Aircraft Maintenance
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Lecture – 09
Aircraft Electrical System

Hello friends. We are now into week 3 of our aircraft maintenance course. So, far we have seen different systems hydraulic system fuel system landing gear system. This week, we are going to understand what an aircraft electrical system is; what are the different components in the aircraft electrical system, what are the functions; different circuits in the electrical system different lights the lighting systems on an aircraft. So, this aircraft electrical system is a very important system for any aircraft maintenance personnel proper functioning of any aircraft is very much dependent on a good and proper aircraft electrical system.

So, let us see what an aircraft electrical system is all about.

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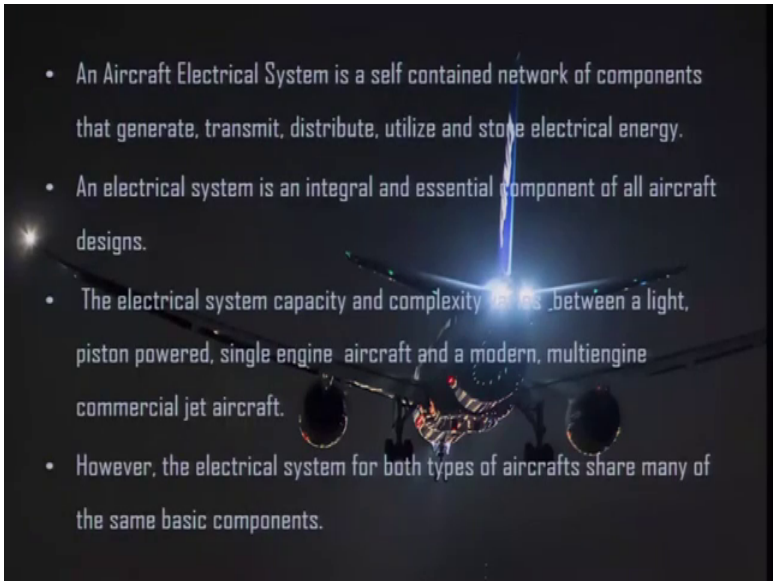

So, aircraft electrical system and aircraft electrical system is a self-contained network of components that generate transmit distribute utilize and store electrical energy. So, an electrical system in an aircraft has the capability to generate transmit distribute utilize

and at the same time store electrical energy an electrical system is an integral and essential component of all aircraft designs.

The electrical system capacity and complexity varies between a light piston powered single engine aircraft and a modern multi engine commercial jet aircraft. So, depending on the type of aircraft depending on the complexity of the aircraft the electrical system varies from aircraft to aircraft from a single piston engine aircraft to a modern multi commercial jet aircraft.

The electrical systems for both types of aircrafts share many of the same basic components the basic components in both types of electrical systems are the same.

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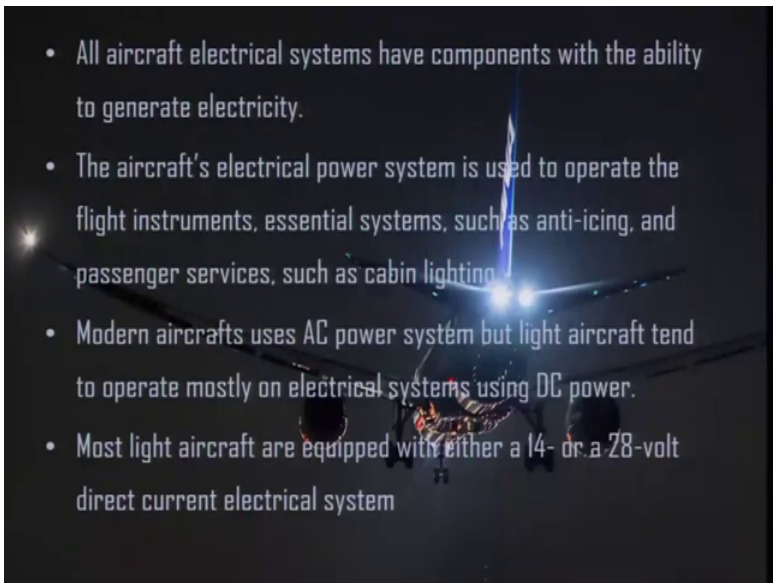

All aircraft electrical systems have components with the ability to generate electricity. So, both types of electrical systems have components which will be generating electricity the aircrafts electrical power system is used to operate flight instruments essential systems such as anti icing passenger services such as cabin lighting.

So, various systems require electrical power the systems which require electrical power some of them are essential systems like anti icing system passenger services such as cabin lighting and some flight instruments modern aircrafts use AC power system, but light aircraft operate mostly on electrical systems using DC power most light aircrafts are

equipped with either a 14 or a 28 volt direct current electrical system. So, light aircrafts are equipped with a 14 volt or a 28 volt direct current electrical system.

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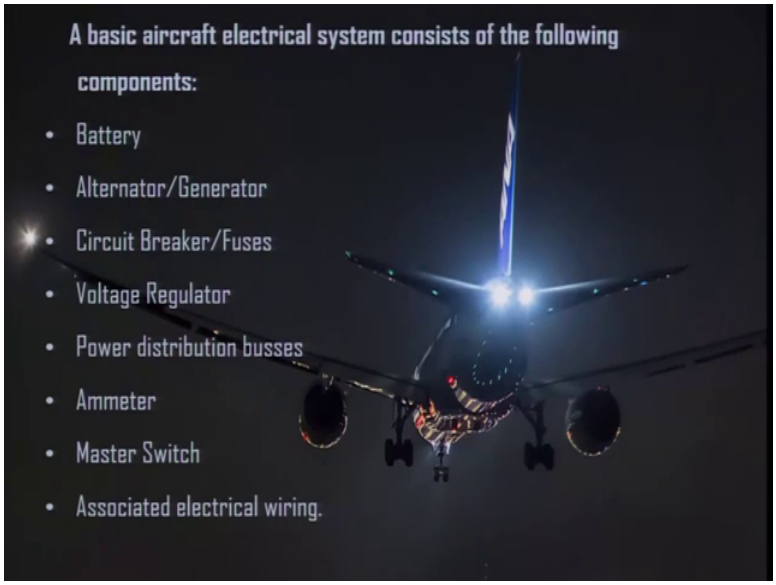

Basic aircraft electrical system consists of the following components. So, some of the basic components in a simple electrical system are battery alternator or generator, circuit breakers, fuses, voltage regulator, power distribution busses, ammeter, master switch and associated electrical wiring. So, these are some of the basic components.

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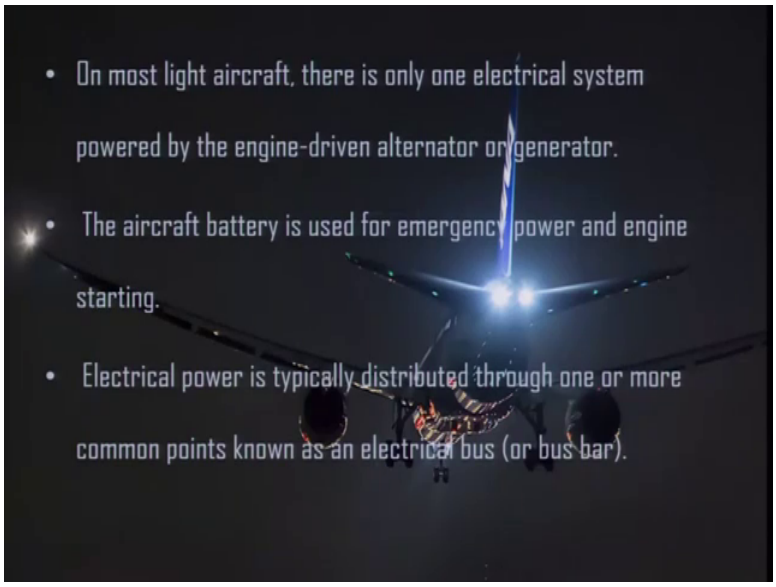

In a single precision engine aircraft electrical system on most light aircraft, there is only one electrical system powered by the engine driven alternator or generator

So, on light aircrafts on simple aircrafts single engine aircrafts, there is only one electrical system which is powered by an alternator or a generator which is engine driven the aircraft battery is used for emergency power and engine starting electrical power is distributed through one or more common points known as an electrical bus or bus bar.

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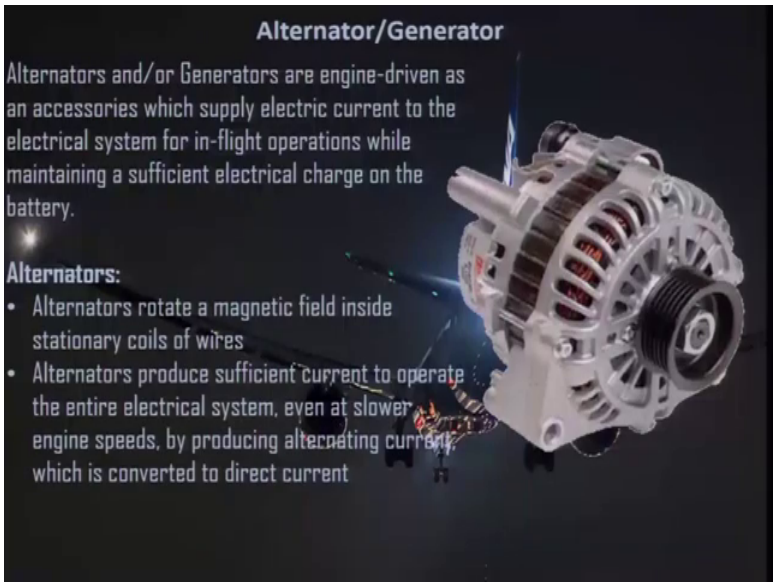

Now, coming to alternator or generator alternators and or generators are engine driven as an accessory which supply electric current to the electrical system for in flight operations while maintaining a sufficient electrical charge on the battery. So, alternators or generators they are in general and they generate electricity and supply electricity for flight operations and also to maintain sufficient electrical charge on the battery.

Alternators rotate a magnetic field inside the stationary coils of wires alternators produce sufficient current to operate the entire electrical system even at slower engine speeds by producing alternating current which is converted to direct current. So, these alternators they produce alternating current which is later converted to direct current for the electrical system.

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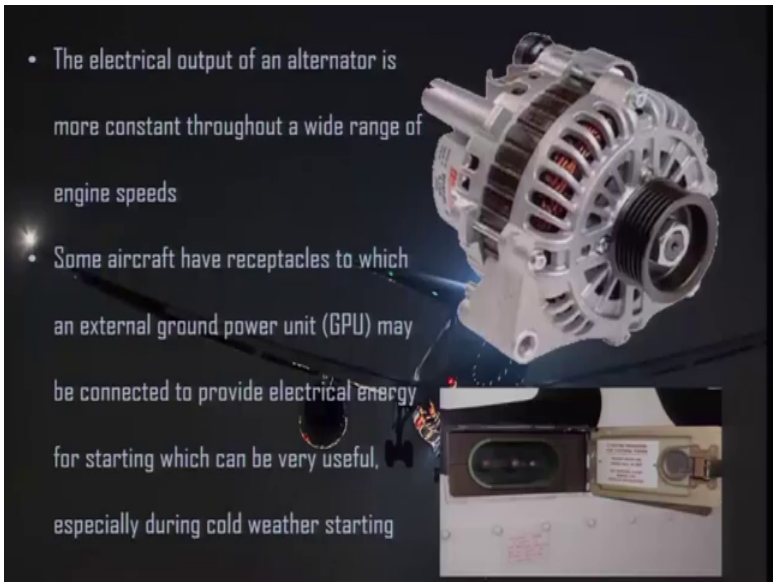

Electrical output of an alternator is more constant throughout a wide range of engine speeds some aircrafts have receptacles to which an external ground power unit may be connected to provide electrical energy for starting which can be very useful especially during cold weather starting.

So, in the figure, you can see the top figure is showing you an alternator and the bottom figure you can see, there is a receptacles which is for the external power with the help of this external power you can start the engine and you can save power in your battery this external power is quite useful especially during cold weather startings. So, in this figure you can see the receptacle for the external power.

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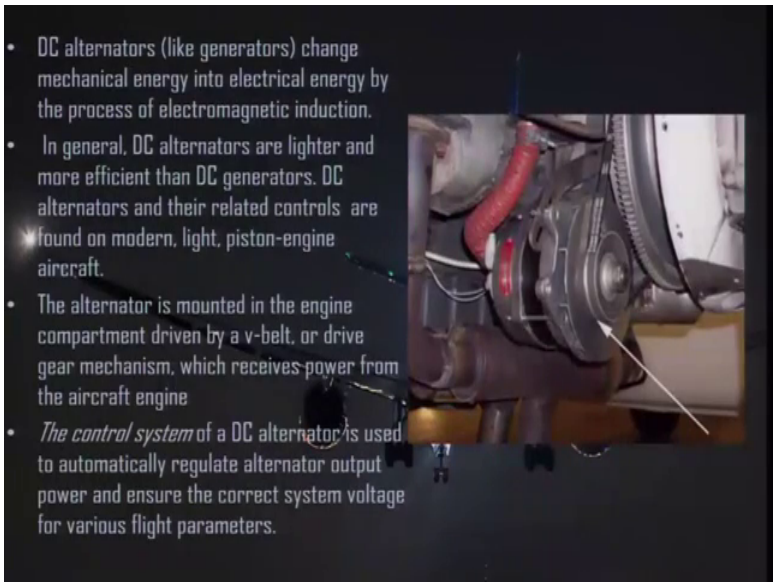

DC alternators like generators change mechanical energy into electrical energy. So, basically alternators they are converting mechanical energy into electrical energy by the process of electromagnetic induction in general DC alternators are lighter and more efficient than DC generators. So, DC alternators, they are light more efficient as compared to DC generators DC alternators and the related controls are found on modern light piston engine aircrafts since these alternators, these DC alternators, they are light in weight more efficient. So, they are being used on all modern light piston engine aircrafts.

The alternator is mounted in the engine compartment driven by a v-belt. So, here in the diagram you can see this is the v-belt, this is your v-belt, the alternator is mounted in the engine compartment. This is the alternator which is mounted in this is the alternator this is mounted in the engine compartment and is driven by a v-belt. This is the belt or drive gear mechanism which receives power from the aircraft engine 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.

So, the control system of a DC alternator will automatically regulate the alternator output power and will ensure that correct voltage is available for various flight parameters.

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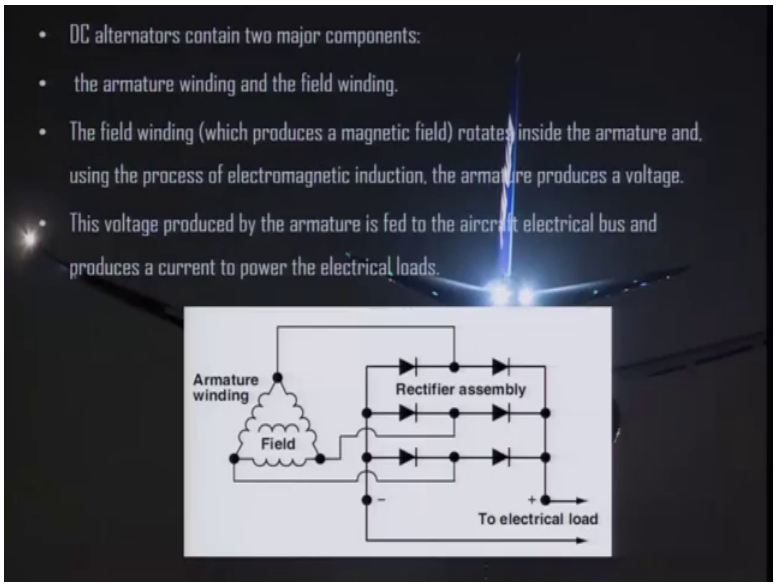

Dc alternators contain two major components the armature winding and the field winding. So, in the figure here you can see there are two types of windings one is the armature winding another is the field winding the field winding which produces a magnetic field rotates inside the armature and using the process of electromagnetic induction the armature produces a voltage.

So, the field winding is rotating inside the armature and by the process of electromagnetic induction is producing voltage this voltage produced by the armature is fed to the aircraft electrical bus and produces a current to power the electrical loads. So, the voltage produced by the armature is fed to the electrical bus and it produces current to power various electrical loads.

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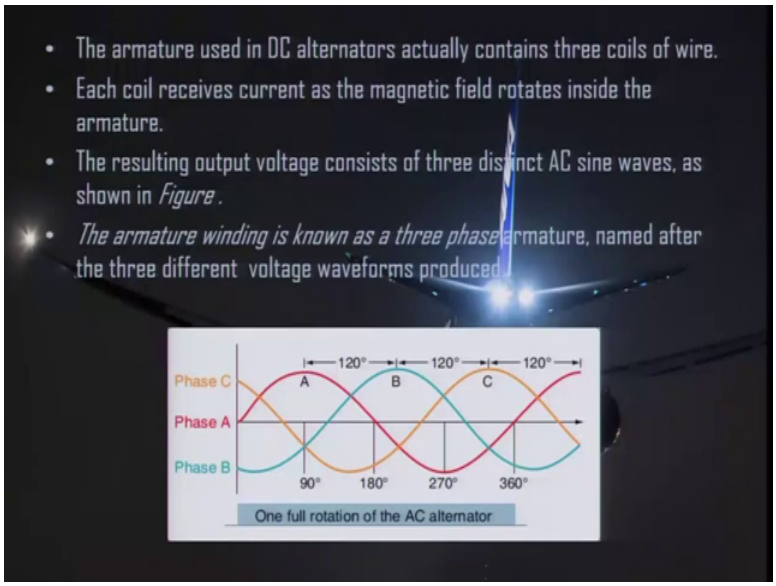

The armature used in DC alternator actually contains 3 coils of wire each coil receives current as the magnetic field rotates inside the armature the resulting output voltage consists of 3 distinct AC sine waves as shown in the figure. So, you can see 3 waves 3 sine waves here the armature winding is known as a 3 phase armature named after the different 3 different voltage waveforms produced.

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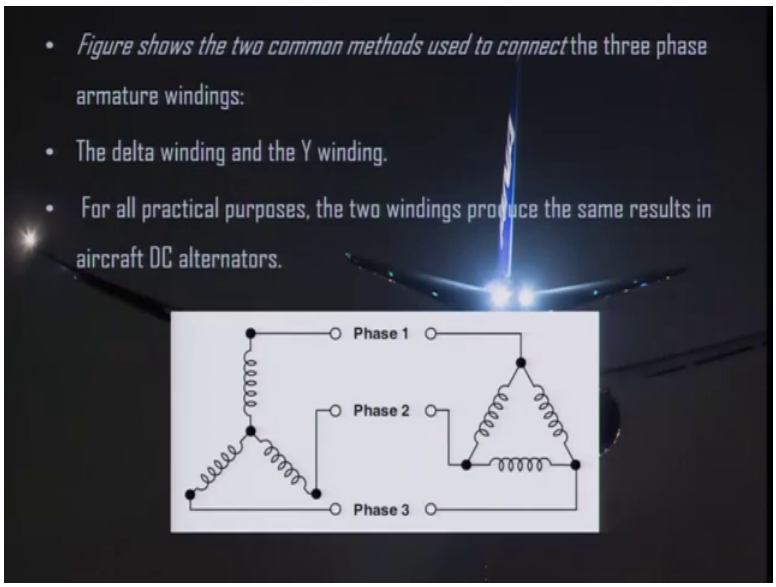

Now, in this figure you can see two common methods which are used to connect the 3 phase armature windings delta winding and the Y winding in both the cases windings produce the same results in a craft DC alternatives.

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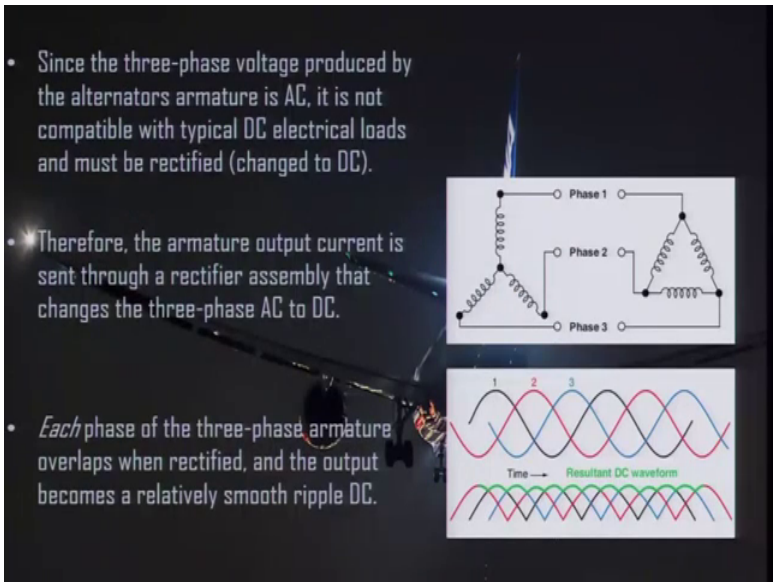

Since the 3 phase produced by the alternator armature is AC it is not compatible with typical DC electrical loads and must be rectified change to DC now the 3 phase voltage which is produced by the alternator armature is AC it has to be converted to DC therefore, the armature output current is sent through a rectifier assembly that changes the 3 phase AC to DC.

So, the armature output current is fed through a rectifier assembly and this rectifier assembly converts AC into DC. So, in the previous diagram this diagram you can see, there is a rectifier assembly shown. So, the AC current is passed through this rectifier and it is converted into DC each phase of the 3 phase armature overlaps when rectified and the output becomes a relatively smooth ripple DC. So, in the bottom diagram you can see that the 3 phase armature overlaps after rectification and the output is a relatively smooth ripple DC.

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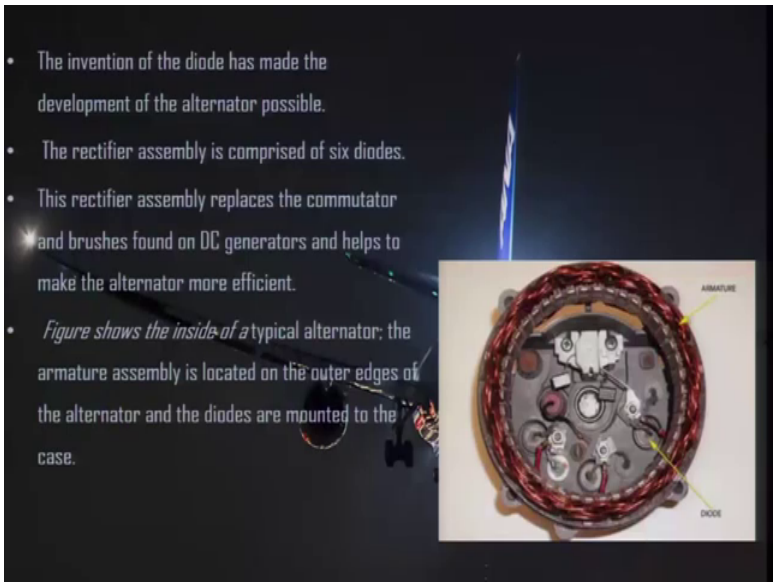

You can see in the figure; this figure the rectifier assembly is comprised of 6 diodes you can see these are the diodes 1, 2, 3, 4, 5, 6; this rectifier assembly replaces the commutator and brushes found on DC generators and helps to make the alternator more efficient. So, these this rectifier assembly has replaced commutator and brushes which were found on DC generators and has made the alternator more efficient figure shows inside of a typical alternator the armature assembly is located on the outer edges of the alternator you can see here this is the armature this is located on the outer edges of the alternator and the diodes are mounted in the case.

So, these are the diodes and this is your armature which is located on the outer edges of the alternator this is the field winding this is mounted on a rotor shaft. So, that it can spin inside of the armature assembly.

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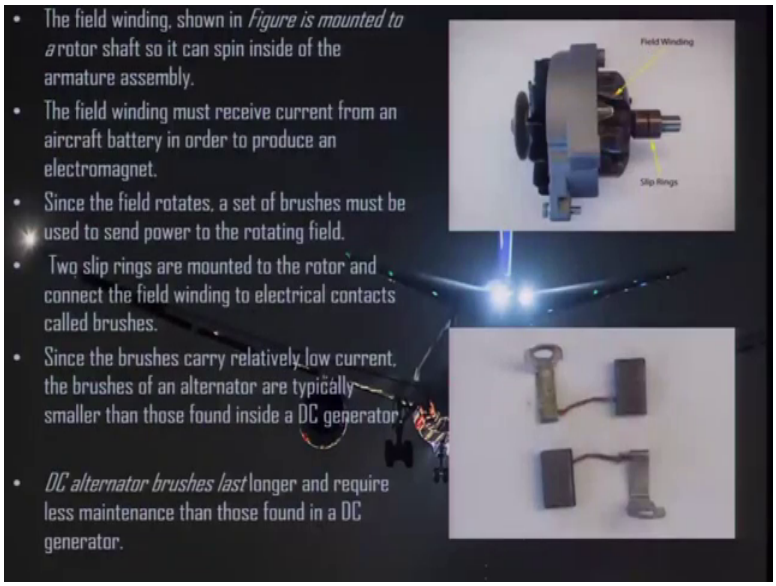

So, this field winding which is mounted on the rotor shaft this spins inside the armature assembly the field winding must receive current from an aircraft battery in order to produce an electromagnet. So, field winding has to receive current from an aircraft battery.

So, as to produce an electromagnet, since the field rotates now the field is rotating a set of brushes must be used to send power to the rotating field two slip rings are mounted to the rotor. So, to slip rings these are the slip rings, they are mounted to the rotor and connect the field winding to the electrical contacts called brushes now slip rings which are mounted on the rotor, they connect the field windings 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 DC alternator brushes last longer and require less maintenance than those found in a DC generator.

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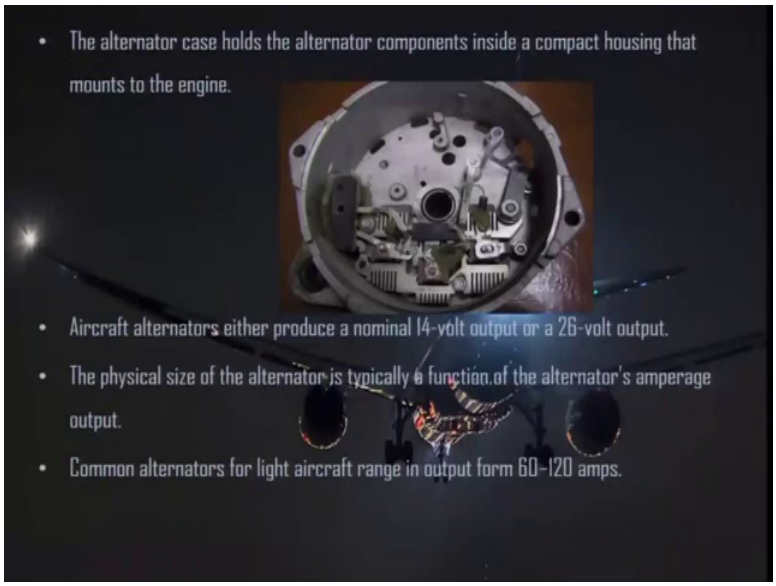

The alternator case you can see this is the alternator case here this is the alternator case this holds the alternator components inside the compact housing that mounts to the engine aircraft alternators either produce a nominal 14 volt output or a 26 volt output the physical size of the alternator is typically a function of the alternators and pure h output common alternators for light aircraft ranges in output from 60 to 120 amperes.

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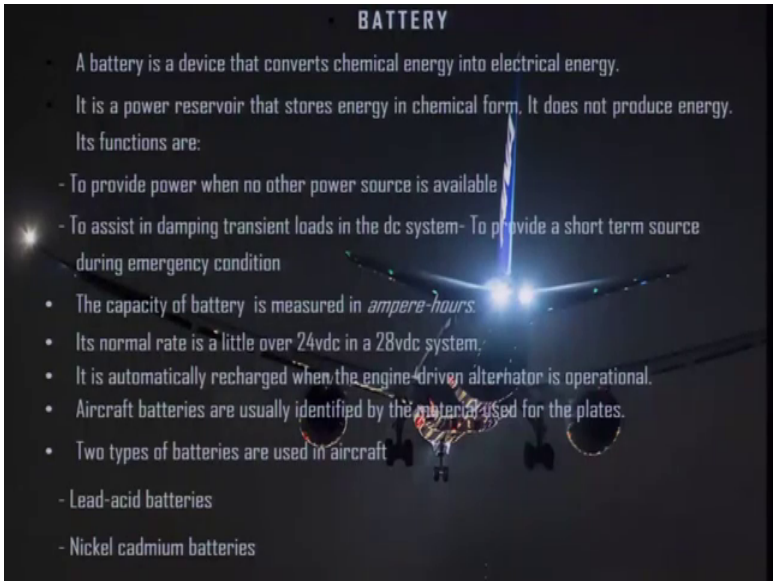

Battery another component very important component in an aircraft electrical system battery it is a device that converts chemical energy into electrical energy; it is a power

reservoir that stores energy in chemical form. So, battery is basically storing energy in a chemical form, it does not produce energy its functions are to provide power where no other power source is available to assist in damping transient loads in the dc system to provide a short term source of power during emergency condition the capacity of battery is measured in ampere hours.

So, the battery capacity is measured in ampere hours, its normal rate is a little over 24 volt dc in a 28 volt dc system, it has automatically recharged when the engine driven alternator is operational aircraft batteries are usually identified by the material used for the plates 2 types of batteries are used in the aircraft they are lead acid batteries and nickel cadmium batteries. So, there are 2 types of batteries being used on aircrafts lead acid or nickel cadmium.

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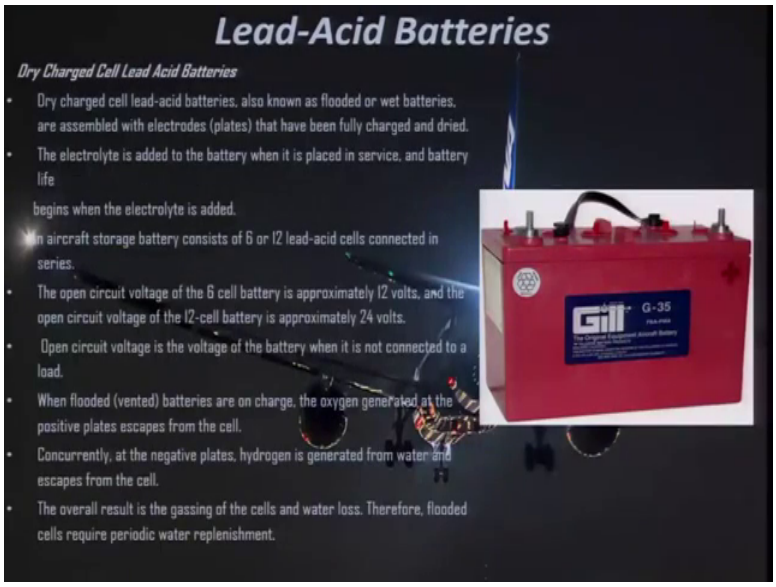

Now, coming to lead acid batteries dry charge cell lead acid batteries, they are also known as flooded or wet batteries assembled with electrodes or plates that have been fully charged and dry the electrolyte is added to the battery when it is placed in service and battery life begins when the electrolyte is added in aircraft storage battery sorry and aircraft storage battery consists of 6 or 12 lead acid cells which are connected in series. So, a battery has either 6 cells or 12 lead acid cells which are connected in series the open circuit voltage of the 6 cell battery is approximately 12 volts open circuit voltage is the voltage of the battery when it is not connected to a load. So, when the battery is not

connected to a load that voltage is called the open circuit voltage and the open circuit voltage on the 6 cell battery is approximately 12 volts and of a 12 cell battery is approximately 24 volts.

When flooded vented batteries are on charge the oxygen generated at the positive plates escapes from the cell. So, when flooded batteries are on charge oxygen is generated at the positive plates which escapes from the cell concurrently at the negative plates hydrogen is generated from water and that escapes from the cell. So, oxygen is being generated at the positive plate hydrogen is being generated from water at the negative plates and they are escaping from the cell the overall result is the gassing of the cells and water loss therefore, flooded cells require periodic water replenishment.

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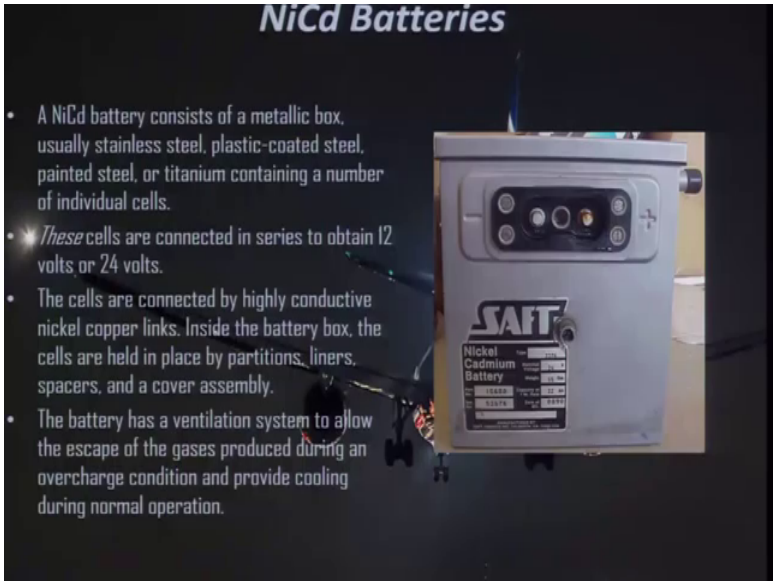

Now, coming to nickel cadmium batteries are nickel cadmium battery consists of a metallic box usually stainless steel plastic coated steel painted steel or titanium containing a number of individual swells. So, it may be in a metallic box of stainless steel or plastic coated steel or a painted steel or a titanium which may be having number of individual cells these cells are connected in series to obtain 12 volts or 24 volts. So, again the cells are connected in series they may be either 12 volts or 24 volts, the cells are connected by highly conductive nickel copper links inside the battery box, the cells are held in place by partitions liners spacers and a cover assembly the battery has a ventilation system to allow the escape of the gases produced during an overcharge

condition and provide cooling during normal operation. So, this battery has a ventilation system which will allow gases to escape and also provide cooling during normal operation.

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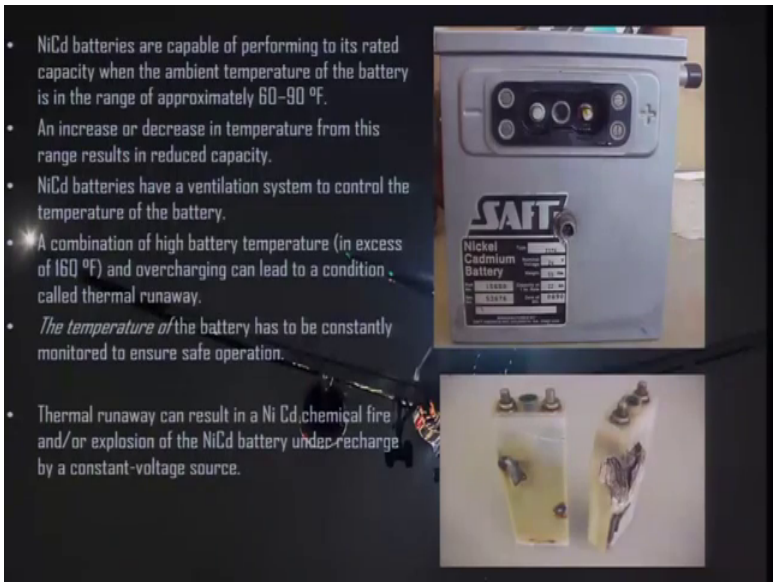

Nickel cadmium batteries are capable of performing to its rated capacity when the ambient temperature of the battery is in the range of approximately 60 to 90 degrees Fahrenheit. So, in the range of 60 to 90 degrees Fahrenheit of ambient temperature nickel batteries will perform to the rated capacity an increase or decrease in temperature from this range results in reduced capacity nickel cadmium batteries have a ventilation system to control the temperature of the battery a combination of high battery temperature and overcharging can lead to a condition called thermal runaway.

So, high temperature and overcharging can cause a condition called thermal runaway the temperature of the battery has to be constantly monitored to ensure safe operation thermal runaway can result in a nickel cadmium chemical fire and or explosion of the nickel cadmium battery under recharge by a constant voltage source in the diagram you can see the damage because of thermal runaway. So, high temperature high battery temperature and overcharging are the conditions which may lead to thermal runaway. So, we need to be careful about this.

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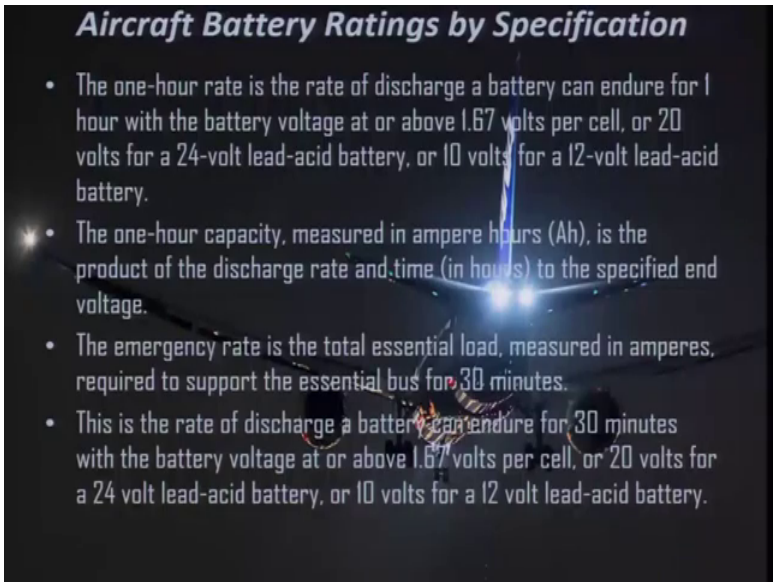

Aircraft battery ratings by specification the one hour rate is the rate of discharge a battery can endure for one hour with the battery voltage at or above 1.67 volts per cell or twenty volts for a 24 volt lead acid battery or 10 volts for a 12 volt lead acid battery. So, the batteries are rated in ampere hours the one hour capacity measured in ampere hours is the product of discharge rate and time in hours. So, discharge rate is in amperes time is in hours.

So, one hour capacity is measured in ampere hours that is the product of discharge rate and time to the specified and voltage the again the emergency rate is the total essential load measured in amperes required to support the essential bus for 30 minutes the essential load which is measured in amperes that is the emergency rate this is the rate of discharge a battery can endure for 30 minutes with the battery voltage at or above 1.67 volts per cell or 20 volts for a 24 volt lead acid battery or 10 volts for a 12 volt lead acid battery.

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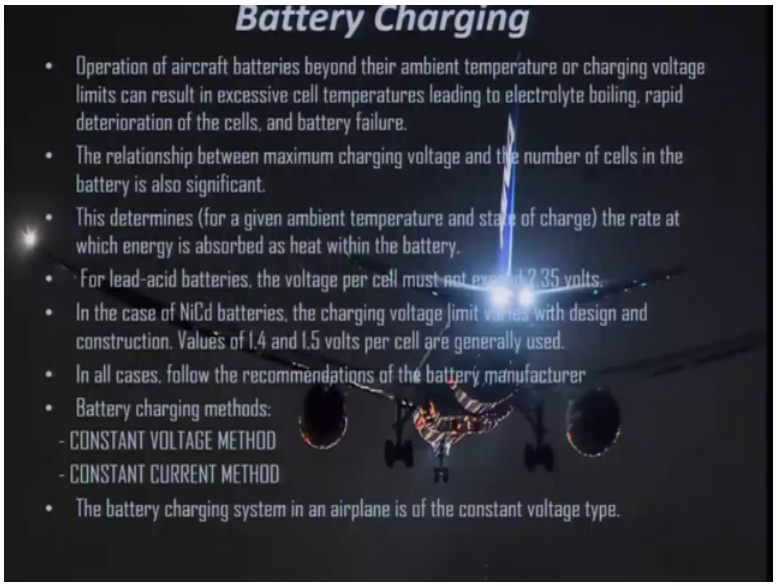

Operation of aircraft batteries beyond their ambient temperature or charging voltage limits can result in excessive cell temperatures leading to electrolyte boiling rapid deterioration of the cells and battery failure the relationship between maximum charging voltage and the number of cells in the battery is also significant this determines the rate at which energy is absorbed as heat within the battery for lead acid batteries the voltage per cell must not exceed 2.35 volts in the case of nickel cadmium batteries.

The charging voltage limit varies with design and construction values of 1.4 and 1.5 volts per cell are generally used in all cases the recommendations of the battery manufacturer should be followed there are various battery charging methods mainly 2 methods constant voltage method and constant current method. So, batteries can be charged by 2 methods constant voltage method or constant current method the battery charging system in an airplane is of the constant voltage type.

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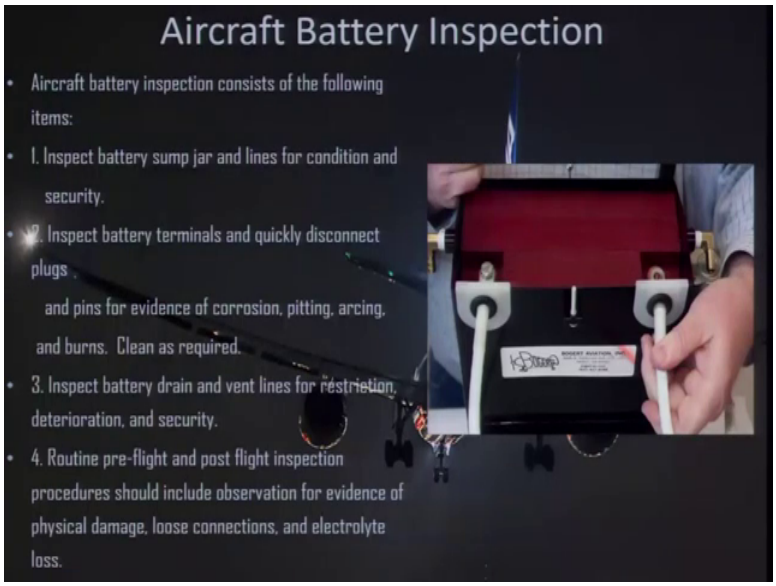

So, the battery being charged in the aircraft is by constant voltage method now inspection on aircraft batteries aircraft battery inspection consists of the following items inspect battery some jar and lines for condition and security inspect battery terminals and quick disconnect plates and pins for evidence of corrosion pitting arcing and burns clean as required inspect battery drain and vent lines for restriction deterioration and security routine pre flight and post flight inspection procedures should include observation for evidence of physical damage loose connections and electrolyte loss. So, in the pre flight inspections post flight inspections, we need to observe any physical damage any loose connections electrolyte loss in the battery.

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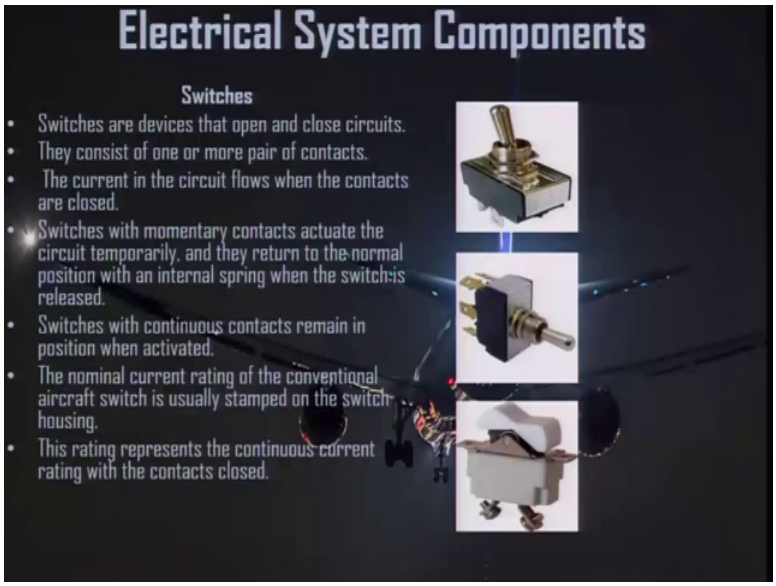

Now, coming to various electrical system components the various electrical system components very important parts switches they are the devices that open and close circuits they consist of one or more pair of contacts the current in the circuit flows when the contacts are closed. So, when the contacts are closed the current will flow in the circuit switches with momentary contacts actuate the circuit temporarily.

So, there are switches with which will have momentary contact and will actuate the circuit temporarily and they return to the normal position with an internal spring when the switch is released switches with continuous contacts remain in position when activated the nominal current rating of the conventional aircrafts switch is usually stamped on the switch housing this rating represents the continuous current rating with the context closed.

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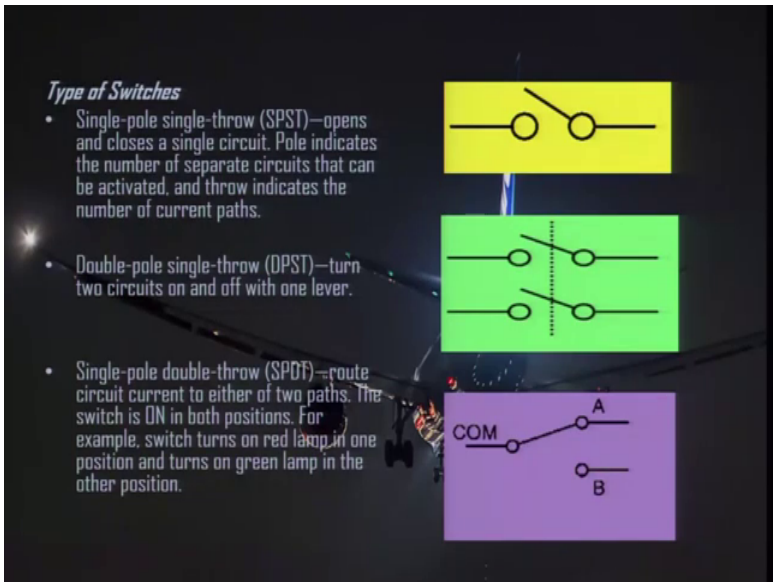

Now, types of switches there are various types of switches single pole single throw switch this opens and closes a single circuit pole indicates the number of separate circuits that can be activated and throw indicates the number of current paths. So, pole indicates the number of separate circuits that can be activated and throw indicates the number of current paths.

So, in the first diagram you can see, it is a single pole single throw then double pole single throw will turn 2 circuits on and off with one lever. So, with one lever it is turning 2 circuits on and off single pole double throw will root circuit current to either of the 2 paths the switch is on in both positions. For example, switch turns on red lamp in one position and turns on green lamp in the other position. So, in the bottom diagram you can see this is a single pole double throw this will route circuit current to either of the 2 paths the switch is on in both the positions, for example, switch will turn on red lamp in one position and turn on green lamp in the other position.

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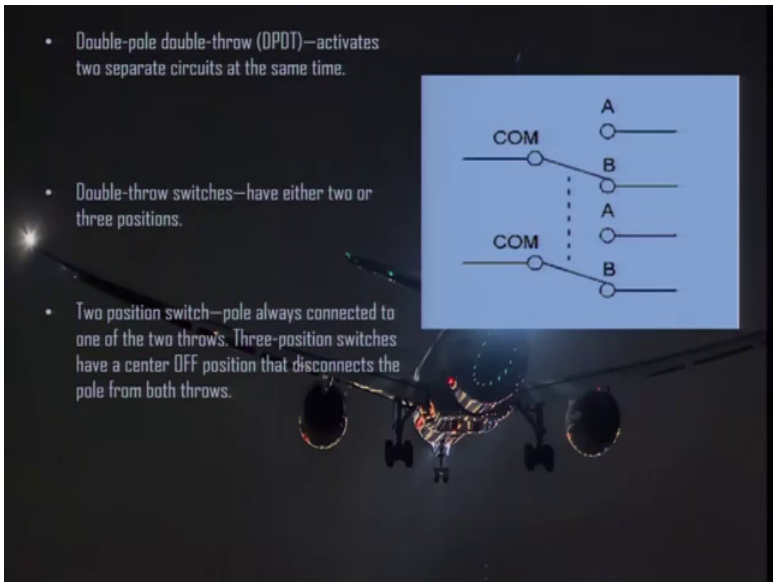

Double pole double throw this will activate 2 separate circuits at the same time. So, this diagram, you can see, this is a double pour double throw switch. This will activate 2 separate circuits at the same time double throw switches have either 2 or 3 positions to position switch pole is always connected to one of the 2 throws 3 position switches have a center of position that disconnects the pole from both throws.

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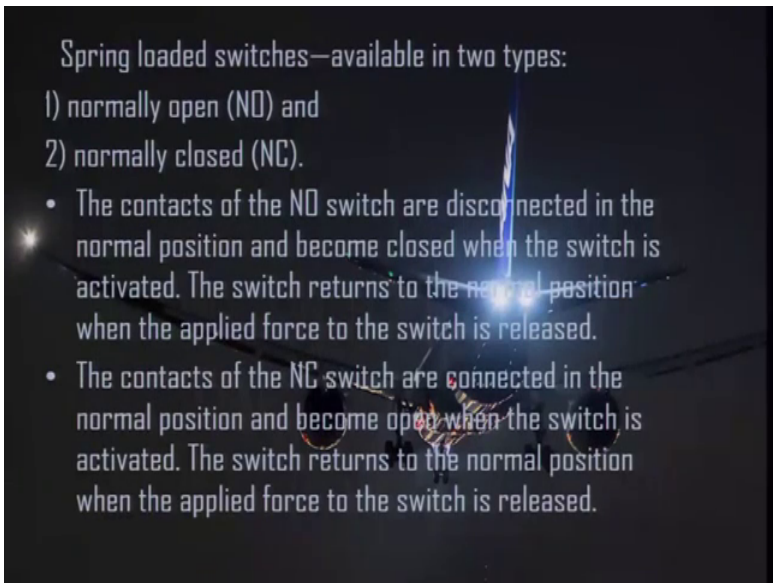

Now, another type of switches spring loaded switches they are available in 2 types normally open we call them a no condition and normally closed nc switch the context of

the a no switch are disconnected in the normal position they are normally open. So, the contacts are disconnected in the normal position and become closed when the switches activated.

So, when you activate the switch the contacts closed since this is a normally open switch in the normal condition the contacts are open and when you activate the switch the contacts are closed the switch returns to the normal position when the applied force to the switch is released. So, when the force is released the switch returns to the normal position which is the normal open position in this case the context of the normal closed switch are connected in the normal position and become open when the switch is activated.

So, in the normal condition the switches the contexts are closed and when the switch is activated the contacts open the switch returns to the normal position when the applied force to the switches released.

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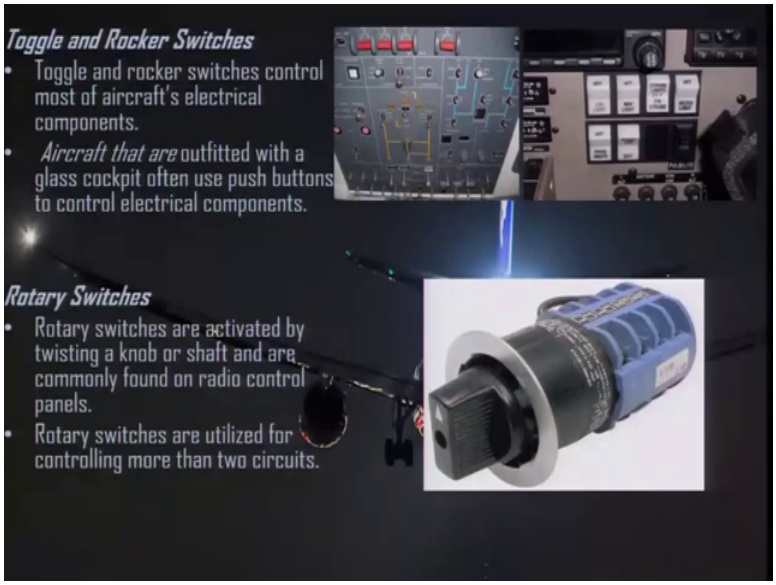

Now, toggle switches and rocker switches in the diagram this diagram you can see these are the toggle switches this is the toggle switch various types of toggle switches, you can see this toggle and these are the rocker arm switches toggle and rocker switches control most of the aircrafts electrical components aircrafts which have glass cockpit are generally using push buttons to control electrical components rotary switches rotary

switches are activated by twisting a knob or shaft and are commonly found on radio control panels rotary switches are utilized for controlling more than 2 circuits.

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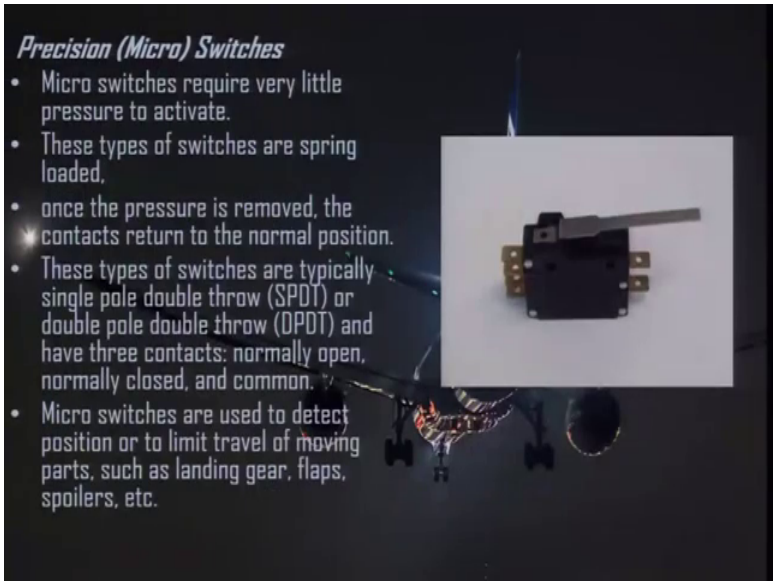

Precision micro switches micro switches require very little pressure to activate these type of switches are spring loaded once the pressure is removed the contacts return to the normal position these types of switches are mainly single pole double throw or double pole double throw and have 3 contacts normally open normally closed and common micro switches are used to detect position or to limit travel of moving parts such as landing gears flaps spoilers etcetera.

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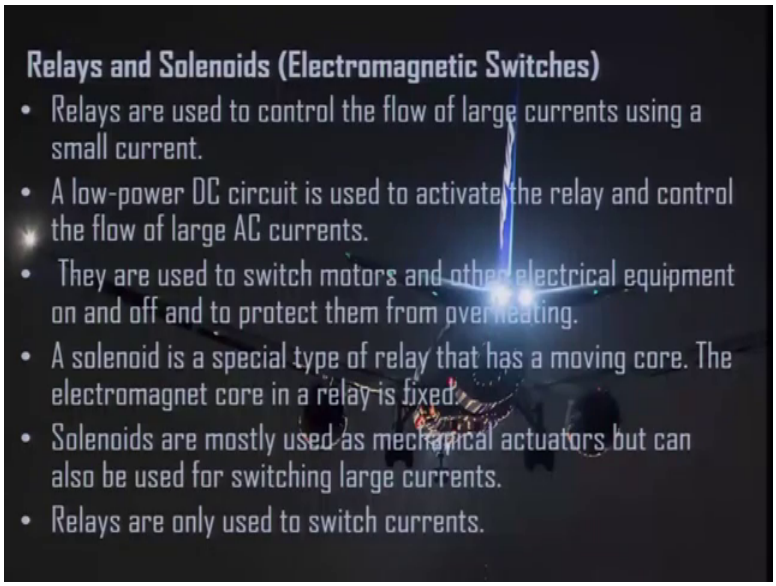

Relays and solenoids electromagnetic switches they are also called electromagnetic switches relays are used to control the flow of large currents using a small current. So, relays are mainly used to control the flow of large currents by using a small current a low power DC circuit is used to activate the relay and control the flow of large AC currents they are used to switch motors and other electrical equipments on and off and to protect them from overheating a solenoid is a special type of relay that has a moving core the electromagnet core in a relay is fixed.

So, in a relay the electromagnet, core is fixed in a solenoid the relay in a solenoid the core is moving solenoids are mostly used as mechanical actuators, but can also be used for switching large currents relays are only used to switch currents.

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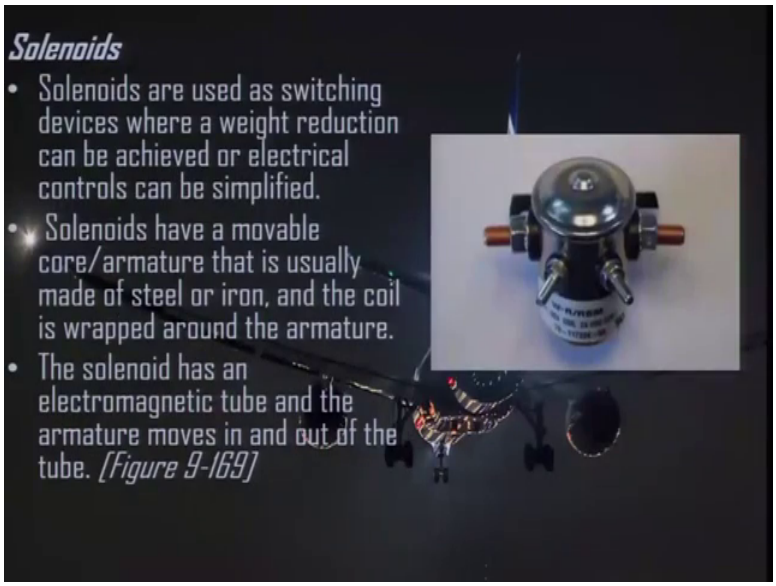

Solenoids are used as switching devices where a weight reduction can be achieved or electrical controls can be simplified solenoids have a moveable core that is usually made of steel or iron and the coil is wrapped around the armature the solenoid has an electromagnetic tube and the armature moves in and out of the tube.

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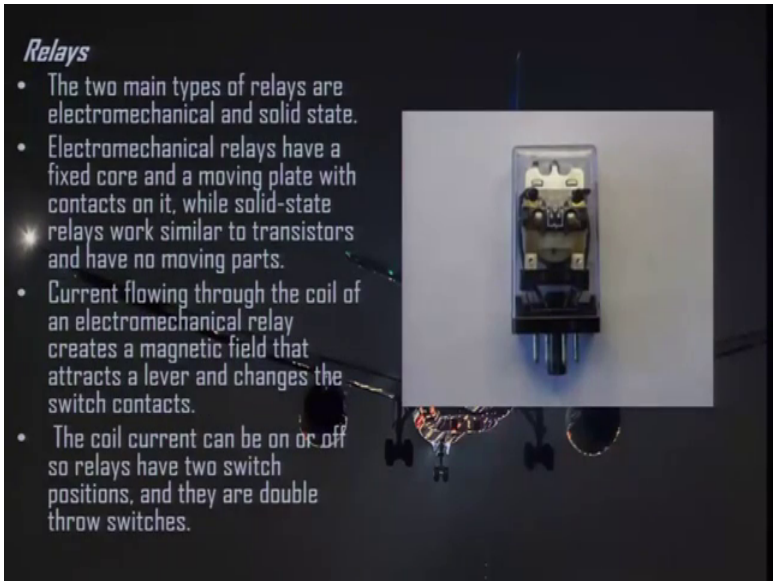

Relays the 2 main types of relays are electromechanical and solid state. So, 2 types of relays are mainly used either electromechanical or solid state electromechanical relays

have a fixed core and a moving plate with contacts on it while solid state relays work similar to transistors and have no moving parts.

So, electromechanical relays they have a fixed core and a moving plate with contacts on it while solid state relays is working on similar to transistors and have no booming parts current flowing through the coil of an electromechanical relay creates a magnetic field that attracts a lever and changes the switch contacts. So, current which is flowing through the coil of an electromechanical relay will create a magnetic field because of this magnetic field it will attract a lever and the switch contacts will contact the coil current can be on or off. So, relays have to switch positions and they are double throw switches.

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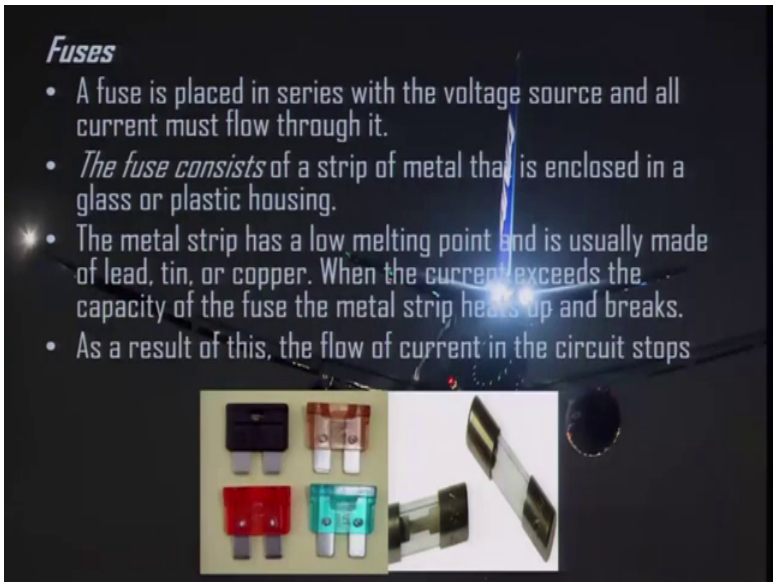

Fuses; a fuse is placed in series with the voltage source and all current must flow through it, the fuse consists of a strip of metal that is enclosed in a glass or plastic housing the metal strip has a low melting point and is usually made of lead tin or copper when the current exceeds the capacity of the fuse the metal strip heats up and breaks as a result of this the flow of current in the circuit it stops. So, fuses; they are a strip of metal which are which is enclosed in a glass or plastic housing the strip has a low melting point and when the current exceeds the capacity of the fuse this metal strip will heat up and break due to which the current flow in the circuit will stop.

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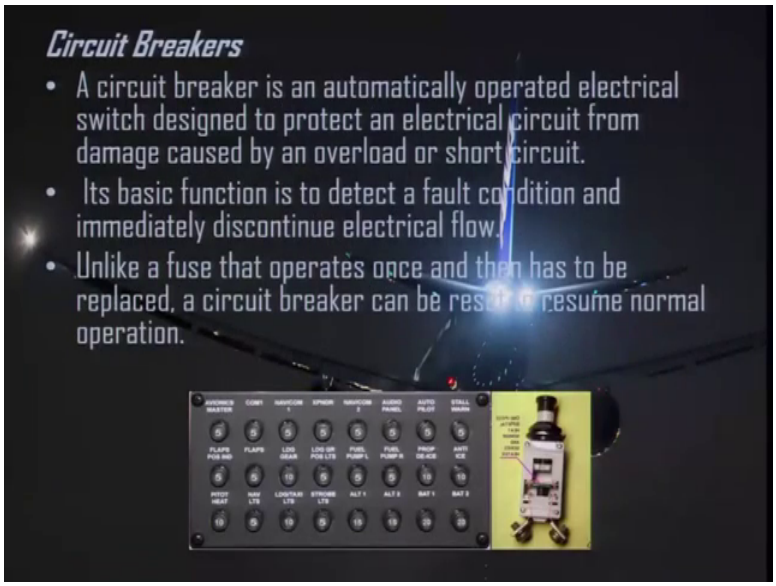

Now, circuit breakers; a circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by an overload or short-circuit. So, this is an automatically operated electrical switch which will which is designed to protect an electrical circuit from a condition of overload or a 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 a circuit breaker can be reset to resume normal operation.

So, in the diagram you can see in the figure there are various circuit breakers CB,s we call them CBs; circuit breakers, these circuit breakers for different systems they are shown in this diagram.

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Next is voltage regulator voltage regulator controls the rate of charge to the battery and also stabilizes the alternator or generator output. So, voltage regulator this will control the rate of charge to the battery and will stabilize the alternator or generator output the general concept of the voltage regulator control of alternator output is by adjusting its field current control the operation of voltage regulators in DC alternator and DC generators are similar most modern aircrafts use either vibrating relay or solid state regulators. So, generally vibrating relay regulators or solid state regulators are being used.

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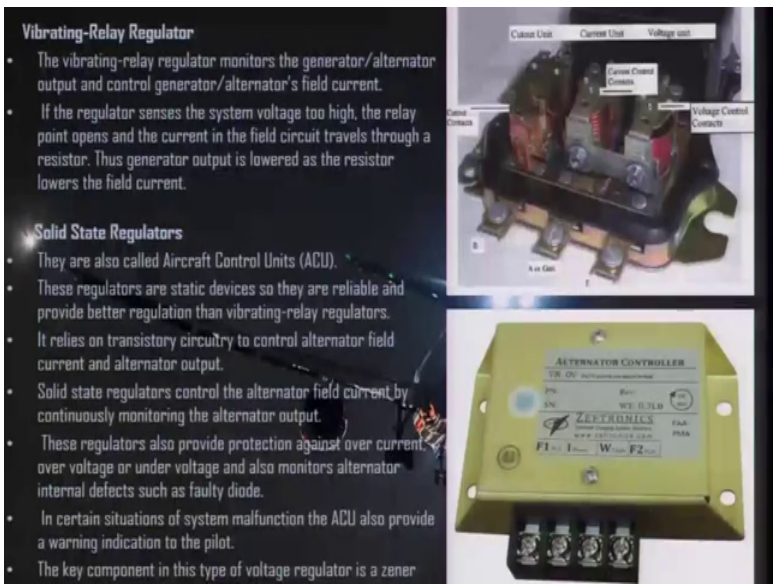

Vibrating relay regulator; the vibrating relay regulator monitors the generator or alternator output and control generator or alternators field current. So, by controlling the field current the relay monitors the output of the alternator or generator if the regulator senses the system voltage too high the relay point opens and the current in the field circuit travels through a resistor thus generated output is lowered as the resistor lowers the field current now solid state regulators they are also called alternator control units these regulators are static devices.

So, they are reliable and provide better regulation than vibrating relay regulators it relies on transistory circuitry to control alternator field current and alternator output solid state regulators control the alternator field current by continuously monitoring the alternator output.

So, same concept being used the field current is being continuously monitored by controlling the field current, you can control the alternator output these regulators they also provide protection against overcurrent over voltage or under voltage and also monitors alternator internal defects such as faulty diodes in certain situations of system malfunction the ACU also provides a warning indication to the pilot one of the key components in this voltage regulator is a diode a Zener diode.

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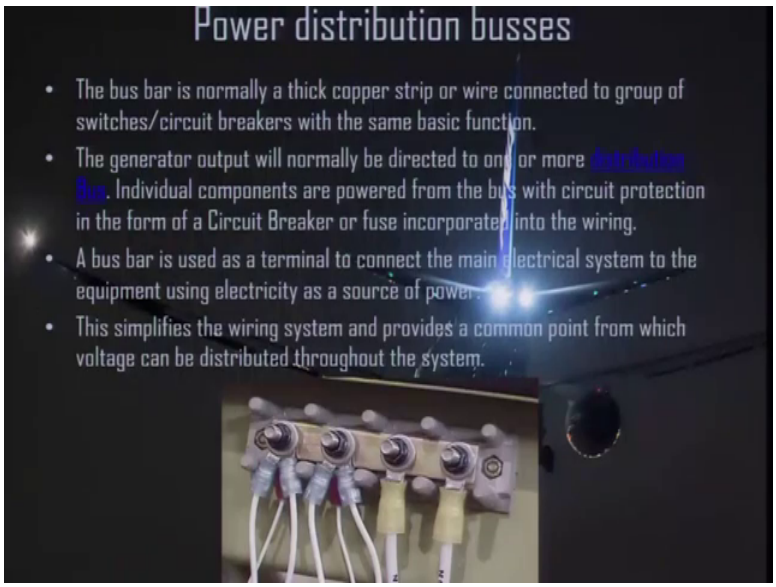

Next is power distribution buses the bus bar is normally a thick copper strip or wire connected to group of switches or circuit breakers with the same basic function the

generator output will normally be directed to one or more distribution bus individual components are powered from the bus with circuit protection in the form of a circuit breaker or fuse incorporated into the wiring a bus bar is used as a terminal to connect the main electrical system to the equipment using electricity as a source of power, this simplifies the wiring system and provides a common point from which the voltage can be distributed throughout the system.

So, in the figure, you can see this is a thick copper strip this is the bus bar this becomes the distribution point from this point the electrical load is distributed to various circuits.

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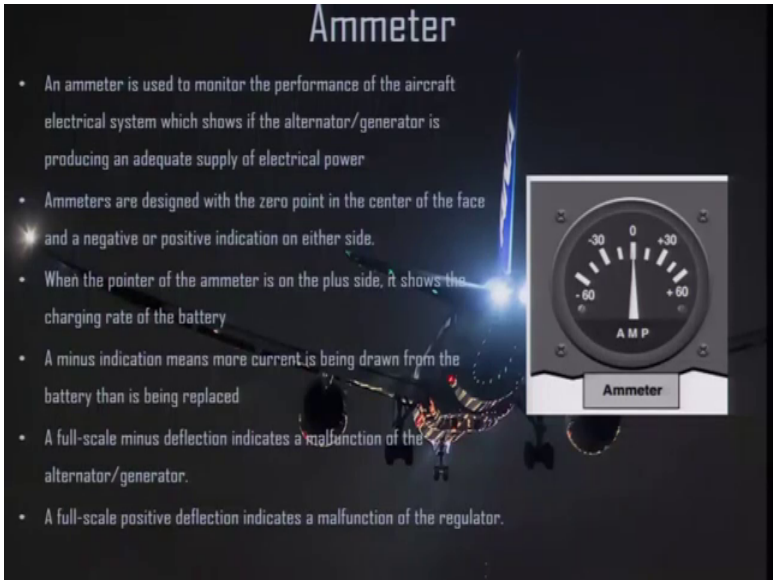

Ammeter an ammeter is used to monitor the performance of the aircraft electrical system which shows if the alternator or generator is producing an adequate supply of electrical power ammeters are designed with the 0 point in the center of the face and a negative or positive indication on either side when the pointer of the ammeter is on the plus side, it shows the charging rate of the battery a minus indication means more current is being drawn from the battery than is being replaced a full scale minus deflection indicates a malfunction of the alternator or generator a full scale positive deflection indicates a malfunction of the regulator.

So, in case, if there is a full scale positive deflection, then your regulator is malfunctioning or if there is a full scale negative deflection that indicates malfunction of your alternator or generator.

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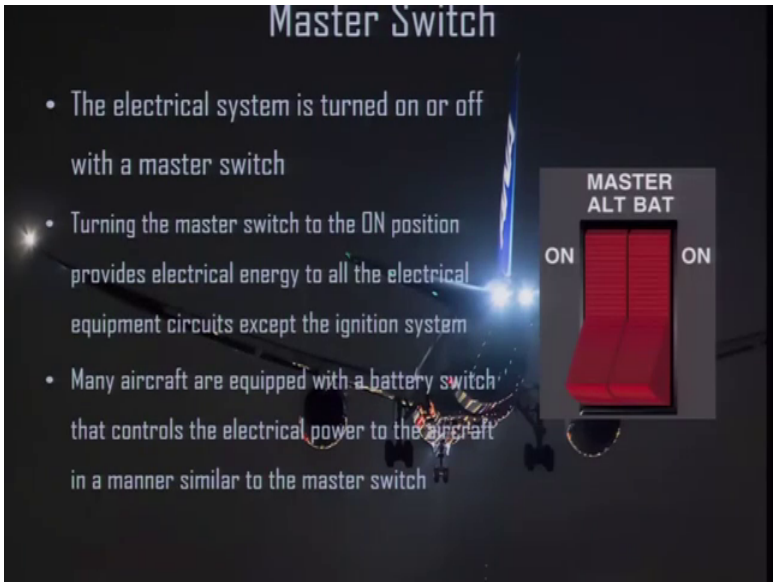

Excess master switch; the electrical system in an aircraft is turned on or off with the master switch this is a very important switch in an aircraft to turn on or off the electrical system master switch is used. So, this master switch is a very very important component of the aircraft electrical system turning the master switch to the on position provides electrical energy to all the electrical equipment circuits except the ignition system.

So, when you switch on the master switch you provide electrical energy to all the circuits except the ignition system many aircrafts are equipped with a battery switch that controls the electrical power to the aircraft in a manner similar to master switch. So, in some of the aircrafts a battery switch is being used in place of a master switch.

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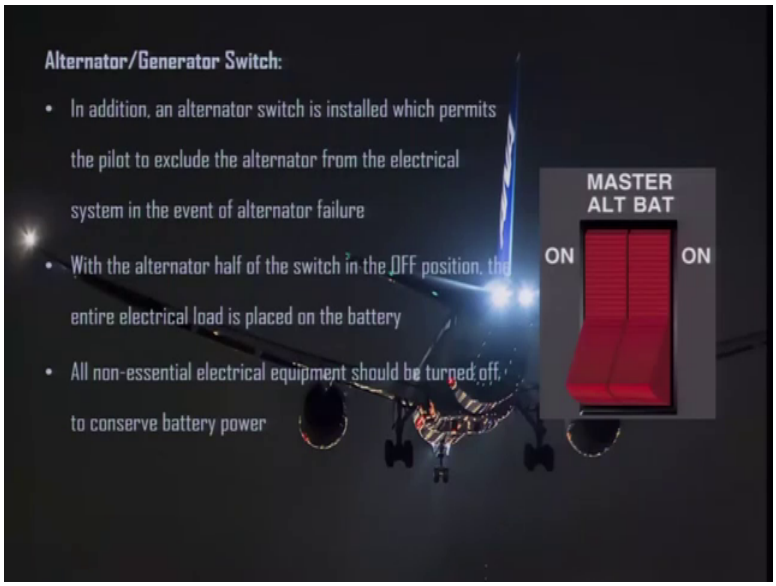

Now, alternator or generator switch in addition an alternator switch is installed which permits the pilot to exclude the alternator from the electrical system in the event of alternator failure. So, you can see in this master switch first off the left part is the alternator part, right part is the battery part alternator switch permits the pilot to exclude the alternator from the electrical system in case if alternator fails with the alternator half of the switch in the off position the entire electrical load is placed on the battery.

So, if the alternator switch in the master switch is switched off the entire load of the electrical system will be on the battery in that case all non essential electrical equipments should be turned off to conserve battery power.