



Commercial Pilot Ground School

Day 7 - Advanced Systems

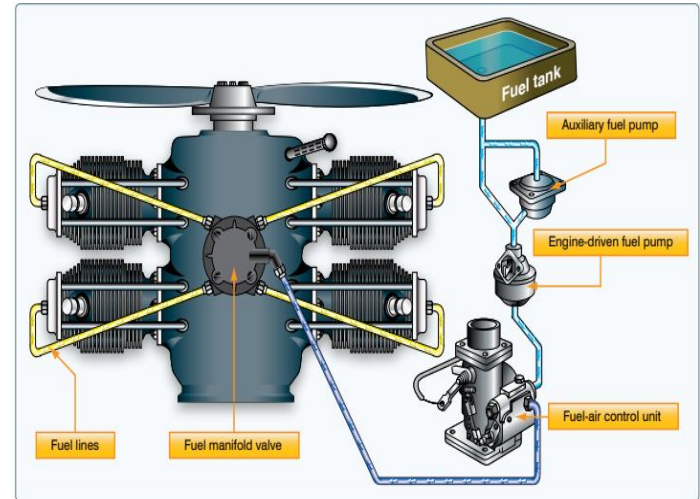
High Performance Powerplants

- FAA defines a complex airplane as one that has retractable landing gear, flaps, and a controllable pitch propeller or a full authority digital engine control (FADEC) system.
- A high performance airplane has an engine of more than 200 horsepower.



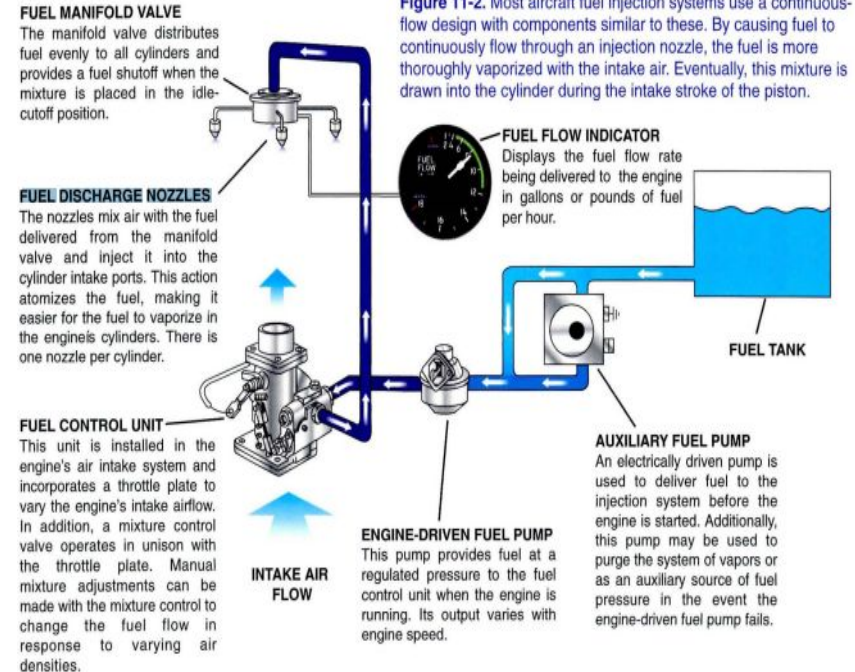
Fuel Injection Systems

- Over time, aircraft engine manufacturers have improved product safety and efficiency by applying new design technology. One of the most significant improvements was a better method of delivering fuel to an engine's cylinders.
- In order to overcome the carburetor performance limitations, manufacturers have utilized fuel injection systems in nearly all modern, high-powered, reciprocating engine aircraft.



Fuel Injection Systems

- Although a variety of fuel injection models are in use today, each essentially performs the same functions. Simply stated, these functions include pressurizing the fuel, proportionally metering it for a specific amount of engine power, and then atomizing the metered fuel directly into each cylinder intake port.
- Main components of fuel injection system are:
 - ❖ Fuel Manifold Valve
 - ❖ Fuel Discharge Nozzles
 - ❖ Fuel Control Unit
 - ❖ Fuel Flow Indicator
 - ❖ Auxiliary Fuel Pump
 - ❖ Engine Driven Pump



Starting Procedures

- Because of the manner in which engine priming is accomplished, starting a fuel-injected engine is probably one of the more difficult procedures for most new pilots.
- If a pilot does not know proper priming procedures, it can lead to flooded engine and lean engine.
- Another area of difficulty involves developing the proper techniques for manipulating the engine controls during starting. Although injected engines are equipped with conventional throttle and mixture control levers, control operation during starting can be significantly different from carbureted engines.



Normal Starts

- A normal starting technique can be used when mild to warm ambient temperatures exist, and the engine is cool. With these conditions, the engine should only require a small amount of priming.



Hot starts

- A fuel-injected engine tends to be difficult to restart right after shut down, particularly if it has been running for an extended period of time. This is a result of the engine's tendency to vapor lock, which is caused by the fuel vaporizing in the injection system's lines and components.
- Without the flow of cooling air through the engine cowl, the engine's heat causes the fuel in the injection system to boil. The boiling fuel produces vapor that blocks fuel flow in the injection system.



Flooded Starts

- If too much fuel is allowed to flow to the engine during the priming procedure, engine flooding may occur. If the engine shows no sign of starting after about 30 seconds of cranking, disengage the starter to prevent it from overheating.
- .While allowing the starter motor to cool, you should determine if the engine is flooded by checking for the presence of fuel running out onto the ground from the intake manifold drain line. If you observe fuel, you should attempt a flooded engine start procedure.



Engine Monitoring

- Among the instruments used to monitor performance of fuel-injected engines are the **exhaust gas temperature** and **cylinder head temperature gauges**.
- Although these gauges may be found on many carbureted airplanes, they are almost always found on fuel-injected airplanes.
- They provide you with a means to adjust the fuel/air mixture to optimize engine efficiency, reliability, and safety.



Engine Starts



Exhaust Gas Temperature Gauge

- The exhaust gas temperature gauge (EGT), as the name implies, measures the temperature of the exhaust gases leaving the combustion chamber. Generally speaking, the exhaust temperature increases as you lean the mixture until the optimum fuel/air ratio is achieved.
- Although there are various designs and features for EGT systems, most use one or more probes, called thermocouples, to generate a voltage in conjunction with different temperatures. In response to the voltage, an indicator needle is deflected a proportionate amount.



Cylinder Head Temperature Gauge

- A cylinder head temperature gauge (CHT) is usually installed in most complex or high performance aircraft and, in fact, is a required instrument if the aircraft is equipped with cowl flaps.
- The instrument works similarly to an EGT gauge, using one or more thermocouple probes for temperature sensing. The display is marked with colored range markings and numerical temperature values to denote the engine's normal and extreme temperature parameters.



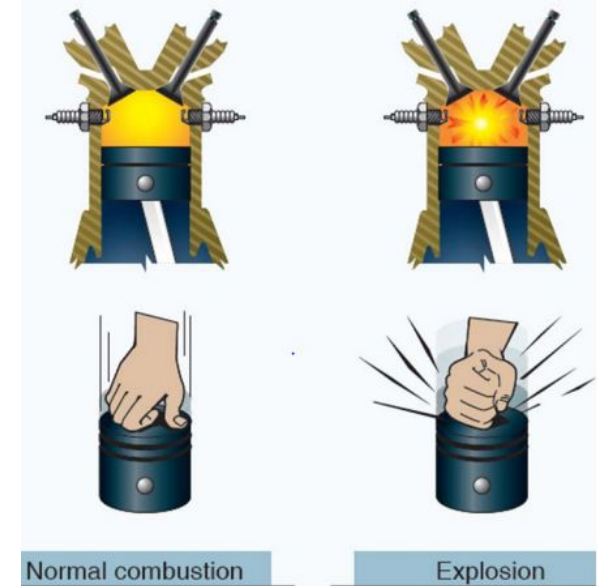
Cylinder Head Temperature Gauge

- Although its operating range is fairly large, a typical procedure is to maintain a relatively constant reading toward the upper two thirds of the scale. To obtain the desired temperature, you can vary the mixture, adjust the flight attitude of the aircraft or, if installed, vary the cowl flap position to change cooling airflow.



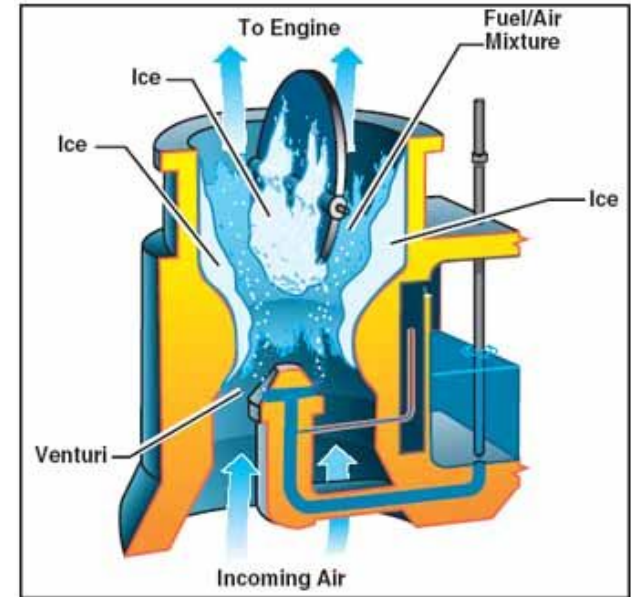
Abnormal Combustion

- The normal combustion process is accomplished when the spark plugs ignite the fuel/air mixture to produce smooth and even burning. For normal combustion, the mixture must be in the correct proportion, and the engine's ignition event must occur at the proper time
- If either of these conditions are not met, **abnormal combustion** may result. This can be in the form of detonation or pre ignition, which, if not corrected, can cause substantial engine damage or a total loss of power.
- **Detonation** is the uncontrolled, explosive combustion of fuel, which produces excessive pressures and temperatures inside the engine's combustion chambers.
- **Preignition** can occur when the fuel/air mixture ignites prior to the engine's normal ignition event.



Induction Icing

- Since internal icing of a fuel injection system is less likely to occur than in a carbureted system, there is no need to incorporate an induction air preheater like those used for carburetor heat.
- However, blockage can form over the induction air filter or intake air scoop of either system, as a result of impact ice. Impact icing forms when the aircraft is operated in visible moisture with the air temperature at or below freezing.
- As the intake becomes blocked, the engine's performance will begin to decrease due to the restricted airflow.
- To maintain engine operation, most manufacturers incorporate an alternate air source to provide warm, unfiltered intake air to the engine



Propeller Principles

- A propeller blade is an airfoil with its plane of rotation approximately perpendicular to the airplane's longitudinal axis. As a result, the blades of a conventional tractor (pulling) propeller cause an aerodynamic lifting force to be directed forward, thereby producing thrust.
- With this in mind, you can apply the same terminology to define a propeller blade cross section as you would for an airplane wing. In other words, a propeller blade has a chord, camber, and angle of attack.



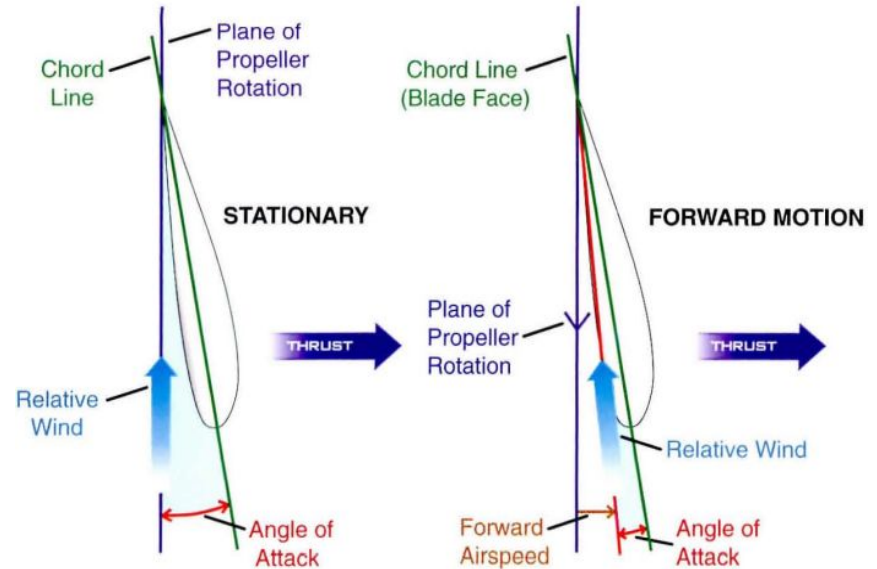
Propeller Principles

- In addition, if either the angle of attack or rotational velocity of the blade increases, its thrust production also will increase. On the other hand, a propeller experiences an aerodynamic force that is not generally considered with an airplane wing.
- Dynamic airflow from the airplane's forward velocity causes a shift in the relative wind in relation to the propeller blade. This action causes the blade's angle of attack to vary with different aircraft airspeeds.(Figure)



Propeller Principles

- The angle of attack of a propeller is determined by the blade's chord line and the direction of the relative wind. The illustration on the left shows the effect of relative airflow over a rotating propeller on a stationary airplane.
- The illustration on the right shows the effects on the angle of attack caused by the shifting of the relative wind due to the forward airspeed of the airplane.



Constant Speed Propellers

- A constant-speed propeller is a system that you will usually find on either a complex or high performance airplane. The propeller's design allows you to control the angle of its blades in order to obtain the maximum amount of thrust for the engine's brake horsepower (BHP).
- When comparing efficiency, a constant-speed propeller design is far better than a fixed-pitch propeller because the constant-speed system allows you to obtain the optimum combination of engine r.p.m. and manifold pressure for the type of operation you are conducting.

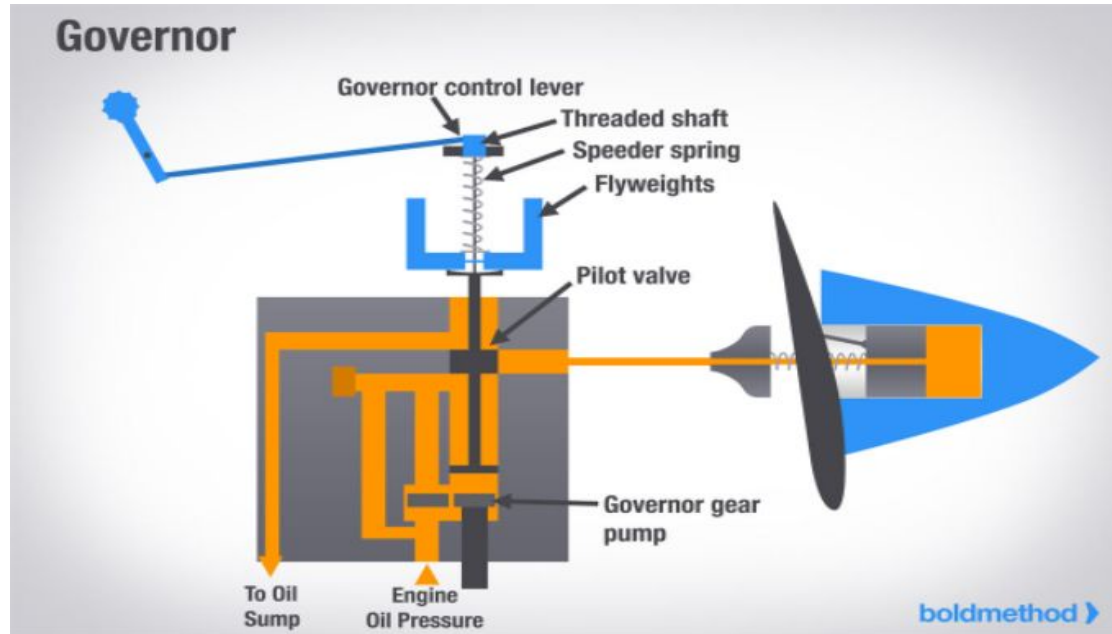


Constant Speed Propellers

- This means you can obtain the best overall performance by achieving a high rate of climb, increasing cruise airspeed, or extending endurance by reducing fuel consumption. In addition, a constant-speed propeller can automatically change its blade angle so the load on the engine can be varied, thereby increasing the engine's efficiency, reliability, and service life.



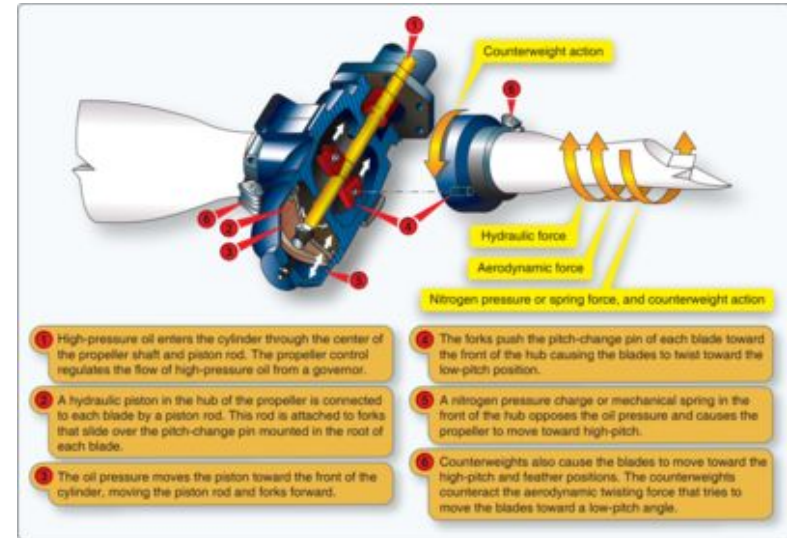
Constant Speed Propeller



Source: <https://www.boldmethod.com/learn-to-fly/aircraft-systems/how-a-constant-speed-prop-works/>

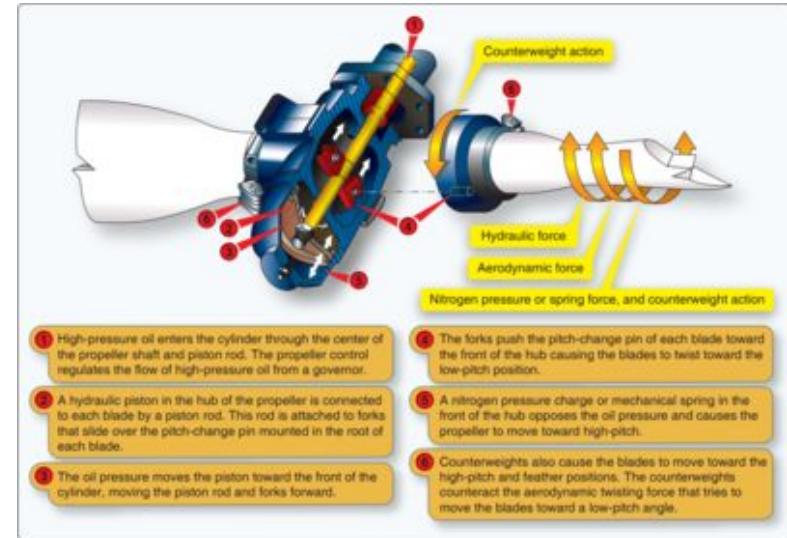
Constant Speed Propeller Operation

- The main advantage of a constant-speed propeller is that it converts a high percentage of the engine's power into thrust over a wide range of r.p.m. and airspeed combinations.
- In addition, once you have selected certain r.p.m. settings for the propeller, a device called a governor can automatically adjust the blade angle to maintain the selected r.p.m. For example, during cruise flight, an increase in airspeed or reduction in propeller load will cause the blade angle to increase, thereby maintaining the selected r.p.m.



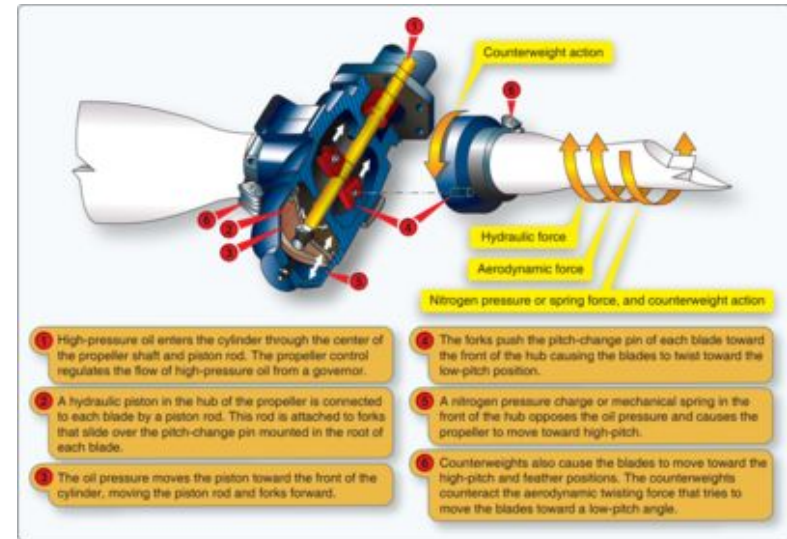
Constant Speed Propeller Operation

- On the other hand, a reduction in airspeed or increase in propeller load will cause the propeller blade angle to decrease.
- The range of possible blade angles for a constant-speed propeller is called the propeller's **governing range** and is defined by the limits of the blade's travel between high and low blade angle pitch stops.
- As long as the propeller blade angle is within the governing range and not against either pitch stop, a constant engine r.p.m. will be maintained.



Constant Speed Propeller Operation

- However, once the propeller blade reaches its pitch-stop limit, the engine r.p.m. will increase or decrease, as appropriate, with changes in airspeed and propeller load.
- For example, once you have selected a specific r.p.m., if the airplane's speed decreases enough, the propeller blades will reduce pitch until they contact their low-pitch stops. When these stops are reached, any further reduction in airspeed will cause the engine's r.p.m. to decrease.



Power Controls

- On airplanes that are equipped with a constant-speed propeller, engine power is controlled by the throttle and indicated on the manifold pressure gauge. The propeller blade angle, on the other hand, is controlled by a propeller control and the resulting change in engine r.p.m., caused by a change in blade angle, is indicated on the tachometer.
- By providing you with a means of controlling both engine power output and propeller blade angle, the most efficient setting combinations are maintained for a variety of flight conditions.



Source:

<https://www.boldmethod.com/learn-to-fly/aircraft-systems/how-a-constant-speed-prop-works/>

Power Controls

- For example, during takeoff, you want the engine to develop its maximum power. Therefore, the throttle and propeller control should be positioned full forward so the engine can turn at its maximum r.p.m. while also developing the maximum amount of thrust horsepower. On the other hand, to help establish the airplane in a climb after takeoff, the throttle and propeller controls can be retarded in order to achieve more economical fuel consumption.
- The order and manner in which the engine and propeller controls are operated are important considerations.
- As an additional consideration, you should avoid rapid throttle movement when making engine power adjustments. This is because harmonic balance weights are often installed on the engine's crankshaft.



Source:
<https://www.boldmethod.com/learn-to-fly/aircraft-systems/how-a-constant-speed-prop-works/>

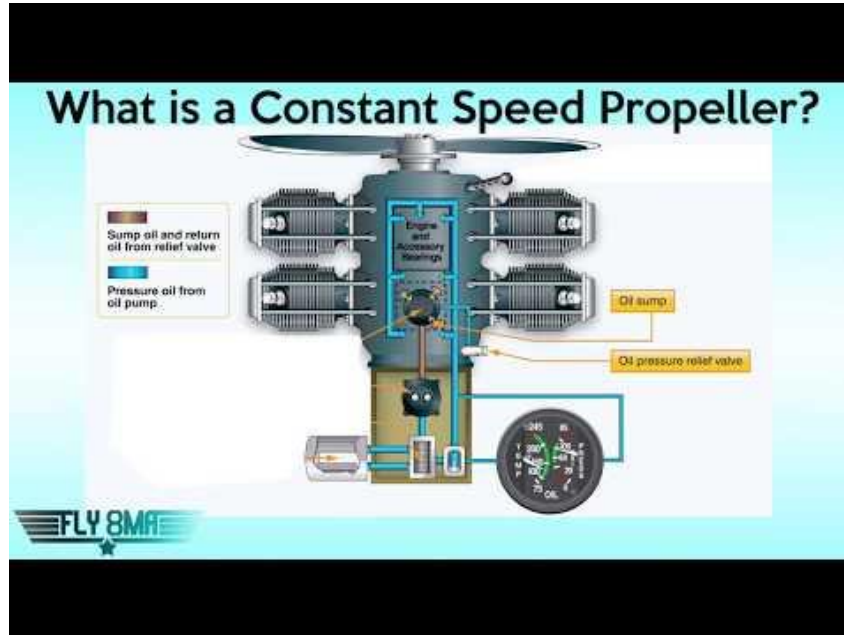
Power Controls

- These weights are designed to position themselves by the inertia forces generated during crankshaft rotation to effectively absorb and dampen crankshaft vibration.
- If the throttle is abruptly moved, the balance weights may be shifted away from the optimum position, causing the crankshaft to receive a large amount of vibrational stress.
- This condition is referred to as detuning because of the balance weights' association with harmonic vibrations.
- In severe cases, rapid throttle movements can produce such significant detuning stresses that the crankshaft fails.



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Constant Speed Propeller Operation



Retractable Landing Gear

- Landing gear have a simple function: to absorb the load imposed during a landing, in order to protect the airplane's fuselage and preserve the comfort of those on board. You may not give much thought to the fixed gear on an airplane, except to ensure they are aligned with the runway upon touchdown.
- However, when you fly an aircraft with retractable landing gear, you assume more responsibility in exchange for the advantages afforded by the more complex design.
- You will find certain differences when operating an aircraft with retractable landing gear.



Landing Gear System

- Most aircraft with retractable landing gear use some type of mechanical aid to help the pilot raise the gear into the belly of the airplane and extend it again for landing.
- The gear may be operated either through a hydraulic system or an electric motor, or a hybrid of the two methods. Since systems differ between aircraft, you should familiarize yourself with the landing gear system in your airplane, using the recommendations outlined in the aircraft's POH.
- On some aircraft, the main gear retract into the wings or fuselage on either side. The nose gear generally retracts into the forward fuselage, below the engine compartment. Gear doors may be installed to further streamline the fuselage after the gear has retracted.



Electrical Gear Systems

- Some aircraft employ an electrically driven motor for gear operation. The electrical gear system consists of a motor that is reversible to facilitate both raising and lowering the gear, and this motor drives a series of rods, levers, cables, and bellcranks that form what is essentially a motorized jack.
- Struts are also actuated that open and close the gear doors during the gear cycle. The gear cycle refers to the process that the gear goes through during extension and retraction.
- The electric motor moves up or down and it will continue to operate until the up or down limit switch on the motor's gearbox is tripped.



Hydraulic Gear Systems

- Other aircraft utilize a hydraulic gear system to actuate the linkages that raise and lower the gear. When the gear switch is retracted, hydraulic fluid, like that used in many brake systems, is pressurized and directed into the gear up line.
- The fluid flows through sequence valves and downlocks to the nose gear and main gear actuating cylinders.
- A similar process occurs during gear extension. The pump which pressurizes the fluid in the system can be either engine driven or electrically powered. If an electrically powered pump is used to pressurize the fluid, the system is referred to as an electrohydraulic system.

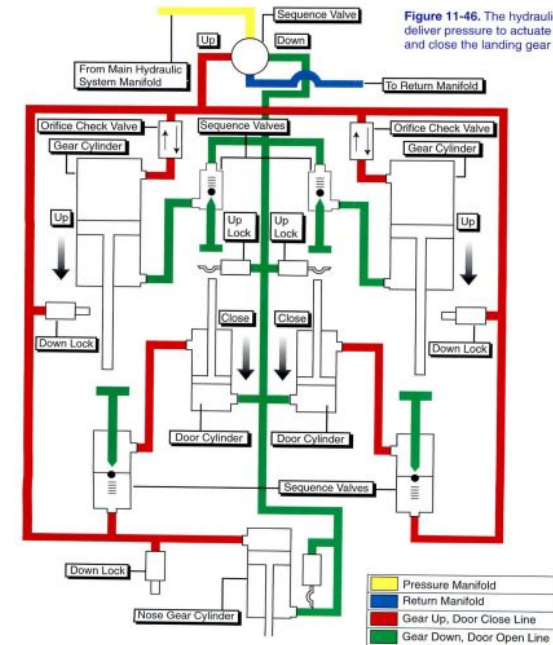
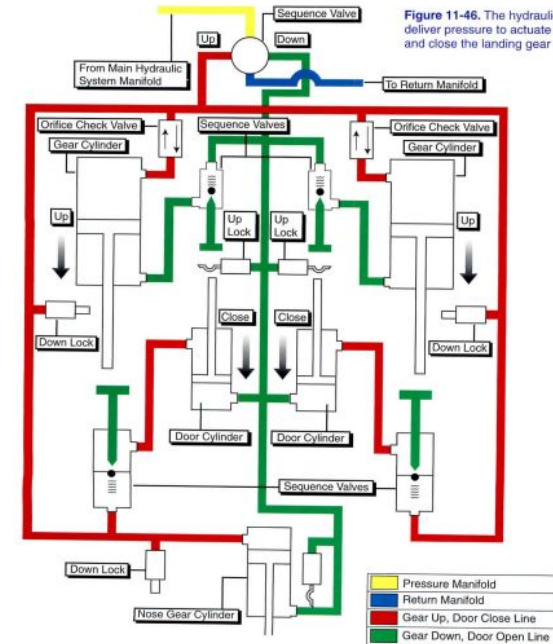


Figure 11-46. The hydraulic system may also deliver pressure to actuate cylinders that open and close the landing gear doors.

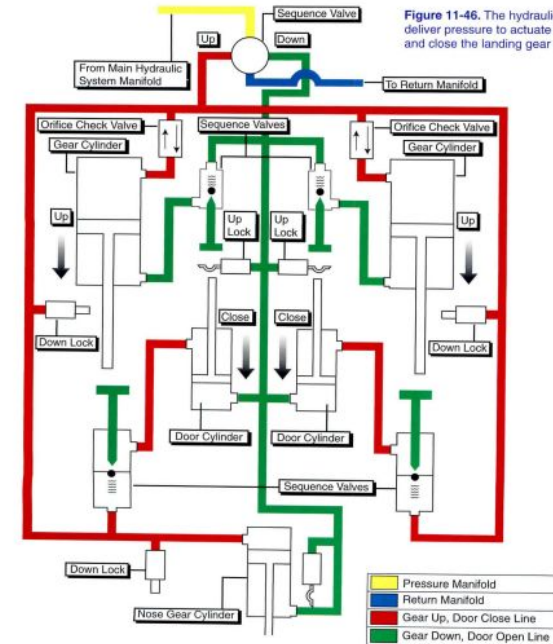
Hydraulic Gear Systems

- The hydraulic pump, regardless of its power source, is designed to operate within a specific range. pump, regardless of its power source, is designed to operate within a specific range. When a sensor detects excessive pressure, a relief valve within the pump opens, and hydraulic fluid is routed back to the reservoir.
- A second type of relief valve prevents the excess pressure associated with thermal expansion. The hydraulic pressure is also regulated by limit switches on each of the landing gear.



Hydraulic Gear Systems

- Each gear has two switches, one dedicated to extension, and one for retraction. These switches de-energize the hydraulic pump after the landing gear has completed a gear cycle. In case any of these switches fail, a backup valve will relieve excess pressure in the system.
- The hydraulic system may also deliver pressure to actuate cylinders that open and close the landing gear doors.



Gear System Safety

- With the benefits of retractable landing gear come additional complexity and potential problems. To deal with these issues, aircraft manufacturers have installed various devices on aircraft with retractable gear to enhance safety and ease of operation.



Gear Position Indicators

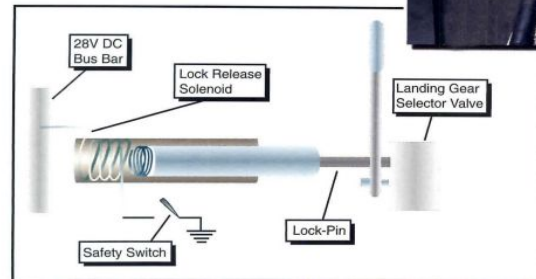
- In most aircraft, not all of the landing gear are visible from the cockpit. Therefore, one of several different types of gear position indicators is installed to help you keep track of where the gear is in the gear cycle.
- Position lights are one common type of indicator. Often, the grouping will consist of one red light and one or three green lights.
- The red light is illuminated when the gear are in transit or unsafe for landing, and the green lights indicate when each gear is down and locked.
- Other position indicators include miniature gear icons electrically placed by the movement of the actual gear, or an arrow indicator showing gear position, and some models have separate lights that illuminate solely when the gear is in transit.



Gear Warning Horn

- As a reminder to pilots, most aircraft with retractable gear have a gear warning horn that will sound when the aircraft is configured for landing and the gear is still in an unsafe position.
- Usually, the horn is linked to the throttle or flap position, and/or the airspeed indicator, so that when the aircraft is below a certain airspeed, configuration, or power setting with the gear retracted, the warning horn will sound.
- The horn generally differs in sound from the stall warning horn, so that you will know which condition you are being alerted to. Some aircraft have other safety systems installed to help you avoid a gear-up landing.

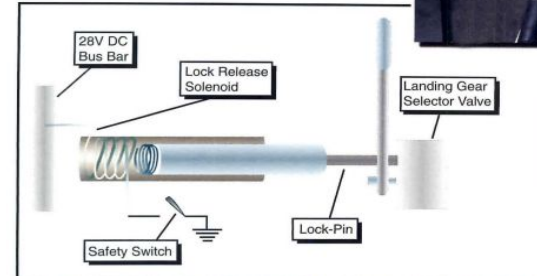
Figure 11-49. This safety switch is located on the left main gear. While some safety switches prevent gear retraction by opening the electrical circuit, some keep the gear switch inside the cockpit from moving.



Safety Switches

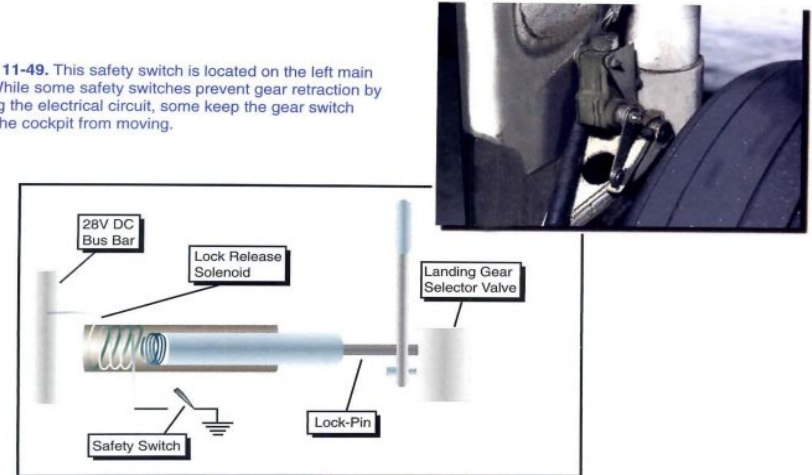
- Most retractable landing gear systems incorporate a mechanical safety switch that prevents the retraction of the gear when the aircraft is on the ground.
- The switch, sometimes referred to as a squat switch, is usually found on one of the main gear struts. When the strut is compressed, the switch opens the electrical circuit to the motor or mechanism that powers retraction.
- That way, if the gear switch in the cockpit is moved to the retract position when weight is on the gear, such as during taxi, the gear will remain extended.

Figure 11-49. This safety switch is located on the left main gear. While some safety switches prevent gear retraction by opening the electrical circuit, some keep the gear switch inside the cockpit from moving.



Safety Switches

- However, the gear warning horn may sound as an alert to the unsafe condition. If the gear switch remains in the retract position during takeoff, once the weight is off of the gear, the safety switch will release and the gear will retract. If the aircraft does not have a positive rate of climb, it may settle back to the ground with the gear retracted. This safety switch is located on the left main gear.
- While some safety switches prevent gear retraction by opening the electrical circuit, some keep the gear switch inside the cockpit from moving.



Airspeeds Limitations

- Limiting airspeeds are established for gear operation in order to protect the gear components from becoming overstressed during flight.
- The operating loads placed on the gear at faster speeds may cause structural damage due to the forces of the airstream.



Airspeeds Limitations

- Though you will not see these speeds on the airspeed indicator, they are usually found on placards in the airplane, and published in the POH.
- The maximum landing gear extended speed (V_{LE}) is the maximum speed at which you can fly the aircraft with the landing gear extended. The maximum landing gear operating speed (V_{LO}) is the highest speed at which you may operate the landing gear through its cycle.



Operating Procedures

- Many potential gear system problems can be prevented if you conduct a thorough preflight. Because the system is more complex, retractable landing gear demand a close inspection before every flight.
- The wheel wells need to be clear of any obstructions, as a foreign object may damage the gear or cause it to become lodged inside the wells.
- Bent gear doors could be a sign of other problems with gear operation, and they may also become stuck during extension or retraction.
- Cracks, corrosion, or loose bolts in the linkage may lead to gear failure at a later time, so look carefully at each component of the system.



Operating Procedures

- When you fly a particular aircraft for the first time, you should check for any ADs pertaining to the landing gear system to ensure they have been performed.
- Also, many gear switches have a wheel shape, so that you can feel the difference between the flap switch and the gear switch.
- However, familiarize yourself with your aircraft thoroughly, as some airplanes have different flap/gear switch locations.
- The gear takes several seconds to complete a cycle, so you should factor in this delay when you determine the point at which you will raise or lower the gear





Gear System Malfunctions

- The position indicator lights in the cockpit are your primary means of determining whether the gear has extended or retracted correctly, but the flight characteristics mentioned above are another clue as to the status of the gear.
- An observer on the ground may also be able to check for you, if you question whether or not the gear has extended or retracted properly.
- If the position indicator lights fail to illuminate when you move the gear switch, there are several things to consider before you extend the gear manually.
- First of all, if you felt a change in pitch and/or airspeed, the gear may well be down, and one or more of the position indicator light bulbs is burned out. Replace the suspect bulb with a working one and check it again.
- If you did not notice any other signs that the gear has operated, check the circuit breakers to see if an overload has caused a breaker to pop out



Emergency Gear Extensions

- When you establish that the gear has failed to extend, you should be ready to use whatever type of emergency landing gear system is available in the aircraft.
- The most common kinds you will see are the hand crank, hand pump hydraulic, free fall, and carbon dioxide (CO₂) pressurized systems.
- Study the POH for the proper method and any caveats that apply to a particular system. Also, practice a manual gear extension with an instructor if it is feasible in your airplane.
- Also, practice a manual gear extension with an instructor if it is feasible in your airplane.
- If you practice an emergency extension, make sure that you stow the hand crank or pump (if used) properly, as failure to do so may keep the landing gear circuit open and leave you unable to extend or retract the gear normally.

Emergency Gear Extensions

- A hand crank system is often found on aircraft with electric gear systems.
- The crank is employed to turn the gears that operate the actuators manually instead of through the electric motor.
- When you use this system, you will need to turn the crank a specific number of revolutions before the gear is fully extended.
- A good reason to practice this extension method in flight is that the position you must be in to turn the crank may be awkward, and the crank may be difficult to turn. I



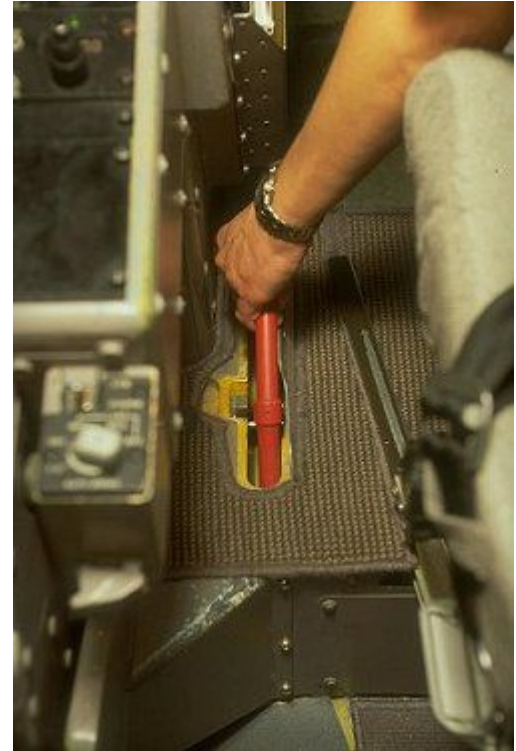
Emergency Gear Extensions

- If you fly an aircraft with a hydraulic system, you may use a hand pump hydraulic system to extend the gear when the primary pump fails.
- You will supply the necessary hydraulic fluid pressure to the actuator cylinders by pumping a hand pump. With some systems, you will need to put the gear switch in the DOWN position before operating the pump.
- A freefall system is another method of gear extension used on aircraft that have hydraulic gear systems.



Emergency Gear Extensions

- A control lever is used to open a valve that releases the system pressure. Hydraulic pressure equalizes on both sides of the gear actuators and allows the landing gear to fall into position through the force of gravity and aerodynamic loads.
- In the carbon dioxide (CO2) pressurized system, compressed gas is used to apply the pressure to extend the gear if the hydraulic part of a gear system fails.
- When the CO2 extension handle is pulled, pressure is released from a cylinder and directed through tubes to each landing gear actuator, which then extends the gear.
- Some CO2 canisters may operate only once per flight, so consult your POH before extending the gear in this manner. You may need to be in a position where you can leave the gear down for the remainder of the flight





THE END

Before tomorrow's class:

- Jeppesen Multi-Engine Pilot Manual, Chapter 2, Section A
- Reference 1: Jeppesen ICM - Manual, Chapter 11, Section B