. This rectified dc voltage is used by the GCU voltage regulator to control the dc voltage applied to the windings of the generator's exciter field and GCU power supply. The Permanent Magnet Generator (PMG) supplies the exciter field through the Generator Control Relay (GCR) and the Generator Control Unit through a Rectifier Unit. The stationary magnetic field produced by the direct current in the windings of the exciter field induces a 3-phase ac voltage in the rotating windings of the exciter armature (rotor).

This ac voltage is converted to dc voltage by the rotating rectifier assembly on the armature. By applying this dc voltage to the main generator field, current flows in the field winding producing a magnetic field rotating with the generator shaft. This rotating magnetic field induces an ac voltage in the windings of the main generator stator. The generator output is fed through the generator current transformers inside the IDG and through the terminal block on the IDG housing. The excitation control and regulation module keeps the voltage at the nominal value at the Point Of Regulation(POR).

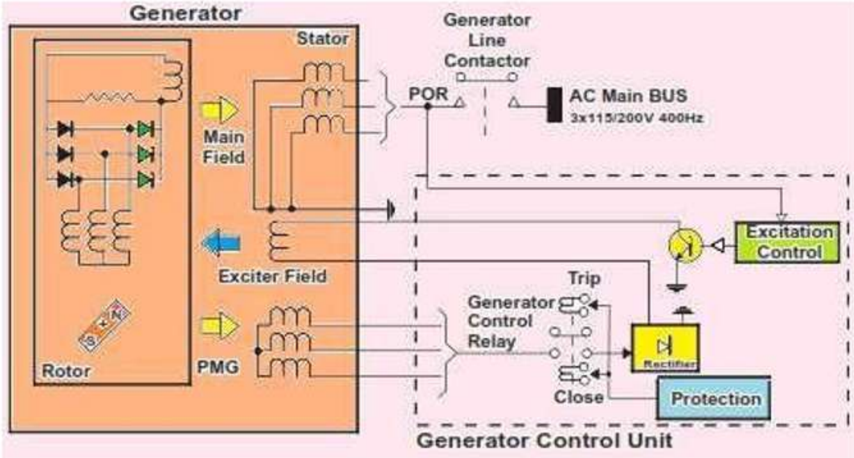


Figure 49 : Generator and Excitation Control

The voltage regulator is enabled when PMG frequency exceeds a POR equivalent PMG frequency of 350 Hz. The voltage regulator is disabled when the POR equivalent PMG frequency falls below 250 Hz or when the GCR protective trip latch is set. The voltage regulator has both 3 phase average and highest phase regulation and is compensated by the REAL load CT loop, REACTIVE load CT loop and TOTAL generator LOAD.

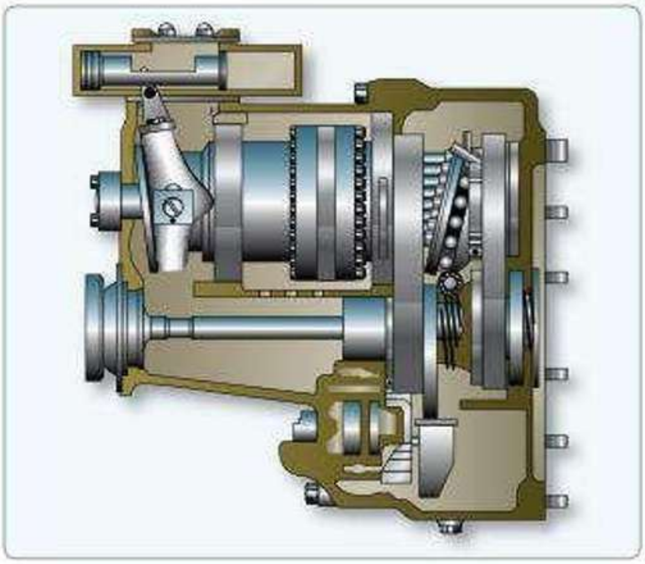
INTEGRATED DRIVE GENERATOR (IDG)

The unit shown in Figure 50, contains an alternator assembly combined with an automatic drive mechanism. The automatic drive controls the alternator's rotational speed which allows the alternator to maintain a constant 400-Hz AC output. All AC alternators must rotate at a specific rpm to keep the frequency of the AC voltage within limits. Aircraft AC alternators should produce a frequency of approximately 400 Hz. If the frequency strays more than 10 percent from this value, the electrical systems do not operate correctly. A unit called a constant-speed drive
(CSD) is used to ensure the alternator rotates at the correct speed to ensure a 400- Hz frequency. The CSD can be an independent unit or mounted within the alternator housing. When the CSD and the alternator are contained within one unit, the assembly is known as an integrated drive generator(IDG).

If the aircraft engine changes speed, the alternator speed remains constant. A typical hydraulic type drive is shown in Figure 51. This unit can be controlled either electrically or mechanically. Modern aircraft employ an electronic system. The constant-speed drive enables the alternator to produce the same frequency at slightly above engine idle rpm as it does at maximum engine rpm. The hydraulic transmission is, mounted between the AC alternator and the aircraft engine. Hydraulic oil or engine oil is used to operate the hydraulic transmission, which creates a constant output speed to drive the alternator. In some cases, this same oil is used to cool the alternator as shown in the CSD cutawayview.

Figure 50

Figure 51



The input drive shaft is powered by the aircraft engine gear case. The output drive shaft, on the opposite end of the transmission, engages the drive shaft of the alternator. The CSD employs a hydraulic pump assembly, a mechanical speed control, and a hydraulic drive. Engine rpm drives the hydraulic pump; the hydraulic drive turns the alternator. The speed control unit is made up of a wobble plate that adjusts hydraulic pressure to control output speed.

Figure 52, shows a typical electrical circuit used to control alternator speed. The circuit controls the hydraulic assembly found in a typical CSD. As shown, the alternator input speed is monitored by a tachometer (tach) generator. The tach generator signal is rectified and sent to the valve assembly. The valve assembly contains three electromagnetic coils that operate the valve. The AC alternator output is sent through a control circuit that also feeds the hydraulic valve assembly. By balancing the force created by the three electromagnets, the valve assembly controls the flow of fluid through the automatic transmission and controls the speed of the AC alternator. It should be noted that an AC alternator also produces a constant 400 Hz if that alternator is driven directly by an engine that rotates at a constant speed. On many aircraft, the auxiliary power unit operates at a constant rpm. AC alternators driven by these APUs are typically driven directly by the engine, and there is no CSD required. For these units, the APU engine controls monitor the alternator output frequency. If the alternator output frequency varies from 400 Hz, the APU speed control adjusts the engine rpm accordingly to keep the alternator output within limits.

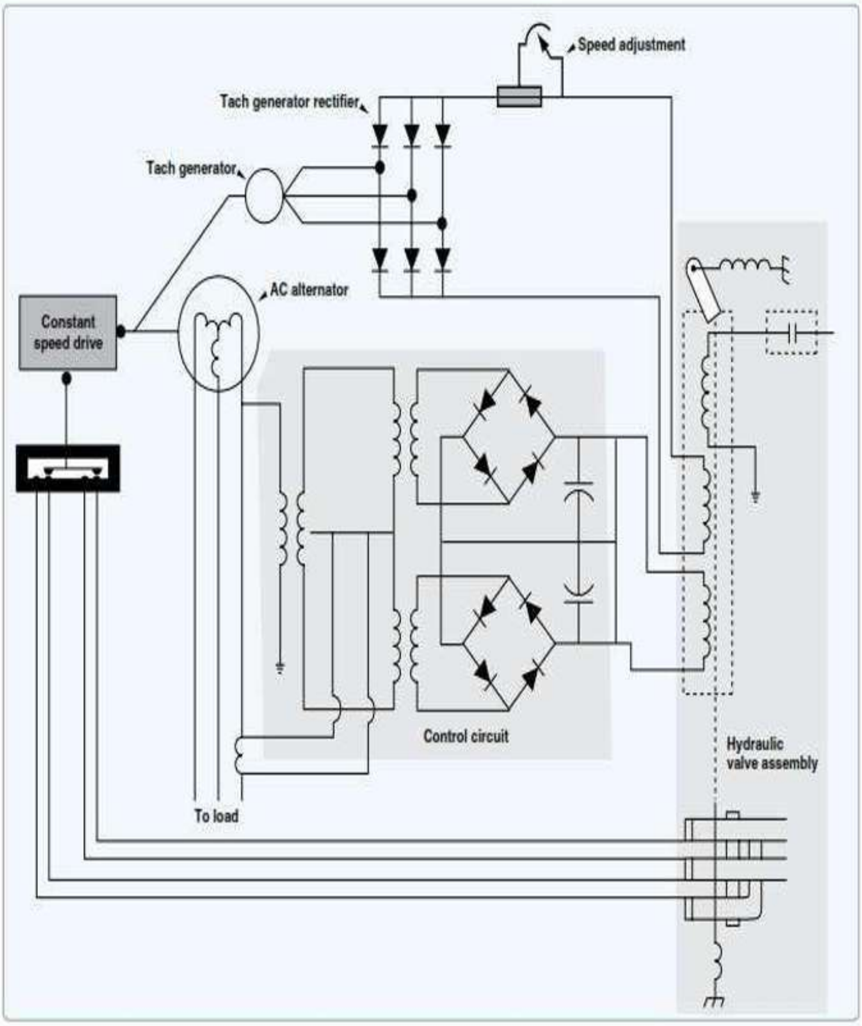


Figure 52 : Typical Electrical Circuit Used to Control Alternator Speed

VARIABLE SPEED CONSTANT FREQUENCY (VSCF) ALTERNATORS

The VSCF systems are the latest attempt to eliminate moving parts from the various electrical components on the aircraft. This system utilizes a large DC alternator which is not reliant on a constant input speed. The mechanically complex constant speed drive unit is therefore not required. The DC output voltage from the alternator is sent to a solid-state device which converts the DC to an AC voltage of a constant 400 hertz. This unit is typically referred to as an inverter. The electronic control circuitry for VSCF system is quite complex: however, the reliability of the electrical system should outperform the CSD needed for the typical AC alternator. It is very likely that future AC power systems will rely on the VSCF system due to their enhanced reliability.[Figure-53]

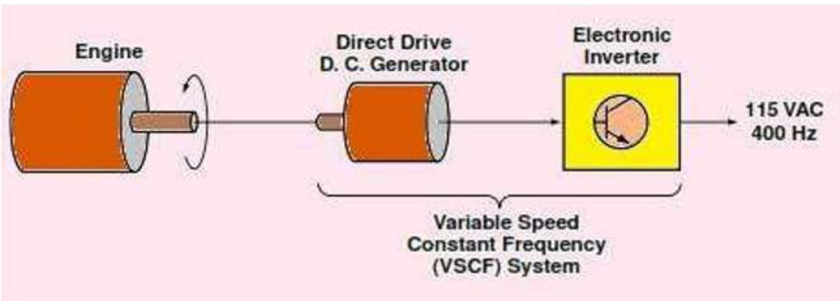


Figure 53 : VSCF Principle AC ALTERNATORS CONTROL SYSTEMS

Modern aircraft that employ AC alternators use several computerized control units, typically located in the aircraft's equipment bay for the regulation of AC power throughout theaircraft. Figure 9-81 shows a photo of a typical equipment bay and computerized control units. Since AC alternators are found on large transport category aircraft designed to carry hundreds of passengers, their control systems always have redundant computers that provide safety in the event of a system failure.

Unlike DC systems, AC systems must ensure that the output frequency of the alternator stays within limits. If the frequency of an alternator varies from 400 Hz, or if two or more alternators connected to the same bus are out of phase, damage occurs to the system.

All AC alternator control units contain circuitry that regulates both voltage and frequency. These control units also monitor a variety of factors to detect any system failures and take protective measures to ensure the integrity of the electrical system. The two most common units used to control AC alternators are the bus power control unit (BPCU) and the GCU. In this case, the term "generator" is used, and not alternator, although the meaning is the same. The GCU is the main computer that controls alternator functions. The BPCU is the computer that controls the distribution of AC power to the power distribution busses located throughout the aircraft. There is typically one GCU used to monitor and control each AC alternator, and there can be one or more BPCUs on the aircraft. BPCUs are described later in this chapter; however, please note that the BPCU works in conjunction with the GCUs to control AC on modern aircraft. A typical GCU ensures the AC alternator maintains a constant voltage, typically between 115 to 120 volts. The GCU ensures the maximum power output of the alternator is never exceeded.

Figure 54

The GCU provides fault detection and circuit protection in the event of an alternator failure. The GCU monitors AC frequency and ensures the output if the alternator remains 400 Hz. The basic method of voltage regulation is similar to that found in all alternator systems; the output of the alternator is controlled by changing the strength of a magnetic field. As shown in Figure 55, the GCU controls the exciter field magnetism within the brushless alternator to control alternator output voltage. The frequency is controlled by the CDS hydraulic unit in conjunction with signals monitored by the GCU.

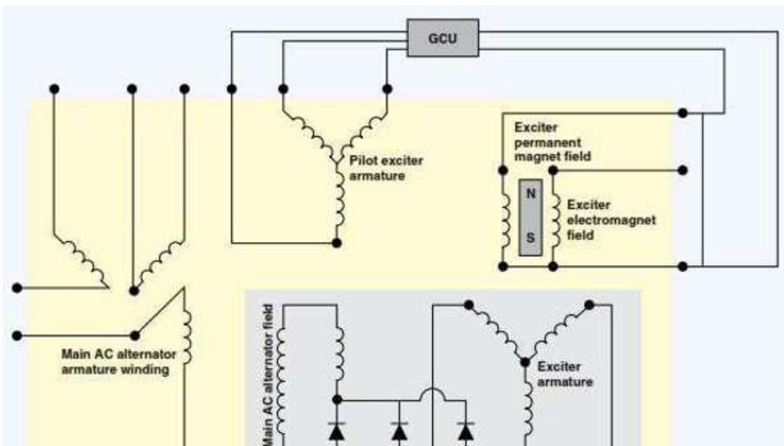


Figure 55

The GCU is also used to turn the AC alternator on or off. When the pilot selects the operation of an AC alternator, the GCU monitors the alternator's output to ensure voltage and frequency are within limits. If the GCU is satisfied with the alternator's output, the GCU sends a signal to an electrical contactor that connects the alternator to the appropriate AC distribution bus. The contactor, often call the generator breaker, is basically an electromagnetic solenoid that controls a set of large contact points. The large contact points are necessary in order to handle the large amounts of current produced by most AC alternators. This same contactor is activated in the event the GCU detects a fault in the alternator output; however, in this case the contactor would disconnect the alternator from the bus.

BATTERY

1. INTRODUCTION

The battery is an essential component of almost all aircraft electrical systems. Batteries are used to start engines and auxiliary power units, to provide emergency backup power for essential avionics equipment, to assure no-break power for navigation units and fly-by-wire computers, and to provide ground power capability for maintenance and preflight checkouts. Many of these functions are mission critical, so the performance and reliability of an aircraft battery is of considerable importance.

2. IMPORTANTTERMS

- AMPERE-HOURCAPACITY

The quantity of stored electrical energy, measured in ampere-hours that the battery can deliver from its completely charged state to its discharged state. The dischargeable capacity depends on the rate at which the battery is discharged; at higher discharge rates the available capacity isreduced.

- C-RATE

The discharge rate, in amperes, at which a battery can deliver 1 h of capacity to a fixed voltage endpoint (typically 18 or 20 V for a 24V battery). Fractions or multiples of the C-rate also are used. C/2 refers to the rate at which a battery will discharge its capacity in 2 h; 2C is twice the C rate or that rate at which the battery will discharge its capacity in 0.5 h. This rating system helps to compare the performance of different sizes of cells.

- CCA

This term is the peak power typically defined for lead acid battery knowm as cold-cranking amperes, or CCA rating. The numerical value of the current, in amperes, that a fully charged lead-acid battery can deliver at -18°C (0°F) for 30 s to a voltage of 1.2 V per cell (i.e., 14.4 V for a 24V battery). In some cases, 60 s is used instead of 30 s. CCA stands for cold cranking amperes.

- ELECTROLYTE

An ionically conductive, liquid medium that allows ions to flow between the positive and negative plates of a cell. In lead-acid cells, the electrolyte is a mixture of sulfuric acid (H2SO4) and deionized water. In nickel-cadmium cells, the electrolyte is a mixture of potassium hydroxide (KOH) dissolved in deionizedwater.

- IMPRATING

This term is a peak power rating used typically for nickel- cadmium batteries defined as the current at maximum power, or Imp rating. The numerical value of the current, in amperes, delivered after 15 s during a constant voltage discharge of 0.6 V per cell (i.e., at 12 V for a 24-V battery). The Imp rating normally is based on a battery temperature of 23°C (75°F), but manufacturers generally can supply Imp data at lower temperatures aswell.

- MONOBLOC

A group of two or more cells connected in series and housed in a one-piece enclosure with suitable dividing walls between cell compartments. Typical monoblocs come in 6V, 12V, or 24V configurations. Monoblocs are commonly used in lead-acid batteries, but rarely used in nickelcadmium aircraftbatteries.

- NEGATIVEELECTRODE

The electrode from which electrons flow when the battery is discharging into an external circuit. Reactants are electrochemically oxidized at the negative electrode.

- POSITIVEELECTRODE

The electrode to which electrons flow when the battery is discharging into an external circuit. Reactants are electrochemically reduced at the positive electrode.

- NOMINALVOLTAGE

The characteristic operating voltage of a cell or battery. The nominal voltage is 2.0 V for lead-acid cells and 1.2 V for nickel-cadmium cells. These voltage levels represent the approximate cell voltage during discharge at the C-rate under room-temperature conditions. The actual discharge voltage depends on

i. Thestate-of-charge
ii. State-of-health
iii. Dischargetime
iv. Rateand
v. Temperature

- SEPARATOR

An electrically insulating material that is used to prevent metallic contact between the positive and negative plates in a cell, but permits the flow of ions between the plates. In flooded cells, the separator includes a gas barrier to prevent gas diffusion and recombination of oxygen. In sealed cells, the separator is intended to allow gas diffusion to promote high recombinationefficiency.

- STATE-OF-CHARGE

The available capacity of a battery divided by the capacity available when fully charged, normally expressed on a percentage basis. Sometimes referred to as “true state-of- charge.”

- STATE-OF-HEALTH

The available capacity of a fully charged battery divided by the rated capacity of the battery, normally expressed on a percentage basis. Sometimes referred to as “apparent state-ofcharge.”

- ELECTROMOTIVE FORCE (E)

The energy supplied by a cell to one coulomb of charge is called e.m.f. It is the potential difference between two electrodes.

- INTERNAL RESISTANCE (R)

The opposition offered to the flow of current by the internal composition of the cell itself is called internal resistance.

- TERMINAL VOLTAGE(V)

The potential difference across the terminals of the cells at load is called terminal voltage.

Thus, $V = E - I \times r$

- SULPHATION

If ead acid battery allowed to remain in the discharged state for a prolonged time period, the battery becomes damaged by “sulfation.” Sulfation occurs when lead sulfate forms into large, hard crystals, blocking the pores in the active material. The sulfation creates a high impedance condition that makes it difficult for the battery to accept recharge. The sulfation may or may not be reversible, depending on the discharge conditions and specific celldesign.

3. TYPES OF BATTERY’S CELL PRIMARY CELL

Primary cells are not rechargeable and must be replaced once the reactants are depleted. In these cells chemical action is not reversible are called as primary cells. Examples of primary cells include carbon-zinc (Leclanche or dry cell), alkaline- manganese, mercuryzinc, silver-zinc, and lithium cells (e.g., lithium-manganese dioxide, lithium-sulfur dioxide, and lithium- thionyl chloride). In this type, during discharging one of the plate is consumed which cannot recovered by reversing the direction of flow of current. Thus chemical action is not reversible. So primary cells are expansive source of energy.

SECONDARY CELL

Secondary cells are rechargeable and require a DC charging source to restore reactants to their fully charged state. In these cells chemical action is reversible Examples of secondary cells include lead-lead dioxide (lead-acid), nickel-cadmium, nickel-iron, nickel-hydrogen, nickel-metal hydride, silver- zinc, silver-cadmium, and lithium-ion. In these cells, no electrode is consumed during discharging, however chemical composition of the plates is changed. When the direction of flow of current is reversed, the plates regain their original composition. That why these cells are also reffered to as storagecells.

NOTE

For aircraft applications, secondary cells are the most prominent, but primary cells are sometimes used for powering critical avionics equipment (e.g., flight data recorders, ELT).

4. PRINCIPLE

Batteries operate by converting chemical energy into electrical energy through electrochemical discharge reactions. Batteries are composed of one or more cells, each containing a positive electrode, negative, electrode, separator, and electrolyte as shown in Figure 1 below

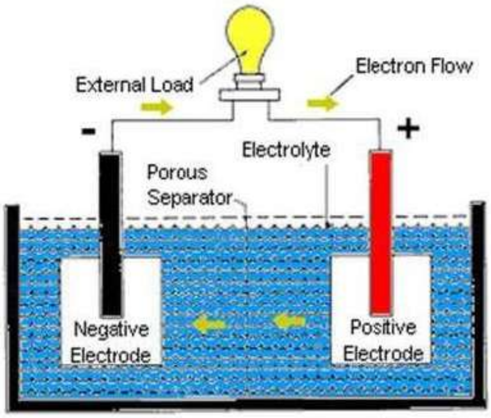


Figure 1

5. PURPOSE OF THEBATTERY

• ENGINE ISOFF

Electricity from the battery is used to operate lighting, accessories, or other electrical systems when the engine is not running.

• ENGINESTARTING

Electricity from the battery is used to operate the starter motor (or also known as starter generator) and to provide current for the ignition system during engine cranking. Starting the aircraft engine is the battery's most important function.

• ENGINERUNNING

Electricityfromthebatterymaybeneededtosupplement the charging system when the aircraft's electrical load

requirements exceed the charging system's ability to produce electricity. Both the battery and the generator, supply electricity when demand is high For example- one of the engine failure and rest of the engines has to take load.

6. GROUPING OFCELLS

When a number of cells are connected in such a way that the negative terminal of one cell is connected to the positive terminal of the other and so on, the cells are said to be connected in series grouping.
Current delivered to the load, $I = n E/ R + nr$ Where,
n = No. of cells connected in series, E = e.m.f. of each cell,
R = Internal resistance, R = Loadresistance

1. SERIES CONNECTED BATTERY

Positive terminal of one cell is connected to the negative terminal of the next, is called a series connected battery. The voltage of this type of battery is the sum of a individual cell voltages.

r = Internal resistance of eachcell

E = e.m.f. of each cell, R = loadresistance

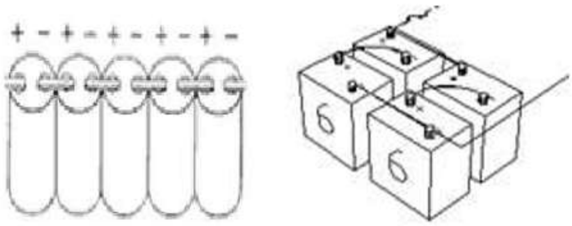


Figure 1 & 2 : Series Connected Batteries

2. PARALLELGROUPING

When a number of cells are connected in such a way that the positive terminals of all the cells are connected together and negative terminals are connected together separately, the cells are said to be connected in parallel.

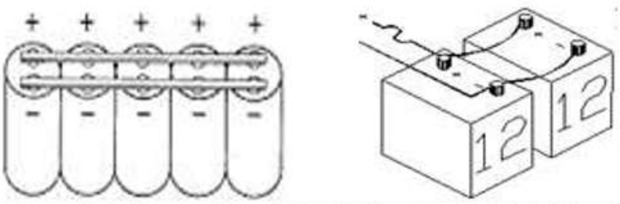


Figure 3 & 4 : Parallel Grouping SERIES - PARALLEL GROUPING

The grouping in which a number of cells are connected in series in one row and a number of such rows are connected in parallel is called series-parallel grouping of cells.

Current delivered to the load, $I = n E/R + (nr/m)$ Where,

n = No. of cells inseries,

m = No. of rows connected inparallel,

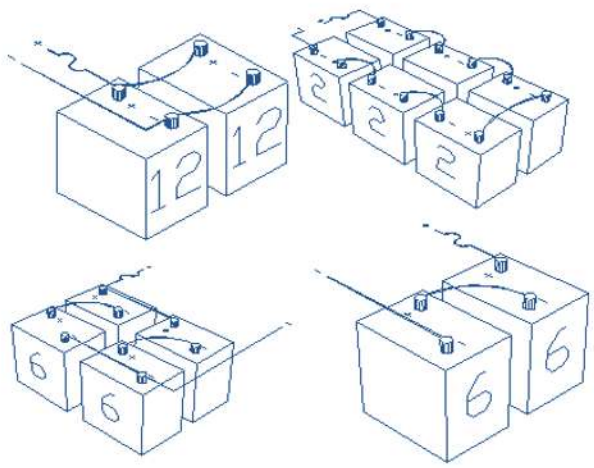


Figure 5 : Series-Parallel Connected Batteries EXAMPLE 1

How many cells, each having an e.m.f. of 1.5 V and internal resistance of 0.25 ohm would be required to pass a current of 1.5 A through a resistance of 15 ohm, when connected in series?

SOLUTION

Let, n be the number of cells connected in series. Current delivered to load, $I = nE / (R + nr)$

Here, E = 1.5 V, R = 15 ohm, r = 0.25 ohm and I = 1.5 A 1.5 = n X 1.5 / (15 + n X 0.25)
n = 20(Answer)

7. AIRCRAFTBATTERIES

The main uses of battery in aircraft systems are:

- To supply power for engine or APUstarting.
- To provide emergency power for the Inertial Navigation System (INS) or Inertial Reference System(IRS).
- To provide under emergency conditions limited amounts of power to operate essential flight instruments and radio communications equipment.
- To provide power for emergency lighting.

7.1. AIRCRAFT LEAD ACIDBATTERY

Lead-acid batteries are the most commonly used type of battery in light general aviation aircraft.

7.1.1. TYPES

There are two basic types of lead-acid battery:

A. FLOODED LEAD-ACIDBATTERIES:

Flooded cells are those where the electrode plates are immersed in the electrolyte. As gases created during charging are vented to the atmosphere, distilled water must be occasionally added to bring the electrolyte back to its required level.

B. SEALED LEAD-ACIDBATTERIES

These battery types confine the electrolyte, but have a vent or valve to allow gases to escape if its internal pressure exceeds a certain safety threshold. Too high a rate of charge may result in a case rupture, thermal runaway or internal mechanical damage.

Figure 6 : Sealed Lead-Acid Batteries

Therefore, the valve-regulated battery is the most common type of sealed battery and these have a spring-controlled valve that vents gases at a predetermined pressure, typical 2 to 5 psi, depending on the battery design. Although the term 'valve-regulated' is often used synonymously to describe sealed lead-acid batteries, not all sealed batteries are valve-regulated. Some battery designs use replaceable vent plugs or other mechanisms to relieve excess pressure. Sealed batteries were developed to reduce maintenance requirements for batteries in active service. Since electrolyte levels are preserved by trapping and reabsorbing gasses, there should not be any need to add distilled water over the life of the battery. These batteries are often misnamed 'maintenance free ' but in reality, all maintenance practices applicable to unsealed type batteries are applicable to sealed type batteries with the exception of electrolyte level replenishment. Sealed batteries are oftenusedforaircraftbackupandemergencypowerapplications, e.g. emergency exit lighting, but as their state of charge cannot be checked by the usual specific gravity measurement, they are subjected to specific time period maintenance checks. However, one disadvantage of the sealed battery is its susceptibility to high temperature and so they are location sensitive, especially in an aircraft environment.

7.1.2. CONSTRUCTION

A battery consists of a number of cells and each cell of the battery consists of the following components.

1. Battery case /Container
2. PositivePlate
3. NegativePlate
4. Separator
5. Electrolyte
6. Cell covers and ventplugs
7. Cellconnectors
8. Batteryterminals

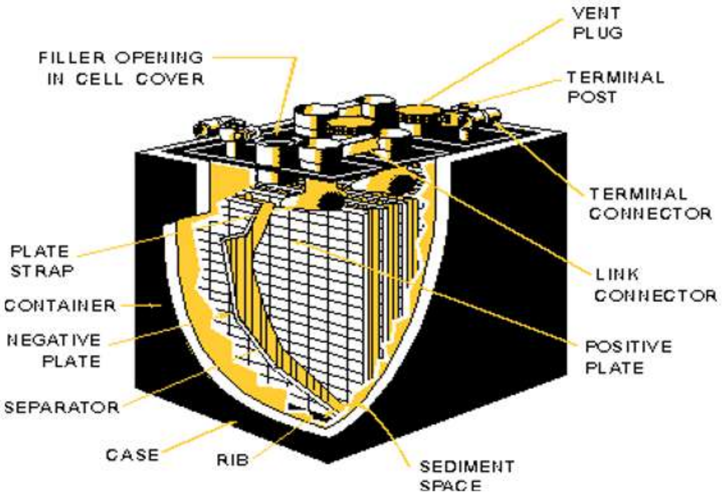


FIGURE 7 : Lead-Acid Aircraft Battery

1. BATTERY CASE /CONTAINER

The container houses the plates and the electrolyte. It is made of acid resisting materials like glass or hard rubber depending upon service requirements. The cell container must be impervious to the action of dilute sulphuric acid and is typically made of a plasticmaterial.

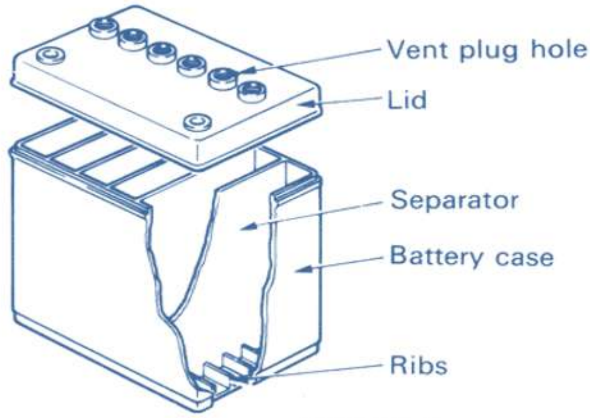


FIGURE8

2. POSITIVEPLATE

Positive plate is made of lead peroxide (PbO2) deposited on a grid frame. The grid frame is made of antimony-lead alloy. The color of the positive plate is darkbrown.

3. NEGATIVEPLATE

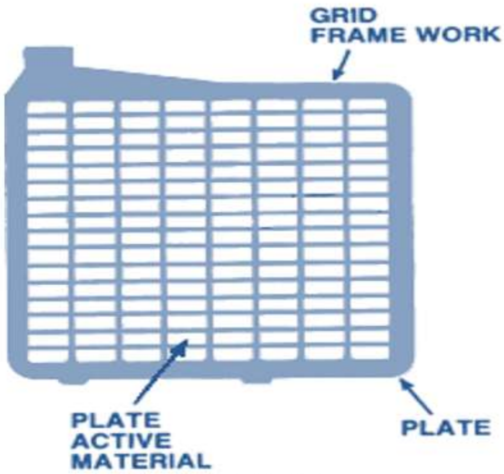


FIGURE 9

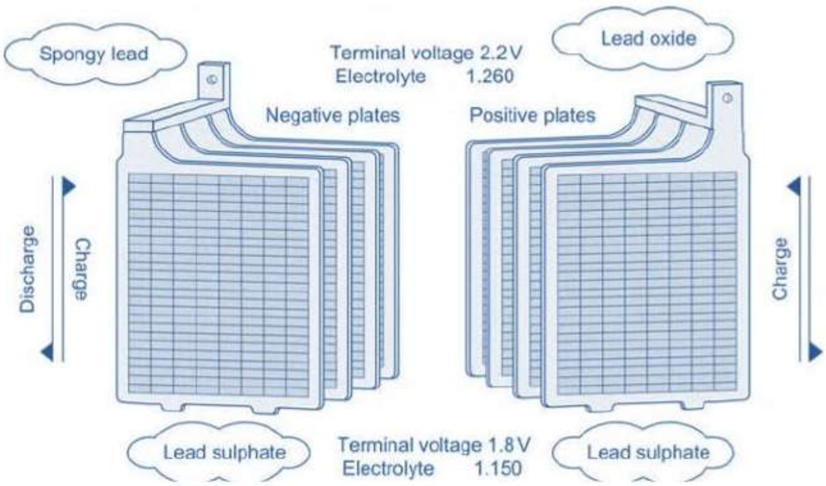


Figure 10 : A Lead–Acid Cell

Negative plate is made spongy lead (Pb). It is also deposited on a grid frame for stiffness and strength. The color of the negative plate is grey. The number of negative plates in a battery is always one more than the positive plates to make use of both the sides of the positive plate mosteffectively.

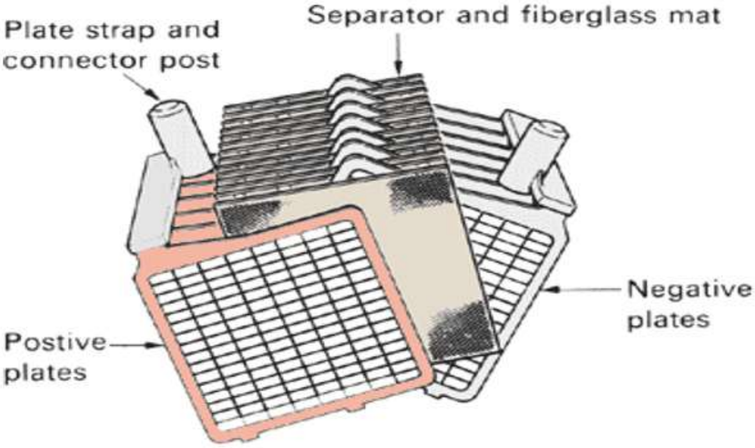


Figure 11 : A Lead–Acid Cell

4. SEPARATOR

It is made of thin sheet of porous insulating materials. Separators are placed between positive and negative plates. The positive and negative plates are separated electrically by the separators. The separators must allow free circulation of the electrolyte between the plates. These are made of specially treated wood, glass, rubberetc.

5. ELECTROLYTE

The electrolyte is dilute sulphuric acid (H2SO4). Battery grade sulphuric acid is used for the preparation of electrolyte. The electrolyte of pure sulphuric acid diluted with distilled water must be of the correct specific gravity (relative density), typically 1.25 to 1.27. Checking the specific gravity of the electrolyte is the best way to determine the state of charge of the battery. Specific gravity of a battery varies inversely with temperature and electrolyte level.

NOTE

Specific gravity of a liquid is the ratio of a given volume of liquid to the weight of a comparable volume of water at the same temperature. If one cubic centimetre of water weighs one gram and one cubic centimetre of electrolyte at the same temperature weighs 1.2 grams, the ratio, i.e. specific gravity of the electrolyte, is 1.2:1.0 this is simply written as 1.2.

6. CELL COVERS AND VENT PLUGS

Each cell has a cover made of moulded hard rubber. Openings are provided in these covers for two terminal posts and vent plug. Vent plug has a vent hole for easy escape of gas formed inside the cell during charging. Vent plugs can be easily removed for adding electrolyte.

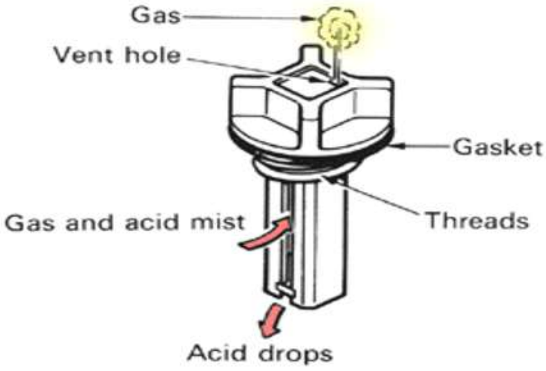


Figure 12 : Vent Plugs

7. CELLCONNECTORS

Cell connectors are used to connect the individual cells in series to give the required voltage. Lead alloys are the material normally used as cell connector. Corrosion due to sulphuric acid is normally avoided by proper coating.

Figure-13 & 14 : Cell Connectors

8. BATTERYTERMINALS

A battery has two terminals, the +ve and the –ve. The polaritiesaremarkedontheterminals.Theterminalsare generally made of lead alloys and the +ve terminal is made larger than –ve terminal.

Figure 15 : Battery + ve Terminal

7.1.3. CHEMICALREACTION

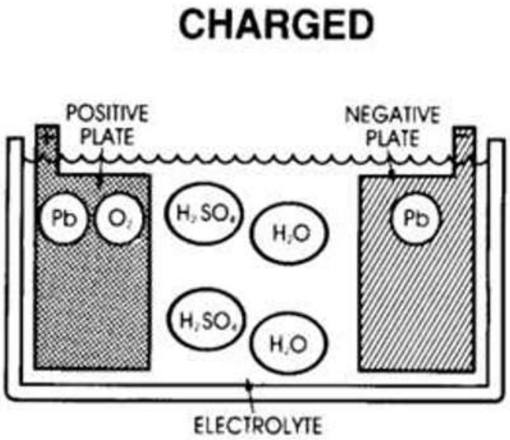


Figure 16

Indications of a fully charged cell are:

7.1.4. INDICATIONS

1. FULLYCHARGED

A fully charged battery contains a negative plate of sponge lead (Pb), a positive plate of lead peroxide (Pb02), and electrolyte of sulphuric acid (H2SO4) and water (H20).

process releases hydrogen and oxygen, which is fully absorbed into the electrolyte. On completion of charge the electrolyte no longer absorb these gases which are released by the plates and rise to the surface in the form of a constant stream of bubbles. This is known as gassing and is the third sign of completion of thecharge.

NOTE 1
However the state of battery can be checked by checking Colors of plates. When battery is fully charged , the anode is of chocolate color and cathode is of grey color.

NOTE 2

To check the specific gravity of sulphuric acid , an instrument called hydrometer is used which works on Archimedes principle.

NOTE 3

Charge must not be considered complete until all three indications have been sustained for one hour.

2. FULLYDISCHARGED

In a fully discharged battery, both plates are covered with lead sulfate (PbSO4) and the electrolyte is diluted to mostly water(H2O).

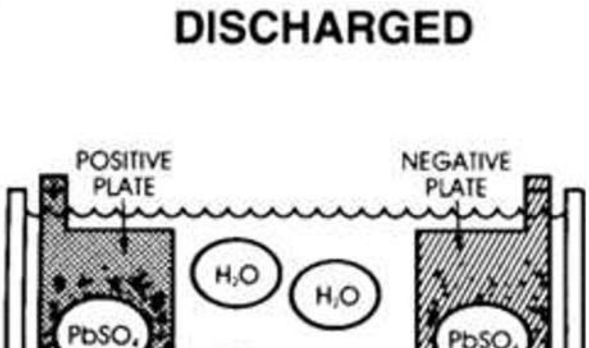


Figure 17

INDICATION FOR FULLY DISCHARGED BATTERY

1. Voltage “On load” falls to1.8V
2. Specific gravity falls to minimum value i.e. 1.130(as as stated by manufacturer instruction and these instructions prevailed always)
3. The two indications should always be considered together, as single indication maymislead.

NOTE

In this condition, the color of both plates is whitish. To get good life of battery keep the specific gravity more than 1.18.

3. DISCHARGING

Asthebatteryisdischarging,theelectrolytebecomesdiluted - +
and the plates become sulphated. The electrolyte divides into hydrogen (H2) and sulfate (S04). The hydrogen (H2) combines with oxygen (0) from the positive plate toform more water (H20). The sulphate combines with the lead (Pb) in both plates to form lead sulfate(PbS04) discharge

As the cell discharges, more water is formed, lowering the specific gravityof Atcathode, Pb +SO4

PbSO4 the electrolyte.

Atanode, PbO+H2SO4 PbSO4 +H2O

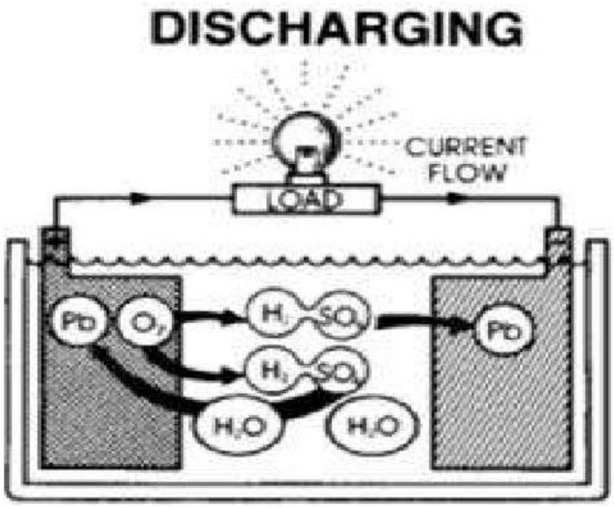


Figure 18

H2SO4 + H2O
Figure 19 INDICATION DURING DISCHARGING
1. Both plates are converted to leadsulphate

2. Specific gravity of sulphuric acid is1.15
3. Terminal voltage fall from 2.0 V to 1.8V
4. Chemical energy changes to electricalenergy

4. CHARGING

During charging, the chemical action is reversed. Sulfate (S04) leaves the plates and combines with hydrogen (H2) to become sulphuric acid (H2SO4). Free oxygen (02) combines with lead (Pb) on the positive plate to form lead dioxide (Pb02). Gassing occurs as the battery nears full charge, and hydrogen bubbles out at the negative plates, oxygen at the positive.

At anode, $PbSO_4 + O + H_2O \quad PbO_2 + H_2SO_4$

At cathode, $PbSO_4 + 2H \quad Pb + H_2SO_4$

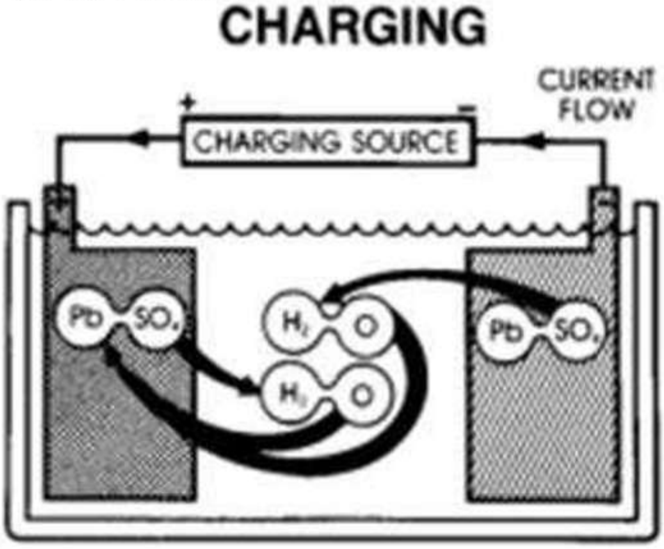


Figure 20 INDICATION DURING RECHARGING

1. Plates regain their original composition
2. Specific gravity of acid become1.28
3. Terminal voltage increases from 1.8 V to 2.0V
4. Electrical energy converted to chemical energy which is stored incell.

Specific Gravity	Condition	% age
1.280 to 1.290	Fully charged	100 %
1.230 to 1.250	Charged	75 %
1.190 to 1.200	Charged	50 %
1.150 to 1.160	Charged	25 %
Below 1.130	Fully discharged	0%

Table 1 : Shows the various conditions collectively

7.1.5. FACTORS AFFECTINGCHARGING

Five factors affect battery charging by increasing its internal resistance and CEMF (counter-electromotive force produced by the electrochemical reaction)

- TEMPERATURE

As the temperature decreases the electrolyte resists charging. A cold battery will take more time to charge; a warm battery, less time. Never attempt to charge a frozenbattery.

- STATE-OF-CHARGE

The condition of the battery's active materials will affect charging. A battery that is severely discharged will have hard sulfate crystals on its plates. The vehicle's charging system may charge at too high of a rate to remove such sulphates.

- PLATEAREA

Small plates are charged faster than large plates. When sulfation covers most of the plate area, the charging system may not be able to restore the battery.

- IMPURITIES

Dirt and other impurities in the electrolyte increase charging difficulty.

- GASSING

Hydrogen and oxygen bubbles form at the plates during charging. As these bubble out, they wash away active material, cause water loss, and increase chargingdifficulty.

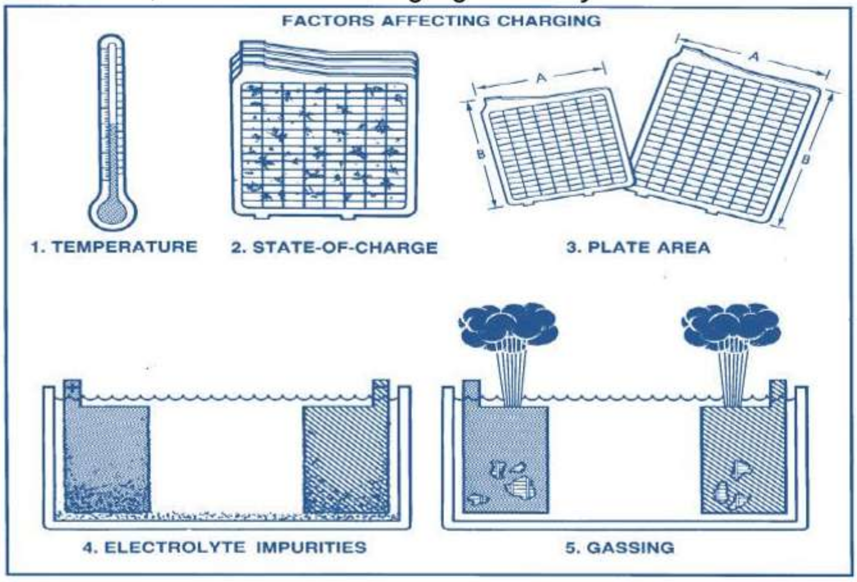


Figure 21 : Factors Affecting Charging

7.1.6. CAPACITY AND RATING OF A LEAD ACIDBATTERY

A battery's capacity is measured in Ampere-Hours (AH). This is calculated by multiplying the battery's current output in amperes and the time in hours during which the battery will supply this current. The ampere-hour capacity varies inversely with the discharge current, e.g. a 50 ampere-hour battery will deliver 50 amperes for 1 hour or 10 amperes for 5 hours.

Batteries are rated according to their rate of discharge and ampere-hour capacity and most are rated according to a 20-hour rate of discharge, i.e. if a fully charged battery is completely discharged during a 20-hour period, it is discharged at the 20-hour rate. Consequently, if a battery can deliver 20 amperes

continuously for 20 hours, the battery has a rating of 20 amperes × 20 hours, or 400 ampere-hours. Therefore, the 20-hour rating is equal to the average current that a battery is capable of supplying without interruption for an interval of 20 hours.

NOTE

As stated above, this method is used for most batteries, but aircraft batteries are always rated according to a 1-hour rate of discharge.The ampere-hour capacity of a battery depends upon its total effective plate area. Connecting batteries in parallel increases ampere-hour capacity. Connecting batteries in series increases the total voltage but not the ampere-hour capacity.

7.1.7. DISCHARGEPERFORMANCE

Battery performance characteristics usually are described by plotting voltage, current, or power vs. discharge time, starting from a fully charged condition. Typical discharge performance data for aircraft batteries are illustrated in Figures-22 and 23. Figure-24, shows the effect of temperature on the capacity when discharged at the C-rate. Manufacturers' data should be obtained for current information on specific batteries ofinterest.

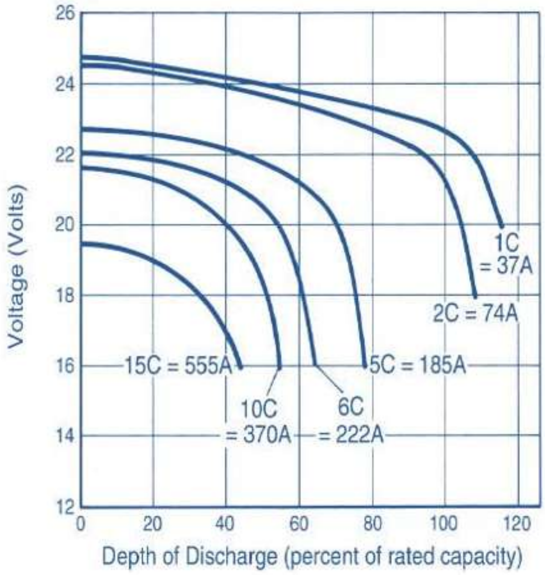


Figure 22 : Discharge Curve at 25°C for a 24 V/37 Ah Aircraft Battery

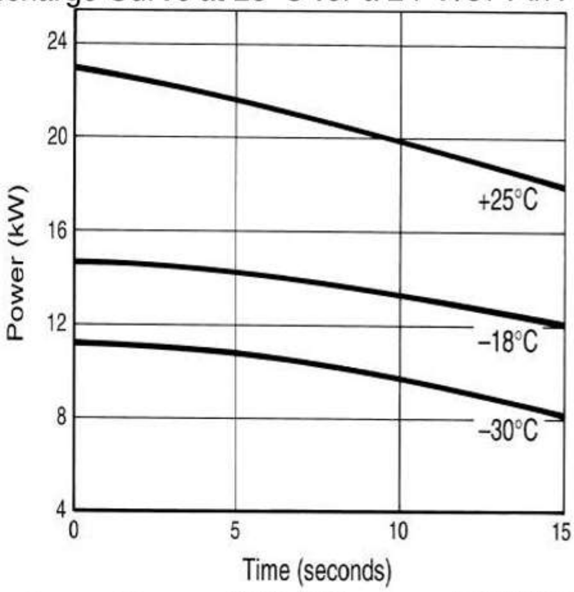


Figure 23 : Maximum Power Curves (12 V Discharge) 24 V/37 Ah Aircraft Battery

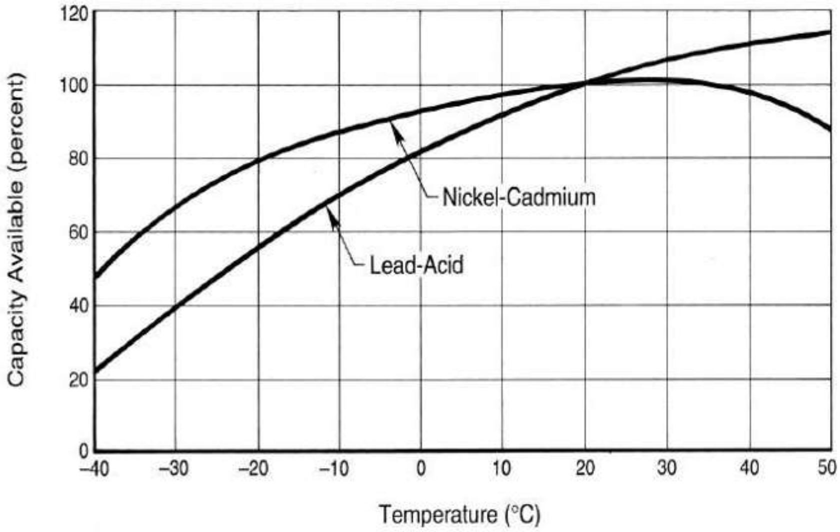


Figure 23 : Capacity vs. Temperature for Aircraft Batteries at the C-Rate

7.1.8. CHARGE METHOD FOR LEAD ACIDBATTERY

Constant voltage charging at 2.3 to 2.4V per cell is the preferred method of charging lead-acid aircraft batteries. For a 12-cell battery, this equates to 27.6 to 28.8 V which generally is compatible with the voltage available from the aircraft's 28-V DC bus. Thus, lead-acid aircraft batteries normally can be charged by direct connection to the DC bus, avoiding the need for a dedicated battery charger. If the voltage regulation on the DC bus is not controlled sufficiently, however, the battery will be overcharged or undercharged causing premature failure. In this case, a regulated voltage source may be necessary to achieve acceptable battery life. Some aircraft use voltage regulators that compensate, either manually or automatically, for the battery temperature by increasing the voltage when cold and decreasing the voltage when hot. Adjusting the charging voltage in this manner has the beneficial effect of prolonging the battery's service life at high temperature and achieving faster recharge at lowtemperatures.

7.1.9. TEMPERATURE EFFECTS ANDLIMITATIONS

Lead-acid batteries generally are rated at 25°C (77°F) and operate best around this temperature. Exposure to low ambient temperatures results in performance decline, whereas exposure to high ambient temperatures results in shortened life. The lower temperature limit is dictated by the freezing point of the electrolyte. The electrolyte freezing point varies with acid concentration, as shown in Table-2 . The minimum freezing point is a chilly 70°C(-95°F) at a specific gravity (SG) of 1.30. Since fully charged batteries have SGs in the range of 1.28 to 1.33, they are not generally susceptible to freezing even under extreme cold

conditions. However, when the battery is discharged, the SG drops and the freezing point rises. At low SG, the electrolyte first will turn to slush as the temperature drops. This is because the water content freezes first, gradually raising the SG of the remaining liquid so that it remains unfrozen. Solid freezing of the electrolyte in a discharged battery requires temperatures well below the slush point; a practical lower limit of -30°C is often specified. Solid freezing can damage the battery permanently (i.e., by cracking cell containers), so precautions should be taken to keep the battery charged or heated when exposed to temperatures below-30°C.

The upper temperature limit is generally in the range of 60 to 70°C. Capacity loss is accelerated greatly when charged above this temperature range due to vigorous gassing and/or rapid grid corrosion. The capacity loss generally is irreversible when the battery is cooled.

Specific Gravity at 15°C	Cell OCV (Volts)	Battery OCV (Volts)	Freezing Point	
			(°C)	(°F)
1.000	1.84	22.08	0	+32
1.050	1.89	22.68	-3	+26
1.100	1.94	23.28	-8	+18
1.150	1.99	23.88	-15	+5
1.200	2.04	24.48	-27	-17
1.250	2.09	25.08	-52	-62
1.300	2.14	25.68	-70	-95
1.350	2.19	26.28	-49	-56
1.400	2.24	26.88	-36	-33

Table 2 : Freezing Points of Sulfuric Acid-Water Mixtures

7.1.10.NEUTRALISING AGENTS FOR LEAD ACID BATTERY

The neutralising agents for Sulphuric Acid:

a. Saturated solution of bicarbonate of soda.
b. Ammoniapowder.
c. Boraxpowder.

The acid should be soaked up with sawdust which should then be removed and buried. The affected area should be treated with one of the above, followed by washing down with copious amounts of fresh water.

7.1.11.FAILURE MODES AND FAULT DETECTION

The predominant failure modes of lead-acid cells are summarized as follows:

- Shorts caused by growth on the positive grid, shedding or massing of active material, or mechanical defects protruding from the grid, manifested by inability of the battery to hold a charge (rapid decline in open circuitvoltage).

- Loss of electrode capacity due to active material shedding, excessive grid corrosion, sulfation, or passivation, manifested by low capacity and/or inability to hold voltage underload.

- Water loss and resulting cell dry-out due to leaking seal, repeated cell reversals, or excessive overcharge (this mode applies to sealed cells or to vented cells that are improperly maintained), manifested by low capacity and/or inability to hold voltage underload

7.1.12.STORAGECHARACTERISTICS

A charged battery which is to be stored for any length of time.

- Should be in the “fully charged”condition.
- Before storing, the electrolyte levels should be checked and the battery bench-charged in accordance with manufacturer’s instructions.
- When fully charged, the battery should be stored in a cool, dry, well ventilated store on an acid resistanttray.
- Batteries may also be stored in the dry, unchargedstate.

Additional points to note are as follows:

- Every 4 to 6 weeks (depending on manufacturer's instructions) the battery should be removed from storage and fully recharged, i.e. until voltage and specific gravity readings cease to rise.

NOTE

Damage to the battery will occur if it is allowed to stand idle beyond the period for charging specified by the manufacturer.

- Regardless of periodic check charges, the battery should be given a complete charge and capacity check immediately before being put intoservice.

- For new batteries, a complete capacity test to the manufacturer's instructions should be made every 6 months, but if the battery has been in service this test should be made every 3months.

- Every 12 months, or earlier if a leak is suspected, an insulation resistance test should be carried out to the manufacturer's instructions.

- If the conditions mentioned in the previous paragraphs are observed, abatterymayremaininstorageupto18months.A battery should not be allowed to stand in a discharged condition, and electrolyte temperatures should not exceed 48.8ºC.

NOTE

Trickle charging at low rates is not recommended as damage will occur if idle batteries are subjected to this.

8. NICKEL-CADMIUMBATTERY

8.1. GENERAL

The Nickel-Cadmium Cell, usually shortened to NiCad, is superior to the lead-acid cell in several ways. The NiCad cell construction differs greatly to the lead-acid cell in that its anode, cathode and electrolyte are made of different materials. Typically NiCad aircraft battery has twenty (20) cells versus a Lead Acid's twelve (12). Larger nickel–cadmium batteries are used for as the essential power source in some aircraft and can even start up some aircraft engines. They are also found as backup power systems where very high currents, low temperature conditions, and reliability are important factors. Due to these superior characteristics and capabilities the nickel-cadmium cells are being used extensively in many aircraft applications that require a high discharge rate.

There are two basic cell types: vented and recombinant. Vented cells have a flooded electrolyte, and the hydrogen and oxygen gases generated during charging are vented from the cell container. Recombinant cells have a starved electrolyte, and the oxygen generated from the positive electrode during charging diffuses to the negative electrode where it recombines to form cadmium hydroxide by the followingreaction:

The recombination reaction suppresses hydrogen evolution at the negative electrode, thereby allowing the cell to be sealed. Unlike valve-regulated lead-acid cells, recombinant nickel-cadmium cells are sealed with a high-pressure vent that releases only during abusive conditions. Thus, these cells remain sealed under normal charging conditions. However, provisions for gas escape must still be provided when designing battery cases since abnormal conditions may be encountered periodically (e.g., in the event of a charger failure that causes an over current condition).

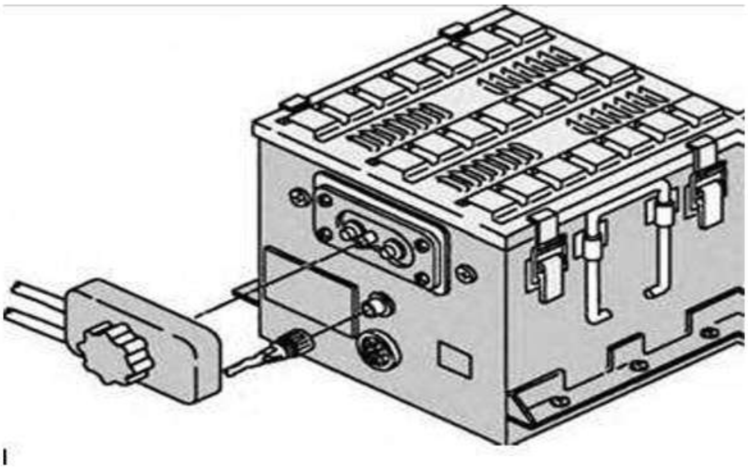


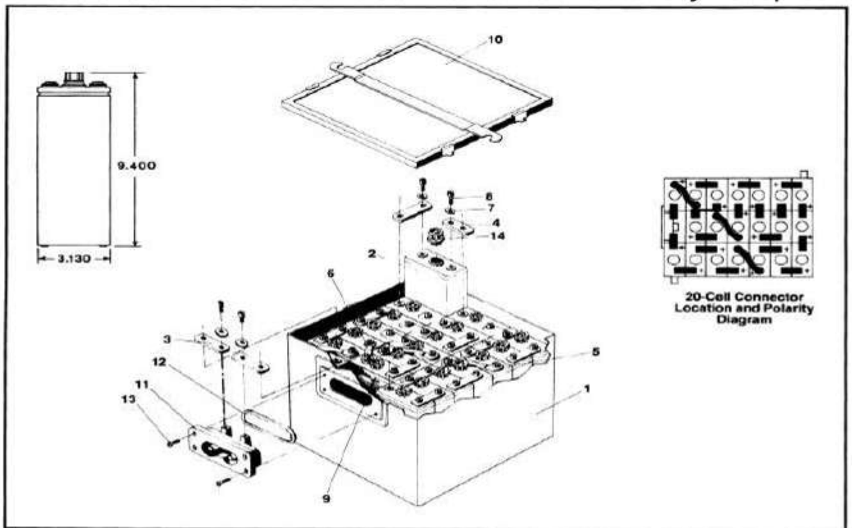
Figure 24 : A typical Ni-Cd Aircraft Battery

8.2. CELLCONSTRUCTION

The construction of nickel-cadmium cells varies significantly, depending on the manufacturer. In general, cells feature alternating positive and negative plates with separator layers interleaved between them, a potassium hydroxide (KOH) electrolyte of approximately 31% concentration by weight (specific gravity1.30), and a prismatic cell container with the cell terminals extending through the cover. The positive plate is impregnated with nickel hydroxide and the negative plate is impregnated with cadmium hydroxide. Cell containers typically are made of nylon, polyamide, or steel. One main difference between vented cells and sealed (recombinant) cells is the type of separator. Vented cells use a gas barrier layer to prevent gases from diffusing between adjacent plates. Recombinant cells feature a porous separator system that permits gas diffusion between plates.

8.3. BATTERYCONSTRUCTION

Nickel-cadmium aircraft batteries generally consist of a steel case containing identical, individual cells connected in series. The number of cells depends on the particular application, but generally 19 or 20 cells are used. The end cells of the series are connected to the battery receptacle located on the outside of



Item	Description	Quantity	Item	Description	Quantity
1	Can Assembly	1	8	Socket Head Cap Screw	42
2	Cell Assembly	20	9	Spacer	1
3	Connector	12	10	Cover Assembly	1
4	Connector	5	11	Receptacle Assembly	1
5	Connector	3	12	Rectangular Ring	1
6	Connector	1	13	Phillips Head Screw	4
7	Belleville Spring	42	14	Filler Cap and Vent Assembly	20

the case. Cases are vented by means of vent tubes or louvers to allow escape of gases produced during overcharge. Some battery designs have provisions for forced air cooling, particularly for engine start applications. Thermostatically controlled heating pads sometimes are employed on the inside or outside of the battery case to improve low-temperature performance. A typical aircraft battery assembly is shown in Figure24.

Figure 25 : Assembly Drawing of a Nickel-Cadmium Aircraft Battery

8.4. VOLTAGE OF NI CADBATTERY

- Fully charged1.5V
- Nominal voltage1.2V
- Fully discharge1.0V

8.5. DISCHARGEPERFORMANCE

Typical discharge performance data for aircraft batteries are illustrated below in Figures 26 and 27.

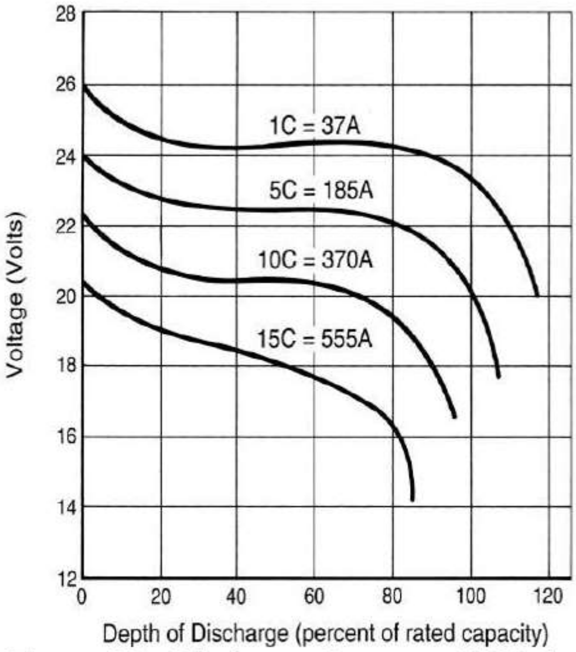


Figure 26 : Discharge Curves at 25°C for a 24 V/37 Ah Aircraft Battery

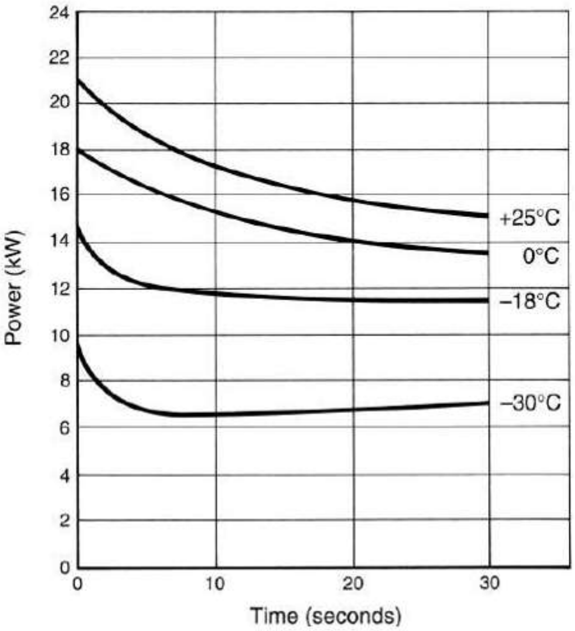


Figure 27 : Maximum Power Curves (12 V Discharge) for a 24 V/37 Ah AircraftBattery

Figure 26, shows the effect of temperature on discharge capacity at the C-rate. Compared with lead-acid batteries, nickel-cadmium batteries tend to have more available capacity at low temperature, but less available capacity at hightemperature.

8.6. CHARGEMETHODS

A variety of methods are employed to charge nickel-cadmium aircraft batteries. The key requirement is to strike an optimum balance between overcharging and undercharging, while achieving full charge in the required time frame. Overcharging results in excessive water loss (vented cells) or heating (sealed cells). Undercharging results in capacity fading. Some overcharge is necessary, however, to overcome coulombic inefficiencies associated with the electrochemical reactions.
For vented-cell batteries, common methods of charging include constant potential, constant current, or pulse current. Constant potential charging is the oldest method and normally is accomplished by floating a 19-cell battery on a 28-V DC bus. The constant current method requires a dedicated charger and typically uses a 0.5 to 1.5 C-rate charging current.Theconstant current method is more complicated, but results in less gassing and electrolyte spewage during overcharge. Pulse current methods are similar to the constant current methods, except the charging current is pulsed rather thatconstant.

For sealed-cell batteries, only constant current or pulse current methods should be used. Constant potential charging can cause excessive heating, resulting in thermal runaway. Special attention must be given to the charge termination technique in sealed-cell batteries, because the voltage profile is relatively flat as the battery becomess fully charged. For example, it may be necessary to rely on the battery's temperature rise rather than voltage rise as the signal for chargetermination.

8.7. THERMALRUNWAY

If a nickel cad cell is subjected to an excessively high charging rate, even though its internal resistance low, it can become overheated. When this occurs, its internal resistance drops further. The lower internal resistance allows the cell to take more current from the charger and more heat is generated. This condition is known as thermal runway and it can destroy a cell. Sealed nickel cadmium cells are vented to relieve the pressure that could build up to a dangerous level under thermal runway conditions. The problem of thermal runway is minimized by using aConstant

Current Charger that limits the amount of current that can put into the cell.

8.8. CELLMEMORY

Nickel-cadmium cells have a characteristic that causes them to lose capacity if they are repeatedly discharged and charged to only a small percentage of their capacity. For example, if 20% of a cell's capacity is taken out of it and the cell is recharged repeatedly, the cell will lose some of its capacity and it will never accept a full charge. A cell that has had its capacity decreased by repeated shallow charges can be restored to its full capacity by completely discharging it and overcharging it to approximately 140%of its rated AH capacity nown as a deepcycling.

8.9. TEMPERATURE EFFECTS ANDLIMITATIONS

Nickel-cadmium batteries, like lead-acid batteries, normally are rated at room temperature (25°C) and operate best around this temperature. Exposure to low ambient temperatures results in performance decline, and exposure to high ambient temperatures results in shortened life. The lower temperature limit is dictated by the freezing point of the electrolyte. Most cells are filled with an electrolyte concentration of 31% KOH, which freezes at -66°C. Lower concentrations will freeze at higher temperatures, as shown in Table 3.

Specific Gravity at 15°C	Concentration Weight %	Freezing Point	
		(°C)	(°F)
1.000	0	0	+32
1.045	5	-3	+27
1.092	10	-8	+18
1.140	15	-15	+5
1.118	20	-24	-11
1.239	25	-38	-36
1.290	30	-59	-74
1.300	31	-66	-87
1.344	35	-50	-58

Table 3 : Freezing Points of KOH - Water Mixture

For practical purposes, a lower operating temperature limit of 40°C often is quoted. The upper temperature limit is generally in the range of 50 to 60°C; significant capacity loss occurs when batteries are operated (i.e., repeated charge/discharge cycles) above this temperature range. The battery capacity often is recoverable, however, when the battery is cooled to room temperature and subjected to several deep discharge cycles.

8.10. STATE OFCHARGE

For a battery to work properly, its electrolyte must contain a certain amount of active ingredient be it acid or alkaline. As the active ingredient of NiCad Cell is usually dissolved in water, That's why its amount cannot be directly measured and therefore, an indirect method is used, which measures the electrolyte's Specific Gravity.

8.11. ADVANTAGE

When compared to other forms of rechargeable battery, the NiCad battery has a number of distinct advantages:

- Their major advantage is that they generally require less maintenance throughout their service life in comparison to lead-acidcells.

- At high discharge rates the nickel-cadmium cell can deliver greater power and can maintain its output for longer. Sealed NiCad cells are equipped with 'jelly roll' electrodes that allow efficient high currentdelivery.

- The batteries are more difficult to damage than other batteries, tolerating deep discharge for long periods. In fact, NiCad batteries in long-term storage are typically stored fully discharged. This is in contrast, for example, to lithium ion batteries, which are highly volatile and will be permanently damaged if discharged below a minimumvoltage.

- NiCad batteries typically last longer, in terms of number of charge/discharge cycles, than other rechargeable batteries. Compared to lead-acid batteries, NiCad batteries have a much higher energydensity.

- A NiCad battery is smaller and lighter than a comparable lead- acid battery. In cases where size and weight are important considerations (for example, aircraft), NiCad batteries are preferred over the cheaper lead acidbatteries

- All NiCad batteries are capable of:

- Delivering exceptionally highcurrents
- Being charged and discharged any number of times without any appreciabledamage
- Being rapidly recharged hundreds oftimes
- Tolerance to abuse such as over-discharging or overcharging
- Being charged in a shortertime
- Staying idle longer in any state of charge and keeping a full charge when stored for a longer period of time

8.12. NEUTRALIZING AGENT FOR NI CADBATTERY

The neutralising agents for Potassium Hydroxide (KOH):

a. Boric acid solution.
b. Boric acid crystals or powder.

NOTE

The alkali should be soaked up with sawdust, which should then be removed and buried. The affected area should be treated with one of the above, followed by washing down with copious amounts of freshwater

8.13. STORAGECHARACTERISTICS

- Nickel-cadmium batteries can be stored in any state of charge and over a broad temperature range (i.e.,-65 to 60°C). For maximum shelf life, however, it is best to store batteries between 0° and30°C.

- Vented cell batteries normally are stored with the terminals shorted together. Shorting of sealed-cell batteries during storage is not recommended, however, since it may cause cell venting and/or cellreversal.

- When left on open circuit during periods of non-operation, nickel-cadmium batteries will self-discharge at a relatively fast rate. As a rule of thumb, the self-discharge rate of sealed cells is approximately 1%/day at 20°C (when averaged over 30 days), and the rate increases by 1%/day for every 10°C rise in temperature(e.g., 2%/day at 30°C, 3%/day at 40°C,etc.).

8.14. FAILURE MODES AND FAULTDETECTION

The predominant failure modes of nickel-cadmium cells are summarized as follows :

- Shorts caused by cadmium migration through the separator, swelling of the positive electrode, degradation of the separator, or mechanical defects protruding from the electrode. Manifested by inability of the battery to hold a charge (soft shorts) or dead cells (hardshorts).

- Water loss and resulting cell dry-out due to leaking seal, repeated cell reversal, or excessive overcharge (this mode applies to sealed cells or to vented cells that are improperly maintained). Manifested by low capacity and/or inability to hold voltage underload.

• Loss of negative (cadmium) electrode capacity due to passivation or active material degradation. Manifested by low capacity and/or inability to hold voltage under load. Usually reversible by deep discharge followed by shorting cell terminals, or by "reflex" charging (pulse charging with momentary discharge betweenpulses).
• Loss of positive (nickel) electrode capacity due to swelling or active material degradation. Manifested by low capacity that is nonrestorable.

9. SERVICING AND TESTEQUIPMENT

1. Servicing of aircraft batteries should be carried out in accordance with the instructions contained in the manufacturers' MaintenanceManual.

2. In addition to the general engineering hand tools which may be required for aircraft battery servicing, the following specialised items will also be required:

a. Hydrometers
b. Thermometers
c. Battery kits (as supplied by batterymanufacturers)
d. Capacity testsets
e. Leakage tester (lead-acidbatteries)
f. Filler pumps (for transferring of liquids from one container toanother)
g. Calibrated test equipment :
i. Insulation resistancetester
ii. Universal testmeter.
iii. Digitalvoltmeter.

10. PRECAUTIONS

10.1. PRECAUTIONS FOR LEAD ACID BATTERY CAUTION

• Hydrogen gas given off during charging and shortly after charging is highly explosive. Open flames and sparks must be avoided in theseareas.
• Turn battery charger off before connecting battery to charger and before moving battery fromcharger.
• Battery charging area must be well,ventilated.
• When mixing electrolyte, always pour acid into water while slowly and continually stirring, do not pour water intoacid.
• Use only glass, hard rubber or other suitable containers for mixingelectrolyte.

• Do not use freshly prepared electrolyte until it has cooled to at least 90°F. Considerable heat is generated, which can damage thebattery.

1. DO NOT use a wire brush to clean battery. Use a stiff bristle brush. Wipe with cloth dampened with bicarbonate of soda solution (one part of soda to 20 parts of water) to neutralize any spilled electrolyte solution.

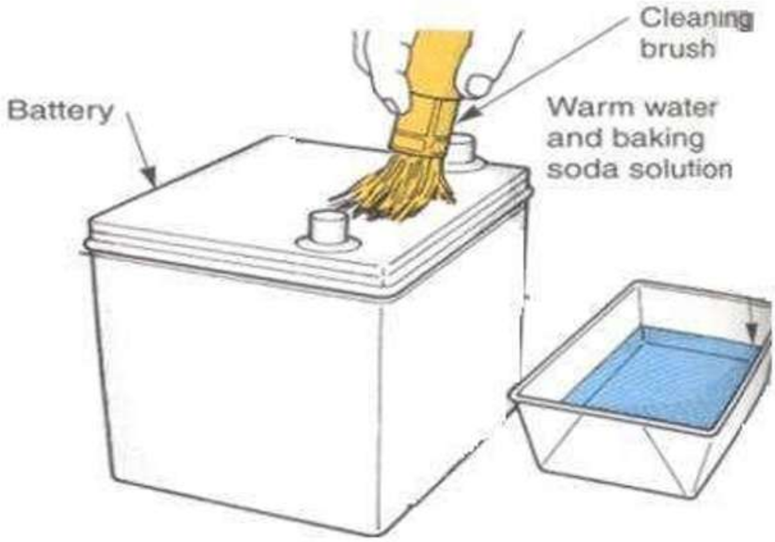


Figure 28 : Bristle Brush for Cleaning

2. To prevent the risk of burns, such personal items as rings, metal watches, watchstraps and identification bracelets should be removed, to avoid contact with connecting links and terminals.

3. Always disconnect battery's negative cable first and connect it last during installation.

10.2. PRECAUTIONS FOR NICKEL-CADBATTERIES

- The batteries are alkaline type and require absolute internal cleanliness. Avoid anycontamination.

CAUTION

Do not use any tools, jars or instruments in common with acid batteries. Acid and alkali do not mix.

- Alkaline electrolyte has a strong corrosive effect on most metals. In case of spills, immediately neutralize area with either a solution of six ounces of boric acid to one gallon water or a solution of one part vinegar to three parts water. Do not flush with water prior to neutralizing as this will only enlarge the area of contamination.

- Alkaline electrolyte is harmful to human skin. If a splash occurs, immediately rinse area with water then neutralize with either a solution of six ounces boric acid to one gallon water or a solution of one part vinegar to three parts water followed by washing with soap andwater.

- Do not use a wire brush to clean cells. Use a bristle brush andwater.

- Always disconnect battery's negative cable firstand connect it last during installation.

11. GENERAL MAINTENANCE OF ABATTERY

Following should be checked as per the Maintenance Schedule:

- Terminals should be periodically checked for cleanliness and good electrical connection. The battery casing should be checked for cleanliness and evidence ofdamage.

- Since there is virtually no chemical change taking place during nickel-cadmium cell charging or discharging, the condition of the electrolyte does not provide an indication of the battery's condition. Cell terminal voltage does not provide an indication of charge since it remains relatively constant. The only accurate and practical way to determine the condition of the nickel cadmium battery is with a measured discharge in the workshop. The fully charged battery is tested after a two hour ‘resting’ period, after which the electrolyte is topped up using distilled or demineralized water. Note that since the electrolyte level depends on the state of charge, water should never be added to the battery on the aircraft. This could lead to the electrolyte overflowing when the battery discharges, leading to corrosion and self- discharging (both of which could lead to premature failure of the battery). Ni-Cd batteries emit gas near the end of the charging process and during overcharging. This is an explosive mixture and must be prevented from accumulating; maintenance of the venting system is essential.

In the event of electrolyte spillage/leaks (always refer to the aircraft maintenance manual for specific details):

- Reportincident
- Mop electrolyte with damp rag orsponge
- Cover the area with a dilute solution of acetic acid, 5% solution of chromic acid, or 10% solution of boricacid.

- Press moist piece of red litmus paper on affected area; change of colour to blue indicates presence ofalkaline.
- Leave for a minumum of 24 hours, check forcorrosion.
- Restore protectivefinish.

11.1. CLEANING OFBATTERIES

1. Remove batteries fromaircraft.

CAUTION

In order to avoid shorting resulting in possible cell damage, it is recommended that the batteries be discharged prior to disassembly for cleaning.

2. Discharge batteries through a resistance high enough to permit a current flow depending on the battery AH capacity. When voltage is approximately 9.5 volts, placing a shorting clip (8- gage stranded wire, 6 inches long with insulated alligator clips) across each cell’s terminals with the load applied. When 15 cells are shorted out, place a 1.0 ohm, 2 watt resistor across each of the remaining cells and allow the battery to remain shorted for 3 hours before removing the shorting straps and resistors.

3. After battery has been discharged, remove shorting clips and all intercell connecting links. During removal, mark all connecting hardware to ensure proper reinstallation. Remove any white deposits (potassium carbonate) from top of cells and case with a bristlebrush.

4. Loosen vent plugs, using a ventwrench.

5. After washing cells with tap water and drying, inspect for cracks and leaks. Store cells in a dry, cleanarea.

6. Wash battery case with tap water and dry with compressed air. Replace cells in case, making certain to insert with the polarity symbols in the right direction. Cells are connected plus to minus.

12. BATTERY CHARGING

Depending on the initial condition of the battery, it can be charged in the followingways:

1. Initialcharge
2. Normalcharge

3. Equalisingcharge
4. Tricklecharge
5. Fastcharge

1. INITIALCHARGE

New batteries are sometimes shipped dry, and so are in an uncharged condition. After adding electrolyte, it is necessary to charge the battery and this is usually accomplished by via a long, low - rate initial charge in accordance with the manufacturer'sinstructions.

2. NORMALCHARGE

A normal charge is the routine maintenance charge given in accordance with the manufacturer’s instructions or nameplate data during an ordinary operation cycle to restore the battery to its fully chargedcondition.

3. EQUALISINGCHARGE

An equalising charge is a special extended normal charge, given periodically as part of a long term maintenance routine. It ensures that all the plates are cleared of sulphates and the cells are restored to maximum specific gravity. The equalising charge is continued until the specific gravity of all cells, corrected for temperature, shows no change for at least a 4- hour period.

4. TRICKLECHARGE

With a trickle charge, the charging rate is determined by the battery voltage rather than by a definite current value. The trickle charge keeps the battery fully charged when it is idle or only being used for light currents. It is also referred to as a floating charge and is achieved with low current.

5. FASTCHARGE

A fast charge is used when a battery must be recharged in the shortest possible time. The charge starts at a much higher rate than normal and should really only be used in an emergency, as too many of these charges can harm thebattery.

NOTE

Normally, the battery charging rate is given in the appropriate Maintenance Manual or on the battery nameplate. However, the rate should never be as high as to creating violent gassing.

13. CHARGINGROOM

Charging Room for Aircraft Batteries(lead acid as well as Ni cad battery).

- In no circumstance should the same facility be used for both nickel-cadmium and lead-acid battery charging; and the ventilation arrangements shall be such that no cross contamination canoccur.

- Buildings and rooms used for the purpose of charging batteries should be well lit and cool and should have a ventilation system which is capable of exhausting all the gases and fumes which may be present during the servicing and charging operations.

- The level of lighting within the charging rooms should be sufficient to enable the levelof the electrolyte in individual cells of batteries to be easily determined without additional lighting. To prevent accidental ignition of gases all electrical fittings should be of a spark proofdesign.

• Hydrogen is given off at all stages of lead-acid battery servicing; the highest concentration being at the end of the charging cycle. Hydrogen is also produced when nickel- cadmium batteries reach the fully charged state; i.e. at the 'overcharge' point and for a 24 hour periodthereafter.

• Heavy corrosive fumes are also emitted when mixing of electrolytes takes place. Therefore, a ventilation system is required which is capable of extracting all gases and fumes, whether heavier or lighter thanair.

• The maximum permissible electrolyte temperature during charging is normally50°C(122°F).

• Environmental temperatures exceeding 27°C (81°F) for lead- acid batteries and 21°C (70°F) for nickel-cadmium batteries impose time penalties in reaching the fully charged state and may also be deleterious to thebatteries.

• Transformer/rectifiers which normally provide rectified a.c. for charging board supplies should be sited in a fume free, dry and cool position, preferably in a separate room, located as near as possible to the charging boards. Charging boards which require 240 volts mains supply should be supplied from a ring mainsystem.

14. BATTERY ROOMTEST

All tests on batteries must be carried out in accordance with the manufacturer's instructions, which are supplied with each battery. The following descriptions are typical tests, these include

14.1. CapacityTest
14.2. Cell BalanceTest
14.3. InsulationTest
14.4. Cell Vent PressureTest

14.1. CAPACITYTEST

1. Fully Charge the battery and allow it to stand for 15-24 Hours.

2. Connect a discharge test panel, which must be incorporate a variable-load resistance, ammeter and ampere-hour meter and a voltmeter. If the control panel is not of the automatic type, then accurate monitoring and control of current must be maintained manually throughout thetest.
3. The battery should be discharge at a rate corresponding to the rating of the battery. For example, if the battery is rated at 18Ah at the one hour rate then the discharge would be set to 18 amps. Note the time of switch-on.
4. Monitor the voltage until it falls to the discharged value 21.6V (1.8 volts/cell) for a lead acid battery, 20V (1 volt/cell) for a Ni-Cad battery. Note thetime.

5. Calculate the capacity as follows : Actual time/rated time x 100% e.g. If the time to discharge was 54 min. then the capacity will be 54/60 x100%.

Generally the minimum acceptable capacity for aircraft use is 80%. However, inspection of the battery record card should be made to check the previous capacity tests to see if there is any [trend. Note the capacity on the battery record card together with date.

14.2. CELL BALANCETEST

If Ni cad battery fails its capacity test then a cell balance test should be carried out as a follow-on test as follows:

- Short out each cell with 1Ω, 2 wattresistor.
- Allow to stand for15-24Hrs.
- Check each cellvoltage.
- Discharge at the 1 Hr. rate and monitor the cellsvoltage.
- Short circuit any cell which falls below 1V in the first 48 minutes (less than 80%capacity).

- Continue the discharge until the terminal voltage is an average of 1V percell.
- Replace the short circuited cells.
- If five or more cells are short circuited, either at one time or over a period of time, then all the cells should be replaced as it is most likely that the remaining cells have been damaged and will need to be replaced in the nearfuture.
- Recharge the battery and repeat the cell balance procedure (all cells should meet the 80%capacity).
- Recharge thebattery.

14.3. INSULATIONTEST

A breakdown in a electrical insulation between the cells and the battery case will result in a 'leakage' current which, over a period of time can discharge the battery. The most common cause for loss of insulation is the leakage of electrolyte from the cells which can act as a conductor between the cell plates (or terminals) and the batterycontainer.

The procedure is as follows:

1. Place the (clean and dry) battery on a clean corrosion free metalplate.
2. Connect a 250V insulation tester between the metal plate and the batteryterminals.
3. Operate the tester and the minimum acceptable value should be 1MΩ for a lead acid and 10MΩ for Ni cad battery with the steelcase.

An alternative method is:

1. Disconnect thebattery.

2. Connect a 50 Ω resistor, 10mA ammeter and a 50-volt DC powersupply.
3. Place one probe of the test apparatus to the battery negative terminal and the other probe to the batterycase.
4. Check the current leakage doesn't exceed 50mA.

14.4. CELL VENT CAPACITYTEST

For lead acid batteries remove the vent caps. Hold the tester firmly over each vent in turn and pressurise each cell to 2 PSI. There should be no detectable leakage after a period of not less than 15 seconds. For Ni-Cads each cell vent is typically checked by applying a pressure via a compressed air line with the valve immersed in water. The pressure is raised and the valve should open between 2 and 10PSI.

15. SERVICE LIFE OF LEAD ACID NI CADBATTERY

The service life of a nickel-cadmium aircraft battery depends on many factors, including the type of use it experiences

- Rate ofcharge
- Frequency, and depth of discharge
- Environmental conditions (e.g., temperature andvibration)
- Charging methodand
- The care with which it is maintained andreconditioned.
- To extend service life of the lead acid batteries, the batteries must be kept at or near full charge, proper electrolyte level maintained, battery kept clean and notovercharged.

For Lead Acid Battery	
Depth of Discharge (% of Rated Capacity)	Number of Cycles to End of Life
80	250
100	200

Table4

For Lead Acid Battery	
Depth of Discharge (% of Rated Capacity)	Number of Cycles to End of Life
10	2000
30	670
50	400

For Ni Cad Battery	
Depth of Discharge (% of Rated Capacity)	Number of Cycles to End of Life
30	7500
50	4500
60	3000
80	1500
100	1000

Table5

Table 4 & Table 5, shows typical representative life cycle data as a function of the depth of discharge for Lead acid and Ni cad Battery respectively.
All things being equal, the service life of a nickel-cadmium battery is inherently longer than that of a lead-acidbattery.

16. EXTENTION OF BATTERY SERVICELIFE

- To extend the service life of the nickel-cadmium batteries, the batteries should be removed from the aircraft and a complete discharge and recharge cycle be performed in accordance with current inspectionintervals.

17. OVERHEATING WARNINGSYSTEM

- The battery system also incorporates a battery overheat warning system. The system consists of two thermoswitches (lo-limit and hi-limit) installed in each battery and warning lights. Generally warning lights are installed in pilot’s subpanel or in the glareshield.

- The optional temperature indicating system consists of a dual indicator mounted normally on the copilot's switch panel or in the center pedestal, a circuit breaker located on the copilot's circuit breaker panel and a temperature sensor located in eachbattery.

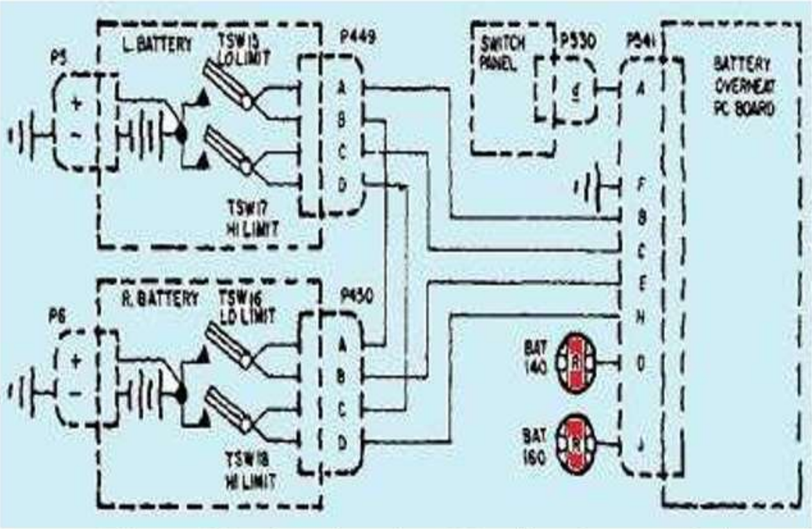


Figure 29 : Overheating Warning System Schematic

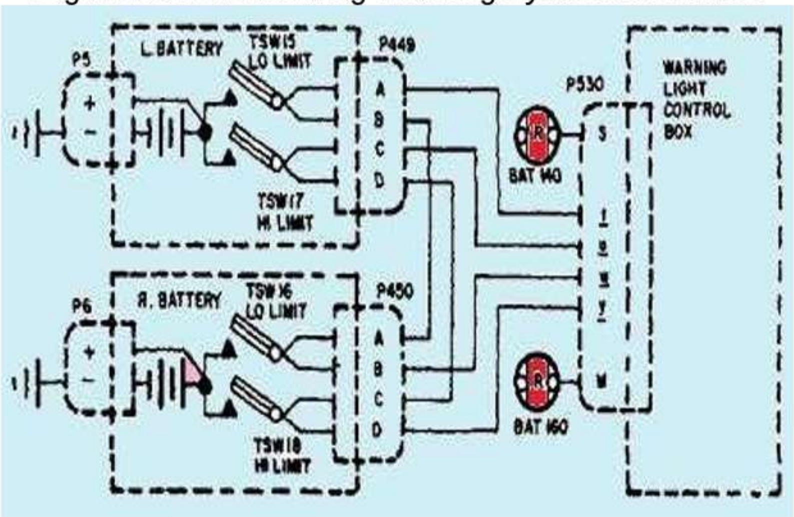


Figure 30 : Overheating Warning System Schematic

If battery temperature reaches 140°F, the lo-limit thermoswitch energizes the BAT 140 (red) warning light. If battery temperature reaches 160°F, the hi-limit thermoswitch energizes the BAT 160 (red) warning light. If at any time during flight or ground operation, including engine start, either overheat warning light illuminates, the batteries must be removed from the aircraft and the discharge-recharge reconditioning cycle must beperformed.

BATTERY CIRCUIT

The aircraft battery and battery circuit is used to supply power for engine starting and to provide a secondary power supply in the event of an alternator (or generator) failure. A schematic of a typical battery circuit is shown in Figure 56. This diagram shows the relationship of the starter and external power circuits that are discussed later in this chapter. The bold lines found on the diagram represent large wire (see the wire leaving thebattery positive connection), which is used in the battery circuit due to the heavy current provided through these wires. Because batteries can supply large current flows, a battery is typically connected to the system through an electrical solenoid.

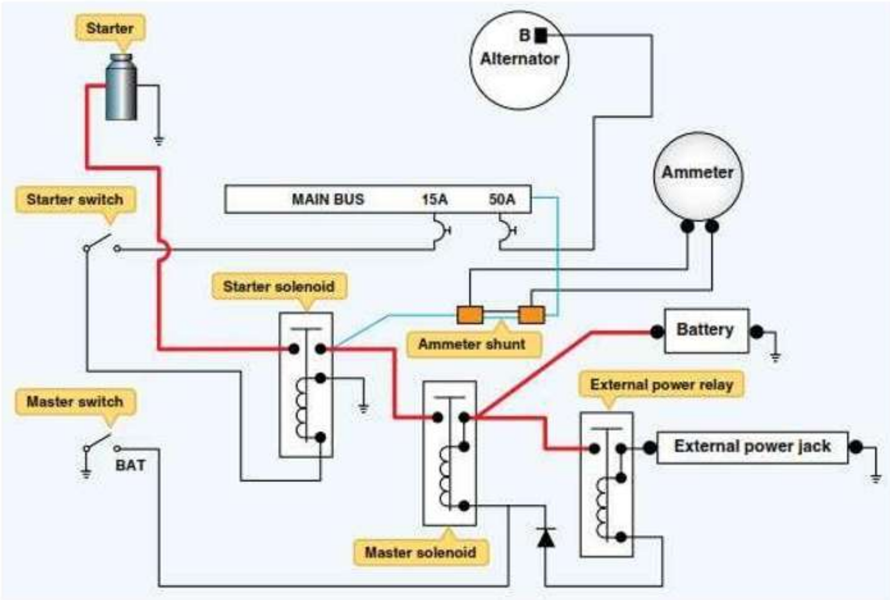


Figure 56 : Battery Circuit

At the start/end of each flight, the battery is connected / disconnected from the electrical distribution bus through the solenoid contacts. A battery master switch on the flight deck is used to control the solenoid. Although they are very similar, there is often confusion between the terms "solenoid" and "relay". A solenoid is typically used for switching high current circuits and relays used to control lower current circuits. To help illuminate the confusion, the term "contactor" is often used when describing a magnetically operated switch. For general purposes, anaircrafttechnicianmayconsiderthetermsrelay,solenoid,and contactor synonymous. Each of these three terms may be used on diagrams and schematics to describe electrical switches controlled by an electromagnet. Here it can be seen that the battery positive wire is connected to the electrical bus when the battery master switch is active. A battery solenoid is shown in Figure57.

The battery switch is often referred to as the master switch since it turns off or on virtually all electrical power by controlling the battery connection. Note how the electrical connections of the battery solenoid are protected from electrical shorts by rubber covers at the end of each wire. The ammeter shown in the battery circuit is used to monitor the current flow from the battery to the distribution bus. When all systems are operating properly, battery current should flow from the main bus to the battery giving a positive indication on the ammeter. In this case, the battery is being charged. If the aircraft alternator (or generator) experiences a malfunction, the ammeter indicates a negative value. A negative indication means current is leaving the battery to power any electrical load connected to the bus. The battery is being discharged and the aircraft is in danger of losing all electrical power.

Figure 57 : Battery Solenoid GENERATOR CIRCUIT

Generator circuits are used to control electrical power between the aircraft generator and the distribution bus. Typically, these circuits are found on older aircraft that have not upgraded to an alternator. Generator circuits control power to the field winding and electrical power from the generator to the electrical bus. A generator master switch is used to turn on the generator typically by controlling field current. If the generator is spinning and current is sent to the field circuit, the generator produces electrical power. The power output of the generator is controlled through the generator control unit (or voltage regulator). A simplified generator control circuit is shown in Figure 58. As can be seen in Figure 58, the generator switch controls the power to the generator field (F terminal). The generator output current is supplied to the aircraft bus through the armature circuit (A terminal) of the generator.

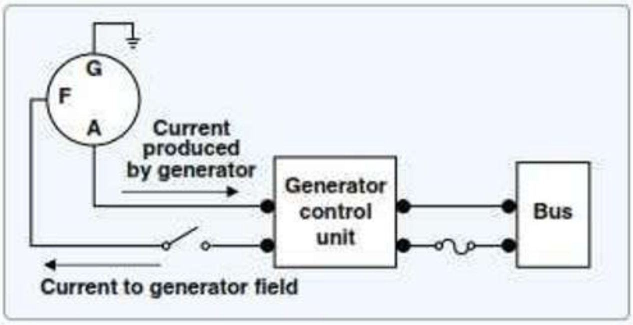


Figure 58 : Typical Generator Circuit

Alternator Circuit Alternator circuits, like generator circuits, must control power both to and from the alternator. The alternator is controlled by the pilot through the alternator master switch. The

alternator master switch in turn operates a circuit within the alternator control unit (or voltage regulator) and sends current to the alternator field. If the alternator is powered by the aircraft engine, the alternator produces electrical power for the aircraft electrical loads. The alternator control circuit contains the three major components of the alternator circuit: alternator, voltage regulator, and alternator master switch. [Figure 59]

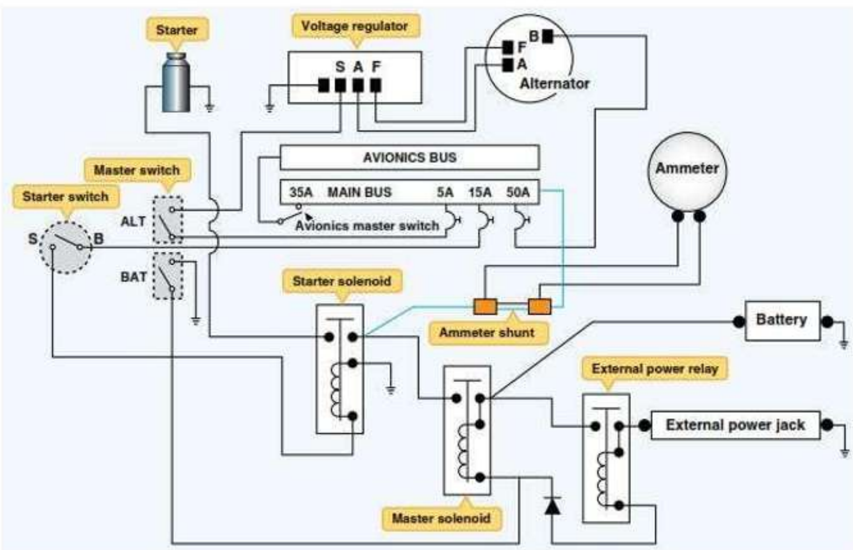


Figure 59 : Alternator Control Circuit

The voltage regulator controls the generator field current according to aircraft electrical load. If the aircraft engine is running and the alternator master switch is on, the voltage regulator adjusts current to the alternator field as needed. If more current flows to the alternator field, the alternator output increases and feeds the aircraft loads through the distribution bus. All alternators must be monitored for correct output. Most light aircraft employ an ammeter to monitor alternatoroutput.

Figure 60, shows a typical ammeter circuit used to monitor alternator output. An ammeter placed in the alternator circuit is a single polarity meter that shows current flow in only one direction. This flow is from the alternator to the bus. Since the alternator contains diodes in the armature circuit, current cannot reverse flow from the bus to the alternator. When troubleshooting an alternator system, be sure to monitor the aircraft ammeter. If the alternator system is inoperative, the ammeter gives azero indication. In this case, the battery is beingdischarged.

A voltmeter is also a valuable tool when troubleshooting an alternator system. The voltmeter should be installed in the electrical system while the engine is running and the alternator operating. A system operating normally produces a voltage within the specified limits (approximately 14 volts or 28 volts depending on the electrical system). Consult the aircraft manual and verify the system voltage is correct. If the voltage is below specified values, the charging system should be inspected. the alternator contains diodes in the armature circuit, current cannot reverse flow from the bus to the alternator. When troubleshooting an alternator system, be sure to monitor the aircraft ammeter. If the alternator system is inoperative, the ammeter gives a zero indication. In this case, the battery is being discharged. A voltmeter is also a valuable tool when troubleshooting an alternator system. The voltmeter should be installed in the electrical system while the engine is running and the alternator operating. A system operating normally produces a voltage within the specified limits (approximately 14 volts or 28 volts depending on the electrical system). Consult the aircraft manual and verify the system voltage is correct. If the voltage is below specified values, the charging system should beinspected.

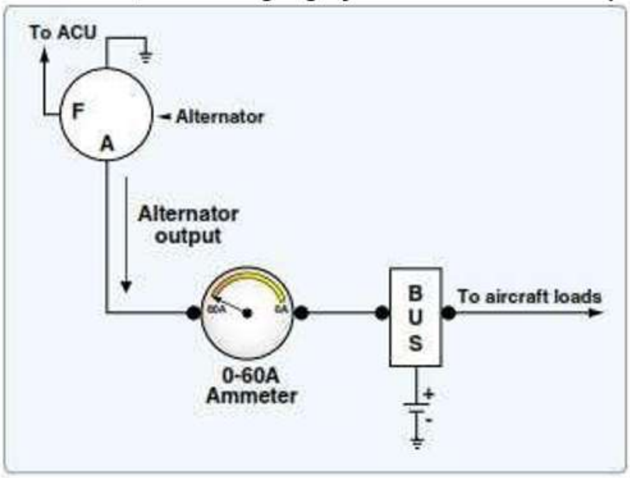


Figure 60

STARTER CIRCUIT

Virtually all modern aircraft employ an electric motor to start the aircraft engine. Since starting the engine requires several horsepower, the starter motor can often draw 100 or more amperes. For this reason, all starter motors are controlled through a solenoid. [Figure 61] The starter circuit must be connected as close as practical to the battery since large wire is needed to power the starter motor and weight savings can be achieved when the battery and the starter are installed close to each other in the aircraft. As shown in the starter circuit diagram, the start switch can be part of a multifunction switch that is also used to control the engine magnetos. [Figure 62] The starter can be powered by either the aircraft battery or the external power supply. Often when the aircraft battery is weak or in need of charging, the external power circuit is used to power the starter. During most typical operations, the starter is powered by the aircraft battery. The battery master must be on and the master solenoid closed in order to start the engine with thebattery.

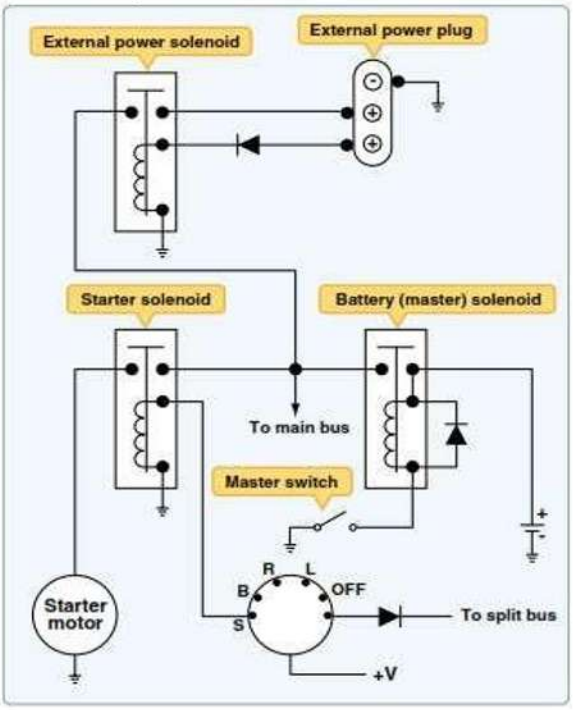


Figure 61

Figure 62 AVIONICS POWER CIRCUIT

Many aircraft contain a separate power distribution bus specifically for electronics equipment. This bus is often referred to as an avionics bus. Since modern avionics equipment employs sensitive electronic circuits, it is often advantageous to disconnect all avionics from electrical power to protect their circuits. For example, the avionics bus is often depowered when the starter motor is activated. This helps to prevent any transient voltage spikes produced by the starter from entering the sensitive avionics. [Figure63]

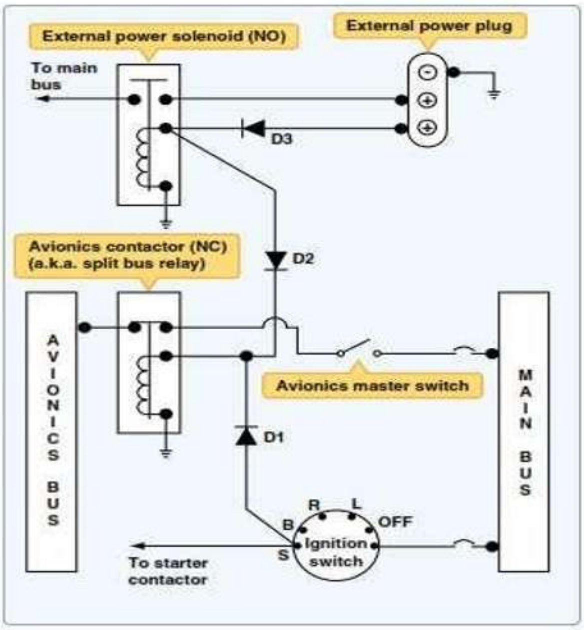


Figure 63

The circuit employs a normally closed (NC) solenoid that connects the avionics bus to the main power bus. The electromagnet of the solenoid is activated whenever the starter is engaged. Current is sent from the starter switch through Diode D1, causing the solenoid to open and depower the avionics bus. At that time, all electronics connected to the avionics bus will lose power. The avionics contactor is also activated whenever external power is connected to the aircraft. In this case, current travels through diodes D2 and D3 to the avionics bus contactor. A separate avionics power switch may also be used to disconnect the entire avionics bus. A typical avionics power switch is shown wired in series with the avionics power bus. In some cases, this switch is combined with a circuit breaker and performs two functions (called a circuit breaker switch). It should also be noted that the avionics contactor is often referred to as a split bus relay, since the contactor separates (splits) the avionics bus from the main bus.

LANDING GEAR CIRCUIT

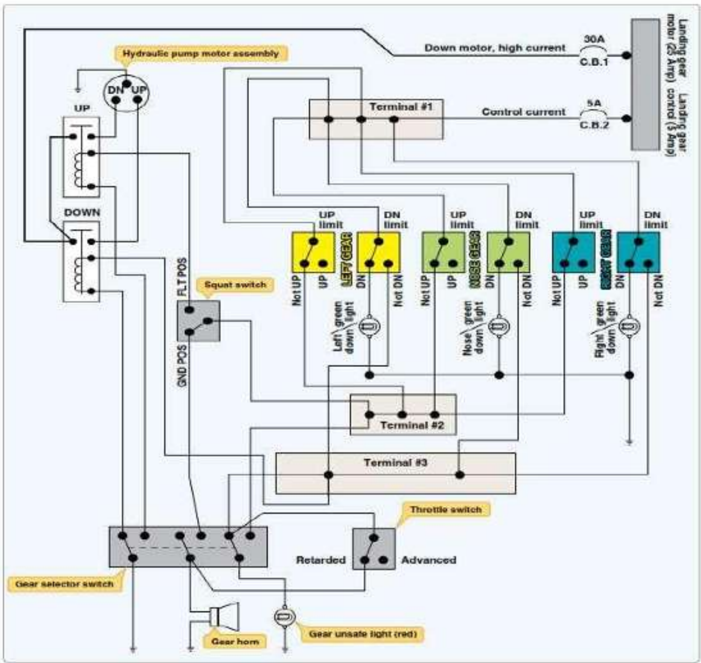
Another common circuit found on light aircraft operates the retractable landing gear systems on high-performance light aircraft. These airplanes typically employ a hydraulic system to move the gear. After takeoff, the pilot moves the gear position switch to the retract position, starting an electric motor. The motor operates a hydraulic pump, and the hydraulic system moves the landing gear. To ensure correct operation of the system, the landing gear electrical system is relatively complex. The electrical system must detect the position of each gear (right, left, nose) and determine when each reaches full up or down; the motor is then controlled accordingly. There are safety systems to help prevent accidental actuation of the gear. A series of limit switches are needed to monitor the position of each gear during the operation of the system. (A limit switch is simply a spring-loaded, momentary contact switch that is activated when a gear reaches it limit of travel.) Typically, there are six limit switches located in the landing gear wheel wells. The three up-limit switches are used to detect when the gear reaches the full retract (UP) position. Three down-limit switches are used to detect when the gear reach the full extended (DOWN) position. Each of these switches is mechanically activated by a component of the landinggear

assembly when the appropriate gear reaches a given limit. The landing gear system must also provide an indication to the pilot that the gear is in a safe position for landing.

Many aircraft employ a series of three green lights when all three gears are down and locked in the landing position. These three lights are activated by the up and down limit switches found in the gear wheel well. A typical instrument panel showing the landing gear position switch and the three gears down indicators is shown in Figure 64.

Figure 64

The hydraulic motor/pump assembly located in the upper left corner of Figure 9-95 is powered through either the UP or DOWN solenoids (top left). The solenoids are controlled by the gear selector switch (bottom left) and the six landing gear limit switches (located in the center of Figure 65). The three ear DOWN indicators are individual green lights (center of Figure 65) controlled by the three gear DOWN switches. As each gear reaches it's DOWN position, the limit switch moves to the DOWN position, and the light is illuminated. Figure 65 shows the landing gear in the full DOWN position. It is always important to know gear position when reading landing gear electrical diagrams. Knowing gear position helps the technician to analyze the diagram and understand correct operation of the circuits. Another



important concept is that more than one circuit is used to operate the landinggear.

Figure 65

On this system, there is a low current control circuit fused at 5 amps (CB2, top right of Figure 65). This circuit is used for indicator lights and the control of the gear motor contactors. There is a separate circuit to power the gear motor fused at 30 amps (CB3, top right of (Figure 65). Since this circuit carries a large current flow, the wires would be as short as practical and carefully protected with rubber boots or nylon insulators.

Figure 66 shows current flow when the gear is traveling to the extend (DOWN) position. Current flow is highlighted in red for each description. To run the gear DOWN motor, current must flow in the control circuit leaving CB2 through terminal 1 to the NOT DOWN contacts of the DOWN limit switches, through terminal 3, to the DOWN solenoid positive terminal (upperleft).

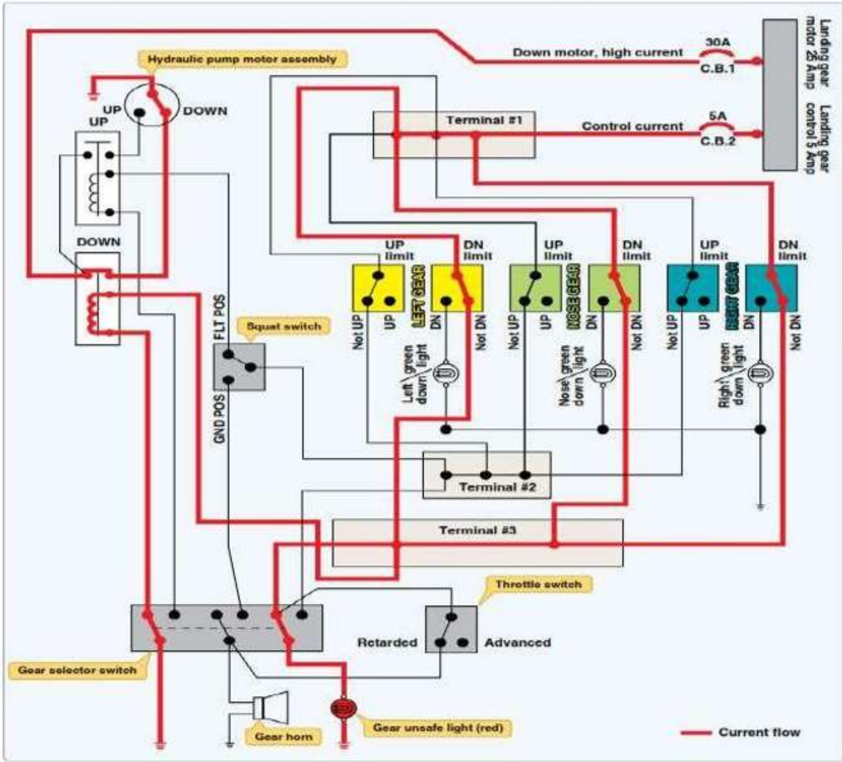


Figure 66

The negative side of the DOWN solenoid coil is connected to ground through the gear selector switch. Remember, the gear DOWN switches are wired in parallel and activated when the gear reach the full-DOWN position. All three gears must reach full- DOWN to shut off the gear DOWN motor. Also note that the gear selector switch controls the negative side of the gear solenoids. The selector switch has independent control of the gear UP and DOWN motors through control of the ground circuit to both the UP and DOWN solenoids.

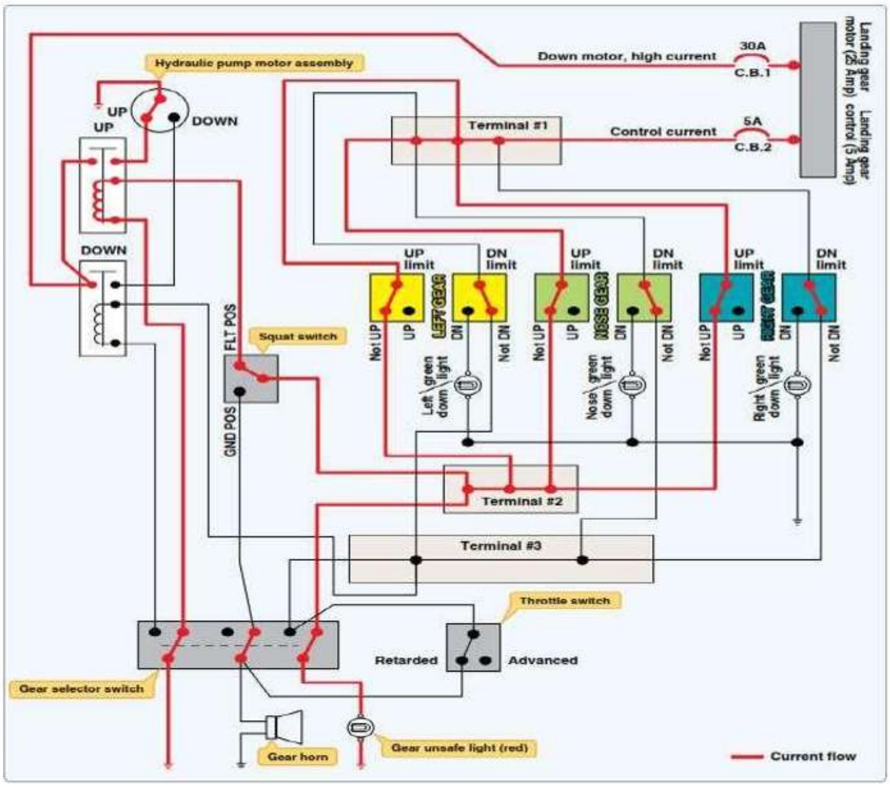


Figure 67

When the landing gear control circuit is sending a positive voltage to the DOWN solenoid, and the gear selector switch is sending negative voltage, the solenoid magnet is energized. When the gear-DOWN solenoid is energized, the high-current gear motor circuit sends current from CB1 through the down solenoid contact points to the gear DOWN motor. When the motor runs, the hydraulic pump produces pressure and the gear begins to move. When all three gears reach the DOWN position, the gear-DOWN switches move to the DOWN position, the three green lights illuminate, and the gear motor turns off completing the gear- DOWN cycle. Figure 67 shows the landing gear electrical diagram with the current flow path shown in red as the gear moves to the retract (UP)position.

Starting in the top right corner of the diagram, current must flow through CB2 in the control circuit through terminal 1 to each of the three gear-UP switches. With the gear-UP switches in the not UP position, current flows to terminal 2 and eventually through the squat switch to the UP solenoid electromagnet coil. The UP solenoid coil receives negative voltage through the gear selector switch. With the UP solenoid coil activated, the UP solenoid closes and power travels through the motor circuit. To power the motor, current leaves the bus through CB1 to the terminal at the DOWN solenoid onward through the UP solenoid to the UP motor. (Remember, current cannot travel through the DOWN solenoid at this time since the DOWN solenoid is notactivated.)

As the UP motor runs, each gear travels to the retract position. As this occurs, the gear UP switches move from the NOT UP position to the UP position. When the last gear reaches up, the current no longer travels to terminal 2 and the gear motor turns off. It should be noted that similar to DOWN, the gear switches are wired in parallel, which means the gear motor continues to run until all three gear reach the required position. During both the DOWN and UP cycles of the landing gear operation, current travels from the limit switches to terminal 2. From terminal 2, there is a current path through the gear selector switch to the gear unsafe light. If the gear selector disagrees with the current gear position (e.g., gear is DOWN and pilot has selected UP), the unsafe light is illuminated. The gear unsafe light is shown at the bottom of Figure66.
The squat switch (shown mid left of Figure 66) is used to determine if the aircraft is on the GROUND or

in FLIGHT. This switch is located on a landing gear strut. When the weight of the

aircraft compresses the strut, the switch is activated and moved to the GROUND position. When the switch is in the GROUND position, the gear cannot be retracted and a warning horn sounds if the pilot selects gear UP. The squat switch is sometimes referred to as the weight-on-wheels switch. A throttle switch is also used in conjunction with landing gear circuits on most aircraft. If the throttle is retarded (closed) beyond a certain point, the aircraft descends and eventually lands. Therefore, manymanufacturers activate a throttle switch whenever engine power is reduced. If engine power is reduced too low, a warning horn sounds telling the pilot to lower the landing gear. Of course, this horn need not sound if the gear is already DOWN or the pilot has selected the DOWN position on the gear switch. This same horn also sounds if the aircraft is on the ground, and the gear handle is moved to the UP position. Figure 66 shows the gear warning horn in the bottom leftcorner.

POWER DISTRIBUTION SYSTEMS

PARALLELING ALTERNATORS OR GENERATORS

Since two alternators (or generators) are used on twin engine aircraft, it becomes vital to ensure both alternators share the electrical load equally. This process of equalizing alternator outputs is often called paralleling. In general, paralleling is a simple process when dealing with DC power systems found on light aircraft. If both alternators are connected to the same load bus and both alternators produce the same output voltage, the alternators share the loadequally.

Therefore, the paralleling systems must ensure both power producers maintain system voltage within a few tenths of a volt. For most twin-engine aircraft, the voltage would be between 26.5- volt and 28-volt DC with the alternators operating.

A simple vibrating point system used for paralleling alternators is found in Figure 67. As can be seen in Figure 67, both left and right voltage regulators contain a paralleling coil connected to the output of each alternator. This paralleling coil works in conjunction with the voltage coil of the regulator to ensure proper alternator output. The paralleling coils are wired in series between the output terminals of both alternators. Therefore, if the two alternators provide equal voltages, the paralleling coil has no effect. If one alternator has a higher voltage output, the paralleling coils create the appropriate magnetic force to open/close the contact points, controlling field current and control alternator output. Today's aircraft employ solid-state control circuits to ensure proper paralleling of the alternators. Older aircraft use vibrating point voltage regulators or carbon-pile regulators to monitor and control alternator output. For the most part, all carbon-pile regulators have been replaced except on historic aircraft. Many aircraft still maintain a vibrating point system, although these systems are no longer being used on contemporary aircraft.

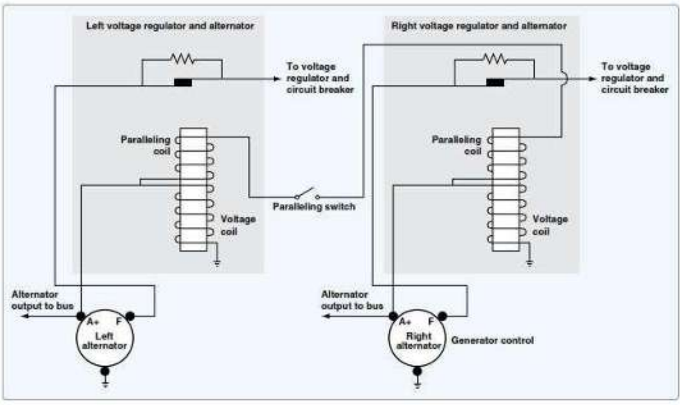


Figure 67 LIGHT MULTIENGINE AIRCRAFT

Multiengine aircraft typically fly faster, higher, and farther than single engine aircraft. Multiengine aircraft are designed for added safety and redundancy and, therefore, often contain a more complex power distribution system when compared to light single-engine aircraft. With two engines, these aircraft can drive two alternators (or generators) that supply current to the various loads of the aircraft. The electrical distribution bus system is also divided into two or more systems. These us systems are typically connected through a series of circuit protectors, diodes, and relays. The bus system is designed to create a power distribution system that is extremely reliable by supplying current to most loads through more than onesource.

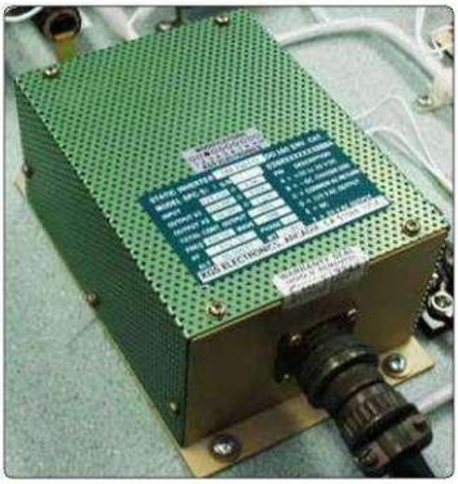


Figure68

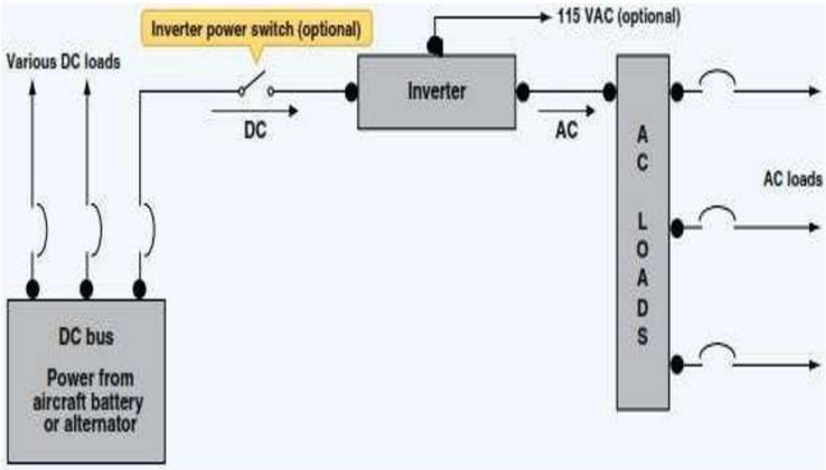


Figure69

POWER DISTRIBUTION ON MULTIENGINE AIRCRAFT

The power distribution systems found on modern multiengine aircraft contain several distribution points busses) and a varietyof

control and protection components to ensure the reliability of electrical power. As aircraft employ more electronics to perform various tasks, the electrical power systems becomes more complex and more reliable. One means to increase reliability is to ensure more than one power source can be used to power any given load. Another important design concept is to supply critical electrical loads from more than one bus. Twin-engine aircraft, such as a typical corporate jet or commuter aircraft, have two DC generators; they also have multiple distribution busses fed from each generator. Figure 70 shows a simplified diagram of the power distribution system for a twin-engine turboprop aircraft. This aircraft contains two starter generator units used to start the engines and generate DC electrical power. The system is typically defined as a split-bus power distribution system since there is a left and right generator bus that splits shares) the electrical loads by connecting to each sub-bus through a diode and current limiter. The generators are operated in parallel and equally carry the loads. The primary power supplied for this aircraft is DC, although small amounts of AC are supplied by twoinverters.

The aircraft diagram shows the AC power distribution at the top and mid left side of the diagram. One inverter is used for main AC power and the second operated in standby and ready as a backup. Both inverters produce 26-volt AC and 115-volt AC. There is an inverter select relay operated by a pilot controlled switch used to choose which inverter is active. The hot battery bus (right side of Figure 70) shows a direct connection to the aircraft battery. This bus is always hot if there is a charged battery in the aircraft. Items powered by this bus may include some basics like the entry door lighting and the aircraft clock, which should always have power available. Other items on this bus would be critical to flight safety, such as fire extinguishers, fuel shut offs, and fuel pumps. During massive system failure, the hot battery bus is the last bus on the aircraft that should fail. If the battery switch is closed and the battery relay activated, battery power is connected to the main battery bus and the isolation bus. The main battery bus carries current for engine starts and external power. So the main battery bus must be large enough to carry the heaviest current loads of the aircraft. It is logical to place this bus as close as practical to the battery and starters and to ensure the bus is well protected from shorts to ground.

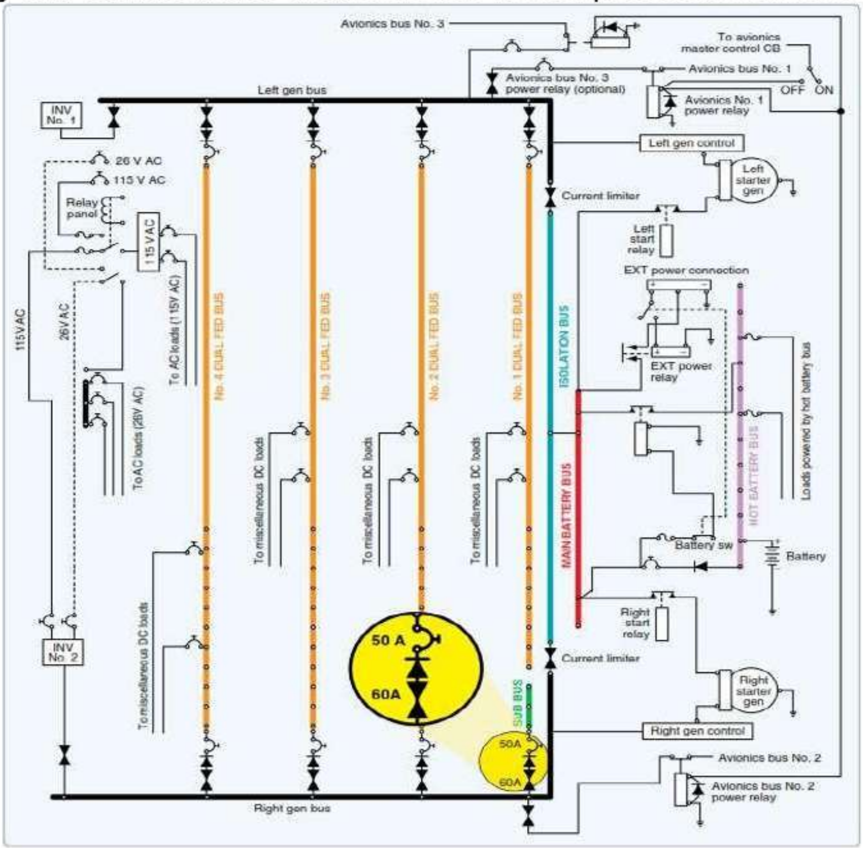


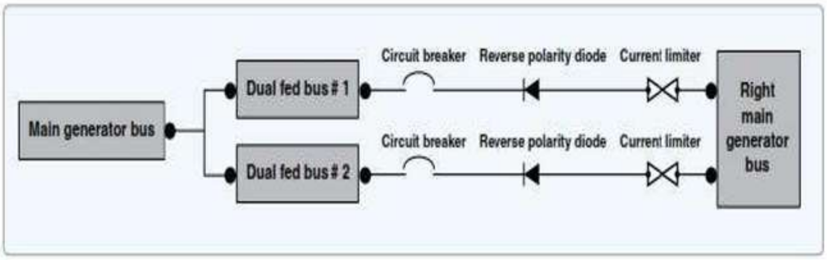
Figure 70

The isolation bus connects to the left and right busses and receives power whenever the main battery bus is energized. The isolation bus connects output of the left and right generators in parallel. The output of the two generators is then sent to the loads through additional busses. The generator busses are connected to the isolation bus through a fuse known as a current limiter. Current limiters are high amperage fuses that isolate busses if a short circuit occurs. There are several current limiters used in this system for protection between busses.

As can be seen in Figure 70, a current limiter symbol looks like two triangles pointed toward each other. The current limiter between the isolation bus and the main generator busses are rated at 325 amps and can only be replaced on the ground. Most current limiters are designed for ground replacement only and only after the malfunction that caused the excess current draw is repaired. The left and right DC generators are connected to their respective main generator busses. Each generator feeds its respective bus, and since the busses are connected under normal circumstances, the generators operate in parallel. Both generators feed all loads together. If one generator fails or a current limiter opens,the generators can operate independently. This design allows for redundancy in the event of failure and provides battery backup in the event of a dual generatorfailure.

In the center of Figure 70 are four dual-feed electrical busses. These busses are considered dual-feed since they receive power from both the left and right generator b busses. If a fault occurs, either generator bus can power any or all loads on a dual-feed bus. During the design phase of the aircraft, the electrical loads must be evenly distributed between each of the dual-feed busses. It is also important to power redundant systems from different busses. For example, the pilot's windshield heat would be powered by a different bus from the one that powers the copilot's windshield heat. If one bus fails, at least one windshield heat continues to work properly, and the aircraft can be landed safely inicing conditions. Notice that the dual-feed busses are connected to the main generator busses through both a current limiter and a diode. Remember, a diode allows current flow in only one direction. [Figure 71]

The current can flow from the generator bus to the dual-feed bus, but the current cannot flow from the dual fed bus to the main generator bus. The diode is placed in the circuit so the main bus must be more positive than the sub bus for current flow. This circuit also contains a current limiter and a circuit breaker. The circuit breaker is located on the flight deck and can be reset by the pilot. The current limiter can only be replaced on the ground by a technician. The circuit breaker is rated at a slightly lower current value than the current limiter; therefore, the circuit breaker should open if a current overload exists. If the circuit breaker fails to open, the current limiter provides backup protection and disconnects



thecircuit.

Figure 71

POWER DISTRIBUTION ON LARGE MULTIENGINE AIRCRAFT

Transport category aircraft typically carry hundreds of passengers and fly thousands of miles each trip. Therefore, large aircraft require extremely reliable power distribution systems that are computer controlled. These aircraft have multiple power sources (AC generators) and a variety of distribution busses. A typical airliner contains two or more main AC generators driven by the aircraft turbine engines, as well as more than one backup AC generator. DC systems are also employed on large aircraft and the ship's battery is used to supply emergency power in case of a multiple failures. The AC generator (sometimes called an alternator) produces three-phase 115-volt AC at 400 Hz. AC generators were discussed previously in this chapter. Since most modern transport category aircraft designed with two engines, there are two main AC generators. The APU also drives an AC generator. This unit is available during flight if one of the main generators fails. The main and auxiliary generators are typically similar in output capacity and supply a maximum of 110 kilovolt amps (KVA). A fourth generator, driven by an emergency ram air turbine, is also available in the event the two main generators and one auxiliary generator fail. The emergency generator is typically smaller and produces less power. With four AC generators available on modern aircraft, it is highly unlikely that a complete power failure occurs. However, if all AC generators are lost, the aircraft battery will continue to supply DC electrical power to operate vital systems.

Transport category aircraft use large amounts of electrical power for a variety of systems. Passenger comfort requires power for lighting, audio visual systems, and galley power for food warmers and beverage coolers. A variety of electrical systems are required to fly the aircraft, such as flight control systems, electronic engine controls, communication, and navigation systems. The output capacity of one engine-driven AC generator can typically power all necessary electrical systems. A second engine-driven generator is operated during flight to share the electrical loads and provide redundancy. The complexity of multiple generators and a variety of distribution busses requires several control units to maintainaconstantsupplyofsafeelectricalpower.The AC electrical system must maintain a constant output of 115 to 120 volts at a frequency of 400 Hz (±10 percent).

The system must ensure power limits are not exceeded. AC generators are connected to the appropriate distribution busses at the appropriate time, and generators are in phase when needed. There is also the need to monitor and control any external power supplied to the aircraft, as well as control of all DC electrical power. Two electronic line replaceable units are used to control the electrical power on a typical large aircraft. The generator control unit (GCU) is used for control of AC generator functions, such as voltage regulation and frequency control. The bus power control unit (BPCU) is used to control the distribution of electrical power between the various distribution busses on the aircraft. The GCU and BPCU work together to control electrical power, detect faults, take corrective actions when needed, and report any defect to the pilots and the aircraft's central maintenancesystem.

There is typically one GCU for each AC generator and at least one BPCU to control bus connections. These LRUs are located in the aircraft's electronics equipment bay and are designed for easy replacement. When the pilot calls for generator power by activating the generator control switch on the flight deck, the GCU monitors the system to ensure correct operation. If all systems are operating within limits, the GCU energizes the appropriate generator circuits and provides voltage regulation for the system. The GCU also monitors AC output to ensure a constant 400-Hzfrequency.

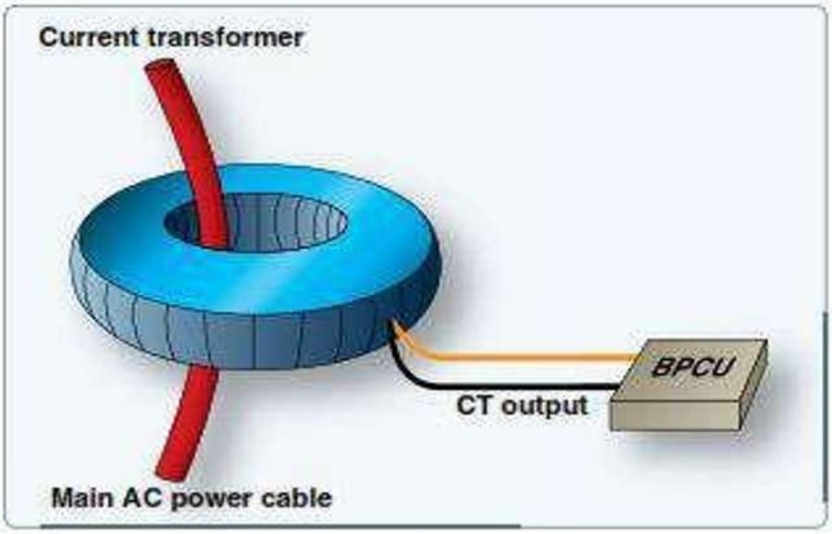


Figure 72

If t he generator output is within limits, the GCU then connects the electrical power to the main generator bus through an electrical contactor (solenoid). These contactors are often called generator breakers (GB) since they break (open) or make (close) the main generator circuit. After generator power is available, the BPCU activates various contact or or to distribute the electrical power. The BPCU monitors the complete electrical system and communicates with the GCU to ensure proper operation. The BPCU employs remote current sensors known as a current transformers (CT) to monitor the system. [Figure72]

A CT is an inductive unit that surrounds the main power cables of the electrical distribution system. As AC power flows through the main cables, the CT receives an induced voltage. The amount of CT voltage is directly related to the current flowing through the cable. The CT connects to the BPCU, which allows accurate current monitoring of the system. A typical aircraft employs several CTs throughout the electrical system. The BPCU is a dedicated computer that controls the electrical connections between the various distribution busses found on the aircraft. The BPCU uses contactors (solenoids) called bus tie breakers (BTB) for connection of various circuits. These BTBs open/close the connections between the busses as needed for system operation as called for by the pilots and the BPCU. This sounds like a simple task, yet to ensure proper operation under a variety of conditions, the bus system becomes very complex.

COMMON TYPES OF POWER DISTRIBUTION BUS SYSTEMS

There are three common types of distribution bus systems found on transport category aircraft:

1. Split Bus Power Distribution System
2. Parallel Bus System and
3. Split Parallel System

1. SPLIT-BUS POWER DISTRIBUTIONSYSTEM

Modern twin-engine aircraft, such as the Boeing 737, 757, 777, Airbus A-300, A-320, and A-310, employ asplit-bus power distribution system. During normal conditions, each engine-driven AC generator powers only one main AC bus. The busses are kept split from each other, and two generators can never power the same bus simultaneously. This is very important since the generator output current is not phase regulated. (If two out-of-phase generators were connected to the same bus, damage to the system would occur.) The split- bus system does allow both engine-driven generators to power any given bus, but not at the same time. Generatorsmust remainisolatedfromeachothertoavoiddamage.TheGCUs

and BPCU ensures proper generator operation and power distribution.

On all modern split bus systems, the APU can be started and operated during flight. This allows the APU generator to provide back-up power in the event of a main generator failure. A fourth emergency generator powered by the ram air turbine is also available if the other generators fail. The four AC generators are shown at t hebottom of Figure 73. These generators are connected to their respective busses through the generator breakers. For example, generator 1 sends current through GB1 to AC bus1. AC bus 1 feeds a variety of primary electrical loads, and also feeds sub-busses that in turn power additionalloads.

With both generators operating and all systems normal, AC bus 1 and AC bus 2 are kept isolated. Typically during flight, the APB (bottom center of Figure 9-104) would be open and the APU generator off; the emergency generator (bottom right) would also be off and disconnected. If generator one should fail, the followinghappens:

- The GB 1 is opened by the GCU to disconnect the failed generator.
- The BPCU closes BTB 1 and BTB 2. This supplies AC power to AC bus 1 from generator 2.
- The pilots start the APU and connect the APU generator. At that time, the BPCU and GCUs move the appropriate BTBs to correctly configure the system so the APU powers bus 1 and generator 2 powers bus 2.Once again; two AC generators operate independently to power AC bus 1 and2.

If all generators fail, AC is also available through the static inverter (center of Figure 9-104). The inverter is poweredfrom the hot battery bus and used for essential AC loads if all AC generators fail. Of course, the GCUs and BPCU take the appropriate actions to disconnect defective units and continue to feed essential AC loads using inverter power. To produce DC power, AC bus 1 sends current to its transformer rectifier (TR), TR 1 (center left of Figure 73). The TR unit is used to change AC to DC. The

TR contains a transformer to step down the voltage from 115-volt AC to 26-volt AC and a rectifier to change the 26- volt AC to 26 volt DC. The output of the TR is therefore compatible with the aircraft battery at 26-volt DC. Since DC power is not phase sensitive, the DC busses are connected during normal operation. In the event of a bus problem, the BPCU may isolate one or more DC busses to ensure correct distribution of DC power. This aircraft contains two batteries that are used to supply emergency DCpower.

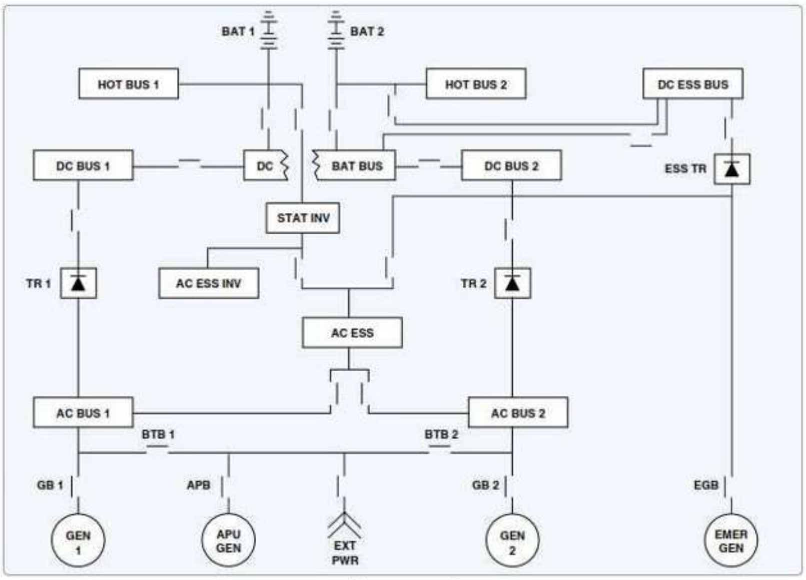


Figure 73

2. PARALLEL BUSSYSTEMS

Multiengine aircraft, such as the Boeing 727, MD-11, and the early Boeing 747, employ a parallel power distribution system. During normal flight conditions, all engine-driven generators connect together and power the AC loads. In this configuration, the generators are operated in parallel; hence the name parallel power distribution system. In a parallel system, all generator output current must be phase regulated. Before generators are connected to the same bus, their output frequency must be adjusted to ensure the AC output reaches the positive and negative peaks simultaneously. During the flight, generators must maintain this in-phase condition for proper operation.One advantage of parallel systems is that in
the event of a generator failure, the busses are already connected and the defective generator need only be isolated from the system. A paralleling bus, or synchronizing bus, is used to connect the generators during flight.

The synchronizing bus is often referred to as the sync bus. Most of these systems are less automated and require that flight crew monitor systems and manually control bus contactors. BTBs are operated by the flight crew through the electrical control panel and used to connect all necessary busses. GBs are used to connect and disconnect the generators. Figure 74 shows a simplified parallel power distribution system. This aircraft employs three main-engine driven generators and one APU generator. The APU (bottom right) is not operational in flight and cannot provide backup power. The APU generator is for ground operations only. The three main generators (bottom of Figure 74) are connected to their respective AC bus through GBs one, two, andthree.

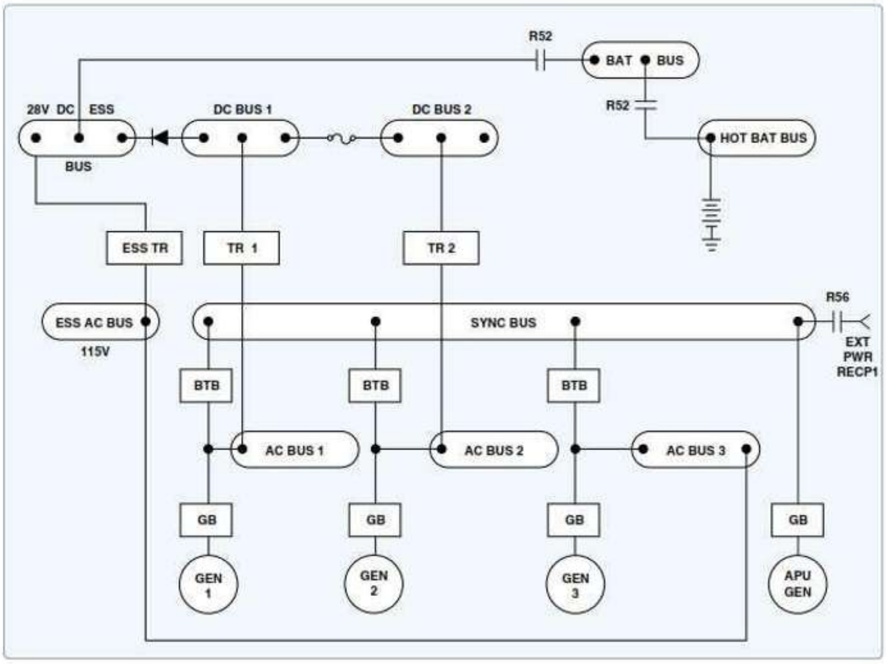


Figure 74

The AC busses are connected to the sync bus through three BTBs. In this manner, all three generators share the entire AC electrical loads. Keep in mind, all generators connected to the sync bus must be in phase. If a generator fails, the flight crew would simply isolate the defective generator and the flight would continue without interruption. The number one and two DC busses (Figure 9-105 top left) are used to feed the DC electrical loads of the aircraft. DC bus 1 receives power form AC bus 1 though TR1. DC bus 2 is fed in a similar manner from AC bus 2. The DC busses also connect to the battery bus and eventually to the battery. The essential DC bus (top left) can be fed from DC bus 1 or the essential TR. A diode prevents the essential DC bus from powering DC bus 1. The essential DC bus receives power from the essential TR, which receives power from the essential AC bus. This provides an extra layer of redundancy since the essential AC bus can be isolated and fed from any main generator. Figure 74 shows generator 3 powering the essential AC bus.

3. SPLIT-PARALLELSYSTEMS

A split-parallel bus basically employs the best of both split- bus and the parallel-bus systems. The split-parallel system is found on the Boeing 747-400 and contains four generators driven by the main engines and two APU-driven generators. The system can operate with all generators in parallel, or the generators can be operated independently as in a split-bus system. During a normal flight, all four engine-driven generators are operated in parallel. The system is operated in split-bus mode only under certain failure conditions or when using external power. The Boeing 747-400 split parallel system is computer controlled using four GCU and two BPCU. There is one GCU controlling each generator; BPCU 1 controls the left side bus power distribution, and BPCU 2 controls the right side bus power. The GCUs and BPCUs operate similarly to those previously discussed under the split- bus system. Figure 75 shows a simplified split parallel power distribution system.

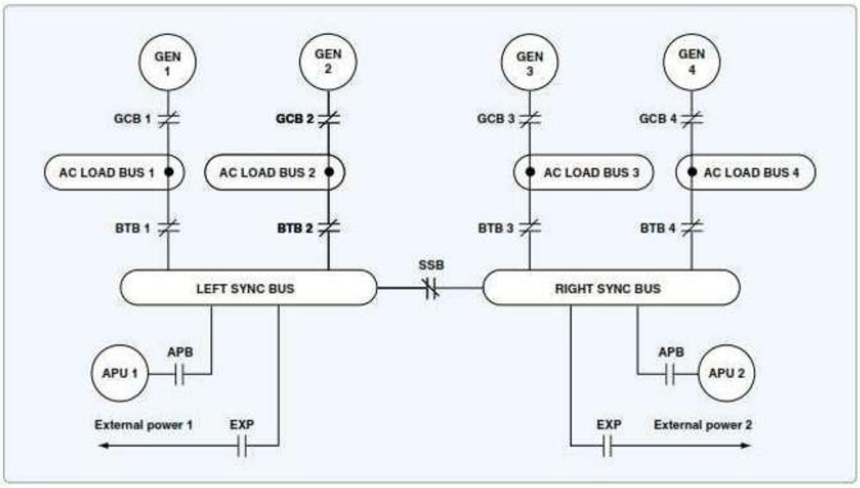


Figure 75

The main generators (top of Figure 75) are driven by the main turbine engines. Each generator is connected to its load bus through a generator control breaker (GCB). The generator control unit closes the GCB when the pilot calls for generator power and all systems are operating normally. Each load bus is connected to various electrical systems and additional sub- busses. The BTB are controlled by the BPCU and connect each load bus to the left and right sync bus. A split systems breaker (SSB) is used to connect the left and right sync busses and is closed during a normal flight. With the SSB, GCBs, and BTBs, in the closed position the generators operate in parallel. When operating in parallel, all generators must be in phase. If the aircraft electrical system experiences a malfunction, the control units make the appropriate adjustments to ensure all necessary loads receive electrical power.

For example, if generator 1 fails, GCU 1 detects the fault and command GCB 1 to open. With GCB 1 open, load bus 1 now

feeds from the sync bus and the three operating generators. In another example, if load bus 4 should short to ground, BPCU 4 opens the GCB 4 and BTB 4. This isolates the shorted bus (load bus 4). All loads on the shorted bus are no longer powered, and generator 4 is no longer available. However, with three remaining generators operational, the flight continues safely. As do all large aircraft, the Boeing 747-400 contains a DC power distribution system. The DC system is used for battery and emergency operations. The DC system is similar to those previously discussed, powered by TR units. The TRs are connected to the AC busses and convert AC into 26-volt DC. The DC power systems are the final backups in the event of a catastrophic electrical failure. The systems most critical to fly the aircraft can typically receive power from the battery. This aircraft also contains two static inverters to provide emergency AC power when needed.

AC DISTRIBUTION

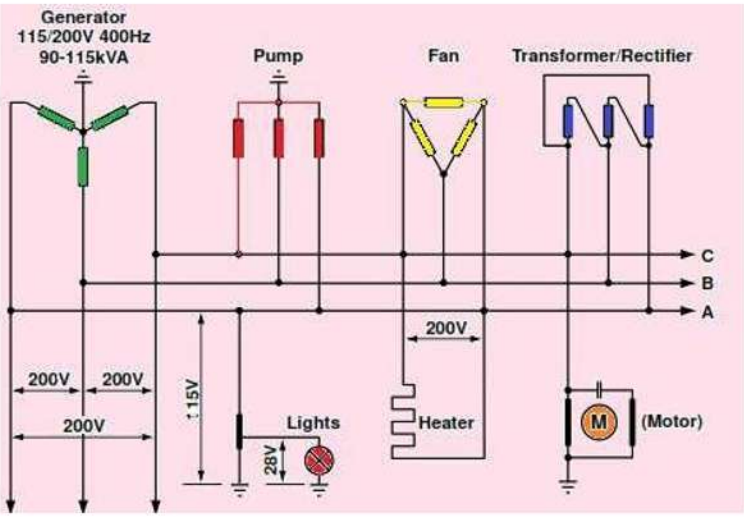


Figure 76

The three phase current network of commercial aircrafts is feeding symmetrical loads (3 phase heaters and motors) and assymetrical loads (single phase 115V) and 200V consumer). Due of assymetrical load, a neutral current flowing through the aircraft structure. That means the metallic structure of the aircraft is conducting high currents. Therefore low resistance connections to the structure must be granted. (Electrical Bonding)

DC DISTRIBUTION

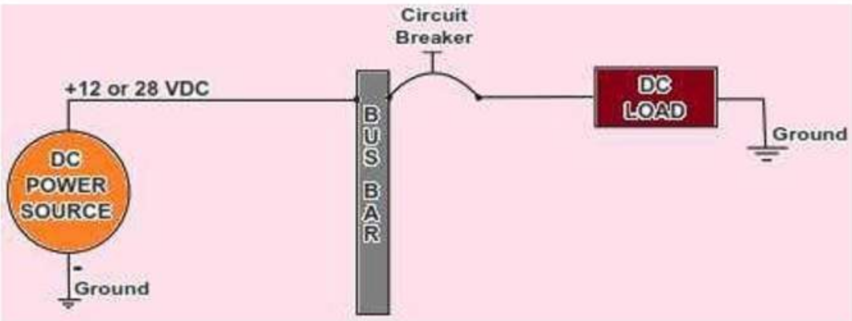


Figure 76

The positive pole of DC power sources like Tranformer/Rectifiers and aircraft batteries is routed via wiring to the DC-loads. The aircraft structure is used as the return conductor the negative pole of the power source.

GENERATOR INSTALLATION

Reference should always be made to the relevant Maintenance Manuals in which the specific installation instructions are given. The arrangements for the installation of generators depend primarily upon the type of engine and, in some cases, also upon theparticulartypeofaircraft.Beforeinstallinganygeneratora check should be made to ensure that its type, part number and direction of rotation are correct for the particular installation. These details are given on a name plate attached to the generator yoke or casing. The rotation is specified as the direction of armature rotation when viewed from the driving end. Housings and terminals should be checked for cleanliness and freedom from corrosion, distortion, cracks or other damage. The movement of armatures should also be checked for freedom by manually rotating the appropriate assembly at the driving end. On generators employing drive shafts, a light coating of grease or engine oil should be applied to the splines after first removing any protective compound from the shaft. Reference should always be made to the relevant generator and aircraft Maintenance Manuals for details of the type of lubricant to beused.

In belt-driven generator installations, drive pulleys and belts should be checked for security and condition. After installation, belts should also be checked to ensure that they have the correct tension. Low tension will permit belt slippage, with a resulting rapid belt wear and low or erratic generator output, while excessive tension will cause rapid wear on the belt and on the generator bearing. The tension may be checked either by measuring the torque required to slip the belt at the generator pulley, or by measuring the amount of belt deflection caused by a predetermined load. Reference should always be made to the Maintenance Manuals for details of the measuring procedure and permissible limits. The appropriate generator mountings at engine drive units should be inspected for cleanliness and damage, paying particular attention to mounting studs and driveshafts.

If gaskets are employed between mounting faces these should be checked for serviceability and renewed as necessary. When locating generators of the splined drive type they should be turned slightly in each direction about the drive axis to facilitate proper

engagement of the splines. After a generator has been correctly orientated on its mounting it should be secured by the appropriate method (e.g. self-locking nuts and studs, bolts, or Mandrel ring), paying particular attention to any torque values specified for tightening. Installation and not be allowed to hang on their drive shafts or mounting studs. Generator cables should be checked to ensure that they are free from damage to terminations, fraying and chafing of insulation covering. The alignment of cable ends should also be checked to ensure that cables are not subjected to strain particularly at points of entry to terminal boxes. The identification of terminations should be checked and connections made in accordance with relevant generator and aircraft installation wiring diagrams. Before connecting cooling ducts they should be inspected for cleanliness, signs of damage and for correct orientation. Gaskets, where applicable, should also be inspected for condition and renewed as necessary. Where cooling ducts or scoops are fitted to movable cowlings, the alignment of cooling duct to generator cooling air entry should be checked. After installation, a check should be made that all associated electrical circuits are in a safe condition for operation, and a generator function test carried out to the requirements specified in the relevant aircraft Maintenance Manual.

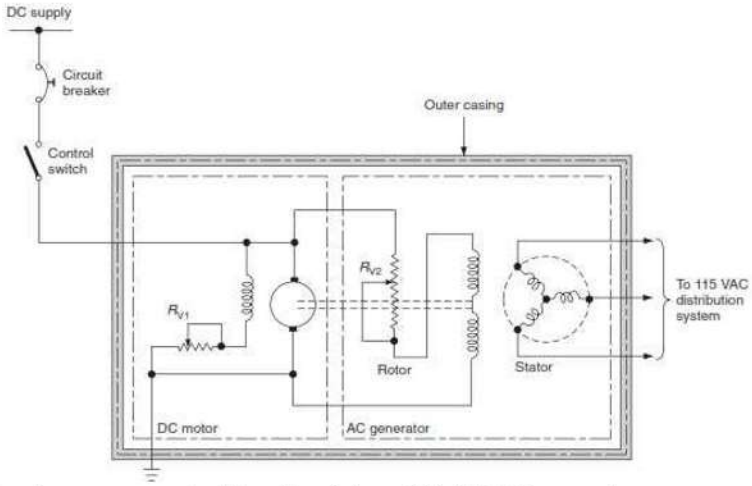
POWER CONVERSION

Equipment used on aircraft to provide secondary power supplies include:

1. Inverters
2. Transformer Rectifier Units(TRU)
3. Transformers.

1. INVERTERS

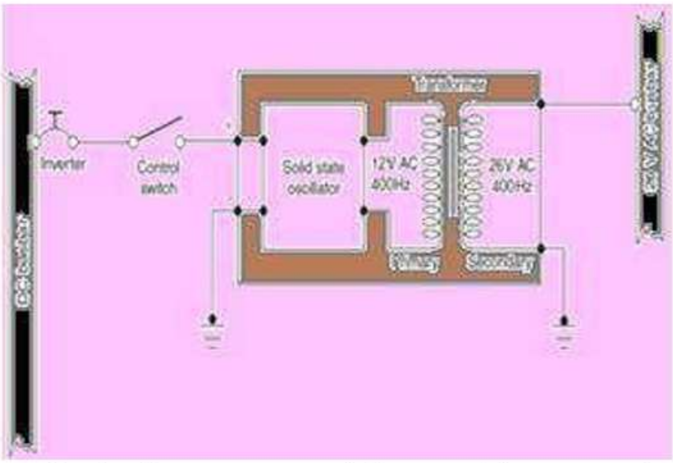
To 115 VAC distribution system Inverters are used to convert direct current into alternating current. The input is typically from the battery; the output can be a low voltage (26 V AC) for use in instruments, or high voltage (115 V AC single or three phase) for driving loads such as pumps. Older rotary inverter technology uses a DC motor to drive an AC generator, see Fig.- . A typical rotary inverter has a four-pole compound DC motor driving a star- wound AC generator. The desired output frequency of a rotary inverter is determined by the DC input voltage. The outputs can be single- or three phase; 26 V AC, or 115 V AC. The desired output frequency of 400 Hz is determined by the DC input voltage. Various regulation methods are employed, e.g. a trimming resistor (R) connected in series with the DC motor



field sets the correct speed when connected to the 14 or 28 V DC supply.

Figure 77 : Rotary Inverter Schematic

Modern aircraft equipment is based on the static inverter; it is solid state, i.e. it has no moving parts (see Fig-78). The DC power supply is connected to an oscillator; this produces a low-voltage 400Hz output. This output is stepped up to the desired AC output voltage via a transformer. The static inverter can either be used as the sole source of AC power or to supply specific equipment in the event that the main



generator has failed. Alternatively they are used to provide power for passenger use, e.g. lap-top computers. The DC input voltage is applied to an oscillator that produces a sinusoidal output voltage. This output is connected to a transformer that provides the required output voltage. Frequency and voltage controls are usually integrated within the static inverter; it therefore has no external means ofadjustment.

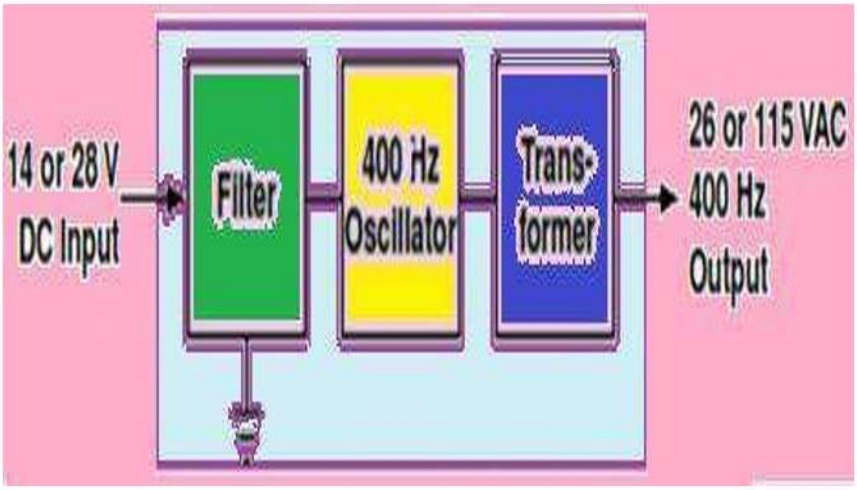


Figure 78 : Static Inverter

A typical inverter used on a large commercial aircraft can produce 1 kVA. Static inverters are located in an electrical equipment bay; a remote on/off switch in the flight compartment is used to isolate the inverter if required. Figure-79 shows an inverter installation in a general aviation aircraft.

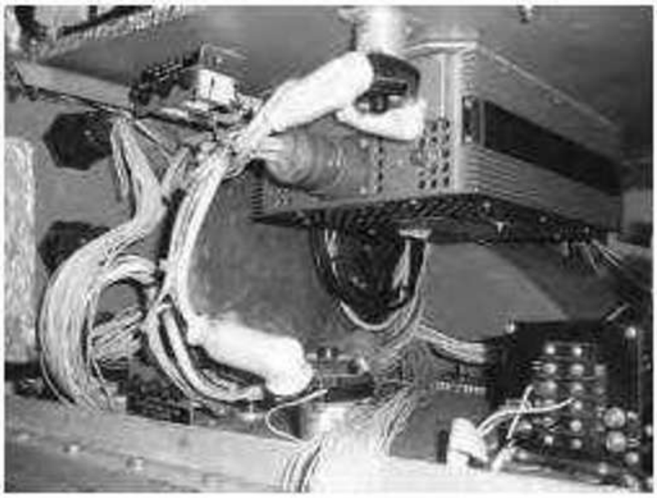


Figure 79 : Static Inverter Installation

2. TRANSFORMER RECTIFIER UNITS

Transformer Rectifier Units (TRU) converts AC into AC; these are often used to charge batteries from AC generators. A schematic diagram for a TRU is shown in Fig. 80. The three-phase 115/200V 400Hz input is connected to star-wound primary windings of a transformer. The dual secondary windings are wound in star and delta configuration. Outputs from each of the secondary windings are rectified and connected to the main output terminals. A series (shunt) resistor is used to derive the current output of the TRU. Overheat warnings are provided by locating thermal switches at key points within theTRU.

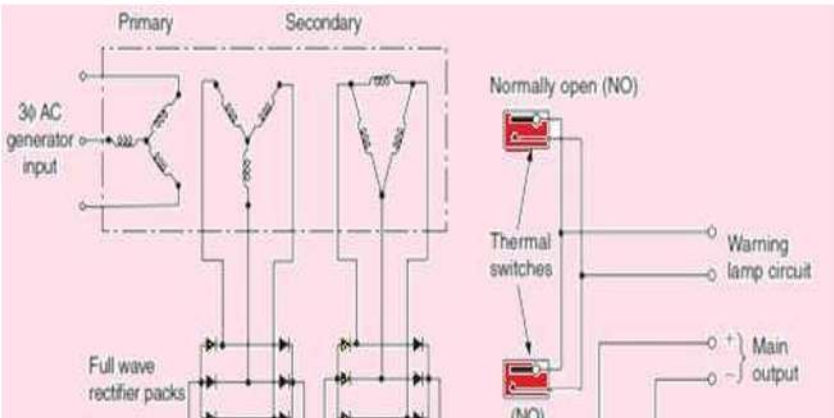


Figure 80 : Transformer Rectifier Unit (TRU) schematic

3. TRANSFORMERS PRINCIPLE

The principle of the transformer is illustrated in Figure -81. The primary and secondary windings are wound on a common low-reluctance magnetic core consisting of a number of steel laminations. All of the alternating flux generated by the primary winding is therefore coupled into the secondary winding (very little flux escapes due to leakage). A sinusoidal current flowing in the primary winding produces a sinusoidal flux within the transformer core.

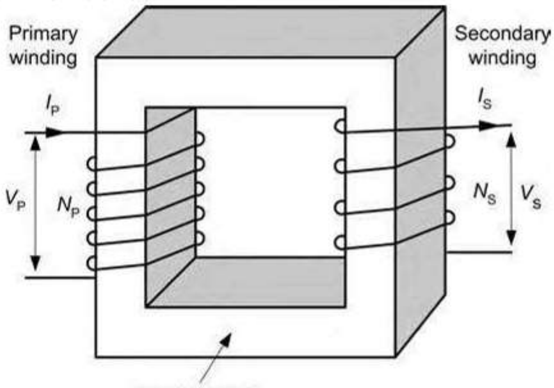


Figure 81 : The Principle of the Transformer

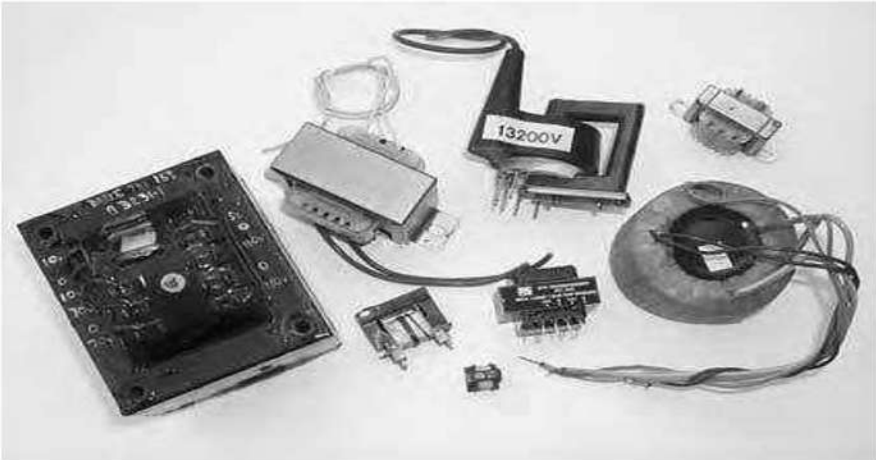
At any instant the flux , Φ, in the transformer core is given by the equation:
$\Phi = \Phi$ max. sin (ω t) Where,
Φ max is the maximum value of flux (in Wb)
t is the time in seconds
The r.m.s. value of the primary voltage (Vp) is given by:

Vp = 4.44 fNpΦ max

Similarly, the r.m.s. value of the secondary voltage (VS) is given by:

Vs = 4.44 fNsΦ max

From these two relationships (and since the same magnetic flux appears in both the primary and secondary windings) we can infer that Figure 82.



$V_p/V_s = N_p/N_s$

Figure 82 : Transformer Turns and Voltages

If the transformer is loss-free the primary and secondary powers will be equal.

Thus:
$P_p = P_s$
$P_p = I_p \times V_p$ and $P_s = I_s \times V_s$

So,
$I_p \times V_p = I_s \times V_s$ From which
$I_p / I_s = V_s / V_p$ thus $I_p / I_s = N_s / N_p$

Furthermore, assuming that no power is lost in the transformer (i.e. as long as the primary and secondary powers are the same) we can concludethat:

$I_p / I_s = N_s / N_p$

The ratio of primary turns to secondary turns (Ns/Np) is known as the turns ratio.

Furthermore, since ratio of primary voltage to primary turns is the same as the ratio of secondary turns to secondary voltage, we can conclude that, for a particular transformer:

Turns – per - volt (t.p.v.) = $V_p / N_p = V_s / N_s$

The t.p.v. rating can be quite useful when it comes to designing transformers with multiple secondary windings.

TRANSFORMER APPLICATIONS

Transformers provide us with a means of coupling AC power from one circuit to another without a direct connection between the two.

Table-1
Table 1 Above, summarizes the properties of some common types of transformer (note how the choice of core material is largely responsible for determining the characteristics of the transformer). A further advantage of transformers is that voltage may be stepped-up (secondary voltage greater than primary voltage) or stepped-down (secondary voltage less than primary voltage). Since no increase in power is

possible (like resistors, capacitors and inductors, transformers are passive components) an increase in secondary voltage can only be achieved at the expense of a corresponding reduction in secondary current, and vice versa (in fact, the secondary power will be very slightly less than the primary power due to losses within the transformer).

Typical applications for transformers include stepping-up or stepping-down voltages in power supplies, coupling signals in audio frequency amplifiers to achieve impedance matching and to isolate the DC potentials that may be present in certain types of circuit. The electrical characteristics of a transformer are determined by a number of factors including the core material and physical dimensions of the component. The specifications for a transformer usually include the rated primary and secondary voltages and currents the required power rating (i.e. the rated power, usually expressed in VA), which can be continuously delivered by the transformer under a given set of conditions, the frequency range for the component (usually stated as upper and lower working frequency limits) and the per-unit regulation of a transformer. As we shall see, this last specification is a measure of the ability of a transformer to maintain its rated output voltage under load.

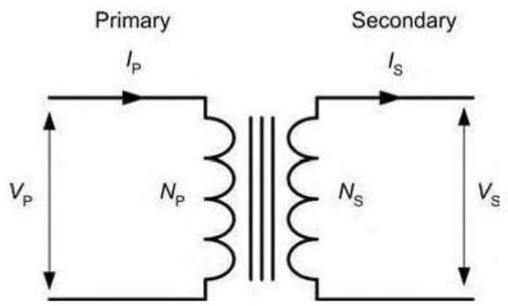


Figure 82 TRANSFORMER REGULATION

The output voltage produced at the secondary of a real transformer falls progressively, as the load imposed on the transformer increases (i.e. as the secondary current increases from its no-load value). The voltage regulation of a transformer is a measure of its ability to keep the secondary output voltage constant over the full range of output load currents (i.e. from no- load to full load) at the same power factor. This change, when divided by the no-load output voltage, is referred to as the per-unit regulation for the transformer. This can be best illustrated by the use of anexample.

TRANSFORMER EFFICIENCY AND LOSSES

As we saw earlier, most transformers operate with very high values of efficiency. Despite this, in high power applications the losses in a transformer cannot be completely neglected. Transformer losses can be divided into two types of loss:

- Losses in the magnetic core (often referred to as ironloss).
- Losses due to the resistance of the coil windings (often referred to as copperloss).

Iron loss can be further divided into hysteresis loss (energy lost in repeatedly cycling the magnet flux in the core backwards and forwards) and eddy current loss (energy lost due to current circulating in the steel core). Hysteresis loss can be reduced by using material for the magnetic core that is easily magnetized and has a very high permeability (see Figure 5.174.Note that energy loss is proportional to the area inside the B–H curve).

transformer. On the other hand, copper loss is zero when a transformer is under no-load conditions and rises to a maximum at full-load. The efficiency of a transformer is given by:

Efficiency = Output Power ÷ Input Power x 100 % From which

Efficiency = Input Power – Losses ÷ Input Power x 100 % Efficiency = 1 – (Losses ÷ Input Power) x 100 %
As we have said, the losses present are attributable to iron and copper loss but the copper loss appears in both the primary and the secondarywindings.

Hence:

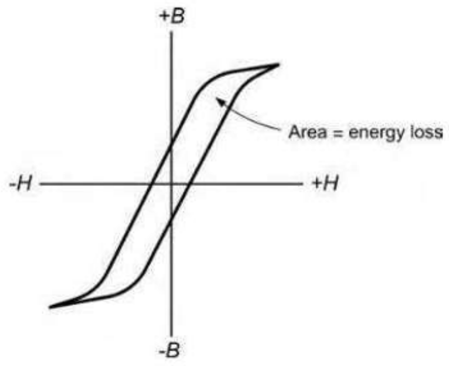


Figure 83 : Hysteresis Curves and Energy Loss

Input Power

Eddy current loss can be reduced by laminating the core (e.g. using E- and I-laminations) and also ensuring that a small gap is present. These laminations and gaps in the core help to ensure that there is no closed path for current to flow. Copper loss results from the resistance of the coil windings and it can be reduced by using wire of large diameter and low resistivity. It is important to note that, since the flux within a transformer varies only slightly between the no-load and full-load conditions, iron loss is substantially constant regardless of the load actually imposed ona

RECTIFIER

Rectifier is a device which convert AC into DC by using Crystal Diodes. There are different types of Rectifier and named as per the output we are getting or construction of diode, For Example halfwaverectifierwhichgivesoutputforonehalf(either+veor –ve cycle depending upon the connection of diode) of the Input AC cycle, full wave centre tapped and full wave Bridge rectifier gives output for both +ve and –ve half of Input Cycle. [Figure 84 to 86]

DIODES

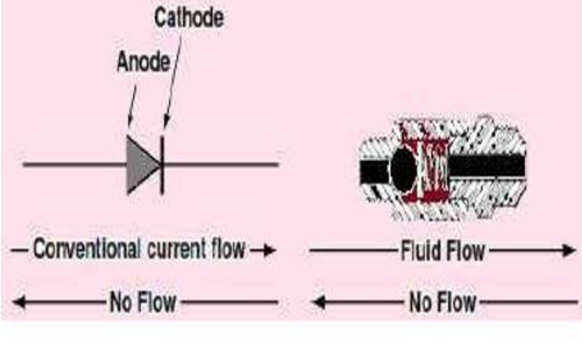


Figure 84 : Diode and a Check-Valve

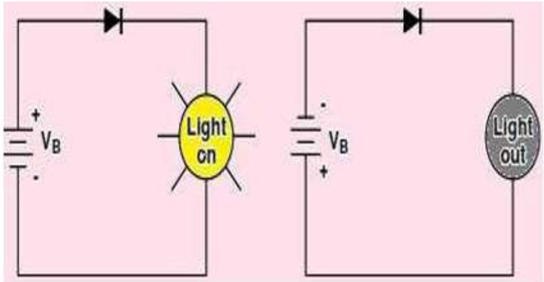


Figure 85 : Conducting and Blocking Diode in an Electric Circuit

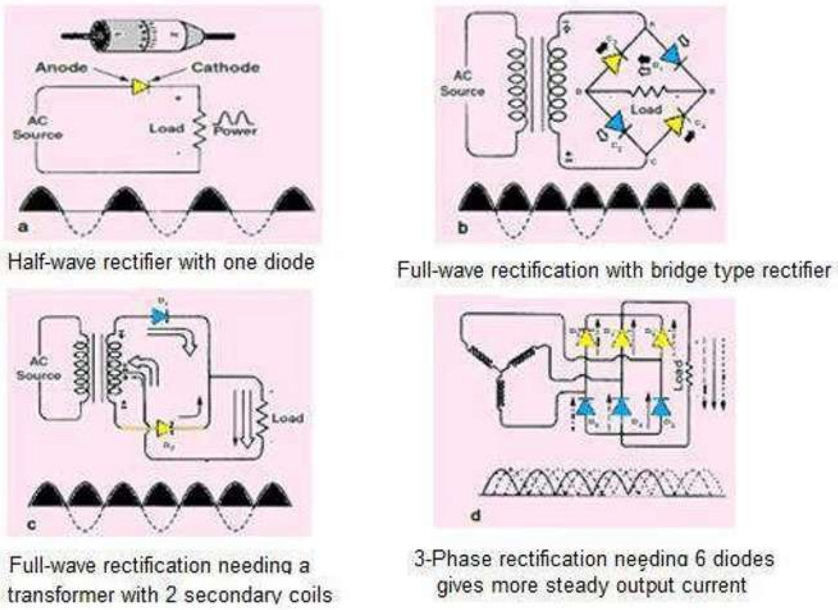


Figure 86 : Various Rectifier Circuits

TRANSFORMER – RECTIFIERS

The primary electrical power source of larger aircrafts are AC Generators producing 115/200 Volts 400 Hertz. Many systems in the airplane uses 28 Volt DC.

To convert the high voltage alternating current into lower voltage, transformers are used. Rectifiers change the alternating current AC into direct current DC. Both devices are built in the sameunit.

AUXILIARY POWER UNIT (APU)

An APU is a relatively small gas turbine engine, typically located in the tail cone of the aircraft. The APU is a two-stage centrifugal compressor with a single turbine. Bleed air is tapped from the compressor and connected into the aircraft's air distribution system. Once started the APU runs at constant speed, i.e. there is no throttle control. The APU shuts down automatically in the event of malfunction. APUs are used for starting the aircraft's main engines via the air distribution system the APU can also provide: [Figure-87]

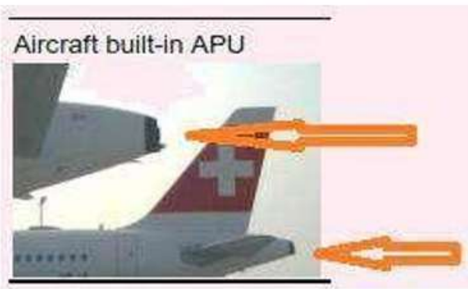
- Provide electrical energy (115V, 400 Hz) for aircraft systems during groundtime;
- Provide air to the environmental control system (air-conditioning) during groundtime;
- Provide air (bleed air) for main enginestart;

- Serve as electric and hydraulic back-up system inflight;

Figure 87 : Auxiliary Power Units for Commercial Aircraft

The APU itself is started from the main aircraft battery. In some aircraft, the APU can also provide electrical power in the air in the event of main generator failure. The Boeing 787 aircraft has more electrical systems and less pneumatic systems than aircraft it is replacing. In this case the APU delivers only electrical power.

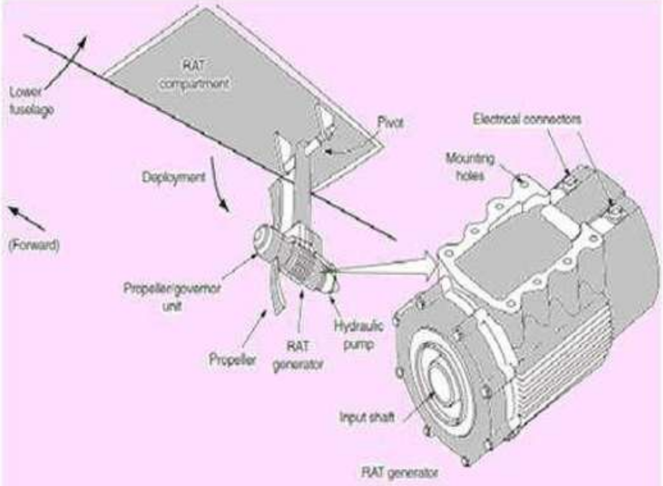
APUs fitted to extended-range twin-engine operations aircraft (ETOPS) are critical to the continued safe flight of the aircraft since they supply electrical power, hydraulic pressure and an air supply in the event of a failed main engine generator or engine. Some APUs on larger four-engined aircraft are not certified



for use while the aircraft is in flight.

Figure 88 EMERGENCY POWER GENERATION RAM AIR TURBINE

In the event of generator failure, continuous power can be provided by a ram air turbine (RAT). Also referred to as an air- driven generator, this is an emergency source of power that can be called upon



when normal power sources are not available. The RAT is an air-driven device that is stowed in the wing or fuselage and deployed in the event that the aircraft loses normal power. When deployed, it derives energy from the airflow, seefigure RATs typically comprises a two-bladed fan, or propeller that drives the generator shaft via a governor unit and gearbox; the gear ratios increase the generator shaftspeed.

Figure 89 : Ram Air Turbine.

The RAT can be deployed between aircraft speeds of 120 to 430 knots; some RATs feature variable pitch blades operated by a hydraulic motor to maintain the device at typical speeds of 4,800 r.p.m. Typical RAT generators produces an AC output of 7.5 VA to a TRU. Heaters are installed in the RAT generator to prevent ice formation. RATs can weigh up to 400 lbs on very large transport aircraft, with blade diameters of between 40 and 60 inches depending on powerrequirements.

AIR DRIVEN GENERATOR

In case of need, the pilot extends the ADG into the airstream. The turbine begins to rotate and drives on its shaft directly the generator. To keep the speed of the generator constant, there is a build in governor in the propeller, adjusting its blade angle.

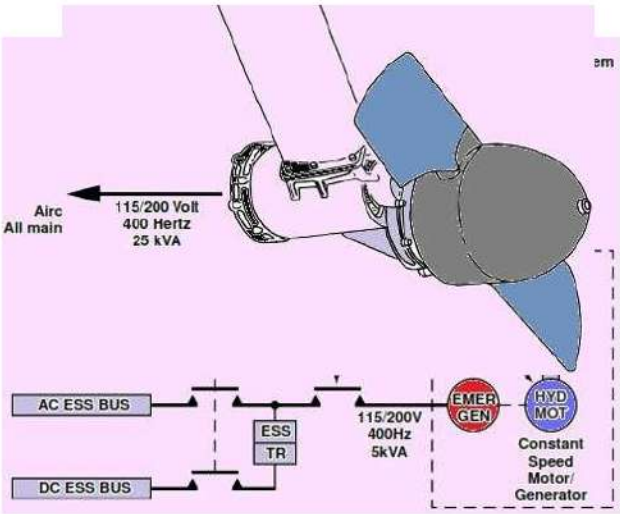


Figure 90 : Air Driven Generator EXTERNAL POWER

Many aircraft employ an external power circuit that provides a means of connecting electrical power from a ground source to the aircraft. External power is often used for starting the engine or maintenance activities on the aircraft.

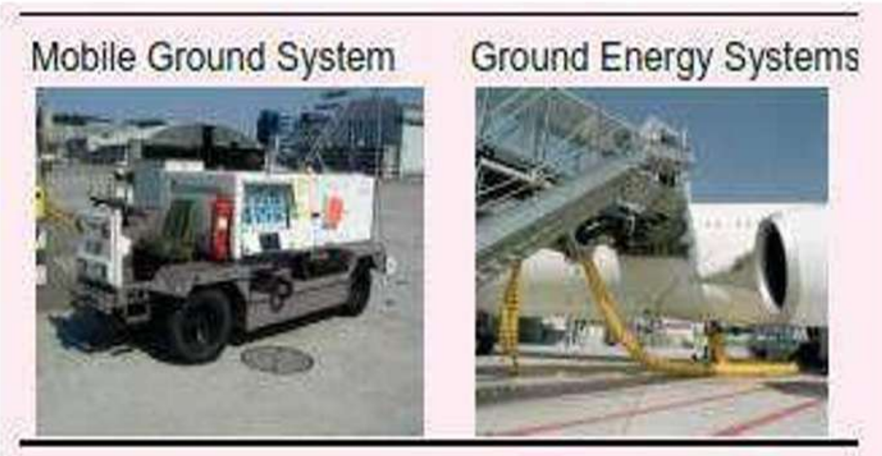


Figure 91

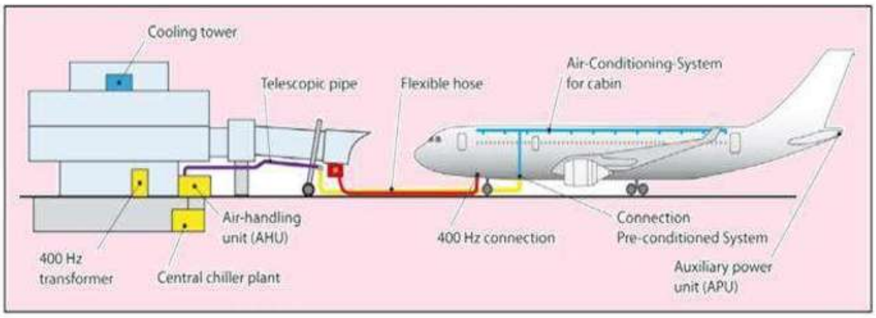


Figure 92 : Basic Layout of Aircraft Ground Energy Systems

The electricity is generated with rotary- or static inverters on ground installations or mobile generator systems driven by a combustion engine. Small aircraft uses a cart carrying batteries or a transformer-rectifier. Power switching from and to aircraft power source to external source or APU source produces short power transients of 100 ms. No Break Power Transfer is function avoids busbar power interruption during supply source transfer on ground in normal configuration.

The system controls simultaneous connection of the two sources for a Short Time External Power with APU, External Power with engine driven generator, APU generator with engine driven generator. To achieve this, both sources are synchronized on a frequency reference signal. Synchronization may take up to 15 seconds for APU GEN with GPU, and some milliseconds in all other cases. For this paralleling, the frequency difference should be less than 0.5 Hz the Phase angle less than 15° If synchronization is not achieved within allowed time transfer is performed anyway (without simultaneous connection of two sources).

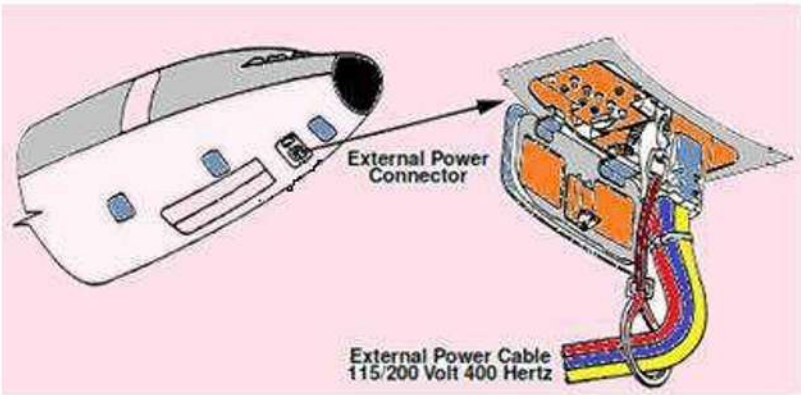


Figure 93 : External Power Receptacle

Figure 94 : Connector EXTERNAL POWER CIRCUIT

External power systems typically consists of an electrical plug located in a convenient area of the fuselage, an electrical solenoid used to connect external power to the bus, and the related wiring for the system. A common external power receptacle is shown in Figure 93. Figure 94, shows how the external power receptacle connects to the external power solenoid through a reverse polarity diode. This diode is used to prevent any accidental connection in the event the external power supply has the incorrect polarity (i.e., a reverse of the positive and negative electrical connections). A reverse polarity connection could be catastrophic to the aircraft's electrical system. If a ground power source with a reverse polarity is connected, the diode blocks current and the external power solenoid does not close. This diagram also shows that external power can be used to charge the aircraft battery or power the aircraft electrical loads. For external power to start the aircraft engine or power electrical loads, the battery master switch must be closed.

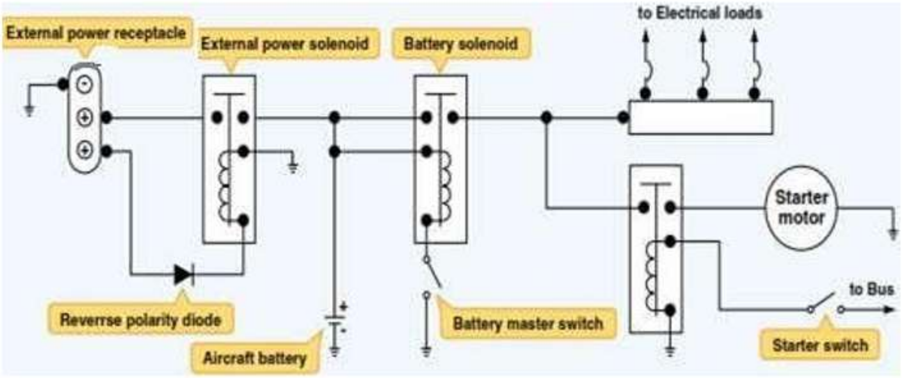


Figure 95

ELECTRICAL CIRCUIT CONTROL AND PROTECTING DEVICES

There are many systems on aircraft that need to be controlled and/or monitored, either manually by the crew, or automatically. A switch provides the simplest form of control and monitoring. For example, the crew needs to know if any doors are not closed as part of their pre-flight check; on larger aircraft the position of control surfaces is displayed in the cockpit. Using these two examples, doors can be either open or closed; control surfaces can move through an infinite number of positions (within their normal limits oftravel).

Many other aircraft parameters need to be measured, e.g. temperature and pressure. Here we shall discuss controls and Protective devices used on aircraft.

The simplest form of switch is the on/off device used to isolate circuits. Other switch types are used to direct the current into pre- determined parts of a circuit. Switches are characterized by Number of poles, Number of switched positions and Type of switched contacts (permanent or momentary). Hazardous errors in switch operation can be avoided by logical and consistent installation. Two-position on/off switches should be mounted so that the on position is reached by an upward or forward movement of the toggle. When the switch controls movable aircraft elements, such as landing gear or flaps, the toggle should move in the same direction as the desired motion. Inadvertent operation of a switch can be

prevented by mounting a suitable guard over the switch. Figure 96, A specifically designed switch should be used in all circuits where a switch malfunction would be hazardous.

Figure 96 : Switch Guard

Nominal system voltage (DC)	Type of load	Derating factor
28V	Lamp	8
28V	Inductive	4
28V	Resistive	2
28V	Motor	3
12V	Lamp	5
12V	Inductive	2
12V	Resistive	1
12V	Motor	2

Table 2 : Derating Table for Switches

Such switches are of rugged construction and have sufficient contact capacity to break, make, and carry continuously the connected load current. Snap action design is generally preferred to obtain rapid opening and closing of contacts regardless of the speed of the operating toggle or plunger, thereby minimizing contact arcing.

Switches are sometimes guarded or wire-locked with fuse wire to prevent inadvertent operation. Some switch designs have to be pulled out of a detent position before the position can be changed. They are designed to be operated in a number of ways, e.g. toggle, push/pull, rocker or rotary selectors etc. These switches are designed with multiple contacts; they can be arranged as permanent or momentary contacts. The nominal current rating of the conventional aircraft switch is usually stamped on the switch housing. This rating represents the continuous current rating with the contacts closed. Switches should be derated from their nominal current rating for the following types ofcircuits:

1. High rush-in circuits—contain incandescent lamps that can draw an initial current 15 times greater than the continuous current. Contact burning or welding may occur when the switch isclosed.

2. Inductive circuits—magnetic energy stored in solenoid coils or relays is released and appears as an arc when the control switch isopened.

3. Motors—DC motors draw several times their ratedcurrent during starting, and magnetic energy stored in their armature and field coils is released when the control switch isopened.

Table 2 is used for selecting the proper nominal switch rating when the continuous load current is known. This election is essentially a derating to obtain reasonable switch efficiency and servicelife.

TOGGLE SWITCH

This is a very basic device; Figure 97 illustrates its internal schematic and external features. Operating the lever/arm opens and closes switch contacts. Operating levers on toggle switches are some- times ganged so that more than one circuit is operated. The simplest switch has two contact surfaces that provide a link between circuits; these links are referred to as poles. Switch contacts can be normally open or closed and this isnormally marked on the switch (NO/NC). The number of circuits that can be linked by a single switch operation is called the throw. The simplest form of switch would be single pole, single throw (SPST). Schematics of switch configurations commonly found in aircraft are illustrated in Figure98.

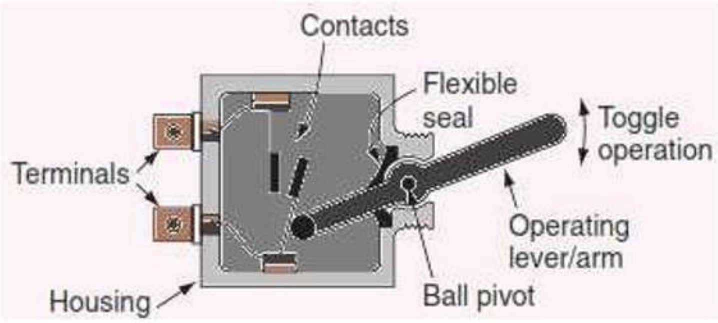


Figure 97 : (a) Internal Schematic Toggle Switch

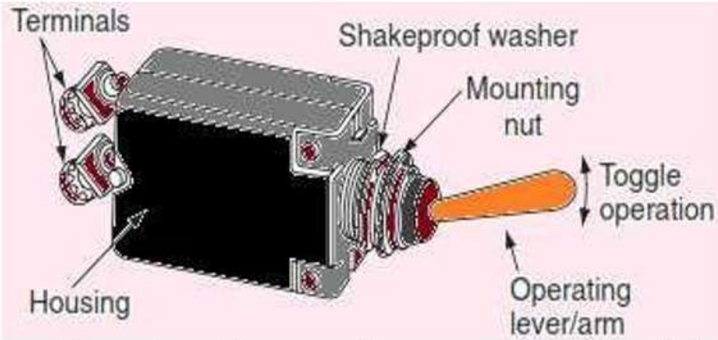


Figure 97 : (b) External Features Toggle Switch

Figure 97 : Aircraft Installed Toggle Switch

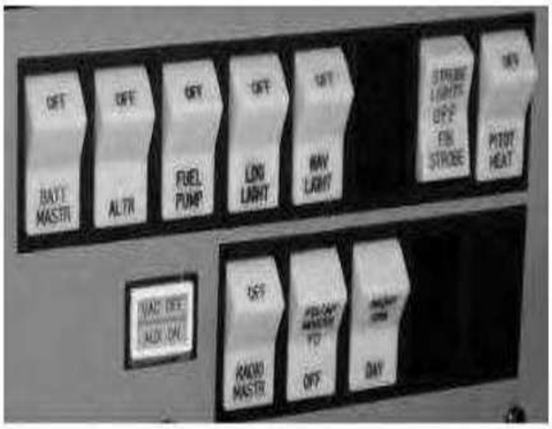


Figure 99 : Rocker Switches

Some switches are designed with instinctive tactile features so that the risk of selecting the wrong system is minimized, e.g. the flap up/down switch-operating lever would be shaped in the form of an aerofoil; the undercarriage selection switch-operating lever Would be shaped in the form of a wheel. Push/pull-operated switches incorporate a spring to hold the contacts open or closed; the switch contacts are therefore push-to-make orpush-to-break.

ROCKER WITCHES

Figure 99, combine the action of toggle and push/pull devices. Rotary switches are formed by discs mounted onto a shaft; the contacts are opened and closed by the control knob.

Modern aircraft panels utilize a combined switch and light display; the display is engraved with a legend or caption indicatingsystemstatus.Thesecanbeusedinavarietyofways
e.g. to show system on/off. The switch portion of the device can be momentary or continuous; small level signals are sent to a computer or high-impedance device. Internal backlighting is from two lights per legend for redundancy; these are projected via coloured filters. The two captions provide such information as press to test (P/TEST). Examples of combined switch/light devices are given in Figure 100below.

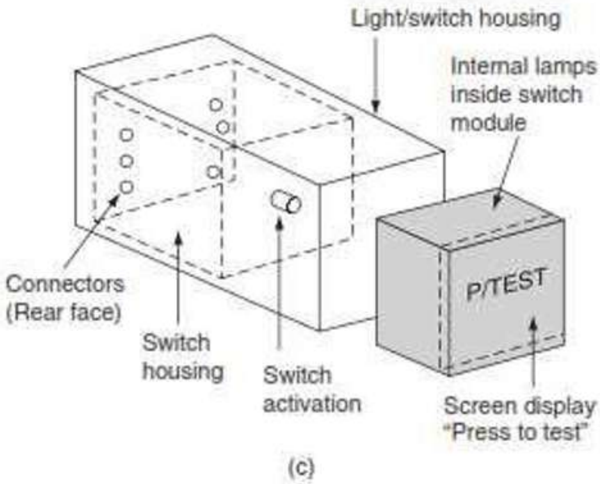


Figure 100 : (a) Typical Installation, (b) Electrical Schematic,
(c) External Features

These are used to sense if a device has moved or has reached its limit of travel, e.g. flap drive or undercarriage mechanisms. Figure 101, illustrates the internal schematic and electrical contacts of a typical micro-switch product. The contacts open and close with a very small movement of the plunger. The distance travelled by the armature between make/break is measured in thousandths of an inch, hence the name ‘micro’.

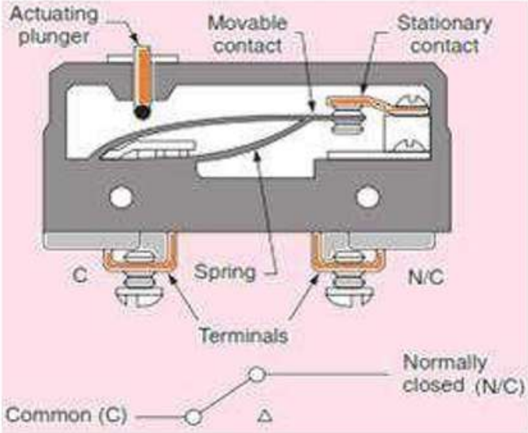


Figure 101 : Internal Schematic

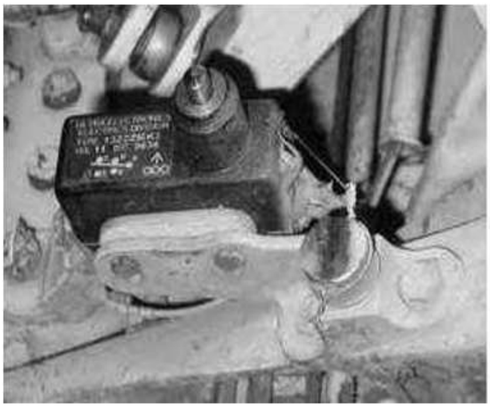


Figure 101 : External Features

Figure 101 : Typical Micro Switch

A snap action is achieved with a contact mechanism that has a pre-tensioned spring. Micro-switches are attached to the structure and the wiring is connected into a control circuit. An example of micro-switch application is to sense when the aircraft is on the ground; this is achieved by mounting a micro-switch on the oleo leg. When the aircraft is on the ground, the oleo leg compresses and the switch is operated. Micro-switches are used to sense the mechanical displacement of a variety of devices, including:

- ControlSurfaces
- Undercarriage
- PressureCapsules
- Bi-metallic TemperatureSensors
- MechanicalTimers

PROXIMITY SWITCHES

They perform the same function as micro-switches; they sense the presence of an object by the interruption of a magnetic circuit. There are two types of proximity switch: reed and solid state.

1. REED PROXIMITYSWITCH

This switch device comprises two hermetically sealed sections as illustrated in Figure 102, One section (the actuator) contains a magnet; the other section (the sensor) contains a reed armature with rhodium-plated contacts. The usual arrangement is for the sensor unit to be fixed to the aircraft structure; the actuator is attached to the item being monitored, e.g. a door. When the gap between the actuator and the sensor reaches a pre-determined distance, the reed contacts close thereby completing the circuit. They open again when the actuator and sensor are moved apart.

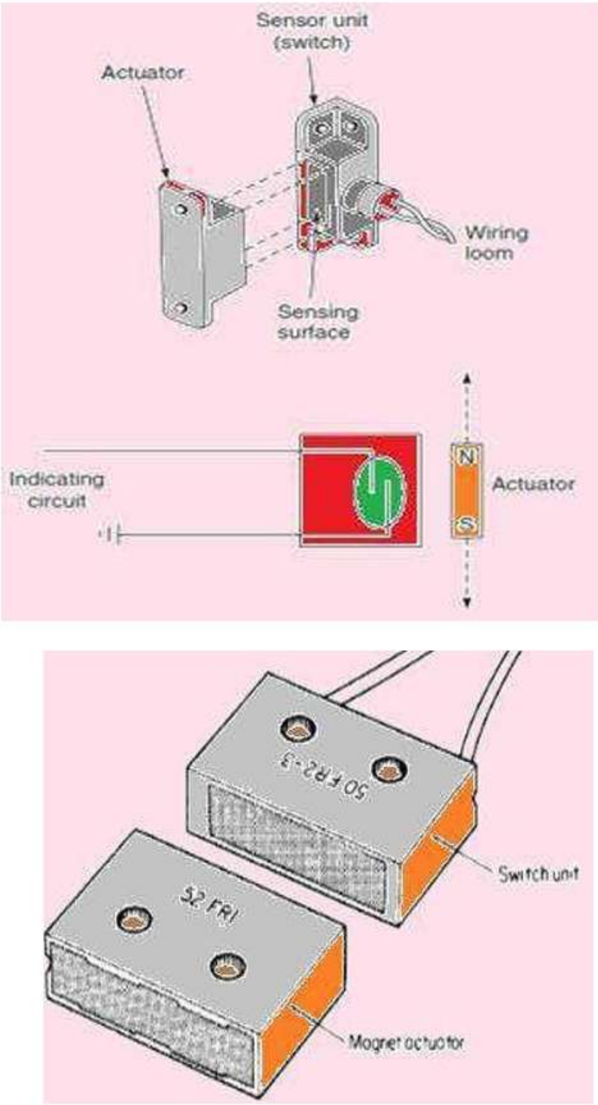


Figure 102 : Reed Proximity Switch Schematic

2. Solid State Proximity Switch [Figure 103]. This inductance loop is the input stage of an electronic switch unit incorporated as part of the actuator. As the target moves closer to the coil, the inductance of the coil changes. An electronic circuit determines when the inductance has reached a pre-determined level. The obvious advantage of this type of switch is that there are no switch contacts, hence higher reliability.

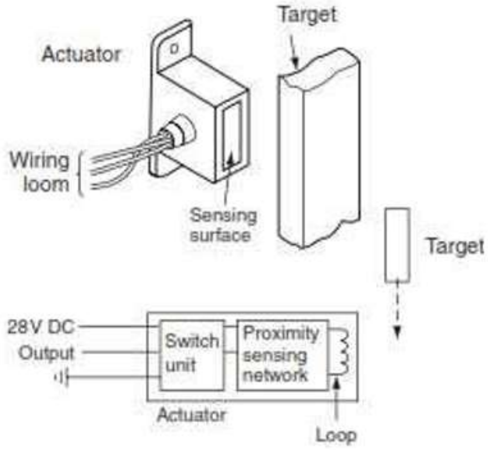


Figure 103 : Proximity Switch (Solid State) Schematic

3. Some aircraft are installed with a proximity switch electronic unit(PSEU).Thisunitreceivesthepositionofvariousitems,
e.g. flaps, gear, doors, etc and communicates this information to other systems including:

- Take-off and landing configurationwarnings
- Landing gear position indicating andwarning
- Air/ground relays
- Air stairs and doorwarnings.

The PSEU is integrated with the master caution system, and used to indicate if a problem exists that has to be corrected before flight.

Variable resistors are mounted on a linear slider or rotary shaft to provide a user-adjustable resistance; typical applications include the control of lighting, audio volume or generator regulator trimming. They are sometimes combined with micro-switches to

provide an on/off control function. Variable resistors are produced as either:

- Potentiometers
- Presetresistors
- Rheostats.

Figure 104, below, provides some examples of symbols used for variable resistors. When the intention is for the pilot or maintenance engineer to adjust the circuit resistance for control purposes, e.g. audio volume or lighting intensity, the variable resistor device is used. If the circuit resistance is only intended to be adjusted in the workshop, a preset device is used.

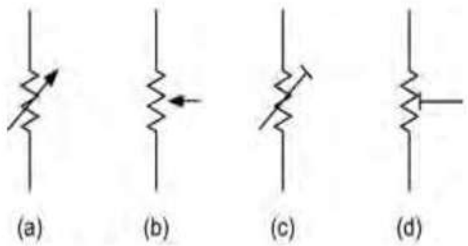


Figure 104 : Variable Resistors : Potentiometers, Preset or Rheostats

POTENTIOMETER

A potentiometer (often called a 'pot' for short) is a type of variable resistor that is normally used as a voltage divider; this is a circuit used to supply a portion of the power supply voltage from a resistive contact. The potentiometer is typically a three- terminal resistor with a sliding centre contact (the wiper). If all three terminals are used, it can be used in the voltage divider application. If only two terminals are used (one end of the resistor and the wiper), it acts as a variable resistor.

RHEOSTATS

A Rheostats are the controlling devices containing a resistance the magnitude of which can be varied, thereby adjusting the current in The circuit in which it is connected. A typical example of this method of control is one adopted for varying the intensity of instrument panel and certain cockpit lighting. Rheostats normally adjust circuit resistance without opening the circuit, although in some cases, they are constructed to serve as a combined on/off switch and variable resistor.

NOTE

A rheostat performs the same function as the potentiometer, but is physically much larger, being designed to handle much higher voltage and/or current. Rheostats are constructed with a resistive wire formed as a toroidal coil, with the centre contact/wiper moving over the surface of the windings.

Relays are used to control the flow of large currents using a small current. A low-power DC circuit is used to activate the relay and control the flow of large AC currents. These are electromechanical devices interrupt or complete a circuit when activated from a remote source, see Figure 105, Changeover relays consist of a coil, moving contact (armature) and external connections. When the coil has current flowing through it the electromagnetic effect pulls in the contact armature. The Armature is pivoted and is held in position by the spring force; with no current flowing, the armature returns to its original position by the spring force. They are used to switch motors and other electrical equipment on and off and to protect them from overheating. A solenoid is a special type of relay that has a moving core. The electromagnetcoreinarelayisfixed.Solenoidsaremostlyused

as mechanical actuators but can also be used for switching large currents. Relays are only used to switch currents.

CONTACTORS

They are operate in the same way as that of relay; the difference between them is their physical construction and application. Relays are generally used for low current applications; contactors (also known as breakers) are used for switching higher currents,
e.g. for connecting battery power to the aircraft. The features of a contactor include the main power contacts and auxiliary contacts used for indication and control of other devices, e.g. lights and relays in power distribution.

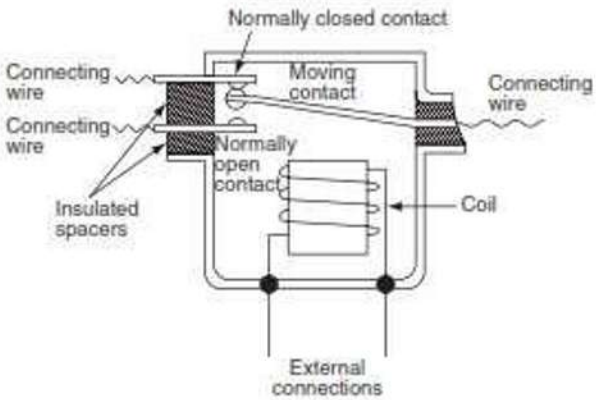


Figure 105 : Changeover Relay Schematic & Typical Relay REED RELAYS
These are used in control circuit applications; they are generally found within components, e.g. mounted onto printed circuit boards.

SLUGGED RELAYS

These have delayed operating times and are needed in specialized applications. The delay in opening/closing the contacts is achieved by a second coil wound around the main coil; the turns are arranged such that the build up of magnetic flux in the main coil is opposed by the build up of magnetic flux in the secondary coil.

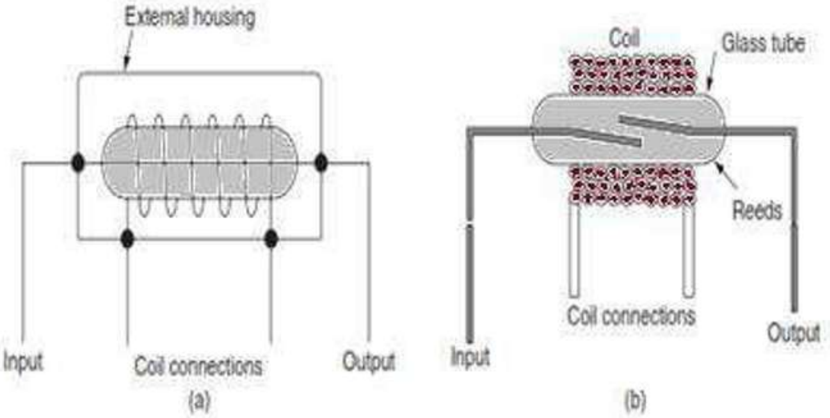
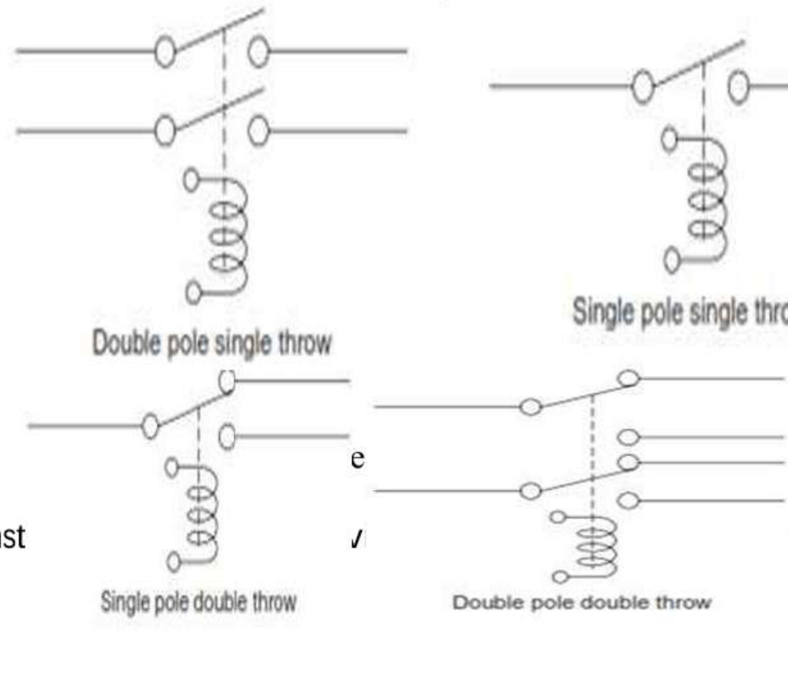


Figure 106 : Reed Relay Schematic (a) External Schematic, (b) Internal Schematic

The simplest relay has two contact surfaces that provide a link between circuits; these links are referred to as poles. Relay contacts can be normally open or closed (NO/NC) and this is normally marked on the body of the relay. The number of circuits that can be linked by a single relay operation is called the throw. The simplest form of relay would be single pole, single throw (SPST). Relay configurations commonly found in aircraft are illustrated in Figure 107.



e

Typical relay inst / ure 108,

Figure 108 : Relay Installation (GA Aircraft)

These are used in control circuits with very low voltages or currents; the relay is extremely sensitive and can respond to levels in the order of mA/mV. This low level is often not suitable for the conventional spring loaded armature device since (at very low pull-in/ drop-out voltages) the contacts would chatter leading to spark erosion. Polarized relays use magnetic forces to attract and repel the armature instead of a spring force. The armature is a permanent magnet, pivoted between two pole faces formed by the frame of high permeability material. When current flows, the poles change and the frame becomes an electromagnet; this exceeds the force exerted by the permanent magnet and the armature changes position. In this position the N-S poles form a strong attractive force and the armature is retained in position. If the supply is interrupted the electromagnetic force is reduced to less than the permanent magnet and the armature returns to its originalposition.

The solenoid is a type of transducer that converts electrical energy into linear displacement. Solenoids are used as switching devices where a weight reduction can be achieved or electrical controls can be simplified. Typical applications include the actuation of pneumatic or hydraulic valves. They are also a electromechanical devices, consisting of an inductive coil wound around a steel or iron armature. The coil is formed such that the armature can be moved in and out of the solenoid's body. The armature is used to provide the mechanical force required to the item being moved Figure109.

Figure 109 : Solenoid

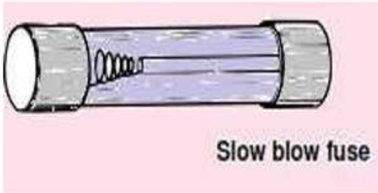
Conductors should be protected with circuit breakers or fuses located as close as possible to the electrical power source bus. Normally, the manufacturer of the electrical equipment specifies the fuse or circuit breaker to be used when installing equipment. The circuit breaker or fuse should open the circuit before the conductor emits smoke. To accomplish this, the time current characteristic of the protection device must fall below that of the associated conductor. Circuit protector characteristics should be matched to obtain the maximum utilization of the connected equipment. Table-3, shows a chart used in selecting the circuit breaker and fuse protection for copper conductors. This limited chart is applicable to a specific set of ambient temperatures and wire bundle sizes and is presented as typical only. It is

important to consult such guides before selecting a conductor for a specific purpose. For example, a wire run individually in the open air may be protected by the circuit breaker of the next higher rating to that shown on thechart.
and the spring will pull the link in two, opening the circuit. The regular fuse has a simple narrow strip of low-melting-point material that will melt as soon as an excess of current flows through it.

FUSES

Wire AN gauge copper	Circuit breaker amperage	Fuse amperage
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	30	20
10	40	30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

Table 3 : Wired & Circuit Protection Chart



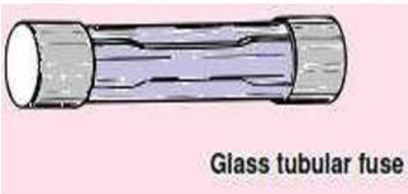
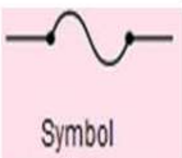


Figure 110 : The Fuse

A fuse is placed in series with th ust flow through it. Figure-16, the fuse consists of a strip of metal that is enclosed in a glass or plastic housing. The metal strip has a low melting point and is usually made of lead, tin, or copper. When the current exceeds the capacity of the fuse the metal strip heats up and breaks. As a result of this, the flow of current in the circuit stops. There are two types of fuses used in aircraft circuits- the regular glass tubular fuse and the slow-blow fuse This is important for electric devices that can quickly be destroyed when too much current flows through them for even a very small amount of time The slow-blow fuse has a larger fusible element that is held under tension by a small coil spring inside the glass tube. This fuse will pass a momentary surge of high current such as you have when the switch in a lighting circuit is closed, but it will soften under a sustained current flow in excess of itsrating,



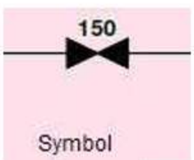


Figure 111

According to the flight regulations aircraft that are equipped with fuses are required to carry at least 50% of any one type of fuse installed on the aircraft. If one fuse of a particular type is installed, one spare of the same rating must be carried on the aircraft at all times. Fuses which are accessible by maintenance personnel only are found on some aircraft. These fuses, commonly called current Limiter, are often used to isolate a complete distribution bus in the event of a short to that bus. The pilot would simply continue the flight without use of the isolated bus and the have problem corrected upon landing.

CIRCUIT BREAKERS

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by an overload or short circuit. Its basic function is to detect a fault condition and immediately discontinue electrical flow. Unlike a fuse that operates once and then has to be replaced, acircuit breaker can be reset to resume normal operation. All resettable circuit breakers should open the circuit in which they are installed regardless of the position of the operating control when an overload or circuit fault exists. Such circuit breakers are referred to as trip-free. Automatic reset circuit breakers automatically reset themselves. They should not be used as circuit protection devices in aircraft. a circuit breaker trips, the electrical circuit should be checked and the fault removed before the circuit breaker is reset. Sometimes circuit breakers trip for no apparent reason, and the circuit breaker can be reset one time. If the circuit breaker trips again, there exists a circuit fault and the technician must troubleshoot the circuit before resetting the circuit breaker. Figure 112.

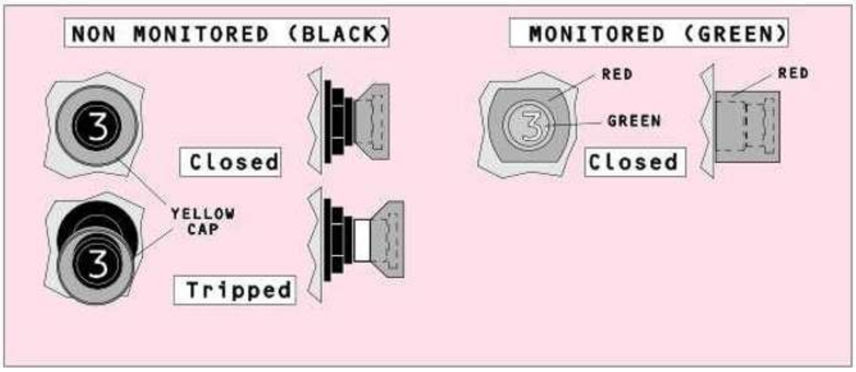


Figure 112 : Circuit Breaker Panel : Typical CB Panel

Figure 112 : Circuit Breaker Panel : Specific Circuit Breakers DIFFERENTIAL CURRENT PROTECTION

There is a danger of short circuit between two generator lines or one generator line and ground. Also an insulation failure of the generator feeders is dangerous. The differential protection prevents the damages of the electrical wiring and the generator windings between the two detection current transformers. One 3- phase current-transformer is located inside the generator and reads the current. If the difference between the current at the generator and the current to the power consumers differs a certain amount, the Generator Line Contactor will open and the generator excitation field is turned off. The three-hole current transformer contains 3 toroidal transformers, one for the each of the power feeder cables. The current ransformer sends its signal who is proportional to the current in its feeder cables to the Generator control unit. If the current from the generator is not equal to the current who flows to the power consumers, that means there must be a failure inside the generator windings or the generator feeder cables who brings the power from the generator to the power distribution center inside theaircraft.

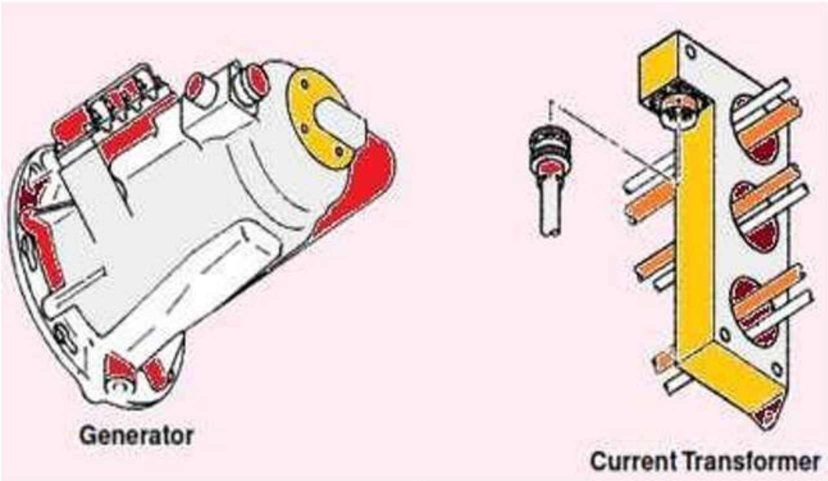


Figure 113

Figure 114 OTHER PROTECTIONS

In commercial aircrafts there are additional electrical protection devices in the generator and power supply system such as:

- Over and UnderFrequency
- Over and Under Voltage
- Incorrect PhaseSequence
- OpenPhase
- GeneratorOverload
- Real and Reactive LoadDivision
- Over and Under Excitation
- ReversePower

In modern aircrafts the protections are controlled via GCU through opening the GCR and GR (GLC). Through opening the GCR the excitation field will be turnedOFF.

INDUCED CURRENT PROTECTION

When current begins to flow through the contactor coil, a strong magnetic field builds up around the coil. But as soon as the switch between the coil and ground is opened, current stops flowing in the coil, and as it stops, the magnetic field collapses across all of the turns of wire in the coil. The collapsing magnetic field produces in the coil a short pulse, or spike, of very high voltage whose polarity is opposite to that of the battery. The amount of induced voltage is determined by the rate at which the magnetic field cuts across the conductor. The faster the current changes, the greater the induced voltage. This voltage spike can damage any electronic equipment connected to the system when the master switch is opened. It can also damage the master switch by causing an arc to jump across the contacts as they are opening. To prevent this kind of damage, a reverse-biased diode or freewheel-diode is connected across the contactor coil. During normal operation, no current can flow through it, but the high-voltage spike that is produced when the master switch is opened forward-biases the diode,andtheinducedcurrentflowsbackthroughthecontactor coil and is dissipated. The induced current will flow in the same direction as the flow of current that produced the magnetic field.

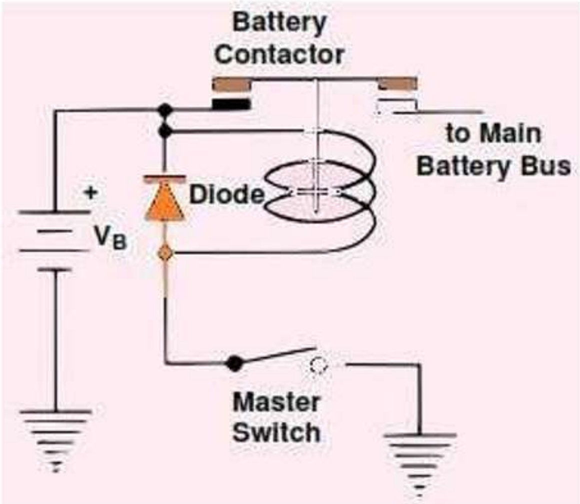


Figure 115

The Aircraft is provided with emergency equipment and installations. They shall be used in case of an emergency on ground, on water (ditching) or in flight according to given procedures.

The types and … e UK Air Navigation Order Schedul…

These are:

- Escape S…
- EscapeR…
- Oxygen…
- Evacuati…
- Loose E…
- Portable…
- Fireaxe
- Protectir…
- SmokeG…
- Portable…
- Livevest…
- VHFTra…
- RadioBe…
- Megaph…
- Flashlig…
- First Aic…
- Dangero…

Layout

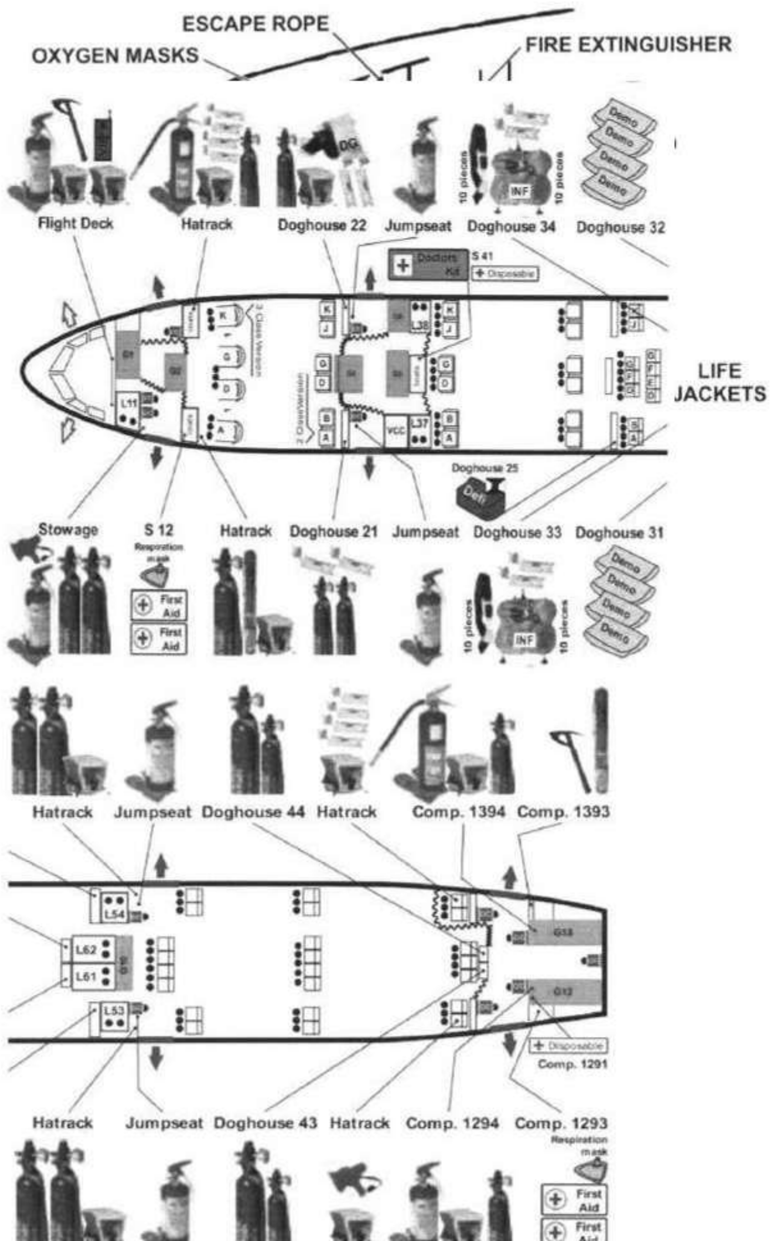

ESCAPE ROPE
OXYGEN MASKS
FIRE EXTINGUISHER
Flight Deck
Hatrack
Doghouse 22
Jumpseat
Doghouse 34
Doghouse 32
LIFE JACKETS
Stowage
S 12
Hatrack
Doghouse 21
Jumpseat
Doghouse 33
Doghouse 31
Hatrack
Jumpseat
Doghouse 44
Hatrack
Comp. 1394
Comp. 1393
Hatrack
Jumpseat
Doghouse 43
Hatrack
Comp. 1294
Comp. 1293

Fig. 7.3 Cabin equipment lay-out

Fire Gloves

Fire gloves are stored close to a fire extinguisher and may be used for personal protection

Fig. 7.4 Fire gloves Torches

Torches are provided near crew stations for the purposes of illumination and signalling. Their use for other than emergency purposes should be limited to a minimum.

Fig. 7.5 Torch Oxygen Bottles

Oxygen bottles are situated throughout the passenger cabin and flight deck.

In the passenger cabin, they may be used for first aid purposes. They may also be used to protect the crew while they work after an aircraft depressurization or for smoke protection while fire fighting. The flight deck crews also have their own oxygen system for use duringdepressurization.

More information on oxygen bottles is provided in Section 11.15 of these Study Notes.

Fire Extinguishers

These are situated throughout the aircraft and are used for dealing with in-flight cabin fires.

They are mainly of the Halon type, for use on most types of fire except liquid.

More information on fire extinguishers bottles is provided in Section 11.8 of these Study Notes.

Life Vests

Life vests (also known as Life Jackets) will be fitted at each seat position in the aircraft. There may also be an additional stowage for infant life vests.

Life jackets are designed as lightweight items of equipment and as such should be treated with care. Life jackets are normally packed in specially made fabric valises or containers for ease of handling and these also protect the life jacket; they also help to keep the life jacket correctly folded, to facilitate donning. However, care should be taken not to drop a packed life jacket or to place loads upon it. Manufacturers often recommend that a life jacket which has been subjected to such abuse or has been immersed in sea water should be rejected from further operationaluse.

Normally, life jackets are stowed under passenger's seats and in easily accessible positions for crew members. Stowage should be kept clean and dry and the stowage retaining device should be checked periodically for security and case of release.

Lifejackets which have been used for demonstration by crew members should be returned for inspection as if they were time expired. To ensure that this is always done, the demonstration life jackets should be kept out of the normal stowage and a suitable warning label should be attached.
There are several types of life jackets in use and all are basically similar. Buoyancy is obtained by

inflating the jacket with carbon

dioxide (C02) gas, which is stored under pressure in a small cylinder and released by means of a manually operated mechanism. A standby mouth inflation valve is also provided in case the CO2 system is inoperative, or if it is necessary to ‘top-up’ the pressure after a long period of immersion. To assist rescue operations, life jackets are equipped with an identification light, battery and a whistle is also provided. Certain types of life jackets may also carry additional equipment such as fluorescent sea marker dye, shark repellent products and special signalling devices.

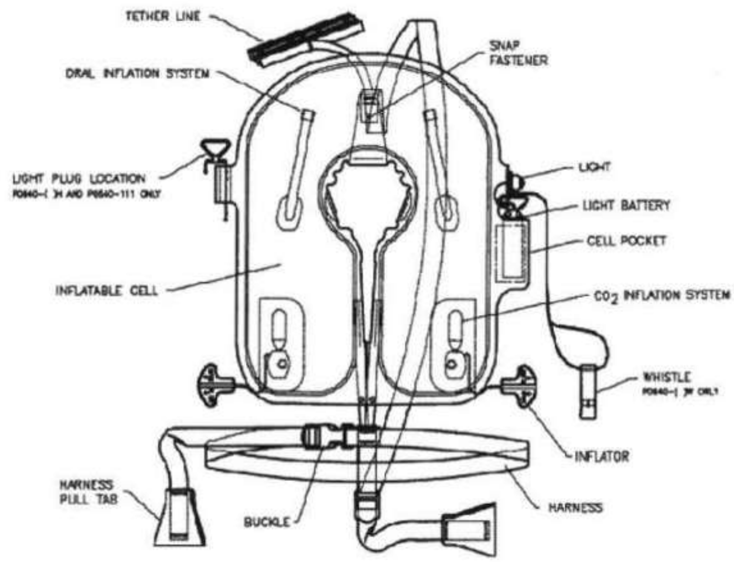


Fig. 7.6 Life vest Megaphone

This may be fitted for use by crew members when the main public address system is not working. Megaphone stowage attachments are subject to the load requirements set-out in EASA CS 25.561 (and 25.1421). This includes, for example, an inertia force requirement of 9g before failure occurs.

Fig. 7.7 Megaphone

EASA EU-OPS specifies the minimum requirements for carrying of megaphones. Among these include the minimum number to be carried aboard the aircraft.

1. For each passengerdeck:

Passenger seating configuration	Number of megaphones required
61 to 99	1
100 or more	2

2. For aeroplanes with more than one passenger deck, in all cases when the total passenger seating configuration ismore than 60. At least one megaphone is required.

Fire Axe

A fire axe is normally installed in the aircraft, to aid in aircraft escape if exits become blocked. The fire axe handle is insulated against high voltage.

Fig. 7.8 Fire Axe Emergency Evacuation

In the pursuit of aesthetic cabin furnishings, aircraft manufacturers and operators must consider one major and important factor when choosing upholstery materials. They must be fireproof and the materials must be prevented from exiting toxic gases. Recent experiments have shown that incapacitation of passengers has resulted from inhalation of toxic gases rather than post crash impact. Legislation is now in progress to ensure that seats and cabin furnishings meet certain EASA and FAA standards with respect to passenger seats. (FAR/EASA CS 25.853 b and c).

Most seat squabs and back supports are manufactured from a foam type material. When heat is applied to this material, cyanide gas is produced during the burning of the material. As a means of slowing down this action, the seats' internal parts are coveredwith a fire blocking material, which is designed to prevent the foam from burning, and consequently allow the occupants a better chance of vacating the aircraft in the event of a cabinfire.

Because of the problem of smoke and the inability of passengers to see in smoke conditions, legislation is in progress to incorporate some means of an exit indicating system that is close to the floor level.

This legislation is applicable to all transport (passenger) aircraft over 5700 kg.

How the emergency escape path lighting will be achieved has to be decided by the aircraft operators or manufacturers. The most popular method is to include small aisle lights in the seat assemblies, which will allow aisle lighting under certain conditions.

The height of the escape path lighting system must not be greater than 4 ft. The escape path system is designed to indicate to passengers the direction in which to go in the event of smoke conditions, and at the same time indicate the areas that contain emergency exits. Escape path lights will be white; red lights will be used to indicate the emergency exit doors.
Although fire blocking material is to be used in seat upholstery, the actual covers are also treated with a fire resistant substance. Oneimportantpointtoconsiderhoweverthatisthefireresistant qualities are gradually reduced when the seat covers is dry- cleaned. In most cases, manufacturers indicate a maximum number of times that the covers may be dry cleaned before the fire resistant treatment has to be reapplied. The number of dry-cleans will depend only upon the manufacturer’srecommendations.

There are a number of seats in addition to passenger seats, which are located throughout the cabin compartment for use by cabin staff during landing and take-off. These seats are normally the folded type, which fold away after use, thus allowing more space in the cabin area.

The seats bottoms are normally cushioned and attached with quick attach/detach pins to allow the seat bottom to become an individual flotation device in the event of the aircraft ditching in the sea. Attached to the seat assembly is a seat harness for use by the seatoccupant.

Emergency Evacuation Requirements

a. Each crew and passenger area must have emergency means to allow rapid evacuation in crash landings, with the landing gear extended as well as with the landing gear retracted, considering the possibility of the aircraft being onfire

b. For aircraft having a seating capacity of more than 44 passengers, it must be shown that the maximum seating capacity, including the number of crew members required by the operating rules for which certification is requested, can be evacuated from the aircraft to the ground under simulated emergency conditions within 90 seconds. Compliance with this requirement must be shown by actual demonstration using the test criteria outlined in EASA CS-25 unless the Authorities findthatacombinationofanalysisandtestingwillprovide data equivalent to that which would be obtained by actual demonstration.

Escape Slides

The emergency equipment provides a means for the flight attendants to assist passengers and passengers to assist themselves in the event of an emergency.

Aircraft with exits above 1.8 meters (6-feet) above ground have to be equipped with slides.

Escape Slides are installed at all the aircraft exits. They provide quick evacuation for the passengers and the crew in an on-land emergency situation. The escape slide pressure cylinders are filled with a mixture of carbon dioxide (C02) and nitrogen (N).

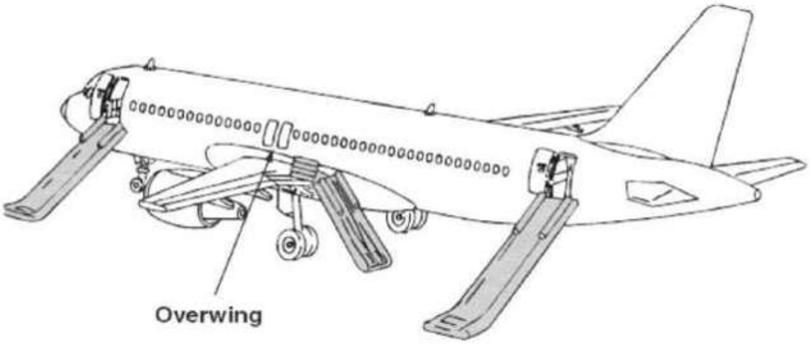


Fig. 7.9 Escape Slides Lay-Out

Slides are inflated automatically. They are built into the door or underneath the door-frame. When the door handle is set to armed, the girt-bar connects the slide to the floor attach fittings. As the door opens, the outboard movement pulls the slide from the slide pack and it begins to fall down. A lanyard pulls the reservoir valve to open. The slide inflates fully in approximately 3 to 10 seconds. When ditching, slides can usually be used as rafts.

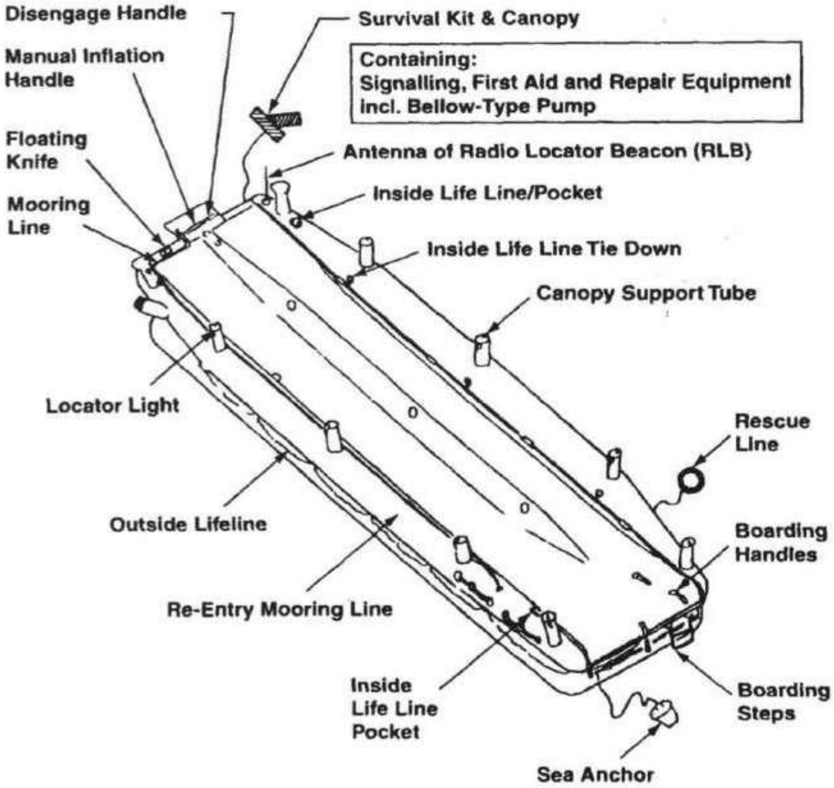


Fig. 7.10 Slide/Raft

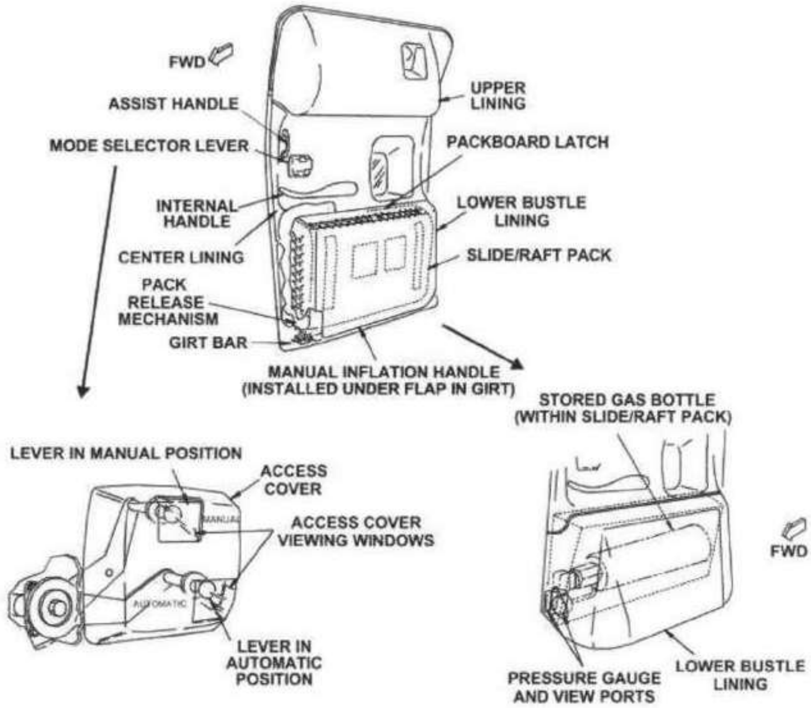


Fig. 7.11 Escape slide mechanism and stowage

Both slides and slide/rafts use a non-explosive, inert gas inflation systems. EASA requires evacuation of the entire aircraft in 90 seconds using 50% of the available evacuation exits. To meet this, all evacuation units need to deploy in less than 10 seconds. For large, wide body aircraft such as A300s and B747s a successful deployment is complete in about 5-7 seconds, depending on conditions (such as cold and winds).

The inflation system usually consists of a pressurized cylinder, a regulating valve, two high pressure hoses and two Aspirators. The

cylinder can be from 100 to about 1000 cubic inches, filled to about 3000 PSI with either gaseous Nitrogen, or a mixture of gaseous C02 and Nitrogen. Once made of steel, most cylinders now are made of aluminium or alloy cores wrapped with fibre glass, or other lightweight, fuel saving materials. The C02 is used to slow down the rate at which the valve expends the gases.

The valve is used to mechanically meter out the gas at a rate of roughly 3 - 600 PSI and 4 CFM. Typically there are two high pressure hoses attached to the valve, which are connected at the other end to 'Aspirators'. These are usually cylindrical, hollow aluminium tubes with sliding cylindrical or internal 'flapper' doors that open when high pressure gas is applied, and close when the gas stream subsides and the internal slide back pressure reaches about 2.5 - 3.0 PSI. They work on the 'Venturi' principle, and draw outside air into the evacuation unit at a rate of about 500:1. A 750 in3 (0.43 ft3) cylinder can fill a slide with about 850 cu ft (24 m3) of air to a pressure of about 3 PSI in about 4-6seconds.

For the slide to deploy correctly, it is packed in a manner that has the aspirators directly under the outer cover. The entire, self contained "slide pack" is approximately 3 ft (0.91 m) wide, 2.5 ft (0.76 m) long and about 1 ft (0.30 m) high, depending on aircraft type. In the centre, forward part of the pack, a multi-layered piece of heavy urethane or neoprene/nylon fabric, called the 'girt', is left hanging out to a length of about 2 ft (0.61 m). When installed in the aircraft, a 'girt bar' is put through the centre, outside end of the girt and attached to the interior floor, just inside and in front of the exit door. On the face of the girt are instructions in large red lettering, and a handle with the word 'PULL' on it.

This is rarely used however, because the lanyard attached to the handle runs through the girt to the valve, which is several inches too short when the girt is extended fully. When the slide is in the 'armed' position and the door is opened, the slide pack falls free of the door bustle (a semi rigid outer container) and the weight and momentum of the slide pulls the lanyard from the valve, initiating the flow of gas. At about the same time, a metal pin that holds the centre of the Valise closed is also pulled, releasing a 'daisy chain' and the two halves of the cover. When the cover is released and the inflation system activated, the two aspirators come shooting out of the pack, gulping vast quantities of air and restrained only by the fabric tubes to which they are securely fastened.

To compensate for any wind, new evacuation slides contain internal baffles, which cause the ends nearest the aircraft to inflate first, which are constructed to come out like four elbows and press against the fuselage of the aircraft to the forward and aft sides of the exit door. There are also 'half-tie' restraints which keep the inflating slide from drooping or blowing under the aircraft. These restraints are constructed so that when the slide becomes fairly rigid, around 1.5 - 2.0 psi, they detach very quickly (there are usually two), and since the header tubes are already against the fuselage, the slide 'pops' almost horizontally out from the door, then drops relatively gently to the ground. Tests in 25-knot (46 km/h) cross winds have shown these deployment systems to be very effective.

Independent of the inflation system, all slides are equipped with at least one pressure relief device per inflation chamber. This protects the chamber from catastrophic failure due to over pressurizing. (Typically, modern slides are made of at least 2 inflation chambers, and should be able evacuate an aircraft even when one chamber loses allpressure.)

All new evacuation slides are tested on a mock-up of an aircraft exit door and filmed prior to being certified as 'airworthy' and delivered to a customer. Also, new units are usually constructed of

urethane materials and impregnated or coated with an aluminized coating so that the slide will survive for a short while even if fire is nearby. Older slides are yellow and made of neoprene/nylon fabric.

Flight Crew Emergency Exits

For aircraft in which the proximity of passenger emergency exits to the flight crew area does not offer a convenient and readily accessible means of evacuation of the flight crew, and for all aircraft having a passenger seating capacity greater than 20, flight crew exits shall be located in the flight crew area. Such exits shall be of sufficient size and so located as to permit rapid evacuation by the crew. One exit shall be provided on each side of the aircraft; or, alternatively, a top hatch shall be provided. Each exit must encompass an unobstructed rectangular opening of at least 19 by 20 inches (482.6 by 508 mm.) unless satisfactory exit utility can be demonstrated by a typical crewmember.

Emergency Ropes

In civil passenger aircraft which have emergency exits without escape chutes, emergency ropes are provided. They are also fitted by over wing emergency exits. They are attached to the structure beside, or above, the exits. In the case of over wing passenger emergency exists they are usually only accessible once the emergency window has been opened and are provided with a hook which may be clipped into a fitting in the upper surface of the wing. They enable the passengers to remain on the wing after a ditching.

Emergency ropes are also fitted beside the crew emergency exits. The crew may escape from the cockpit by sliding down these ropes tosafety.

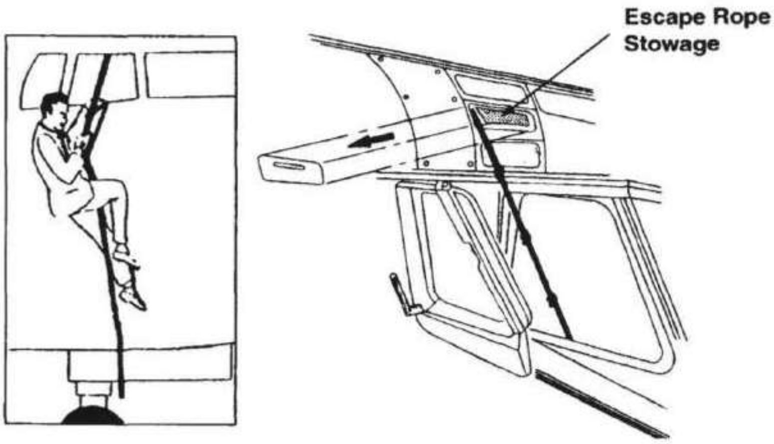


Fig. 7.12 Escape Rope Cockpit Layout

The cockpit of older aircraft is normally equipped with up to four pilot seats (Captain, First Officer, Flight Engineer and Navigator). Since the computer technology has taken over the Navigator's and later also the Flight Engineer's job, modern aircraft are usually equipped with two pilot seats and up to two or three Observer Seats.

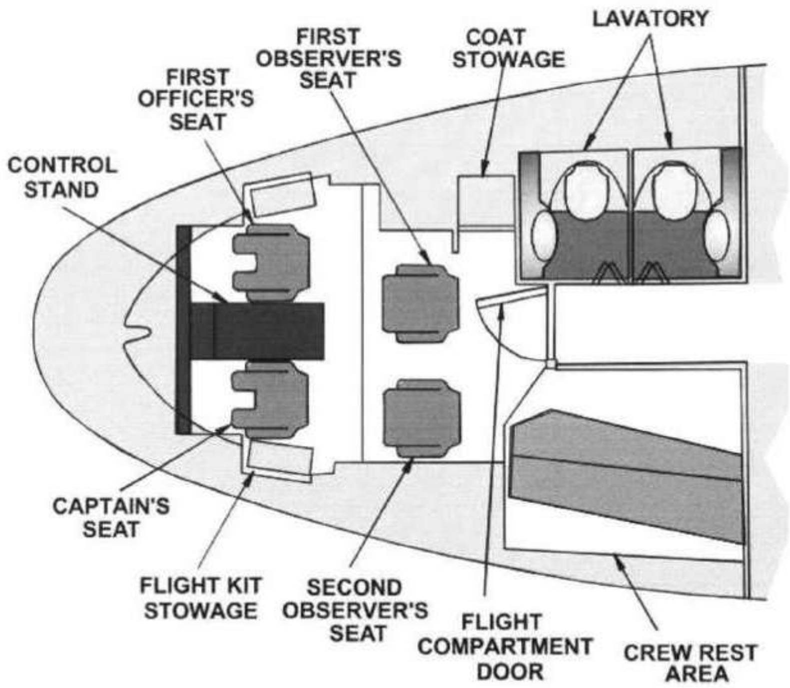


Fig. 7.13: Modern Cockpit Layout

Pilot's Seats

The two Pilot Seats are usually electrically operated. In case of an Electrical Power loss, it is always possible to operate the seats manually. They can move longitudinally and vertically. For more comfort, there are a few possibilities to fine adjust the seat to the pilots individual setting.

There is also a safety harness installed.

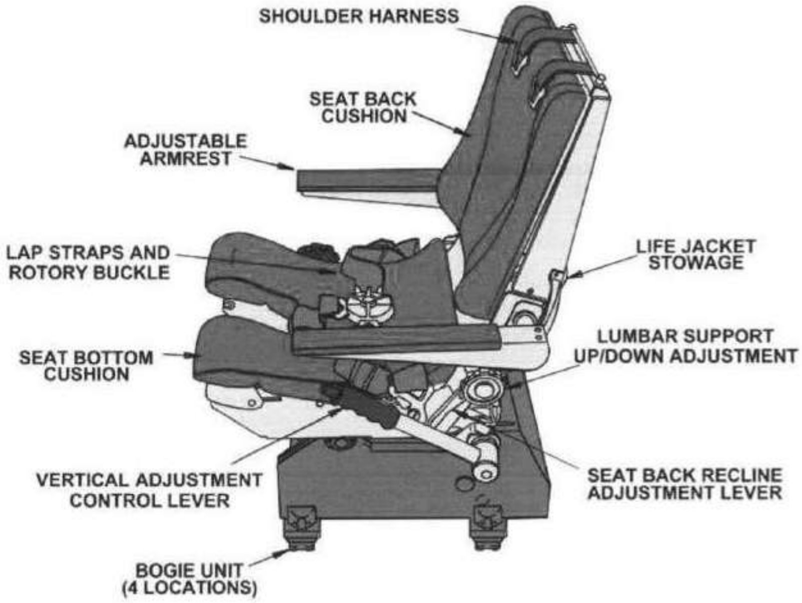


Fig. 7.14 Captain and First Officer Seat

Observer's Seats

Also known as Occupant's seat or Jump seat. These seats are not as comfortable as the pilot seats. In small cockpits, they are normally of the folding type.

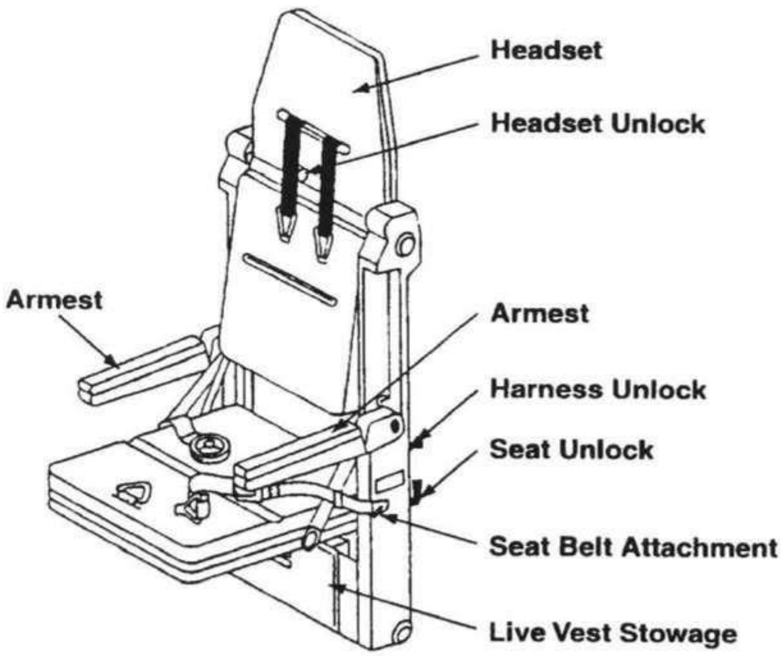


Fig. 7.15 Observer's Seats Attendant's Seats

The cabin crew seats are installed near the doors. This ensures that in the event of an emergency, a cabin crew member is immediately available to open the door. Therefore, seat belts on attendant seats are equipped with quick release buckles.Figure

7.16 shows a typical 4- point restraint system with reels (self reeling).

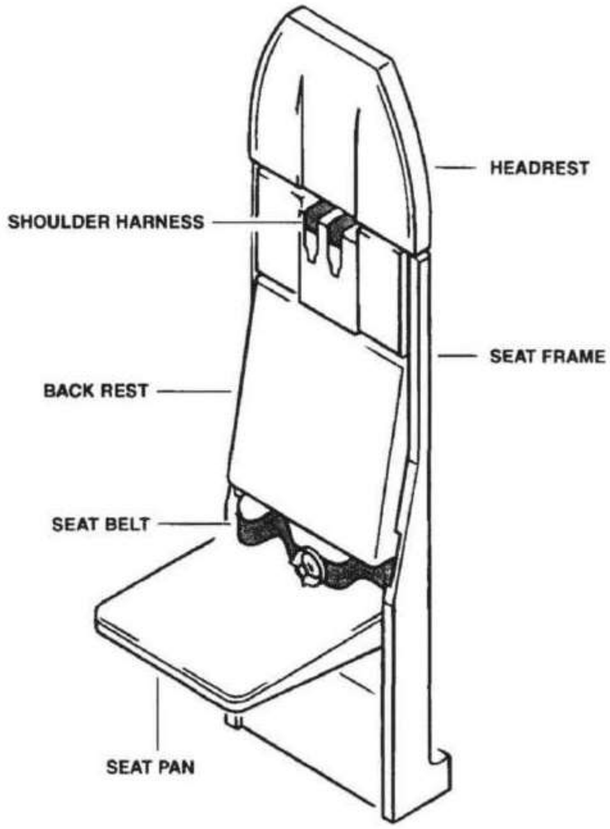


Fig. 7.16 Attendant's Seat

Seat Belts and Shoulder Harnesses

Each flight deck and passenger seat is fitted with a seat belt or harness each capable of restraining a person of mass 77 kg (170 pounds) and a load factor of 9g in the forward direction in the event of an emergency landing.

The requirements for seat belts and shoulder harnesses are set out in EASA CS-25.785.

Further requirements are set out by the CAA in Civil Aircraft Airworthiness Information and Procedures (CAAIPs) Leaflet 14- 15.

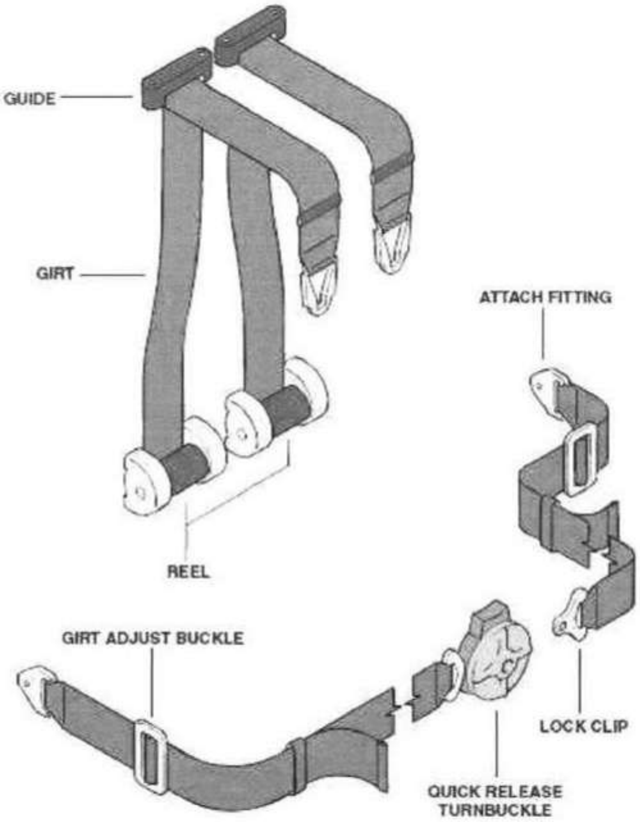


Fig. 7.17 Pilot's harness

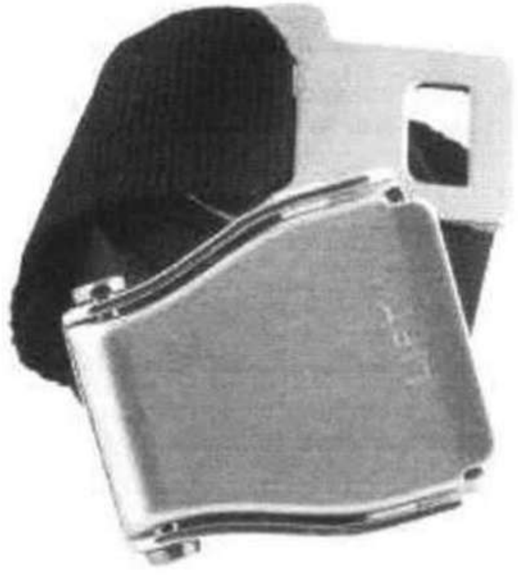


Fig. 7.18 Passenger seat belt Furnishing Materials

All materials used within a passenger cabin must meet stringent Flame Resistance requirements and must have been tested in accordance with the requirements of EASA CS- 25.853.

Further instructions and requirements can be found in the CAA publication Mandatory Requirements for Airworthiness (CAP 747) GR No.13 and GR No.14.

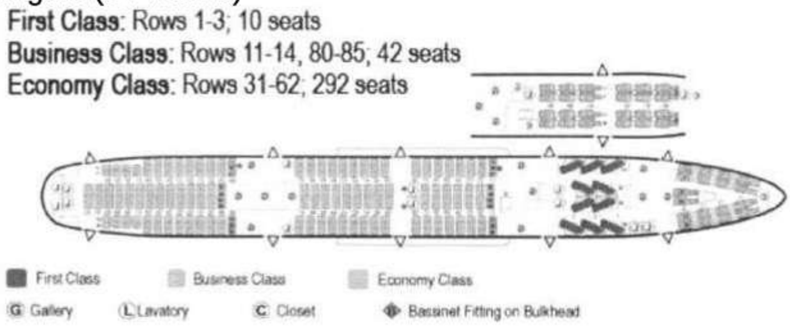
Cabin Layout

Passenger aircraft cabin layouts are one of three types

- Cargo

- Passenger (1st class, business class and economyclass)
- Combi (a combination of Passenger andCargo)

Boeing B 747-400 Passengers (344 seats)



Boeing B 747-400 Combi (280 seats)

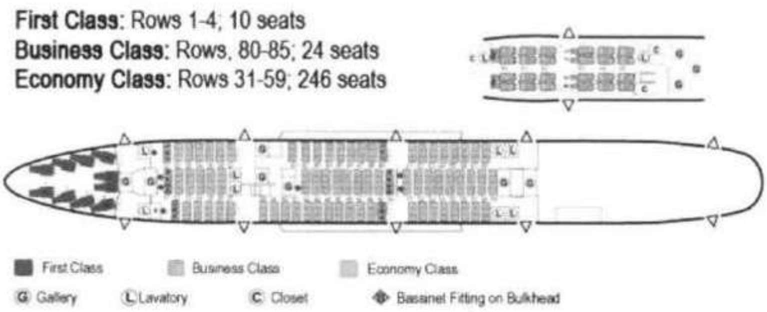


Fig. 7.19 Passenger and Combi configurations

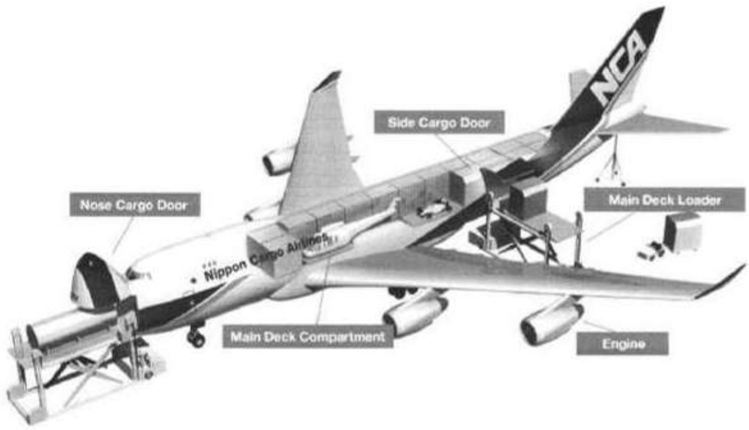


Fig. 7.20 Cargo configuration and loading access

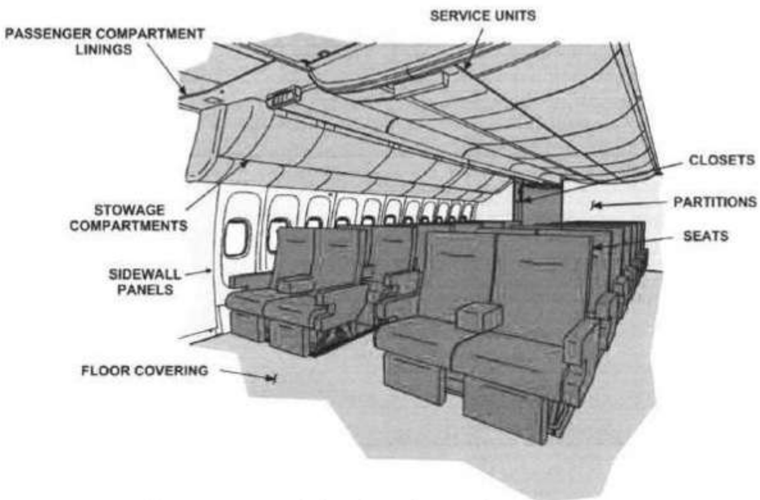


Fig. 7.21 Cabin furniture layout

The Regulating Authority is required to approve the cabin interior layout of each aircraft on the UK register.
As part of that approval each seat type shall be approved as required by EASA CS-25.785

At the initial evaluation of a seat an assessment of the limiting conditions of use is made and, when agreed with the seat manufacturer, these are specified on the GA drawing, on the Declaration of Design and Performance (DDP) or specifically highlighted in a letter of approval. Included in these limitations is a minimum seat pitch at which approval for installation on an aeroplane has been granted. This minimum pitch is defined taking into account head, trunk and leg strike areas of the seat in front, the ability to occupy the seat and, if necessary, quickly vacate the seat and enter the aisle in anemergency.

To formalize minimum acceptable seating standards the normal design extremes used for certification purposes for all occupied zones, namely the anthropometric data for the 5th percentile female to the 95th percentile male, have been taken into account. In this regard the critical dimension for the seated occupant is the buttock-knee length. Additionally, affecting the ease with which the occupant can stand up and move from the seat to the main cabin aisle, is the minimum distance and the vertically projected distance between the seat and any seat or fixed structure immediately ahead of the occupant.

The minimum distance between the back support cushion of a seat and the back of the seat or other fixed structure in front, shall be 26 inches. (Figure 7.22, DimensionA.)

The minimum distance between a seat and the seat or other fixed structure in front, shall be 7 inches. (Figure 7.22, Dimension B.)

The minimum vertically projected distance between seat rows or between a seat and any fixed structure forward of the seat, shall be 3 inches. (Figure 7.22, Dimension C.)

The measurements required for the demonstration of compliance with the requirement given above are as follows.

- From a datum point in the centre of the seat back at a height of 3 inches above the mean uncompressed seat squab height to the seat or other fixed structure in front made in both vertical and horizontal arcs up to a limiting height of 25 inches above the carpeted floor level, over the full seat place width 'X'. (See Figure7.22.)
- From any point on the seat back within the centre one half 'Y' of the seat place width at a height of 3 inches above the mean uncompressed seat squab height to the seat or other fixed structure within the central 12 inch region in front made in vertical and horizontal arcs up to a limiting height of 25

inches above the carpeted floorlevel.

The full width of the forward edges of the seat squab cushion and the seat arm rests shall be used as the datum points for the measurements of the minimum distance required by the above. From these points the measurement of the distance shall be made in both horizontal and vertical unlimited arcs.

The vertically projected distance required shall be measured between the forward edge of the seat squab cushion or the most forward extremity of the armrests and the most aft part of the seat or fixed structure in front.

Where a magazine rack is provided for the normal stowage of the cabin safety leaflet, sick bag and in-flight reading material provided by the operator, such normally provided material shall be in place during the measurements. Similarly, any fold down or other type of meal table attached to either seat or fixed structure should be in its normal stowed (take-off and landing) position for allmeasurements.

All measurements shall be made with the seats in the upright (take-off and landing) position, and the armrests shall be down.

No alleviation to these requirements will be granted on the basis of deformable softfurnishings.

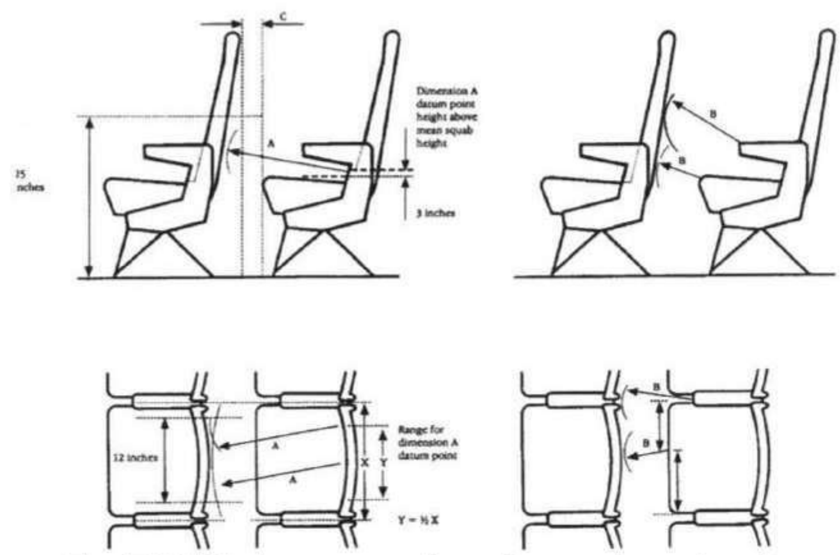


Fig. 7.22 Minimum seat dimensions and spacings Passenger Seats

Depending on the operator’s cabin layout, the passenger seats are designed from very simple to very comfortable. Seats have to meet special requirements given by law. Each seat is provided with a seat-belt and a life-vest for passengersafety.

Passenger seats attach to tracks on the compartment floor. The tracks are continuous extrusions with circular cut-outs, which receive the seat attachment fittings and allow them to be positioned in 1-inchincrements.

The rear seat attachment is usually stronger than the front seat attachment, as this normally experiences more stress in the event of a sudden stop of the aircraft. The forward, the rear or both seat attachments will have an adjustable device to eliminate rattle as the attachmentwears.

Passenger seats are attached to seat tracks in the floor, and may be rearranged for different passenger configurations by moving the seats forward or aft on seat tracks. Seat tracks are beams of special cross section and are bolted to the floor structure. Tracks are provided with circular cut-outs for seat studs and lock pins, which lock the seats in position. Cut-outs in the tracks are spaced one inch apart. The seats are triple or double passenger type.

Seat retention studs are mounted in the front and rear of each leg. At the rear of each leg is a pivoted double retaining stud. Seat retention and locking is by a spring loaded shear pin located at the rear of each leg.

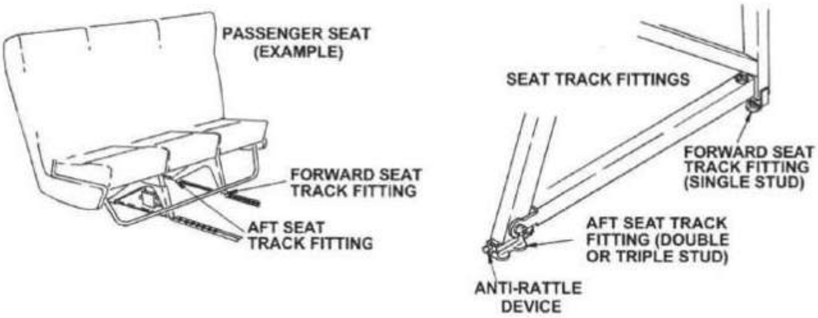


Fig. 7.23 Seat anti-rattle fitting on rear legs

Each seat or berth, and its supporting structure, and each safety belt or harness and its anchorage must be designed for an occupant weight of 77 kg (170 pounds), considering themaximum

load factors, inertia forces, and reactions among the occupant, seat, safety belt, and harness for each relevant flight and ground load condition (including the emergency landingconditions).

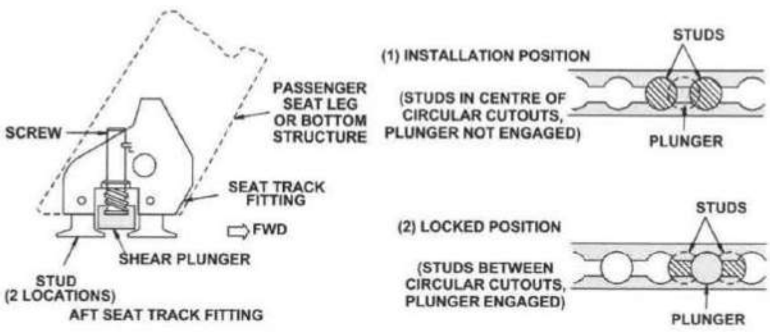


Fig. 7.24 Seat track fittings

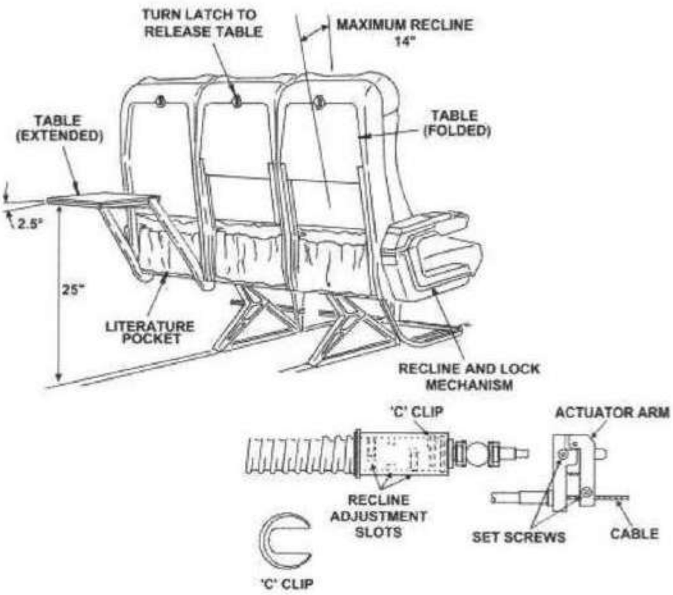


Fig. 7.25 Triple and double passenger seat assemblies

First Class Seats

First Class Seats are usually electrically operated. Additionally, there is a Control Panel to make use of the Reading Light, the Attendant Call and the Entertainment System (Music and Video).

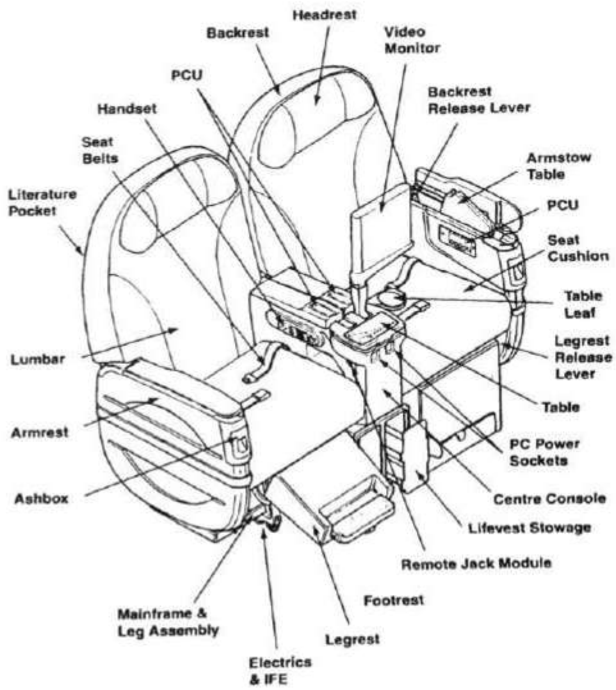


Fig. 7.26 First Class Seat Economy Seats

Economy seats are designed very simple and they must be very light in weight. These seats are manually adjustable only. On long-range aircraft there is usually a simple Control Panel installed (Music andCall).

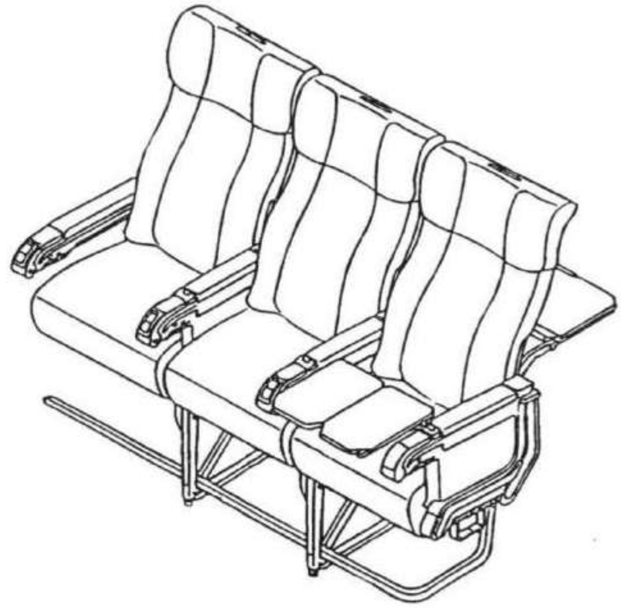


Fig. 7.27 Economy Class Seat Galleys

The purpose of the galleys is to provide food and beverage preparation facilities. The galleys may be installed in the cabin or in the under-floor compartment. Cabin galleys are normally fixed to the seat rails with additional fasteners to the walls and ceiling so that the relatively heavy galley can withstand acceleration well above normal flightloads.

Galleys are normally equipped with:

- Cold WaterTap
- CoffeeMaker
- Hot WaterBoiler
- Oven and/orSteamer
- Fridge
- WasteBin
- Compartments forContainers

The galley equipment must be secured against movement during take-off, turbulences and landing. Several types of locking mechanisms are provided.

The Air Navigation Order 2000 Article 14(6) requires that:- "All equipment installed or carried in an aircraft, whether or not in compliance with this Article, shall be so installed or stowed and so maintained and adjusted as not to be a source of danger in itself or to impair the airworthiness of the aircraft or the proper functioning of any equipment or services necessary for the safety of theaircraft."

Trolleys and items of galley equipment which require electrical power are, unless otherwise specifically agreed by the CAA, classified as 'Controlled Items' of equipment as defined in BCAR Chapter A4-8, paragraph 2.3(d) and approved under one of the procedures of BCAR Chapter A4-8, paragraph 5.

Catering boxes and equipment not requiring electrical power are classified as 'Uncontrolled Items' and are assessed under the procedures detailed in BCAR Chapter A4-8, paragraph 4. It is necessary, therefore, for an appropriately approved Organization to accept responsibility as to the suitability and quality of such equipment.

Catering trolleys, designed for use in standard galleys on a variety of aircraft types, are considered to be common user items and as such are certificated under the accessory procedures of BCAR Chapter A4-8. The design of all galley equipment shall minimize the risk of personal injury to the user, as required by JAR 25X1360 or BCAR Chapter D6-13, paragraph 6.7, as applicable. In particular, vessels containing heated liquids over 45“C shall have closely fitting integral lids. The use of open hotplates and open cooking utensils such as frying pans is not permitted.

Fig. 7.28 Galley Lay-Out

The local attachment factor of 1 -33 applies, in addition to the relevant prescribed acceleration forces, to door hinges, catches and restraint means which form part of the equipment structure, and to structure adjacent to the restraint means provided by the galley or similarstowage.

Doors, including their hinges and catches, of catering boxes, etc., must be of strength compatible with the placarded contents weight, unless use of the box is restricted to stowage in completely enclosed galley, or similar compartments. This also applies to the doors of catering trolleys, but in their case, the total structure of the trolley must also be shown to be in compliance with the strength requirements taking into account means of retention of the trolley in theaircraft.

The design of the trolley should be such that the loads imposed on the aircraft floor, do not exceed any floor loading limitations.

• It is strongly recommended that duplicated catches are provided for means of retention for items which are habitually operated during flight, to allow for failure of one of the catches.

• Where retention of a unit into its stowage compartment is by turn catch, operating the catch should not release more than oneunit.

Where catering trolleys have a facility for the collection of waste, they shall comply with the fire containment requirements of EASACS-25.853(e)

The trolleys must embody a brake system if they are to be removed from their stowage in flight. The brake assembly includesabrakeactuatorpedalassemblyarrangedatoneorboth

ends of the cart to enable locking and unlocking of the wheel assemblies by a pair of colour coded pedals. A centrally arranged swivel connector assembly is operative in association with the brake pedals to effect the locking and unlocking of the wheel assemblies by a pair of brake actuator linkage assemblies.

In the absence of evidence justifying an equivalent minimum braking force then the braking mechanism must be qualified by loading the trolley to its maximum loaded weight and ensuring that the braking mechanism holds the trolley on an incline plane of7-5°.

Trolleys shall carry placardedinstructions:-

- That they must be stored and secured during take-off, turbulent weather andlanding.

- That the gross weight of the unit, or the combined gross weight of the unit and any other galley insert when stowed together, must not exceed the placarded maximum content weight of the compartment wherestowed

- That when removed from their stowage they must not be left unattended.

The installation of all galley equipment shall be such that the size, weight, and means of restraint are compatible with the stowage facility provided, and that under design loads the item will not deform in such a manner so as to free itself from the means of restraint.

Fig. 7.29 Trolleys Lavatories

The lavatories provide sanitary facilities on the aircraft.
Structure in the lavatory area is painted with a protective coating to preventcorrosion.
Water is supplied from the potable water system.
Lavatories are also built as a unit and are attached on the tracks. Lavatories are equipped with:

- Hot and Cold waterTap
- Fresh airOutlet
- OxygenGenerator
- SmokeDetector
- Automatic Fire Extinguisher installed in the Wastebin

There is a RETURN TO SEAT sign in each lavatory. These signs come on when the FASTEN SEAT BELTS signs come on.

Placards
(EASA CS- 25.791)

A placard must be located on or adjacent to the door of each receptacle used for the disposal of flammable waste materials to indicate that use of the receptacle for disposal of cigarettes, etc., is prohibited.

Lavatories must have ‘No Smoking’ or ‘No Smoking in Lavatory’ placards positioned adjacent to each ashtray. The placards must have red letters at least 13 mm (0-5 inches) high on a white background of at least 25 mm (1 0 inches) high. (A No Smoking symbol may be included on the placard.)

Symbols that clearly express the intent of the sign or placard may be used in lieu of letters.

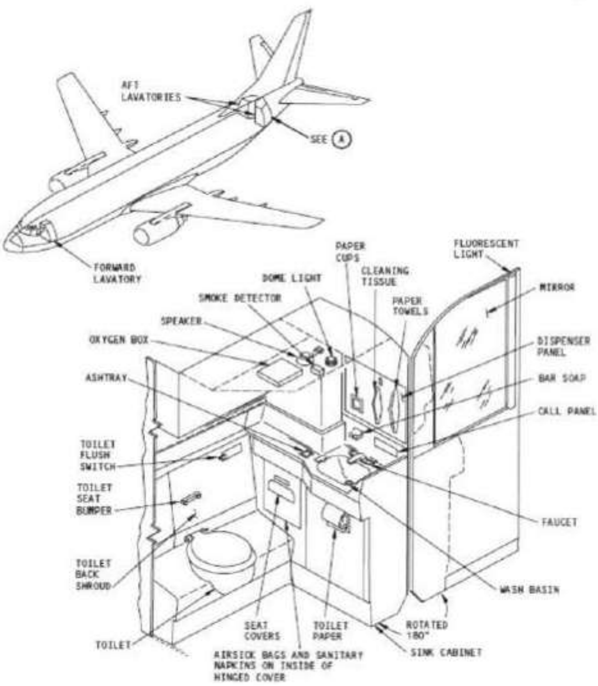


Fig. 7.30 Toilet layout Cargo Compartments

Cargo compartments provide space for carrying luggage; freight, equipment, and part of them are usually ventilated to carry living animals.

In passenger carrying aircraft, cargo is usually carried in the lower deck cargo compartment. Freighters also use the floor where the passenger seats are. In this case, we speak of "main deck cargo compartment". There are aircraft in service with a mixed configuration. Beside the lower cargo compartment, the main deck is split into a passenger compartment and a cargo compartment, located in the back of theaircraft.

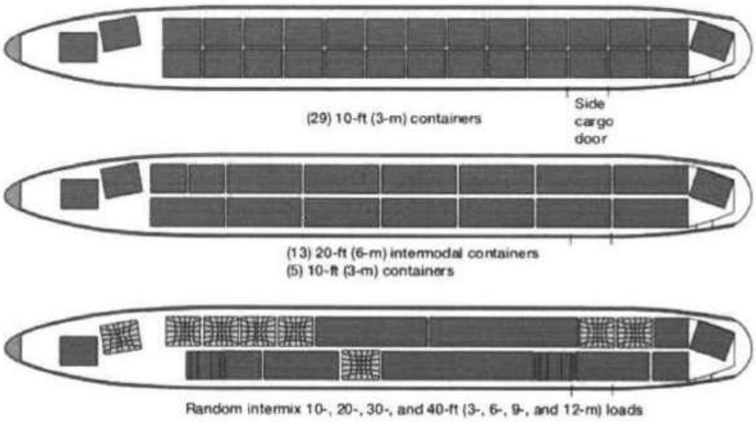


Fig. 7.31 Main deck cargo configurations (Boeing 747)

Two kinds of compartments are used:

- Bulk compartments (looseobjects)
- Container or PalletCompartments

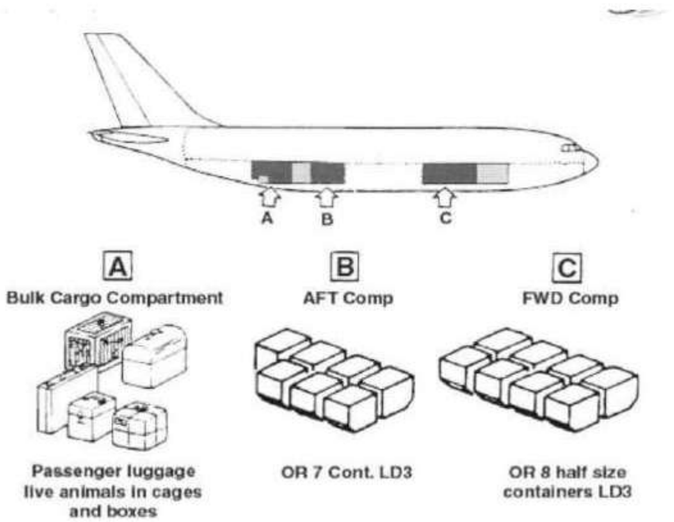


Fig. 7.32 Cargo compartment lay-out

Bulk Cargo Compartments

Transport aircraft are provided with such compartments to carry loose objects and living animals. A cargo net suspended across the compartment prevents cargo from shifting when the aircraft is in flight.

The net webbing is attached to anchor plates on the side walls and loop fittings on the ceilings. Cargo nets are usually constructed from nylon or polyester.

Container Cargo Compartments

Cargo which is to be loaded may be in containers or pallets. These containers are usually closed using a vinylcurtain.

Normally loading device (LD) containers areused.

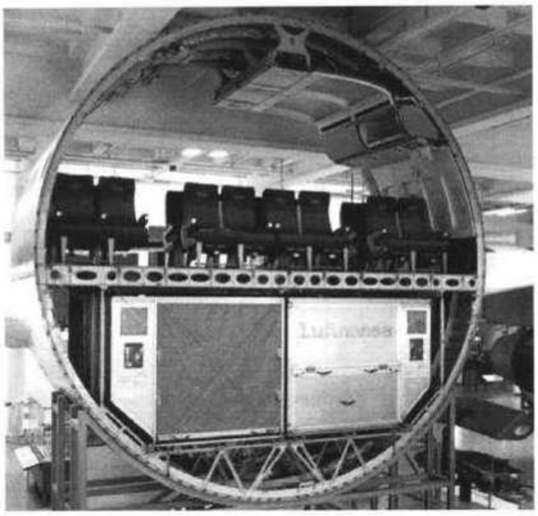


Fig. 7.33 Section of an Airbus A300 showing LD-3 containers

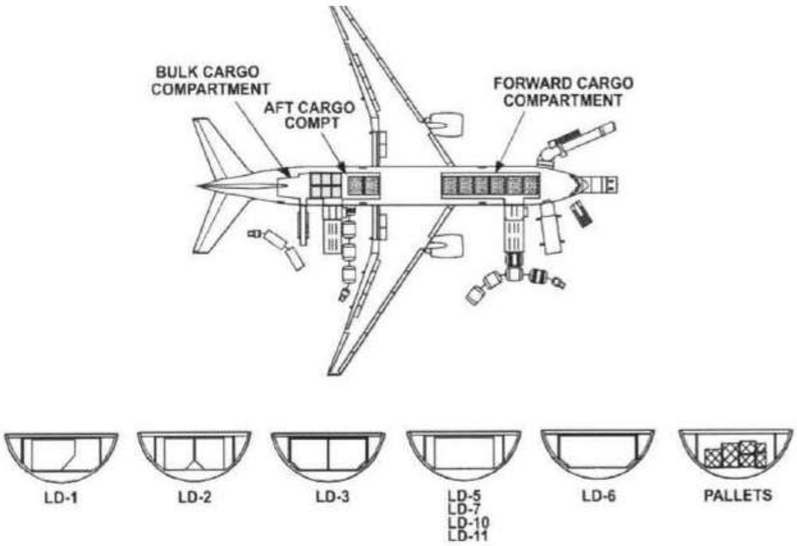


Fig. 7.34 Loading Devices (LD) container types Cargo Compartment Linings

The compartment ceilings and sidewalls are usually lined with fibre glass panels which are held in place by depressor and cap strips.

The cargo compartment bulkheads are often lined with aluminium alloy panels. The panels are riveted in place or are held by quarter-turn fasteners, which are spaced around the panel edges, plastic or sheet metal grille covers the blowout panel opening.

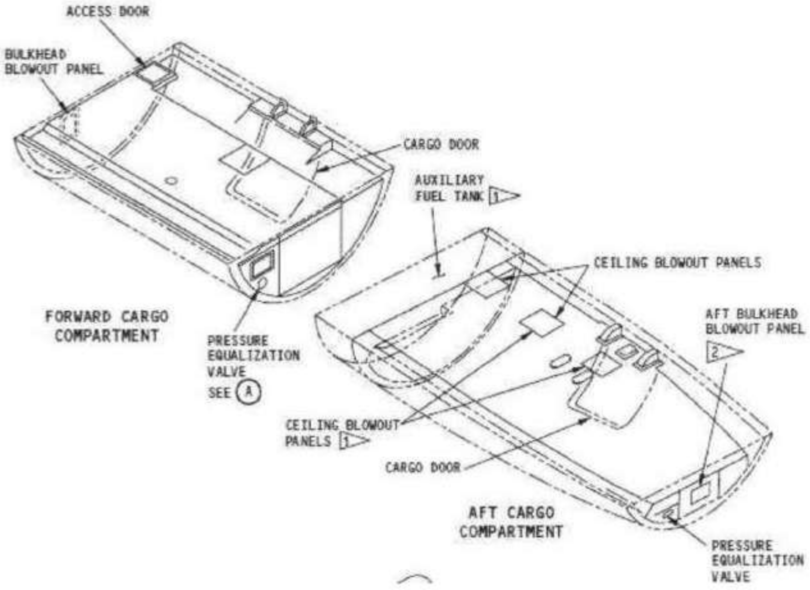


Fig. 7.35 Cargo compartment showing access, blowout panels and pressure equalization features

Cargo Handling and Retention Equipment

Container cargo compartments are equipped with loading systems. The semi automatic cargo loading system is very popular and used in most transport aircraft.

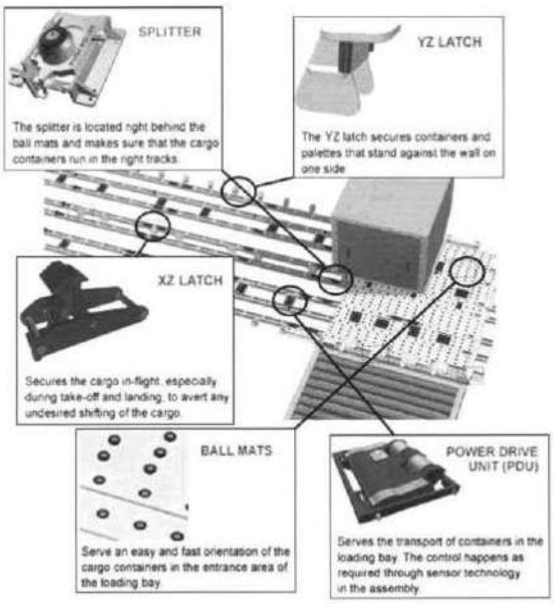


Fig. 7.36 Cargo loading Systems

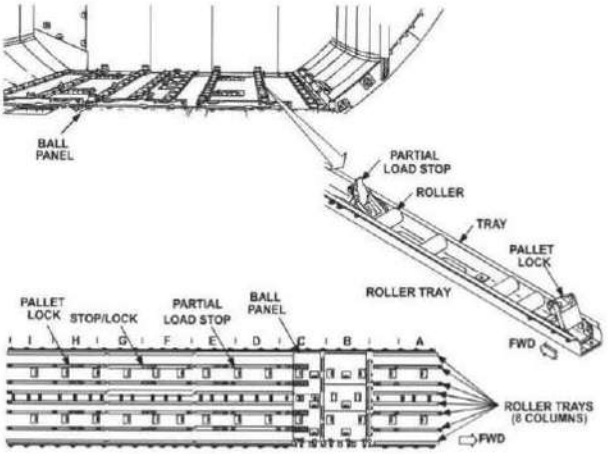


Fig. 7.37 Cargo loading systems

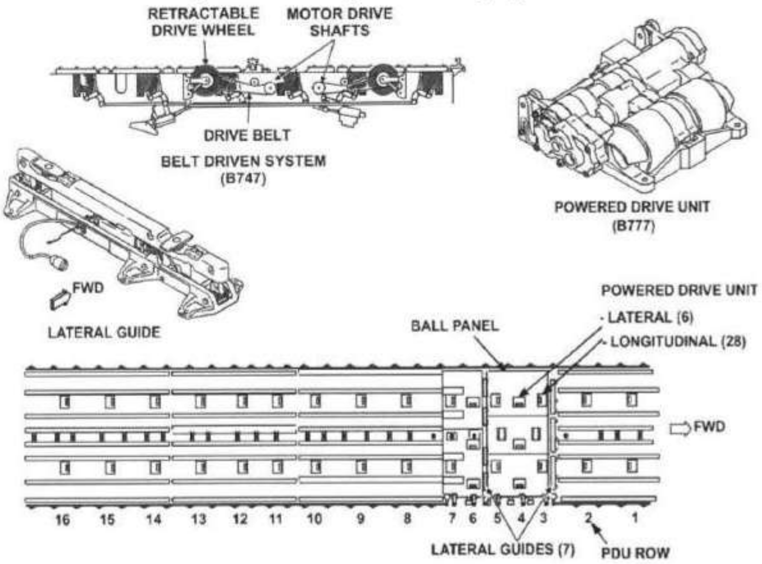


Figure 7.38 Motorized cargo loading systems Webbing and Nets

A cargo net is installed forward and aft of the door across each cargo compartment. Each net is divided into two sections joined together with quick-release fasteners. A vertical centre net is installed between the two cross-compartment nets.

One-inch wide nylon or polyester fabric straps are sewed together to form the webbing. Solid cloth panels are sewed to the straps in some areas to fill the openings between the straps. Quick-release tie down fasteners are sewed to the strap ends in some places on the outboard edges of the nets. Other strap ends have snap latches or buckles.

A stanchion fits into holes in the tie down tracks. Webbing can be attached to loop fittings on the stanchion.

Webbing and net material is normally polyester

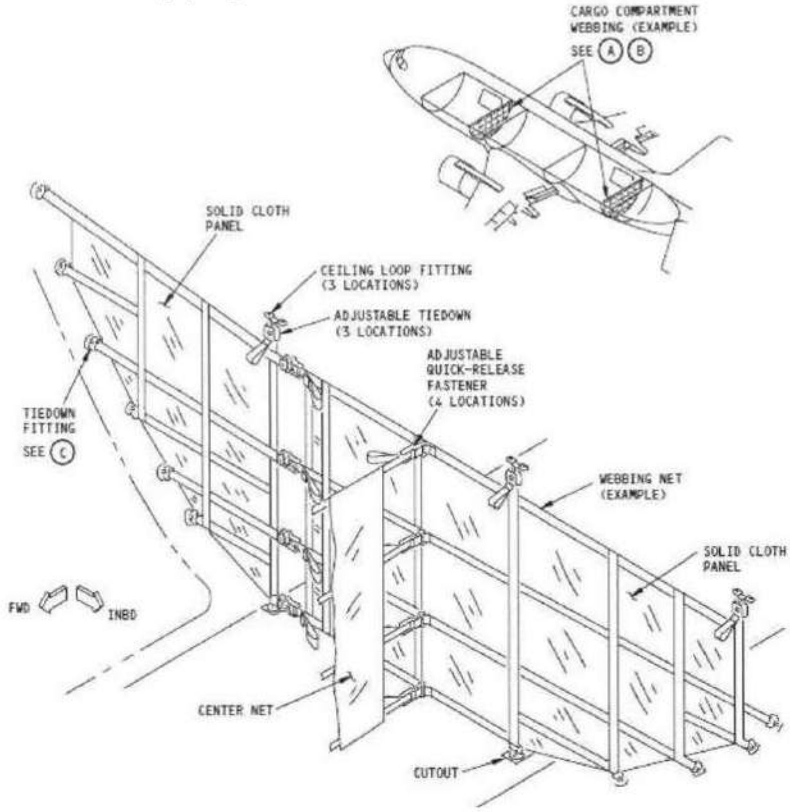


Fig. 7.39 Cargo webbing

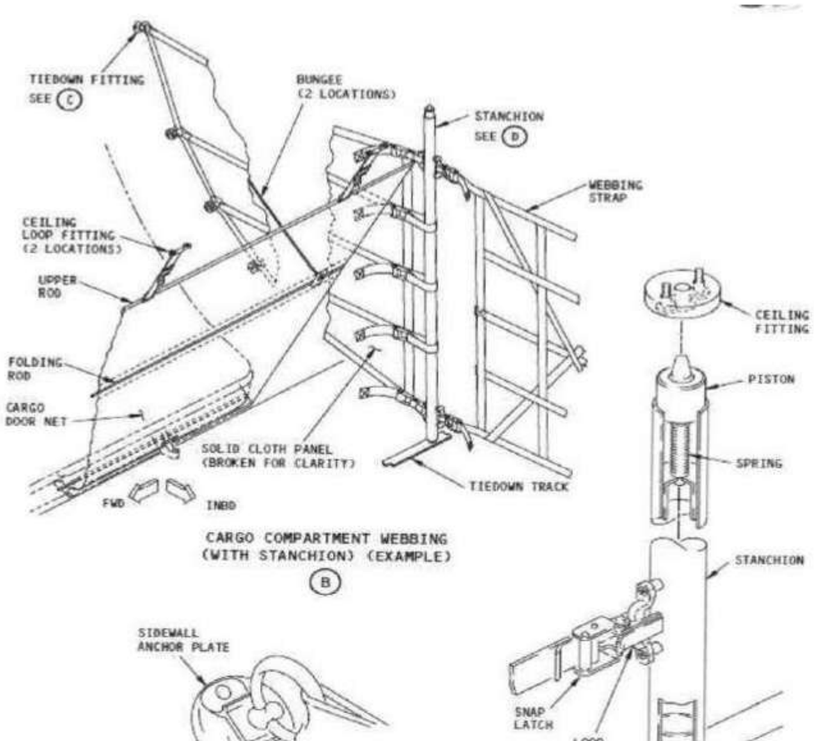


Fig. 7.40 Cargo webbing detail and stanchion Passenger Service Units (PSU)

General

Above the passenger seats are Passenger Service Units (PSU). These typically contain a reading light, air vent, and a flight attendant call button. The units frequently have small "Fasten Seat Belt" and "No Smoking" illuminated signage and may also contain a speaker for the cabin public addresssystem.

The PSU will also normally contain the drop-down oxygen masks which are activated if there is a sudden drop in cabin pressure. These are supplied with oxygen by means of a chemical oxygen generator.

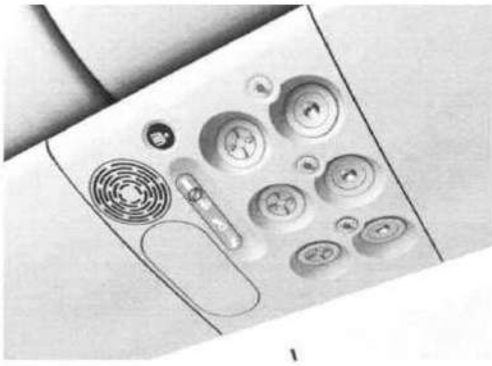


Fig. 7.41 Typical Passenger Service Unit

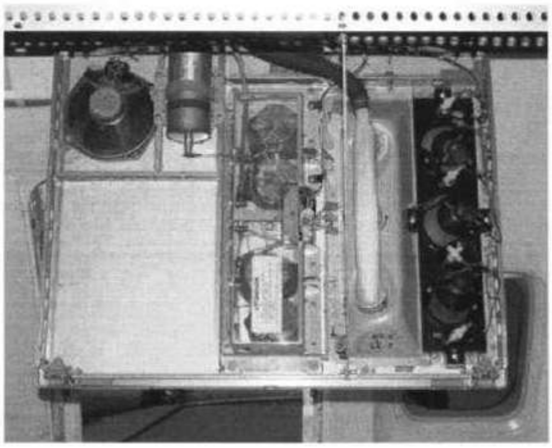


Fig. 7.42 Typical Passenger Service Unit lowered for access. From left to right: Speaker, Oxygen Generator, Oxygen masks, passenger signs, fresh air supply and louvres, reading light

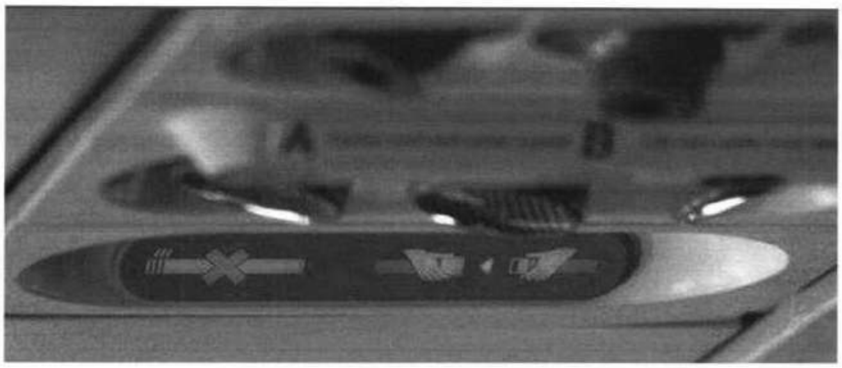


Fig. 7.43 Typical passenger signs in a Passenger ServiceUnit Passengersigns

Passenger signs give information to persons in the passenger compartment during a flight of the aeroplane. These signs tell the passengers and attendants when not to smoke, when to go back to their seats, and when to put on their seat belts.

The NO SMOKING signs tell the passengers and attendants when not to smoke. There is a sign in each Passenger Service Unit (PSU) and attendant'sstation.

On some aeroplane the NO SMOKING signs are operated with a switch in the flight deck. To operate these signs manually, the pilot sets this switch to the on position. When the switch is set to the automatic position, these signs come on automatically during takeoffs andlandings.

On some aeroplanes the NO SMOKING signs stay on during each flight of the aeroplane. You cannot make the signs go off with the NO SMOKING switch in the flight deck. This switch has a jumper wire installed to always keep the circuit closed.
The incandescent lamps in each NO SMOKING sign operate with the 28 volts AC of electrical power.
With the switch set to the automatic position, the signs come on when the landing gear lever is set to the down position.

When the NO SMOKING signs come on, the 28 volts dc also is supplied to the passenger address amplifier. The amplifier makes a chime sound .

The FASTEN SEAT BELT signs tell the passengers and attendants when to put on their seat belts. There is a sign in each Passenger Service Unit (PSU) and attendant's station.
The switch for these signs is in the flight deck. When the pilot sets this switch to the on position, the signs come on.

Some aeroplanes have an "AUTO" position on the "FASTEN BELTS" switch. When the switch is set to the automatic position, these signs come on only during takeoffs and landings. With the switch set to the automatic position, a relay is energized when the landing gear lever or the trailing edge flaps are in the down position. These conditions cause the signs to come on.

The incandescent lamps in each FASTEN SEAT BELT sign operate with the 28 volts AC of electrical power.

When the FASTEN SEAT BELT signs come on, the 28 volts DC also is supplied to the amplifier of the passenger address system. The passenger address system makes a chime sound.

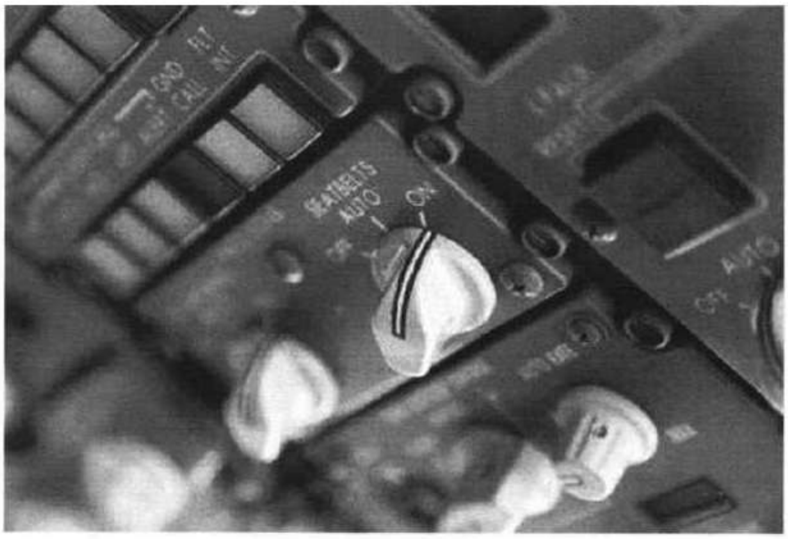


Fig. 7.44 Seat belt signs control on flight deck overhead panel Attendant Call

There is a call switch on each passenger service unit (PSU). The passenger pushes the switch to make a call. On the inner side of each PSU, there is a select switch. This switch controls which call light will come on when a passenger pushes the call switch.

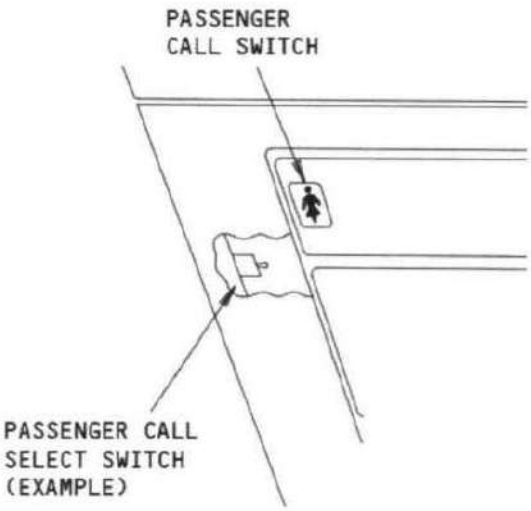


Fig. 7.45 Passenger call switch on the PSU

A call light shows the location of the person who has set a call switch to the on position to make a call for an attendant's aid. Each call light is installed on the bottom of an exit locator sign or on an attendant's service unit.

Each time a call is made, the call light for that location comes on and the passenger address system makes a chime sound.

The colour of the call light identifies the location of the person who made the call and type of aid that is necessary.

When a passenger call switch is pushed, then a passenger calls light and chime come on. The call light is supplied 28 volts DC. The passenger address amplifier operates on the same electrical power to make the chime sound.

You can push the call switch again to make the call light and chime go off. You can also make the call light and chime go off from the attendant's station.

Air stairs
General

The purpose of air stairs is to permit loading and unloading of passengers without the use of ground equipment. They;

- Can be retracted or extended with aircraft battery power or with aircraft 115 volt AC power. Others are hydraulically driven byactuators.

- Can be controlled from inside or outside theaircraft.

- Can be used with variations in cabin floor heights above the ground.

Air stairs consist of a rail installation upon which rides a carriage and ladder assembly with a handrail. The carriage and ladder assemblies are driven by an electric motor driven actuator. Other stairs are integrated in the passenger door.

Control circuits consist of limit switches and relays that sequence the driving of the air stairs door and air stairs actuators. Control selection can be either normal powered or a manual mode

The air stairs door is in the fuselage skin under the forward entry door or integrated in the door or folded into the aft section of the fuselage.

Fig. 7.46 Folding air stairs

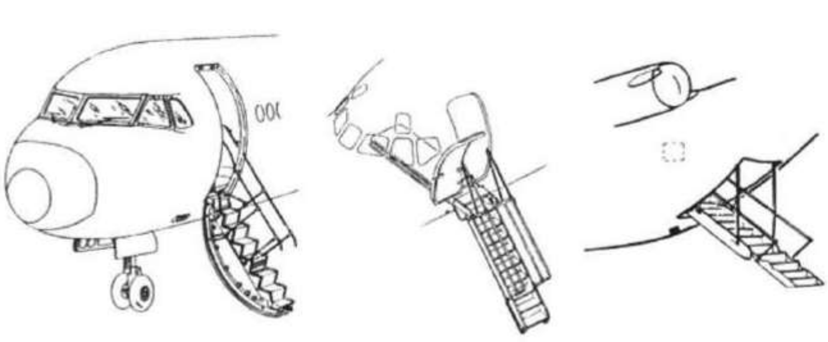


Fig. 7.47 Air stairs Examples

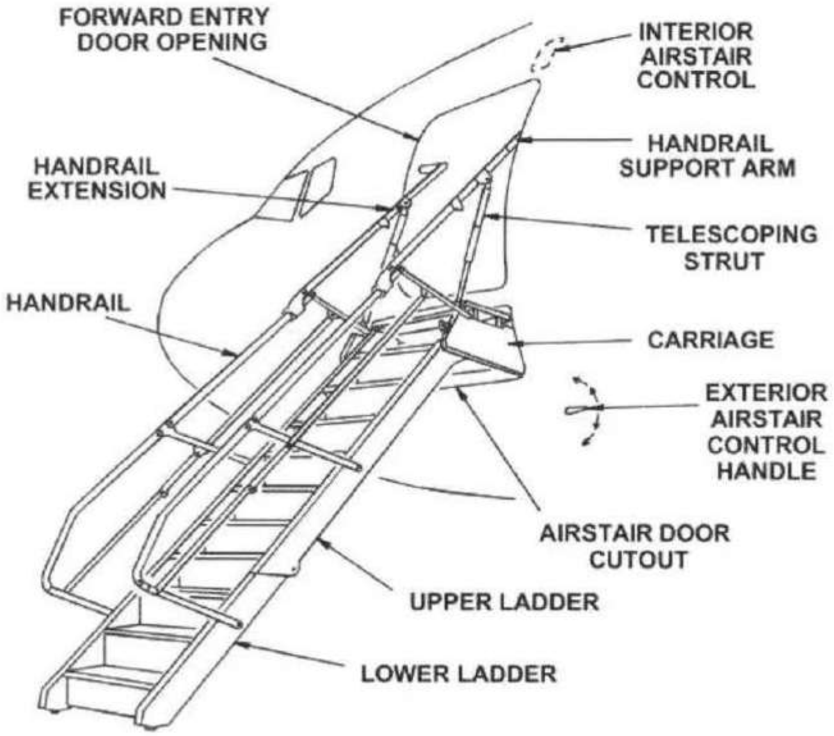
Folding / Retractable Air stairs

The folding / retractable air stair is an integral part of the aeroplane and, when extended, is used to load and unload passengers at the entry door. When retracted, the air stair is contained in an area under the passenger cabin floor at the entry door location. When the air stair is in the retracted position, the air stair door closes the cut-out in the fuselage directly below the forward entry door to form a smooth contour with the fuselage exterior skin.

The air stair is electromechanically operated and is provided with both normal and standby operating systems. The standby system provides the capability for air stair operation in the event of an electrical failure in the normal system.

The air stair operation can be controlled from either inside or outside the aeroplane. Control from inside the aeroplane is from a control panel located near the upper forward corner of the forward entry door. Control from outside the aeroplane is from a control handle located near the lower aft corner of the forward air stair door. The STAIRS OPERATING light on the interior control panel comes on when the air stair door and the stair are in an operating cycle. The light will remain on as long as the stair is in any position other than full extended with the air stair door open, or full retracted with the air stair door closed. The STAIRS OPERATING light will operate if dc power is provided by the normal aeroplane system either in normal or standby mode. If dc power is lost, the battery will provide power for air stair operation, but the STAIRS OPERATING light will not be active.

Inadvertent extension of the air stair while the aeroplane is in flight is prevented by a latch pin which prevents the air stair door frommovinginwardfromtheclosedposition.Thelatchpincan only be retracted by opening the forward entry door or by operating the air stair exterior control handle.
The air stair door is provided with micro switches which energize door warning lights on the control cabin forward overhead panel and master caution lights on the flight crew panel. These lights come on whenever the air stair door is UNLOCKED or OPEN and go off when the door is CLOSED and

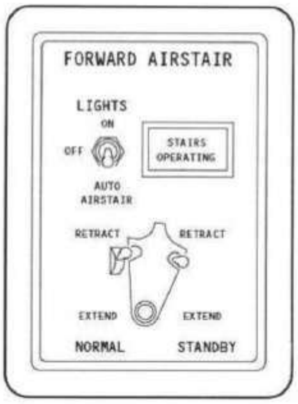


LOCKED.

Fig. 7.48 Folding air stairs components

Normal system uses aeroplane AC and DC power for operation. The standby system uses aeroplane DC and/or battery DC power for operation. Battery power is locked out whenever aeroplane DC power is available.

There are three modes of operation for the forward air stair and door; normal, standby, and manual. For normal operation, the air stair uses 115-volt AC 3-phase 400-cycle power and the air stair door uses 28-volt DC power. For standby operation, the air stair and the air stair door both use 28-volt DC aeroplane or battery power from the battery bus. When standby operation is selected, the handrail stowed limit switches are bypassed. During the retract cycle, it is important the handrails are stowed to avoid structural damage. For maintenance or emergency purposes, the air stair may be extended and/or retracted manually, and the air stair door may be operated manually and independent of the air stair. Air stair must be resequenced prior to power operation following manual extension and/or retraction.



During maintenance or when power is not available, the air stair door may be operated manually by removing the standby motor and applying torque to the input drive shaft of the actuator.

Fig. 7.49 Folding air stairs interior control panel

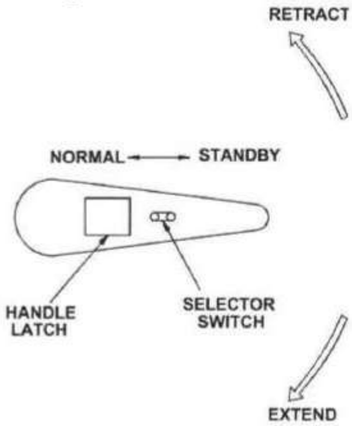


Fig. 7.50 Folding air stairs exterior control handle Air stair Operation

Mechanical System - The air stair actuation system consists of a
control assembly, motor- driven actuator, right angle gearboxes, ball screws, pinions, and various shafts and couplings.

The control assembly is used to engage and disengage the carriage drive pinions during removal and installation of the carriage for maintenance. The control consists of a cable, fork, and carriage pinion disconnect lever. The lever is located on the carriage at the outboard end of the aft beam. The lever is connected to a control cable which in turn is connected to the actuator transmission by a linkage and fork fitting.

Once the air stair is installed, the lever is lock wired and remains in the locked position.

The motor-driven actuator contains the transmission which transmits power through drive shafts to the carriage pinions and through drive shafts to the right angle gearboxes for the ball screws, which drive the upper ladder in the carriage tracks.

From the motion imparted to the carriage and upper ladder by the actuator, the carriage step, the lower ladder, and the handrails are operated by a series of cranks, linkage, and gear throughout various phases of the extend and retract cycles.

Electrical System - The air stair electrical system consists of a normal system ac stair motor, a standby system dc stair motor, relays, switches, circuit breakers, stair tread light, controls, and swing arms.
The motors are equipped with brakes to allow stopping the retract or extend cycles at any point in the cycle while preventing creep of the stairmechanism.

The relays and switches are used to provide power to the system components in the proper sequence to perform smooth operation of the airstair.

The circuit breakers in the aeroplane provide a means of power disconnect at the power bus to isolate the air stairs circuits.

There are lights provided to illuminate the stair treads. The lights are controlled to come on automatically when the air stair is fully extended and automatically go off when the air stair starts to retract.

The lights may be manually turned on or off when the air stair is in any position. The tread light control switch is located on the attendant's forward auxiliarypanel.

Swing arms are provided to give protection and support to the

electrical cabling between the rails and carriage and between the carriage and upper ladder. The swing arms are of tubular construction with a coil spring centre segment to provide flexibility when the carriage is in motion, relative to the rails, and when the upper ladder is in motion relative to the carriage.

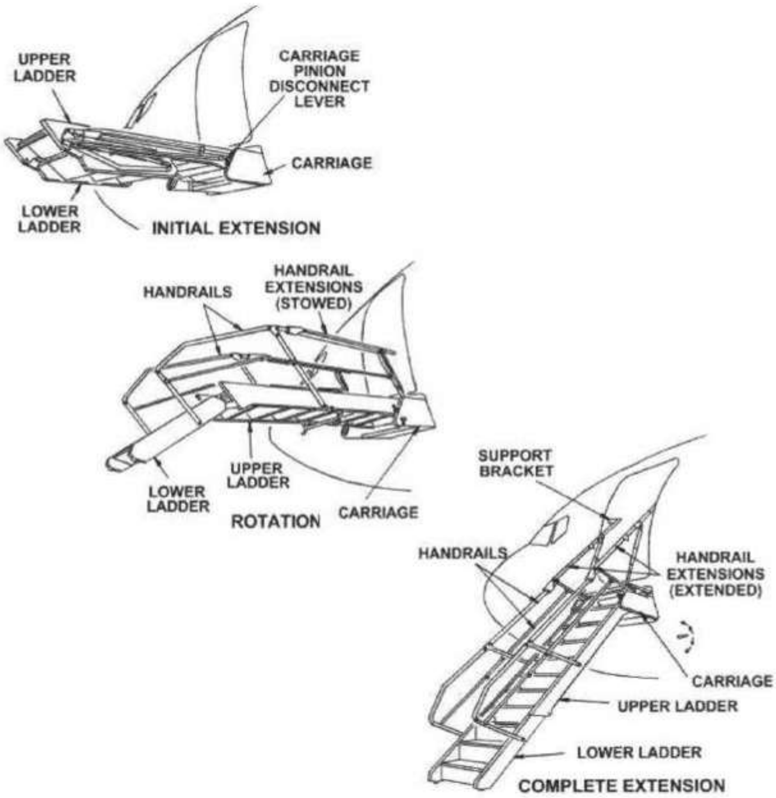


Fig. 7.51 Folding air stairs extension / retraction sequence Cabin Entertainment Systems Section 11.20 describes the In Flight Entertainment System in detail. The following description is an introduction to that system only.

In Flight Entertainment (IFE)

Passengers like to be entertained during the whole flight. The following entertainment and services are available.

Kind of entertainment	Performed by:
Food and Beverages Special Attention	Flight Attendants
Music	PES Audiotapes or CD's
Video Films and Games	PES Video Tape Reproducers or DVD's
Video Games interactive	PES Processors
Maps and Infos	Passenger Visual Information System
Telephone	Handset via SATCOM
Reading Light Control Attendand Call	PSS Passenger Service System

Table 7.1: Passenger Entertainment Systems Passenger Entertainment System (PES) Video, Music, Interactive Video Games and In-seat Telephone System Passenger Service System (PSS). Attendant Call, Individual Reading Light Control and No Smoking Light on/off Video Entertainment.

System

Installed in short and medium range aeroplanes, the purpose is:

- Passenger visual emergency instruction (Oxygen Mask, Life- vest)
- Advertising for tax freeshopping
- Flight Information Maps (Passenger Visual Information System)
- Information about arrival atdestination
- Shortmovies

The Passenger Entertainment Video System provides pre-recorded video programs through the LCD-monitors which are installed in the cabin as hat-rack mounted display units. The video sound can be heard from the cabin loudspeakers.

Video Tape Reproducer (VTR)

The video tape reproducer plays video cassettes. Beside regular controls of the reproducer there are controls for advanced presentation options like repeat and random access mode.

Video System Control Unit

Different controls allowing the management and distribution of video and sound to the cabin. The following controls are possible.

- Powerswitching

- Signal source selection VTR or InformationSystem
- Monitor selection (Display Units) in various cabinareas
- Previewing of avideo

Hat-rack Mounted Display Units

Retractable LCD screens are located in the hat-rack overhead the passenger. They are stowed if the system is not in use, or an unexpected force is applied e.g. passenger's head touches the screen.

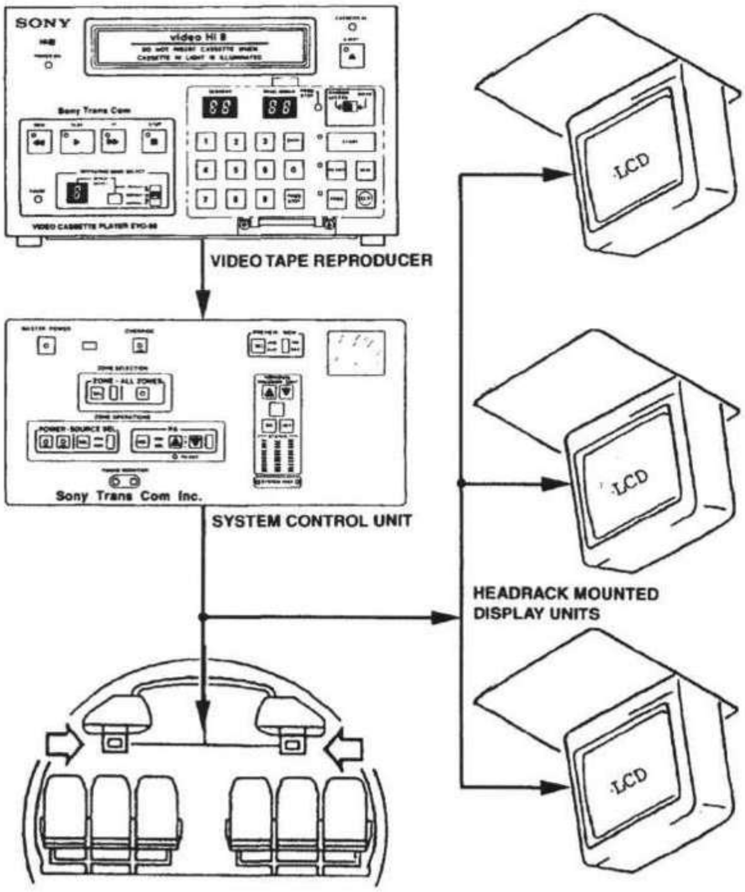


Fig. 7.52 Video Entertainment and Information System Passenger Visual Information System

The Passenger Visual Information System supplies the Passengers

with information on ambier aircraft flight data, times and aircraft position in the flight plan. The information is displayed on the monitors of the Passenger Entertainment System.

The system receives data from various Navigation Systems and the Aircraft Communication Addressing and Reporting System (ACARS).

The Remote Control Unit (RCU) is the input unit on which the shown information is selected by the use of menus. Its front plate has four switches in line under an LCD, for control.

The Digital Interface Unit (DIU) computer processes data for use with the stored menus, transforms the digital data into video signals and sends them to the monitors. The available information menus and the data used from the different input buses (e.g. altitude, static air temperature, heading and drift angle, ground speed and present position).

The following information can be selected and shown to the passengers:

- Airline logo or othersymbols
- Present aircraft groundspeed
- Time required to reach thedestination
- Present flightaltitude
- Outside airtemperature
- Local time at the destinationairport
- Flight route already completed on differently scaledmaps
- Present aircraft position on differently scaledmaps
- Special points of interest along the flight path on a map

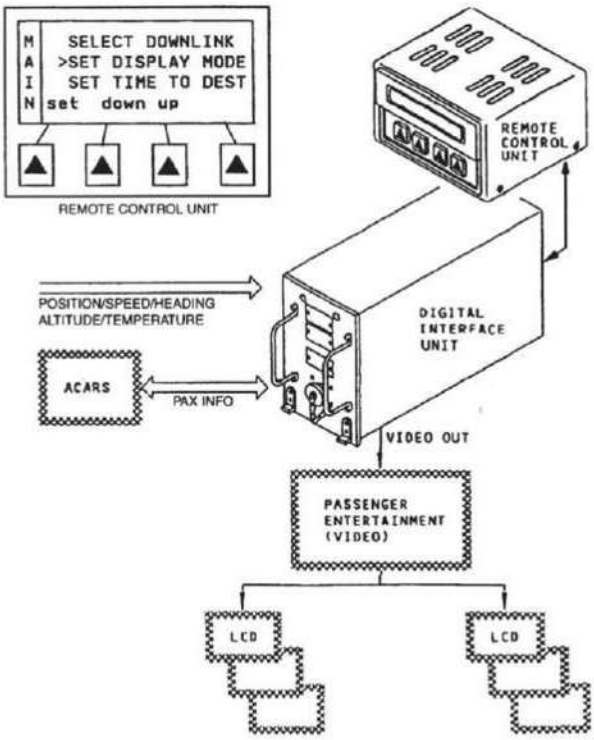


Fig. 7.53 Info and Map Display

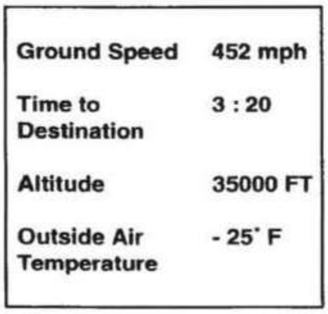


Fig.7.48 PVIS

Passenger Entertainment System (PES)

Long haul aircraft will be equipped with more complex systems. The systems may provide the following features:

- Video on individualscreens
- Music and film tracksound
- InteractiveGames
- Inseat Telephone

Video entertainment

Video entertainment is provided via a large video screen at the front of a cabin section, as well as smaller monitors situated every few rows above the aisles. Sound is supplied via the same headphones distributed for audio entertainment.

However, personal televisions (PTVs) for every passenger are providing passengers with channels broadcasting new and classic films, as well as comedies, documentaries, children's shows and drama series. Some airlines also present news and current affairs programming, which are often pre-recorded and delivered in the early morning before flights commence.

Fig. 7.54 Personal television (PTV) displays

PTVs are operated via an In-flight Management System which stores pre-recorded channels on a central server, and streams them to PTV equipped seats during flight via multiplexing techniques. AVOD systems store individual programs separately, allowing a passenger to have a specific program streamed to them privately, and be able to control the playback.

Some airlines also provide video games as part of the video entertainment system.

Closed Captioning technology started in 2008. It is text streamed along with video and audio. This will enable passengers to enable or disable the subtitle/caption language. Closed Captioning is capable to stream various text languages. The technology is currently based on Scenarist file multiplexing so far; however, portable media players tend to use alternative technology.

In-flight movies

Regularly scheduled in flight movies began to premiere in 1961 on flights from New York to Los Angeles. Personal on-demand videos are stored in an aircraft main IFE computer system. From there they can be viewed on demand by the user. Along with the on-demand concept comes the ability for the user to pause, rewind, fast forward, or jump to any point in the movie. There are also the movies that are shown throughout the aircraft at one time, usually on a screen in the front of thecabin.

Personal Television (PTV)

Some airlines have now installed personal televisions (otherwise known as PTVs) for every passenger on most long-haul routes. These televisions are usually located in the seat-backs or tucked away in the armrests for front row seats and first class. Some show direct broadcast satellite television which enables passengers to view live TV broadcasts. Some airlines also offer video games using PTV equipment.

Audio-video on demand (AVOD)

Entertainment has also been introduced. These enable passengers to pause, rewind, and fast-forward or stop a program that they have been watching.

This is in contrast to older entertainment systems where no interactivity is provided for. AVOD also allows the passengers to choose among movies stored in the aircraft computer system

In addition to the personal televisions that are installed in the seatbacks, a new portable media player (PMP) revolution is under way. There are two types available: commercial off the shelf (COTS) based players, and proprietary players. PMPs can be handed out and collected by the cabin crew, or can be "semi- embedded" into the seatback or seat arm. In both of these scenarios, the PMP can pop in and out of an enclosure built into the seat, or an arm enclosure.

Passenger Control Units and/or Passenger Handsets are used to control the PES/PSS. For the satellite telephone system the reverse side of the handset isused.

In-Flight Games

Video games are another emerging facet of in-flight entertainment. Some game systems are networked to allow interactive playing by multiple passengers.

Later generations of IFE games began to shift focus from pure entertainment to learning. The best example of this changing trend is Berlitz Word Traveller that allows passengers to learn a new language in their own language. Appearing as a mixture of lessons and mini games, passengers can learn the basics of a new language while being entertained. Many more learning applications continue to appear in the IFE market.

Fig. 7.55 IFE control integrated in an arm rest Multiplex Techniques

The idea of multiplexing/de-multiplexing is to send data from several sources down the one data transmission line - thus saving weight. A multiplexer is a device that allows digital information from several sources to be routed onto a single line for transmission over that line to a common destination. The basic multiplexer has several data-input lines and a single output line. It also has data select inputs (or address lines), which permit digital data on any one of the inputs to be switched to the output line. A multiplexer with 2 data select lines will have 22 = 4 data inputs. A multiplexer with 3 data select lines will have 23 = 8 data inputs and so on.

One example is in passenger entertainment systems where the passenger can select one audio/visual channel from amongst many channels supplied to the seat. These channels (inputs) are “multiplexed” in that each input is sampled and passed in serial fashion along a data line.

When the passenger selects the required service e.g. the film channel, then only the information on that line relevant to the film channel is selected by a "de-multiplexer" and fed to the passenger.

A multiplexer / de-multiplexer system can be likened to a train service with several trains waiting at the platforms of say a major London station. They are all destined to go to the same town — say Manchester — with the same number of platforms, but only one main line between the two cities. Each train leaves its platform in turn and is caused to go onto the main line by a set of points (multiplexer). It travels on the main line until it reaches its destination station where it is caused to go its own platform by another set of points(de-multiplexer).

Each train is sent down the same main line in this fashion. Data can be transmitted like this, but at much greater speeds of course.

Figure 7.56 shows four data channels operating at 200 bits/sec. The buffer store is a holding store until access to the data highway is signaled. This store is a shift register, in that its function is to store convert parallel data, and release it as serial data.

The duration of each bit is 1/200s or 5ms (5 milliseconds) so an 8 bit word occupies 40ms. The common line is operated at input channel speed times the number of channels i.e. 4 x 200 =
800 bits/sec. So each bit will have a time slot of 1,25ms.

Data from the systems connected to Channels 1, 2, 3 and 4 are fed

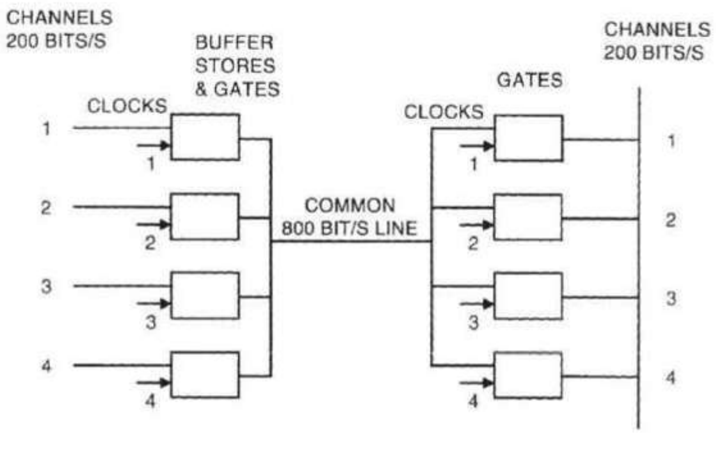
into a Buffer Store, until each store is signalled by the clock pulse to output its data onto the common line in sequence.

As can be seen from the diagram there must be some way of converting these signals to the appropriate receiving channel, i.e. channel 1 input signal data to be picked up by channel 1 receiving channel.

This will be by a de-multiplexer, a device with a single input but with multiple outputs.

There obviously has to be synchronization between the input and output channels to ensure that each data goes to the correct channel. Thus all the system works on the command of the clock (electronic). To ensure that the DMUX receives the clock pulse simultaneously with the receipt of the data, the clock pulse is carried on a separate line between the MUX and DMUX (not shown on the diagram).

Fig. 7.56 4-channel multiplexor system



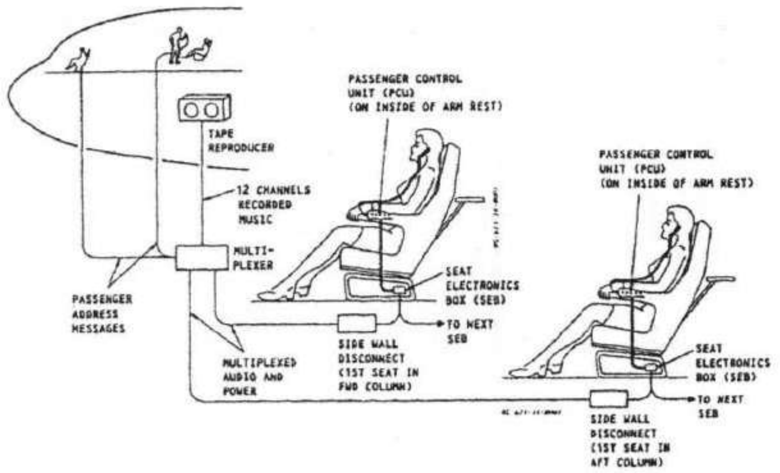


Fig. 7.57 A practical multiplexed system System Controls

A very important requirement is that the Passenger Address System must interrupt all other inputs to the loudspeakers and to the displays and earphones in the seat in order to get all the passengers' attention.

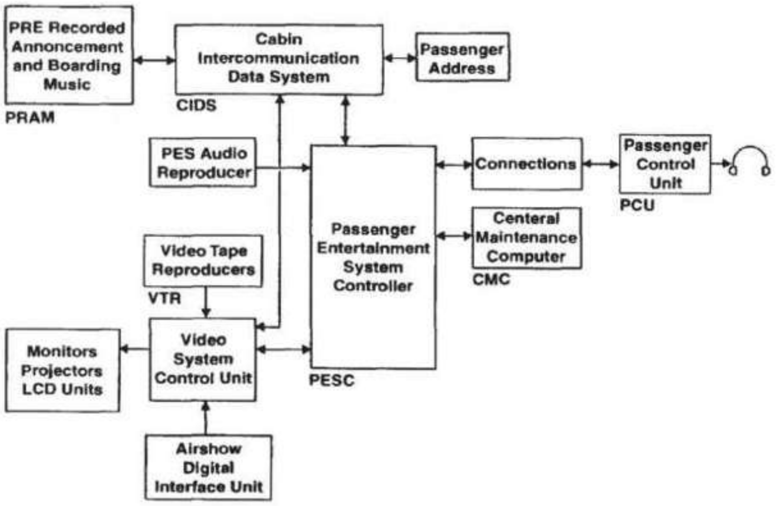


Fig. 7.58 PES Audio and Interface to PSS simplified

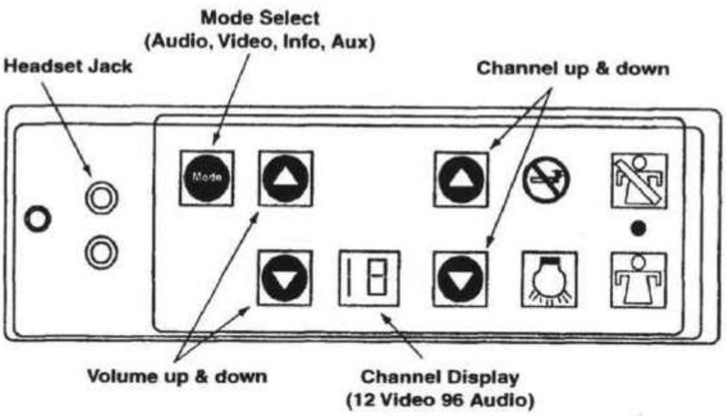


Fig.7.59 Passenger Control Unit (PES Controls) Passenger Service System

Reading light control and attendant call is controlled via this subsystem. In comparison with conventional wiring, a reduction of wiring will result.

A passenger reading light command for example, coming from the handset in the seat passenger control unit, makes its way through the passenger entertainment system controller and further on to the CIDS system where the correct passenger service unit above a seat must be addressed and the correct reading light must be illuminated.

Both systems, the CIDS and the Passenger Entertainment System, must work correctly together to make sure that all functions are available.

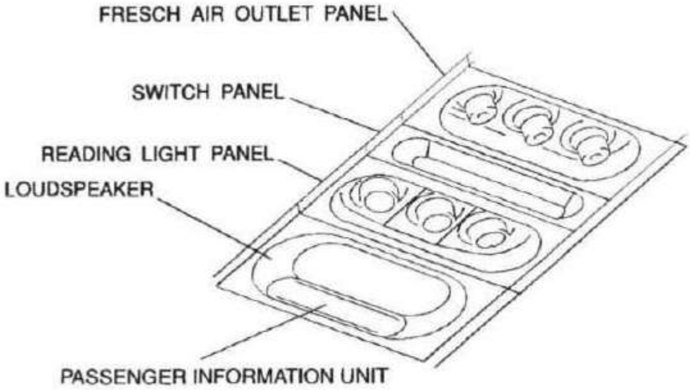


Fig. 7.60 PassengerServiceUnit

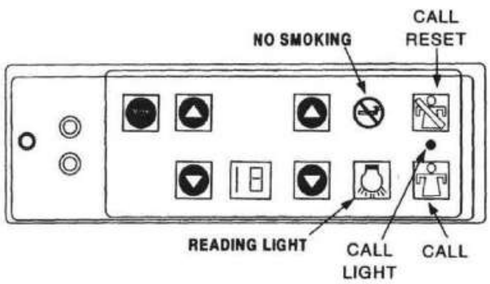


Figure 7.56: Passenger Control Unit (PSS Controls)

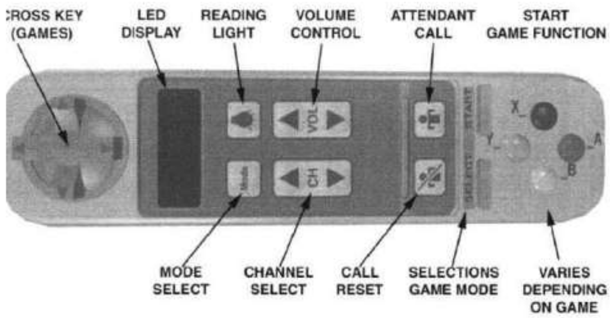


Fig. 7.61 Passenger Handset

Matsushita System 2000E

The design of passenger entertainment and service systems is continuously developing. Here the MAS2000 is briefly explained.

System 2000E is an interactive, fully integrated passenger entertainment system.

The system is designed with a modular approach to support Overhead and In-seat Video, Audio, Telephone, and Interactive Services.

Audio:
- Up to 96 Channels of Hi-FiAudio
- Up to 48 Digital AudioInputs
- Up to 72 Analogue Audio Inputs
- Up to 6 Passenger Address (PA)Inputs

Video:
- Up to 24 Channels. Supporting a wide variety ofinputs:
- Video CassettePlayers
- TVTuners
- Passenger Video InformationSystems
- VideoCameras
- Video On Demand (VOD)

Telephone services can be made available at each seat:
- Air-to-Groundcalls
- Seat to seat calling
- Fax and Datatransmission

A variety of interactive options to customize the cabin environment and passengerexperience:
- VideoGames

Nintendo oWindows-based
- ShoppingServices
- BusinessServices
- Passenger Information Services
- ProgramInformation
- Audio/Video

Passenger Service System provides the passenger with an interface to:
- ReadingLights
- Attendant CallLights

Fire Classes

Fire is the result of a chemical reaction between some types of fuel and oxygen. When this reaction occurs, energy is released in the form of heat and light. For a fire to start there must be fuel, oxygen, and a high enough temperature to start the reaction. Fires may be extinguished by removing the fuel or oxygen or by reducing the temperature to a level below that needed for the reaction.

Fires are categorized by the European regulation EN3 and are identified by the types of extinguishing agents best used on each type. The five categories are Classes A, B, C, D and F.

- Class A fires are fuelled by solid combustible materials such as wood, paper, and cloth. These fires typically occur in aircraft cabins and cockpits, so any extinguishing agent used for Class-A fires must be safe for theoccupants.

- Class B fires are fuelled by combustible liquids such as gasoline, turbine- engine fuel, lubricating oil, and hydraulic fluid. Those fires occur in enginecompartments.

- Class C fires involving gases such as butane, methane and propane.
- Class D fires are those in which some metal such as magnesium burns. These fires typically occur in the brakes and wheels, and burn with a ferocious intensity. Never use water on a burning metal, it only intensifies thefire.

- Class F fires are those involving cooking oils andfats.

There was a Class E, those fires involving electrical equipment. However, that class has been removed, as electricity is technically not a fuel for fire, but rather a source of ignition and the fuel can be any of the types listed above. You may see the Class E listed in some texts and safety wall charts however.

In the USA, Australia and Asia, the classes of fire are somewhat different from the European designations. EASA occasionally use the USA designations in their regulatory literature.

Requirements for Fire

The fire triangle or combustion triangle is a simple model for understanding the ingredients necessary for most fires.

Fig. 8.1Hire triangle

The triangle illustrates a fire requires three elements: heat, fuel, and an oxidizing agent (usually oxygen). The fire is prevented or extinguished by removing any one of them. A fire naturally occurs when the elements are combined in the right mixture.

Without sufficient heat, a fire cannot begin, and it cannot continue. Heat can be removed by the application of a substance which reduces the amount of heat available to the fire reaction. This is often water, which requires heat for phase change from water to steam. Introducing sufficient quantities and types of powder or gas in the flame reduces the amount of heat available for the fire reaction in the same manner. Scraping embers from a burning structure also removes the heat source. Turning off the electricity in an electrical fire removes the ignition source.

Without fuel, a fire will stop. Fuel can be removed naturally, as where the fire has consumed all the burnable fuel, or manually, by mechanically or chemically removing the fuel from the fire.

Without sufficient oxygen, a fire cannot begin, and it cannot continue. With a decreased oxygen concentration, the combustion process slows. In most cases, there is plenty of air left when the fire goes out so this is commonly not a major factor.

Fire and Explosion Protection Systems on Aircraft

There are five general types of fire and explosion protection applications for aircraft:
- total-flood fireextinguishment
- total-flood firesuppression
- streaming fireextinguishment
- explosion suppression,and
- inertion against explosions andfires.

In total-flood applications, an extinguishing agent is discharged into an enclosed space to achieve a concentration sufficient to extinguish or suppress an existing fire. The agent concentration that a system/agent combination is designed to produce is termed the "design concentration." Total-flood extinguishment usually uses fixed systems (e.g.,non-portable systems attached to a

protected structure) with either manual or automatic activation. Automatic systems detect a fire and automatically discharge the extinguishing agent. Total-flood applications include protection of enclosed spaces, such as aircraft cargo compartments.

In streaming applications, an agent is applied directly onto a fire or into the region of a fire. This is usually accomplished using manually operated, wheeled, or portable extinguishers. Hand-held portable extinguishers provide fire protection in aircraft passenger compartments.

The fire protection system includes:
- Fire detection systemand
- Fire extinguishingsystem

The Overheat Detection System detects temperatures that are too high. It is related to the fire alarm system. Overheat detection methods use thermal switches or overheat detectors.

The Fire Detection System consists of fire sensing elements and smoke detectors. Fire sensing elements can operate on the basis of change in resistance, change in resistance and capacity and pressure increase.

Smoke detectors detect the smoke arising from fire. There are two types of smoke detectors: ionizing and optical smoke detectors.

Fixed fire extinguishers are available for fighting a fire in engines, in the Auxiliary Power Unit compartment and in the cargo and baggage compartments.

Portable fire extinguishers are used to fight fires in cockpit, cabin and lavatories.

Aircraft Fire Zones

For the purposes of fire protection and extinguishing, all compartments of an aeroplane are classified A, B, C or E, as follows:

- Class A - Visual detection of smoke and have an accessible in- flight fire extinguisheravailable.

- Class B - There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station. There is sufficient access in flight to enable a crewmember to effectively reach any part of the compartment with the contents of a hand fire extinguisher. When access provisions are being used, no hazardous quantity of smoke, flames, or suppression agent can enter any compartment occupied by the crew or passengers. There are means to control ventilation and drafts within thecompartment.

- Class C - here is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station. There is an approved built-in fire extinguishing or suppression system controllable from the flight deck. There are means to exclude hazardous quantities of smoke, flames, or suppression agent from any compartment occupied by the crew or passengers. There are means to control ventilation and drafts within the compartment so that the suppression agent used can control any fire that may start within the compartment.

- Class D - Classification removed in1998.

- Class E - Cargo-only aircraft. There is a separate approved smokeorfiredetectorsystemtogivewarningatthepilotor

flight engineer station. There are means to shut off the ventilating airflow to, or within, the compartment, and the controls for these means are accessible to the flight crew in the crew compartment. There are means to exclude hazardous quantities of smoke, flames, or noxious gasses from the flight crew compartment. The required crew emergency exits are accessible under any cargo loading condition.

Fig 8.2 Fire protection in a typical cargo compartment. This main deck cargo compartment illustrates two types of fire protection: liners on the sidewalls and smoke detectors running overhead.

Fire Detection Systems General

A complete fire detection system consists of fire detectors; overheat detectors, rate-of- temperature-rise detectors, smoke detectors, and carbon monoxide detectors. We will discuss each ofthese.

Requirements for a fire detection system:
- Thesystemmustnotgivefalsewarningsunderanyflightor
ground operating condition
- The system must give a rapid indication of a fire and accurately identify itslocation.
- The system must accurately indicate when a fire has been extinguished.
- The system must sound a warning if a firere-ignites
- The system must continue to indicate the presence of a fire as long as the fireexists.
- The integrity of the system must be able to be tested from the cockpit.
- Detectors must not be damaged by exposure to oil, water, vibration, extremes of temperature, and the handling encountered in normalmaintenance.
- Detectors must be lightweight and adaptable to any mounting position.
- Detector circuitry must operate directly from the aircraft electricalsystem.
- The detector circuitry must require a minimum of electrical current when it is not indicating afire.
- Each detection system should actuate an audible alarm and a cockpit light that shows the location of thefire.
- There must be a separate detection system for eachengine

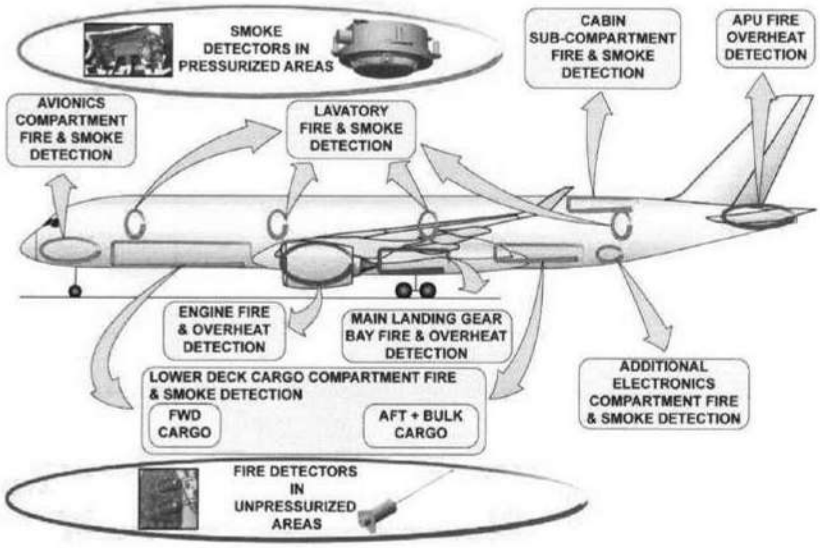


Fig. 8.3 Areas of a typical transport category aircraft that contain fire and smoke detection systems (Airbus A350)

Types of Fire Detector System Unit Type Detectors
These include the following types, although some are now fitted only on older types of aircraft and are not considered further in this Leaflet.

- Melting-link Switches: These switches consist of a pair of contacts held apart by a mechanism which is released when a fusible compound melts. At a predetermined temperature the compound melts, allowing the contacts to come together and complete the circuit to a warninglamp.

- Thermo-coupleDetectors:Theseunitsareusedtooperatea

sensitive relay or electronic circuit when a predetermined temperature is exceeded.

- Differential Expansion Switch: This type of unit detector is often used in engine installations and combustion heater zones. The switches operate on the principle of the difference in the coefficients of expansion of dissimilar metals, and reset automatically when the ambient temperature is reduced below the warninglevel.

Continuous Type Detectors

To ensure efficient detection of fire a considerable number of unit detectors may be necessary in some installations, and in such cases continuous type detectors are normallyused.

- Continuous Wire Type Detectors: These detectors operate on either of two principles, the mode of operation depending on the type of control unit fitted to the system. Detector elements are manufactured in various lengths and may be joined together to form a continuous detector loop which is routed round the installation as required. An element consists of a stainless steel or inconel tube, with one or two centre electrodes insulated from the tube by a temperature sensitive material. In certain circumstances elements are enclosed in a perforated armoured sheath which gives protection from randomdamage.

- Resistance Type: The resistance of the insulating material decreases with an increase in temperature until, at the warning temperature, sufficient current passes to operate a warning circuit the element is fed with a current which is passed through a control box for operation of the warning system.

- Capacitance Type: The element forms a capacitor, the capacitance of which increases with increased temperature. The central electrode is fed with halfwave alternating current which it stores and returns to a control unit during the second half of the cycle. The stored charge increases with the temperature and, when the warning temperature is reached, the back current is sufficient to operate a relay in the warning circuit. The main advantage of the capacitance system is that a short circuit grounding the element or wiring does not result in a falsefirewarning.

Older (Obsolete)Types

- Liquid Type Detector: This detector consists of a tube and expansion chamber filled with liquid. If a short length of the tube undergoes a sudden rise in temperature, the liquid expands and builds up a pressure differential across an orifice leading to the expansion chamber. A Bourdon tube is thereby deflected to close a pair of electrical contacts.

- Pyrotechnic Flame Switch: This consists of a metal capillary housing a pyrotechnic cord which will ignite if sufficient heat or flame touches any part of the capillary length. If this occurs pressure is generated within the capillary and operates a switch mechanism.

Thermal Switches

Thermal switches are switches that have a switching contact provided with a bimetallic strip. If the switch is heated, the bimetallic strip makes the contact in the switch which turns on a warning light on the flight deck.

The single-terminal bimetallic thermoswitch-type spot detector circuit uses a number of spot detectors. When a fire occurs in the area protected by one of the detectors, the detector is heated, and strips on which the contacts are mounted distort and close the contacts, completing the circuit between the loop and ground.

The circuit will signal the presence of a fire even if the loop of wire connecting the detectors is broken. During normal operation the detectors get their power from both ends of the loop, and if the loop is broken at any one point, all of the detectors still have power. If anyone detector senses a fire, its contacts will close and provide a ground for the fire-warning light. Closing the fire- warning test switch energizes the test relay, removes power from one end of the loop and grounds it, turning on the fire-warning light and sounding the bell. If there is an open in the wire between the detectors, there will be no ground for the warning light, and it will not illuminate.

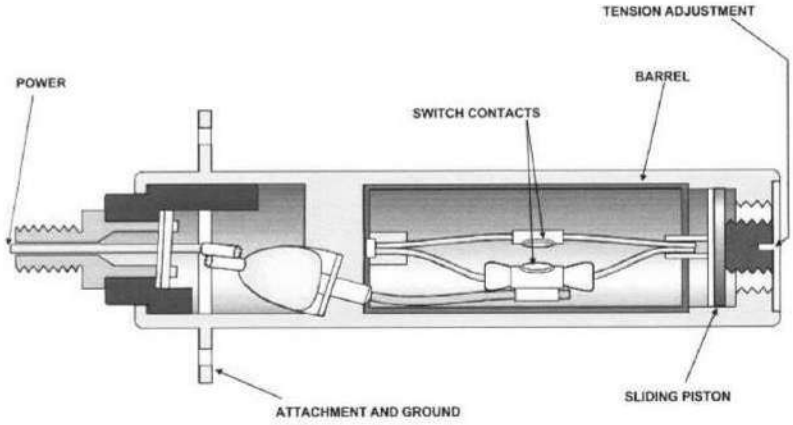


Fig. 8.4 Bimetallic thermal switch

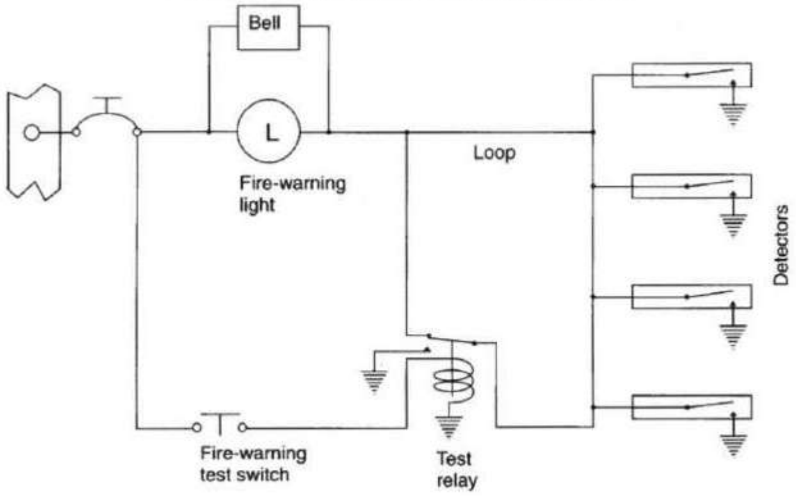


Fig. 8.5 Single loop overheat fire detection circuit Rate-of-Temperature-Rise Detection System

A thermo switch-type detection system initiates a fire warning when any of the individual detectors reaches a predetermined temperature. A fire can have a good start before this temperature is reached. The fire-warning system used initiates a fire warning when the temperature at any specific location in the monitored compartment rises a great deal faster than the temperature of the entire compartment.

Thermocouple-type fire-warning systems are often installed in engine compartments where normal operating temperatures are quite high, but the rise to this temperature is gradual.

A thermocouple is made of two different types of wire welded together, and the point at which the wires are joined is called a junction. When several thermocouples are connected in series in a circuit, a voltage will exist within the circuit that is proportional to the difference in the temperatures of the various junctions. These sensors have a piece of each of the two thermocouple wires, typically iron and constantan, welded together and mounted in the housing that protects them from physical damage, yet allows free circulation of air around the wires.

They form the measuring junctions of the thermocouple, and all of them are connected in series with the coil of a sensitive relay and a test thermocouple.

The sensors are mounted at strategic locations around the monitored compartment. One sensor is mounted inside a thermal insulating shield that protects it from direct air circulation. This sensor is the reference junction. When there is no fire, all of the junctions are at the same temperature and no current flows in the thermocouple circuit.

When the engine is started and the temperature of the engine compartment rises, the temperatures of all of the thermocouples rise together and there is still no current flow.

If there is a fire, the temperature of one or more of the thermocouples will rise immediately while the temperature of the insulated reference thermocouple rises much more slowly. The difference in temperatures will produce a current in the thermocouple loop. If the current is greater than 4 mill amperes, the sensitive relay will close. The slave relay is energized by current through the contacts of the sensitive relay, and the fire- warning light and bell is turned on.

The system is tested by closing the test switch for a specified time. Current flows through the heater inside the test thermocouple housing and heats up the test thermocouple. This cause current to flow in the thermocouple loop, and the fire- warning light and bell will turn on.

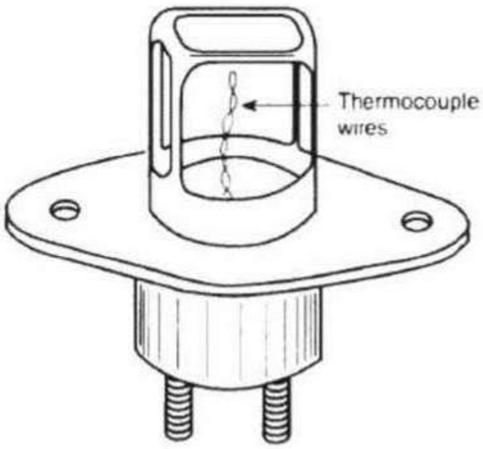


Fig. 8.6 Thermo couple fire sensor

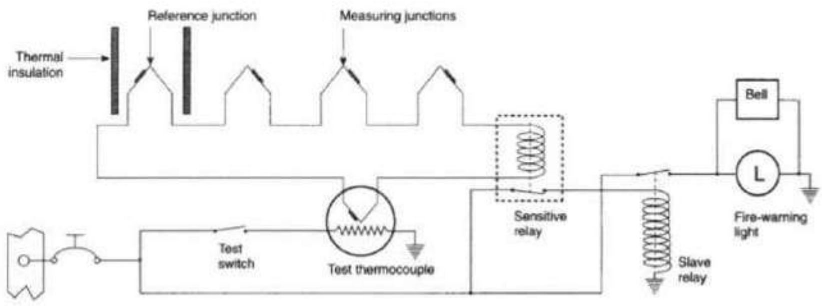


Fig. 8.7 Overheat- Fire- detection circuit Continuous-Loop Detector Systems

A continuous-loop detector or sensing system permits more complete coverage of a fire hazard area than any type of spot-type temperature detectors. The continuous-loop system works on the same basic principle as the spot-type fire detectors, except that instead of using individual thermal switches the continuous-loop system has sensors in the form of a long inconel tube.

These are overheat systems, using heat sensitive units that complete an electrical circuit 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 Fenwall and the Kidde systems.

Fenwall System

The Fenwall system uses a single wire surrounded by a continuous string of ceramic beads in an inconel tube. The beads in this system are wetted with a eutectic salt which possesses the characteristics of suddenly lowering its electrical resistance as the sensing element reaches its alarmtemperature.

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

The Fenwall system uses a magnetic amplifier control unit. This system is non-averaging but will sound an alarm when any portion of its sensing element reaches the alarmtemperature.

Kidde System

In the Kidde continuous-loop system two wires are imbedded in a special ceramic core within an inconel tube. One of the wires 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 an electrical current signal when the ceramic core material changes its resistance with a change intemperature.

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 hot spot.

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

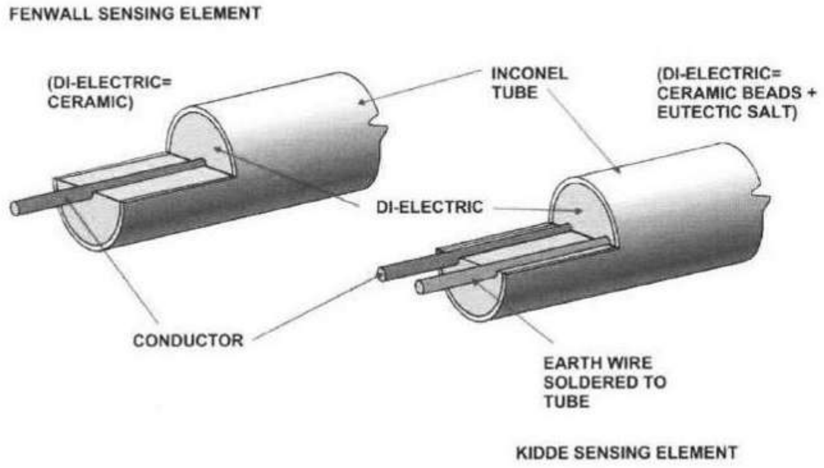


Fig. 8.8 Sensing elements (Fenwall and Kidde)

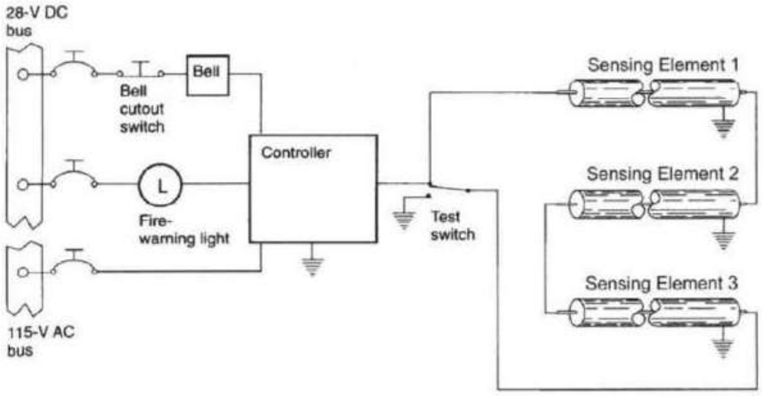


Fig. 8.9 Electrical circuit

Pneumatic Types Fire/Overheat Detectors

The continuous-loop fire detection system initiates a fire warning signal when any portion of the continuous loop reaches a temperature for which the loop element is designed. The pressure- type sensor responder system actuates when any portion of the element reaches a temperature that would signal a fire condition, or when a large portion of the element is exposed to a higher temperature, as could happen in an overheat condition that could cause structural damage, or precede a fire.

The sensitive element of this system consists of a sealed gas-filled tube containing an element that absorbs gas at a low temperature and releases it as the temperature rises. The tube is connected to a pressure switch that will close when the gas pressure in the tube reaches a predetermined value.

Two slightly different types of this system may be found in use, the Lindberg system and the Systron-Donner system.

Lindberg System

The Lindberg fire detection system is a continuous-element type detector consisting of a stainless steel tube containing a discreet element. This element has been processed to absorb gas in proportion to the operating temperature set point. When the temperature rises (due to a fire or overheat condition) to the operating temperature set point, the heat generated causes the gas to be released from the element. Release of the gas causes the pressure in the stainless steel tube to increase. This pressure rise mechanically actuates the diaphragm switch in the responder unit, activating the warning lights and an alarm bell.

To test this system, low-voltage AC is sent through the outer sheath of the element. When this current heats the sheath to the required temperature, the element will release gas and the pressure on the diaphragm will close the contacts and initiate the fire warning. When the test switch is released, the detector element will cool off, the contacts will open, and the fire warning will stop.

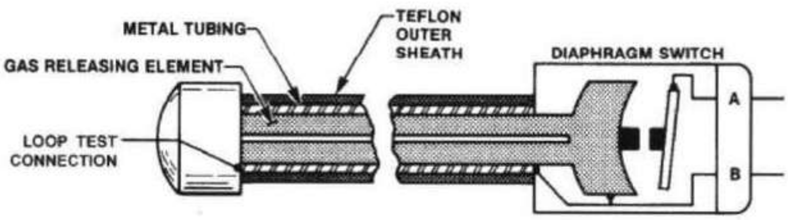


Fig. 8.10 Sensing element (sectioned view)

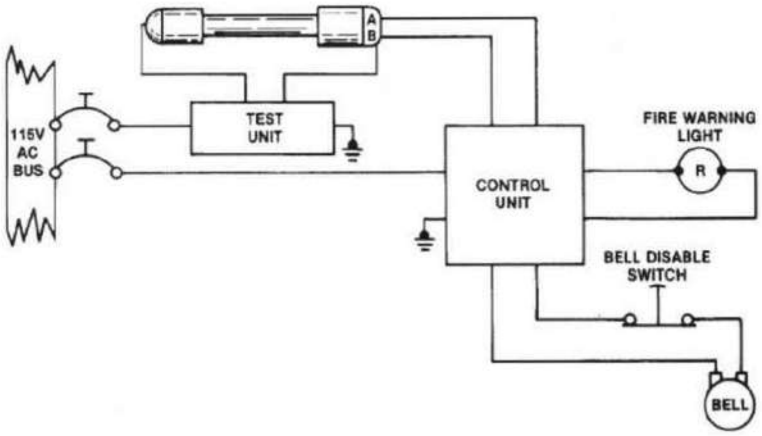


Fig. 8.11 Warning and test circuit Systron-Donner System

The sensing element contains a titanium centre wire, which is the gas absorption material. This material contains hydrogen gas. The centre wire will release of the hydrogen gas when temperatures reach the established level. This wire is installed in a stainless steel tube and is surrounded with helium gas underpressure.

The helium gas provides the averaging, or overheat, function of the sensor. Because the pressure of the helium gas will increase as temperatures rise, it will exert an increasing pressure on the pneumatic switch at the end of the sensor. At a preselected value, the switch will close and signal an overheat condition.

If a fire exists, the localized high temperature will cause a large quantity of hydrogen gas to be released from the titanium wire. This will cause an increase in the total gas pressure in the tube, and will actuate the pneumatic switch. This action is known as the discrete function of the sensor.

When the fire is extinguished and the sensor begins to cool, thehydrogen gas will once again be absorbed by the titanium wire, gas pressure will reduce, and the pneumatic switch will reopen. The system is again ready to indicate overheat or fire conditions.
Test circuits, which include a pressure warning switch, will indicate the operational condition of the system. If helium gas pressure is lost, the test circuit warns the flight crew that the system is not operational.

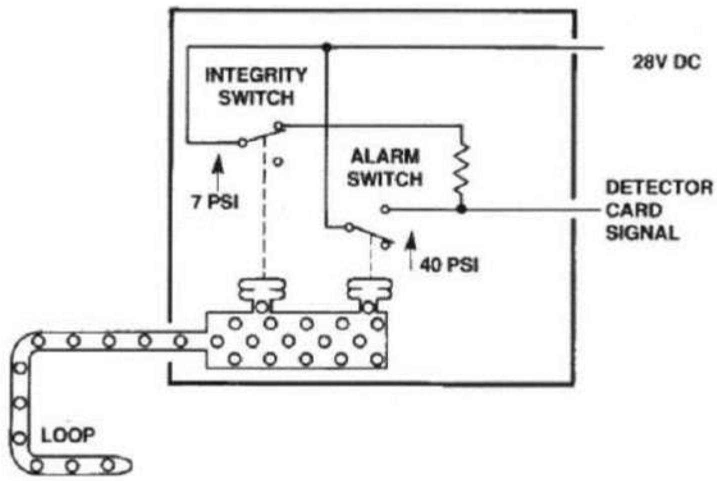


Fig. 8.12 Loop with responder (pressure switches)

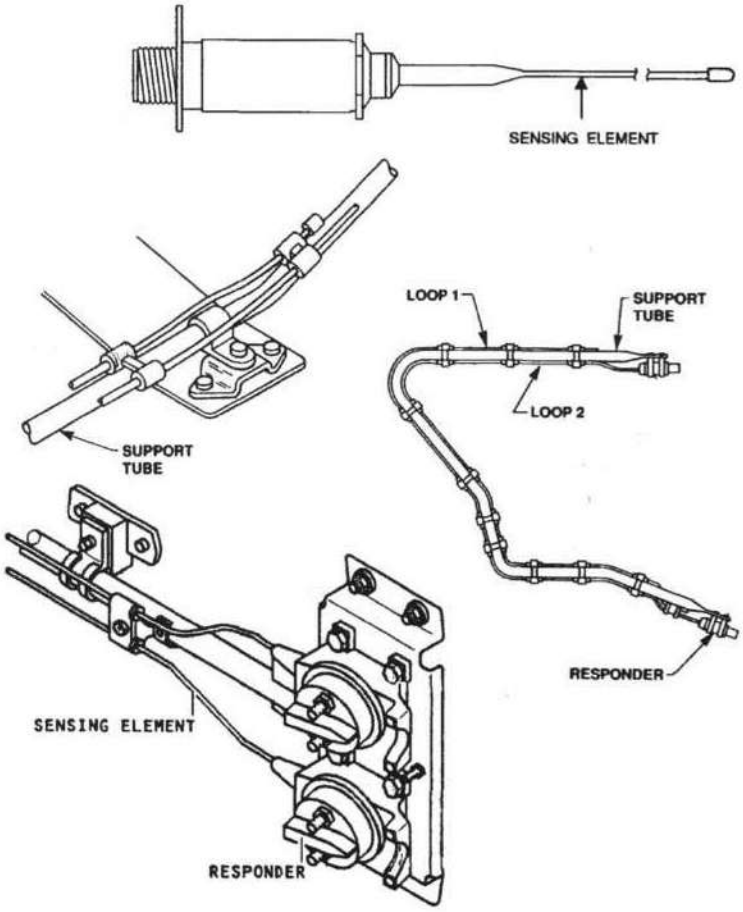


Fig. 8.13 Pneumatic loop Pneumatic Loop Description

The detector is pneumatically operated by heating its sensing element which contains helium gas and a hydrogen charged core material.

- Alarm State - The application of an overall average temperature expands inert gas (helium) which in turn closes the alarm switch. The detector sends a firesignal.

The application of heat to the sensor releases active gas from a hybrid core which in turn closes the alarm switch. The detector sends a fire signal.

- Fault State - In the event of gas pressure loss (pipe fracture or cut off due to a torching flame), the integrity switch opens and generates a faultsignal.

- Precautions - The detector responder is hermetically sealed, and as such, is not field- repairable. Any attempt to disassemble a detector responder will cause serious damage to the unit and render itinoperative.

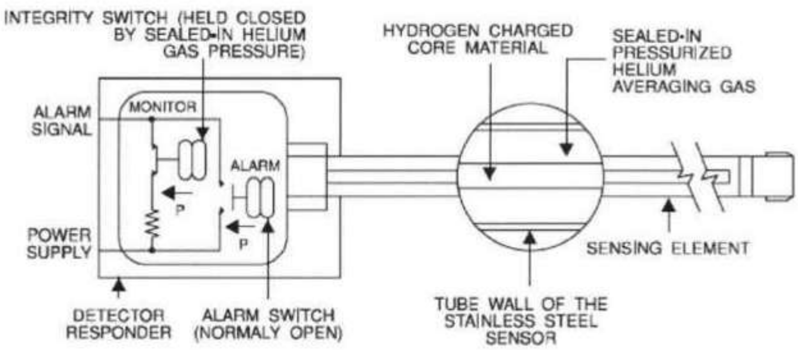


Fig. 8.14 Pneumatic fire detector (Systran Donner)

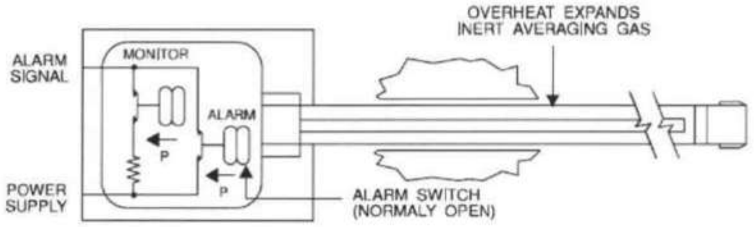


Fig. 8.15 Alarm state overall average overheat

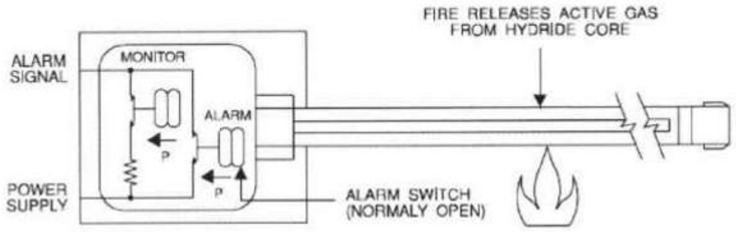


Fig. 8.16 Alarm State local overheat

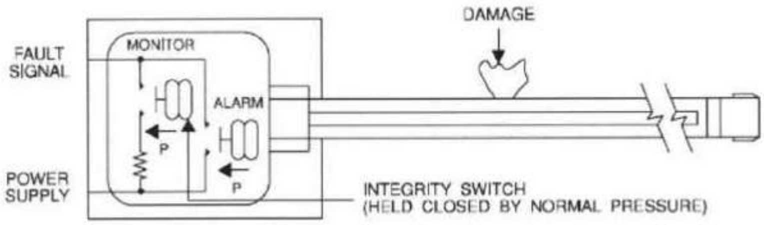
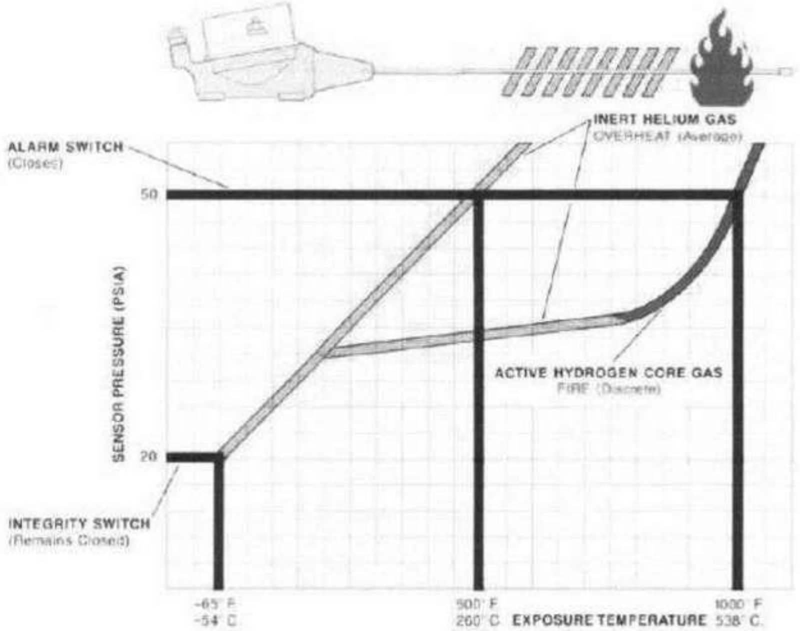


Fig. 8.17: Fault state pressure loss Detector Functions

The detector has two sensing functions. It responds to an overall "average" temperature threshold or to a localized "discrete" temperature caused by impinging flame or hot gases.

- Averaging Function: The detector serves as a fixed volume device filled with helium gas. The helium gas pressure inside the detector increases in proportion to the absolute temperature and will operate the alarm switch at a pre-set "average"temperature.

- Discrete Function: The detector's sensor tube also contains a hydrogen-filled core material. Large quantities of hydrogen gas are released from the detector core whenever a small section of the tube is heated to the pre-set "discrete"temperature. Core out- gassing increases the pressure inside the detector



and actuates the alarm switch.

Fig. 8.18 Alarm pressure vs. temperature (overheat and fire) False Alarms

Mechanical damage to the pneumatic sensor tube will not result in a false alarm. Severe damage such as sensor wear-through will provide a loop fault message.

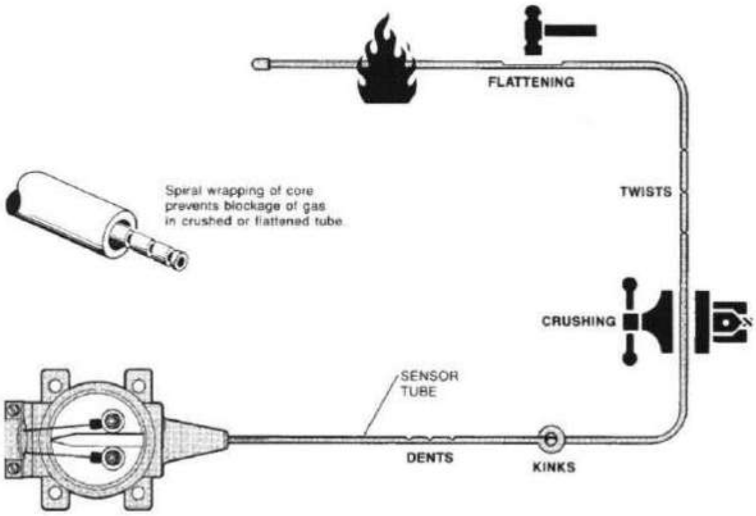


Fig. 8.19 Pneumatic system leak warning Pneumatic System - Leak Warning

Pneumatic leak-warning systems are important to prevent overheat conditions and structure damage in case of a pneumatic duct leak or rupture. In modern aircraft the system is also used to provide an automatic shut off of the affected pneumaticsystem.

Three different techniques are applied to monitor a pneumatic manifold leak or duct rupture.

Leak Detection by Thermal Switches

This method use thermal switches connected in parallel to the warning light and if applicable to the automatic shut off circuit. The thermal switches close if the overheat setting is reached and open after cool down.

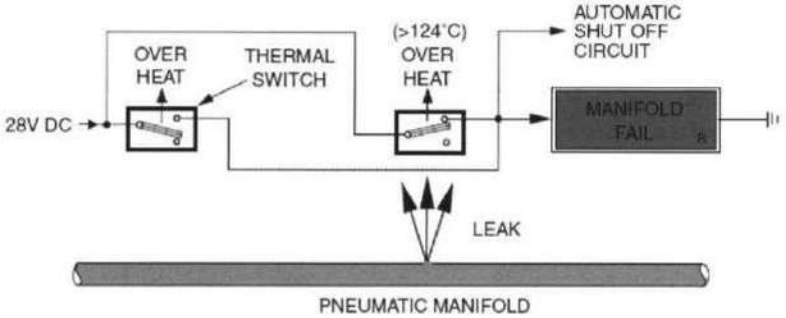


Fig. 8.20 Leak detection by thermalswitches Leak Detection by Manifold FailureLoops

This method is used in modern aircraft. The manifold failure loop is a grounded flexible metallic tube filled with a salt mixture. Embedded in the tube is a conductor insulated by the salt crystal. The conductor is connected via plugs and wires to the sensing device.

If the temperature of the salt mixture reaches the overheat setting, the salt melts and provides a current flow to energize the sensing relay or amplifier. After cool down the salt will crystallize again and interrupt the current for the sensing relay.

The sensing device with the loop test circuit is normally incorporated in a pneumatic controller. But it can also be a separate unit called the Manifold Failure Controller (MFC).
The advantage of this detection system is that in case of a single open loop the leak warning is not lost. The overheat setting of the loops may by different depending on the type of salt mixture. To monitor longer pneumatic ducts multiple loops are connected in series.

The detection system can be tested by energizing a test relay. The test relay opens the loop circuit and sends a ground signal through the loops to energize the sensing relay. The test makes sure that no loop has an open circuit and the sensing relay and the warning light isfunctional.

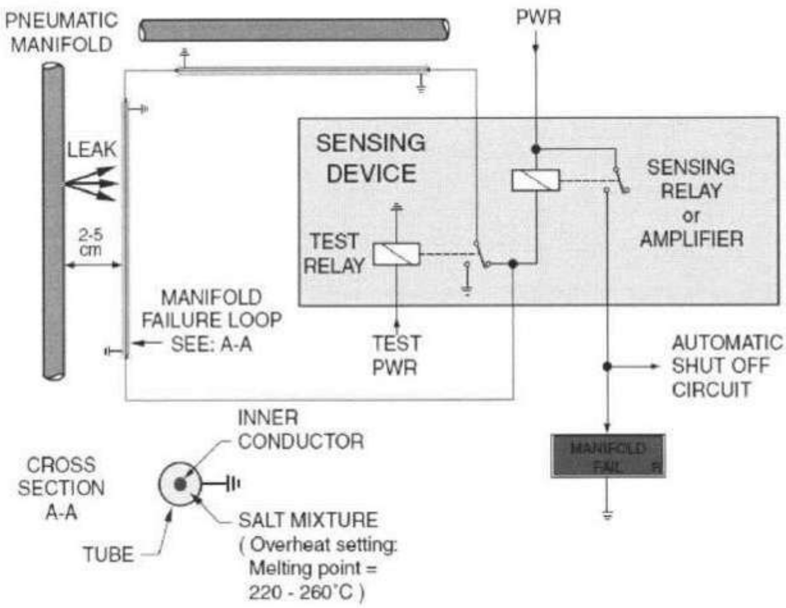


Fig. 8.21 Leak detection by manifold failure loops Leak Detection by Pressure Switches

There are aircraft which have, for safety reasons, double walled pneumatic ducts in the pressurized zones. A leak of the inner duct is monitored by a pressure switch and indicated by a DUCT LEAK light located on the maintenance testpanel.

After repair of the leaky duct, the DUCT LEAK light must be reset by pressing the RESET BUTTON on the maintenance panel.

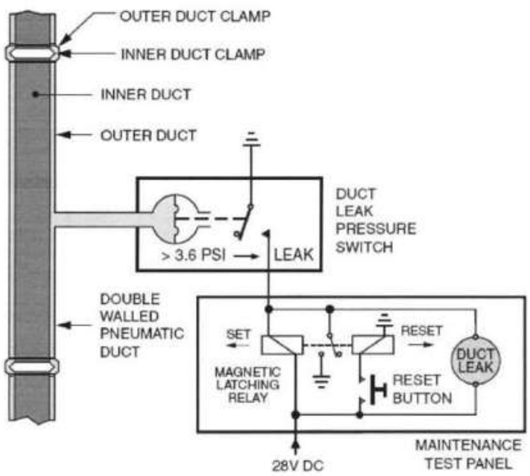


Fig. 8.22 Leak detection by pressure switches Electrical Circuit
The detector's electrical circuit is simple and effective. The normally-open alarm switch closes upon an

overheat or fire condition, causing a short circuit between terminals A and C (Figure 8.23).

During normal operation, a resistance value is maintained across the terminals by a normally- closed integrity switch. Loss of sensor-gas pressure opens the integrity switch, creating an open circuit across the terminals of the faulty detector.

The control module monitors two loops and up to four detectors each, connected in parallel. The control module responds directly to an open condition and continuously monitors the wiring and integrity of each loop. Microprocessor-based maintenance circuitry can isolate failures to the line replaceable unit (LRU), record critical events in non-volatile memory and transmit data to the on-board maintenance computer via an ARINC 429 data bus.

Fire Warning
Fire on Loop A and Loop B
Fire on one Loop, other Loop fault or electrical failure
Loop A and Loop B fault within 5 sec (both Loops broken due a torching flame)
Fault
Hydrogen pressure loss due of leak

Electrical Failure
Wiring between Fire Detector unit and Loop shorted or open

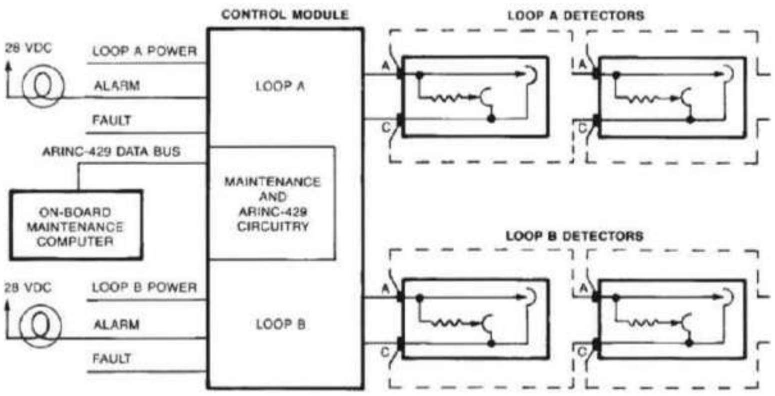


Fig. 8.23 Dual channel fire detection system Fire Detection or Control Unit General

The Fire Detection Unit has two channels capable of detecting any case of fire and loop failure. Each channel follows the same detection logic depending on the loop A and loop Bstatus.

Fire Warning

The Fire Detection Unit generates a fire warning signal if any of the following conditions are met:
- Fire on loop A and fire on loopB.
- Fire on loop A and fault on loopB.
- Fault on loop A and fire on loopB.
- Fault on loop A and fault on loop B within 5 seconds (both loops broken due to a torchingflame).

Loop Fault Warning

The Fire Detection Unit generates a loop fault warning if any of the following conditions are met:
- Electrical failure (loss of power, connector notconnected).
- Failure in adetector.

- Failure in a detectioncircuit.
- Detection of a single loop fire during more than 20s while the other loop is in normalcondition.

Detection Fault Warning

The detection fault logic is based on a dual loop failure. It corresponds to a total loss of the detection system.

Fire Test

A fire test pushbutton simultaneously checksthe condition ofthe:
- fire detectors (loops A andB),
- Fire DetectionUnit,
- indications andwarnings

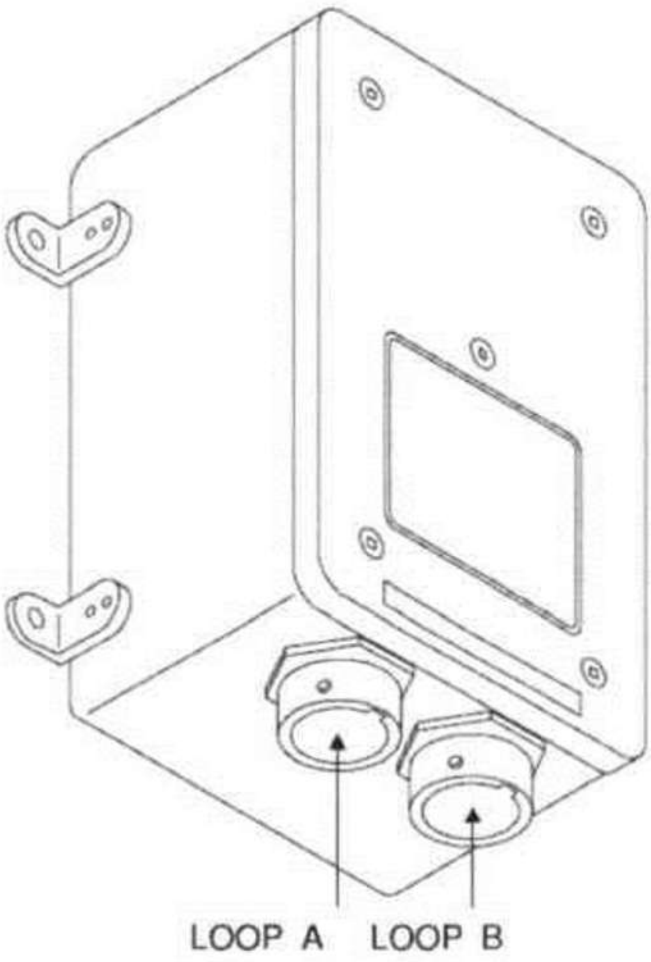


Fig. 8.24 Fire detection unit Detector Installation Continuous Element Detector Systems
Except for the types which are enclosed within an armoured sheath, continuous elements are vulnerable to rough handling and it is essential that every precaution is taken to maintain the integrity of the system and to check its function at frequent intervals.

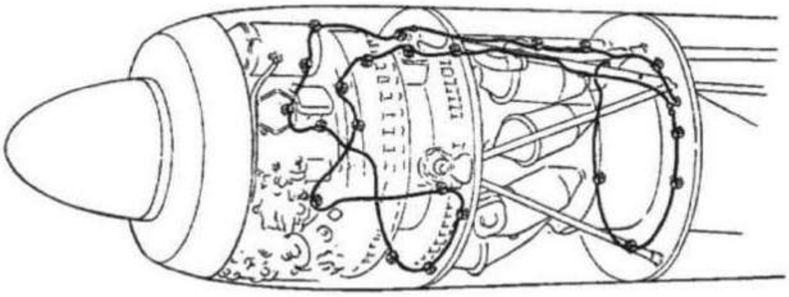


Figure 8.25: Typical continuous element installation

There are several types of element, each type being manufactured in a variety of lengths and suitable for either fire detection or overheat warning. Before fitting a new element the part number should be checked, the element inspected for cleanliness or damage, and an electrical check carried out to ensure that continuity and insulation resistance are within the limits quoted in the relevant Maintenance Manual. Testing should be carried out at normal room temperature since an elevated temperature would result in different readings being obtained.

The manner in which the element is attached to the structure is most important. It is clipped 4 inches from end fittings and at approximately 6 inch intervals along its length, and the clips, which are often of the quick-release type, must be positioned so that no damage can be caused to the element by rubbing or vibration. Installation details are normally shown pictorially in the relevant Maintenance Manual.

Care is also necessary when bending the element and curves should be kept smooth and not less than the minimum radius quoted by the manufacturer. Clip bushes should be correctly positioned at each clip and care taken to eliminate strain on the element. Excessive bending could result in work-hardening of the capillary, so that kinks or bends which are within the specified limits should be left and not straightened. Elements vary slightly in length and any excess should be spread throughout therun.

The end fittings of each element, and of the other components in the system, are protected by caps during storage. These caps should only be removed for testing purposes or immediately before coupling up. New sealing washers must be fitted whenever a connection is broken and all parts must be perfectly clean and dry. Coupling nuts should be torque tightened to the appropriate values, using two spanners to prevent twisting the capillary.

Different types of control unit are often identical in appearance and care must be taken to ensure that the correct types are fitted. Electrical connections to the units may be by terminal posts, plugs and sockets, edge connectors or contact buttons, and whichever type is used care must be taken to ensure that the contacts are clean. Where electrical connection (between the control unit and its mounting base) is by spring-loaded contact buttons, operation of the buttons should also be checked.

When installation has been completed, operation of the system should be checked by use of the appropriate test switch. If this test proves satisfactory all nuts which have been re-connected should be wire locked.

Unit Detector Systems

These are normally simple DC circuits in which a number of unit detectors are connected in parallel so that actuation of any one detector will complete the circuit through a warning lamp. In some circuits the detectors are connected between two wiring loops, either of which may be supplied through a magnetic circuit breaker. A short circuit in the energized loop results in operation of the magnetic circuit breaker and the supply is then routed to the second loop, thus preventing a spurious indication offire.

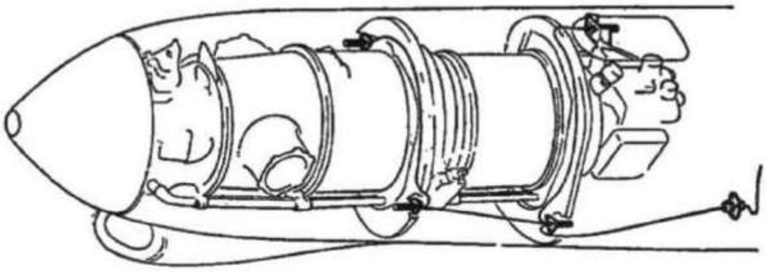


Figure 8.26: Typical unit detector installation

The operating temperature of any particular unit detector depends on its position in the engine bay and care is necessary to ensure that the correct type is fitted at each position. Details of temperature settings are contained in the relevant Maintenance Manual and the setting of a particular detector is sometimes included in its part number.

The detector units are rigidly mounted in position and are of comparatively robust design, although severe blows could upset the temperature setting. Installation of the electrical wiring, however, requires considerable care, since if not adequately

supported and clipped it may chafe on the surrounding structure and eventually cause a system failure. Contact with excessive heat, moisture, oil or grease could also cause deterioration of the insulation, and cables should be routed to avoid any form of contamination.

Detector Maintenance Practices General

Fire detector sensing elements are located in many high-activity areas around aircraft engines. Their location, together with their small size, increases the chance of damage to the sensing elements during maintenance. The installation of the sensing elements inside the aircraft cowl panels provides some measure of protection not afforded to 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 theelements.

The efficiency of any detection system depends on the suitable positioning of the detectors and on the proper maintenance of all components within the system. For details of particular installations reference should be made to the relevant manuals for the aircraft concerned but the following paragraphs discuss the servicing requirements of the most common aircraft fire detection systems and indicate the faults which may be found.

Fire detection equipment is located around and adjacent to the engines where maintenance operations are comparatively frequent, and is therefore susceptible o damage from actions unconcerned with the maintenance or testing of the fire detection system. The detectors, whether unit or continuous, and the associated wiring, are attached to the engine or cowlings and are affected by engine vibration and by leakage or spillage of fluids usedintheengine.Whenworkisbeingcarriedoutinanarea
fitted with fire detection equipment extreme care is necessary to prevent damage or contamination of the system since a spurious fire indication or failure to detect an actual fire could result.

False Fire Warnings

Investigations into the incidence of false fire warnings have emphasized the need for correct installation and proper maintenance. Some of the probable causes of false warnings or failure to operate on test are:-

Ingress of Moisture

- Incorrect assembly of sealing washers or glands on detectors or associated wiringaccessories.

- Premature removal of transit caps or seals when fitting new items.
- Inadequate tightening of connectors (a torque loading is usuallyspecified).
- Failure to fit new crushed metal sealing washers (if fitted) when fitting a replacementunit.
- Cracked or chafed elements.

Faulty Installation

- Detection elements too close to heat shields or other surfaces which may attain a temperature high enough to operate the detector.
- Short circuiting of electrical wiring by chafing against structure.
- Damage to detection components through carelessness during routine maintenance of adjacent unrelatedequipment.
- Inadequate support, more particularly of continuous element detectors, with consequent damage from chafing or fracture throughvibration.

- Clip bushes of a material unsuitable for the environment, resulting in damage to a continuous element at clipping positions.
- Incorrect racking of printed circuit cards in fire detection modules, possibly resulting in spuriouswarnings.

Lack of Cleanliness

- Dirt, swarf or other foreign matter in electrical connections causing short or opencircuit.
- Oil or other fluids penetrating connections, either prior to tightening or through incorrect torque loading, and resulting in failure of theinsulation

Inspection

A well rounded inspection and maintenance program for all types of fire detection systems should include the following visual checks. These procedures are provided as examples and should not be used to replace approved local maintenance directives or the applicable manufacturer'sinstructions.

Sensing elements should be inspected for:

1. Cracked or brokensections.
2. Abrasion.
3. Pieces of metal particles which may short the spot detector terminals.
4. Condition of rubber grommets in mountingclamps.
5. Dents and kinks in sensing elementsections.
6. Nuts at the end of the sensing elements for tightness and safetywire.
7. Condition of wiring and connectors to the sensingelements.
8. Sensing element routing andclamping.
9. Interference between a cowl brace and a sensingelement.
10. The split end of the grommet should face the outside of the nearestbend.
11. Mounting brackets for cracks, corrosion, or otherdamage.
12. Test the fire detection system for properoperation.

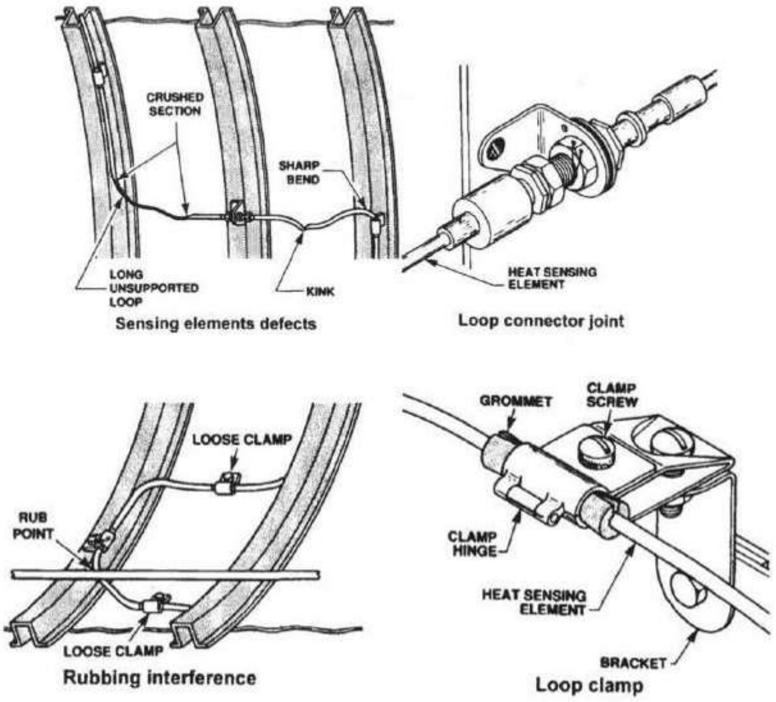


Fig. 8.27 Loop inspections Acceptance Checks

All components should be examined externally for damage which may have occurred in transit, and sealing caps should be removed to ensure that the threads are clean and internal parts of connections are undamaged.

Control units can be bench-checked by means of a special test set, all other components being tested for continuity and insulation resistance. Procedures for the electrical checks vary between installations and reference should be made to the relevant Maintenance Manual for details of the test for a particular component.

Function Test

Test circuits are usually arranged to simulate fault conditions by either grounding the centre electrode of the element (resistance type), or introducing additional capacitance into the circuit (capacitance type). By this means the system is completely checked; provided the visual and audible warnings function when the test switch is operated and cease to function when it is released, the system may be considered serviceable. It should be noted that on some aircraft the engine fire warning lamps are held on by a magnetic relay and are extinguished by moving the test switch to the 're-set' position. On other aircraft, operation of the audible warning may be dependent on throttle or flap position, or aircraft altitude. These variations will be fully described in the appropriate Maintenance Manual.

Periodic Checks

At the intervals prescribed in the approved Maintenance Schedule all components should be examined, in situ, for security, damage, corrosion or deterioration. Any damage found on elements should be compared with the limits laid down in the manufacturer's manual and components replaced as necessary. Parts with acceptable physical damage should be given an electrical check to ensure that insulation resistance remains satisfactory.

The dressing of dents, gouges, kinks, etc., is not permitted.

When required by the Maintenance Schedule, the detector elements should be removed from the aircraft so that all components can be properly cleaned and inspected. Particular attention should be paid to the centre pin and ceramic insulation of connections and to those parts of the element which were not accessible for visual examination in the aircraft. Control units should be given a thorough electrical check in accordance with the relevant manual; a special test set normally being used for this purpose. When the components are re-installed, new sealing washers must be fitted and every precaution taken to keep connections clean anddry.

NOTE: The time interval between these checks varies considerably and is based on experience gained with each particular aircraft installation. On some aircraft, detector elements are only removed when they become unserviceable

Cleaning

Cleanliness of all components in the system is essential. Dry foreign matter in end fittings and couplings should be removed with a camel hair brush, but if oil or other liquids are present they should be removed by brushing with a small quantity of approved cleaning fluid. The part should then be allowed to dry for at least
10 minutes or blown out with dry bottled air or nitrogen to remove all traces of liquid. Normal compressed air supplies are unsuitable for this purpose since they normally contain moisture oroil.

Smoke and Flame Detectors General

A smoke detection system monitors certain areas of the aircraft forthepresenceofsmoke,whichisindicativeofafire condition A smoke detection system is used where the type of fire anticipated is expected to generate a substantial amount of smoke before temperature changes are sufficient to activate a heat detection system.

The presence of carbon monoxide gas (CO) or nitrous oxides are dangerous to flight crew and passengers. Their presence may indicate a leak or failure of exhaust components and heaters, or may indicate a fire condition. Detection of the presence of either or both of these gases could be the earliest warning of a dangerous situation.

Certain areas in an aircraft can produce a great deal of smoke before any flames actually appear, and it is important in these areas to detect the first indication of smoke. Baggage and cargo compartments are typically protected by smoke detectors, of which there are four types: CO detectors, photoelectric detectors, ionization-type detectors, and visual detectors.CO detectors measure the level of carbon monoxide in the air. Photoelectric detectors measure the amount of smoke in a sample of air which obstructs or refracts a beam of light. Ionization-type detectors measure the current that flows through ionized air and visual detectors detect the presence of smoke by actually viewing samples of air that are drawn through the smoke detector chamber. Flame detectors are usually light detectors that are sensitive to infrared radiation. These detectors are mounted in an electrical circuit that amplifies their voltage enough to initiate a fire- warningsignal.
Almost all cargo compartment smoke detectors are based on photoelectric sensing. Smoke particles interfere with a light beam inside the detector, causing the light to scatter onto a photosensitive diode, which increases the photodiode'scurrent

output and generates an alarm. A smoke detector can be described by how the smoke enters the sensing chamber: draw- through or open-area type.

Draw-through type detectors, also known as active smoke detectors, continuously monitor a sample of air drawn from the cargo compartment for the presence of smoke — an indication of a fire condition. A draw-through detection system consists of a distributed network of sampling tubes that bring air sampled through various ports located in the cargo compartment ceiling to the smoke detectors located outside the cargo compartment. The air is also exhausted outside thecompartment.

Open-area type detectors, also known as passive smoke detectors, are installed inside the compartment, usually in the ceiling, and directly exposed to the smoke.

In addition, there are means to allow the crew to perform in-flight system testing of each fire detector circuit to ensure proper function. The effectiveness of the detection system must be shown for all approved operating configurations and conditions.

The cargo compartments of all Boeing aeroplanes are equipped with multiple smoke detectors. For example, the MD-11 freighter main deck cargo compartment has 18 area smoke detectors; 14 distributed axially along the compartment overhead centreline and four located in the forward area of the cargo compartment. A smoke signal from any smoke detector will trigger a fire alarm at the flight deck. This is a “single loop” system because any single detector can set off the fire alarm.

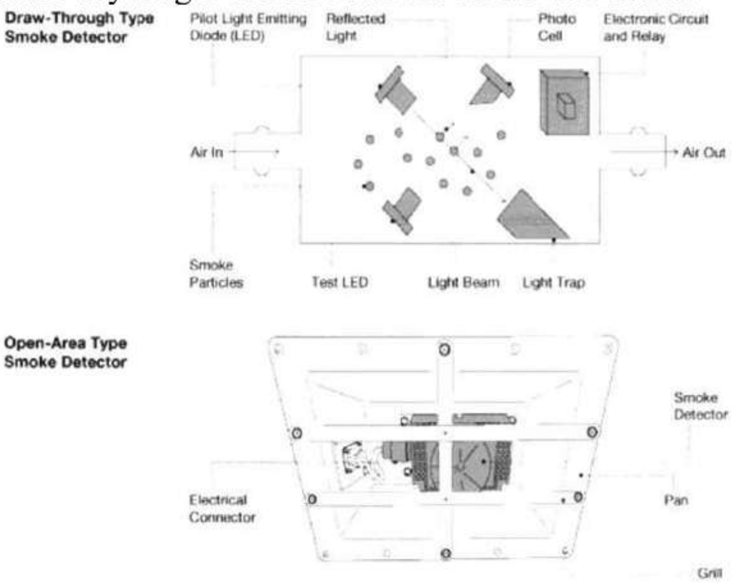


Fig. 8.28 A smoke detector can be described by how the smoke enters the sensingchamber

Carbon Monoxide Detectors

Carbon monoxide is a colourless, odourless gas that is a by- product of incomplete combustion of almost all hydrocarbon fuels and is present in all smoke. It is lethal even in small concentrations, and its presence must be detected early. CO detectors are not usually used in cargo and baggage compartments as are other smoke detectors, but are used in the cabin and cockpit areas.

The most widely used CO detectors are small cards with a transparent pocket containing silica gel crystals that are treated with a chemical that changes colour when it is exposed to CO. Normally the crystals are yellow or tan, but when they are exposedtoCO,theychangecolourtogreenorblack.Themore

drastic the change is, the higher is the content of CO in the air. These small detectors have an adhesive backing that allows them to be attached to the instrument panel, in easy view of the flight crew to warn of the presence of CO. They must be periodically replaced with fresh indicators.

Visual Smoke Detectors

Some jet transport aircraft have visual-type smoke detectors installed on the flight deck. The inside of the chamber is painted non reflective black, and glass observation windows let the flight crew see inside the chamber. A light shines across the chamber in such a way that it will illuminate any smoke that is present. Air pulled from the compartments that are being monitored, flows through the detection chamber. When there is no smoke in this air, no light is visible in the window, but when there is smoke, the light strikes it, and can be seen in the window. Since no light is visible when there is no smoke, a green indicator light on the front of the detector illuminates to show that the light ison.

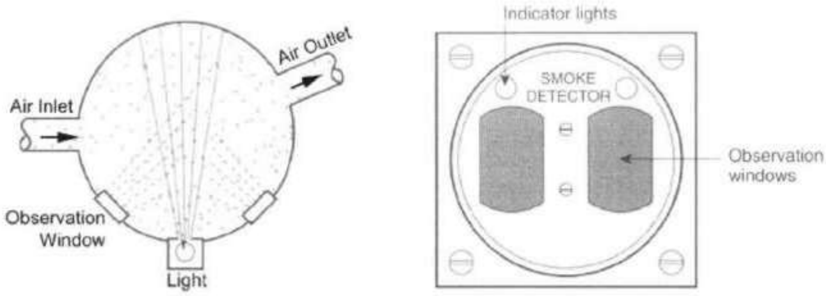


Fig. 8.29 Visual smoke detector Sniffer

Presence of smoke in the avionics compartment or behind circuit breaker panels can be sensed and confirmed by a sniffer. This is a flexible hose that can be held direct to the pilot's nose. A small fan moves the air to this sensitive human smoke detection device.

Photoelectric Smoke Detectors

This type of detector consists of a photoelectric cell, a beacon lamp, and a light trap, all mounted in a labyrinth. Air samples are drawn through the detector unit. An accumulation of 10% smoke in the air causes the photoelectric cell to conduct electric current.

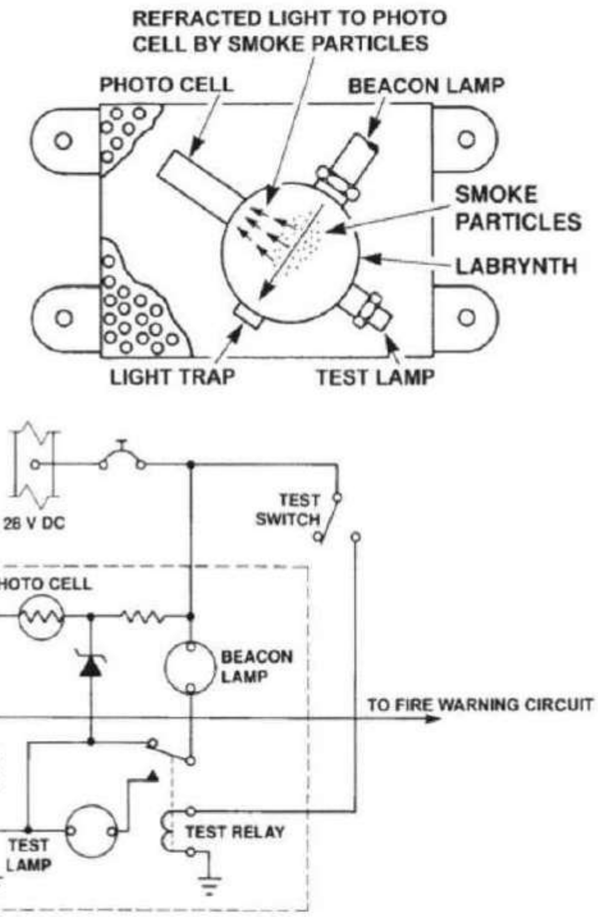


Fig. 8.30 shows the details of the smoke detector and indicates how the smoke particles refract the light to the photoelectric cell. When activated by smoke, the detector supplies a signal to the smoke detector amplifier. The amplifier signal activates a warning bell and light.

A test switch permits checking the operation of the smoke detector. Closing the switch connects 28 VDC to the test relay. When the test relay is energized, voltage is applied through the beacon lamp and test lamp, in series, to ground. An indication will be observed only if the beacon and test lamp, the photoelectric cell, the smoke detector amplifiers, and associated circuits are operable.

Photoelectric optical smoke detectors can only detect visible smoke. The detection takes place by means of light and a photo cell.

When there is no smoke, the light of the pilot lamp shines straight ahead to the light trap and the photo cell receives little or no light.

When smoke reaches the detector, diffusion of light takes place and the photo cell receives more light. This results in a warning.

Fig. 8.30: Photoelectric smoke detector Ionizing Smoke Detectors
Ionization-type smoke detectors work on the basic principle of those detectors found in many buildings.

This group of smoke detectors can detect visible as well as invisible smoke. The ionizing smoke detector is equipped with a detection cell and a reference cell or a reference resistance, electrically connected in series.
The smoke detector has two chambers
- The reference chamber
- The measurement chamber

The reference chamber makes allowances for the differential pressure and temperature differences. This makes sure that the detector operates on the ground and in flight with the same level of sensitivity.

Ionization Principle

The smoke detector ionizes the air particles that pass between the electrodes. As smoke causes the electrical resistance of the circuit to increase, the voltage in the measurement chamber increases to a higher level than the reference chamber.

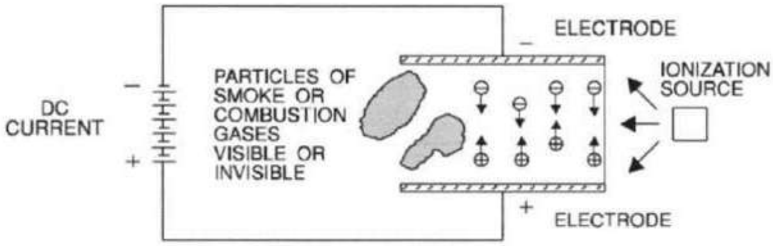


Fig. 8.31 Smoke particles reducing the current

In both cells, there is a small radioactive source which ionizes the air. The reference cell serves to compensate the differences in air density. The resistance of the detection cell depends on the air in

the cell. When it is polluted, the resistance in the detection cell increases. This increase causes the voltage at the detection point to decrease resulting in a signal.

An electronic circuit amplifies and adapts the analogue voltage from the sensor to the detector electronically. The detector electronically continuously compares and monitors the analogue voltage for smoke warning and fault conditions.

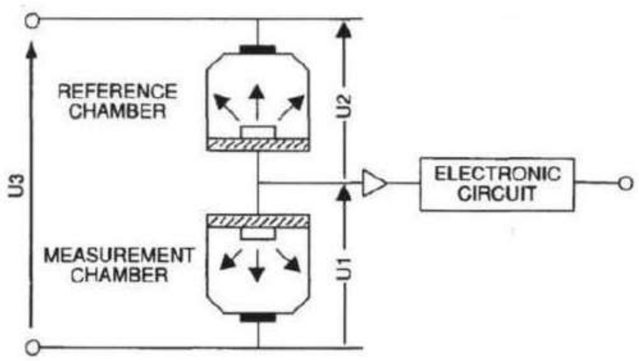


Fig.8.32Smoke detector with measurement and reference chamber

Warning

Do not try to open or repair a smoke detector. The smoke detector contains radioactive americium 241 of approximately 0.4 microcuries. Only workshops authorized by the manufacturer can do work on the smoke detectors.

Fire-Extinguishing Systems General

Fire-Extinguishing Agents

Since fire is the chemical reaction between a fuel with oxygen, it can be controlled by interfering with this reaction. This can involve removing the fuel, smothering the fuel with a substance that excludes the oxygen, or lowering the temperature of the fuel. The most effective method for extinguishing aircraft fires involves using a chemical compound that combines with the oxygen to prevent it from combining with the fuel.

Water - Class A fires can be extinguished with an agent, such as water, that lowers the temperature of the fuel. Small hand-held fire extinguishers contain water that is adequately protected with an antifreeze agent. When the handle of these extinguishers is twisted, the seal in a carbon dioxide (CO2) cartridge is broken, and the CO2 pressurizes the water and discharges it in the form of a spray. When the water changes from a liquid to a vapour, it absorbs heat from the air above the fire and drops its temperature enough to cool the fuel enough to cause the fire to go out. Never use water on Class B, C, or D fires. Most flammable liquids float on water, and the use of water on Class B fires will only spread the fire. Water conducts electricity, and its use on a electrical fire constitutes a definite danger of electrocution. Water sprayed on the burning metal in a Class D fire will actually intensify the fire rather than extinguishit.

Carbon Dioxide - CO2 is heavier than air, and when it is sprayed on a fire it remains on the surface and excludes oxygen from the combustion process, and the fire goes out. CO2 has been a favoured extinguishing agent for many years. It is relatively inexpensive, non-toxic, safe to handle, and has a long life in storage.

C02 extinguishers are found in almost all maintenance shops, on most flightlines, and in most ground vehicles. Most of the older

aircraft had hand-held C02 extinguishers mounted in fixtures in the cabins and cockpits and fixed CO2 extinguishing systems in the engine nacelles. These airborne extinguishers have been replaced in modem aircraft by more efficient types. Hand-held C02 extinguishers can be used to extinguish fires in energized electrical equipment, but they should not be used unless the nozzles are made of a nonconductive material. Fortunately most nozzles are made of pressed nonconductive fibres. C02 is usually a gas, and it is stored in steel bottles under pressure. When it is released, it expands and cools enough to change into a finely divided snow of dry ice. C02 may also be used directly on a tyre by covering the fire with a dry powder such as sodium bicarbonate, potassium bicarbonate, or ammonium phosphate. Dry powder is useful for Class D fires such as fires in an aircraft brake.

Halogenated Hydrocarbons (Halon) - The two most widely used halogenated hydrocarbons are bromotrifluoromethane(CBrF3), widely known as Halon 1301, and bromochlorodifluoromethane (CBrClF2), known as Halon 1211. Both of these compounds, often called by the trade name Freon, have a very low toxicity. Halon 1301 is the least toxic of all commonly used agents. Both are very effective as fire- extinguishing agents. They are non-corrosive, evaporate rapidly, leave no residue, and require no cleanup or neutralization. Halon 1301 does not require any pressurizing agent, but Halon 1211 may be pressurized with nitrogen or with1301.

Hydrocarbons destroy the ozone-layer in the atmosphere

Halogenated hydrocarbons are numbered according to their chemical formulas with five-digit halon numbers, which identify the chemical makeup of the agent. The first digit represents the number of carbon atoms in the compound molecule; the second digit represents the number of fluorine atoms; the third digit represents the number of chlorine atoms; the fourth digit represents the number of bromine atoms; and the fifth digit represents the number of iodine atoms, if any. If there is no iodine present the fifth digit is omitted. For example, bromotriflouromethaneCFsBr is referred to as Halon 1301, or sometimes by the trade name Freon13.

- Halon 1211 is used only in portable extinguishers and is a streamingagent.
- Halon 1301 is used only in fixed extinguisher installationsand is a total flooding agent.

A ban on Halon fire extinguishers was implemented following the Montreal Protocol of 1987 and subsequent extension at Kyoto a decade later. The details are in EC Regulation 3093/94 and EC 2037/2000 and the UK Hazardous Waste regulations 2005

There are only three main exceptions for Halon fire extinguisher usage; in aircraft, military use including vehicles and fuel installations, and in the Channel Tunnel.

A once-popular agent was Methyl Bromide (MB) (Halon 1001). However, this has been discontinued due to its toxicity to personnel and corrosive nature to aluminium alloys, magnesium and zinc.

High-Rate-Discharge (HRD) Extinguishing Systems

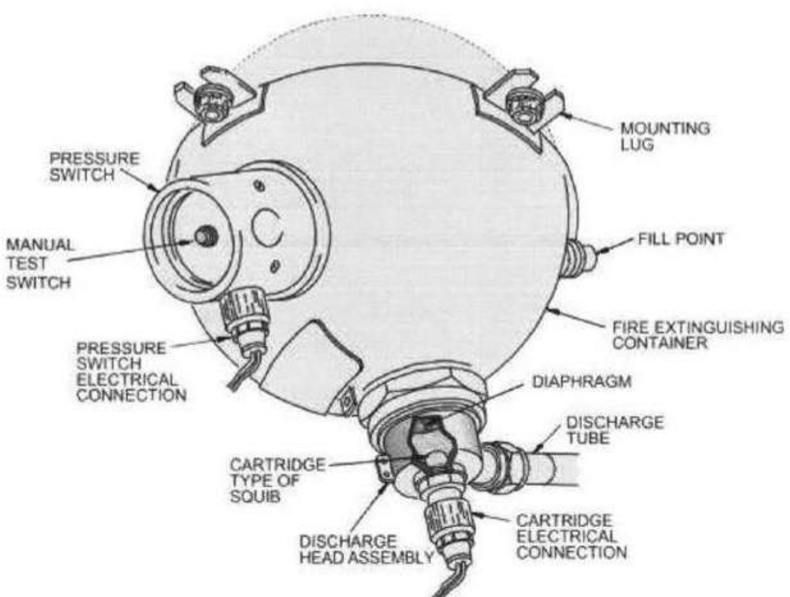
Most modem turbine-engine-powered aircraft have their power plant areas protected by two or more spherical or cylindrical HRD bottles of Halon 1211 or 1301.

A charge of compressed nitrogen is usually placed in the container to ensure that the agent is dispersed in the shortest time possible. The containers are sealed with a frangible disk that is broken when a cutter is fired into it by a powder charge, or squib, which is ignited when the pilot closes the agent discharge switch. The entire contents of the bottle are discharged within about 0.08 second after the agent discharge switch isclosed.

Figure 8.33 shows a cross-sectional view of a typical spherical HRD bottle. The cartridge is electrically ignited, which drives the cutter into the disk and releases the agent. The strainer prevents any of the broken disks from getting into the distribution system.

The safety plug is connected to a red indicator disk on the outside of the aircraft fuselage. If the temperature of the compartment in which the bottle is mounted rises enough to increase the pressure of the gas enough to become dangerous, the safety plug melts and releases the gas, As the gas vents to the atmosphere, it blows out the red indicator disk, showing that the bottle has been discharged because of an overheat condition.
If the bottle is discharged by normal operation of the system, a yellow indicator disk blows out or an amber low pressure warning light in the cockpit comes on. The gauge shows the pressure of the agent and the gas in the container. Newer bottles will not have a pressure gauge. To determine its amount of content, the bottle must be removed from aircraft and weighted.

WARNING



The fire bottle cartridges are explosive. Remove them before working on the bottle. Protective caps must be installed during bottle removal/installation to prevent damage to discharge diaphragm which could result in injury to personnel.

Fig. 8.33 HRD bottle cross sectional view

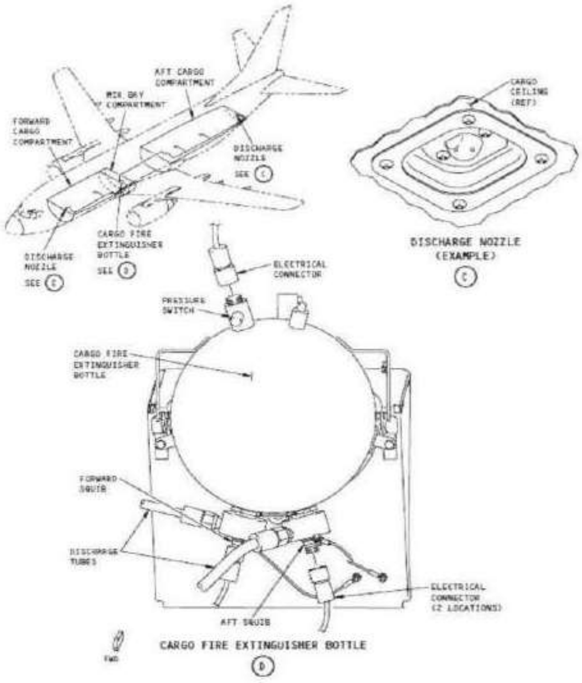


Fig. 8.34 Cargo fire extinguishing system Servicing of Fire-Extinguishing Systems

Bottles of fire-extinguishing agent must be kept fully charged. Some bottles have gauges mounted directly on them. The pressure of the agent varies with its temperature. Bottles without gauges must be removed from the aeroplane and weighted on a scale to determine its content of agent.

Container Pressure Check

A pressure check of fire extinguisher containers is made periodically to determine that the pressure is between the minimum and maximum limits prescribed by the manufacturer.

Changes of pressure with ambient temperature must also fall within prescribed limits. A graph is used to provide maximum and minimum gauge readings, depending on the ambient temperature. If the pressure does not fall within the graph limits, the extinguisher container should be replaced.

Generally, fire extinguisher bottles are charged with nitrogen to a pressure of 600 PSI at a temperature of 15°C.

Container Weight Check

Most fire extinguisher bottles will not have a pressure gauge anymore. To determine the correct amount of its content, the bottle must be periodically removed from the aircraft and weighted on a scale. Its correct weight is written on the type placard, located at the bottle. Verify that this weight is with, or without discharge head(s).

The fully charged weight of an extinguisher should be checked at the periods specified in the approved Maintenance Schedule, and before installation, to verify that no loss of extinguishant has occurred. The weight, including blanking caps and washers, but excluding cartridge units, is normally indicated on the container or operating head. For an extinguisher embodying a discharge indicator switch, the weight of the switch cable assembly is also excluded.

NOTE: The provision of discharge indicators in fixed extinguisher systems does not alter the requirement for periodic weighing which is normally related to calendar time.

The date of weighing and the weight should, where specified, be recorded on record cards made out for each type of extinguisher,

and also on labels for attachment to extinguishers. If the weight of an extinguisher is below the indicated value the extinguisher must be withdrawn from service for recharging.

For extinguishers fitted with pressure gauges, checks must be made to ensure that indicated pressures are within the permissible tolerances relevant to the temperature of the extinguishers.

The relationship between pressures and temperatures is normally presented in the form of a graph contained within the appropriate aircraft Maintenance Manuals.

In certain types of portable extinguishers, a check on the contents is facilitated by means of a disc type pressure indicator in the base of the container. If the charge pressure is below the specified value, the disc can be pushed in by normal thumb pressure.

Discharge Cartridge

WARNING: Cartridges (also known as squibs) are explosive and must be handled or stored by authorized personnel and disposed of by an approved method. Before power is supplied to the aircraft make certain that electrical circuits, upon which work is in progress, areisolated.

When cartridge electrical connectors are disconnected, the cartridge electrical pins must be shunted with a protective shunt which is provided by the manufacturer. A shunt plug or shorting clip will prevent bottle discharge which could cause injury to maintenance personnel.

The cartridge installed must be of the same make as the fire bottle and correspond to the specification indicated in the Maintenance Manual.

A cartridge contains 400 mg detonant. Igniting current is 5A, 28 VDC.

The discharge cartridges or squibs for an HRD container are life- limited components, and the replacement date is measured from the date stamped on the cartridge. If the wrong cartridge is used, there is a possibility that there will not be electrical continuity. It is extremely important when checking the electrical connections to the container to use the recommendations of the manufacturer. Make sure that the current used to test the wiring is less than that required to detonate thesquib.

Circuits controlling explosive or pyrotechnic devices require the use of a special tester whose output current is limited to 10mA even if resistance is unduly low.

The safety ohmmeter is normally used to check fire extinguisher cartridge heads for continuity and resistance.

To carry out a continuity test, the safety ohmmeter is connected as shown. The resistance value is laid down in the AMM and may be within the range 5 to 11 ohms.

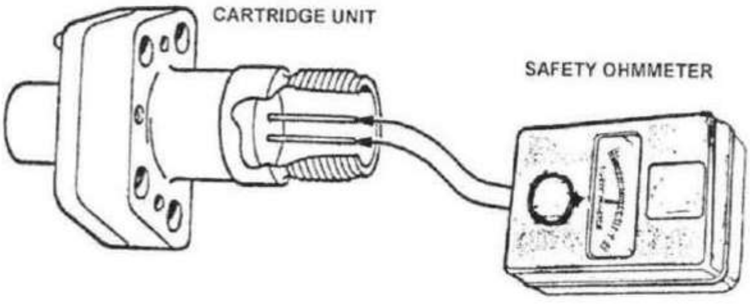


Fig. 8.35 Continuity check of a cartridge unit using a safety ohmmeter

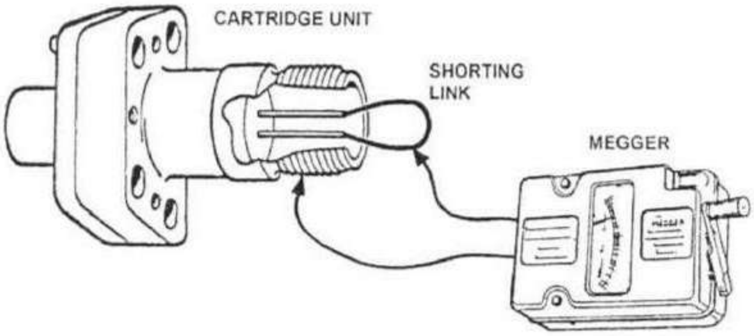


Fig. 8.36: Insulation test of a cartridge unit using a Megger

To carry out an insulation test, connect the Megger as shown with a shorting link across the two pins. The resistance value is laid down in the AMM, for example 20 Megohms.

DANGER: It is important to remember that when testing any detonators/ explosive devices that the explosive head is faced away from the operator and in a safe direction and removed from the firebottle.

Aircraft Fire Protection Systems

A modern jet transport aircraft fire protection system comprises:

- Engines:Fire and overheat detection and extinguishingsystem.
- Auxiliary Power Unit:Fire and overheat detection and extinguishingsystem.
- Cargo Compartments:Smoke detection andextinguishing system.
- Lavatories:Smoke detection system and waste bin extinguishers.
- Avionics Bay:Smoke detectionsystem

The following pages show examples of protection systems.

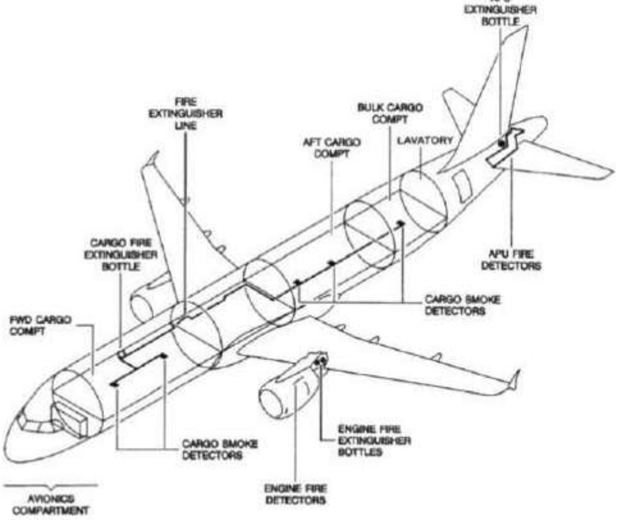


Fig. 8.37: Fire protection of a commercial aircraft APU Fire Protection

The APU is protected with a dual pneumatic loop system. A fire is extinguished by pushing the FIRE switch.

On ground the APU stops automatically and releases the agent.

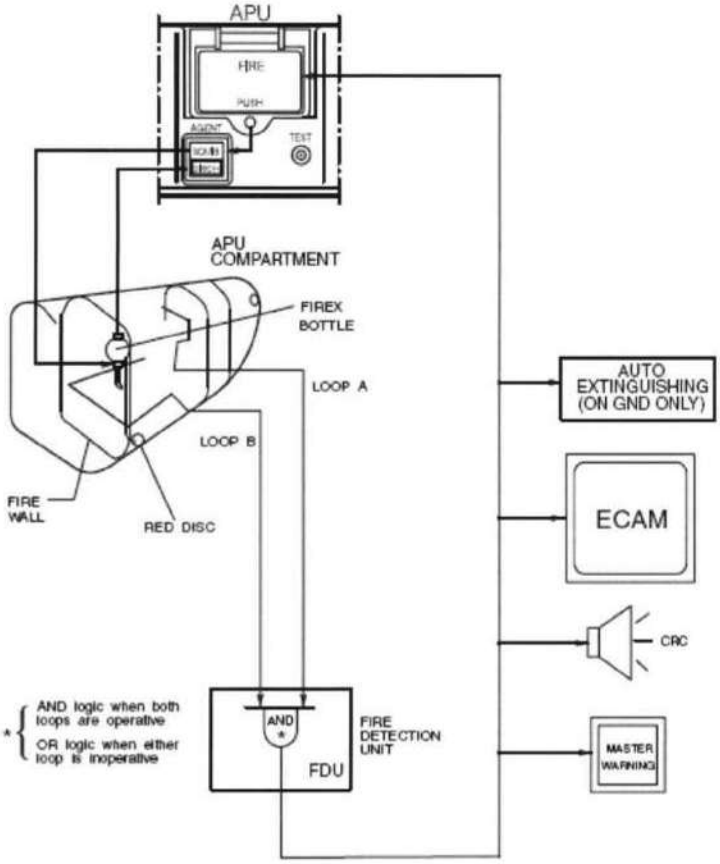


Fig. 8.38: APU fire warning and extinguishing

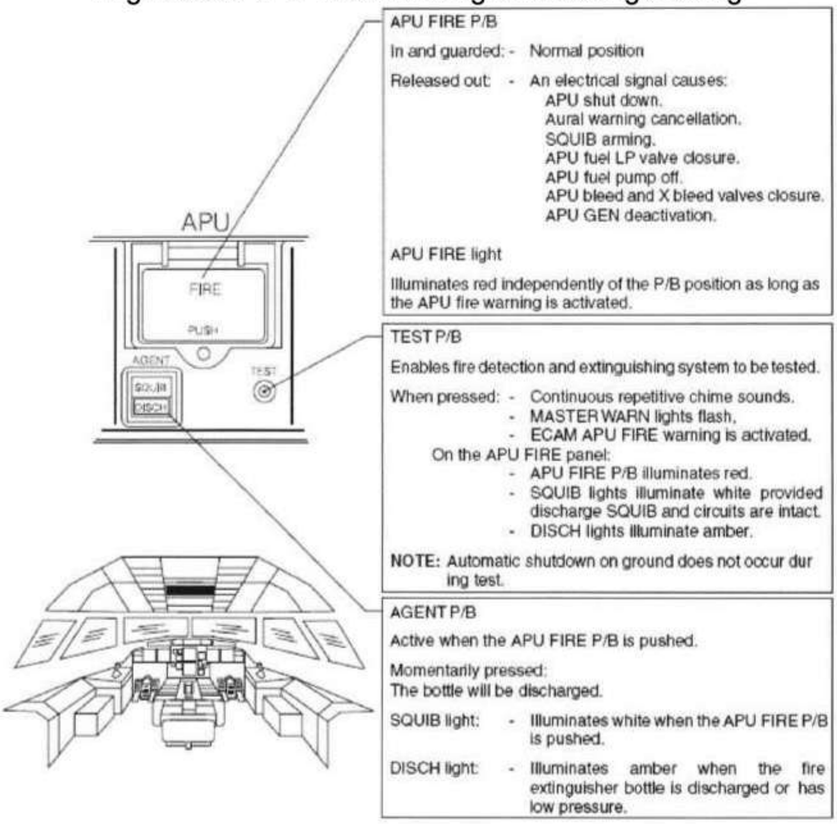


Fig. 8.39: Cockpit controls

- Type of agent:: Halon1301
- Nominal nitrogen pressure at 21^: 600PSI
- Low pressure switch: < 250PSI

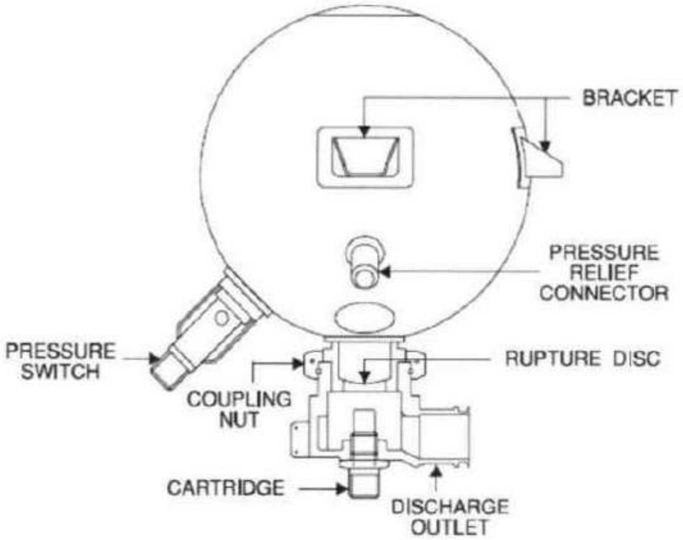


Fig. 8.40: Fire extinguishing bottle

The safety plug is connected to a red indicator disk on the outside of the aircraft fuselage. If the temperature of the compartment in which the bottle is mounted rises enough to increase the pressure of the gas enough to become dangerous, the safety plug melts and releases the gas, As the gas vents to the atmosphere, it blows out the red indicator disk, showing that the bottle has been discharged because of an overheat condition.

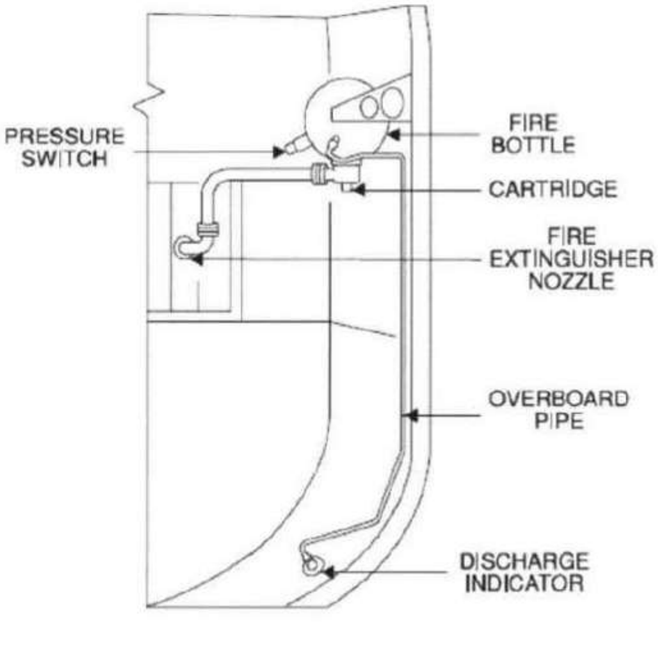


Fig. 8.41: APU fire extinguishing bottle installation Cargo Compartment Fire Protection

Class B, C, and E cargo compartments have smoke detection systems that provide active fire protection. These systems are designed to provide an aural and visual indication to the flight crew in the early, smouldering phase of a fire prior to it breaking out into a large fire. In older model aeroplanes, the time to detect a fire was not quantified by the regulators. Smoke detection systems of that era typically met a five-minute detection time. Using newer technology, smoke detection systems can provide an indication in a shorter time. Based on a simulated smoke source representing a smouldering fire, all newer aeroplanes can detect a fire within one minute. In all cases, the smoke detection systems can detect a fire

at a temperature significantly below that at which the structural integrity of the aeroplane could be adversely affected.

Almost all cargo compartment smoke detectors are based on photoelectric sensing. Smoke particles interfere with a light beam inside the detector, causing the light to scatter onto a photosensitive diode, which increases the photodiode's current output and generates an alarm.

A smoke signal from any smoke detector will trigger a fire alarm at the flight deck. In a "single loop" system, any single detector can set off the fire alarm.

The smoke detection systems in each cargo compartment can also be designed in a dual-loop (two single-loops) configuration. The smoke detectors are organized with one or more detectors associated with each single-loop. In a dual-loop system, two separate smoke signals are required to generate a fire alarm at the flight deck. Most Boeing aeroplanes use a dual-loop configuration for cargo smoke detection systems. For both dual-loop and single- loop systems, there is guidance provided through the master minimum equipment list to allow dispatch if a smoke detector is inoperative.

When smoke is detected in the cargo compartment, visual and aural warnings are provided at the flight deck. Two red master warning lights are located on the glare-shield, one in front of the pilot and one in front of the first officer. In addition, on aeroplanes with engine indicating and crew alerting systems (EICAS), the message FIRE CARGO FWD or FIRE CARGO AFT is displayed on the upper EICAS display located on the main panel to identify the affected lower compartment. On all aeroplanes and on older aeroplanes without the EICAS system, individual red lights for the

cargo compartment with the fire will light (e.g., FWD CARGO FIRE or AFT CARGO FIRE).

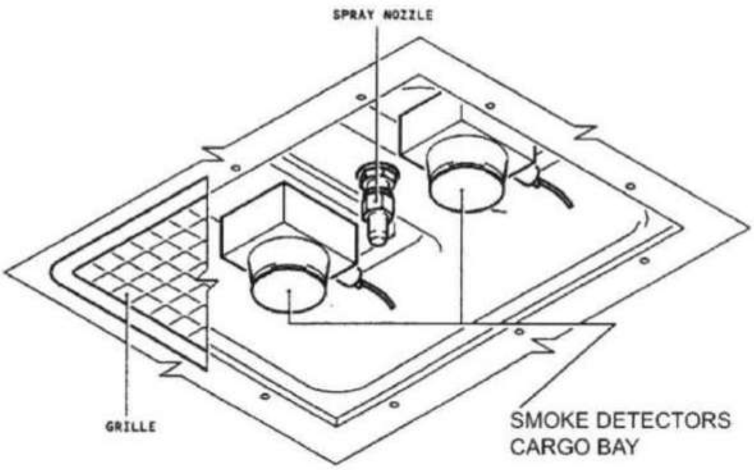


Fig. 8.42 Smoke detector located in cargo compartmentceiling

If a smoke warning is shown in the cockpit, the flight crew pushes the CARGO/SMOKE/AGENT TO FWD or AGENT TO AFT
pushbutton switch. A signal is sent through the Fire Extinguishing Data Converter (FEDC). The Extinguishing agent is then sprayed into the FWD or the AFT and bulk cargo compartments through a diverter valve and sprays nozzles.

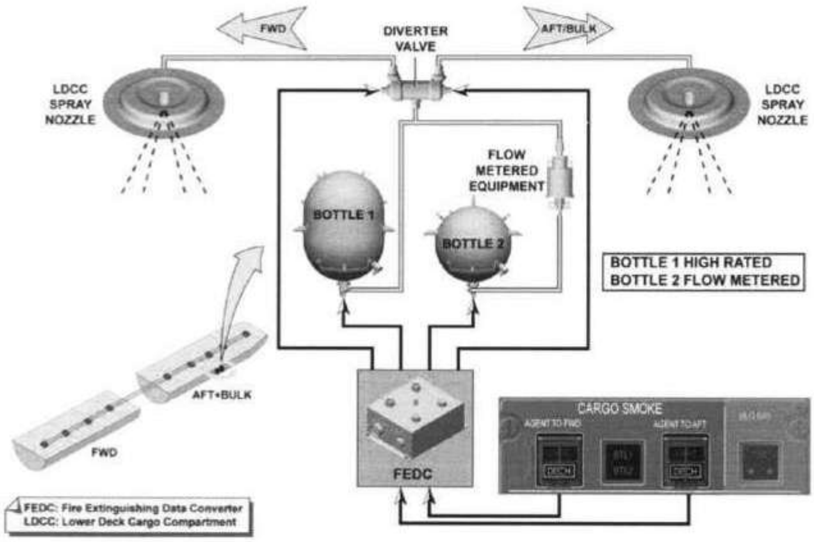


Fig. 8.43 Cargo smoke detection and extinguishing system (Airbus A350)

The first step in controlling and suppressing a fire (after turning off the aural warning) is shutting down the airflow to the cargo compartment. All ventilated cargo compartments have a means for shutting off the airflow from the flight deck. Following airflow shutdown, Class C cargo compartment fire suppression systems provide minimum Halon 1301 concentration coverage for one hour or more, depending on the aeroplane model, sufficient to suppress the fire until the aeroplane lands at the nearest suitable airport. The flight crew commands the discharge of the cargo fire suppression system from the flight deck. This initiates thedischarge of halon from fire suppression bottles, which are generally located next to the cargo compartment. Additional fire suppression capability is designed into the aeroplane as required for Extended Operations and is dependent on airline customer optionconfiguration.

Typically, cargo fire suppression systems have an initial high-rate knockdown discharge, followed by a low-rate metered discharge of Halon 1301, designed to keep the fire suppressed for continued safe flight and landing at the nearest suitable airport.

Halon can be discharged into the forward or aft cargo compartment. The probability of a cargo fire in any compartment is very low, and the likelihood of two simultaneous fires in two cargo compartments is even lower. Because of this, it is not required to have separate halon bottles for each compartment. One set of bottles provides suppression capability to either cargo compartment.

Once a fire is detected and the halon discharged, minimum halon concentrations are required for the remaining duration of flight. Compliance to these requirements is demonstrated by measuring suppression agent concentration at key locations in the compartment during a certification flight test.

The initial knockdown fire suppression systems installed in all Boeing aeroplane cargo compartments consist of Halon 1301 bottles discharged through a distribution tubing system to discharge nozzles in the respective cargo compartment ceiling. This initial discharge knocks down the flames and suppresses a fire with a minimum of 5 percent Halon 1301 concentration by volume. The system is sized as a function of compartment volume, temperature, and cabin altitude and typically takes one to two minutes to reach maximumconcentrations.

A second discharge, a metered system with a flow regulator, is either discharged at the same time as the initial knockdown or after a specified time delay and provides a steady-state halon flow rate to maintain compartment halon concentrations above3 percent for a specified duration. The required metered flow is a function of compartment leakage. The higher the compartment leakage rate, the higher the halon flow rate must be to compensate. Cargo compartments are designed to minimize compartment leakage during a fire to maximize halon retention and to reduce smoke penetrationeffects.

An alternate method for maintaining the minimum required halon concentration is the high-rate discharge fire suppression system. As the concentration of agent from the initial knockdown decays and approaches 3 percent, a subsequent bottle is discharged; the concentration increases and again begins to decay. Depending on system design, additional bottles may be discharged to maintain concentration levels above 3 percent until the aeroplane has landed safely and the passengers and crew evacuated. An aeroplane timer is turned on when the first discharge occurs and subsequent discharges are made manually by the flight crew. The time delay for discharging the additional high-rate bottles is defined in the aeroplane flight manual and is also usually incorporated into the alert messaginglogic.

Fire fighting in a Class E cargo compartment is accomplished by shutting down the airflow to the compartment, depressurizing the aeroplane, and (depending on aeroplane) descending to just below 25,000 feet as conditions permit. If it is not possible to immediately land at a suitable airport, the depressurized aeroplane is maintained at approximately 25,000 feet to minimize the oxygen available to the fire. Supplemental oxygen is provided to the flight crew and any supernumeraries via oxygen masks when the cabin altitude exceeds 10,000feet.

Lavatory Fire Protection

Each lavatory is equipped with fire protection systems designed to detect and extinguish fires and to prevent hazardous quantities of smoke from entering occupied areas. Lavatory fire- protection features include:

- A smoke detection system that provides a warning light on the flight deck, or provides a warning light or audible warning in the passenger cabin that would be readily detected by a flight attendant.
- Each receptacle used for the disposal of flammablewaste material is fully enclosed, constructed of fire-resistant materials, and able to contain fires that might occur.
- Be capable of containing a fire for 30minutes.
- A built-in fire extinguisher for each paper waste disposal receptacle located within the lavatory. The extinguisher is designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle. Most lavatories incorporate the use of Halon 1301 as thesuppression agent in fire extinguishers

All built-in fire extinguishers meet these requirements:

- Noextinguishing agent that is likely to enter personnel compartments can be hazardous to theoccupants,
- No discharge of the extinguisher can cause structural damage,
- The capacity of each extinguishing system must be adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilationrate.

Lavatory Smoke Detection

A smoke detector is installed in each lavatory ceiling in the air outlet cavity. A warning alerts the cabin attendants and pilots if a fire exists. Independent fire extinguishers will automatically relieve their agent into the waste bin, if a passenger used it as an ashtray. In addition, the cabin crew must use portable fire extinguishers.

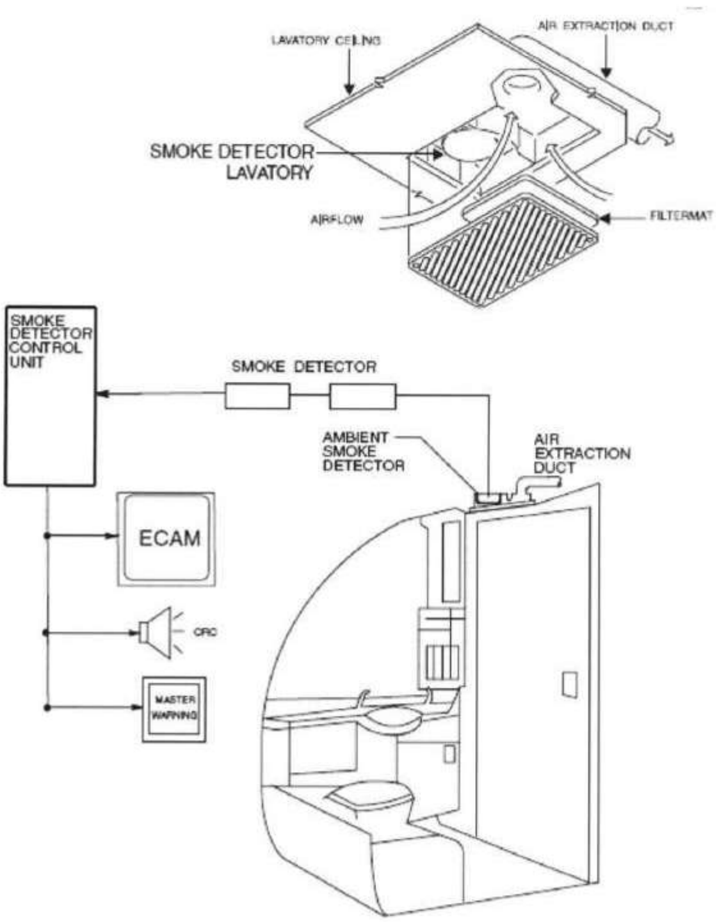


Fig. 8.44 Lavatory smoke detection

A fire / smoke warning is provided in

- the flight deck via the master caution and a dedicated LAV SMOKElight
- the Flight Attendant's panel via a horn and a lavatorylocator light
- the passenger compartment via the lavatory call light and tone and an annunciator on the exit locator sign,and
- a horn and alarm light at the lavatory itself.

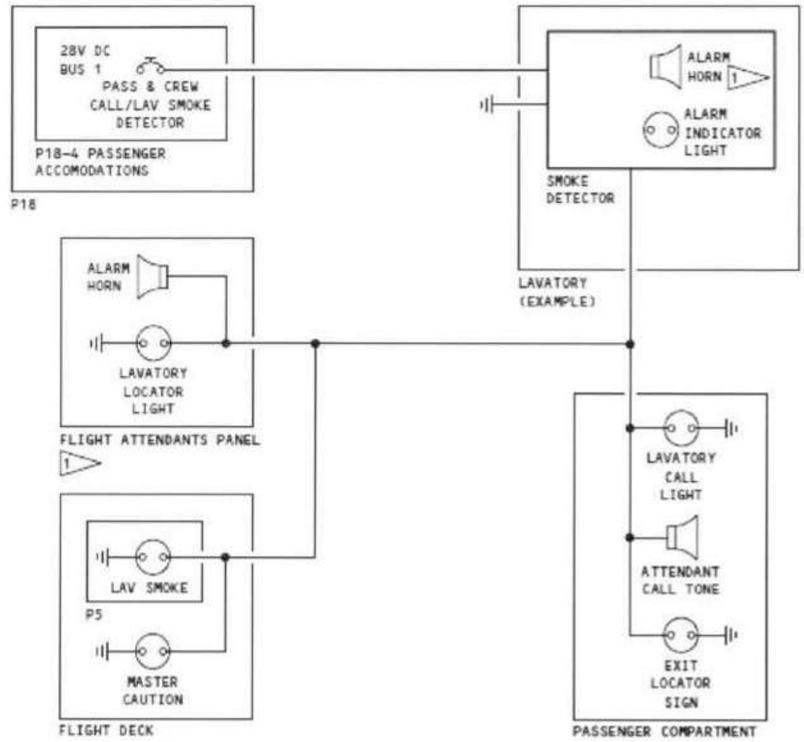


Fig. 8.45 Lavatory smoke detection indication Waste Bin Fire Extinguisher

A fire extinguishing cylinder has been installed near the waste containers in the lavatories. This cylinder discharges automatically into the waste container when the temperature in it rises too high. The shut off device of these cylinders consists of material that has a low melting point (approximately 71<C).

A temperature plate located above the waste bin indicates a temperature exceedance.

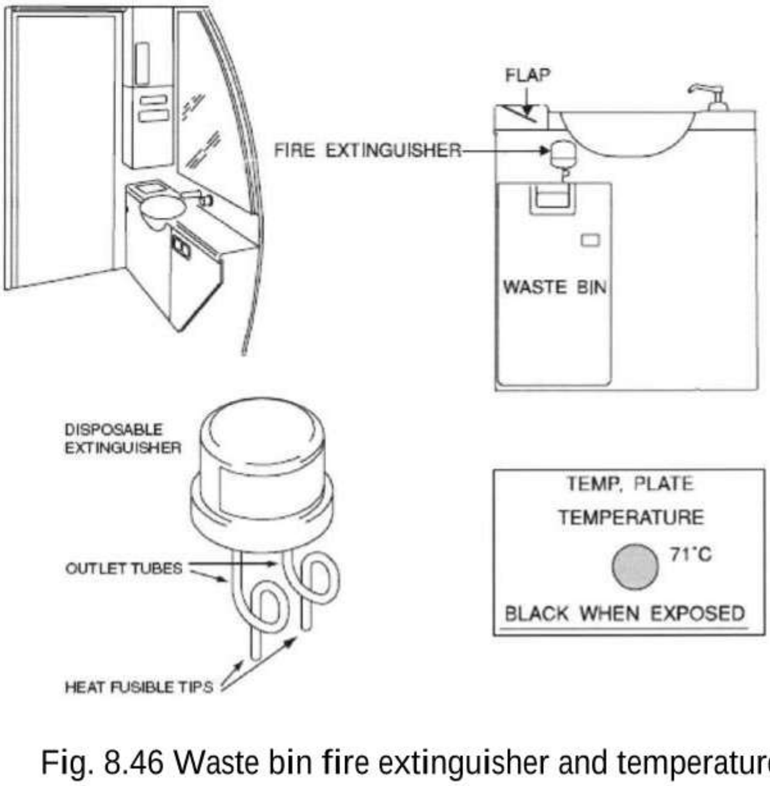


Fig. 8.46 Waste bin fire extinguisher and temperature plate

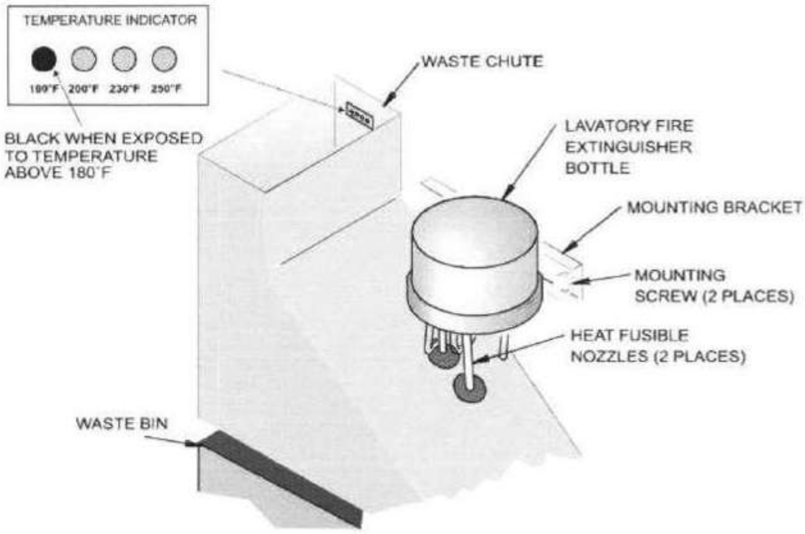


Fig. 8.47 Waste bin fire extinguisher and temperature plate Lavatory Regulatory Requirements Smoking shall not be permitted in toilet compartments

No Smoking placards and ashtrays are required both inside and outside these compartments.

The No Smoking placards shall be displayed so as to be prominent to, and the ashtrays shall be obviously and conveniently placed for, those about to enter and those within thesecompartments.

CAA publication CAP 747 GR No.20 (previously published as Airworthiness Notice No.83) provides guidance on the inspection of lavatories.

At intervals not exceeding 72 hours elapsed time, or at such other

intervals as may be agreed with the CAA on the basis of available data, the following inspection shall be performed:

- All receptacles shall be inspected to ascertain that all entry flaps or doors still operate, fit, seal and latch correctly, ashtrays are fitted, notices installed and receptacle stowage compartment is clean with all debris removed.
- Any defects revealed by the inspection of (a) arecorrected.

This inspection shall be included in the Maintenance Schedules using the normal procedure.

For compliance to be shown, such receptacles shall be constructed of materials which are flame resistant*, and which in addition, will retain sufficient mechanical properties as to contain such a fire as may develop by burning of materials such as paper towels, as may be within the receptacle. (It should be noted that although a thermoplastic material may be flame resistant it would not necessarily retain adequate mechanical properties in the case of a fire.) The receptacle shall be completely enclosed with the exception of a self-closing entry flap or door, which itself shall be rigid, and when closed, form as airtight a seal as is practicable. Entry flaps or doors shall be designed so that they remain self- closing even after exposure to a fire within thereceptacle.

NOTE: Suitable methods for flame resistance testing are contained in EASA CS-25 AppendixF.

It is, however, permissible for receptacles to be open topped provided that they are mounted in a cabinet which itself complies with the regulations. In this instance, the door of the cabinet shall be of a robust construction and such as to ensure an adequate seal and to withstand misuse in service. Such cabinets shall not contain other flammable materials, potential fire sources (e.g. electrical apparatus) or apertures which would either allow air to feed a fire or permit a fire to spread beyond the cabinet (e.g. through apertures provided for services).

It is accepted that some receptacles, e.g. paper towel dispensers, cannot readily be designed to meet the above requirements. In such instances they shall be so designed and positioned within the compartment to ensurethat:

- The likelihood of the depositing of cigarette ends, etc., into them is minimized,and
- A fire, which could be expected to start in another container, cannot readily spread to them; for example, a paper towel dispenser must not be positioned adjacent to,or
- Immediatelyabove,eithertheentryflapordoorofawaste
container or an ashtray provided in the compartment.

Avionics Smoke Detection

Avionics smoke detection is performed by sampling the air extracted from the cockpit panels and avionics equipment racks. The pilots are alerted if avionics systems are under smoke or fire.

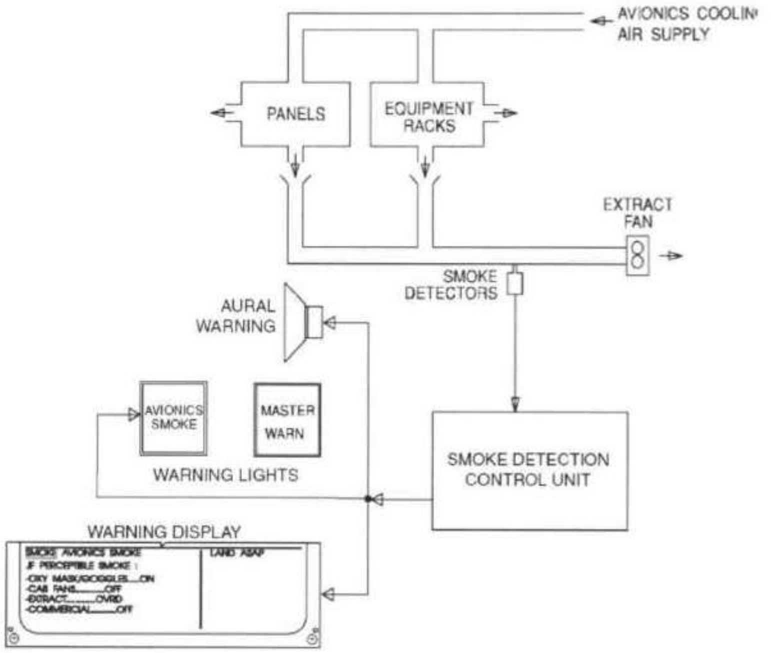


Fig. 8.48 Avionics smoke warning system

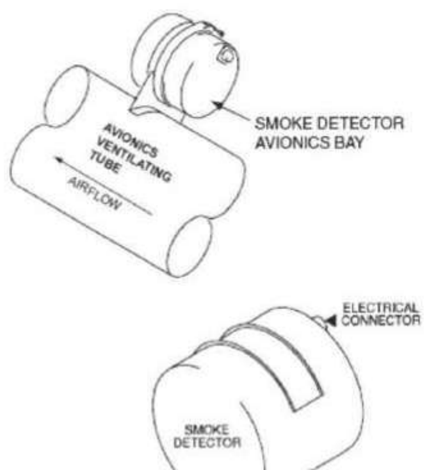


Fig. 8.49: Smoke detector Example System - Boeing 737

Fire and overheat detection systems provide aural and visual alerts whenever overheat or fire is detected.

- Engine firedetection

Dual-loop fire and overheat detection systems are in each engine area. Both loops of a system must sense fire in order for a fire alarm to be given. If one loop is inoperative, then the system may be set to operate on the operativeloop.

- APU firedetection

A single-loop fire detection system is in the APU compartment.

- Wheel well firedetection

A single-loop fire detection system is in the main landing gear wheelwell.

- Wing and lower aft body overheatdetection

Two single-loops overheat detection systems are in the wings, the air conditioning bays, the aft cargo compartment, the keel beam, and the APU area.

- Lavatory smokedetection

A smoke detector unit is located in each lavatory.

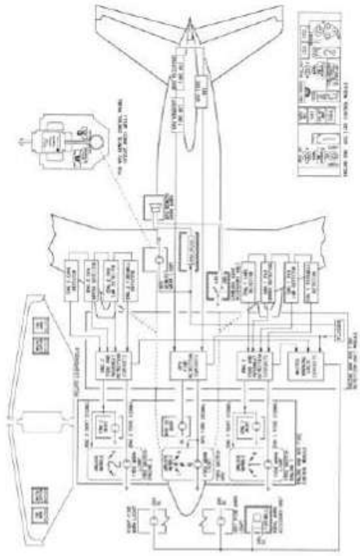


Fig. 8.50 Boeing 737 fire protection system

Engine Fire Extinguishing Systems

These systems are provided for power plants, APUs, and in some types of aircraft, for landing gear wheel bays, baggage compartments and combustion heater installations. A system generally consists of a number of metal containers or bottles, containing an extinguishant which is pressurized with an inert gas and sealed by means of a discharge or operating head. When operated, either by selector switches in the cockpit or crash switches, an electrically fired cartridge ruptures a metal diaphragm within the discharge head and the extinguishant is released to flow through spray pipes, spray rings or discharge nozzles into the appropriate fire zone. Electrical power is 28 volts DC. and is supplied from an essential services busbar or the batterybusbar.

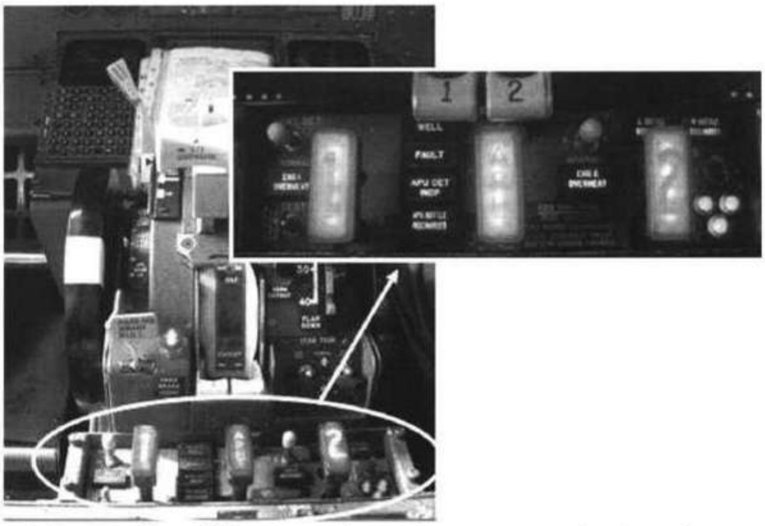


Fig. 8.51 Typical fire extinguisher panel on centre console (Boeing 737).Other aircraft have the fire extinguisher panel located on the overhead panel

Two extinguishing methods are used for power plants. In the first method, which is employed in the majority of older types of aircraft, an individual system is provided for each power plant. The second method, known generally as the 'two-shot system', is the one most widely used and comprises connections between the individual power plant systems, so permitting two separate discharges of extinguishant into any one power plant.

In several types of aircraft, indication that a fire extinguishing circuit has been operated, is provided either by, warning lights or, indicating fuses connected in the circuit. The fuses contain a small charge and are enclosed within a domed cover which is normally transparent. When current flows in the relevant extinguishing circuit the charge is fired, and this causes a red powder to be spattered on the inside of the domed cover, thus furnishing a clear and lasting indication of the operation of an extinguisher.

In some installations special switches are incorporated to automatically operate the extinguishers in the event of a crash. These switches also connect cabin emergency lights to the aircraft battery power supply. Two types of crash switch are in common use: the inertia control type and the frangible type. An inertia controlled switch generally consists of a heavy piston supported on its own spring and so arranged that at the required degree of deceleration (a typical value is 3g), it compresses the spring and causes a bow spring to snap over thereby bridging contacts connected in the extinguishing system circuit. To allow resetting of the switch after operation or rough handling during transit, a reset plunger is incorporated.

Fig. 8.52 Typical fire extinguisher panel on centre console on later aircraft type Typical Large Commercial

Twin Jet Fire Extinguishing System

The fire extinguishing system includes a cockpit control switch, fire extinguishing agent containers, and an agent distribution system.

Figure 8.53 shows a typical container which houses the extinguishing agent. An engine can be protected with one bottle only or a cross-feed system with two or more bottles.

The bottle is pressurized with the extinguishing agent, in the range of 500 to 600 PSI. The gauge indicates the correct charge. The relief valve is a fusible (frangible) disk which will rupture if the bottle were to overheat. To discharge the bottle from the cockpit, an electrical current is applied to the contactor that detonates an

explosive cartridge (commonly called a squib). This shatters a disk located in the bottle outlet. From there the agent flows to the engine.

Figure 8.54 illustrates a twin engine extinguisher system with a cross-feed. A number one engine fire can be extinguished with a number one fire bottle and also number two fire bottle. The same is true for number two engine through the distribution system.

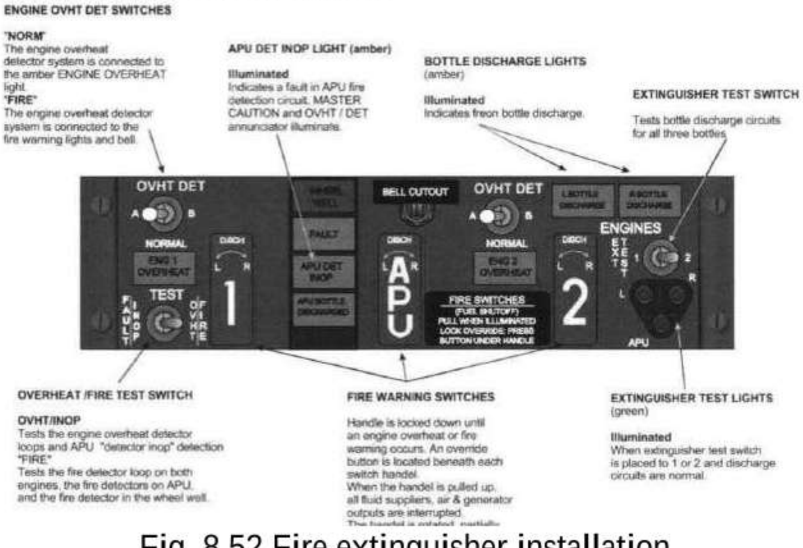


Fig. 8.52 Fire extinguisher installation

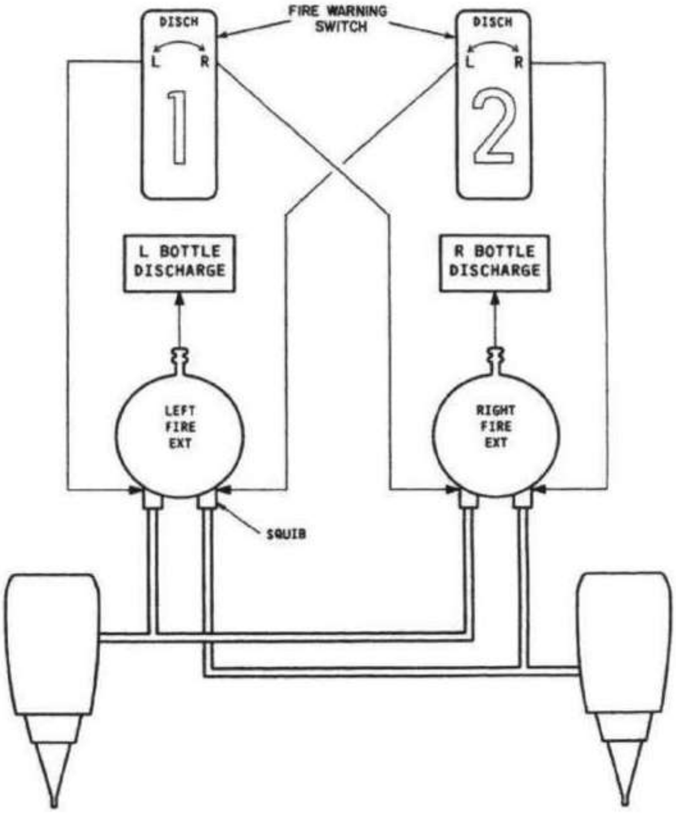


Fig. 8.53 Two-shot system

To operate the fire extinguisher following a fire alarm / red warning light, the pilot will firstly pull the associated discharge handle. This action will:

- disconnect the associated engine's electrical generator field,

thus shutting down the generator which is driven by that engine

- offload the associated hydraulic pump
- close the fuel HP cock supplying that engine

Turning the discharge handle left or right will operate the left or right fire bottle squib respectively, and discharge the contents of that bottle into the engine compartment. If the redwarning light fails to extinguish, or extinguishes but subsequently comes back on, the same fire handle can be turned in the opposite direction, thus discharging the contents of the other fire extinguisher bottle into the same engine. This is known as a two-shot system.

Common Extinguishing Agents, Approved for Engine Fire Extinguishing

Carbon Dioxide (C02) — The oldest type agent used in aviation. It is non-corrosive to metal parts but can cause shock to hot running parts of the engine if used in great quantity. Extinguishes by dissipating oxygen. CO2 is considered toxic.
Bromochlorodifluoromethane (Halon 1211) (CBrCIF2) — It is colourless, non- corrosive and evaporates rapidly leaving no residue whatever. It does not freeze or cause cold bums 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 importantly interferes chemically with the combustion process. It has outstanding properties in preventing reflash after the fire has been extinguished.
Bromotrifloromethane (Halon 1301) (CF3Br) — An expensive nontoxic, non-corrosive agent which is very effective on engine fires. Also considered one of the safest agents from the standpoint of toxicity and corrosion. Halon 1301 has all the characteristics of Halon 1211, and it is less toxic.

Engine Bottle Discharge Indicators

In fire extinguisher systems of the fixed type, provision is made for positive indication of extinguisher discharge as a result of either (a) intentional firing, or (b) inadvertent loss of contents, i.e. pressure relief overboard or leakage. The methods adopted are generally mechanical and electrical inoperation.

Mechanical Indicators - Mechanical indicators are, in many instances, fitted in the operating heads of extinguishers and take the form of a pin that under normal conditions is flush with the cap of the hollow junction box. When an extinguisher has been fired, and after the charge plug has been forced down the hollow junction box, the spigot of the plug strikes the indicator pin causing it to protrude from the cap, thereby providing a visual indication of extinguishantdischarge

Pressure gauges - In the extinguishers employed in some types of aircraft, mechanical type pressure gauges are embodied in the containers and these serve to indicate extinguishant discharge in terms of pressure changes and, in addition, serve as a maintenance check on leakage.

FLIGHT CONTROL SYSTEMS AXIS OF CONTROL

An aircraft is free to rotate around three axes that are perpendicular to each other and intersect at its centre of gravity (CG). To control position and direction a pilot must be able to control rotation about each ofthem.

Lateral Axis

The lateral axis passes through an aircraft from wingtip to wingtip. Rotation about this axis is called pitch. Pitch changes the vertical direction that the aircraft's nose is pointing. The elevators are the primary control surfaces forpitch.

Longitudinal Axis

The longitudinal axis passes through the aircraft from nose to tail. Rotation about this axis is called roll. Rolling motion changes the orientation of the aircraft's wings with respect to the downward force of gravity. The pilot changes bank angle by increasing the lift on one wing and decreasing it on the other. This differential lift causes bank rotation around the longitudinal axis. The ailerons are the primary control of bank. The rudder also has a secondary effect onbank.

Vertical Axis

The vertical axis passes through an aircraft from top to bottom. Rotation about this axis is called yaw. Yaw changes the direction the aircraft's nose is pointing, left or right. The primary control of yaw is with the rudder. Ailerons also have a secondary effect on yaw.

It is important to note that these axes move with the aircraft, and change relative to the earth as the aircraft moves. For example, for an aircraft whose left wing is pointing straight down, its "vertical" axis is parallel with the ground, while its "lateral" axis is perpendicular to the ground.

Primary Control Surfaces Ailerons

Ailerons are mounted on the trailing edge of each wing near the wingtips and move in opposite directions. When the pilot moves the stick left, or turns the wheel counter-clockwise, the left aileron goes up and the right aileron goes down. A raised aileron reduces lift on that wing and a lowered one increases lift, so moving the stick left causes the left wing to drop and the right wing to rise. This causes the aircraft to roll to the left and begin to turn to the left. Centering the stick returns the ailerons to neutral maintaining the bank angle. The aircraft will continue to turn until opposite aileron motion returns the bank angle to zero to fly straight.

Elevator

An elevator is mounted on the trailing edge of thehorizontal stabilizer on each side of the fin in the tail. They move up and down together. When the pilot pulls the stick backward, the elevators go up. Pushing the stick forward causes the elevators to go down. Raised elevators push down on the tail and cause the nose to pitch up. This makes the wings fly at a higher angle of attack, which generates more lift and more drag. Centring the stick returns the elevators to neutral and stops the change of pitch. Many aircraft use a stabilator, a moveable horizontal stabilizer, in place of an elevator. Some aircraft, such as an MD-80, use a servo tabwithintheelevatorsurfacetoaerodynamicallymovethemain surface into position. The direction of travel of the control tab will thus be in a direction opposite to the main control surface.

It is for this reason that an MD-80 tail looks like it has a 'split' elevator system.

Rudder

The rudder is typically mounted on the trailing edge of the vertical stabilizer, part of the empennage. When the pilot pushes the left pedal, the rudder deflects left. Pushing the right pedal causes the rudder to deflect right. Deflecting the rudder right pushes the tail left and causes the nose to yaw to the right. Centring the rudder pedals returns the rudder to neutral and stops the yaw

Secondary Effects of Controls Ailerons
The ailerons primarily control roll. Whenever lift is increased, induced drag is also increased. When the stick is moved left to roll the aircraft to the left, the right aileron is lowered which increases lift on the right wing and therefore increases induced drag on the right wing. Using ailerons causes adverse yaw, meaning the nose of the aircraft yaws in a direction opposite to the aileron application. When moving the stick to the left to bank the wings, adverse yaw moves the nose of the aircraft to the right. Adverse yaw is more pronounced for light aircraft with long wings, such as gliders. It is counteracted by the pilot with the rudder. Differential ailerons are ailerons which have been rigged such that the downgoing aileron deflects less than the upward- moving one, reducing adverse yaw.

Rudder

The rudder is a fundamental control surface, typically controlled by pedals rather than at the stick. It is the primary means of controlling yaw - the rotation of an airplane about its vertical axis. The rudder may also be called upon to counter-act the adverse yaw produced by the roll- controlsurfaces.

If rudder is continuously applied in level flight the aircraft will yaw initially in the direction of the applied rudder - the primary effect of rudder. After a few seconds the aircraft will tend to bank in the direction of yaw.

This arises initially from the increased speed of the wing opposite to the direction of yaw and the reduced speed of the other wing. The faster wing generates more lift and so rises, while the other wing tends to go down because of generating less lift. Continued application of rudder sustains rolling tendency because the aircraft flying at an angle to the airflow - skidding towards the forward wing. In an aircraft with dihedral the left hand wing will have increased angle of attack and the right hand wing will have decreased angle of attack which will result in a roll to the right. An aircraft with anhedral will show the opposite effect. This effect of the rudder is commonly used in model aircraft where if sufficient dihedral or polyhedral is included in the wing design, primary roll control such as ailerons may be omittedaltogether.

Turning the Aircraft

Unlike a boat, turning an aircraft is not normally carried out with the rudder. With aircraft, the turn is caused by the horizontal component of lift. The lifting force, perpendicular to the wings of the aircraft, is tilted in the direction of the intended turn by rolling the aircraft into the turn. As the bank angle is increased the lifting force, which was previously acting only in the vertical, is split into two components: One acting vertically and one acting horizontally.
If the total lift is kept constant, the vertical component of lift will decrease. As the weight of the aircraft is unchanged, this would result in the aircraft descending if not countered. To maintain level flight requires increased positive (up) elevator to increase the angle of attack, increase the total lift generated and keep the vertical component of lift equal with the weight of the aircraft. This cannot continue indefinitely. The wings can only generate a finite amount of lift at a given air speed. As the load factor (commonly called G loading) is increased an accelerated aerodynamic stall will occur, even though the

aircraft is above its 1G stall speed.

The total lift (load factor) required to maintain level flight is directly related to the bank angle. This means that for a given airspeed, level flight can only be maintained up to a certain given angle of bank. Beyond this angle of bank, the aircraft will suffer an accelerated stall if the pilot attempts to generate enough lift to maintain level flight.

Alternate Main ControlSurfaces

Some aircraft configurations have non-standard primary controls. For example instead of elevators at the back of the stabilizers, the entire tailplane may change angle. Some aircraft have a tail in the shape of a V, and the moving parts at the back of those combine the functions of elevators and rudder. Delta wing aircraft may have "elevons" at the back of the wing, which combine the functions of elevators andailerons.

Secondary Control Surfaces

Spoilers

On low drag aircraft like sailplanes, spoilers are used to disrupt airflow over the wing and greatly increase the amount of drag. This allows a glider pilot to lose altitude without gaining excessive airspeed. Spoilers are sometimes called "lift dumpers". Spoilers that can be used asymmetrically are sometimes called “spoilerons” and are able to affect an aircraft's roll.

Flaps

Flaps are mounted on the trailing edge of each wing on the inboard section of each wing (near the wing roots). They are deflected down to increase the effective curvature of the wing. Flaps raise the Maximum Lift Coefficient of the aircraft and therefore reduce its stalling speed. They are used during low speed, high angle of attack flight including take-off and descent for landing. Some aircraft are equipped with "flaperons", which are more commonly called "inboard ailerons". These devices function primarily as ailerons, but on some aircraft, will "droop" when the flaps are deployed, thus acting as both a flap and a roll- control inboardaileron.

Slats

Slats, also known as Leading Edge Devices, are extensions to the front of a wing for lift augmentation, and are intended to reduce the stalling speed by altering the airflow over the wing. Slats may be fixed or retractable - fixed slats give excellent slow speed and STOL capabilities, but compromise higher speed performance. Retractable slats, as seen on most airliners, provide reduced stalling speed for take-off and landing, but are retracted for cruising.

Air Brakes

Air brakes, also called spoilers, are used to increase drag. On a typical airliner, for example, the spoilers are a series of panels on the upper surface of the wing which deploy upwards to disrupt airflow over the wing, thus adding drag. The number of panels that deploy, as well as the degree to which they deploy, depends on the regime of flight in which they are used. For example, if a pilot must descend quickly without increasing speed, he may select a speed brake setting for the desired effect. In such a case, only certain spoiler panels will deploy to create the most efficient reduction in speed without overstressing the wing. On most airliners, spoiler panels on the wings mix with aileron inputs to enhance roll control. For example, a left bank will engage the ailerons as well as deploy certain spoiler panels on the downgoing wing. Ground spoilers are essentially similar to flight spoilers, except that they deploy upon touchdown on the runway, and include all spoiler panels for maximum "lift dump". After touchdown, the ground spoilers deploy, and "dump" the lift generated by the wings, thus placing the aircraft's weight on the wheels, which accomplish the vast majority of braking after touchdown. Most jet airliners also have a thrust reverser, which simply deflects exhaust from the engines forward, helping to slow the aircraftdown.

Trim Controls

Trimming controls allow a pilot to balance the lift and drag being produced by the wings and control surfaces over a wide range of load and airspeed. This reduces the effort required to adjust or maintain a desired flight attitude.

Elevator Trim

Elevator trim balances the control force necessary to maintain the aerodynamic down force on the tail. Whilst carrying out certain flight exercises, a lot of trim could be required to maintain the desired angle of attack. This mainly applies to slow flight, where maintaining a nose-up attitude requires a lot of trim. Elevator trim is correlated with the speed of the airflow over the tail, thus airspeed changes to the aircraft require re-trimming. An important design parameter for aircraft is the stability of the aircraft when trimmed for level flight. Any disturbances such as gusts or turbulence will be damped over a short period of time and the aircraft will return to its level flight trimmed airspeed

Trimming Tailplane

Except for very light aircraft, trim tabs on elevators are often unable to provide the force and range of motion desired. To provide the appropriate trim force the entire horizontal tail plane is made adjustable in pitch. This allows the pilot to select exactly the right amount of positive or negative lift from the tail plane while reducing drag from theelevators.

Control Horn

A control horn is a section of control surface which projects ahead of the pivot point. It generates a force which tends to increase the surface's deflection thus reducing the control pressure experienced by the pilot. Control horns may also incorporate a counterweight which helps to balance the control and prevent it from "fluttering" in the airstream. Some designs feature separate anti-flutter weights.

Spring Trim

In the simplest cases trimming is done by a mechanical spring (or bungee) which adds appropriate force to augment the pilot's control input. The spring is usually connected to an elevator trim lever to allow the pilot to set the spring force applied.

Rudder and aileron trim

Trim often does not only apply to the elevator, as there is also trim for the rudder and ailerons in larger aircraft. The use of this is to counter the effects of slip stream, or to counter the effects of the centre of gravity being to one side. This can be caused by a larger weight on one side of the aircraft compared to the other, such as when one fuel tank has a lot more fuel in it than the other.

External Surfaces

Figure 9.1 shows the external control surfaces, both primary and secondary controls, on a typical transport category aircraft.

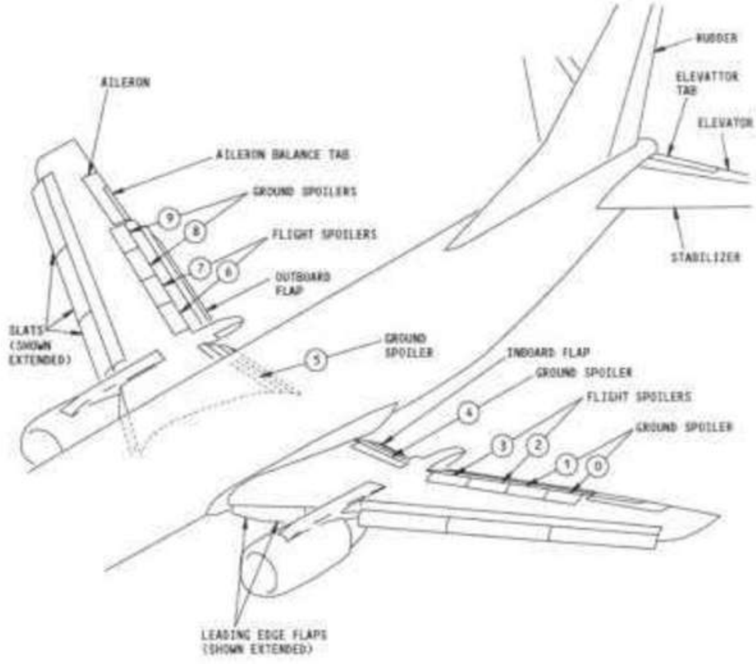


Fig. 9.1 External control surfaces -conventional layout (Boeing 737)

Cockpit Controls

Figure 9.4 shows the cockpit controls, for both primary and secondary controls, on a typical transport category aircraft.

Figure 9.5 shows a photo of a modern fly-by-wire cockpit equipped with sidestick controls, rather than the conventional control column and yoke.

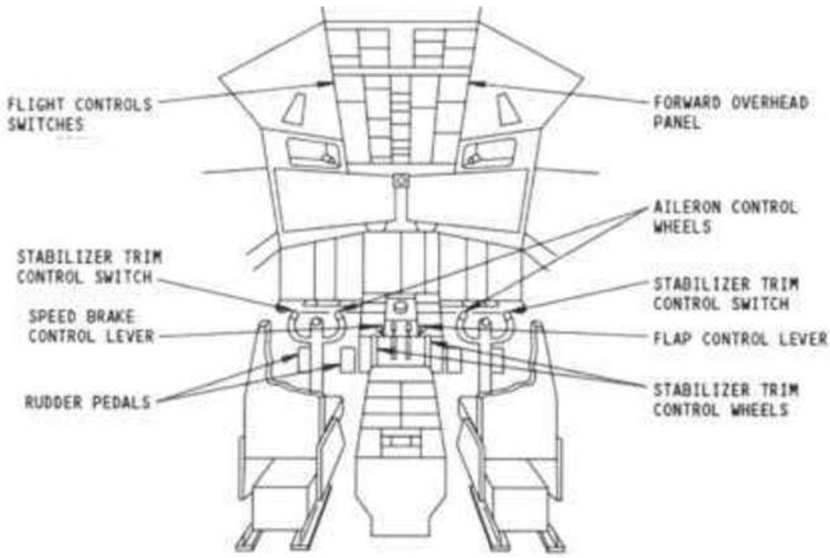


Fig. 9.2Flight deck controls - conventional layout (Boeing 737)

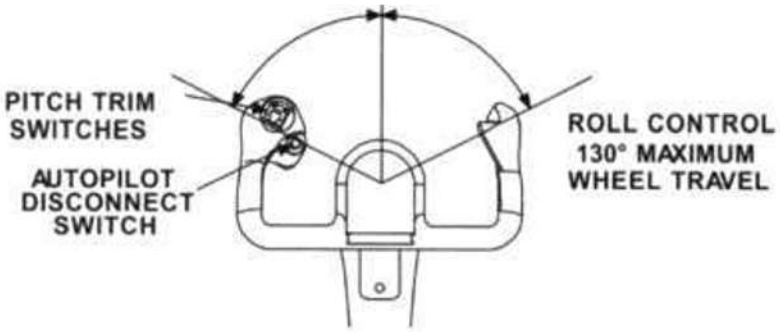


Fig. 9.3 Flight deck control wheel

Fig. 9.4 Flight deck controls - conventional layout (Airbus A300)

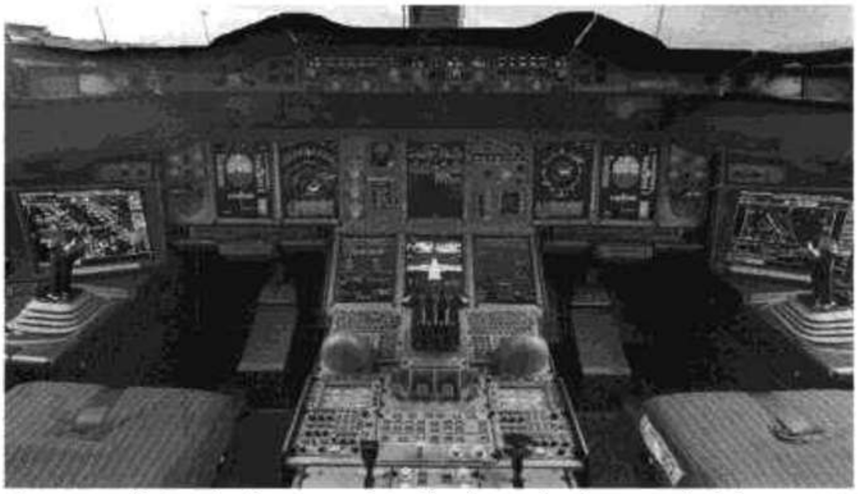


Fig. 9.5 Flight deck controls - fly-by-wire layout (Airbus A380)

Primary Control Systems Operating Methods

Different aircraft manufacturers call units of the primary flight control system by a variety of names. The types and complexity of control mechanisms used depend on the size, speed, and mission of the aircraft. A small or low-speed aircraft may have cockpit controls connected directly to the control surface by cables or push-rods. Some aircraft have both cable and a pushrod system. The force exerted by the pilot is transferred through them to the control surfaces. On large or high-performance aircraft, the control surfaces have high pressure exerted on them by the airflow. It is difficult for the pilot to move the controls manually. As a result, hydraulic actuators are used within the linkage to assist the pilot in moving the control surface. Because these systems reduce pilot fatigue and improve system performance, they are now commonly used. Such systems include automatic pilot, automatic landing

systems, and stability augmentation systems.
See Figure 9.6 for the different operation, transmission and actuation methods.

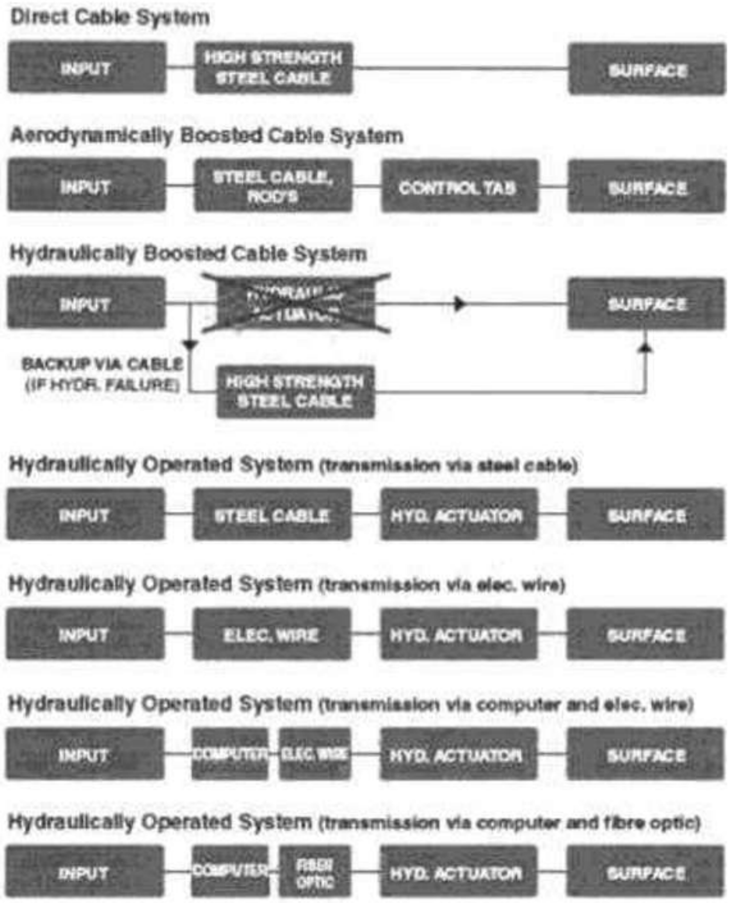


Fig. 9.6 Operation Methods Cable Control Systems

In the direct cable control system, the cockpit controls are connected to the control surfaces with high-strength steel cable. Operation of the control column places tension on the cable. As thecablepassesthroughthefuselage,itissupportedbythe pulleys. The pulleys also enable the direction of the control cable to be changed. Tension of the control cable system is critical. This kind of control is only usable in low speed general aviation aeroplanes.

The force the pilot feels on the steering column while steering the aeroplane is in direct relation to the airspeed and the magnitude of the deflection. Therefore the higher the airspeed, the greater the force on the steering column.

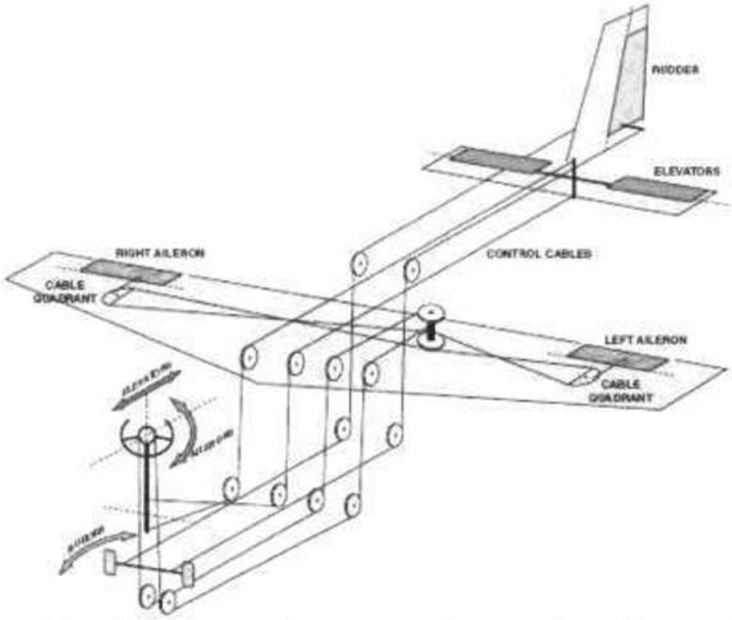


Fig. 9.7 Direct Cable Flight Control System using Steel Cables Push-Pull Rod Systems

A popular type of control actuation system is the push-pull rod system. In this system the cockpit control is connected to the device to be operated with a hollow aluminium tube whose ends are fitted with threaded inserts and a clevis, or more frequently, a rod-end bearing. Figure 9.8 shows an example of usage of such push-pull rods in large aeroplane flight control systems

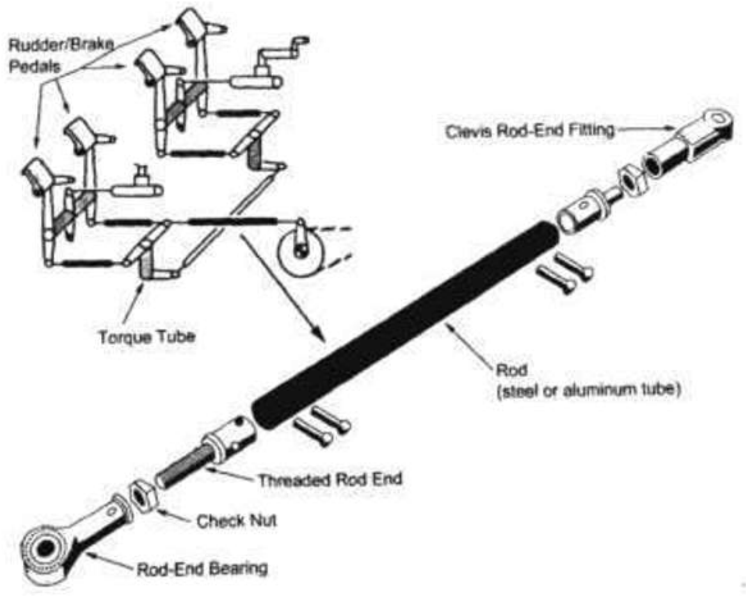


Fig. 9.8 Push-pull rod

Both the cockpit control and the device to be actuated are locked in the correct rigging position, and the rod ends are screwed in or out on the threaded end of the inserts to get the rod to the correct length and the rod end in correct alignment, then the check nuts (or lock-nuts) are screwed tightly against the rod-end fittings to lock them inplace.

Torque Tube Systems