Private Pilot (ASEL) Ground School Course

Lesson 05 | Aircraft Flight Controls and Systems

Lesson Overview

Lesson Objectives:

- Develop a knowledge and understanding of primary and secondary flight controls.
- Gain knowledge, understanding and operations skill of most aircraft systems.

Lesson Completion Standards:

- Student demonstrates satisfactory knowledge of primary and secondary flight controls, and most aircraft systems by answering questions and actively participating in classroom discussions.

Systems - Powerplant

Aircraft Flight Controls and Systems

Powerplant (Engine)

- Engines are the “powerplant” of the airplane. They are responsible for the thrust force in the four forces in most airplanes.
- Some engine power propellers and other turn a large fan (Turbine Fan).
- Another purpose of engine is to power accessories the airplane may need.
  - Alternator/Generator
  - Starter
  - Magnetos
  - Oil pump
  - Fuel Pump

Powerplant (Engine)

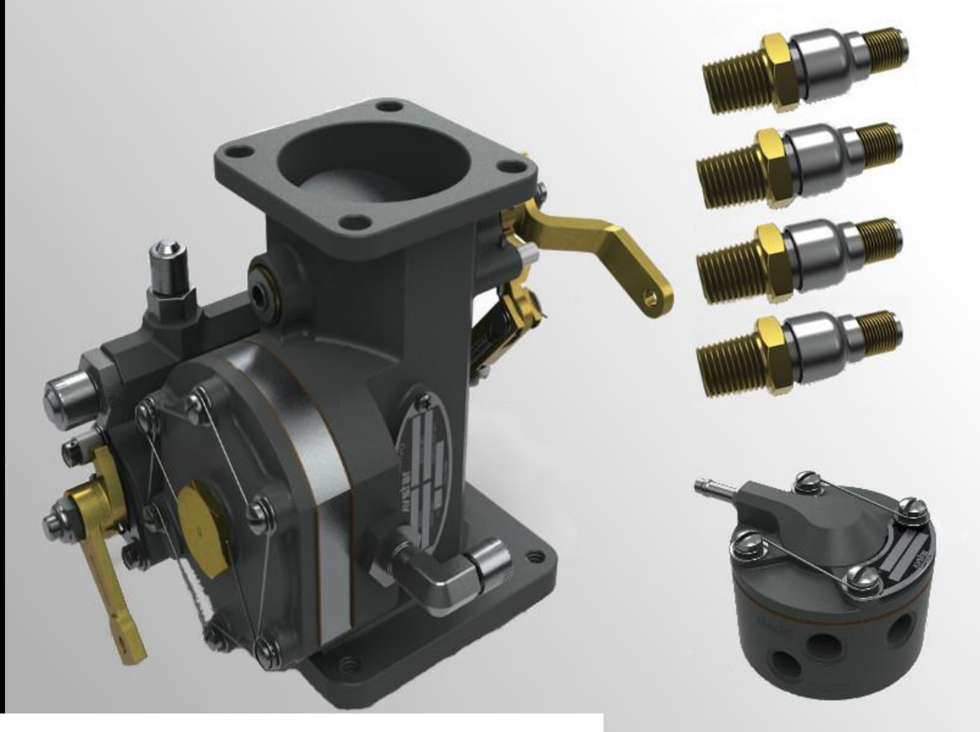
- There are many different types of engines that airplanes can have (*We will be talking in detail about these*)
- Most commonly light airplanes have reciprocating engine
- Lager airplanes have turbine engines. Many types of turbine engines exist:
  - Turbojet
  - Turboshaft
  - Turbofan
  - High Bypass Turbofan

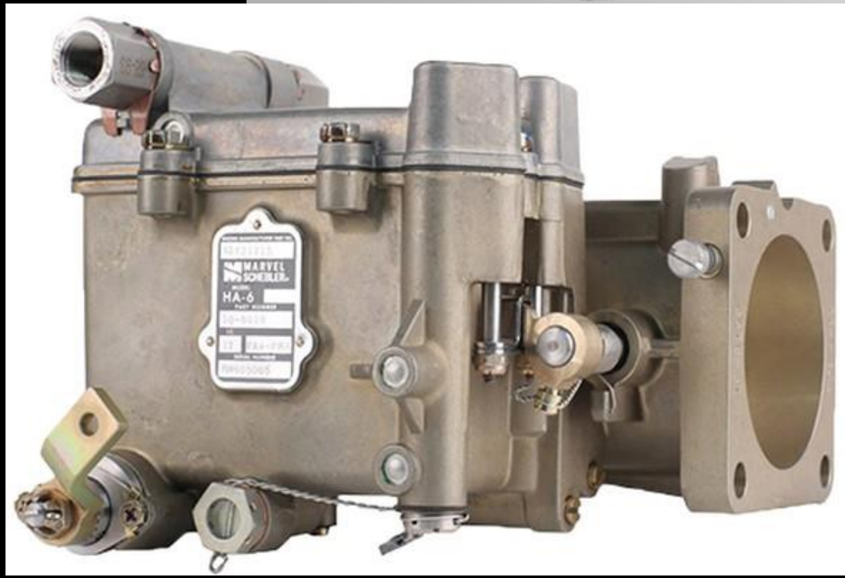
Powerplant (Engine)

- Most small aircraft are designed with reciprocating engines.
- The name is derived from the back-and-forth, or reciprocating, movement of the pistons that produces the mechanical energy necessary to accomplish work.
- Reciprocating engines operate on the basic principle of converting chemical energy (fuel) into mechanical energy.
- This conversion occurs within the cylinders of the engine through the process of combustion.
- Reciprocating engine can be classified by induction type, cylinder arrangement, operating cycle, and cooling type

Powerplant (Engine)

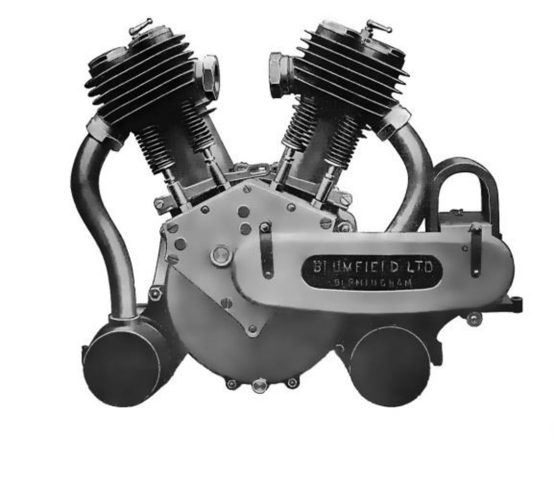
- Induction type refers to how the fuel air mixture is mixed before combustion.
- Both designs have pros and cons
- Common types are:
  - Carbureted
  - Fuel-Injected





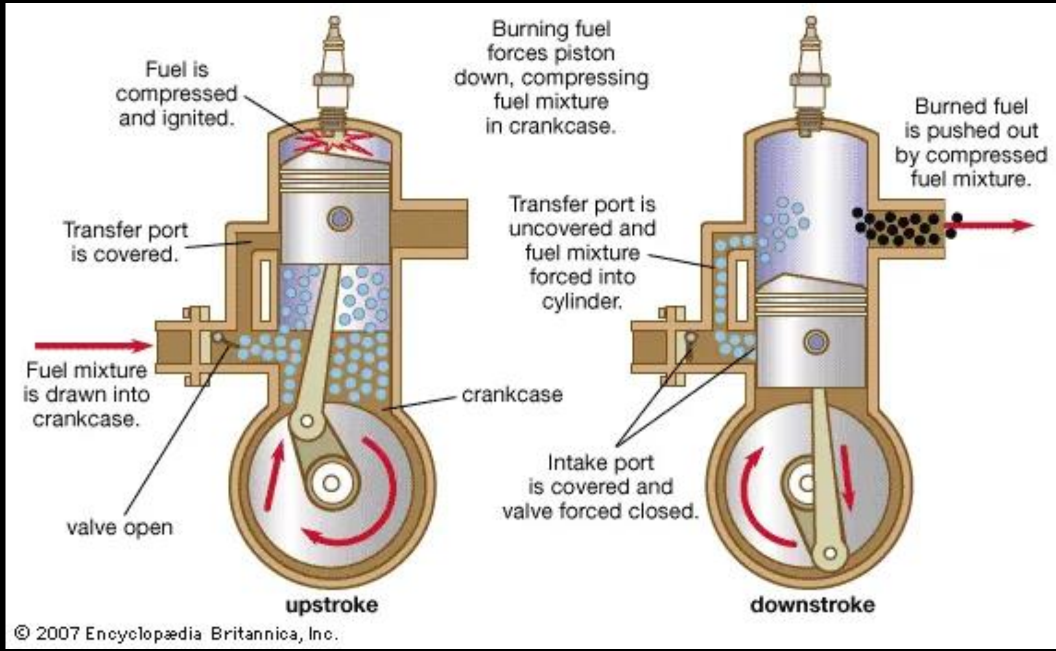
Powerplant (Engine)

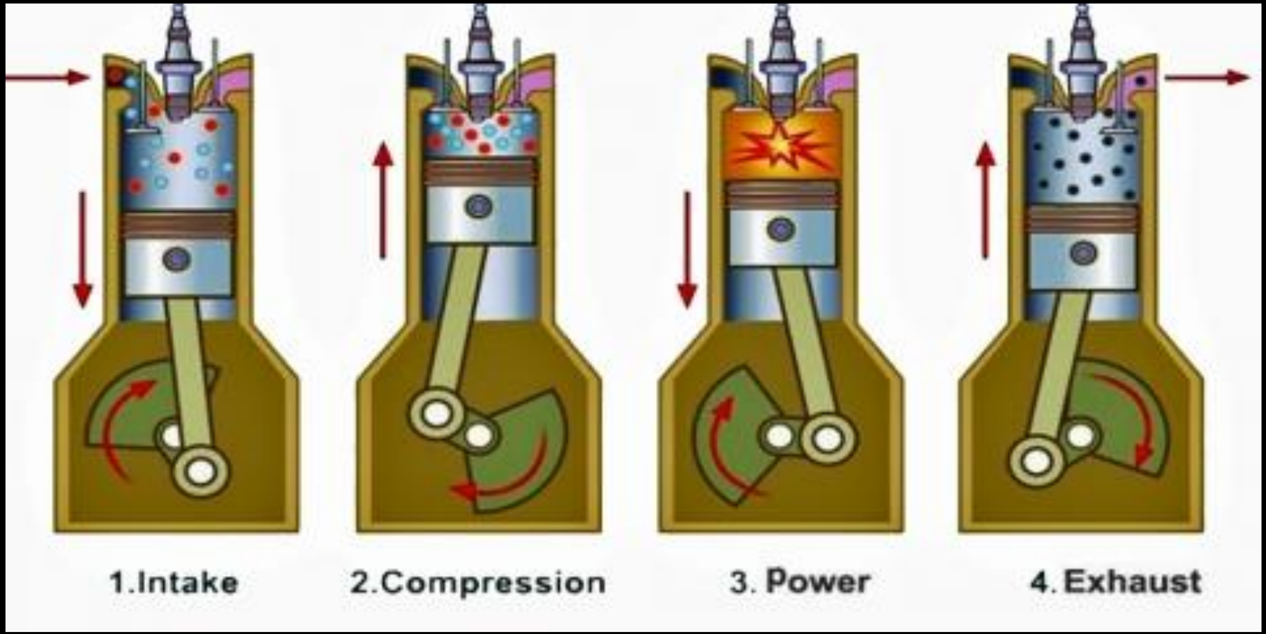
- Cylinder arrangement is the most obvious of the classifications.
- This refers to the placement of the cylinders of the engine. These are the places where fuel is ignited, and combustion occurs.
- Common types are:
    - Horizontally Opposed
    - Radial
    - V-Type
    - In-line



Powerplant (Engine)

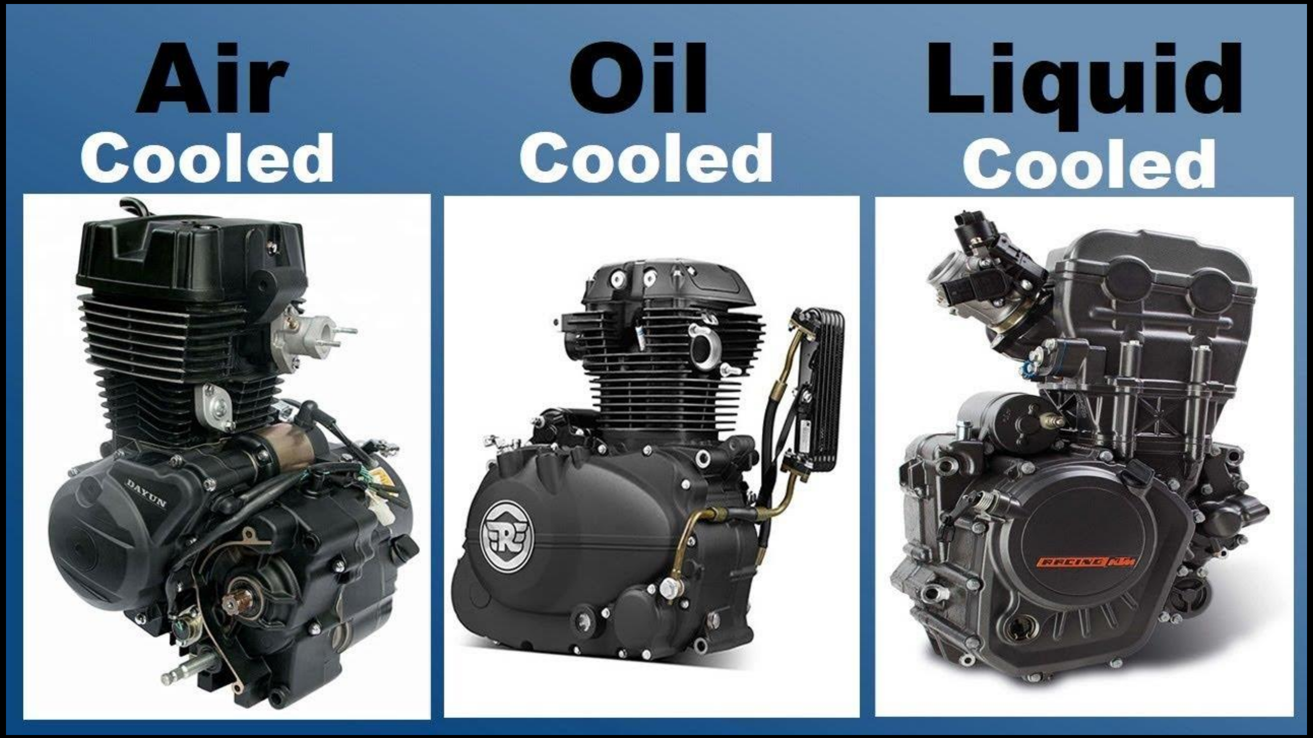
- Operating cycle refers to the number of times the piston moves in the cylinder.
- Most common are:
  - 4-stroke
  - 2-Stroke



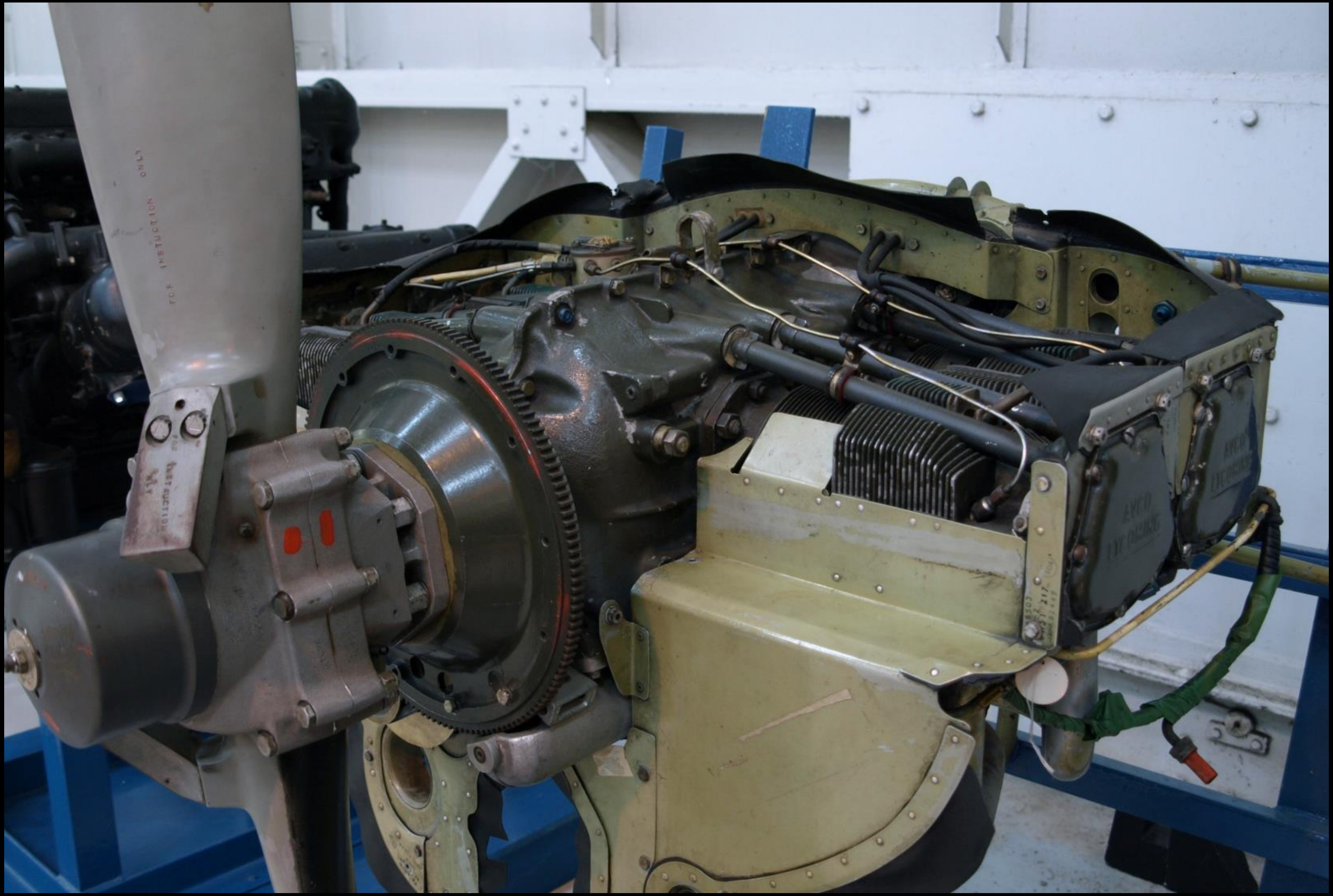


Powerplant (Engine)

- Cooling types refers to how the engine cools itself
- Most training airplanes use oil and air to cool the engine
- Most common are:
  - Oil
  - Liquid
  - Air



Lycoming IO/O-360/320



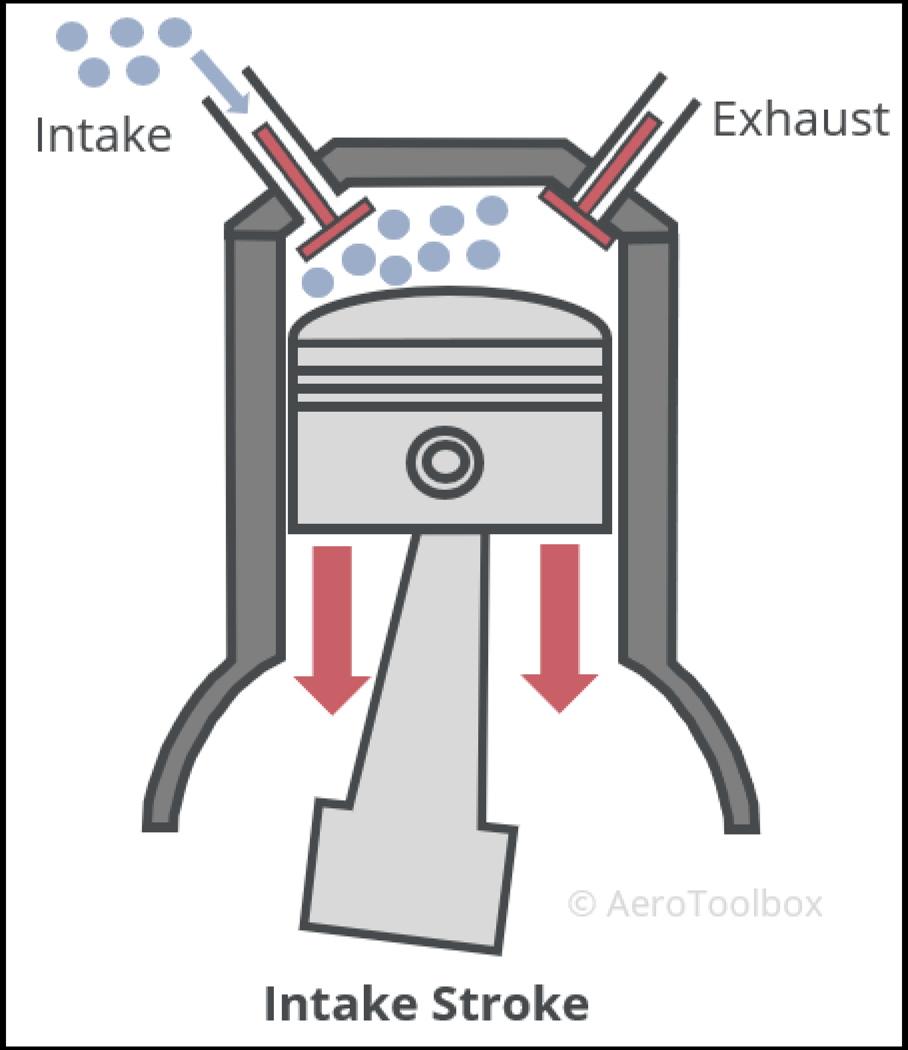
Powerplant (Engine IO/O-360/320)

- This engine operates using a 4-cylinder horizontally opposed cylinder setup. This engine uses a 4-stroke cycle of operation.
- The 4-stroke cycle is the basis of operation for any reciprocating engine.
- Those 4 strokes are
  - Intake
  - Compression
  - Combustion
  - Exhaust

Powerplant (Engine IO/O-360/320)

Intake

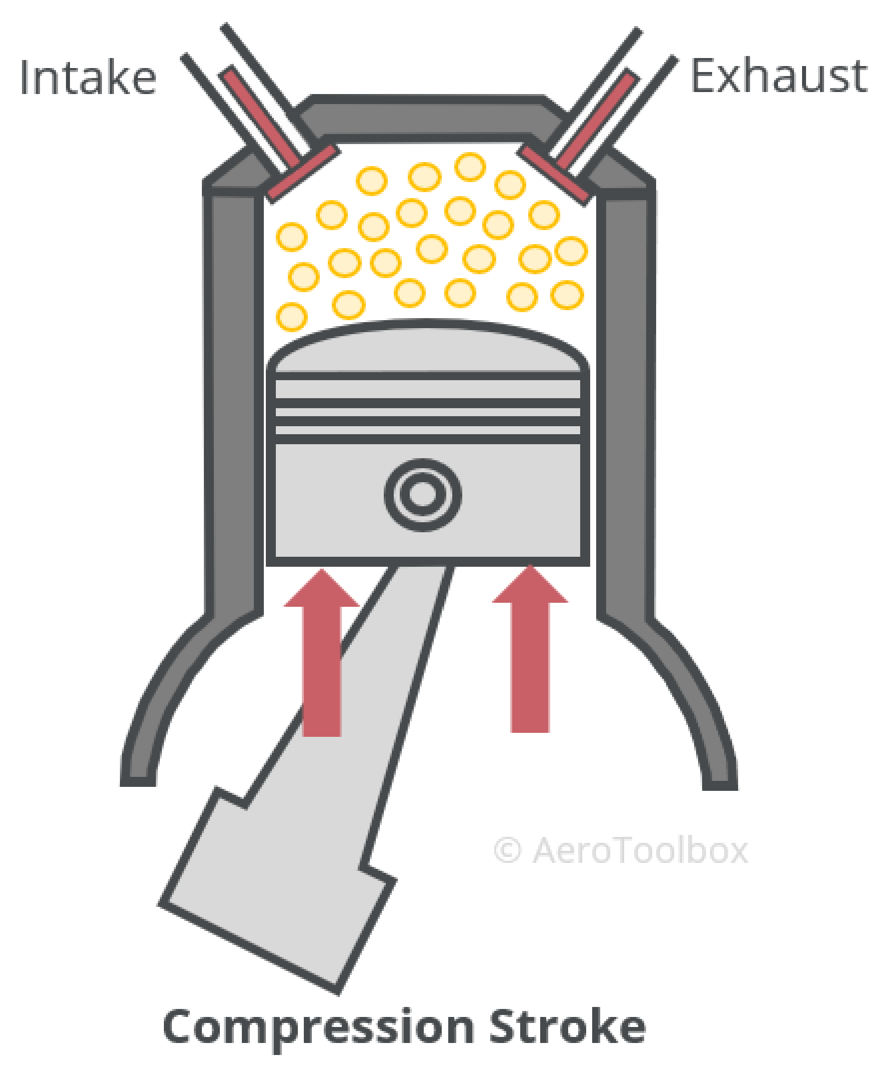
- The two valves at the top are for intake of the fuel/air mixture and exhaust after combustion.
- At the bottom is the cylinder connection to the "crankshaft."
- Intake valve open and air is allowed into the cylinder.
- This displaces the piston down.



Powerplant (Engine IO/O-360/320)

Compression

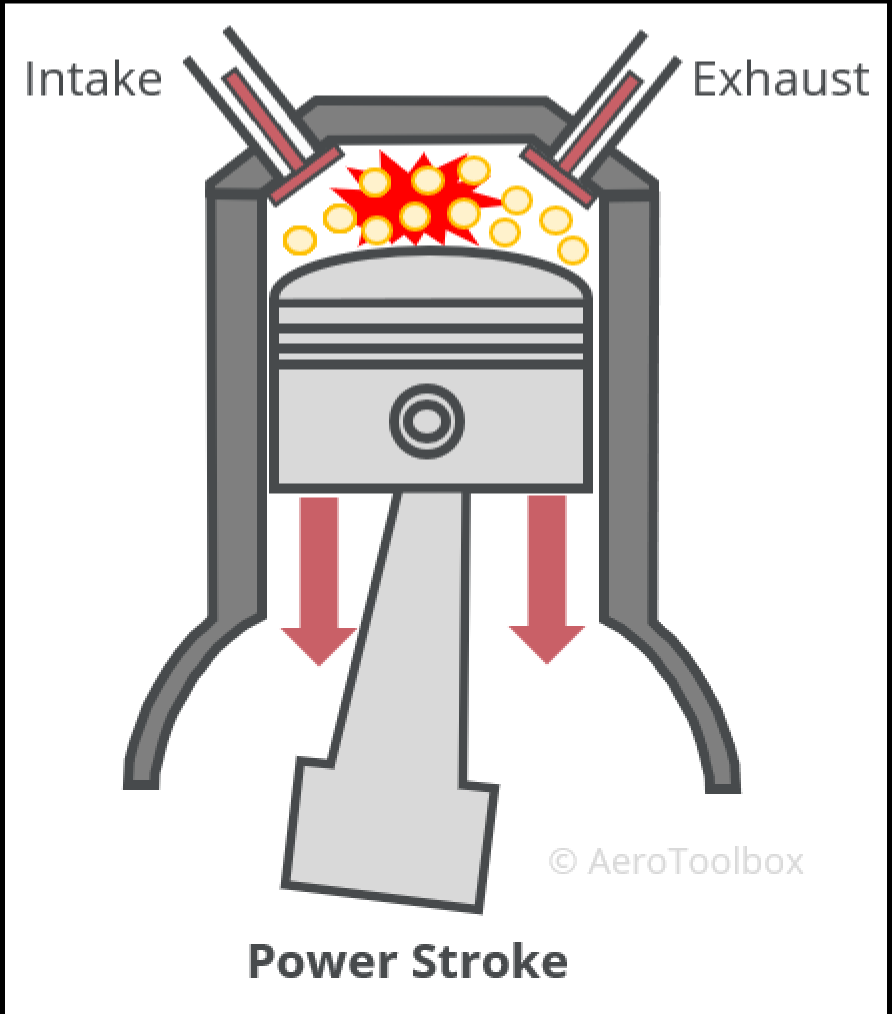
- Both valves at the top are closed.
- The piston is forced back up compression the fuel/air mixture.
- This occurs because another cylinder is in the combustion stroke forcing another piston to move up.



Powerplant (Engine IO/O-360/320)

Combustion (Power)

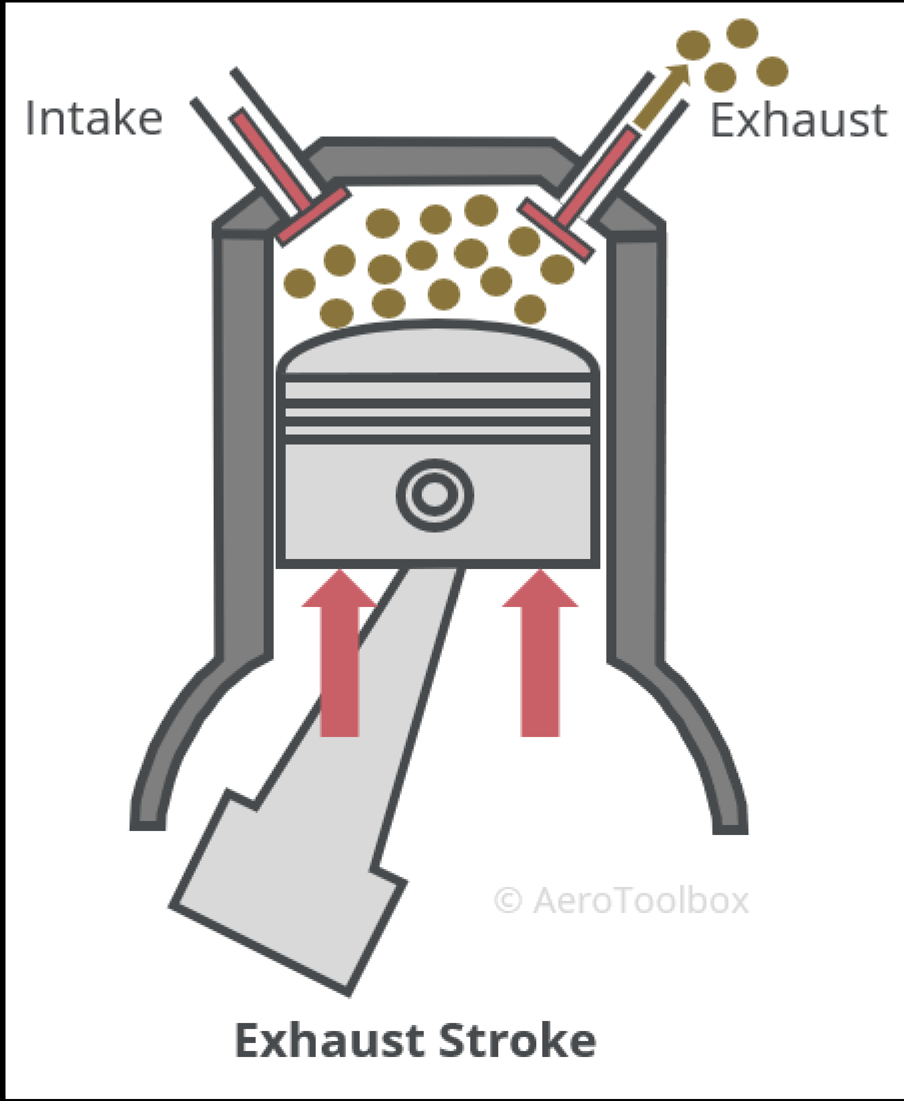
- Once the piston reaches the top of the cylinder the spark plug ignites the fuel air mixture
- This causes a reaction and the gasses expand in the cylinder forcing the piston back down.
- Once cylinder must always be in this stoke to operate.



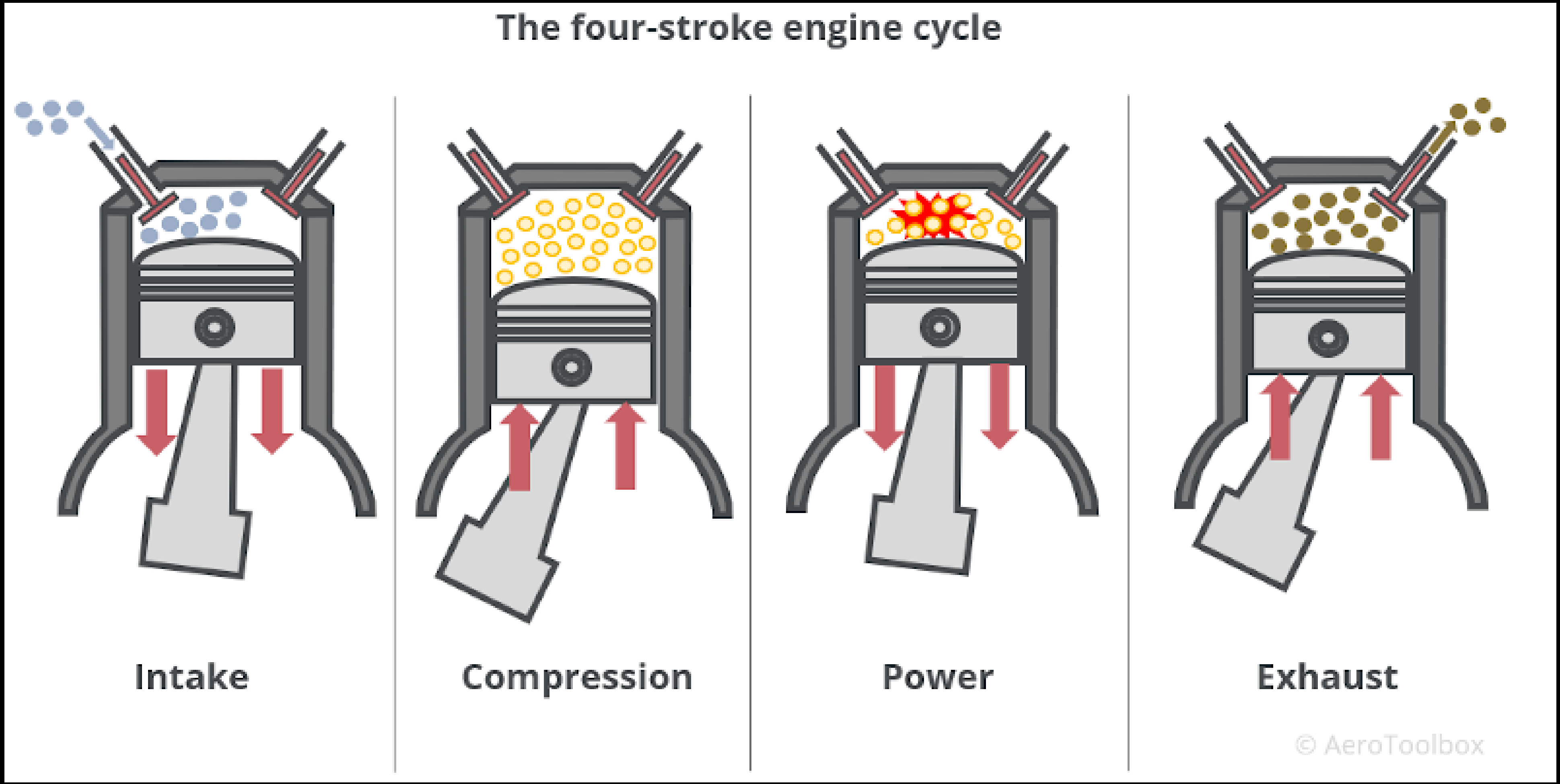
Powerplant (Engine IO/O-360/320)

Exhaust

- The piston is moved back up and the exhaust valve opens.
- This forces the exhaust gases out of the cylinder.
- Then the intake opens and the cycle repeats its self again.



Powerplant (Engine IO/O-360/320)

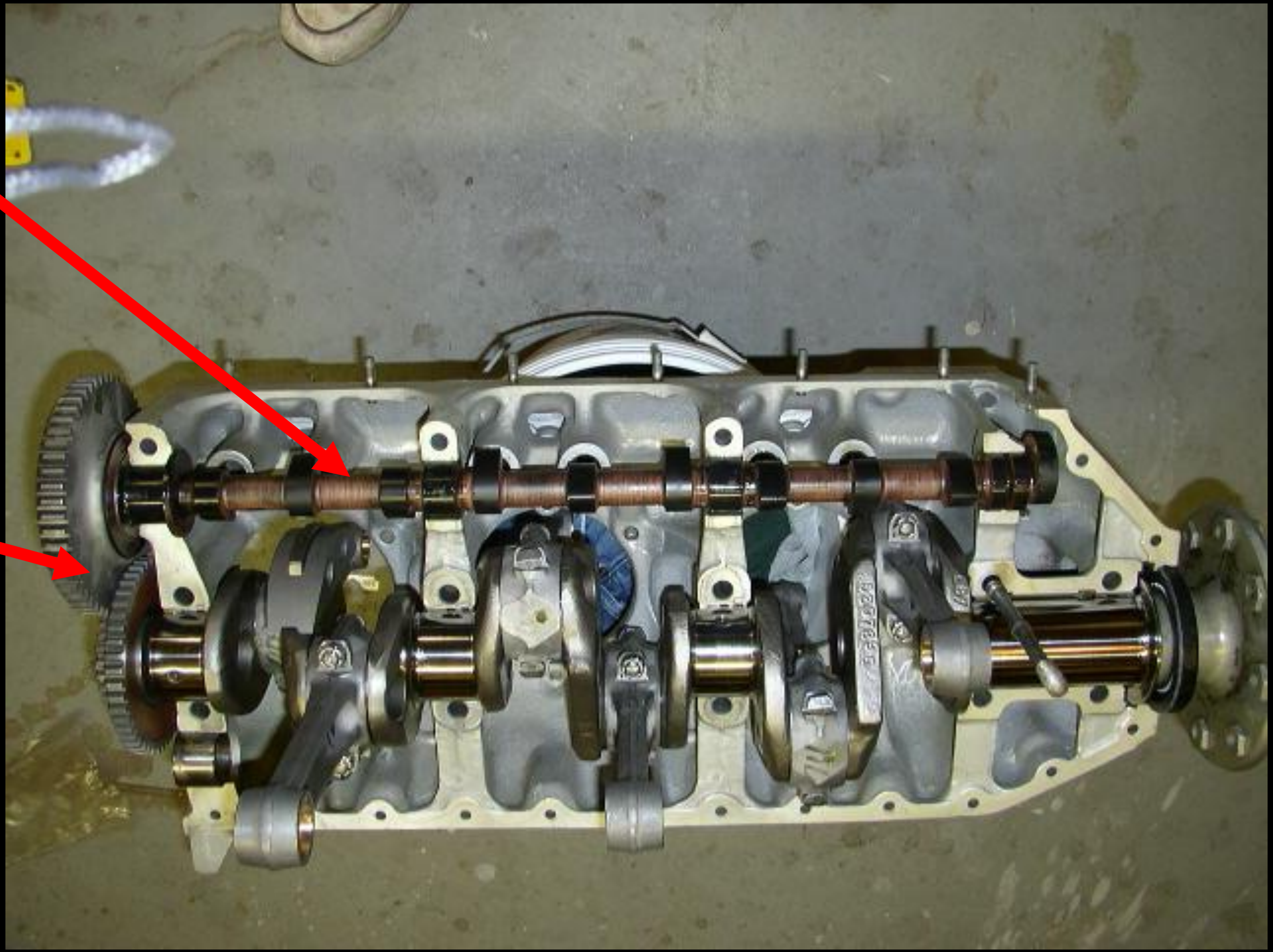


Powerplant (Engine IO/O-360/320)

- The valves play a large role in the engines operation.
- The timing of the valves must be just right for the engine to operate smoothly.
- The valves are operated from a set of push rods, cam shaft, and gears to the crankshaft.

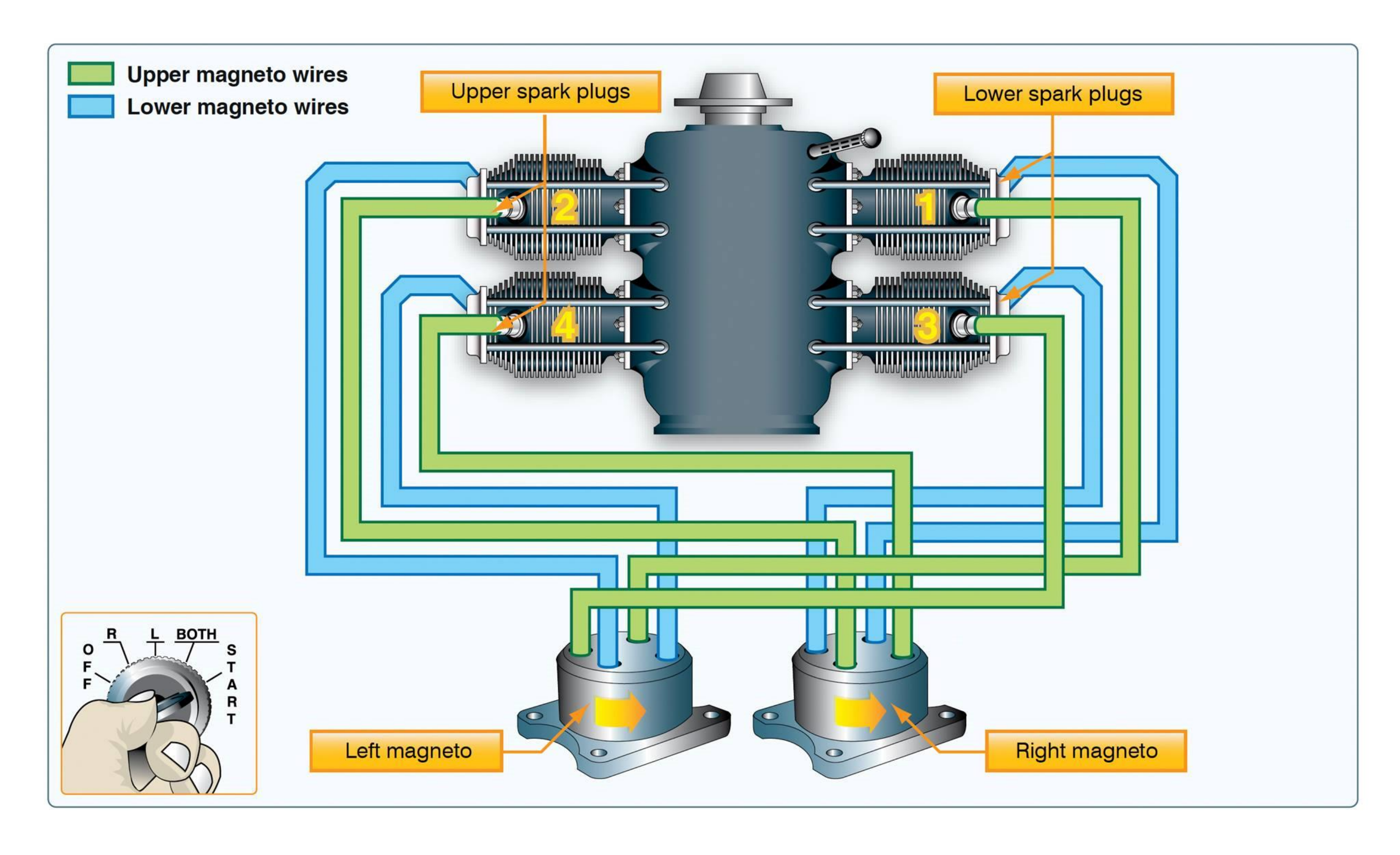
Powerplant (Engine IO/O-360/320)

- The cam shaft is located a the top of the engine with a series of lobes
- Geared to the crankshaft to get the right timing the valves.

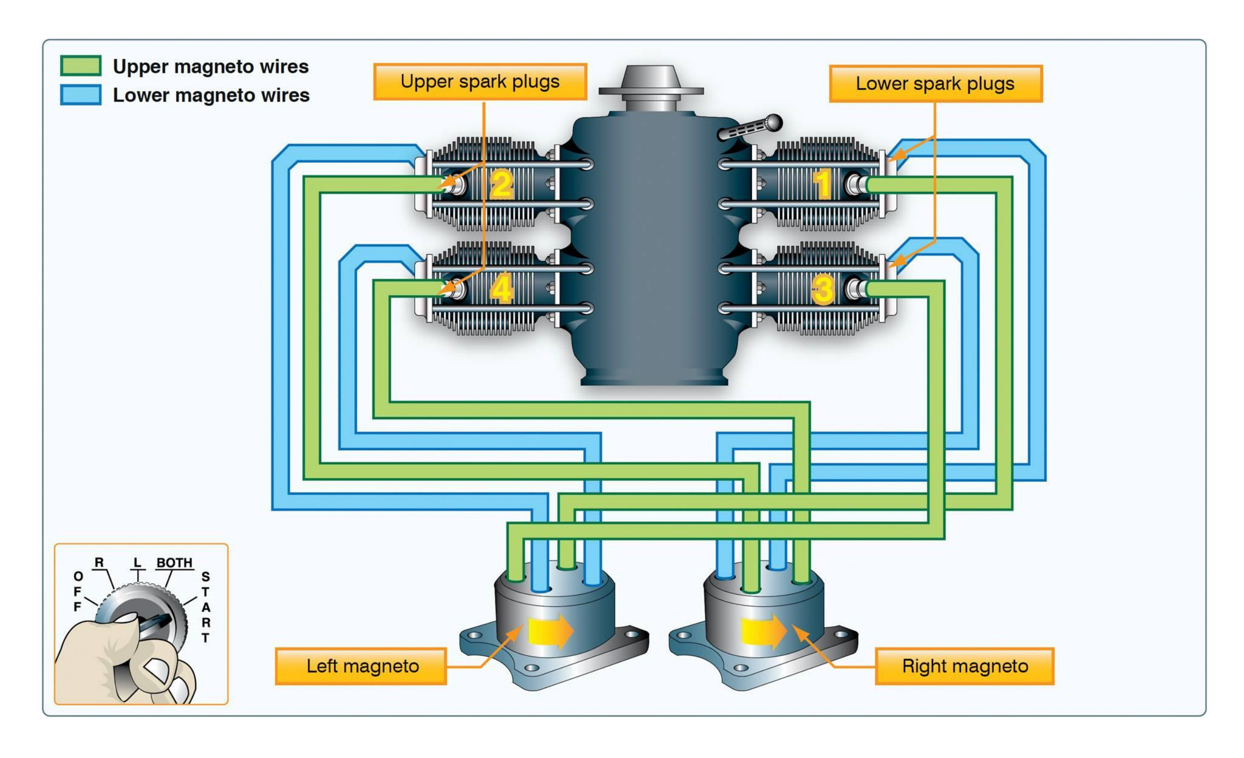


Ignition System

- Ignition system provides a spark that ignites the fuel-air mixture in the cylinders
- Made up of magnetos, spark plugs, high-tension leads, and an ignition switch



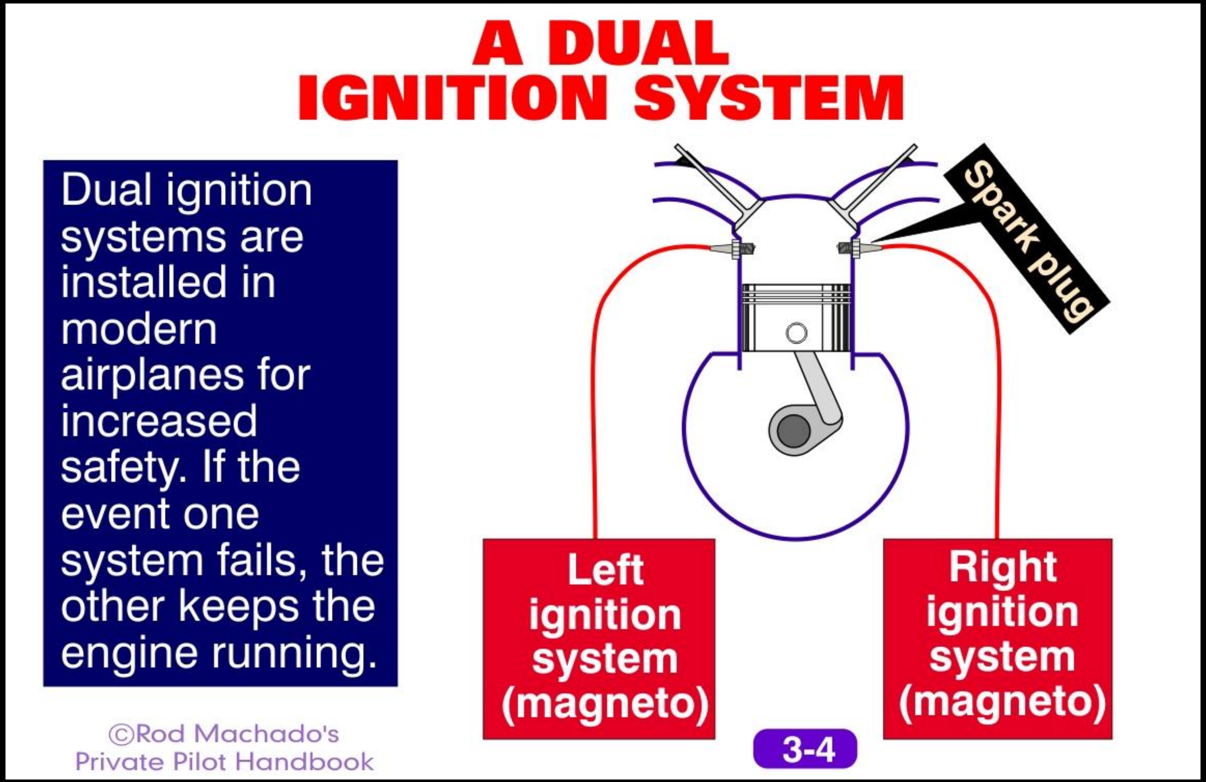
Magnetos



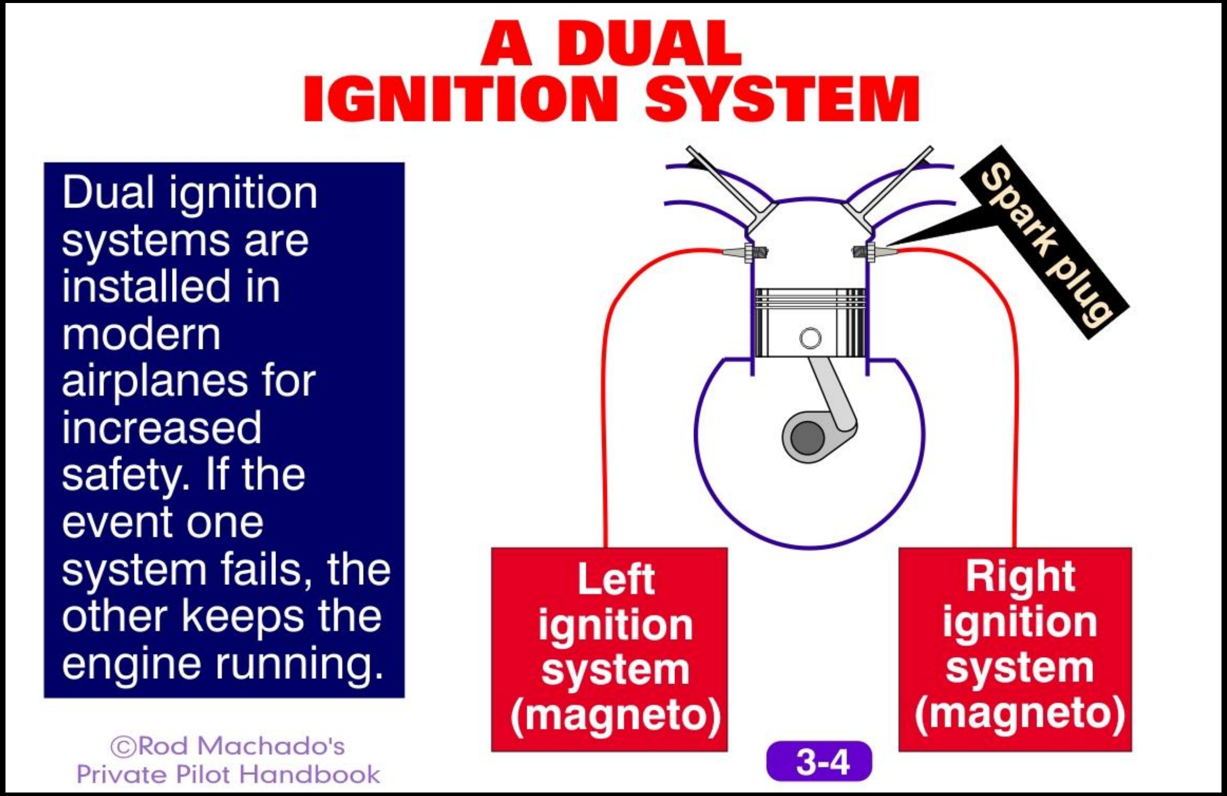
- Use spinnable magnets to generate an electrical current completely independent of the aircraft's electrical system
- Generates sufficiently high voltage to jump a spark across the spark plug gap in each cylinder
- The system begins to fire when the starter is engaged, and the crankshaft begins to turn
- It continues to operate whenever the crankshaft is rotating

Dual Ignition System

- Two individual magnetos, separate sets of wires, and spark plugs to increase reliability of the ignition system
- Each magneto operates independently to fire one of the two spark plugs in each cylinder
- The firing of two spark plugs improves combustion of the fuel-air mixture and results in a slightly higher power output



Dual Ignition System



- If one of the magnetos fails, the other is unaffected
- The engine continues to operate normally although a slight decrease in engine power can be expected
- The same is true if one of the two spark plugs in a cylinder fails

Impulse Couplings

- Mechanical devices inside the magneto that save up a slight amount of spin energy on a spring
- When engine is first started, these springs release their energy causing the internal magnets to spin at a faster speed
- This creates the electrical charge necessary to start the engine without having to equip airplanes with more powerful starters
- Once the engine starts, the impulse coupling stops, because the engine now generates sufficient speed and spark on its own

Ignition Switch

- Five positions:
  - OFF
  - R (right)
  - L (left)
  - BOTH
  - START
- With RIGHT or LEFT selected, only the associated magneto is activated
- The system operates on both magnetos when BOTH is selected

Single Magneto Operation

- If one magneto went bad it could randomly misfire, causing a very rough running engine
- Switch the mag switch from both to the left mag then to the right mag
- If the engine sounds like it has lost power and/or runs rough, switch to the other mag position
- Operating on one magneto causes a decrease in performance (reduced engine RPM)
- Less spark within the cylinders means the combustion process takes longer
- Engine speed typically drops around 100 to 150 RPMs (mag drop)

The P-Lead

- Selecting the right or left magneto deactivates the other mag by grounding it to the airframe (this neutralizes the magneto's ability to generate a spark)
- The absence of a mag drop can indicate that a mag that is supposed to be grounded isn't

The P-Lead

- The mag is grounded to the airframe via a wire called the P-lead
- If the P-lead from a mag is broken or disconnected, it won't be grounded when it should be, including when the airplane is shut down
- In that state, it is possible for the airplane to start (or the engine to at least turn over a bit) if the propeller is turned by hand or accidentally bumped

The P-Lead

- The way to properly shut down an engine is not by turning the ignition switch to off, but rather by pulling out the mixture control knob
- The reason is it leaves the cylinders without fuel in them and thus minimizes the risk of an inadvertent startup in the event of a bad P-lead

P-Lead Check

- Optional P-lead security check just before shutting engine down
- With the engine idling, quickly turn the mag switch from BOTH to OFF, then immediately back to BOTH again
- If the magnetos are grounding properly, the engine should hesitate as you flick through the off part of the sequence
- Engines that keep running as though nothing had happened probably have a magneto that isn’t grounding

Mag Check

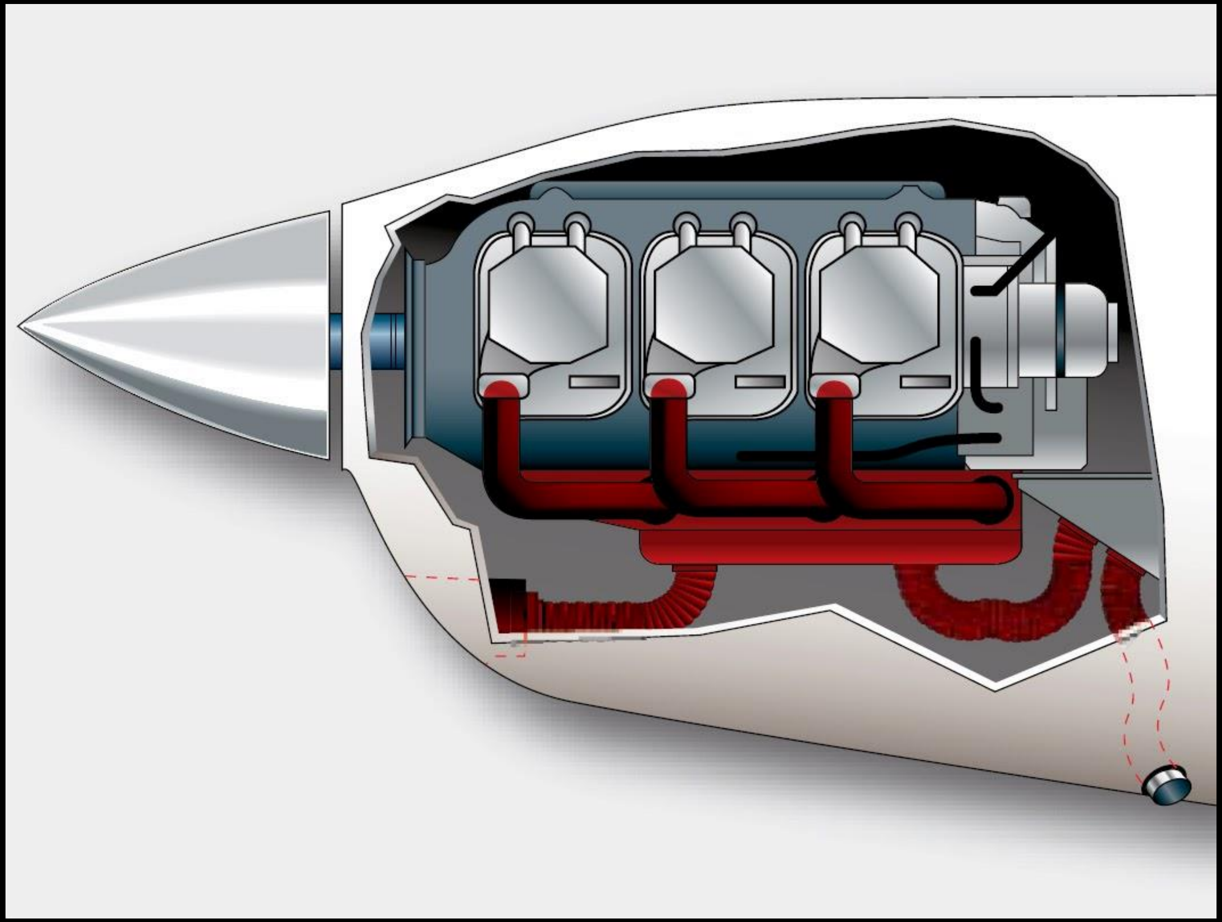
- Observe decrease in rpm that occurs when the ignition switch is first moved from BOTH to RIGHT and then from BOTH to LEFT
- A small decrease in engine rpm is normal during this check
- The permissible decrease is listed in the AFM or POH
- "No drop" in rpm during check is not normal and the aircraft should not be flown
- If the engine stops running when switched to one magneto or if the rpm drop exceeds the allowable limit do not fly the aircraft
- The cause could be fouled plugs, broken or shorted wires between the magneto and the plugs, or improperly timed firing of the plugs

Ignition Malfunctions

- Following engine shutdown, turn the ignition switch to the OFF position
- Even with the battery and master switches OFF, the engine can fire and turn over if the ignition switch is left ON and the propeller is moved because the magneto requires no outside source of electrical power
- Even with the ignition switch in the OFF position, if the ground wire (P-lead) between the magneto and the ignition switch becomes disconnected or broken the engine could accidentally start if the propeller is moved with residual fuel in the cylinder
- If this occurs the only way to stop the engine is to move the mixture lever to the idle cutoff position

Exhaust System

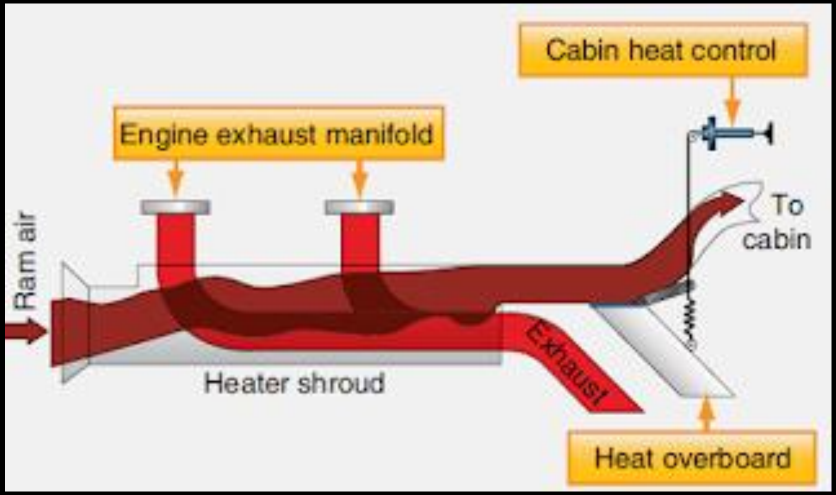
- Vents the burned combustion gases overboard, provide heat for the cabin, and defrost the windshield
- Exhaust piping attached to the cylinders, as well as a muffler and a muffler shroud
- Exhaust gases are pushed out of the cylinder through the exhaust valve and then through the exhaust pipe system to the atmosphere



EGT Gauge

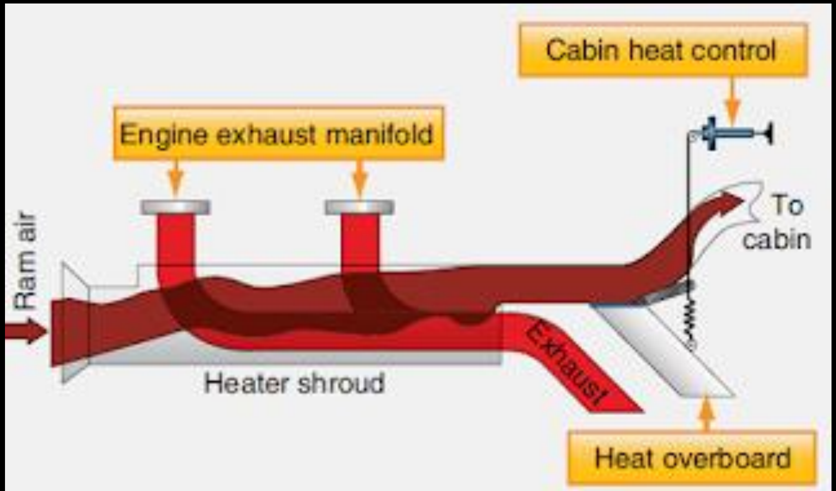
- Measures the temperature of the gases at the exhaust manifold
- This temperature varies with the ratio of fuel to air entering the cylinders and can be used as a basis for regulating the fuel-air mixture
- Highly accurate in indicating the correct fuel-air mixture setting
- When using the EGT to lean the fuel-air mixture fuel consumption is reduced

Cabin Heat



- Outside air is drawn into the air inlet and is ducted through a shroud around the muffler
- The muffler is heated by the exiting exhaust gases and heats the air around the muffler
- This heated air is then ducted to the cabin for heat and defrost applications
- The heat and defrost are controlled in the flight deck and can be adjusted to the desired level

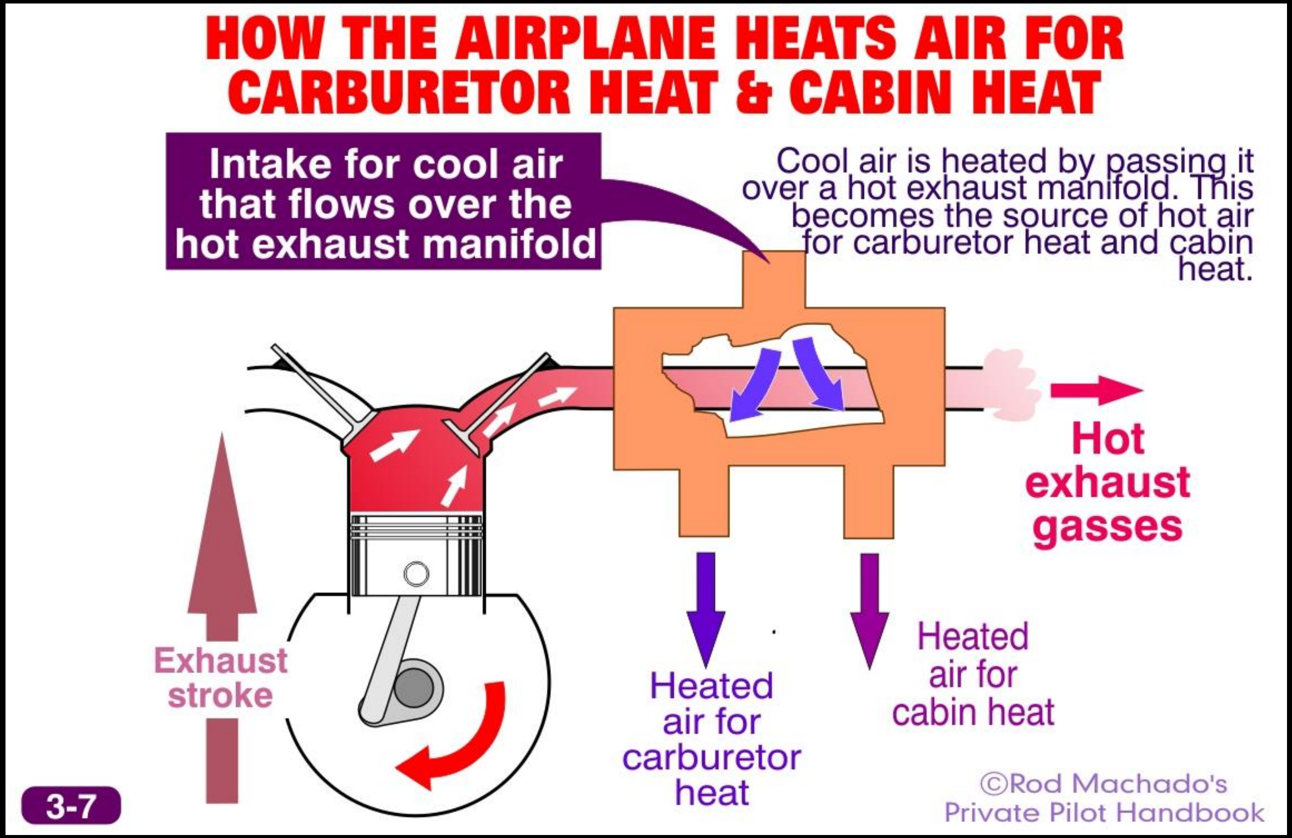
Carbon Monoxide



- Exhaust gases contain large amounts of carbon monoxide, which is odorless and colorless
- Is deadly and its presence is virtually impossible to detect
- To ensure that exhaust gases are properly expelled, the exhaust system must be in good condition and free of cracks

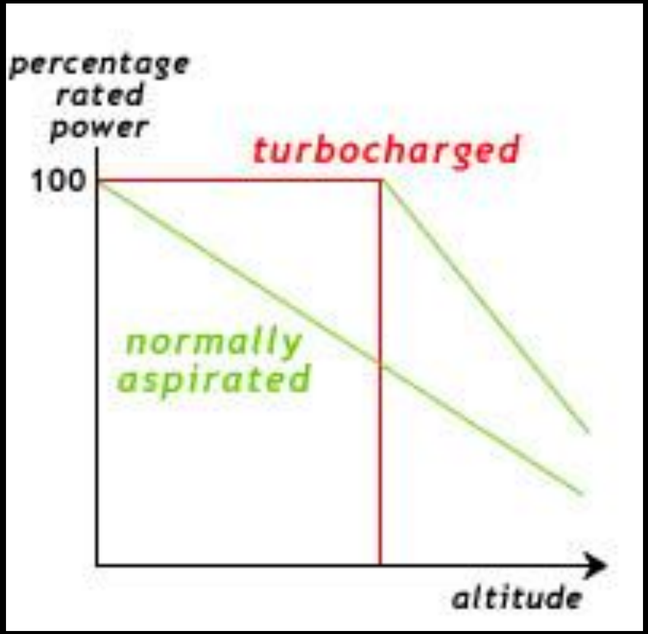
Carburetor Heat

- Heated air is used to raise the temperature of air entering the carburetor
- Buildups of ice within the airplane’s carburetor are prevented
- Melts ice within the carburetor



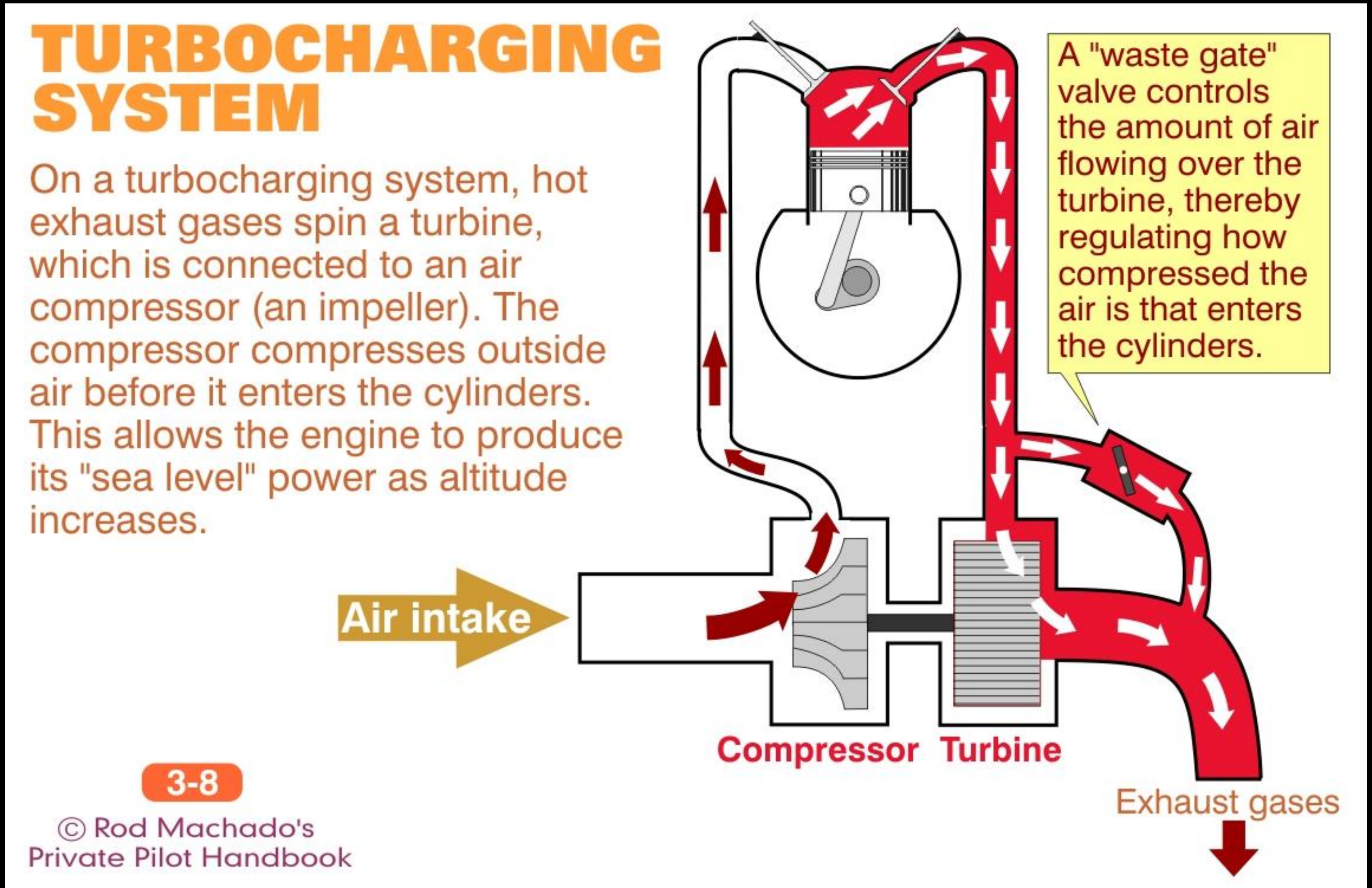
Turbochargers

- Increase HP in an engine by recovering energy from hot exhaust gases that would otherwise be lost
- Increases the pressure of the engine’s induction air allowing the engine to develop sea level or greater HP at higher altitudes
- Critical altitude is the maximum altitude at which a turbocharged engine can produce its rated HP
- Above the critical altitude power output begins to decrease like it does for a normally aspirated engine



Turbocharger

- Allows flight at higher altitudes



Turbocharging System Components

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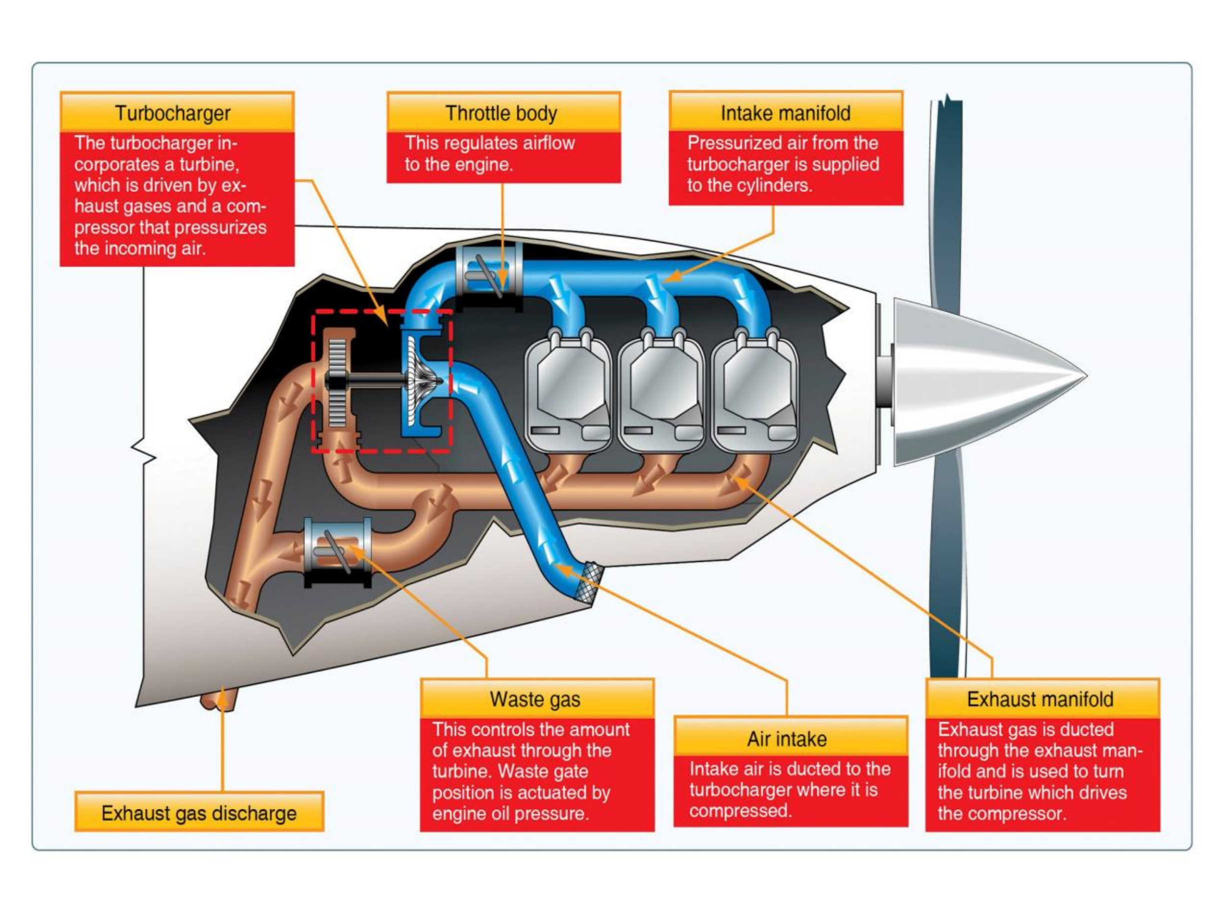
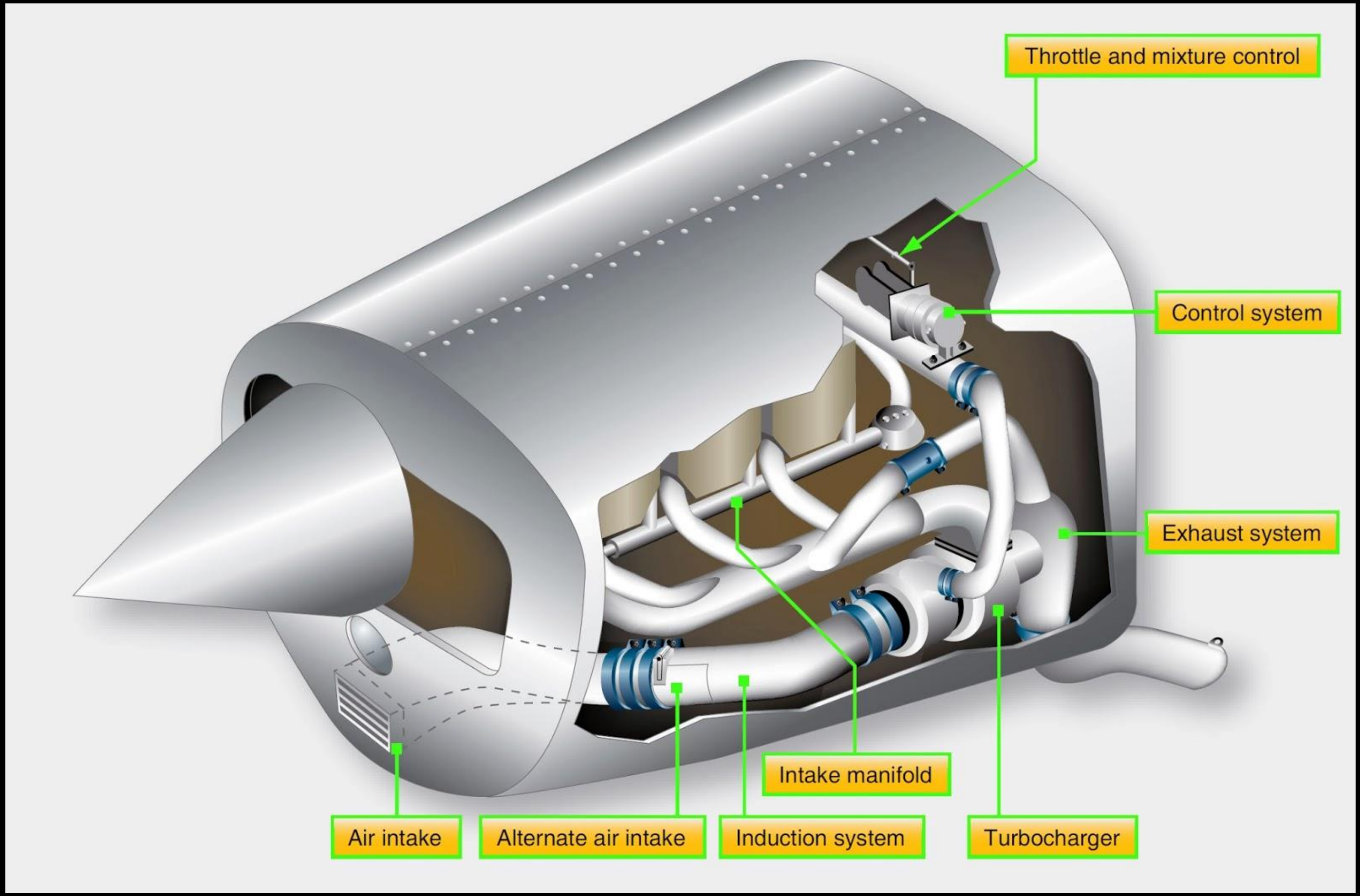


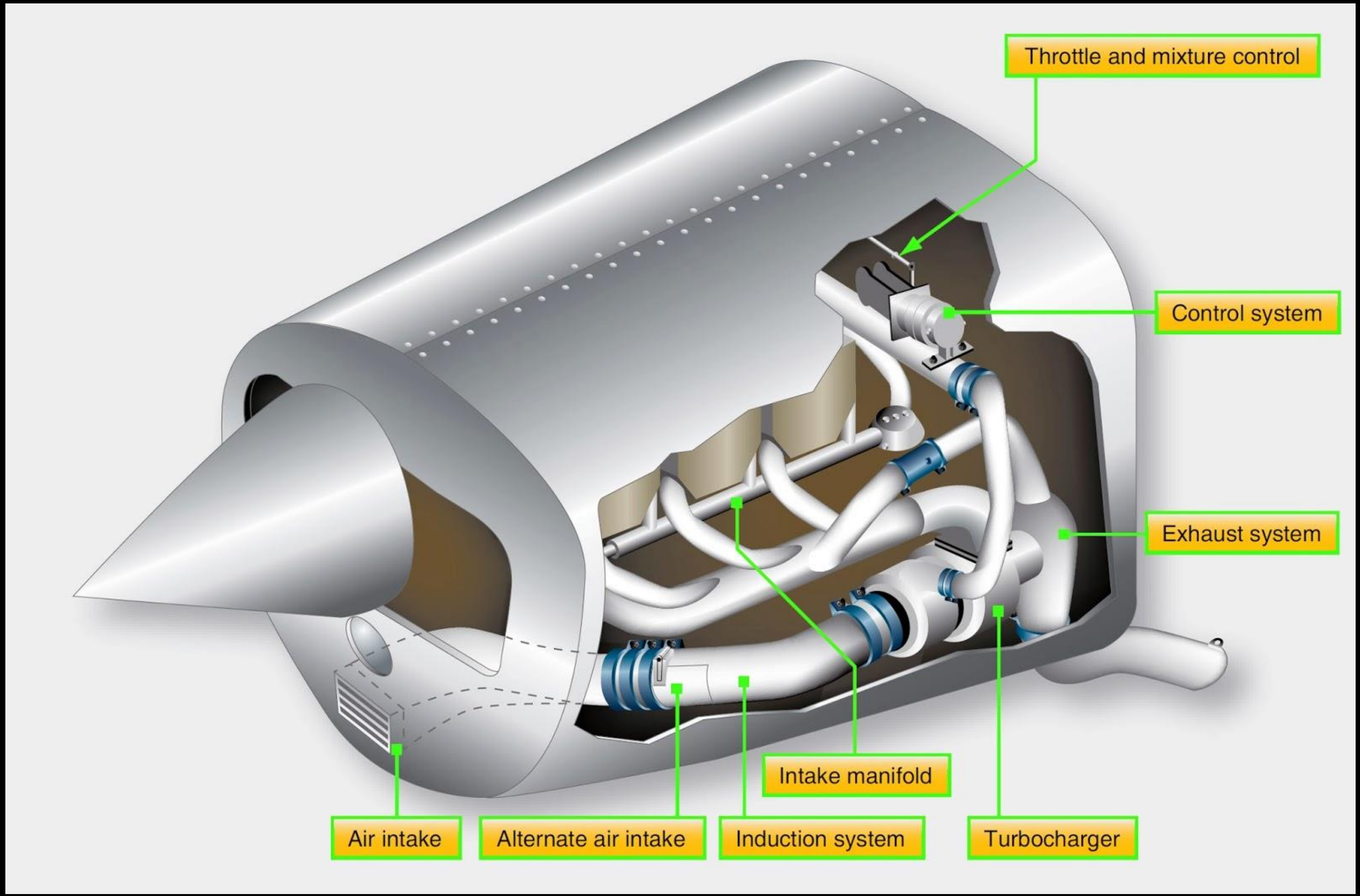
Induction Systems

- Brings in air from the outside, mixes it with fuel, and delivers the fuel-air mixture to the cylinder where combustion occurs
- Outside air enters the induction system through an intake port on the front of the engine cowling
- This port normally contains an air filter that inhibits the entry of dust and other foreign objects



Alternate Air System

- Since the filter may occasionally become clogged, an alternate source of air must be available
- Usually, the alternate air comes from inside the engine cowling, where it bypasses a clogged air filter
- Some alternate air sources function automatically, while others operate manually

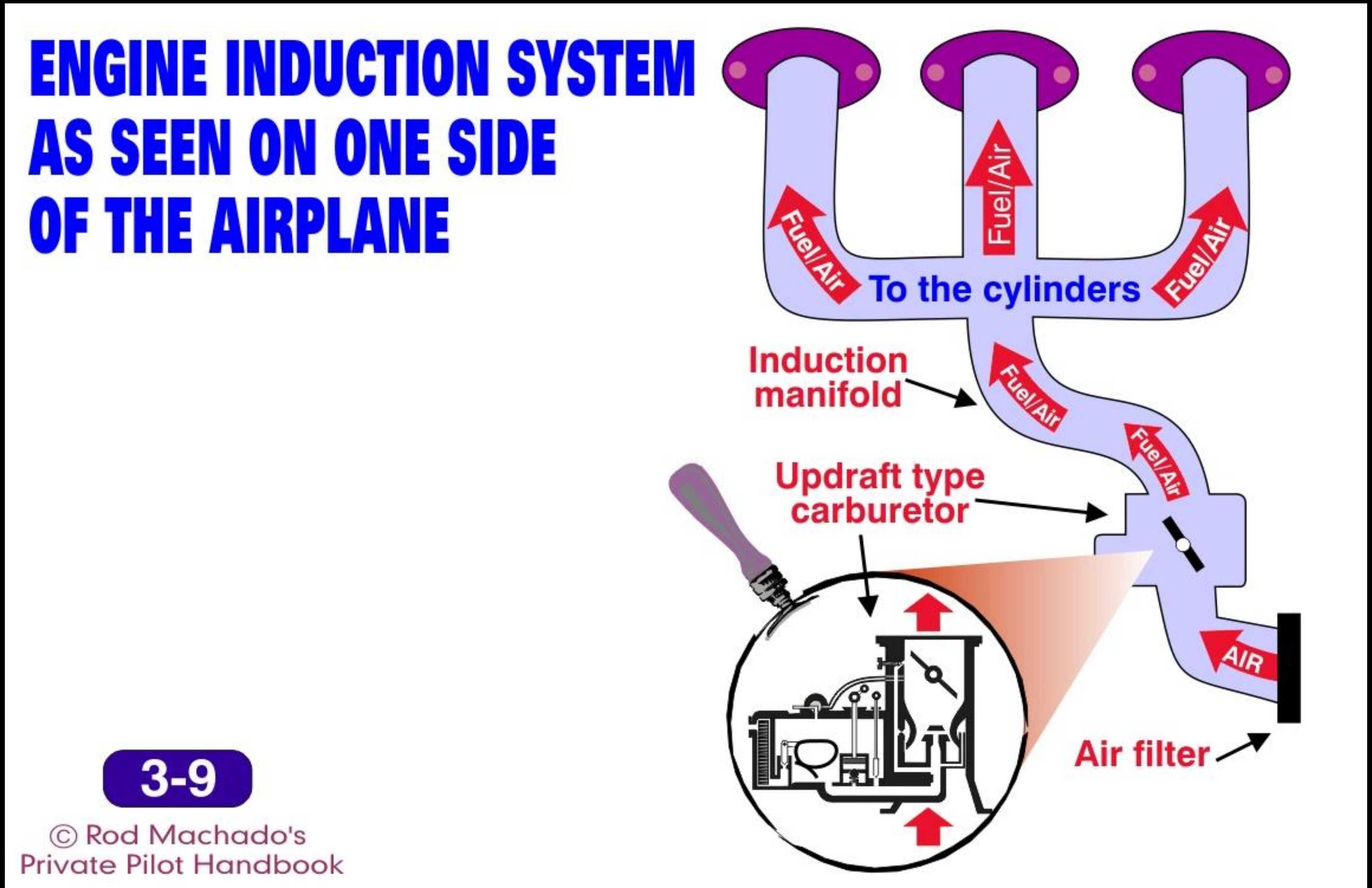


Induction Types

- Two types of induction systems are commonly used in small aircraft engines:
  - 1. The carburetor system mixes the fuel and air in the carburetor before this mixture enters the intake manifold
  - 2. The fuel injection system mixes the fuel and air immediately before entry into each cylinder or injects fuel directly into each cylinder

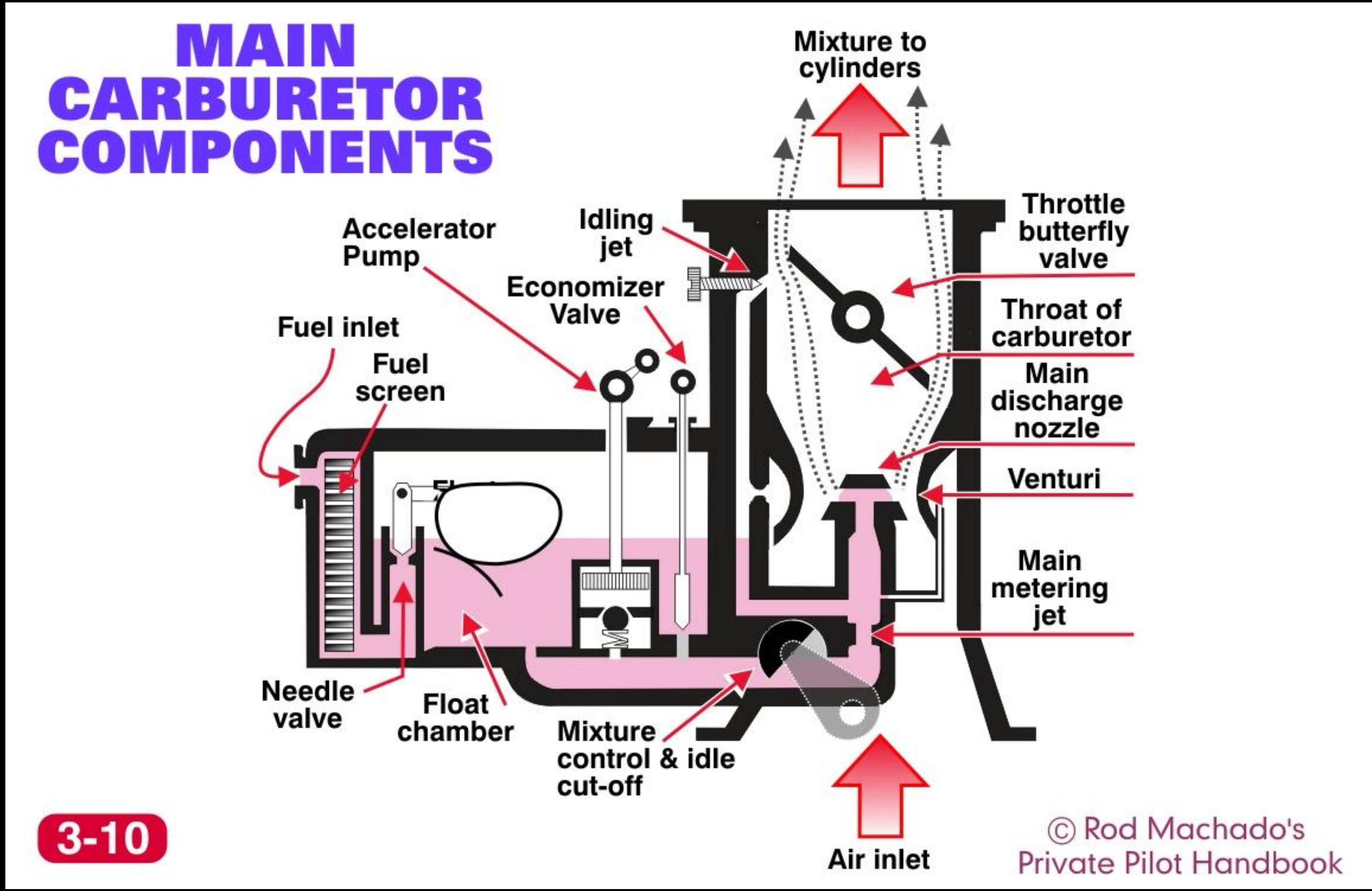
Carburetor Induction System

- The air filter, carburetor and intake manifold (pipes connected to each cylinder) make up the induction system on carburetor-equipped airplanes
- Air flows through the air filter, into the carburetor, then upward into the individual cylinders via the induction manifold



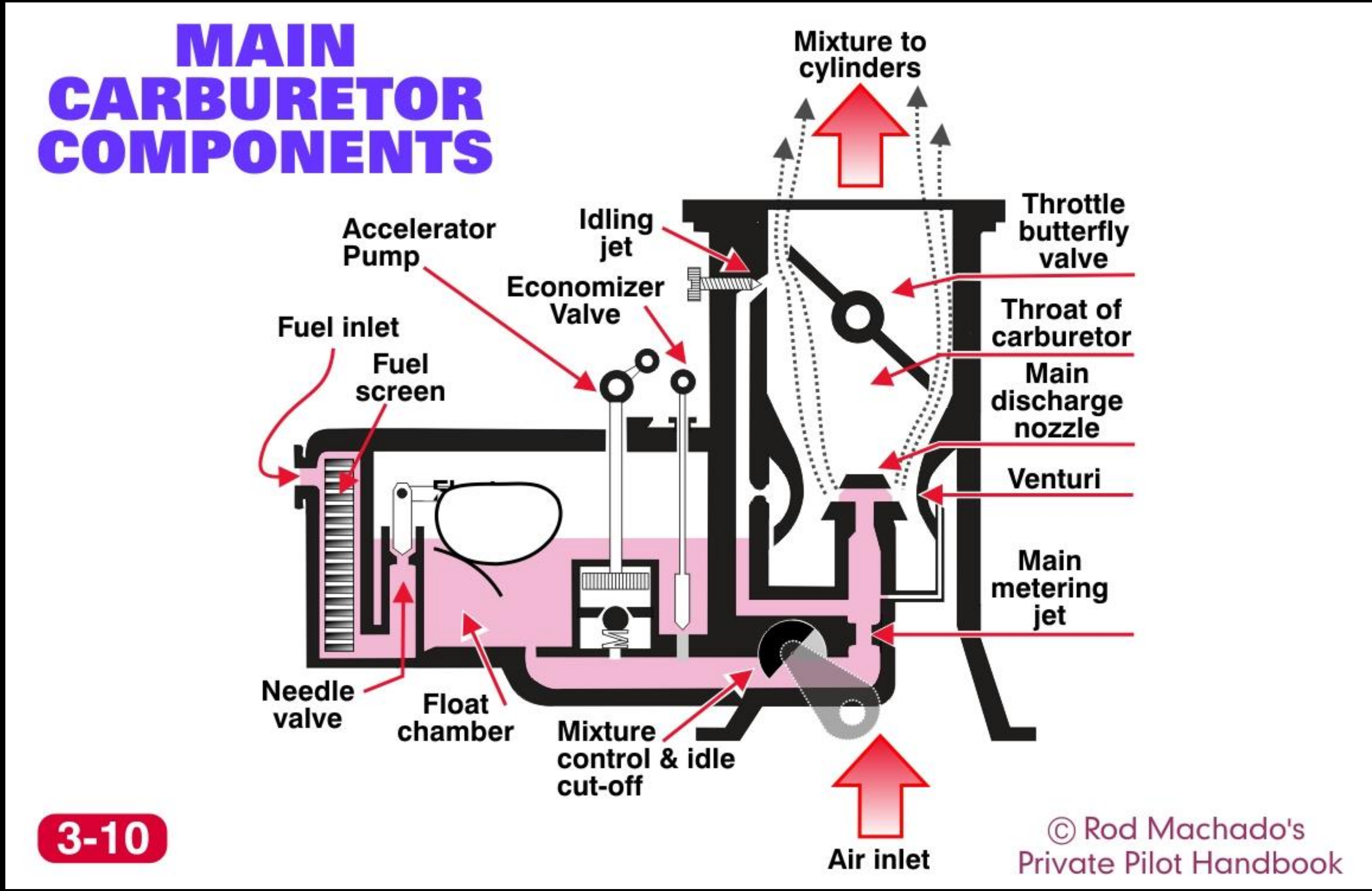
Float-Type Carburetor

- The Carburetor mixes fuel and air in the right proportion for ideal combustion
- If the mixture has too much fuel, or too little air, the engine will not run



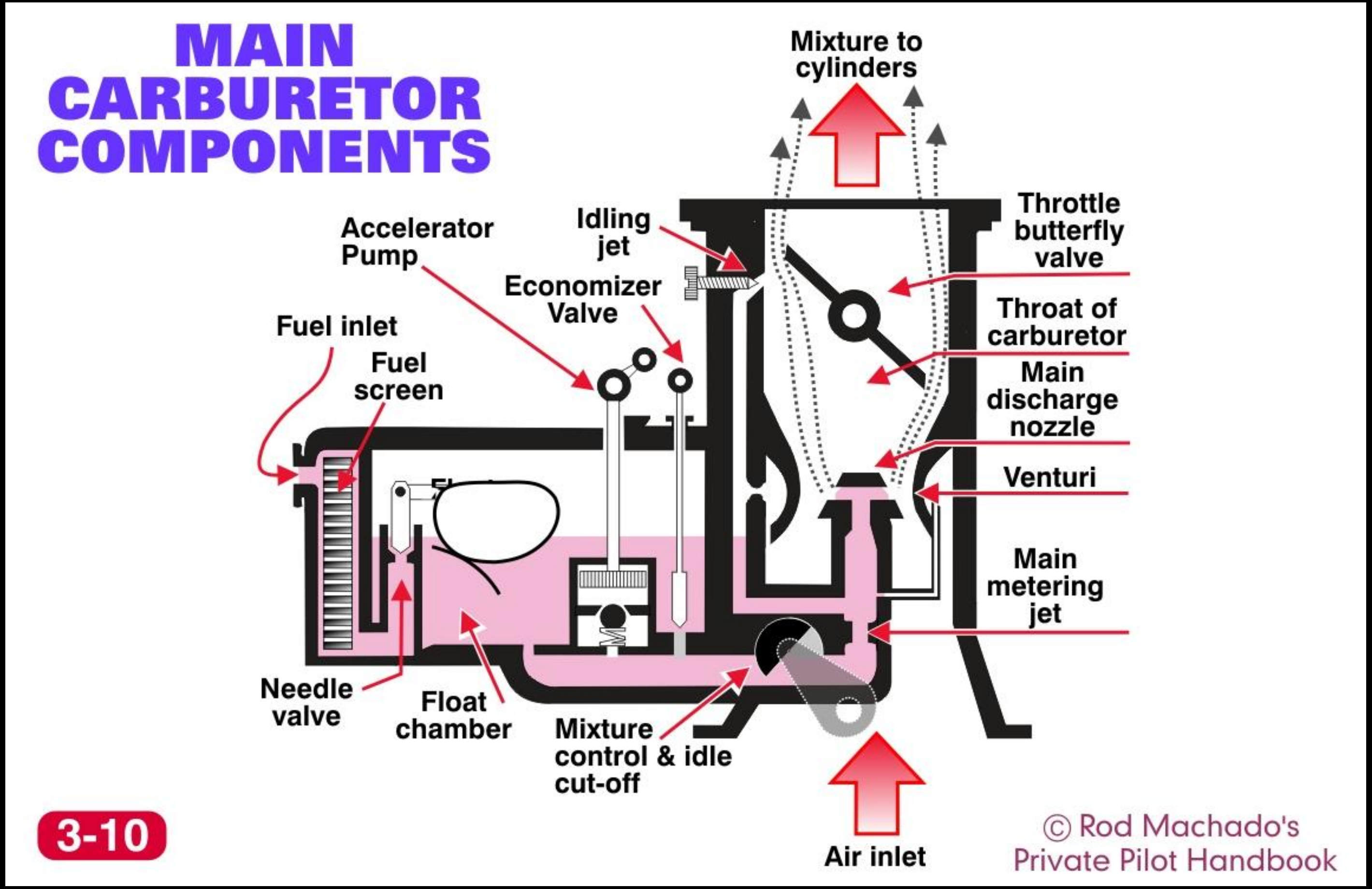
Float-Type Carburetor

- Air is drawn upward into the carburetor's throat by the sucking action of downward-moving pistons and passes through the venturi
- Air velocity increases through the venturi throat and pressure decreases according to Bernoulli's principle
- This reduction in pressure occurs near the outlet of the main discharge nozzle located in the middle of the venturi



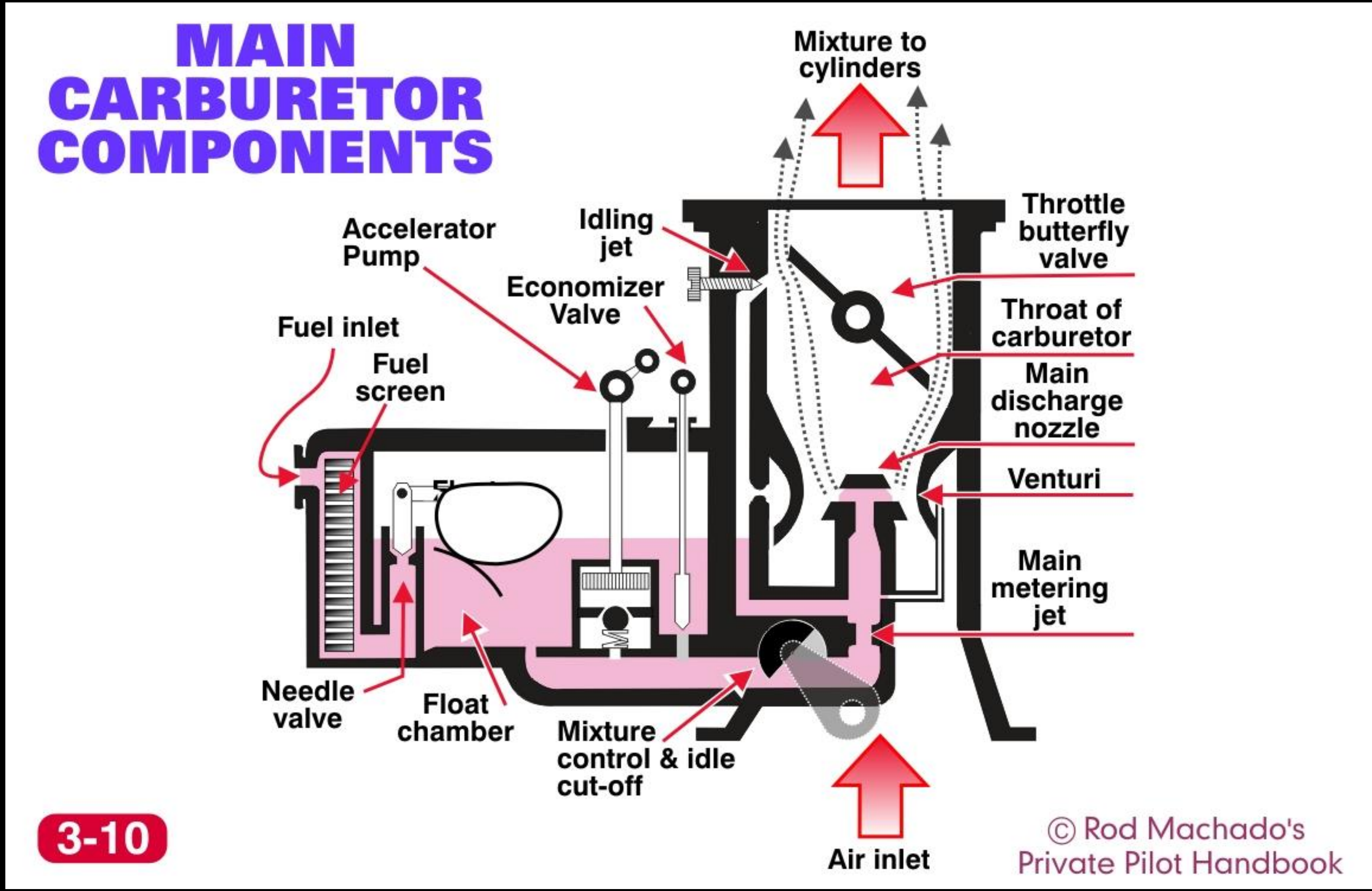
Float-Type Carburetor

- Fuel in the float chamber is under normal atmospheric pressure, while the tip (outlet) of the main discharge nozzle is at lower pressure
- Fuel flows from high pressure to low pressure as it's drawn upward into the carburetor's throat toward the cylinders



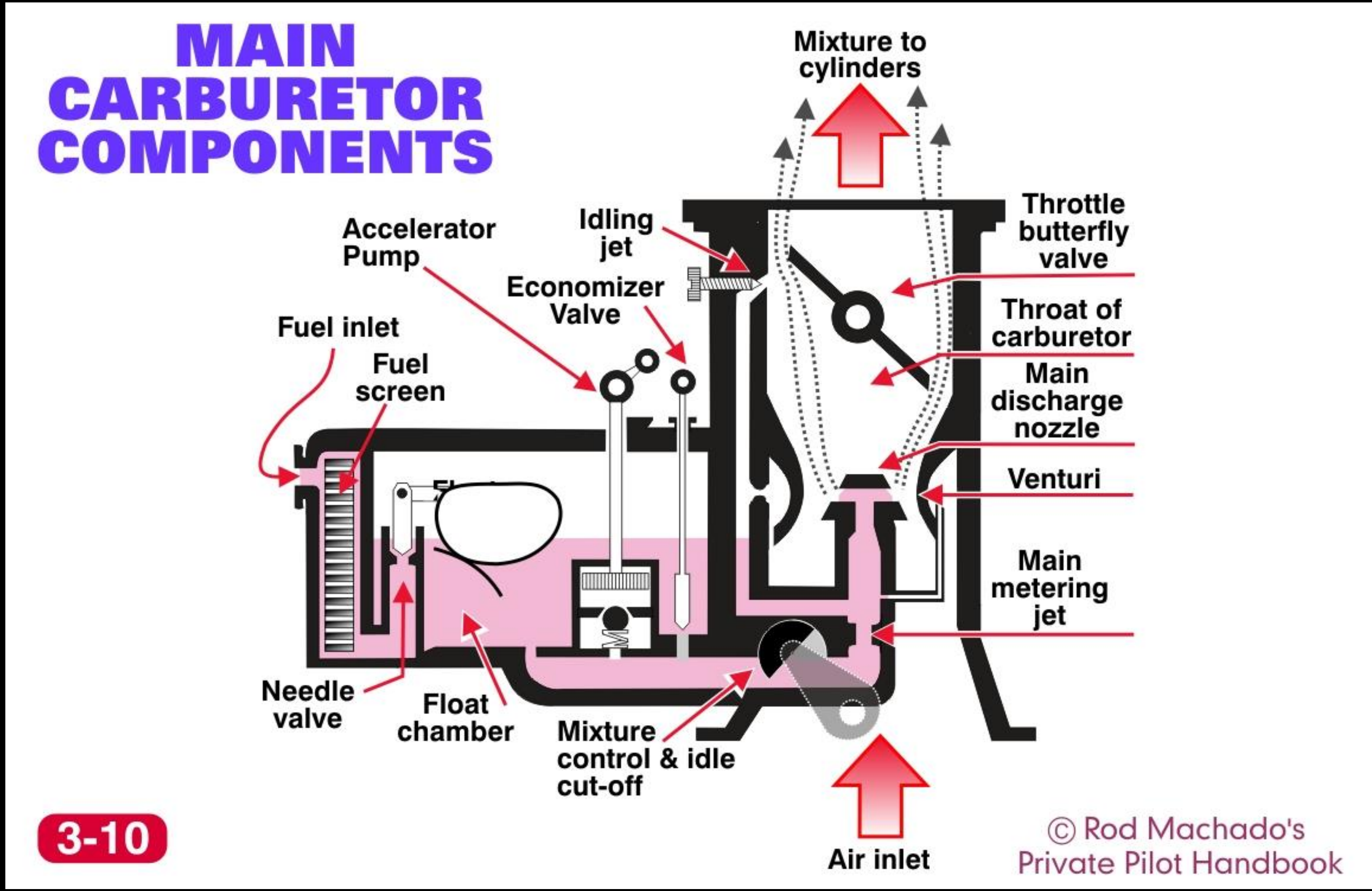
Float-Type Carburetor

- Float rests on fuel within the float chamber
- A needle attached to the float opens and closes an opening at the bottom of the carburetor bowl
- This meters the amount of fuel entering the carburetor, depending upon the position of the float which is controlled by the level of fuel in the float chamber



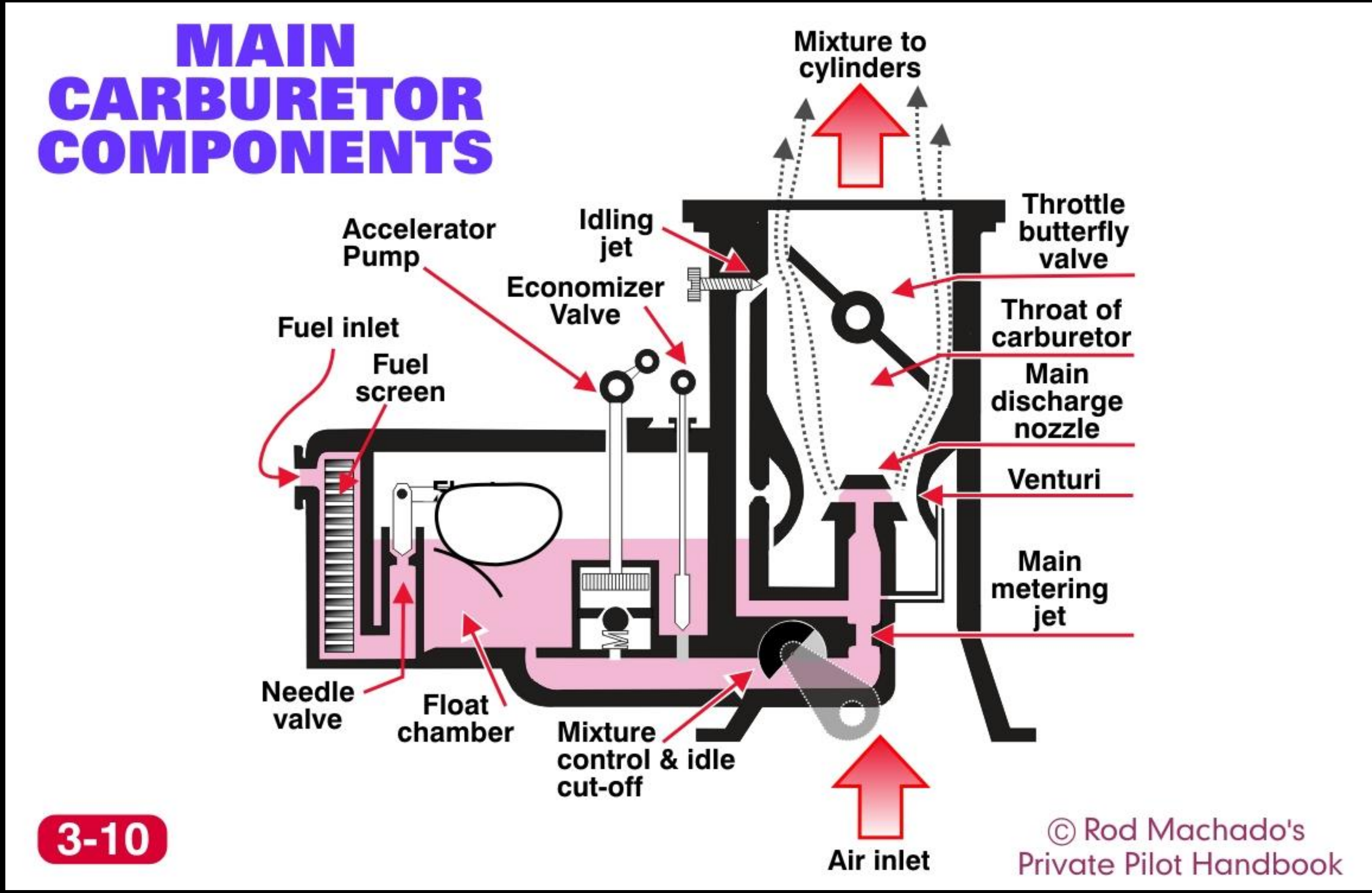
Float-Type Carburetor

- When the level of the fuel forces the float to rise, the needle valve closes the fuel opening and shuts off the fuel flow to the carburetor
- The needle valve opens again when the engine requires additional fuel



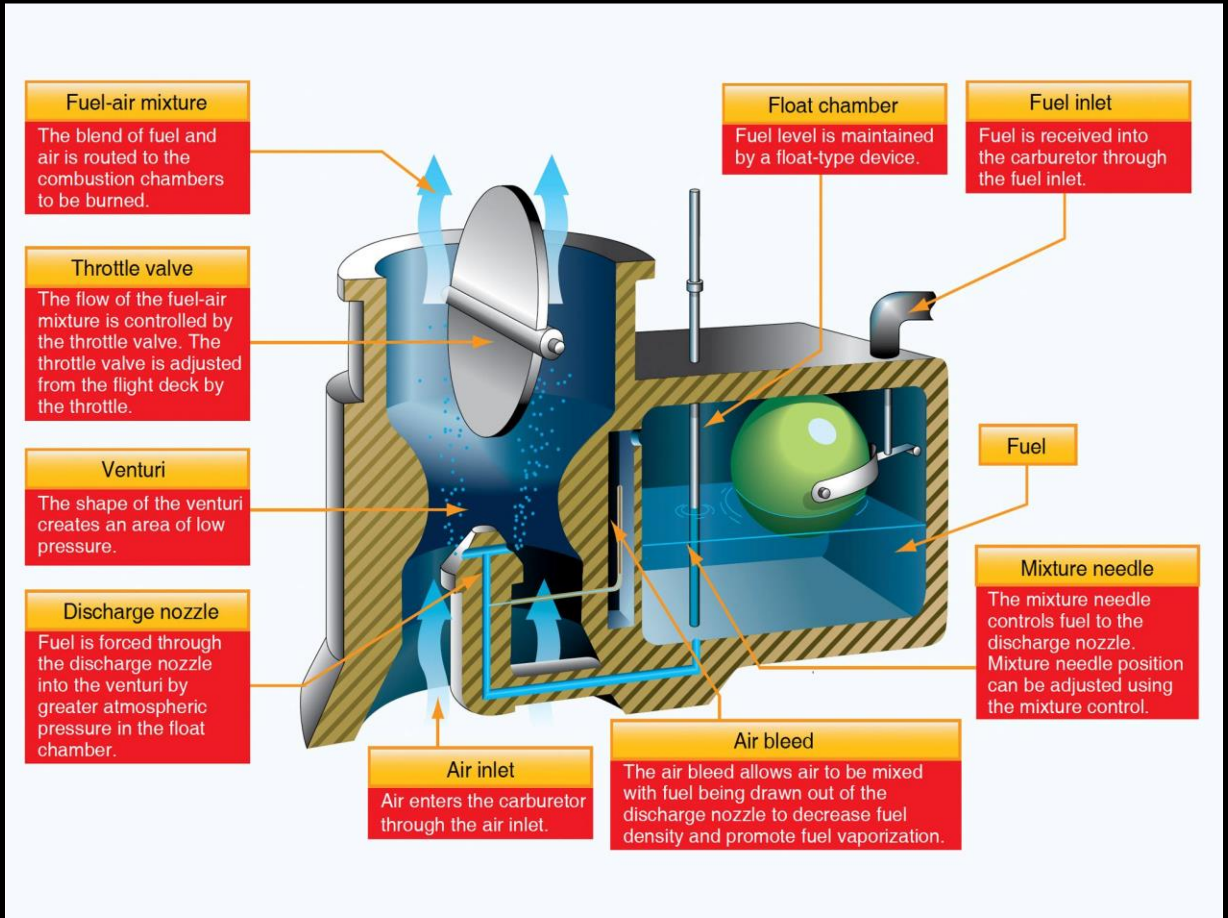
Float-Type Carburetor

- If there were no restriction placed in the carburetor’s throat, the engine would draw in maximum fuel and air and run at full power when started
- The throttle valve restricts airflow in the throat of the carburetor
- The throttle valve is connected directly to the throttle lever located in the cockpit



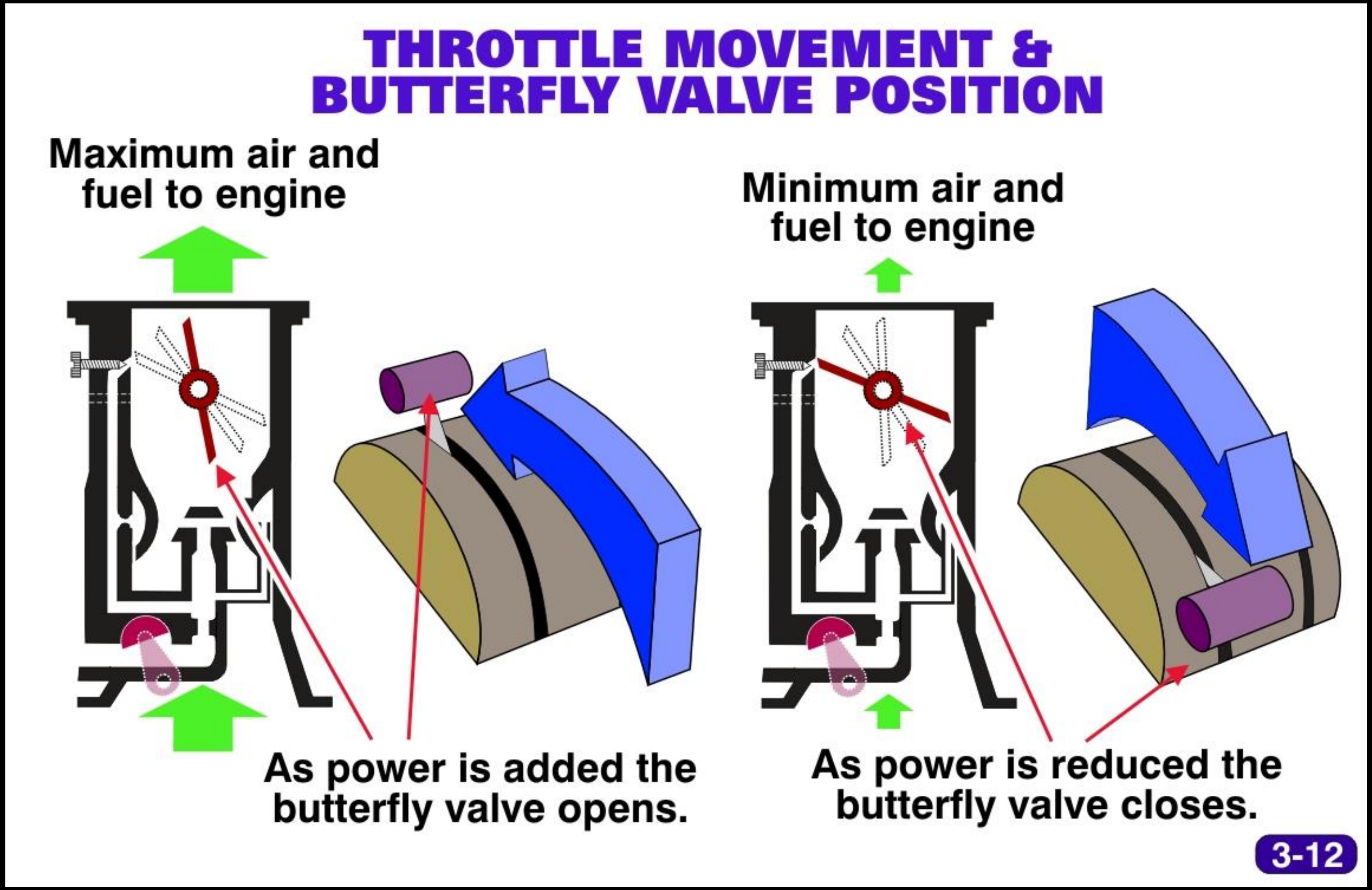
Float-Type Carburetor

- Filtered air flows into the carburetor and through a venturi (narrow throat in the carburetor)
- A low-pressure area is created that forces the fuel to flow through a main fuel jet located at the throat
- Fuel then flows into the airstream where it is mixed with the flowing air
- The fuel-air mixture is then drawn through the intake manifold and into the combustion chambers where it is ignited



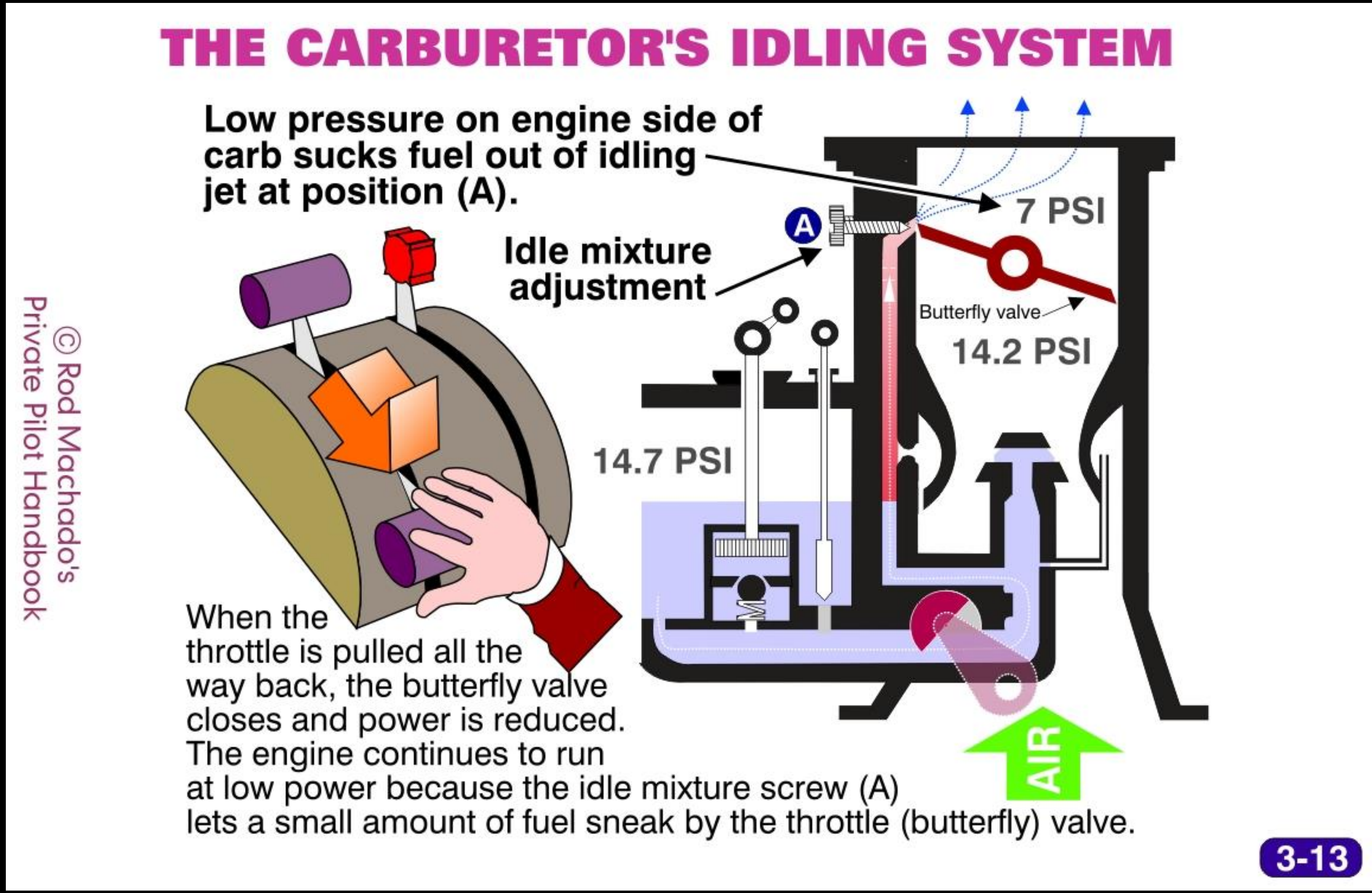
Throttle Valve Flow Regulation

- Moving the throttle forward or aft opens or closes the throttle valve, controlling the amount of air entering the carburetor
- The engine draws in large amounts of fuel and air and runs at full power
- Downward-moving pistons are causing tremendous suction but only a small amount of air and fuel gets past the closed throttle valve
- (just enough to let the engine idle)



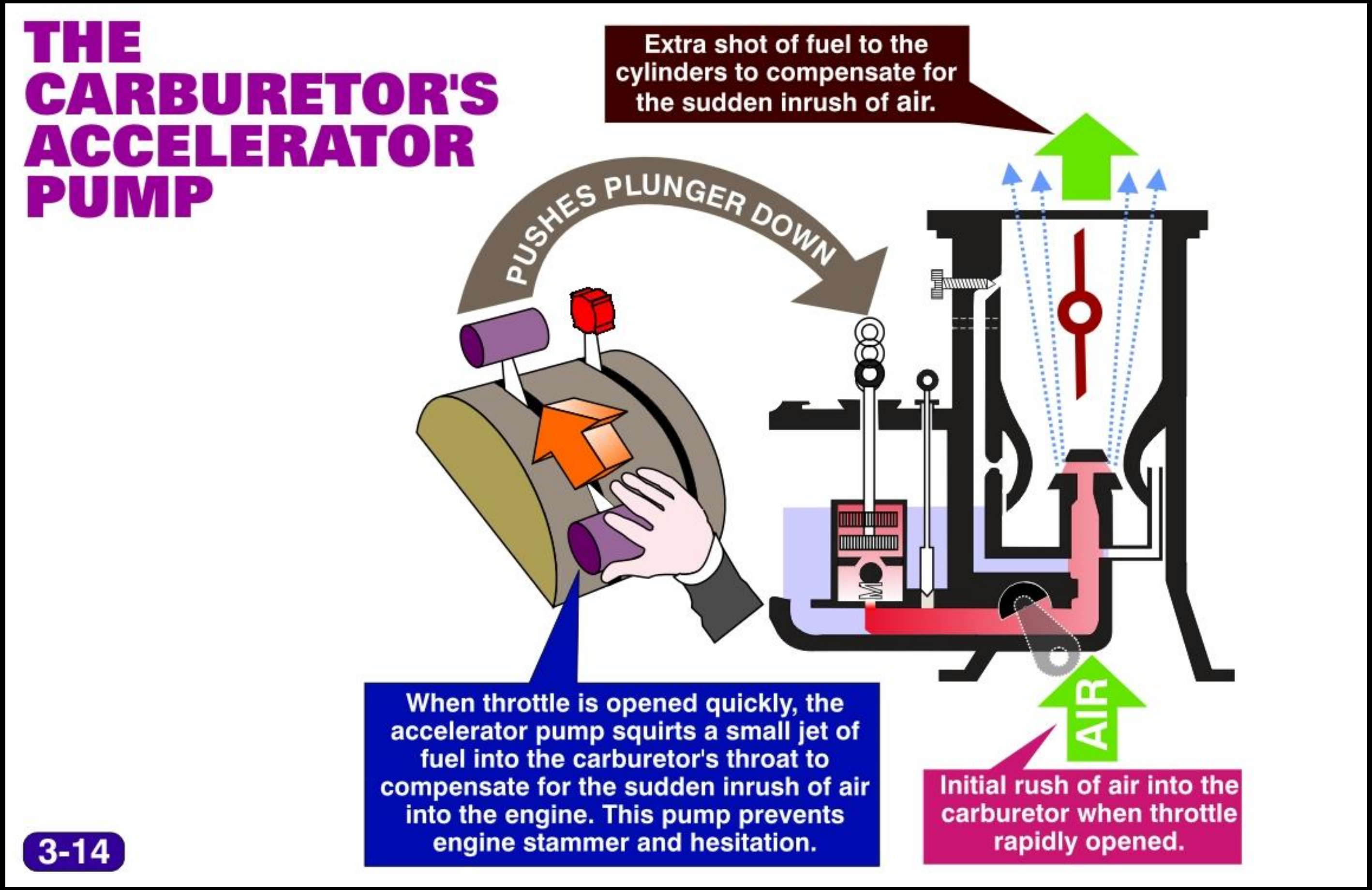
Carburetor Idling System

- The idling jet allows a small amount of fuel and air to flow past the closed throttle valve
- The reduction in pressure downstream of the throttle valve continues to draw a small amount of fuel into the cylinders through the idling jet

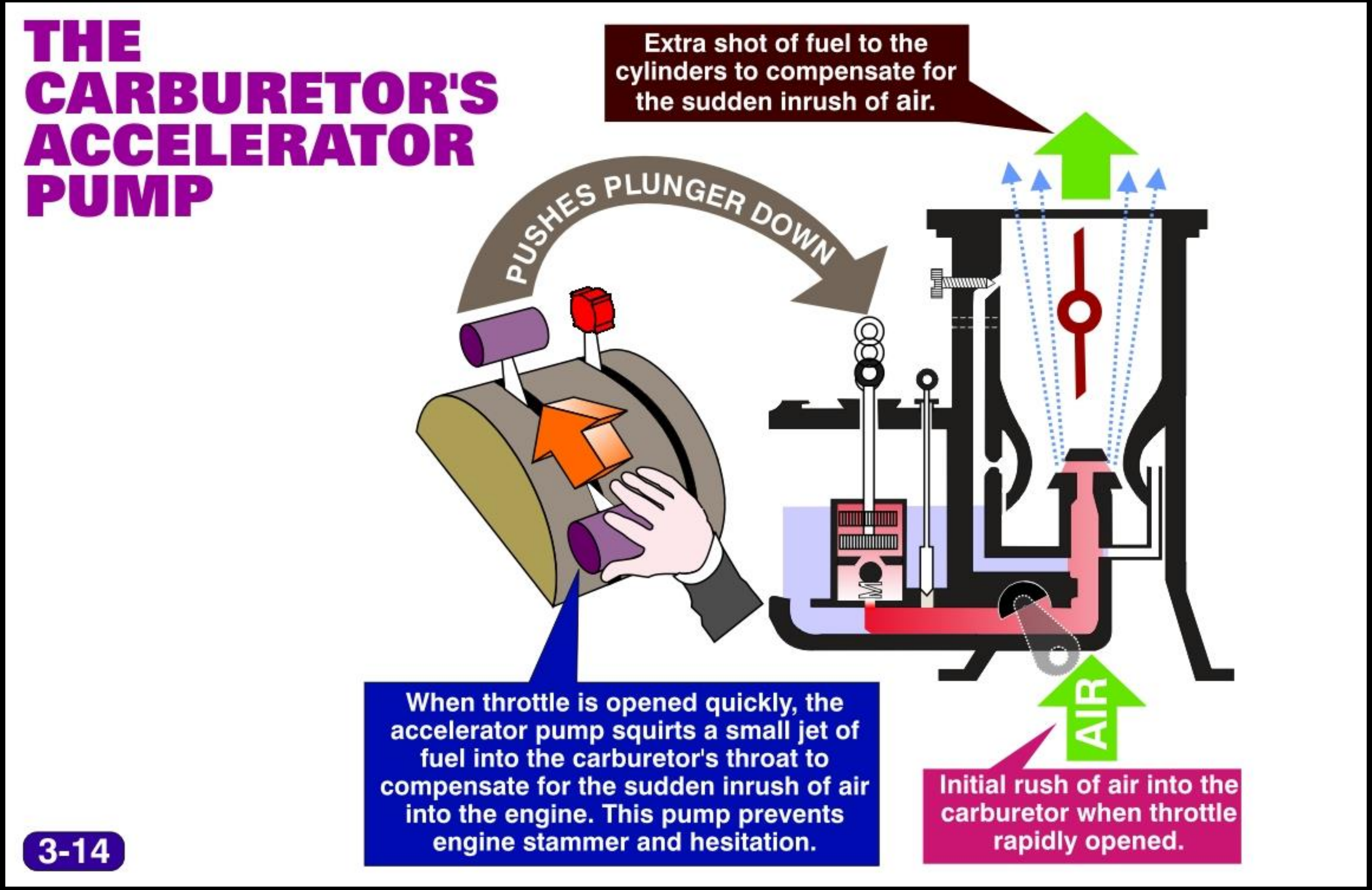


Carburetor Accelerator Pump

- When the throttle is opened quickly, the vacuum created by the pistons could suck too much air for a given amount of fuel
- The initial rush of air over the venturi is so quick that fuel can't be sucked through the nozzle of the metering jet fast enough
- The result would be a sudden hesitation in the development of engine power with rapid throttle application



Carburetor Accelerator Pump



- Pump is a plunger-type mechanism linked to the throttle
- When the throttle is opened quickly, it pushes the plunger downward, forcing an extra shot of fuel from the metering jet into the carburetor’s throat
- This compensates for the sudden in-rush of air that accompanies quick throttle application and provides for a smooth, continuous increase in RPM

Updraft Carburetor

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Updraft Carburetor with Accelerator Pump Caution

- If engine isn't running and the throttle is pumped, the accelerator pump squirts fuel into the carburetor
- Fuel can fall to the bottom of the carburetor, soaking the air filter
- Should the engine backfire during startup, it could cause a fire
- If you insist on priming with the throttle, wait till the starter turns the engine, then pump the throttle
- Any fuel squirted into the carburetor is more likely to be drawn upward into the cylinders

Float-Type Carburetor Disadvantages

- Does not function well during abrupt maneuvers
- Discharge of fuel at low pressure leads to incomplete vaporization
- Main disadvantage is its icing tendency

Atomization of Fuel

- Carburetors break up fuel into millions of tiny, atom-like droplets and mixes them with air
- Makes the fuel-air mixture highly combustible provided the fuel and air are mixed in the proper proportions
- The proportions (or ratios) of fuel to air must fall within certain limits for efficient combustion

Fuel-Air Ratio

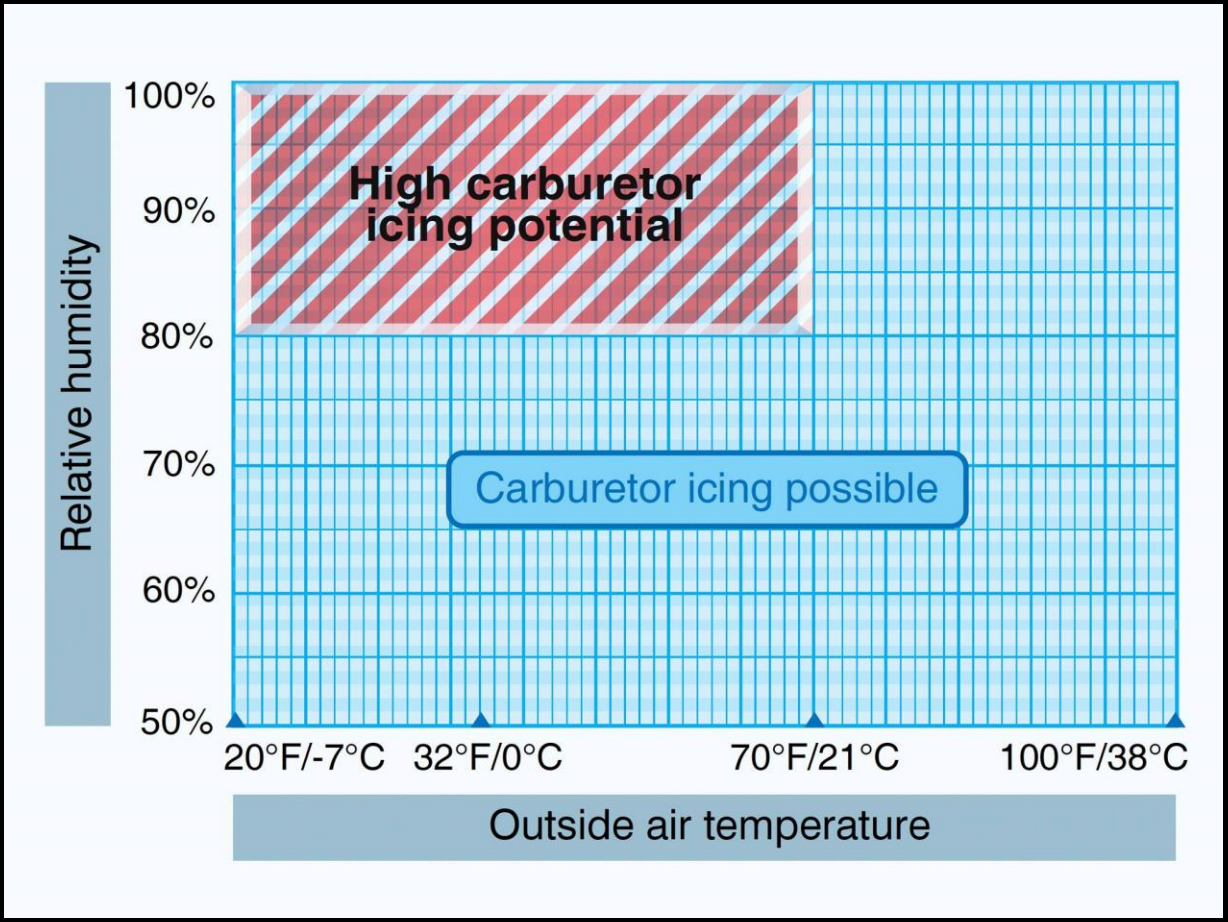
- Fuel-air ratio is the ratio of the weight of fuel to the weight of the air entering the engine
- Fuel-air ratios of approximately 1 part fuel to 13 parts of air are the most efficient for combustion
- This ratio produces a highly powerful mixture within the cylinders
- Too little fuel (1 to 20 fuel-air ratio) means there isn't enough fuel to cause a useful burn in the cylinders
- Too much fuel (1 to 8 fuel-air ratio) means there is not enough air within the cylinders to efficiently burn the fuel that's available

Atomization of Fuel

- Side effect of atomizing fuel and mixing it with air is that temperatures drop downstream of the main discharge nozzle
- Temperature drops of as much as 70°F within the carburetor’s throat are not uncommon
- Because of the considerable drop in temperature any moisture present in the air will freeze

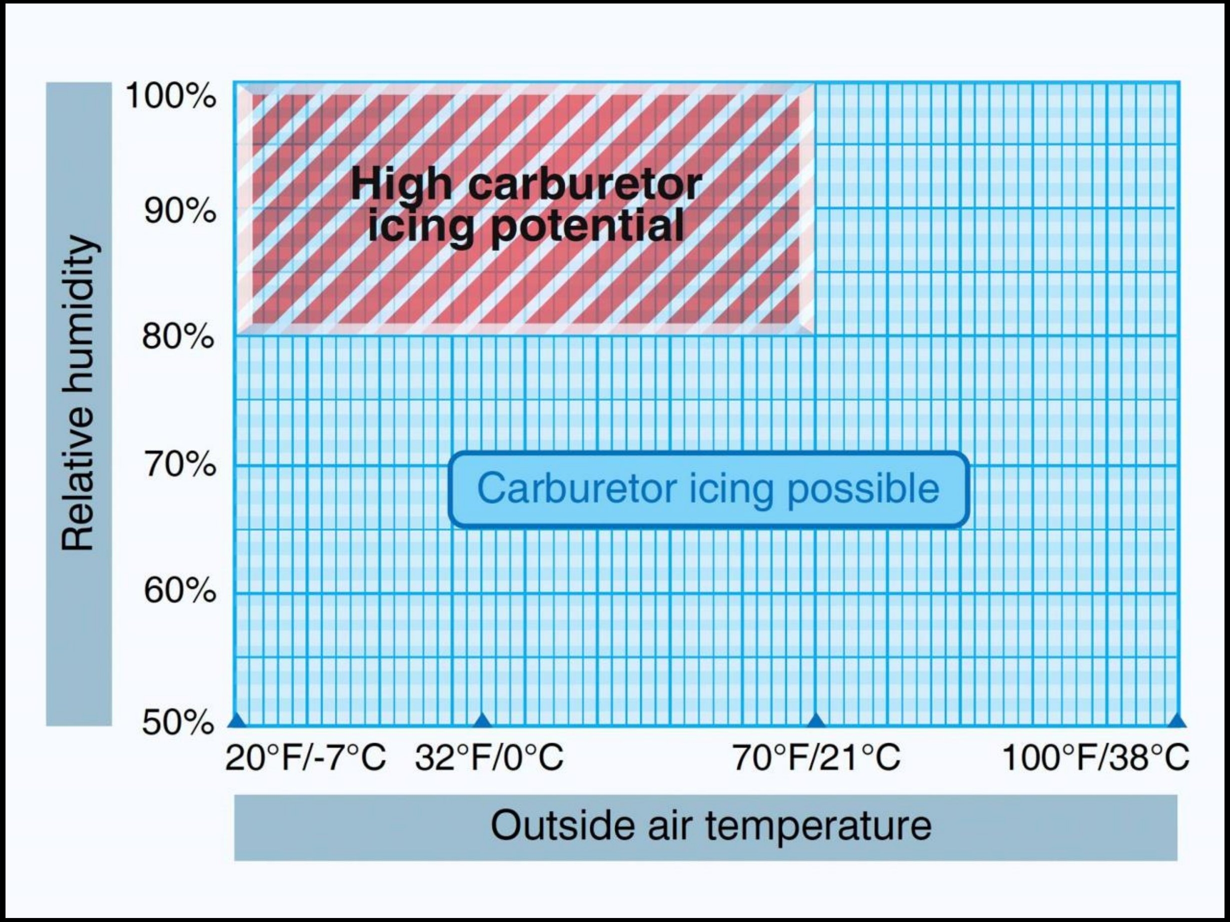
Carburetor Ice Potential

- Most likely to occur when temperatures are below 70°F (21°C) and the relative humidity is above 80%
- Due to sudden cooling that takes place in the carburetor, icing can occur even in OATs as high as 100°F (38°C) and humidity as low as 50%



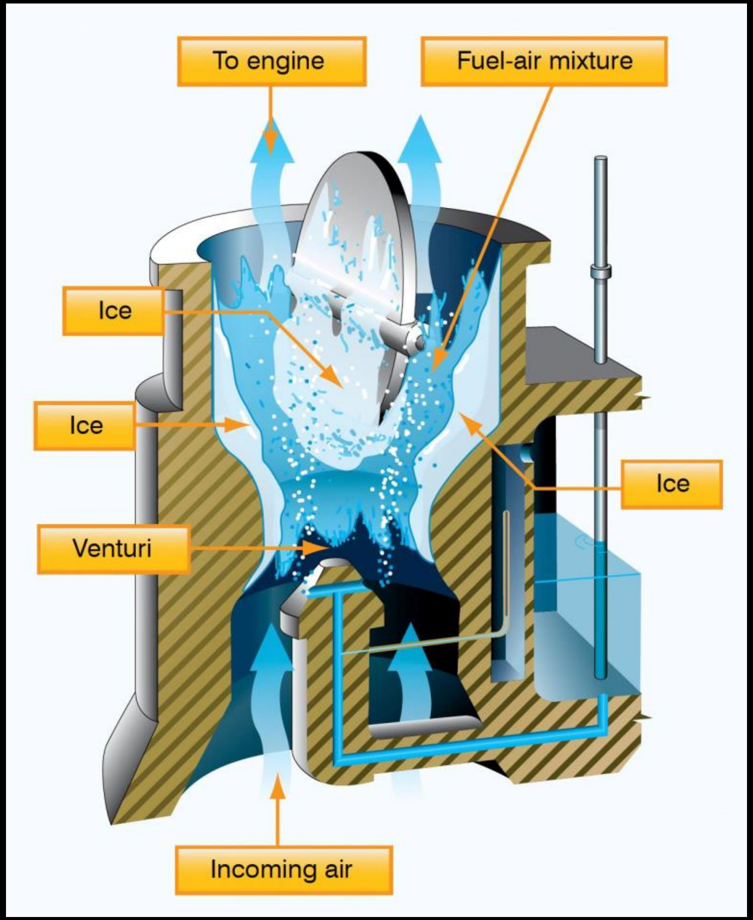
Carburetor Ice Potential

- This temperature drop can be as much as 60 to 70 absolute Fahrenheit degrees
- An OAT of 100°F (38°C), a temperature drop of an absolute 70°F (39°C) results in an air temperature in the carburetor of 30°F (-1°C)



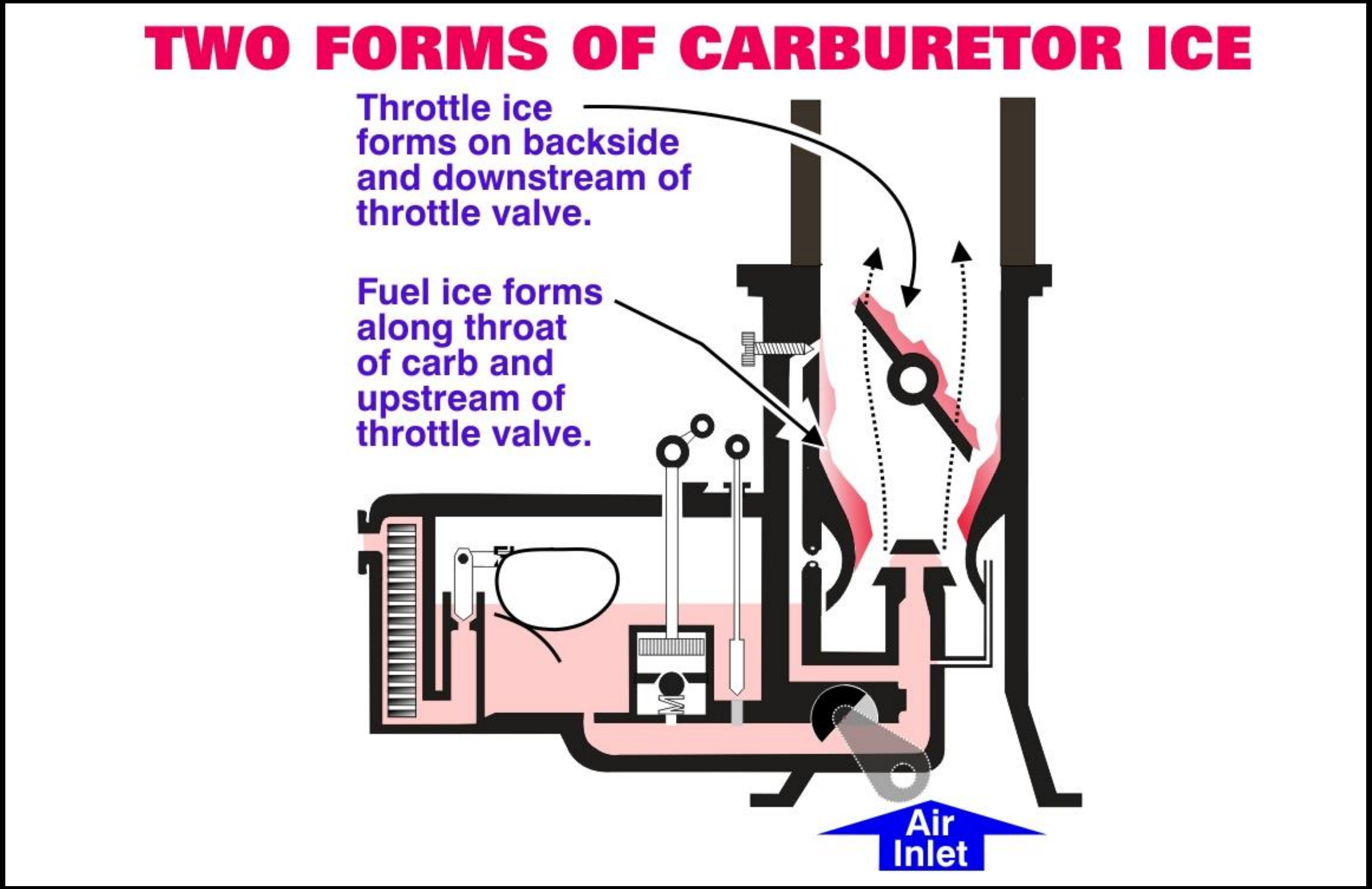
Carburetor Icing

- Carburetor discharges fuel at a point of low pressure
- The discharge nozzle is located at the venturi throat, and the throttle valve is on the engine side of the discharge nozzle
- The drop in temperature due to fuel vaporization takes place within the venturi
- As a result, ice readily forms in the venturi and on the throttle valve



Carburetor Icing

- The reduced air pressure, as well as the vaporization of fuel causes a temperature decrease in the carburetor
- If water vapor in the air condenses when the carburetor temperature is at or below freezing, ice may form on the throttle valve and in the venturi throat
- This restricts the flow of the fuel-air mixture and reduces power
- If enough ice builds up the engine may quit



Carburetor Icing Indications

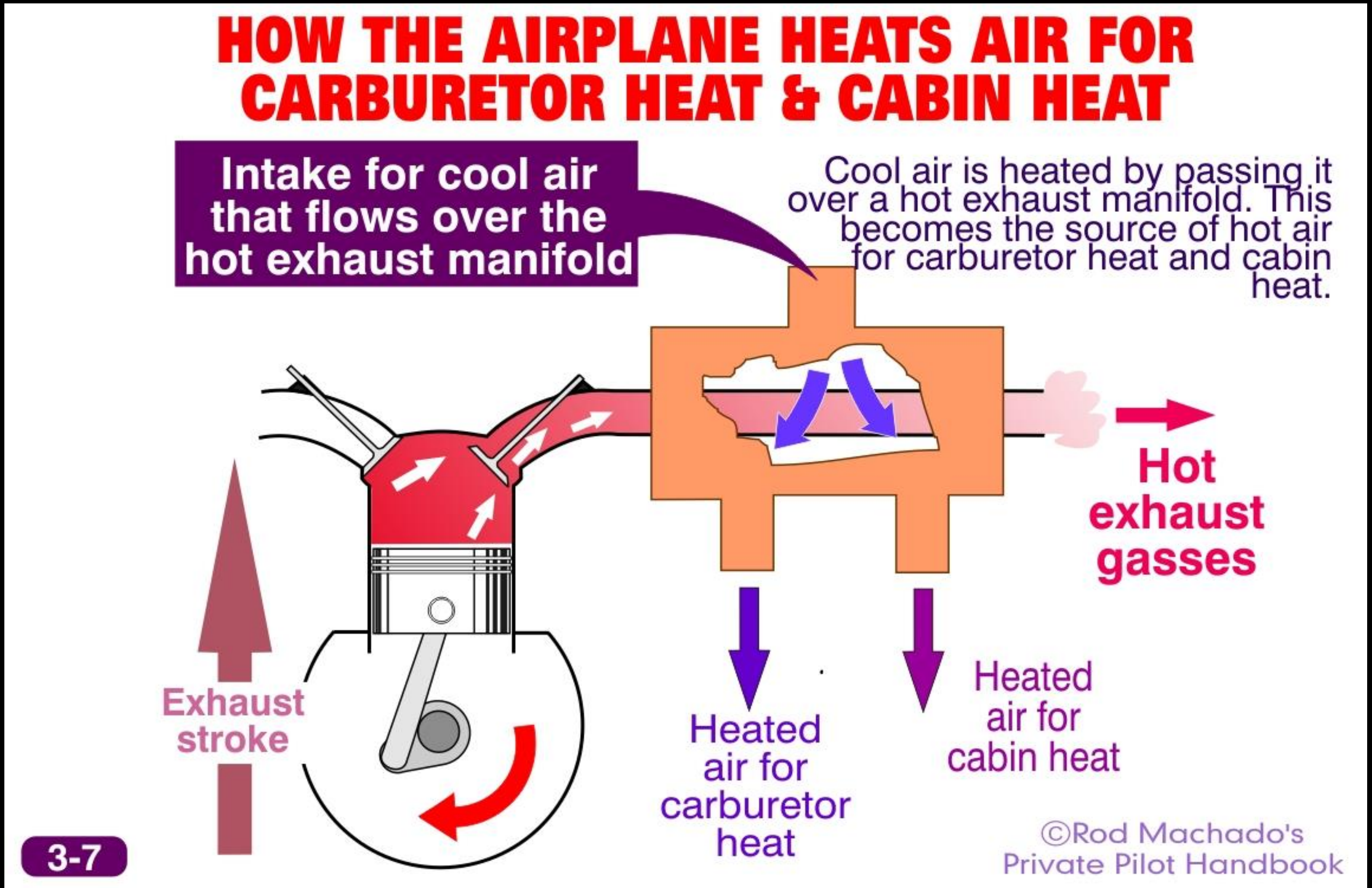
- The first indication of carburetor icing in an aircraft with a fixed-pitch propeller is a decrease in engine rpm, which may be followed by engine roughness
- Although carburetor ice can occur during any phase of flight, it is particularly dangerous when using reduced power during a descent
- Under certain conditions, carburetor ice could build unnoticed until power is added

Carburetor Icing Indications

- In an aircraft with a constant-speed propeller, carburetor icing is usually indicated by a decrease in manifold pressure, but no reduction in rpm
- Propeller pitch is automatically adjusted to compensate for loss of power, so a constant rpm is maintained

Carburetor Heat

- To combat the effects of carburetor ice, engines with float-type carburetors employ a carburetor heat system
- Heated air is obtained for the carburetor by passing air over the exhaust manifold, then piping it directly into the carburetor
- Raises the air temperature within its throat as much as 90°F



Carburetor Heat

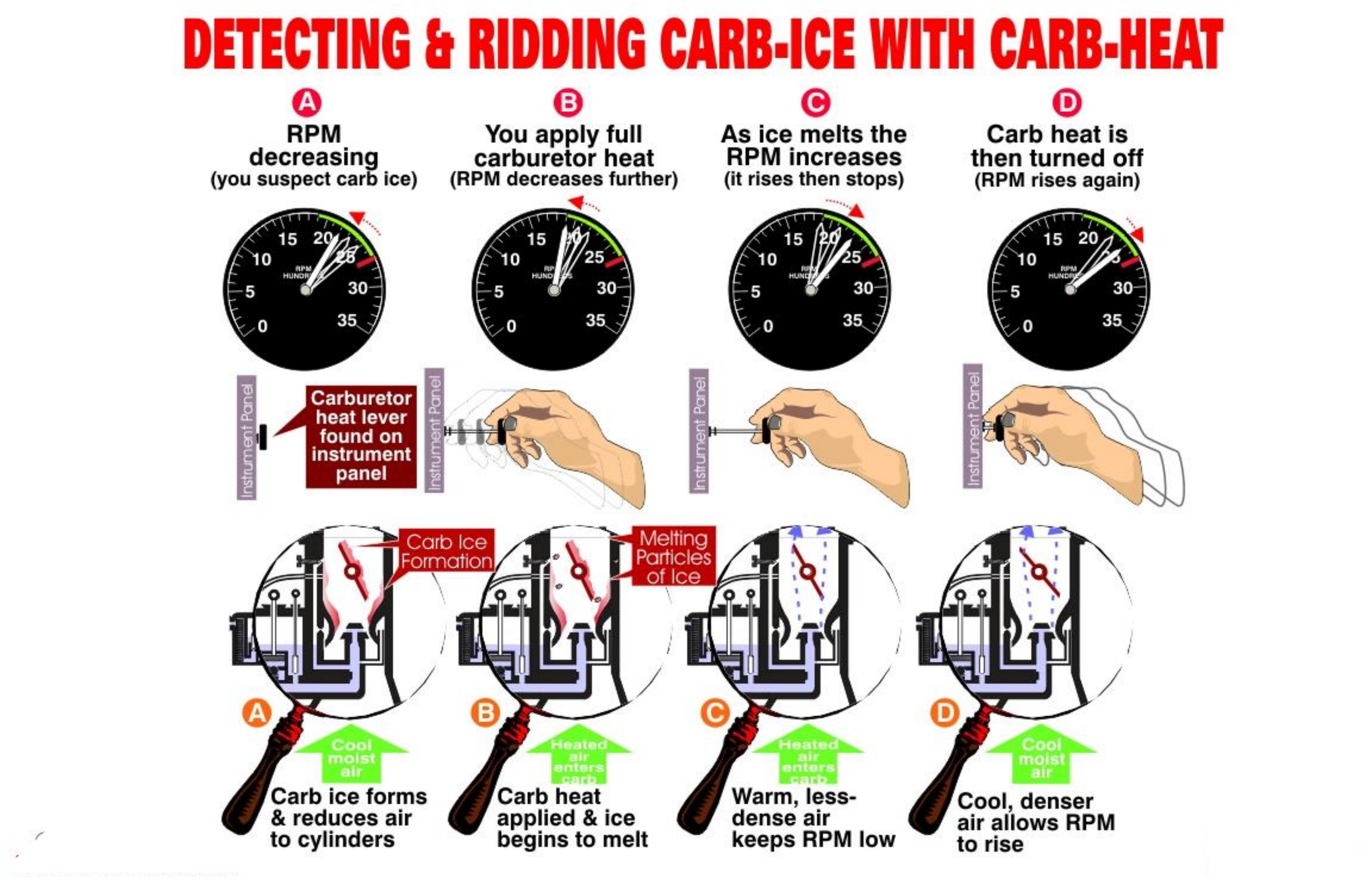
- An anti-icing system that preheats the air before it reaches the carburetor to keep the fuel-air mixture above freezing to prevent carburetor ice
- Can be used to melt ice that has already formed in the carburetor if the accumulation is not too great, but using carburetor heat as a preventative measure is the better option

Carburetor Heat

- Additionally, carburetor heat may be used as an alternate air source if the intake filter clogs, such as in sudden or unexpected airframe icing conditions
- The carburetor heat should be checked during the engine runup
- When using carburetor heat follow the manufacturer’s recommendations

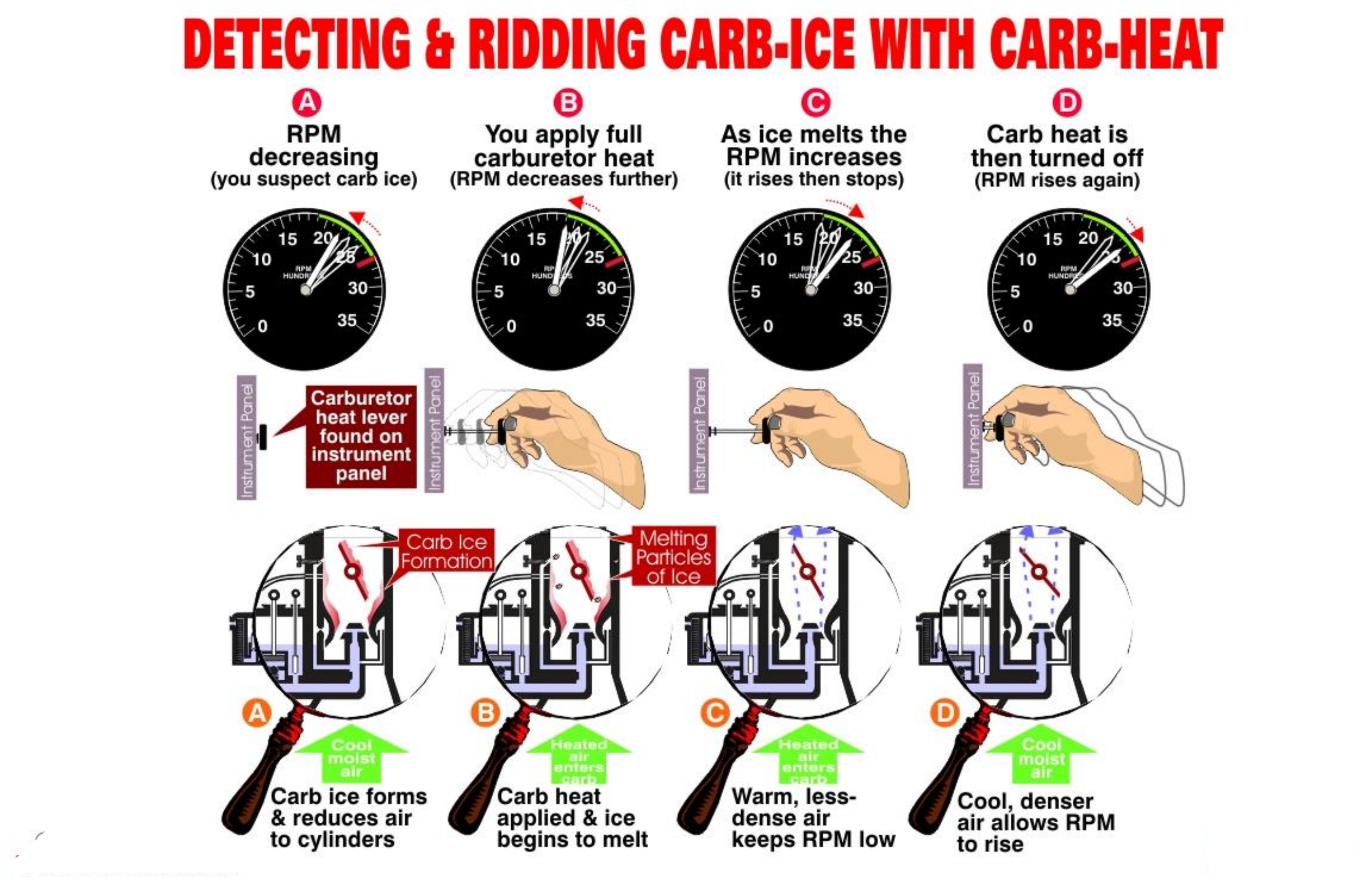
Carb Ice Detection & Removal

- When conditions are conducive to carburetor icing, periodic checks should be made to detect its presence
- If detected, full carburetor heat should be applied immediately, and left in the ON position until all the ice has been removed



Carb Ice Detection & Removal

- If ice is present, applying partial heat or leaving heat on for an insufficient time might aggravate the situation
- In extreme cases of carburetor icing, even after the ice has been removed, full carburetor heat should be used to prevent further ice formation



Carb Ice With Fixed-Pitch Propeller

- When ice is present in an aircraft with a fixed-pitch propeller and carburetor heat is being used, there is a decrease in rpm, followed by a gradual increase in rpm as the ice melts
- The engine should run more smoothly after the ice has been removed
- If ice is not present, the rpm decreases and then remains constant

Carb Ice Prevention

- Whenever the throttle is closed during flight the engine cools rapidly and vaporization of the fuel is less complete
- In this condition the engine is more susceptible to carburetor icing
- If carburetor icing conditions are suspected and closed-throttle operation anticipated, adjust carburetor heat to the full-ON position before closing the throttle and leave it on during the closed-throttle operation
- The heat aids in vaporizing the fuel and helps prevent the formation of carburetor ice
- Periodically, open the throttle smoothly for a few seconds to keep the engine warm, otherwise, the carburetor heater may not provide enough heat to prevent icing

Carb Ice - Pilot Actions

- It is imperative to recognize carburetor ice when it forms during flight to prevent a loss in power, altitude, and/or airspeed
- These symptoms may sometimes be accompanied by vibration or engine roughness

Carb Ice - Pilot Actions

- Once a power loss is noticed, immediate action should be taken to eliminate ice already formed in the carburetor and to prevent further ice formation
- This is accomplished by applying full carburetor heat, which will further reduce power and may cause engine roughness as melted ice goes through the engine
- These symptoms may last from 30 seconds to several minutes depending on the severity of the icing
- Carburetor heat must remain in the full-hot position until normal power returns

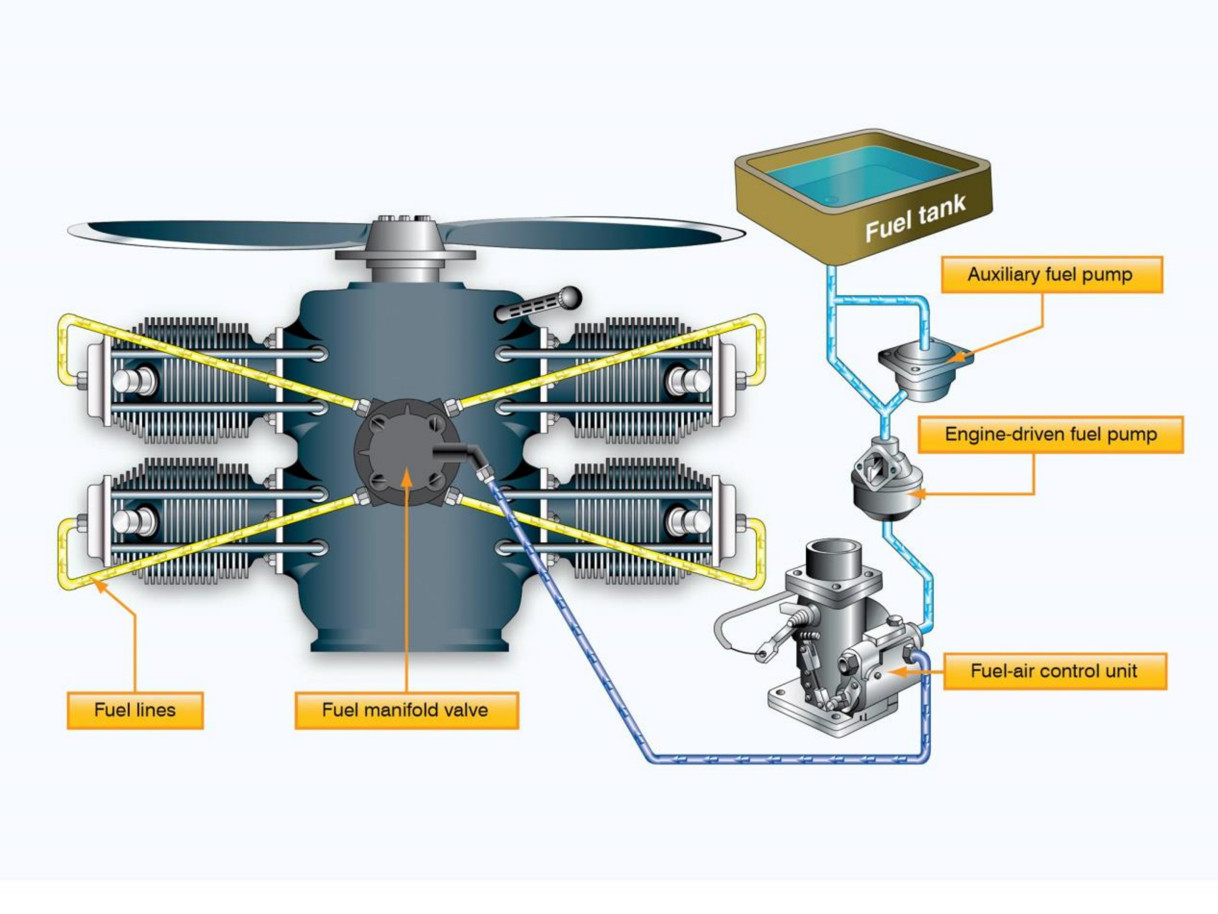
Carb Heat Performance Penalties

- Use of carburetor heat causes a decrease in engine power, sometimes up to 15 percent, because the heated air is less dense than the outside air entering the engine
- This enriches the mixture
- Carburetor heat reduces the power output of the engine and increases the operating temperature
- Should not be used when full power is required (as during takeoff or go-around) or during normal engine operation, except to check for the presence of, or to remove, carburetor ice

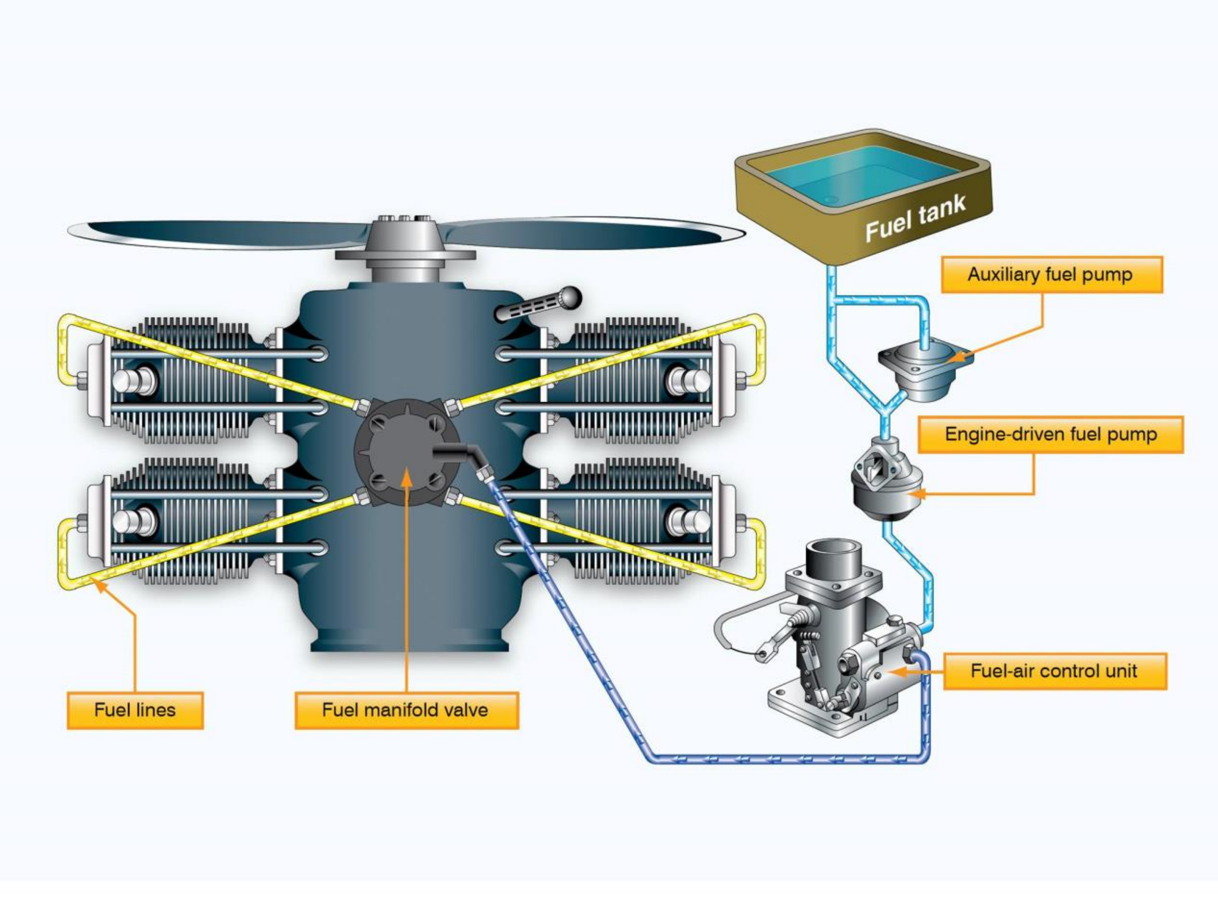
Fuel Injection Systems

- In a fuel injection system, the fuel is injected directly into the cylinders, or just ahead of the intake valve
- A fuel injection system usually incorporates six basic components:

  Engine-driven fuel pump
  Fuel-air control unit
  Fuel manifold (fuel distributor)
  Discharge nozzles
  Auxiliary fuel pump
  Fuel pressure/flow indicators



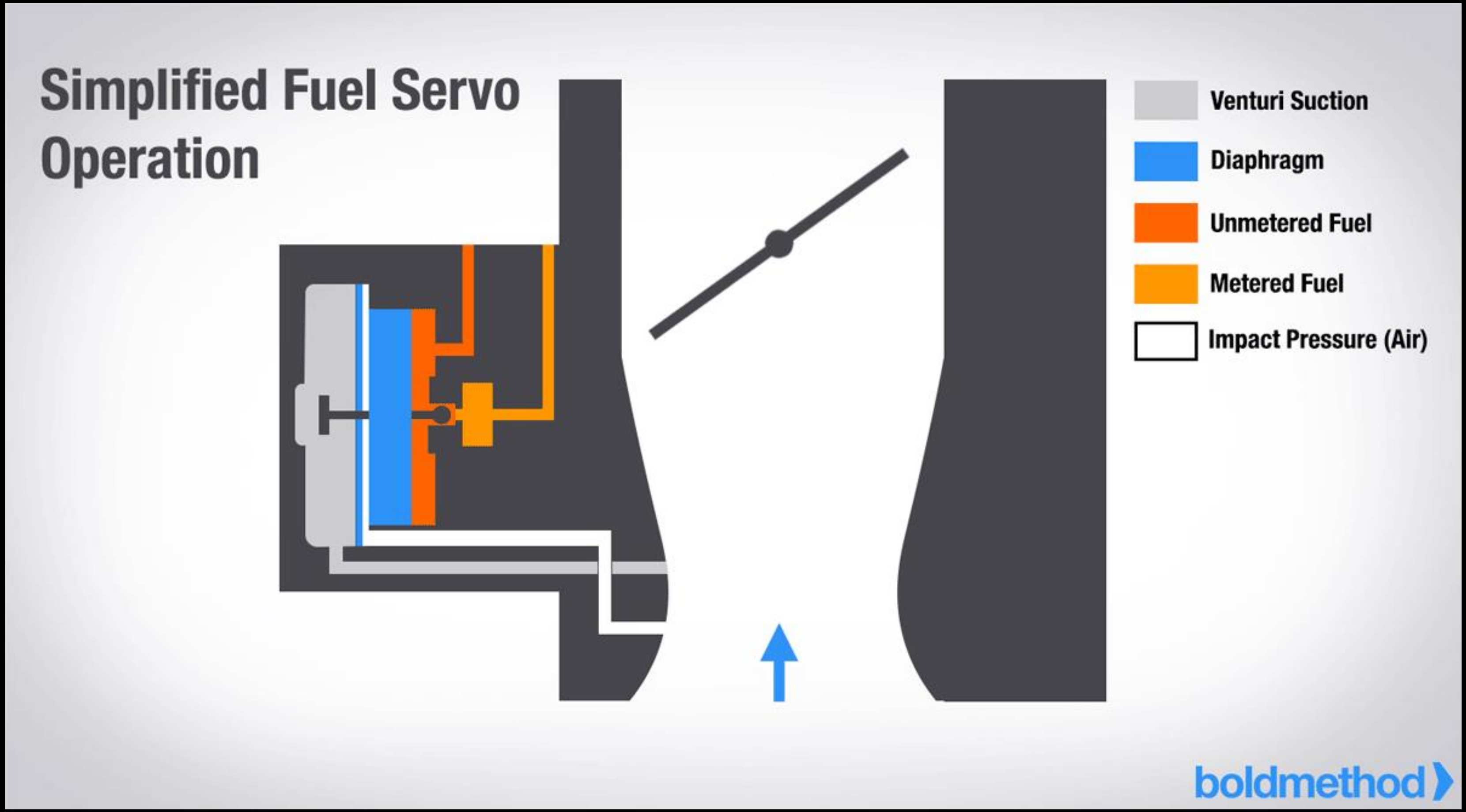
Fuel Injection Systems



- Auxiliary fuel pump provides fuel under pressure to the fuel-air control unit for engine starting and/or emergency use
- After starting, the engine-driven fuel pump provides fuel under pressure from the fuel tank to the fuel-air control unit
- This control unit, which essentially replaces the carburetor, meters fuel based on the mixture control setting and sends it to the fuel manifold valve at a rate controlled by the throttle

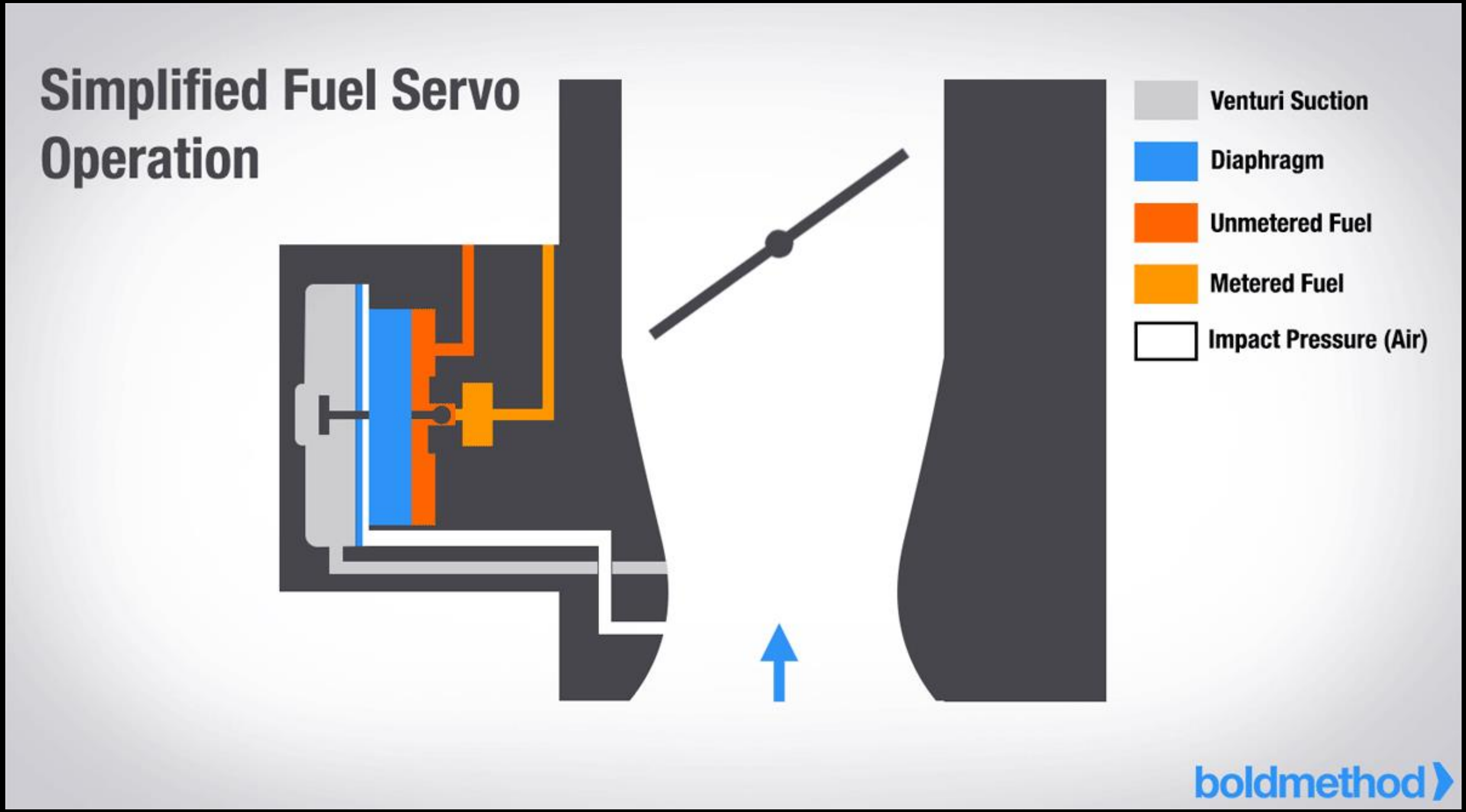
Fuel Injection Systems

- The fuel injector servo regulator works to create the right ratio of air-to-fuel
- This is done by comparing the inlet air pressure to the fuel inlet pressure



Fuel Injection Systems

- As you increase throttle, airflow through the engine increases, causing pressure to drop in the neck of the venturi
- This drop in pressure creates suction, while the impact pressure of the air increases
- This pressure difference causes the diaphragm to move to the left, pulling the ball valve open allowing more fuel flow



Fuel Injection

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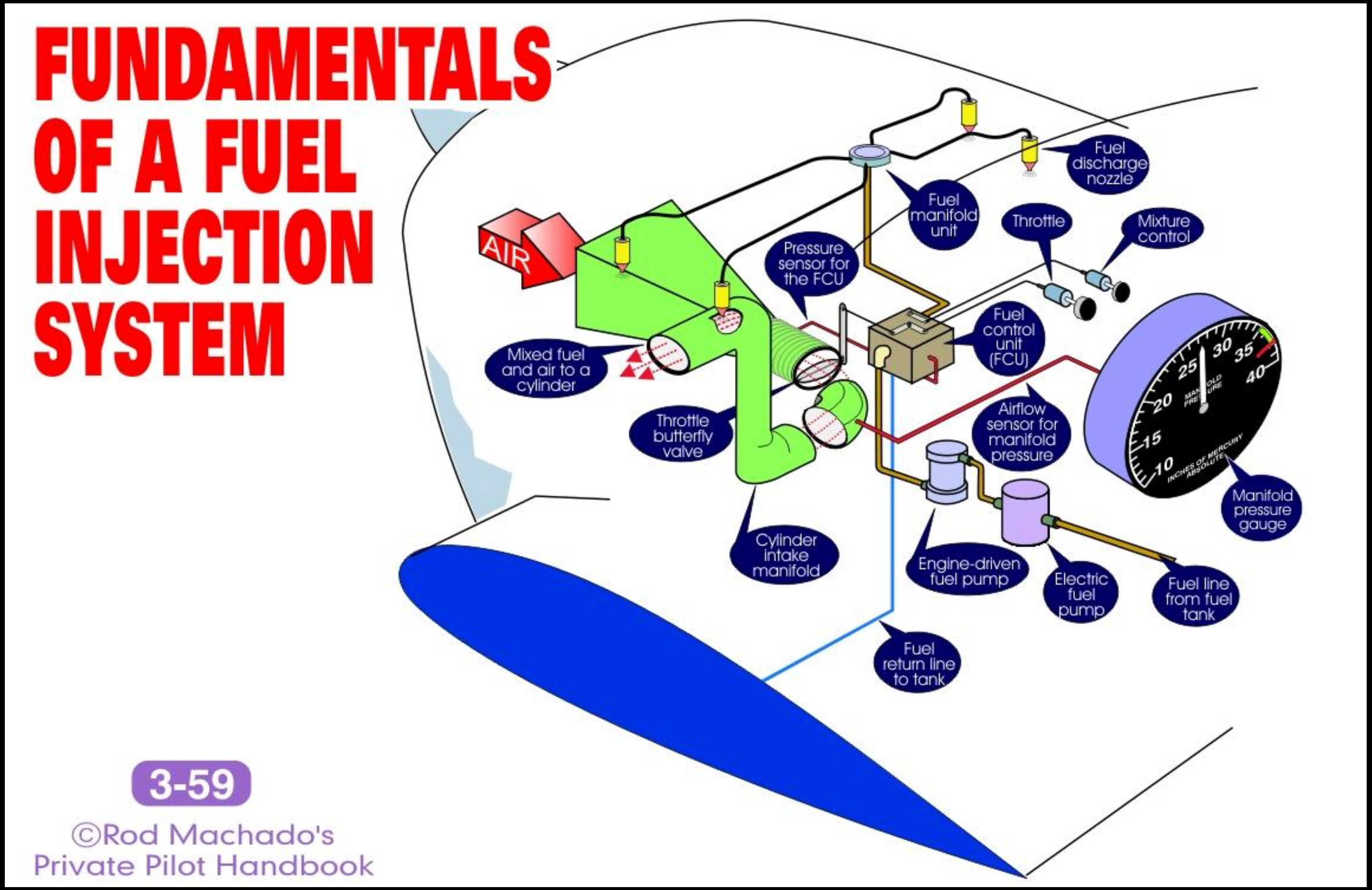
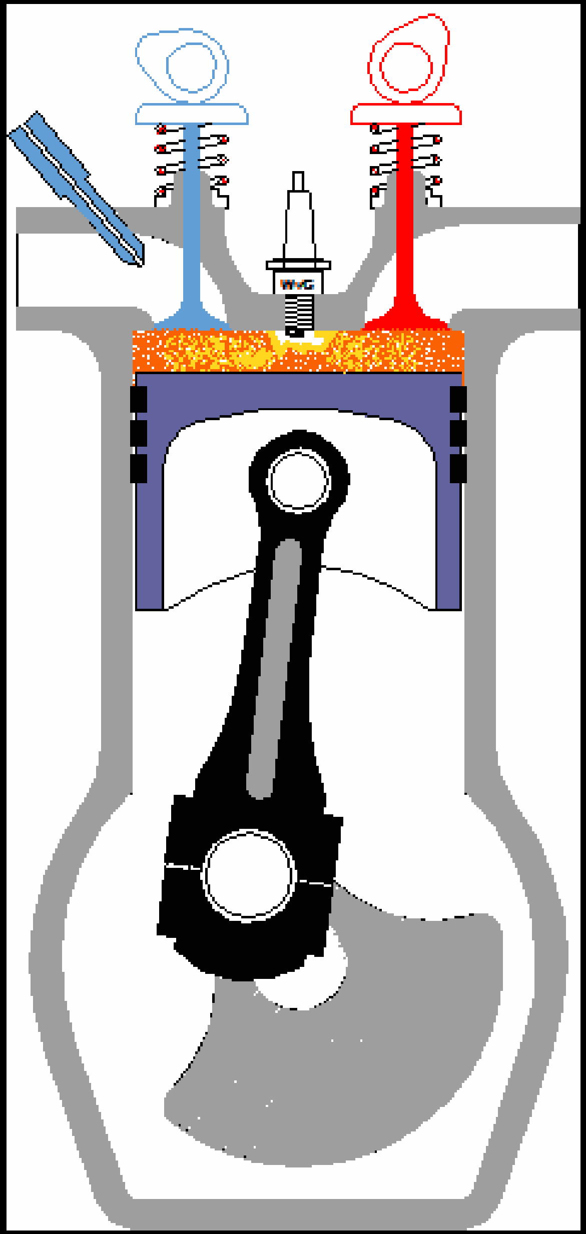


Fuel Discharge Nozzles

- After reaching the fuel manifold valve, the fuel is distributed to the individual fuel discharge nozzles
- The discharge nozzles, which are in each cylinder head, inject the fuel-air mixture directly into each cylinder intake port



Vapor Lock

- Occurs when the liquid fuel changes state from liquid to gas while still in the fuel delivery system
- Disrupts the operation of the fuel pump, causing loss of feed pressure to the fuel injection system
- Restarting the engine from this state may be difficult
- Fuel vaporizes due to being heated by engine, by local climate or due to lower boiling point at high altitude

Fuel Injection

- Advantages

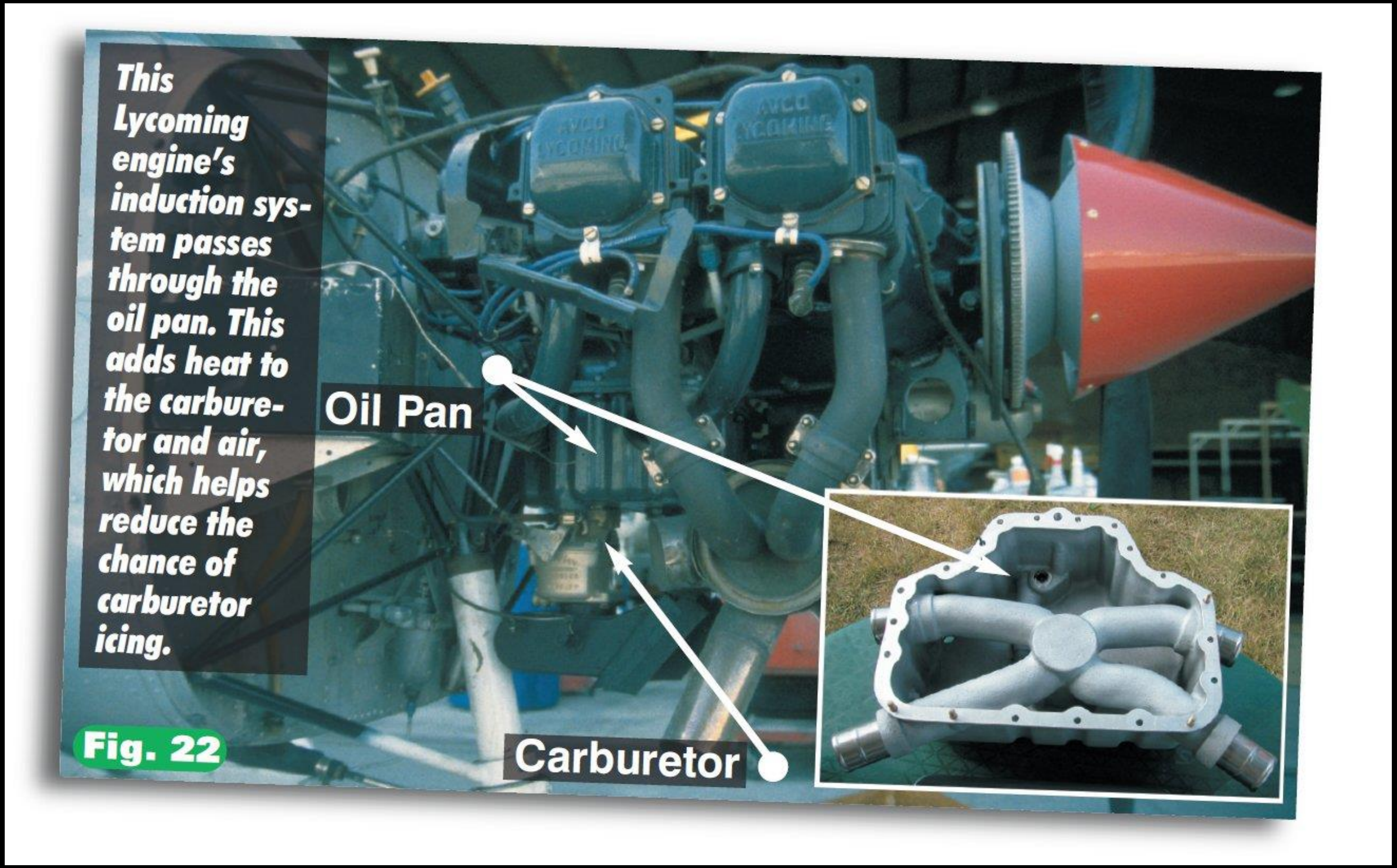
- Reduction in evaporative icing
- Better fuel flow
- Faster throttle response
- Precise control of mixture
- Better fuel distribution
- Easier cold weather starts

- Disadvantages

- Difficulty in starting a hot engine
- Vapor locks during ground operations on hot days
- Problems associated with restarting an engine that quits because of fuel starvation

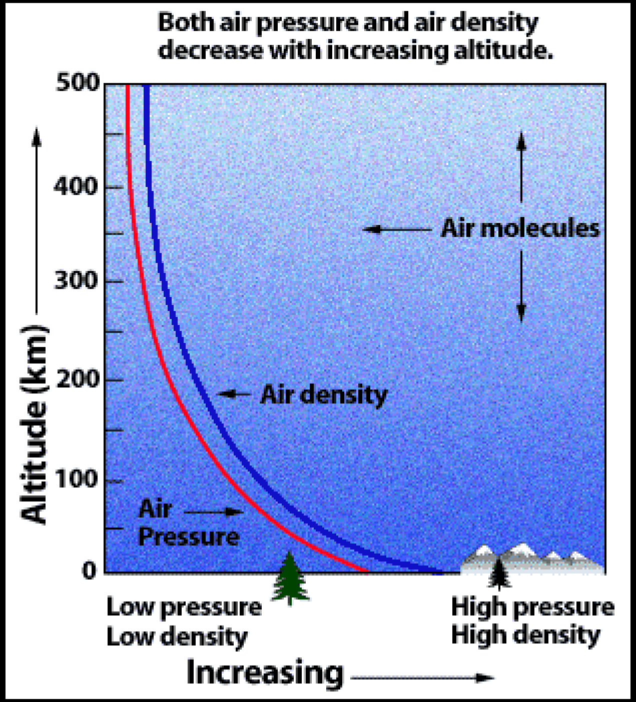
Archer & Warrior Induction Systems

- Lycoming engines with carburetors have their carburetor bolted to the bottom of the oil pan
- An opening in the bottom of the oil pan is part of the induction system through which incoming air is warmed by the oil's radiant heat
- The carburetor is also heated by conduction (touching) from the hot oil pan



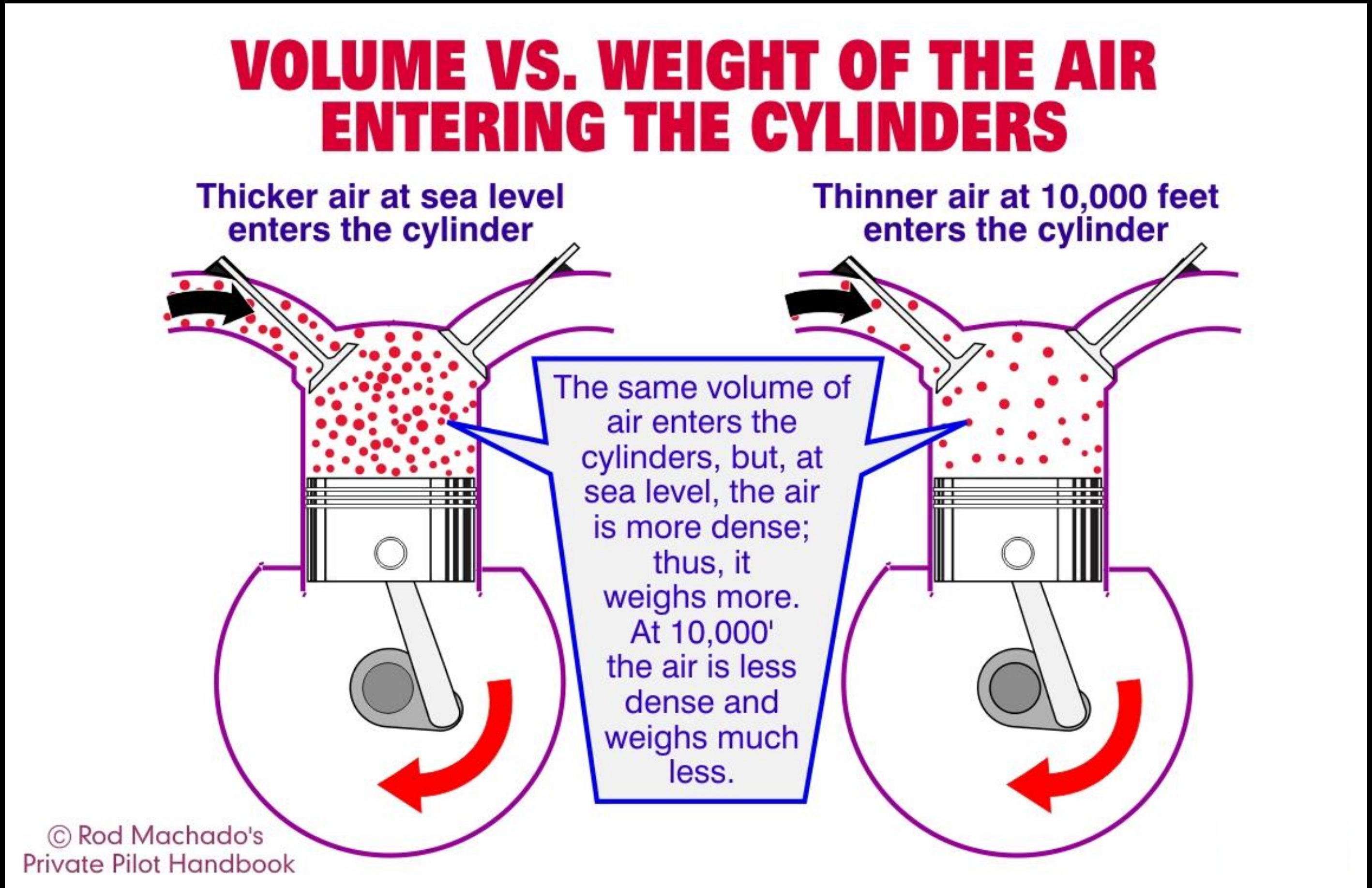
Air Pressure and Density

- If airplanes operated at one altitude (where air density never changes), you wouldn't need to worry about manually changing your fuel-air ratio
- Pilots fly at many altitudes, which means you need to know how to use the mixture control to maintain a specific fuel-air ratio



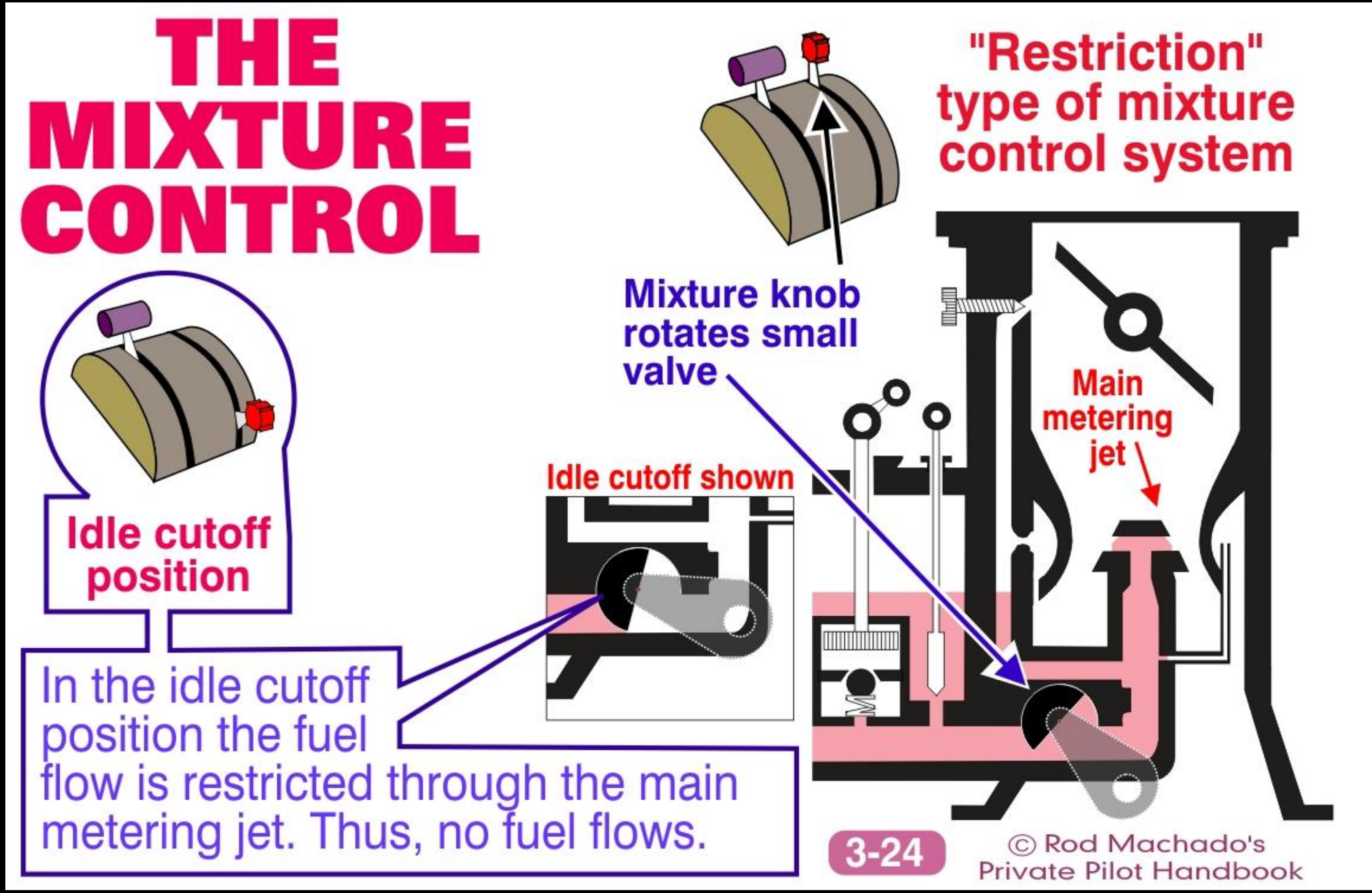
Mixture Control

- Carburetors are normally calibrated at sea-level air pressure where the correct fuel-air mixture ratio is established with the mixture control set in the FULL RICH position
- As altitude increases the density of air entering the carburetor decreases, while the density of the fuel remains the same
- This creates a progressively richer mixture that can result in engine roughness and an appreciable loss of power

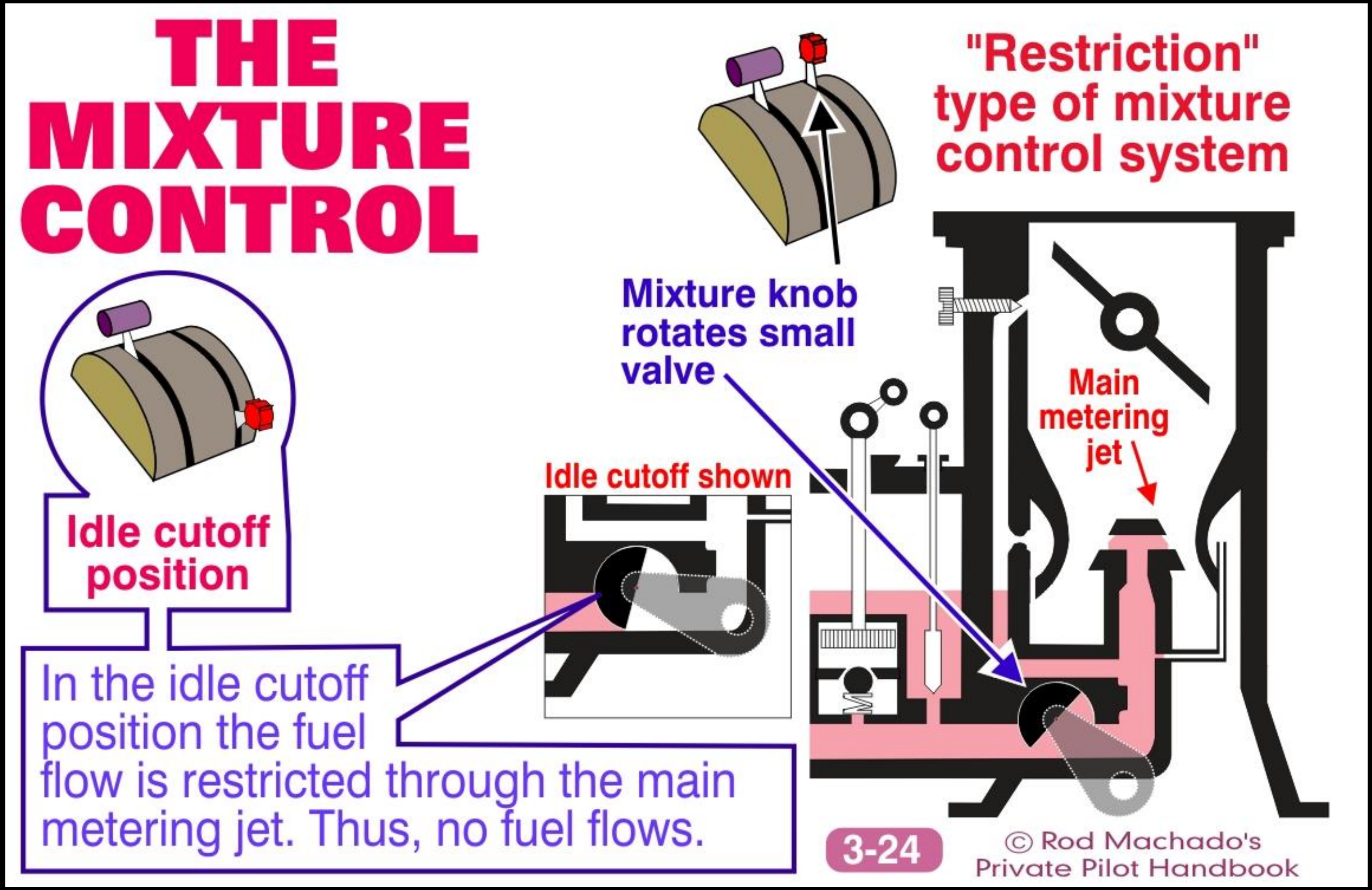


Mixture Control

- Allows you to operate at the proper fuel-air ratio as air density changes with altitude
- Decreases the amount of fuel for a given amount of air entering the engine
- Leaning is accomplished by restricting the flow of fuel through the main metering jet



Mixture Control



- Pulling the mixture control out to its maximum rearward position of travel activates idle cutoff
- This kills the engine by restricting the fuel leaving the carburetor
- We typically pull the mixture to the idle-cutoff position when stopping the engine on the ground at the end of the flight

When to Lean

- At power levels above 75%, the mixture should be in the full rich position
- Most engine manufacturers recommend leaning the mixture whenever operating at or below 75% of the engine's maximum power output

When to Lean

- As the airplane ascends the engine produces less power because there is less air for the combustion process
- If the airplane is operating with full throttle at less than 5,000 feet MSL, the engine is most likely producing more than 75% of its maximum power output
- Don’t lean under these conditions

When to Lean

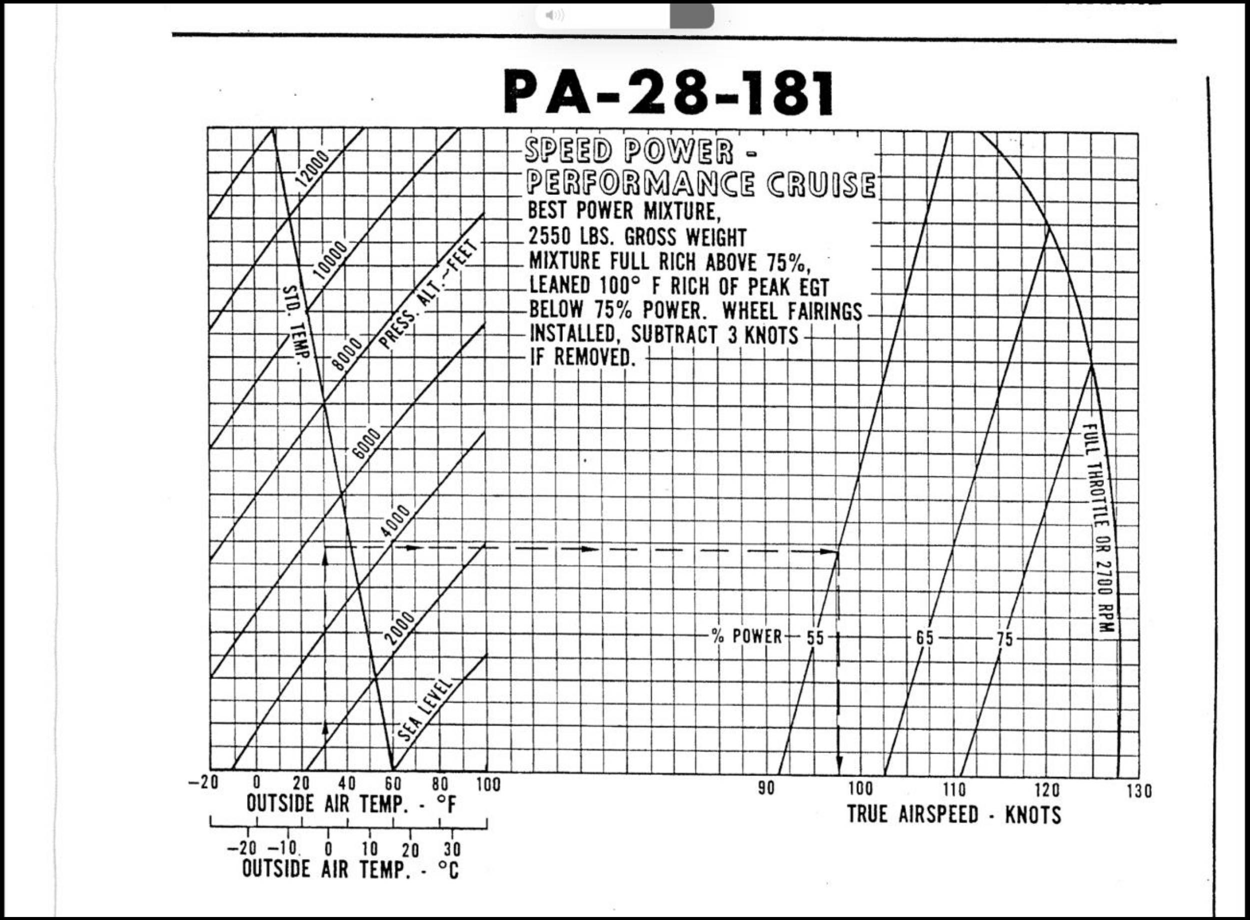
- If climbing (with full throttle) at less than 5,000 feet MSL, the mixture should be full forward
- Above 5,000 feet MSL, where the engine probably produces less than 75% of its maximum power (even with full throttle), lean the mixture for either best economy or best power
- As a rule of thumb, readjust the mixture every thousand feet of altitude change
- Check the POH to find the engine’s power output for a given altitude and power setting

When to Lean

- Since most cruising is done at 55% to 65% power, always lean the engine regardless of your altitude at these power settings
- Check the POH to find the engine’s power output for a given altitude and power setting
- Failure to lean appropriately means you’ll use up an extra portion of fuel unnecessarily

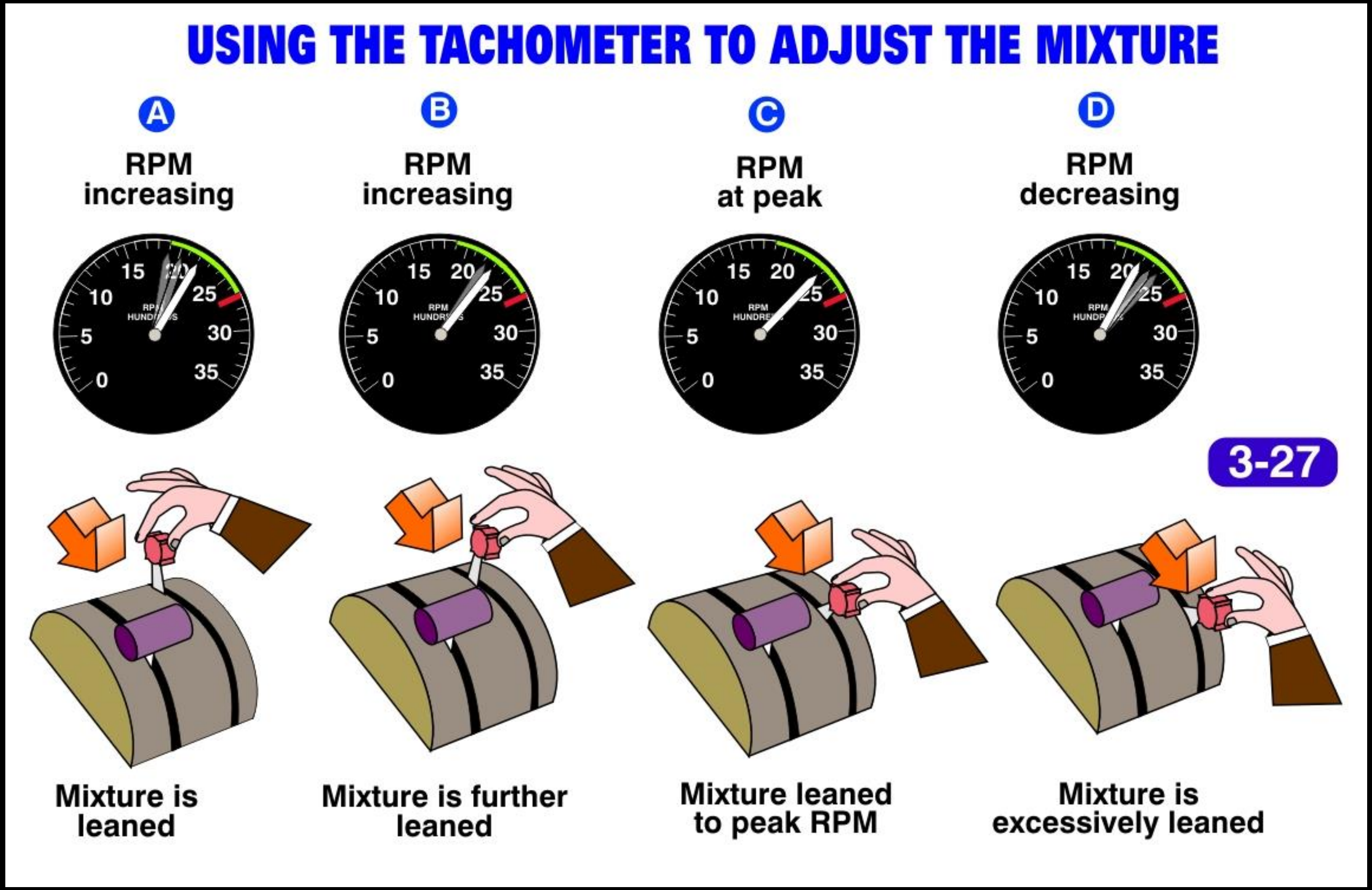
Pilot Operating Handbook

- Check the POH to find the engine's power output for a given altitude and power setting

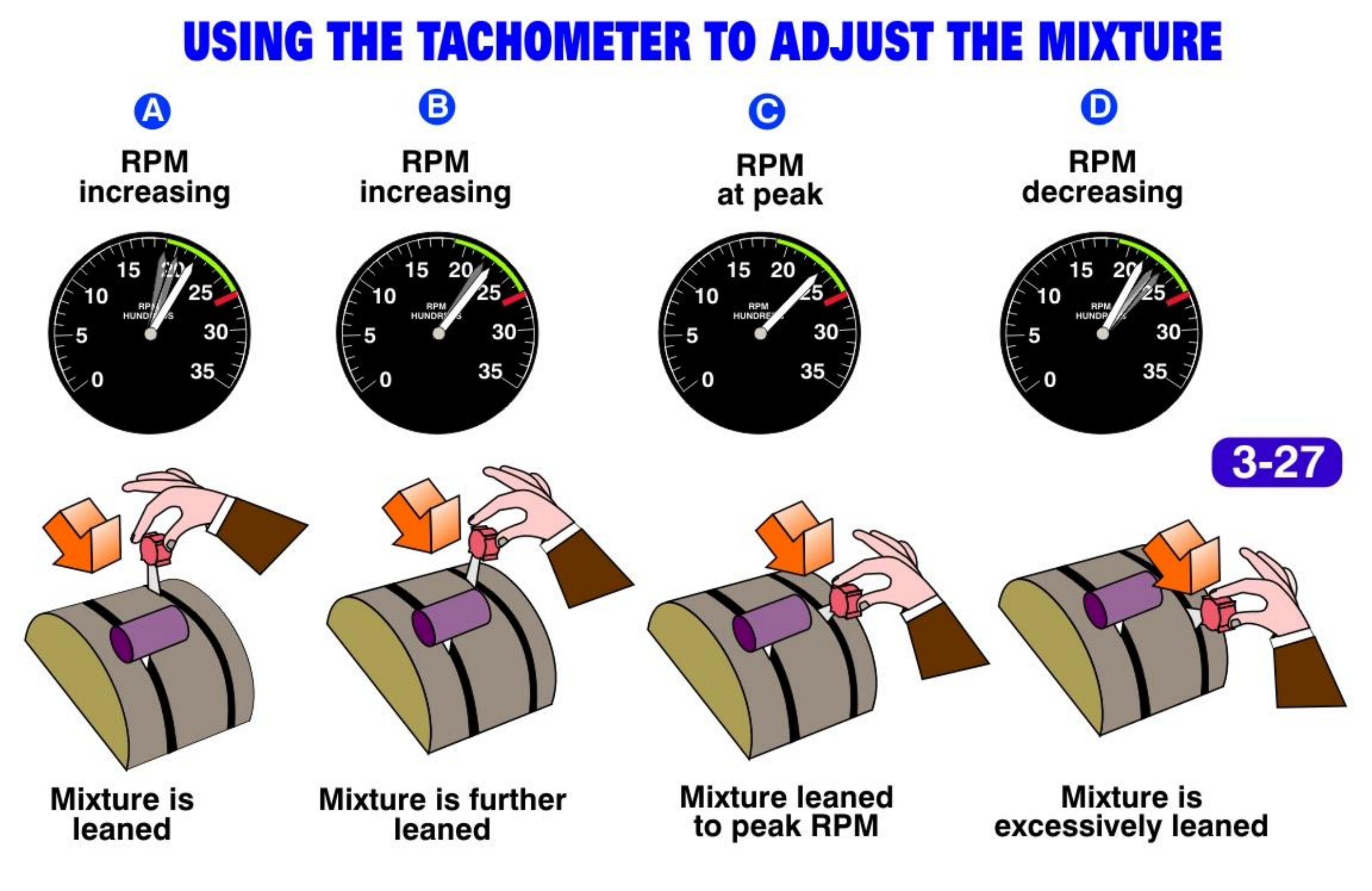


Leaning The Mixture

- To maintain the correct fuel-air mixture the mixture must be leaned using the mixture control
- Leaning the mixture decreases fuel flow, which compensates for the decreased air density at high altitude



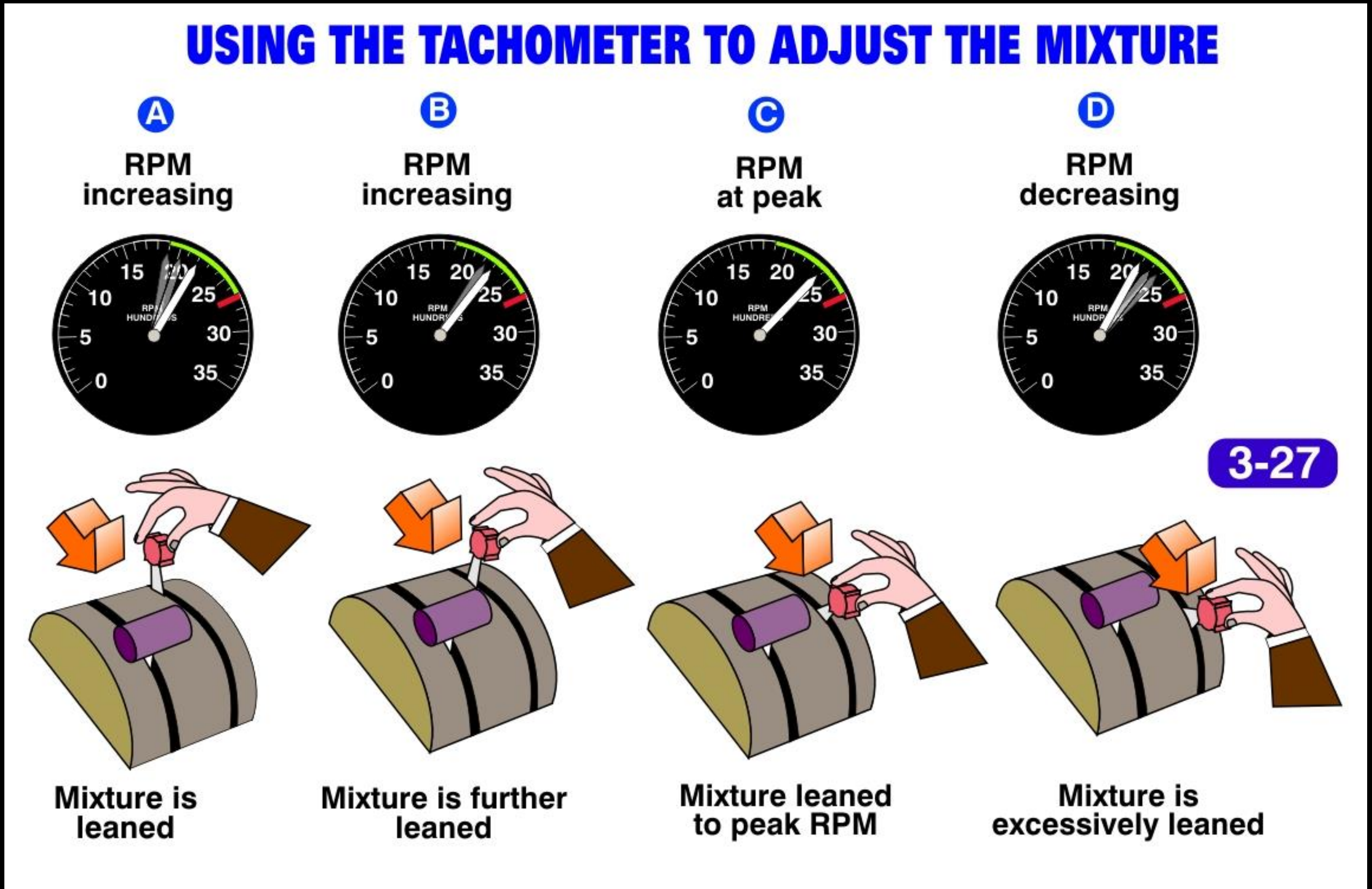
Leaning The Mixture



- When the RPM peaks, you are at the fuel-air ratio that produces maximum power for a given air density and throttle setting
- This is leaning the mixture for best power
- Further pulling of the mixture will cause engine roughness and reduce RPM from over-leaning
- If the engine starts running rough during the leaning process, enrich the mixture slightly until the engine smooths out

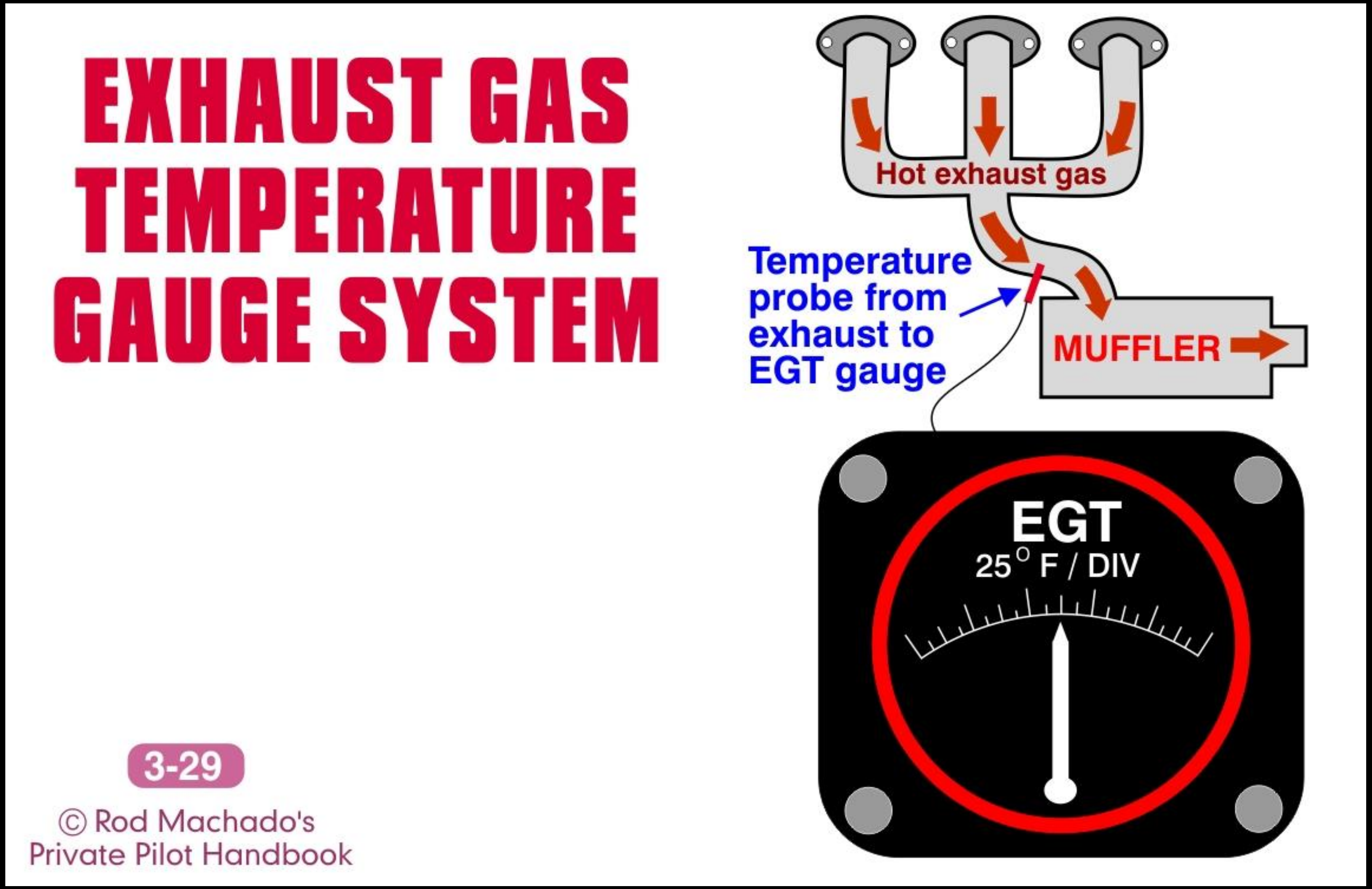
Leaning The Mixture

- During a descent from high altitude, the fuel-air mixture must be enriched, or it may become too lean
- An overly lean mixture causes detonation which may result in rough engine operation, overheating, and/or a loss of power



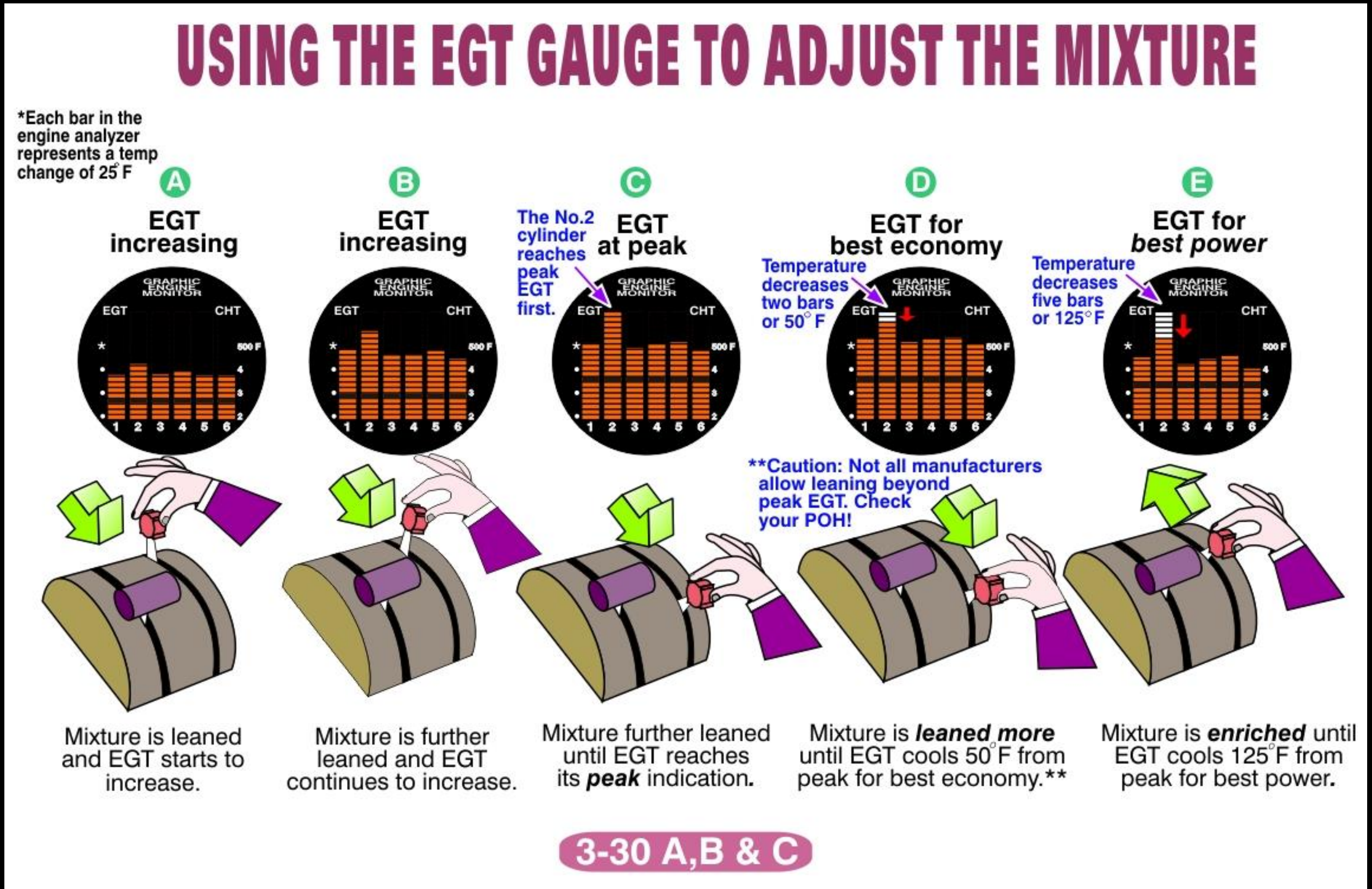
Exhaust Gas Temperature System

- Use of the EGT gauge offers a relatively precise means for leaning the engine



Mixture Adjustment Using EGT

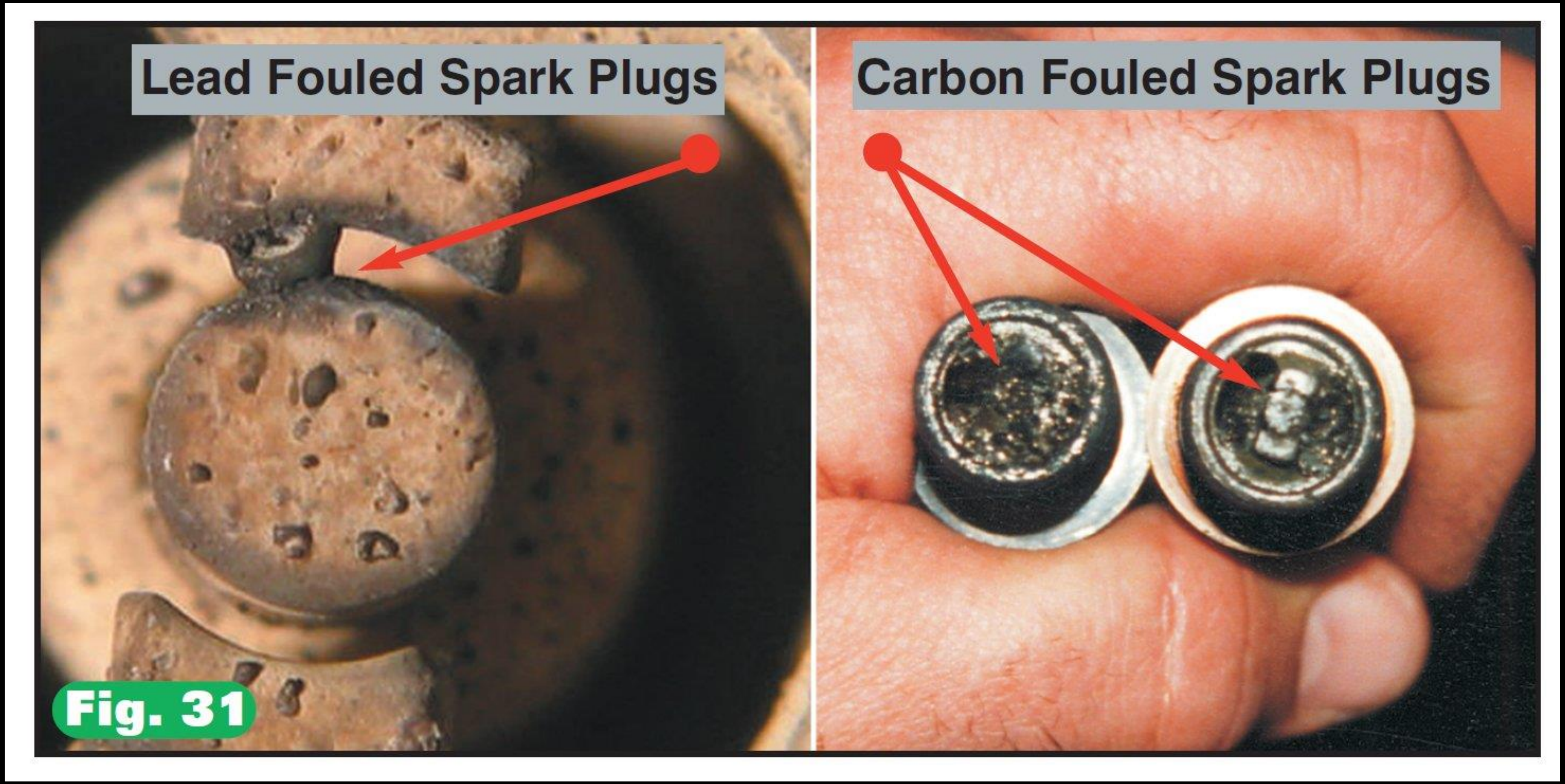
- The best way to maintain the proper fuel-air mixture is to monitor the engine temperature and enrich the mixture as needed
- Proper mixture control and better fuel economy for fuel-injected engines can be achieved by using an exhaust gas temperature (EGT) gauge



Spark Plug Fouling

- Engine roughness due to rich mixture normally is due to spark plug fouling from excessive carbon buildup on the plugs
- Carbon buildup occurs because the rich mixture lowers the temperature inside the cylinder which inhibits complete combustion of the fuel
- This condition may occur during the runup prior to takeoff at high-elevation airports and during climbs or cruise flight at high altitudes

Spark Plug Fouling



Too Rich

- A mixture that is too rich causes engine roughness and reduced power
- Spark plugs are carbon fouled when unburned fuel residue builds up between the plug gap
- Lead, a component of high-octane fuel, can also build up on spark plugs, worsening the fouling process
- An excessively rich mixture contributes to high fuel consumption meaning less range, less endurance, and smaller fuel reserves
- Some estimates show operating at a full-rich mixture instead of a best economy setting can increase fuel consumption by as much as 70%

Too Lean

- Too lean a mixture means less power is produced
- The biggest danger with an excessively lean mixture is that it burns hot
- This exposes the cylinder, piston, and valves to higher temperatures
- High cylinder temperatures also lead to detonation

Leaning & High Altitude Takeoffs

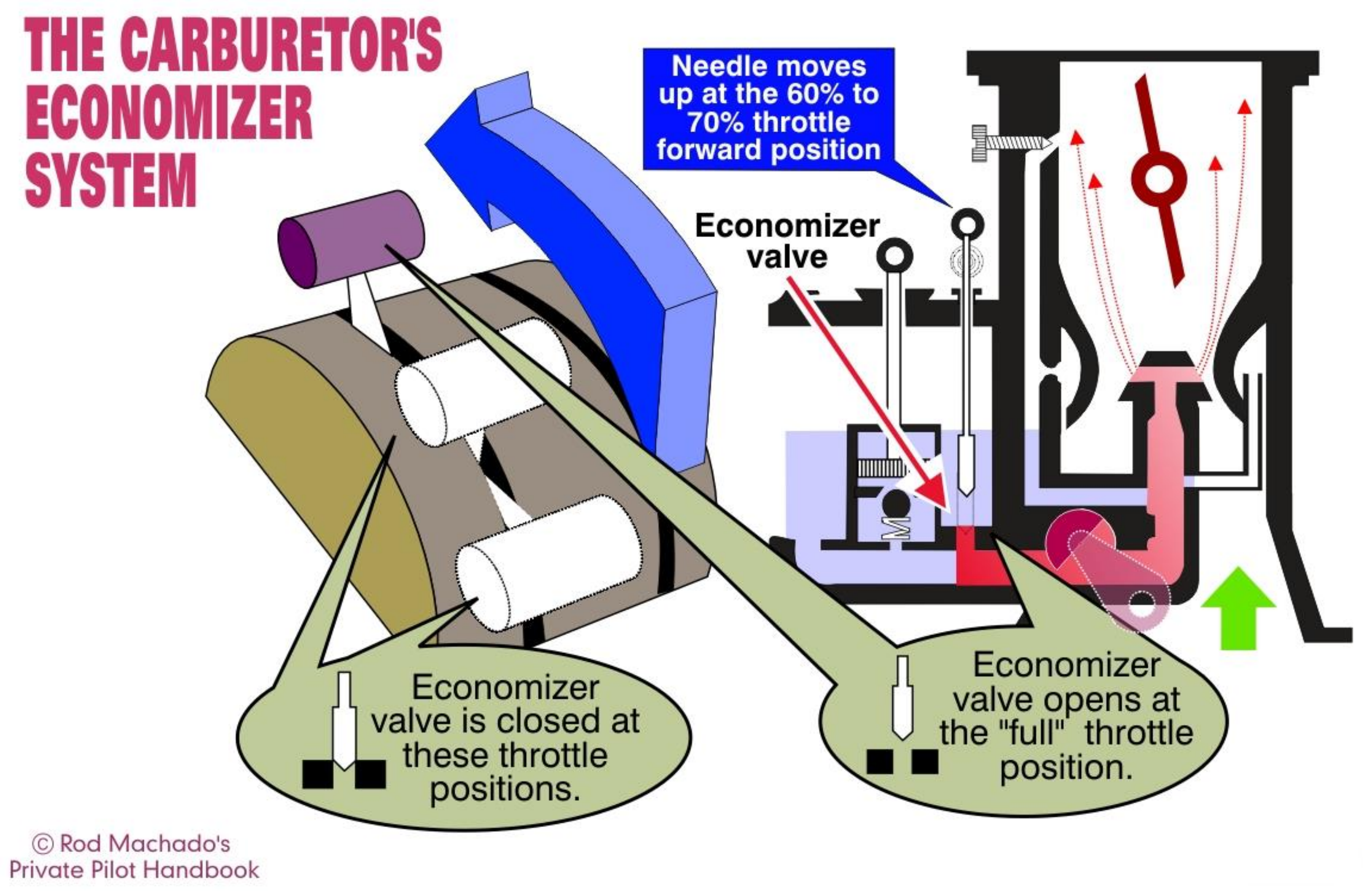
- Takeoffs are normally made with a full-rich mixture
- One exception is high altitudes (any airport above 5,000 feet MSL)
- During the runup hold the brakes, apply full throttle, lean the mixture, then return the throttle to its idle position
- Takeoff should be made at this mixture setting to ensure maximum climb performance

Leaning & High Altitude Takeoffs

- Good idea when departing an airport (regardless of the elevation) where high temperature conditions decrease the air's density
- Under certain conditions, if the outside air temperature is quite high, an airport at 2,000 feet MSL can have air with the same density as an airport at 6,000 feet MSL
- Attempting to depart with a full rich mixture under these conditions produces the same decrease in performance as departing a high-altitude airport

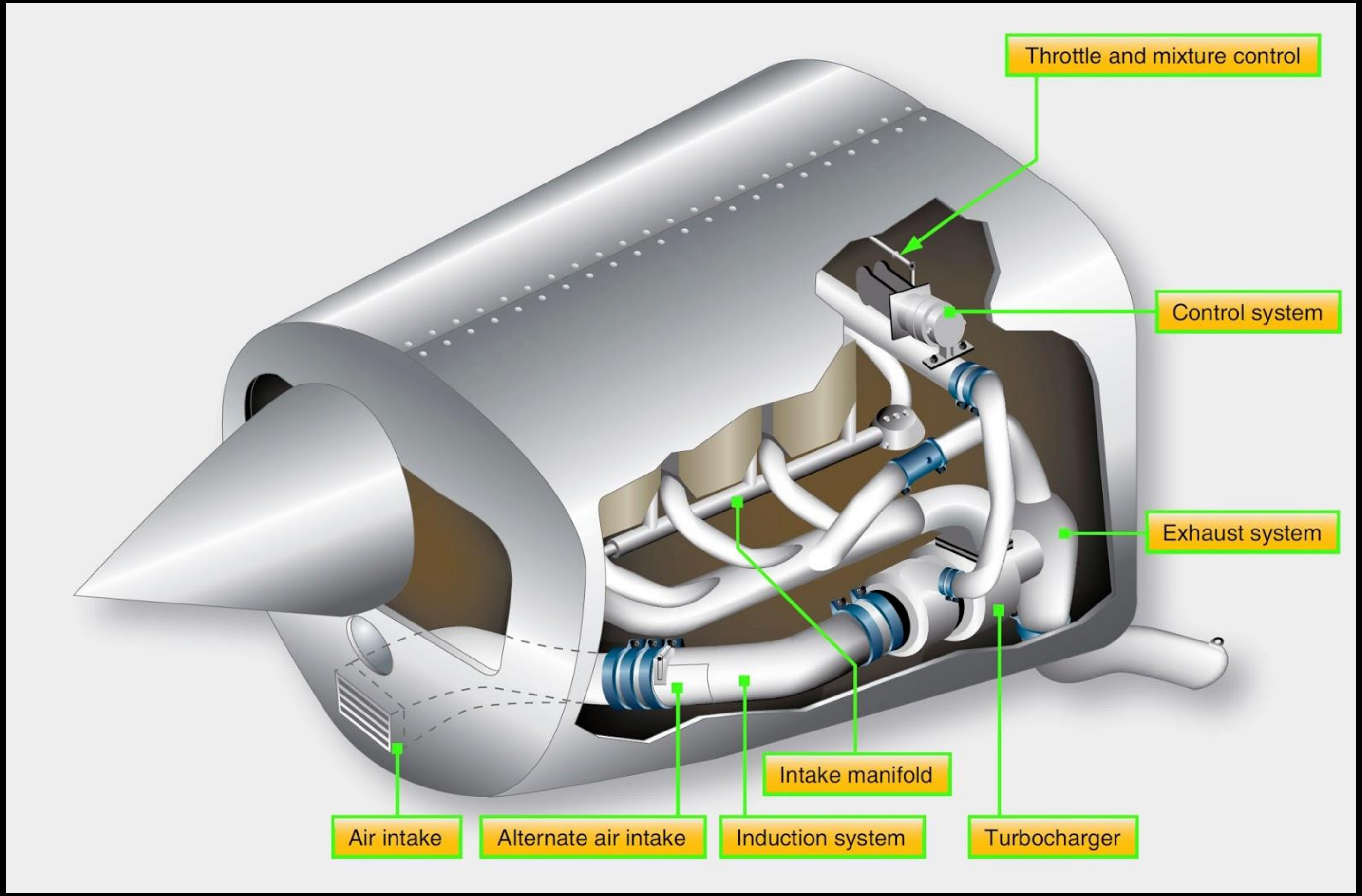
Carburetor Economizer System

- Aids in engine cooling at high power settings (above 75%)
- Extra fuel (10% more) flows into the carburetor's main metering jet
- This extra fuel helps to lower the higher cylinder head temperatures at the higher power settings
- Valve closes at lower power settings



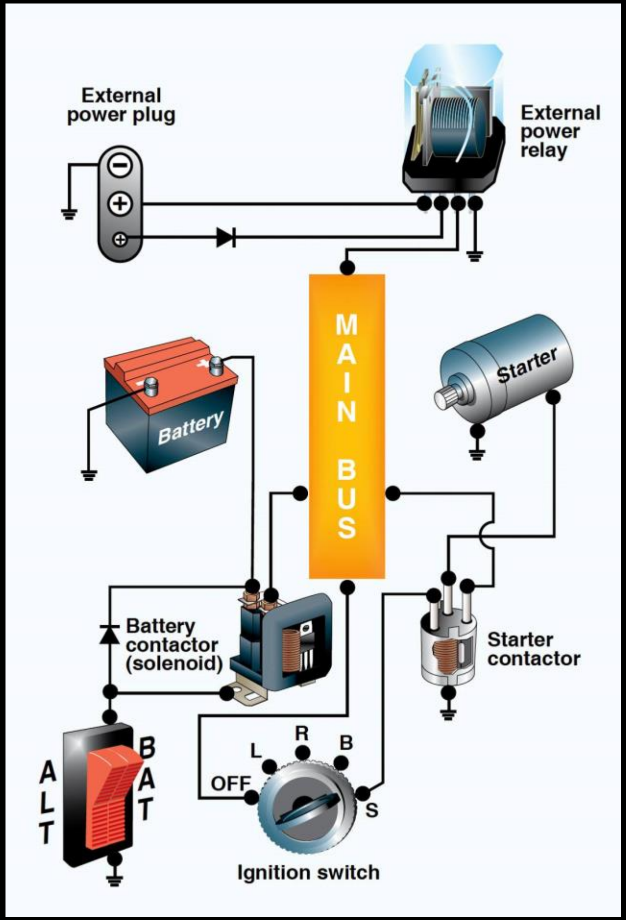
Impact Icing

- A fuel injection system is less susceptible to icing than a carburetor system
- Impact icing on the air intake is a possibility in either system
- Occurs when ice forms on the exterior of the aircraft and blocks openings, such as the air intake for the injection system

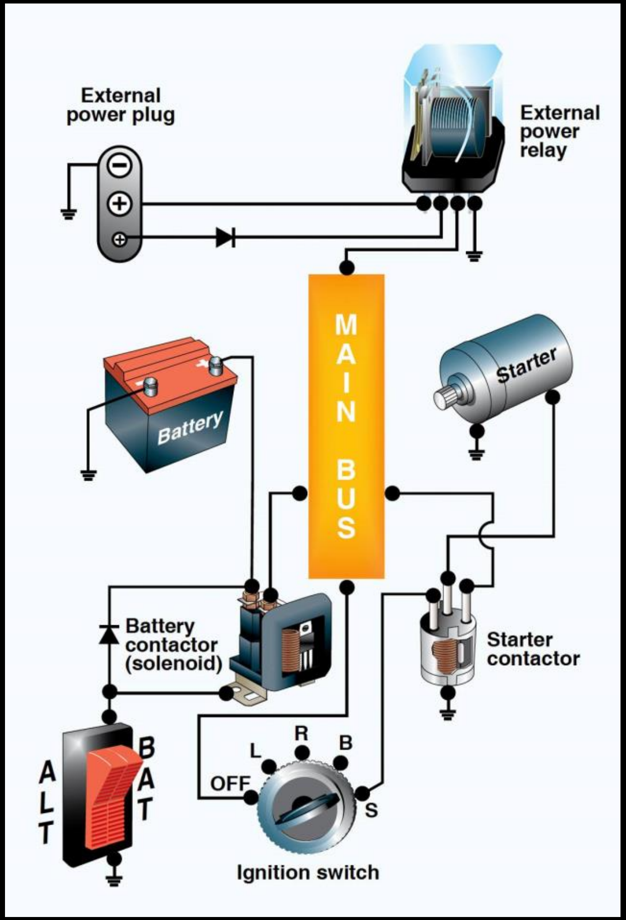


Direct-Cranking Electric Starter

- Consists of a source of electricity, wiring, switches, and solenoids to operate the starter and a starter motor
- Starter automatically engages and disengages when operated
- Electrical power for starting is usually supplied by an onboard battery, but can also be supplied by external power through an external power receptacle



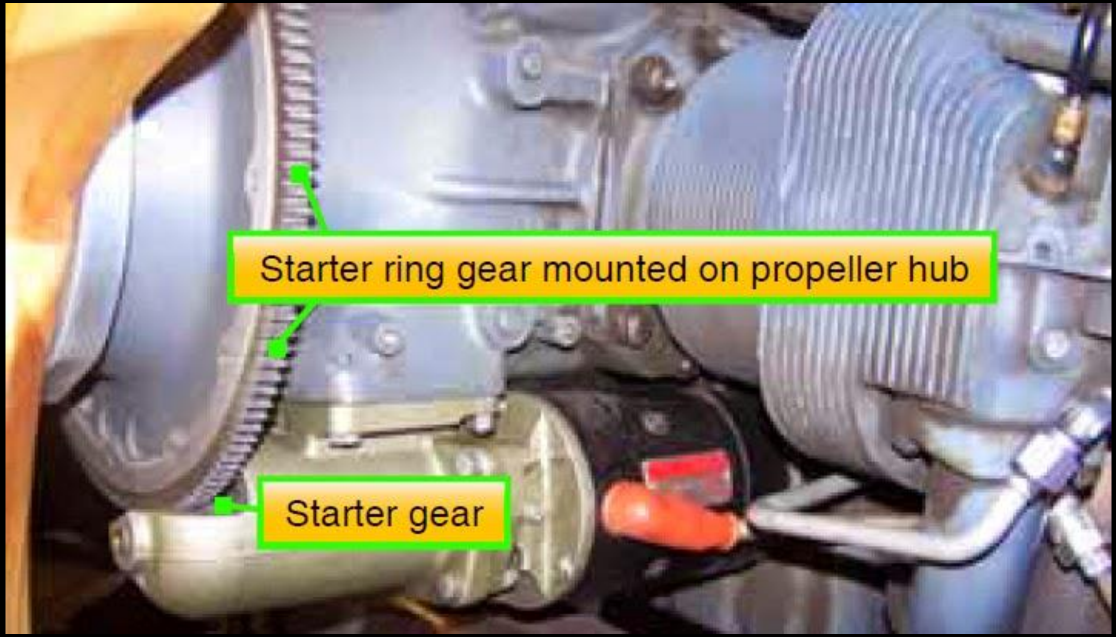
Direct-Cranking Electric Starter



- When the battery switch is turned on, electricity is supplied to the main power bus bar through the battery solenoid
- Both the starter and the starter switch draw current from the main bus bar, but the starter will not operate until the starting solenoid is energized by the starter switch being turned to the “Start” position
- When the starter switch is released from the “start” position the solenoid removes power from the starter motor

Starter

- When the ignition key is turned to the Start position, the starter gear shoots forward from the starter motor housing and engages the flywheel
- The starter motor spins the starter gear, which turns the flywheel, which turns the crankshaft, which forces the pistons up and down in the cylinders
- The starter motor is protected from being driven by the engine through a clutch in the starter drive that allows the engine to run faster than the starter motor



FADEC System

- System consisting of a digital computer and components that control an aircraft's engine and propeller
- FADEC uses speed, temperature, and pressure sensors to monitor the status of each cylinder
- A digital computer calculates the ideal pulse for each injector and adjusts ignition timing as necessary to achieve optimal performance

FADEC Operation

- FADEC systems eliminate the need for magnetos, carburetor heat, mixture controls, and engine priming
- A single throttle lever is characteristic of an aircraft equipped with a FADEC system
- The pilot simply positions the throttle lever to a desired detent, such as start, idle, cruise power, or max power, and the FADEC system adjusts the engine and propeller automatically for the mode selected
- There is no need for the pilot to monitor or control the fuel-air mixture

FADEC Operation

- During aircraft starting the FADEC primes the cylinders, adjusts the mixture, and positions the throttle based on engine temperature and ambient pressure
- During cruise flight the FADEC constantly monitors the engine and adjusts fuel flow and ignition timing individually in each cylinder
- This precise control of the combustion process results in decreased fuel consumption and increased HP

FADEC Redundancy

- FADEC systems are considered an essential part of the engine and propeller control
- May be powered by the aircraft’s main electrical system or use power from a separate generator connected to the engine
- In either case, there is a backup electrical source available because failure of a FADEC system could result in a complete loss of engine thrust
- To prevent loss of thrust two separate and identical digital channels are incorporated for redundancy
- Each channel can provide all engine and propeller functions without limitations

Knowledge Check

What is the primary cause of carburetor icing?

A. Operating at too low of a power setting
B. Venturi Effect
C. Operating to a temperature below 0 C
D. Coriolis Effect

Knowledge Check

What is the primary cause of carburetor icing?

A. ~~Operating at too low of a power setting~~
B. Venturi Effect
C. ~~Operating to a temperature below 0 C~~
D. ~~Coriolis Effect~~

Knowledge Check

What is the proper order of the engine cycle?

A. Intake, Compression, Exhaust, Combustion
B. Compression, Combustion, Intake, Exhaust
C. Intake, Compression, Combustion, Exhaust
D. Intake, Combustion, Compression, Exhaust