Aircraft Systems

Airplanes come in a variety of shapes and sizes, but they all share the same basic components, which make them work. But what are all of these components, and what do they do? In this lesson we are going to explain some aviation terms, discuss the construction of different types of airplanes, and explain how various systems in an airplane work. It is important to understand why airplanes are designed the way they are and how their systems function. That way, if a system malfunction occurs, you can potentially troubleshoot and/or fix the problem.

This lesson will cover:

- The parts of an airplane
- The flight controls
- The powerplant and propeller
- The landing gear
- The fuel, oil, and hydraulic systems
- The electrical system
- And finally, the environmental system

The Parts of an Airplane

Airplanes are made up of hundreds, even thousands of parts, from the simplest pieces of wood and fabric, to newly-designed composite airframes, to the most sophisticated of electrical components. Planes come in all shapes and sizes, but they all share the same basic design components.

The basic components of any airplane are the fuselage, the wings, the empennage, the landing gear, and the powerplant.

The fuselage houses the cabin and cockpit to hold the pilots, passengers, and cargo. The fuselage is considered to be the central component of the airplane, since all the other components are attached to it. Most airplanes manufactured today use something called semi-monocoque construction. This means that underneath the skin of the airplane there are a series of bulkheads and other supports that help hold the airplane together.

As we'll be discussing in lesson 3, *Aerodynamics*, the wings of an aircraft generate lift as air flows around them. The wings are shaped to maximize the amount of lift they produce. The wings can be attached at the top, mid-way, or at the bottom of the fuselage. Most planes have a single set of wings, referred to as a monoplane; but some planes have two or three sets of wings, referred to as biplanes and tri-planes, respectively.

The empennage, derived from a French word having to do with "feathering an arrow," is commonly referred to as the tail section of the aircraft. It consists of two important surfaces: the horizontal and vertical stabilizers. These stabilizers are surfaces on the tail that keep the airplane under control while flying through the air.

Beneath the fuselage sits the landing gear, also known as the undercarriage. This structure is used to support the aircraft while on the ground. There are generally two different types of configurations: tricycle and conventional gear. Tricycle gear is so named because its wheel configuration resembles that of a child's tricycle – that is, it has one lead wheel near the plane's nose, and two main wheels behind it, typically under the wings. Today, this is the more popular of the two types because it allows for easier landings, and improved visibility while moving on the ground, also known as taxiing. Conventional gear, on the other hand, is the older style that was popular a few decades ago. Similar to before, two main wheels are typically situated under the wings, but the third wheel is located under the airplane's tail. This results in the tail of the plane being very close to the ground, while the front of the airplane sits much higher. This obstructs the pilot's forward view because of the airplane's nose-high attitude. However, it does allow for larger engines and propellers to be installed on the aircraft. This setup is also the less stable of the two, making landings more difficult, especially in a crosswind.

Finally, there is the powerplant, which in layman's terms is the engine. Airplanes can have one engine, called a single-engine airplane, or have multiple engines, called multiengine airplanes. In most smaller, general aviation aircraft, reciprocating engines are used, like the ones found in cars. In many ways, however, airplane engines are simpler than car engines. The most basic of reciprocating engines on airplanes are not computer-controlled, are not liquid-cooled, and are not even fuel-injected. If you are unfamiliar with those concepts, don't worry. We'll cover the basics of those topics coming up.

With reciprocating engines also comes the requirement of a propeller. Just as there are different engine configurations, there are also different types of propellers. These propellers can range from the simplest two-bladed propeller made of a solid piece of wood, to a complicated, multi-bladed propeller with additional built-in features. These features can include: the ability to shed off ice, or even change their blade angle during flight. The rotating of the blades is similar in purpose to a car's transmission.

So, there you have it. Those are the major components that make up an airplane. The rest of this lesson will be going over, in greater detail, how many of the airplane's systems work.

Flight Controls

The flight controls consist of various surfaces around the aircraft that manipulate the aerodynamic forces on the plane, allowing the pilot to control the aircraft. Aircraft flight controls are broken into two systems: primary and secondary flight controls. Primary flight controls are simply those flight controls that the pilot primarily uses to control the airplane. The three primary flight controls are the ailerons, elevator, and rudder. Secondary flight controls, on the other hand, are used to change the airplane's performance and lighten the pilot's workload. The two secondary flight controls that we'll discuss are the flaps and trim.

The pilot controls the ailerons and elevator with a yoke or stick, and the rudder with the rudder pedals. In most general aviation airplanes, as the pilot moves the controls, he or she is moving steel cables or push rods, connected through other linkages, that physically move those controls. As the control surface is deflected, the airflow is changed, which results in an aerodynamic force, changing the airplane's path through the air. Let's investigate the three primary flight controls in more detail.

The ailerons are located on the back end of the wings, out towards the tip, and control the aircraft's roll or bank. When the pilot moves the controls to the left, the left aileron is deflected up, creating a downward force, and the right aileron is deflected down, creating an upward force. This results in the airplane rolling to the left. The opposite would happen if the pilot were to move the controls to the right.

The elevator is attached to the back end of the horizontal stabilizer and controls the airplane's pitch, which allows the airplane to climb or descend. When the pilot moves the controls forward or aft, the elevator rotates, deflecting the air and creating a force that results in the airplane's pitch changing. If the pilot pulls back on the controls, the elevator will move up, creating a force that pushes the tail of the airplane down, thereby making the nose pitch up and causing the airplane to start climbing.

Finally, the rudder, which is controlled by the rudder pedals, is attached to the back end of the vertical stabilizer. As the pilot pushes on one of the rudder pedals, a cable connected to the rudder allows the rudder to move. Just like the other flight controls, as air moves around the deflected rudder, a force is applied, making the airplane yaw. Simply, if the pilot pushes the left rudder pedal, the nose of the airplane will slide to the left. The easiest way to envision this is to think of an airplane suspended on a string, above the ground. If you and your friends were to walk up to the rudder and push as hard as you can towards the right, what do you think would happen? The tail of the airplane would move to the right, and the nose would move to the left. It's that simple! We use the rudder in coordination with the ailerons to turn the airplane.

The primary flight controls then, fundamentally work the same. The pilot moves a control in the cockpit, which through cables and other linkages moves that control. As that control is moved, the airflow around it gets deflected, creating a force, and results in the plane either rolling, pitching, or yawing.

In order to help improve the performance of the airplane and make the pilot's job easier, most general aviation airplanes are equipped with flaps and trim, known as secondary flight controls. Let's examine these further.

The flaps are located on the backside of the wing, close to the fuselage. They are primarily used to help increase lift during takeoff and landing. The pilot controls the flaps by moving a lever in the airplane which either electrically moves the flaps by a motor, like on the Cessna 172; or the pilot manually moves the flaps using a lever, like on the Piper Arrow. In either case, as the pilot extends the flaps, the shape of the wing changes, which increases lift. This allows the airplane to fly at slower airspeeds and make steeper approaches to landing. This is extremely beneficial during takeoff from a short runway because it allows the airplane to takeoff at a slower speed, meaning it will use less runway. During landing, the pilot uses flaps to allow the airplane to land at a slower airspeed, using less distance to decelerate and stop.

The other secondary flight control that we'll discuss is trim. The trim is used to make the pilot's job easier and allows the airplane to essentially fly itself with fewer control inputs by the pilot. The Cessna 172, like most training airplanes, has two trims: one that the pilot can directly control through cables on the elevator; and the other, a ground-adjustable tab on the rudder.

The elevator trim is typically controlled through a wheel inside the cockpit that is labeled "nose down" or "nose up." As the pilot moves this wheel, the cables will adjust the elevator trim tab, which is located on the aft or back end of the elevator. Usually during takeoff, the trim tab is in its neutral position, which means it is about flush with the elevator. As the pilot climbs, however, he or she may trim the airplane to help relieve control pressure and prevent pilot fatigue. If he or she wants to climb at a specific airspeed, then the trim can be adjusted to maintain that airspeed.

The rudder has a ground adjustable trim tab. That simply means that it can only be adjusted while on the ground, as the pilot has to manually move it. The rudder's ground adjustable tab helps the pilot during climb because of the left turning tendencies that the plane has while climbing. We will talk more about those turning tendencies in a future lesson.

It is obvious that the flight controls are a necessity for the pilot to fly the airplane. The pilot manipulates these flight controls in order to achieve the desired performance out of the airplane. Now that we have a basic understanding of the components of the airplane and how the pilot controls different surfaces, let's go "under the hood" of the airplane and investigate the powerplant.

Powerplant and Propeller

We've just learned about the basic parts of an airplane and how it is controlled; but it's equally important for us to understand how the power is generated to move the airplane through the air. An airplane has an engine, which is commonly referred to as a powerplant. The reason behind this name is simple: the engine not only powers the airplane to move through the air, it also has other components attached to it in order to create electricity, vacuum suction, and heat, just to name a few. The powerplant of an airplane, like an engine of a car, is one of the most important components, because without it, there is no way to get the plane off the ground. Aviation engines can be separated into two groups: reciprocating engines and turbine engines. While most airlines and corporate airplanes use turbine-powered airplanes, general aviation and training aircraft are equipped with reciprocating engines.

Reciprocating engines have several cylinders. Inside of those cylinders, fuel and air are mixed, compressed, and then ignited. As this fuel/air mixture is ignited, its explosive force moves the piston inward. The pistons are connected to a crankshaft, and when the pistons move in and out, that causes the crankshaft to rotate. The propeller is connected to the crankshaft, so as the crankshaft rotates, so does the propeller.

The cylinders undergo a continuous four-stroke cycle. The four strokes are called intake, compression, power, and exhaust. The first stroke, the intake stroke, is when the piston inside the cylinder moves away from the cylinder head. As the piston moves away, the intake valve opens, and the fuel/air mixture is sucked into the cylinder's combustion chamber.

Once the piston has reached the base of the cylinder, it's time for the second stroke, compression. During this phase, the intake valve is closed, and the piston reverses direction, moving back towards the cylinder head. This compresses the fuel/air mixture, since it has nowhere to escape.

Once the piston approaches the top of the cylinder, we begin the third stroke: power. Two spark plugs at the head of the cylinder each let off a spark, which ignites the fuel mixture and makes it combust. This controlled explosion pushes the piston back inward to the base of the cylinder, which in turn rotates the crankshaft, and, therefore, the propeller.

Finally, we reach the last stroke: exhaust. During this phase, the exhaust valve opens, and the piston moves back towards the cylinder head, pushing out the combusted gasses, commonly called exhaust. Then the process starts all over again, repeating the process thousands of times every minute.

On a typical four-cylinder engine, each one of the cylinders is in the middle of a different stroke. That way one cylinder is always in the power stroke, and the engine is able to keep the crankshaft rotating, and thereby allowing the remaining cylinders to go through their respective stroke.

As we just saw in these four strokes, there are two valves at the head of each cylinder that open and close to allow the fuel mixture in, and the exhaust gasses out. But what controls those valves? That would be the camshaft. The camshaft is a rotating cylinder, situated above the crankshaft, with various oblong lobes protruding from it. These lobes push on rods that connect to each valve, pushing them open. The valves are spring-loaded and will return to the closed position as the camshaft lobes move away from their respective rod.

Getting the valves to open at the exact moment is very crucial for the engine to operate. Because of that, the camshaft is geared to the crankshaft so they will remain synchronized. The camshaft is geared to spin half as fast as the crankshaft. This results in the valves opening twice during the four-stroke cycle.

Now, how do we get the fuel and air into the cylinders? It's simple: the induction system! Inside of the cockpit of most general aviation aircraft, there are the throttle and a mixture controls. The throttle controls the amount of fuel and air that go into the cylinders, while the mixture controls how much fuel is mixed with the air. In simple terms, the mixture controls the ratio between fuel and air. Typically, for every fuel molecule, there are 15 air molecules. The mixture adjusts the amount of fuel necessary to maintain this ratio. The throttle, on the other hand, controls how much of that ratio is let into the cylinders. The more the throttle is open, the more fuel and air enter the cylinders, and therefore, the more powerful the combustion will be, making the engine run faster.

The air that is part of the fuel/air mixture enters the system at the air filter, usually found in the front of the airplane. Once the air passes through the filter, it is metered, and sent on its way to the cylinders. The fuel, on the other hand, is housed onboard the plane, typically inside of the wings. Just like the air, it is metered and then sent to the cylinders.

There are two different potential systems used that can control the fuel/air mixture: the carburetor system and the fuel injection system. Most modern airplanes are equipped with fuel injection systems, so we'll spend a little more time on that, but it's a good idea to still review the basics of a carburetor.

The job of the carburetor is to mix fuel with the air that gets sent to the cylinder combustion chambers. Fuel arrives at the carburetor and sits in the float chamber, waiting to be used. To the side of the float chamber is the venturi which is where the air passes through. As the air passes through the venturi, its velocity increases, which causes the pressure to decrease. Towards the bottom of the venturi we find a fuel discharge nozzle, which is located near the area of low pressure. This draws the fuel out from the float chamber, through the nozzle, and mixes it with the air. Just past the venturi is the throttle valve. This controls how much of the fuel/air mixture is being sent to the cylinders.

In newer airplanes, fuel injection systems are installed, which have many benefits over carbureted engines. Fuel injection engines reduce the amount of fuel required, increase engine power output, and allow for the precise use of fuel. Rather than having a carburetor, a fuel injected system is split up into different components. These consist of fuel pumps, a fuel control unit, a fuel manifold valve, and finally fuel discharge nozzles. The fuel pump pumps fuel from the fuel tanks to the fuel control unit. Then, the fuel control unit regulates the specific amount of fuel needed based on the mixture and throttle settings. The fuel then gets sent to the fuel manifold valve where it is dispersed and heads to the nozzles of each cylinder. This time, the fuel does not mix with the air until immediately before entering the combustion chamber.

Now that we've discussed how we get the fuel and air into the engine cylinders, let's talk about how we get that mixture to ignite. The ignition system is what provides the spark to the mixture. The major components of the ignition system include the magnetos, the spark plugs, wires, and the ignition switch.

Just as its name implies, a magneto consists of a rotating magnet that generates sparks of electricity. The spark that is generated is independent of the airplane's electrical system. That means if the airplane's electrical system were to fail, the magnetos would still be able to generate sparks for the engine to run. The energy generated from the magnetos is sent to the spark plugs. The spark plugs then release that energy which ignites the fuel/air mixture, creating power to turn the propeller. Most airplanes have two magnetos, multiple sets of wires, and two spark plugs per cylinder in order to increase efficiency and reliability of the system. If one magneto fails or one spark plug fails, the engine will still run; however, power output will be slightly reduced, as the engine is operating less efficiently. The last component is the ignition switch, which is the pilot's way of controlling the magnetos. In most general aviation aircraft, the ignition switch is labeled "off", "right", "left", "both", and "start". If the switch was placed "off", the magnetos would not be able to power the sparkplugs. Therefore, the engine would not be able to run and it would turn off. If the switch was placed in the right or left position, then only that respective magneto would be powering its sparkplugs. If the switch was positioned on the both selector, which is its normal position for flight, both magnetos would be powering the sparkplugs. Finally, the start position. This engages the starter, which turns the crankshaft to start the engine.

In the cylinders, the spark plugs ignite the fuel/air mixture, moving the piston in the power stroke. However, there are a few abnormal conditions that can affect the performance of the engine. The first one is called detonation. Detonation is the uncontrolled, explosive ignition of the fuel/air mixture inside of the cylinders. It results in high temperatures and pressures, which can cause cylinder damage. Detonation can happen for a variety of reasons including: using a lower fuel grade than what is recommended, high power settings with the mixture set too lean, or climbing too steeply with cylinder heads not cooling appropriately. If detonation is occurring, the pilot should reduce the power and increase the mixture, which will allow for better cylinder cooling.

Another issue that can develop is preignition. Just as you'd expect, preignition is simply when the fuel/air mixture is ignited prior to its normal time. This phenomenon usually occurs because of a lingering hot spot on the cylinder wall, usually caused by a carbon deposit that is hot enough to ignite the fuel/air mixture.

Even when the engine isn't detonating or experiencing preignition, the temperature of the engine can get quite hot. Like car engines, airplane engines have a cooling system in order to prevent engine damage or engine failure. There are two major ways we cool our engine: oil and air. Oil passes through an oil cooler and proceeds to, not only lubricate, but also cool the engine. As the cool oil touches the hot engine, there is a heat exchange, meaning that the oil becomes warmer, but the engine cooler. Then the oil returns back to the oil filter and oil cooler, and the process starts over. However, we also use air to cool our engines. As the airplane flies through the air, outside air flows through inlets usually found on the front of the airplane like the Cessna 172. This outside air is colder than the engine, so as the air flows over the engine, it cools it in the same manner the oil cools the engine. This method of cooling can be severely restricted, however. When the airplane is running at high power and at a very low speed, such as when climbing, airflow is minimized, causing higher temperatures.

The last step in the four-stroke cycle is the exhaust. The exhaust system has a dual purpose in most general aviation airplanes. As expected, the exhaust system does allow the hot exhaust gases in the cylinder to escape the engine in a quiet manner. Additionally, as we'll talk about later, the exhaust system also provides heat to the cabin.

Now that we have a better understanding of how an engine basically works, we will examine what creates the thrust for the airplane to fly. Remember that as the combustion occurs in the cylinder, the pistons rotate the crankshaft, which directly drives the propeller. The propeller, when closely examined, is actually twisted. This is simply to create equal thrust along the propeller blade. Since the propeller rotates around its hub, or center, the further the propeller extends out of that hub, the faster it spins. To create equal force throughout, manufacturers twist the blade. There are two major types of propellers: fixed pitch propellers and constant speed propellers.

The Cessna 172 is equipped with a fixed pitch propeller. This means that the pilot cannot manipulate the propeller blade. It is installed onto the airplane, and it will always remain exactly how it was installed. An airplane equipped with a fixed propeller only has the throttle to control the engine RPM and, therefore, propeller RPM.

A constant-speed propeller, such as the one on the Diamond DA42, is more efficient than a fixed pitch propeller. With a constant-speed propeller, the pilot can adjust the blade angle of the propeller to obtain maximum performance for different conditions of flight. Airplanes with a constant-speed propeller are not only equipped with a throttle, which still controls the power created by the engine, but they are also equipped with a propeller control. This control, which is usually blue in color, allows the pilot to change the RPM of the propeller, instead of just based on the engine's output. The reason this propeller is called constant-speed is that when throttle movements are made, the rpm, or speed at which the propeller is rotating, will remain the same. This is accomplished by rotating the angle of the blades, which allows them to deflect different amounts of air. A propeller with a low blade angle has little resistance from the air, and is able to spin fast. The higher the blade angle, the more air the propeller deflects, which slows down its RPM. Low blade angles with high RPM are best during a takeoff. High blade angles with lower RPM are best while cruising.

Landing Gear

The landing gear system provides the ground support to the airplane for taxi, takeoff, and landing. There are many types of landing gear systems, with the most common landing gear systems utilizing wheels. Some airplanes do not have wheels. What? No wheels? Yes, some airplanes are designed to operate in water, and those airplanes are equipped with floats.

As previously discussed, airplanes can either contain conventional or tricycle landing gear systems. Airplanes equipped with conventional gear systems are controlled on the ground through the use of differential braking. If a pilot wants to turn left, they step on the left brake, which slows down the left wheel, thereby rotating the plane. With tricycle landing gear systems like those the Cessna 172, as the pilot pushes on the rudder pedals, the nose wheel rotates, allowing the pilot to steer the airplane. Differential braking can also be used on tricycle gear systems to aid the pilot in making tighter turns.

An airplane's landing gear system is also classified in two other categories: fixed or retractable. A fixed landing gear system is one in which the landing gear is permanently extended. Most primary training airplanes like the Cessna 172 are equipped with this system as they are simpler to use, there is no threat to forgetting to put the gear down for landing, and they are cheaper systems, requiring very little maintenance. The wheels of a fixed landing gear system are connected to struts, which absorb the shock of landing and taxiing.

Some general aviation airplanes, like the Piper Arrow or Diamond DA42, are equipped with a retractable landing gear system. After takeoff, the pilot moves a handle, which electrically powers a hydraulic pump that allows the landing gear to rise into the body of the airplane. Prior to landing, the pilot moves the handle down, which again activates the pump, allowing the gear to come down and lock into position. The benefit of having a retractable landing gear system is that it increases performance by streamlining the airplane.

Fuel

After learning about how the engine works, we remember that there are two things that are mixed together for combustion: fuel and air. Let's learn some things about the fuel system! The fuel system is designed to bring fuel from the fuel tanks to the engine. In general aviation airplanes, fuel systems can be broken down into two subsystems: gravity fed systems and fuel pump systems.

High-wing airplanes, such as the Cessna 172, are normally designed to be gravity-fed systems. Because the fuel tank is inside the wing, which is located above the engine, gravity can naturally pull the fuel from the tank to the engine. Although, in normal operation, a fuel pump is not required, many high-wing airplanes are still equipped with some sort of fuel pump, either engine-driven, electrically powered, or both as a backup for emergency operations.

In low-wing airplanes, such as the Piper Arrow, a fuel pump is required to send fuel from the tanks to the engine. Since the fuel is located below the engine, it is simply impossible for gravity to send fuel upwards. For this reason, low-wing airplanes are designed with a fuel-pump system. Normally, there are two fuel pumps. One of the fuel pumps is engine-driven, and the backup is electrically driven.

Some airplanes are equipped with a fuel primer. The fuel primer allows fuel to be injected straight into the cylinder prior to engine start. Fuel priming is especially useful during cold operations. While some airplanes are equipped with a fuel primer, others, like the Cessna 172, are not. However, we'd still like to enjoy the benefits of priming the engine; therefore, it is possible to prime the engine using the electric fuel pump.

Fuel is stored in fuel tanks, which are usually located inside of the wings. These tanks are filled from the top. There is a cap on the top that is easily twisted off, and gas is pumped into that tank until it is visually full. This cap is usually vented to allow outside air pressure to enter the fuel tank in order to prevent a vacuum from being created inside of the fuel tank. If the fuel tank did not have a vent, fuel would initially flow from the tank, but as it empties, there would be nothing to replace that space, which would create a vacuum and eventually stop fuel flow to the engine. Therefore, manufacturers vent the tanks to allow air to replace the fuel that is leaving the tank to the engine. Some airplanes not only have vented fuel caps, but they also have fuel vents that protrude from the wing. As the airplane flies through the air, air enters this vent and is pushed into the fuel tank.

Also inside the fuel tanks are fuel sensors. These fuel sensors send information to the fuel gauge, which shows the pilot the amount of fuel in the tank. These sensors work in many different ways depending on the manufacturer of the airplane. One thing to note, however, is that these fuel gauges are only required to read correctly when the tank is empty. Therefore, it is absolutely critical to visually verify the amount of fuel in the tank. Never entirely trust the fuel gauges.

After visually verifying the quantity of fuel in the tanks, it's also equally important to confirm that there are no contaminants in the fuel, such as water. The fuel tanks are equipped with fuel sumps or drains. The pilot uses a special fuel sump cup that allows fuel to flow out of the tank into the cup. At that point, the pilot visually verifies that there are no impurities in the fuel. Most general aviation airplanes utilize 100 Low-Lead fuel, which is blue in color. Therefore, not only should the pilot check for impurities, the color of the fuel should also be inspected to ensure that the proper fuel was pumped into the tank.

Another component found in the fuel system is the fuel selector. The fuel selector usually has four different positions, but some manufactures may have fewer positions. The four positions are: left, right, both, and off. If the fuel selector is in the left position, then fuel is only drawn from the left tank. Similarly, if the fuel selector is in the right position, then fuel is only drawn from the right tank. In normal operation, the fuel selector is in the both position, which allows fuel from both the left and right tanks to be sent to the engine. In the off position, fuel cannot pass into the engine, which stops the fuel flow to the engine. Ordinarily, the fuel selector is only placed in the off position in an emergency situation, such as an engine fire. The Cessna 172 only has three positions on its fuel selector: left, right, and both. A fuel shutoff valve is instead used to shut off the fuel supply. This valve is located just above the fuel selector, and can be activated by pulling on the knob.

Oil

As we've discovered, an airplane's engine cannot run without fuel. Another valuable fluid that is required for the engine to run is oil. We've already discussed how the oil cools the engine, but other equally important functions of oil is to lubricate the moving parts of the engine, provide a protective coating to prevent corrosion, and remove dirt and other particles from the engine.

There are two types of oil systems: a wet-sump system and a dry-sump system. A wet-sump system, like that of a Cessna 172, is a system in which the oil is located in a tank at the base of the engine. This makes it an integral part of the engine. On the other hand, a dry-sump system has a separate oil tank, which separates the oil system from the engine.

Let's take a journey through the oil system of a typical general aviation airplane. As oil leaves the sump, it is routed through a strainer screen, as to not allow any solid contaminates to flow through the system and damage it. After leaving the strainer, it passes through the pump. Leaving the pump, the oil is then routed either into the oil cooler if it is hot and needs to be cooled, or it bypasses the cooler if it's cool enough. Next, the oil proceeds to the oil filter, which removes any contaminates that made it through the strainer. Finally, the oil is sent to the engine for lubrication, cooling, and cleaning. When the oil has finished its journey, gravity pulls it back to the sump.

Since oil is so important for the engine, it's imperative to check the oil level prior to flying. The minimum and maximum amounts are specified in the airplane's flight manual. While flying, it's also important to regularly check oil pressure and oil temperature. Anything outside of the normal range, which is usually designated by a green arc, may potentially lead to major problems, including engine failure.

Hydraulic

Nearly all airplanes are equipped with a hydraulic system. While small general aviation airplanes may have small, simple hydraulic systems, bigger jets have very complex hydraulic systems. In smaller airplanes, the hydraulic system powers the brakes to stop the airplane, extend and retract the landing gear, and change the blade angle on some constant-speed propellers, as previously discussed. On larger airplanes, like those used by the airlines, the hydraulic system powers a majority of the airplane including the flight controls and flaps.

Usually, a hydraulic system consists of a reservoir where the hydraulic fluid is stored, a pump that moves the fluid, a filter to keep contaminants out of the system, a relief valve in case of a hydraulic malfunction, and actuators, which the hydraulic system operates. The hydraulic system works by pumping incompressible fluid through hydraulic lines from one actuator into another, causing the actuator pistons to extend or contract. The hydraulic pressure exerted throughout the actuators is significant, making hydraulic systems very powerful.

Let's examine the brake system on a typical general aviation airplane. As the pilot presses on the brakes, a piston drives fluid from the brake actuator on the pedal, through hydraulic lines, and then to the actuator near the wheels. The fluid pushes a piston which then mechanically squeezes the brake pads against the brake disk, causing the airplane to slow down.

Electrical

The electrical system provides electrical power to many different systems. From some flight instruments, to aircraft lights, to flaps and landing gear, the electrical system powers them all. The electrical system is usually comprised of a 14 volt or 28 volt direct current or DC system, made up of some basic components. These consist of: an alternator, a battery, switches, circuit breakers or fuses, relays, a voltage regulator, an ammeter or loadmeter, and the electrical wiring which connects it all. Let's study some of these components in more detail.

Similar to a car, the alternator is driven by the engine through an alternator belt, which generates electricity for the entire system. The alternator is the primary means of powering the electrical system during normal operations with the engine running. Not only does the alternator provide power to the electrical system, it also charges the battery. The battery is mainly used to start the engine, or to power the equipment while the engine is not running. In cold weather, the battery capacity can be severely reduced, so it is important that the pilot conserves battery power.

The electrical system is protected either by circuit breakers or fuses. Most modern airplanes are equipped with circuit breakers instead of fuses because they are resettable. A circuit breaker pops when there is excessive voltage, which results in high heat in the electrical wire. Fuses are not the popular choice today. Although they work similar to a circuit breaker, once a fuse burns, it must be replaced and that electrical circuit will not be complete until that fuse is fixed. This is not a very practical thing to do while flying, especially alone.

Circuit breakers are usually grouped together in the cockpit by the bus they are located on. Not the bus that brings you to school, but an electrical bus! An electrical bus is a like a power strip. You can plug multiple things into a strip, and if you turn that strip off, everything plugged into that strip will not be powered. In an electrical system, the same remains true. The components of an electrical system are usually divided into multiple busses. For example, there may be a main bus and an avionics bus. On the main bus, main equipment such as lights are powered, and on the avionics bus, most of the instruments and equipment to run those instruments are powered.

While there may be one electrical bus or many, the entire electrical system needs to be powered safely, in order to prevent a possible electrical fire. In order to do this, a voltage regulator and alternator control unit work to monitor and control the electrical system. The voltage regulator will allow the alternator's generated power to charge the battery and power the system with an acceptable voltage by stabilizing the output of the alternator.

Finally, the pilot can monitor the electrical system by either an ammeter or a loadmeter. An ammeter shows the performance of the electrical system. If the alternator is providing sufficient power to the electrical system and is charging the battery, then the ammeter will show a charge. If the alternator is not charging the battery, or the battery is being used because the alternator has failed, a negative indication can be seen on the ammeter. A zero indication simply means that it is neither charging nor discharging the battery.

While an ammeter shows electrical performance of the alternator in relation to the battery, a load meter shows the load that is being placed on the alternator. So if the alternator's load is 40 amps, then the indication will show 40. If the loadmeter shows zero, then the alternator is either off or has failed. If the alternator fails in any electrical system, the battery will provide power, but not for very long. Depending on the airplane and if there are any back up batteries, an alternator failure may require a diversion from the planned flight.

The Environmental System

The environmental system of the airplane provides fresh air and heat to the cabin. Because airplanes operate in such different temperatures based on where they are in the world, the pilot must be able to control the airflow and heat entering the cabin in order to ensure everyone is comfortable. In general aviation airplanes there are usually two controls: a cabin heat control and a cabin air control.

In the winter months, when the outside air temperature is colder than desired, the pilot may turn on the cabin heat. The cabin heat valve allows outside air to pass over the exhaust muffler shroud, which heats the air. This heated air is then ducted into the cabin.

During the summer, the cabin can be cooled by venting outside air in. By opening the cabin air control, outside air is scooped into the plane and vented into the cabin through the same vents as the heater. Additional vents may also be available that solely bring in cooler outside air. Many general aviation aircraft are not equipped with air conditioners. To cool off, all you have to do is simply climb to a higher altitude, where the air is cooler.

Conclusion

Now that you have taken a look inside a typical airplane, you are well on your way to becoming a great pilot. Just like the driver of a car, or a captain of a ship, knowing how and why things work in your aircraft will make you a safer and more qualified aviator.