Private Pilot (ASEL) Ground School Course

Lesson 06 | Aircraft Flight Controls and Systems

Lesson Overview

Lesson Objectives:

- Develop a knowledge and understanding of fuel systems and engine 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.

Fuel System

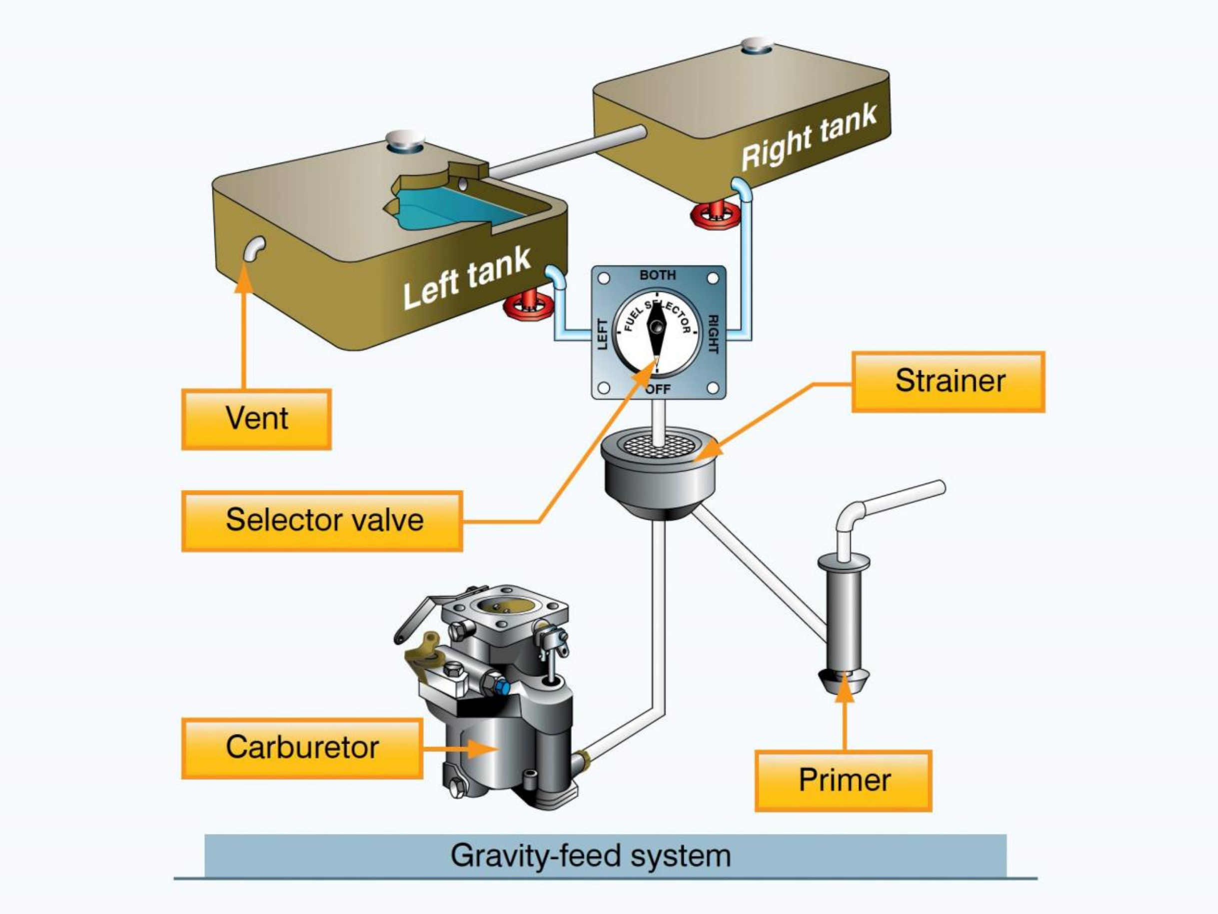
Aircraft Flight Controls and Systems

Fuel Systems

- Designed to provide an uninterrupted flow of clean fuel from the fuel tanks to the engine.
- Fuel must be available to the engine under all conditions of engine power, altitude, attitude, and during all approved flight maneuvers.
- Two common classifications apply to fuel systems in small aircraft:
  - Gravity-feed
  - Fuel-pump systems

Gravity-Feed System

- Utilizes gravity to transfer fuel from tanks to the engine.
- High-wing airplanes typically have fuel tanks installed in the wings.
- Positioning tanks above the carburetor allows gravity-fed fuel flow into the carburetor.
- Fuel pumps are installed if the aircraft design prevents the use of gravity for fuel transfer.



Gravity Fed System

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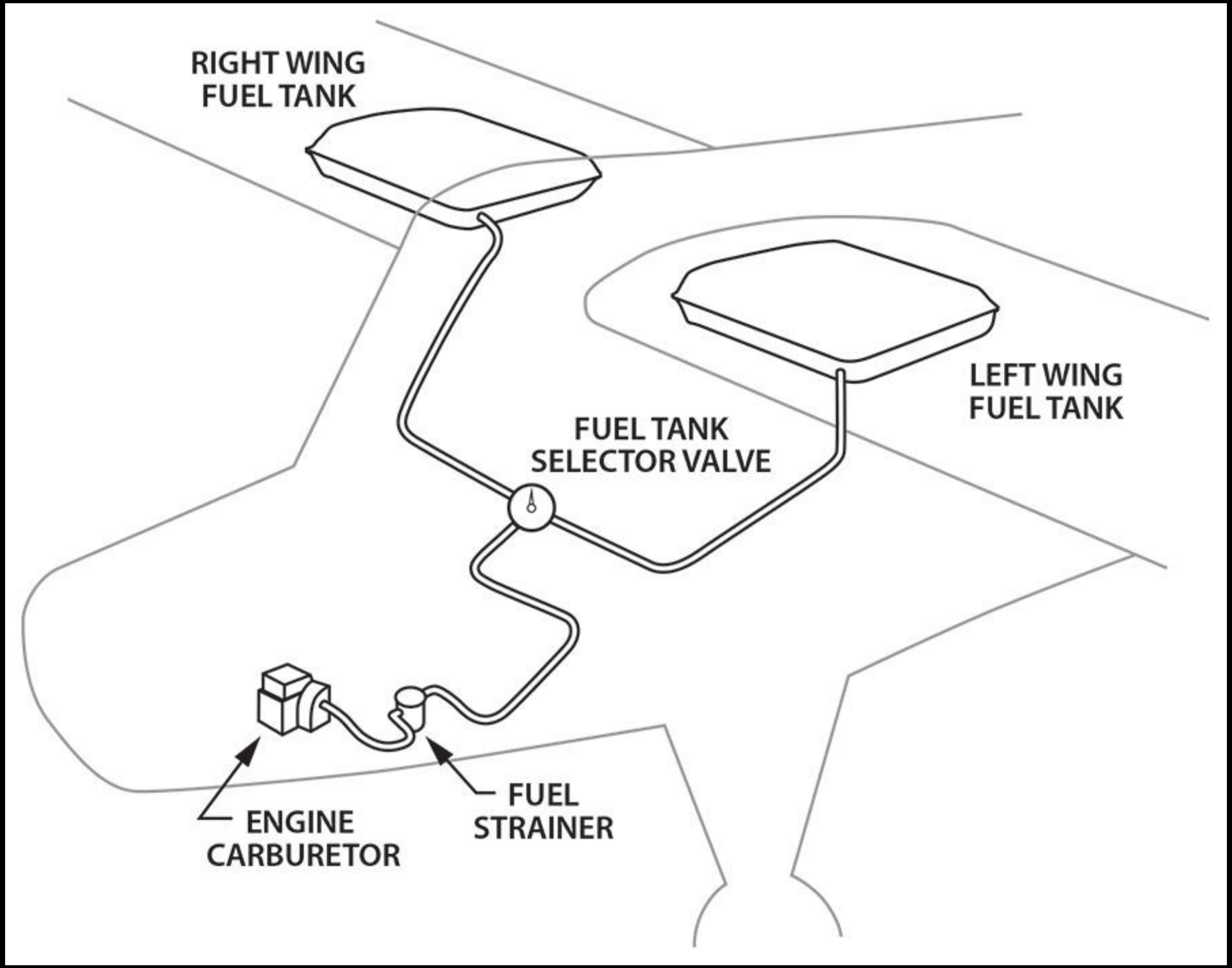
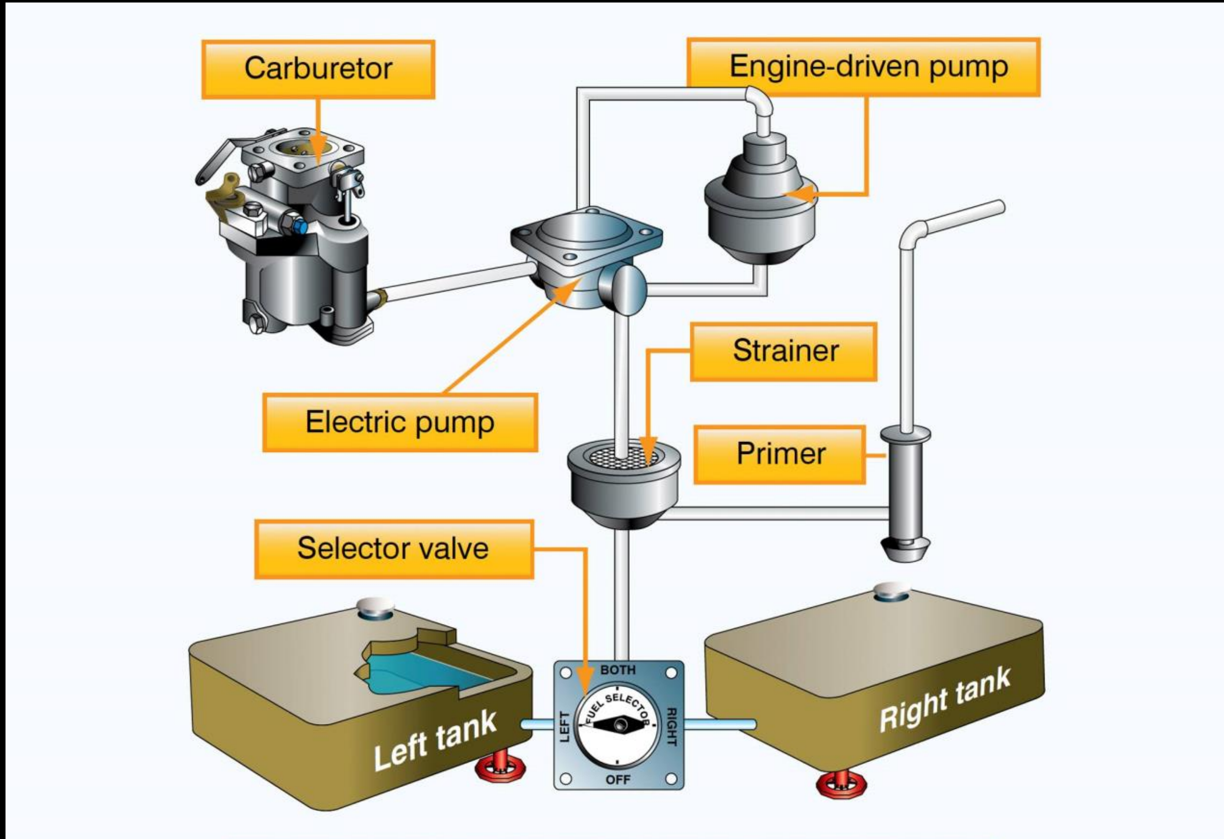


Fuel-Pump System

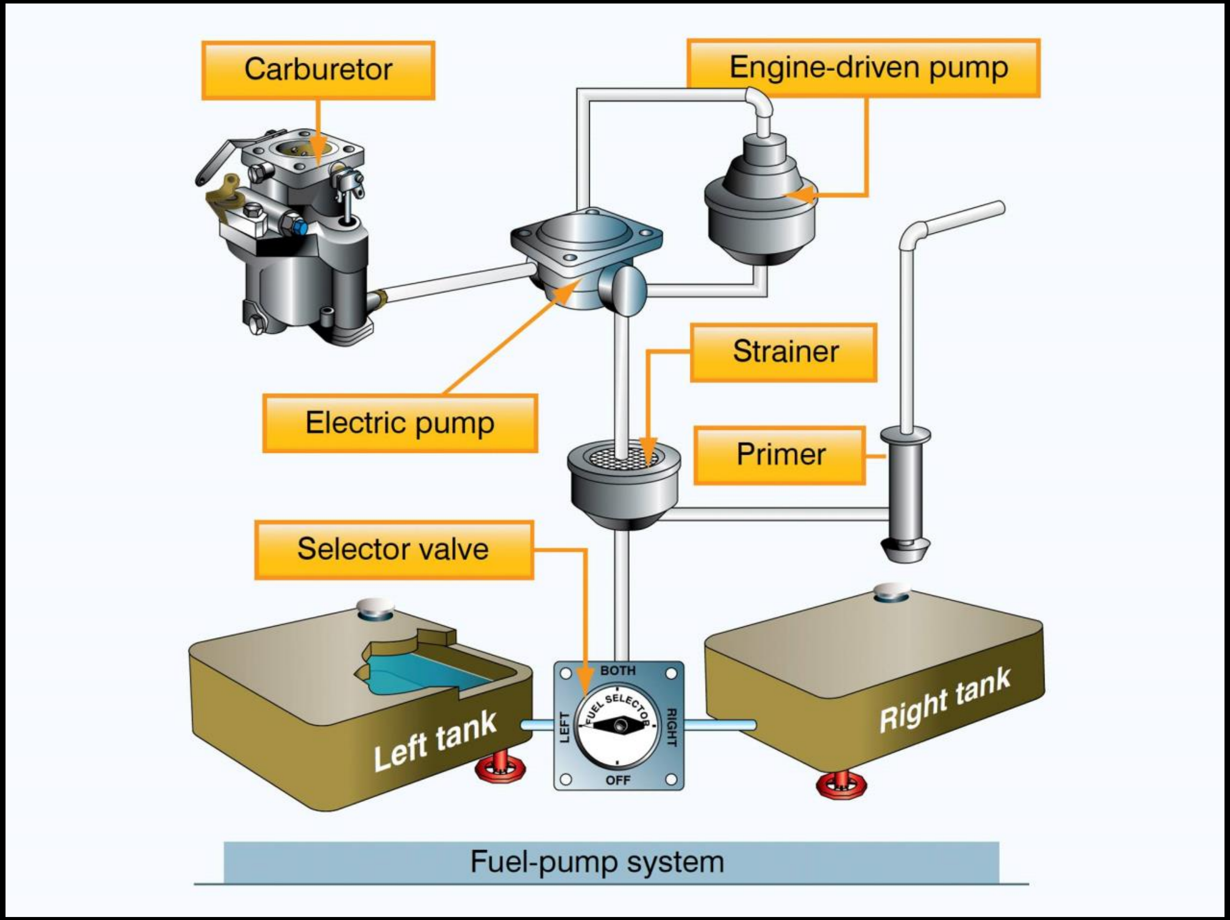
- Low-wing airplanes have fuel tanks in the wings located below the carburetor.
- Fuel-pump systems in low-wing airplanes:
  - Two fuel pumps.
  - Engine-driven main pump system.
  - Electrically-driven auxiliary pump for engine starting and in case of engine pump failure.
  - The auxiliary pump (boost pump) enhances fuel system reliability.
  - Controlled by a switch in the flight deck.



Fuel-pump system

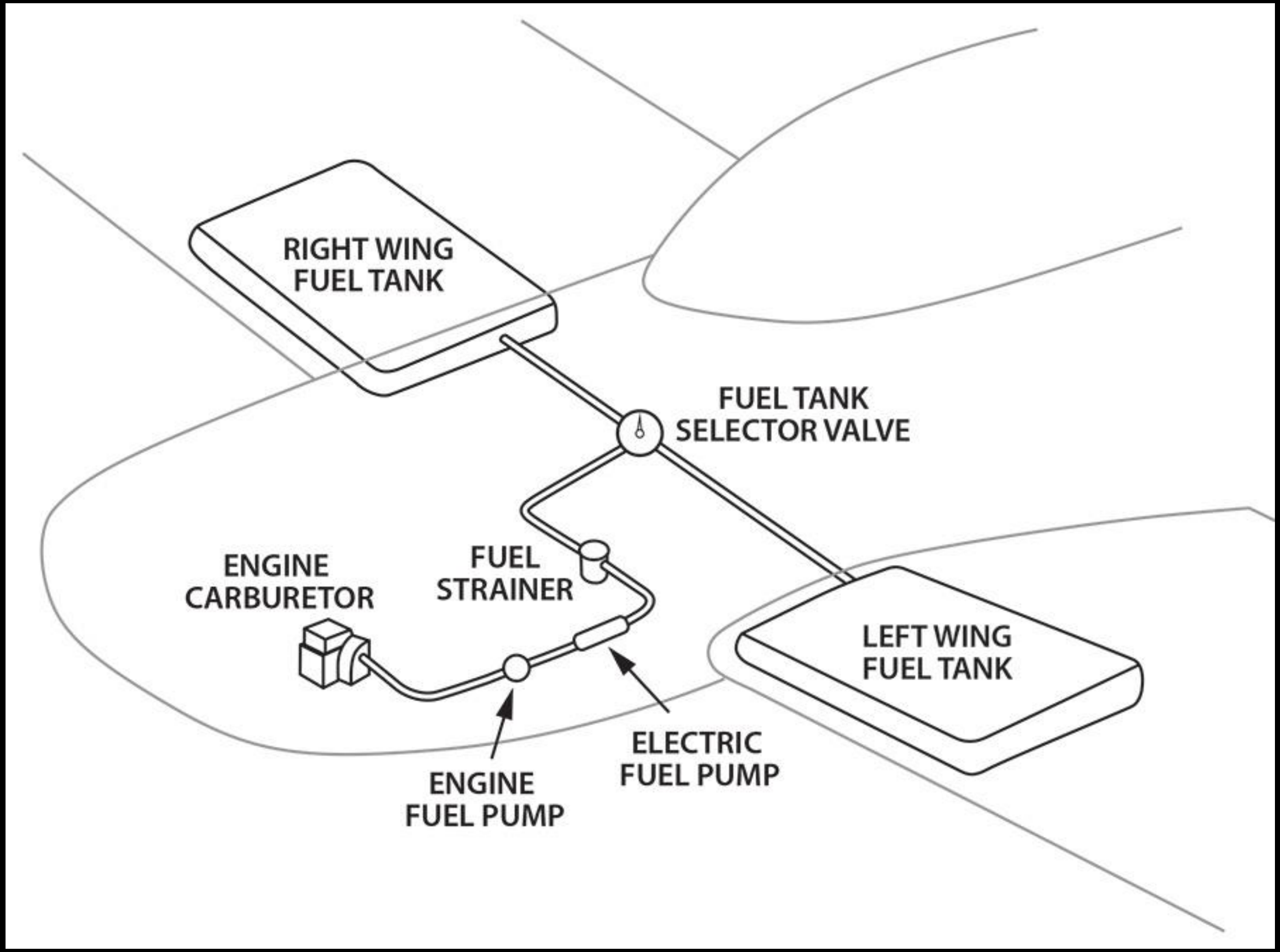
Fuel-Pump System

- Manufacturers recommend activating the boost pump for takeoff until the airplane is at least 1,000 feet Above Ground Level (AGL).
- During descents within 1,000 feet AGL, the boost pump is recommended.
- Critical at lower altitudes due to potential failure of the mechanical fuel pump, as gravity won't feed the system.
- Activate the boost pump when switching fuel tanks to pressurize the system and purge any air in the fuel lines.



Fuel Pressure Gauge

Low Wing Fuel Pump System

- 

Fuel Tanks

- Typically located inside the wings with a top filler opening and covered by a filler cap.
- Vented externally to maintain atmospheric pressure inside the tank, either through the filler cap or a tube extending through the wing surface.
- Equipped with an overflow drain, either standalone or collocated with the fuel tank vent, facilitating fuel expansion with temperature increases without damaging the tank.

Fuel Vents

- As the fuel pump sucks fuel from the tank, air must replace the departing fuel or a vacuum forms
- If that happens, fuel starvation occurs since the pump can't overcome the vacuum
- Always make sure these vent lines are unobstructed

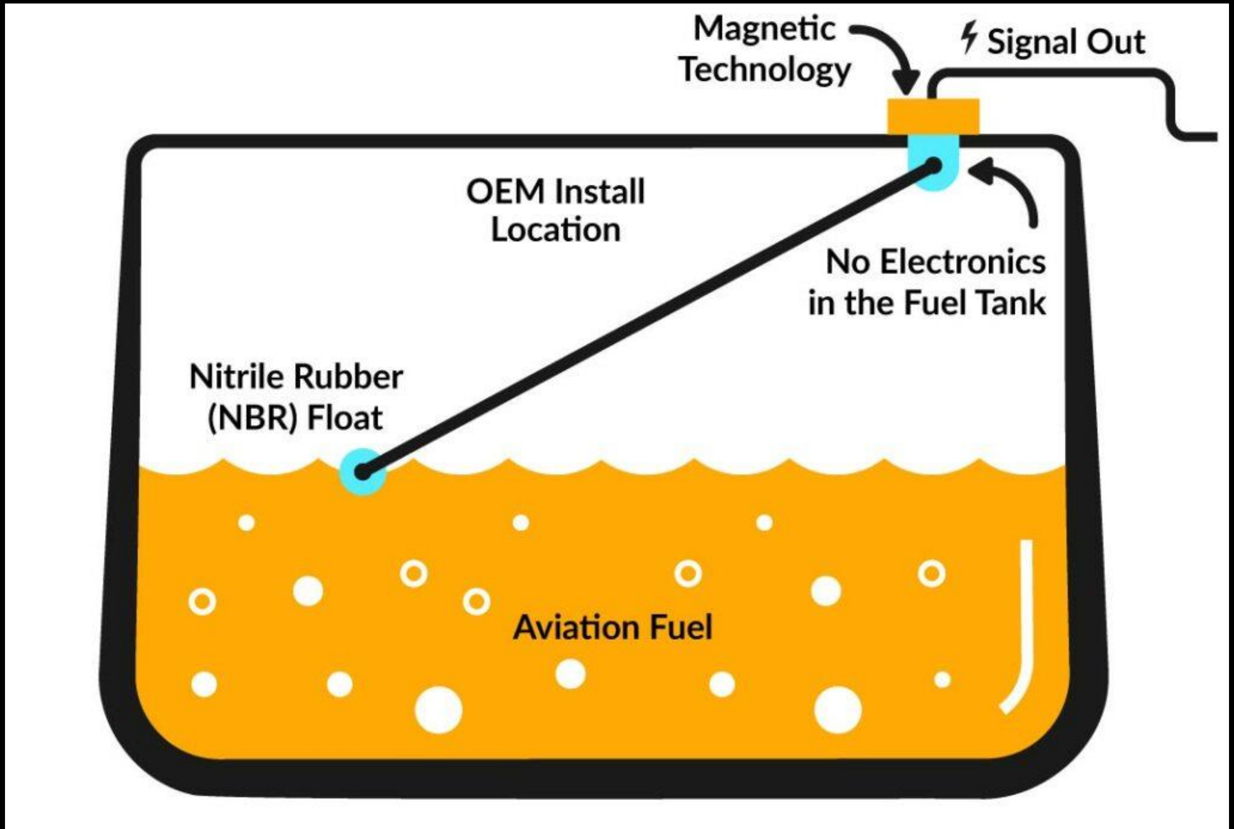
Fuel Primer

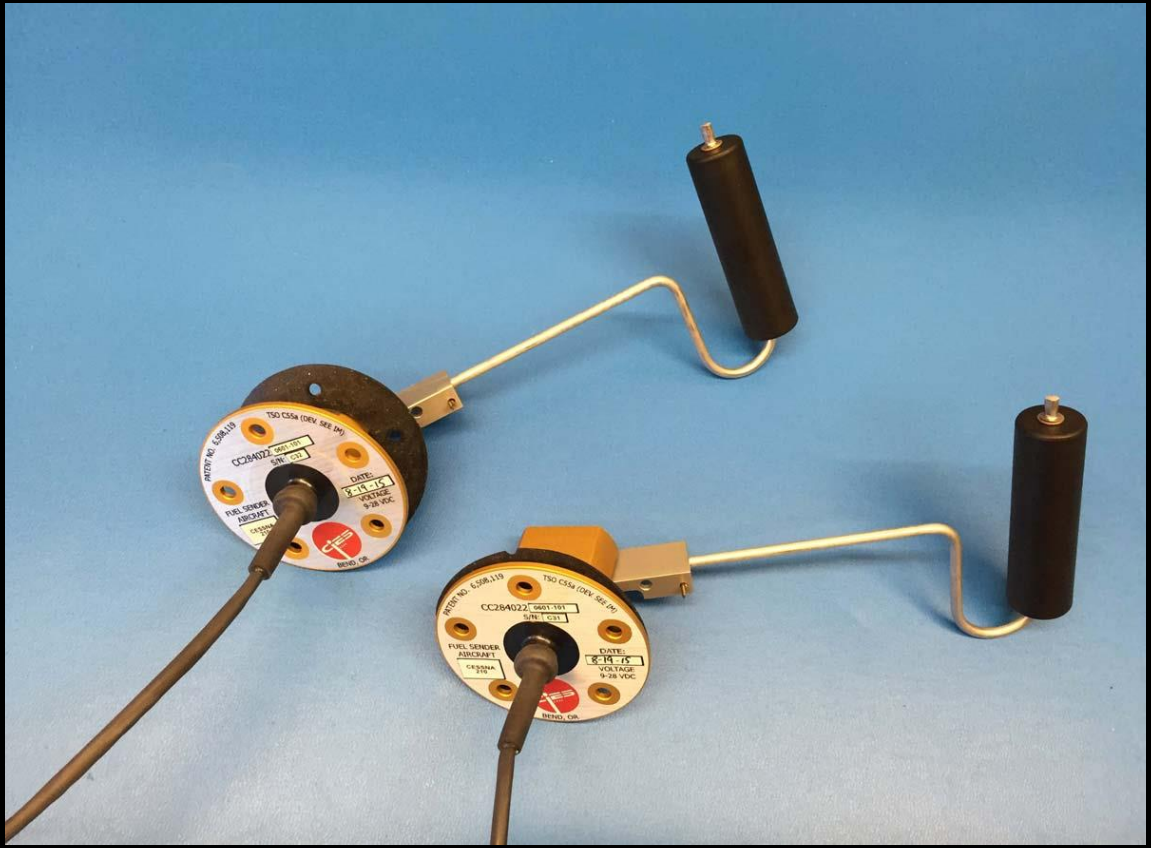
- Draws fuel from the tanks to vaporize directly into the cylinders before starting the engine.
- Useful in cold weather when there's insufficient heat to vaporize fuel in the carburetor.
- Important to lock the primer; if unlocked, it may vibrate out of position during flight, causing an excessively rich fuel-air mixture.

Fuel Gauges

- Fuel indication by sensing unit in gallons/pounds.
- Certification rules for accuracy at "full" or "empty."
- Verify readings other than "empty."
- Don't solely rely on fuel quantity gauges.
- Visually check fuel level during preflight.
- Compare with corresponding fuel quantity indication.
- Fuel pump presence includes a fuel pressure gauge indicating line pressure.

Fuel Gauges


Magnetic Technology
Signal Out
OEM Install Location
No Electronics in the Fuel Tank
Nitrile Rubber (NBR) Float
Aviation Fuel



Fuel Selectors

- Tank Options: LEFT, RIGHT, BOTH, OFF (Pipers lack BOTH).
- LEFT/RIGHT: Feed from respective tank.
- BOTH: Feed from both tanks.
- Balance Fuel: LEFT/RIGHT for wing tank balance.

Fuel Placards

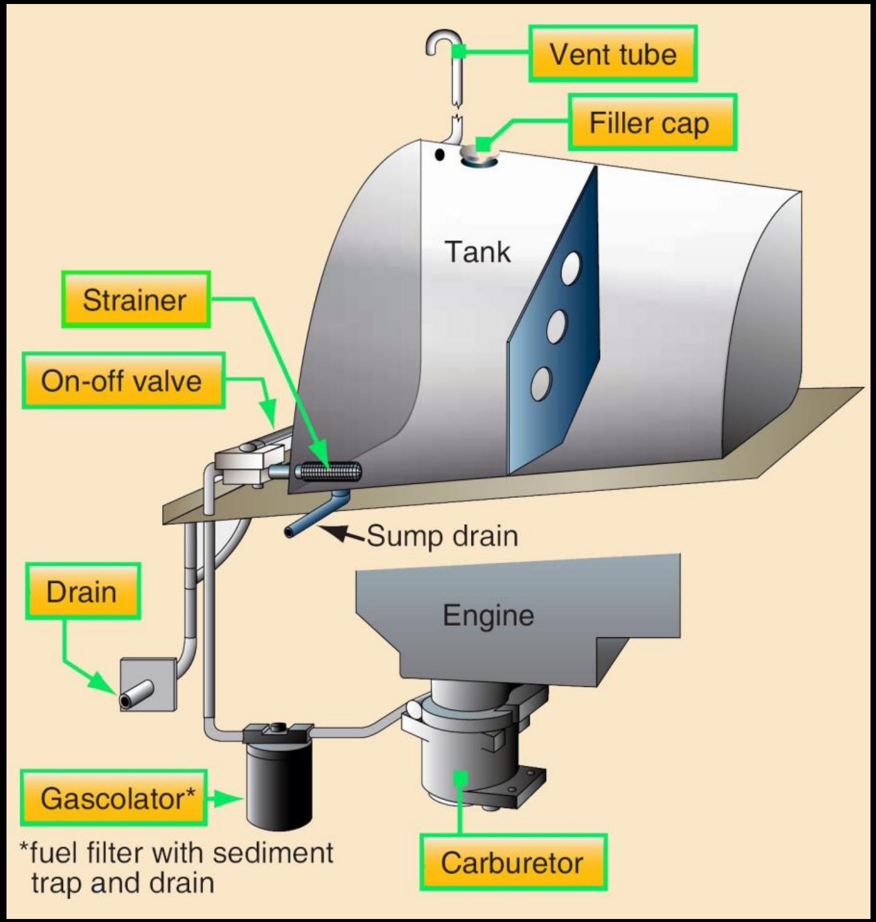
- Fuel Tank Limitations: Be aware of usage restrictions like "level flight only" or "both" for landings/takeoffs.
- Monitor Fuel: Watch fuel consumption closely to avoid running tanks completely dry.
- Risks of Running Dry: Engine stoppage, unbalanced fuel load, and potential vapor lock.
- Vapor Lock (Fuel-Injected Engines): Running dry can cause fuel to vaporize, hindering cylinder fuel supply.

Water

- The most frequent contaminant found in fuel
- Water (8 lb/gal) is heavier than fuel (6 lb/gal)
- If present, water rests on the bottom of fuel tanks where it's the first thing to go to the engine
- To avoid water contamination, fill the fuel tanks after the last flight of the day
- Air usually contains moisture, which when cooled condenses
- By filling the tanks, the air (and its moisture) is forced out

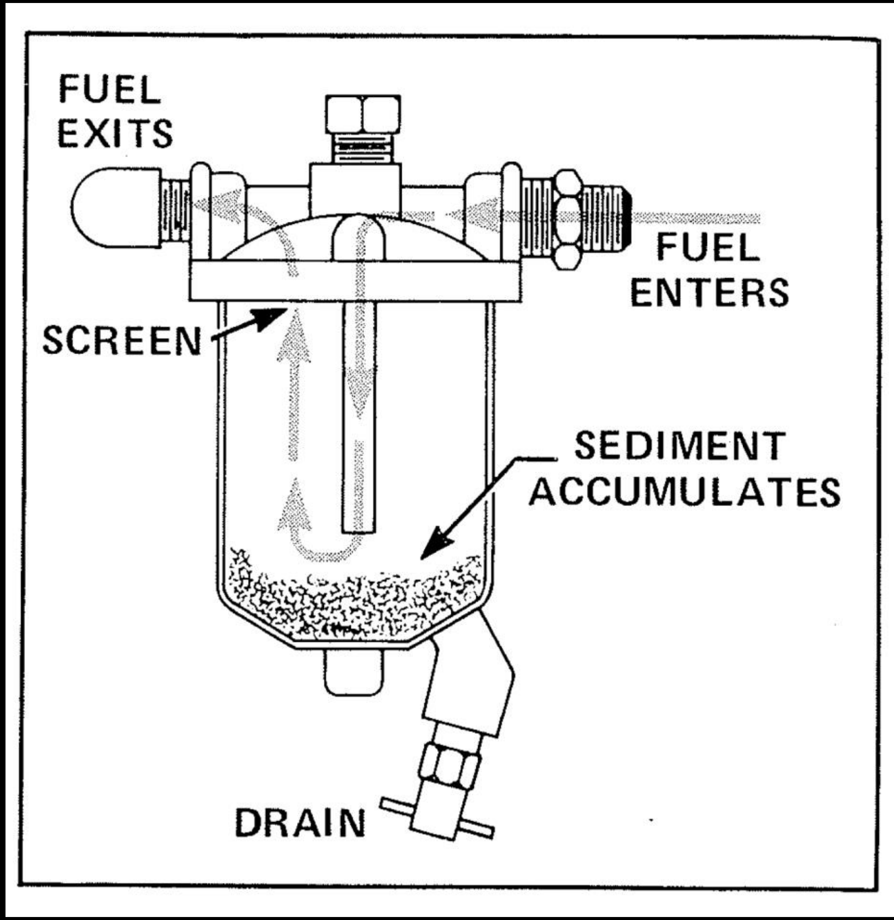
Fuel Strainers, Sumps, and Drains

- Fuel undergoes straining before entering the carburetor.
- Strainer removes moisture and sediments.
- Contaminants, being heavier, settle in a sump.
- Sump serves as a low point in the fuel system.
- Components like sump, fuel strainer, and tank drains may be present in the system.



Fuel Strainers, Sumps, and Drains

- The fuel strainer should be drained before each flight
- Fuel samples should be drained and checked visually for water and contaminants



Water in Sump

- Water in the sump can freeze in cold weather, blocking fuel lines.
- In warm weather, it may flow into the carburetor, causing engine stoppage.
- Presence in the sump indicates likely water in fuel tanks.
- Drain tanks until no evidence of water before takeoff.
- Ensure removal of all water and contaminants from the engine fuel system.

Fuel Grades

- AVGAS identified by octane or performance number.
- Higher grade withstands more pressure without detonation.
- Lower grades for lower-compression engines, ignite at lower temperatures.
- Higher grades for higher-compression engines, ignite at higher temperatures without premature detonation.

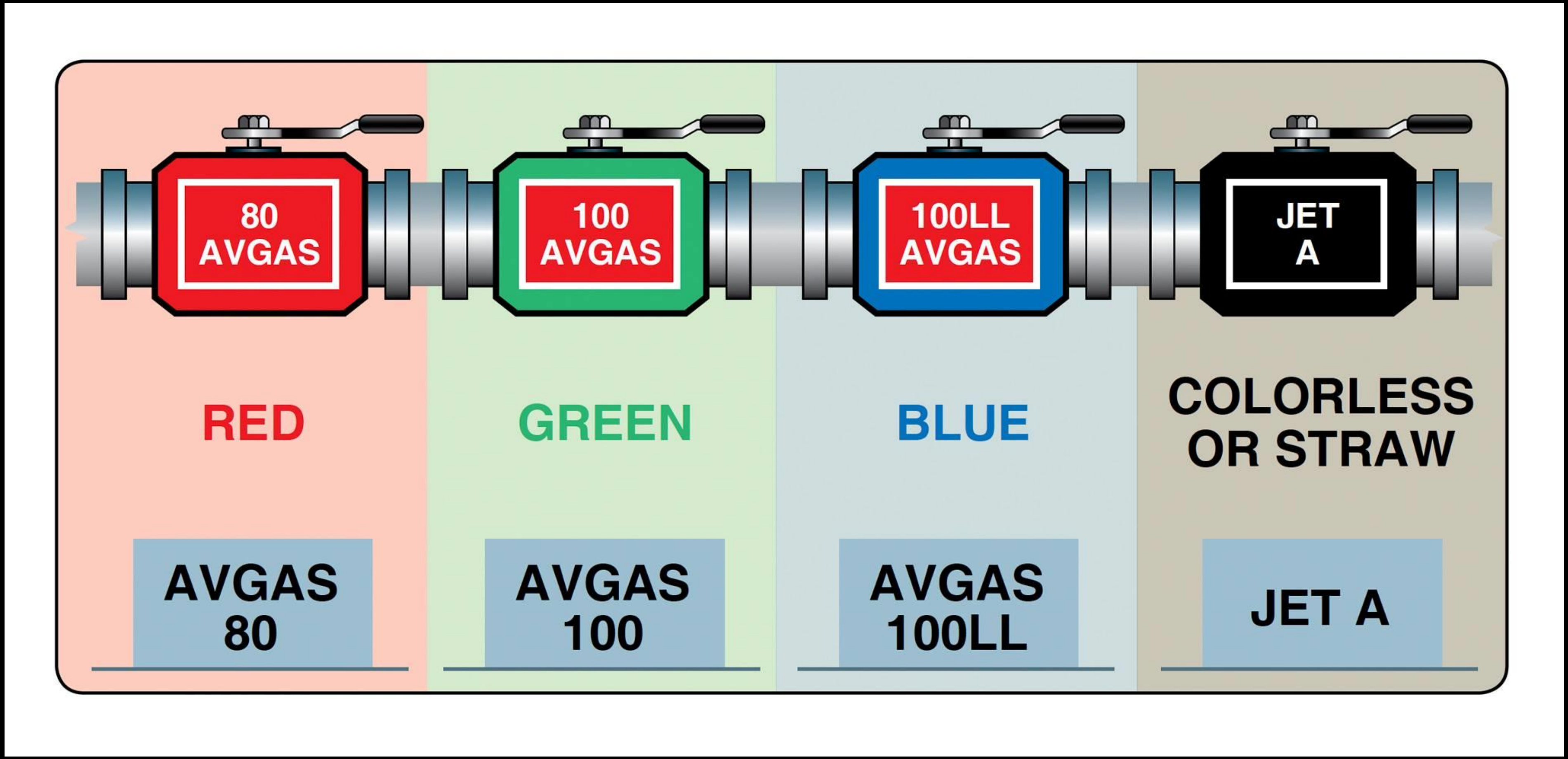
Fuel Grades

- If the proper grade of fuel is not available use the next higher grade as a substitute
- Never use a grade lower than recommended
- This can cause the cylinder head temperature and engine oil temperature to exceed normal operating ranges resulting in detonation

Fuel Grades

- Aircraft with reciprocating engines use AVGAS 80, 100, and 100LL
- Note: Only 100LL is available today
- Jet fuel is basically kerosene and has a distinctive kerosene smell
- Since use of the correct fuel is critical dyes are added to help identify the type and grade of fuel

Fuel Grades


80
AVGAS
100
AVGAS
100LL
AVGAS
JET
A
RED
GREEN
BLUE
COLORLESS
OR STRAW
AVGAS
80
AVGAS
100
AVGAS
100LL
JET A

Automobile Gasoline

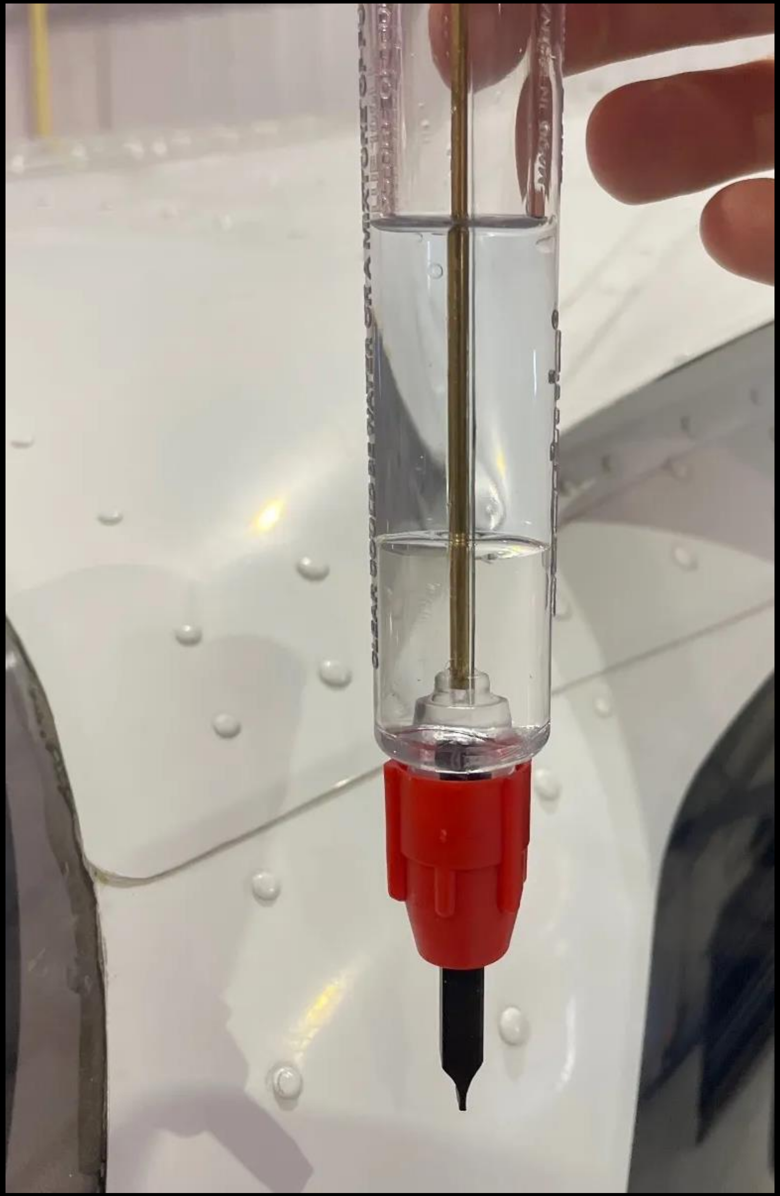
- Never use automobile gasoline in your airplane unless specific approval, in the form of a Supplemental Type Certificate (STC) has been issued for your aircraft
- An STC is FAA permission for a modification to the original configuration or operating parameters of the airplane
- Granted after extensive testing and documentation
- Includes very specific instructions that must be followed

Fuel Contamination

- Accidents attributed to powerplant failure from fuel contamination have often been traced to:
  - Inadequate preflight inspection by the pilot
  - Servicing aircraft with improperly filtered fuel from small tanks or drums
  - Storing aircraft with partially filled fuel tanks (condensation)
  - Lack of proper maintenance

Draining Fuel

- Drain fuel from strainer and each tank sump into a transparent container.
- Check for dirt and water.
- Water may not appear until all fuel is drained.
- Drain enough from strainer to ensure fuel is being drained from the tank.



Draining Fuel

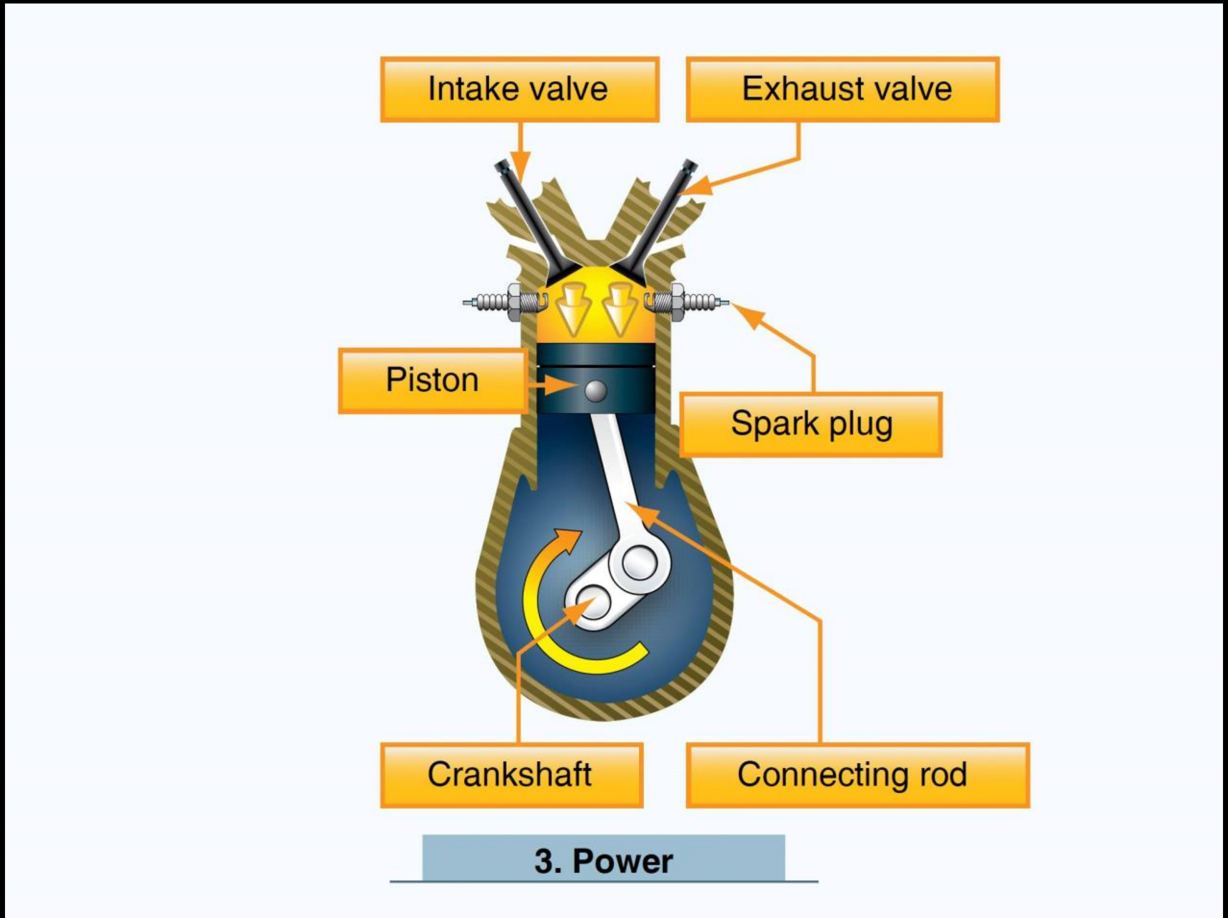
- Drain additional samples if water or contaminants found.
- Drain fuel sumps before every flight in preflight inspection.
- Fill fuel tanks after each flight or last flight of the day to prevent moisture condensation.

Fuel

- What can go wrong?

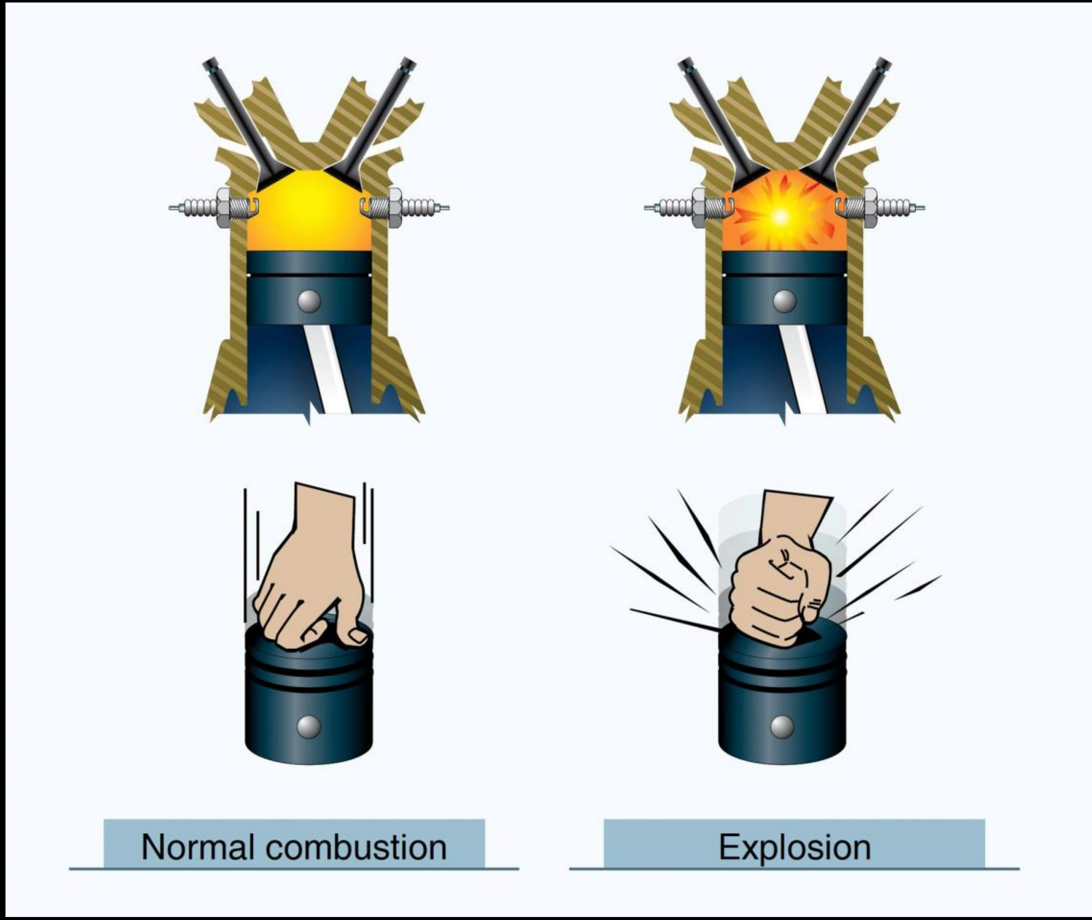
Normal Combustion

- Normal combustion is controlled and predictable.
- It starts at the point ignited by spark plugs.
- Burns away from plugs until completely consumed.
- Results in smooth build-up of temperature and pressure.
- Occurs at the right time in the power stroke.

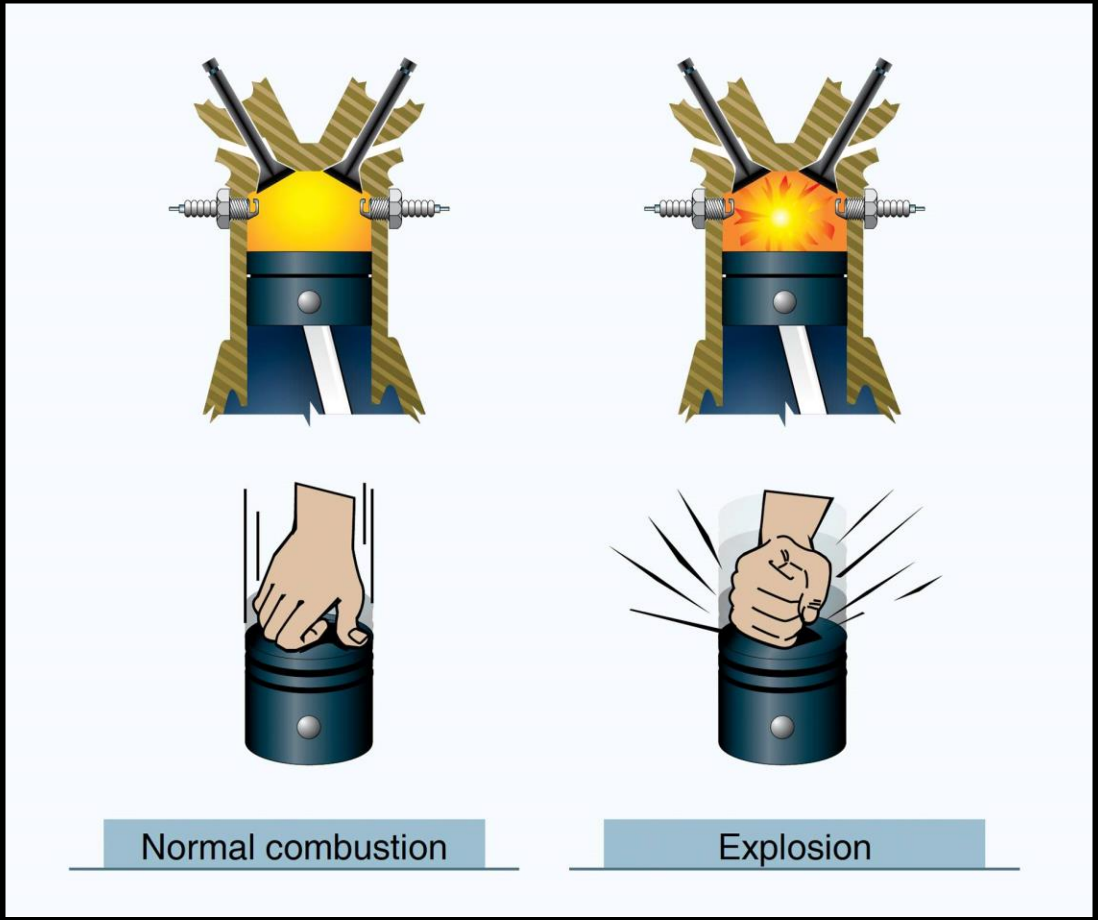


Detonation

- Uncontrolled, explosive ignition in the combustion chamber.
- Causes excessive temperatures and pressures.
- Can lead to failure of piston, cylinder, or valves if not corrected.



Detonation



- In less severe cases causes engine overheating, roughness, or loss of power
- Characterized by high cylinder head temperatures and most likely to occur when operating at high power settings

Causes of Detonation

- Using lower fuel grade than specified.
- High manifold pressures with low rpm.
- High power settings with excessively lean mixture.
- Extended ground operations or steep climbs reducing cylinder cooling.

Preventing Detonation

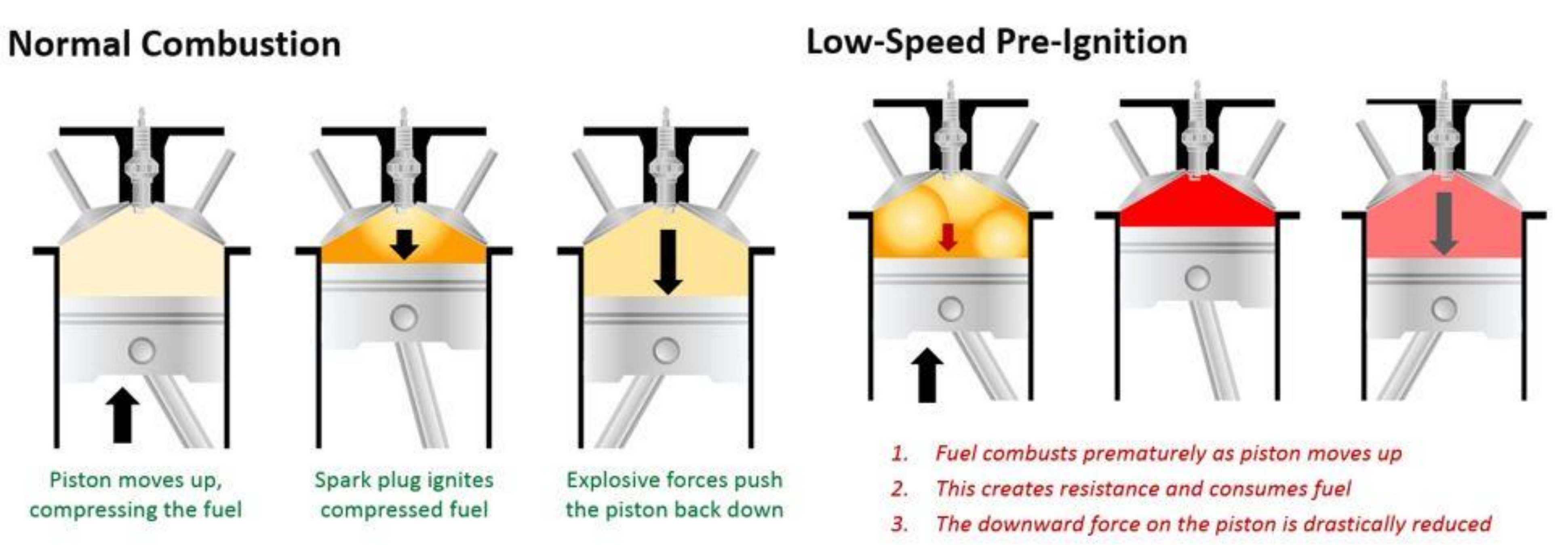
- Use proper fuel grade.
- Keep cowl flaps fully open on the ground.
- Use enriched fuel mixture and shallow climb angle for better cylinder cooling during takeoff and climb.

Preventing Detonation

- Avoid extended, high power, steep climbs
- Operate the engine within its proper temperature, pressure, and rpm ranges
- Monitor engine instruments to verify proper operation according to procedures established by the manufacturer

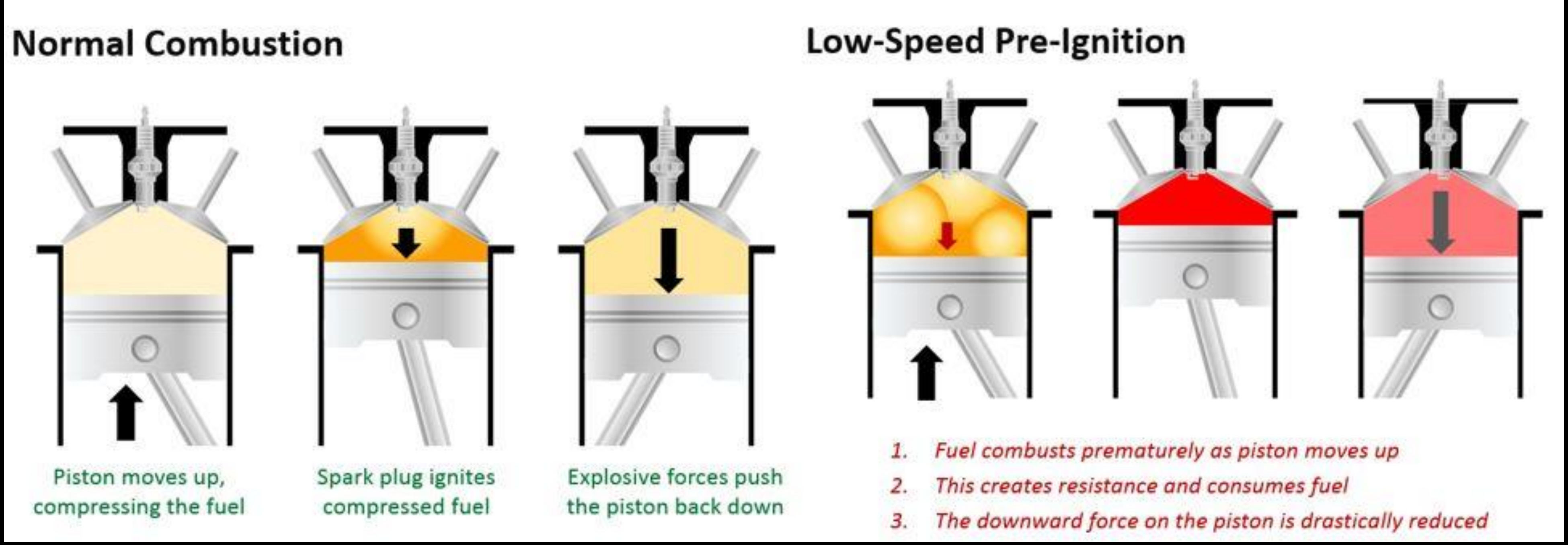
Pre-Ignition

- Premature ignition due to a hot spot in the combustion chamber.
- Hot spot caused by carbon deposit, cracked spark plug, or cylinder damage.



Pre-Ignition

- Causes the engine to lose power and produces high operating temperature
- May cause severe engine damage because the expanding gases exert excessive pressure on the piston while still on its compression stroke



Oil System Functions

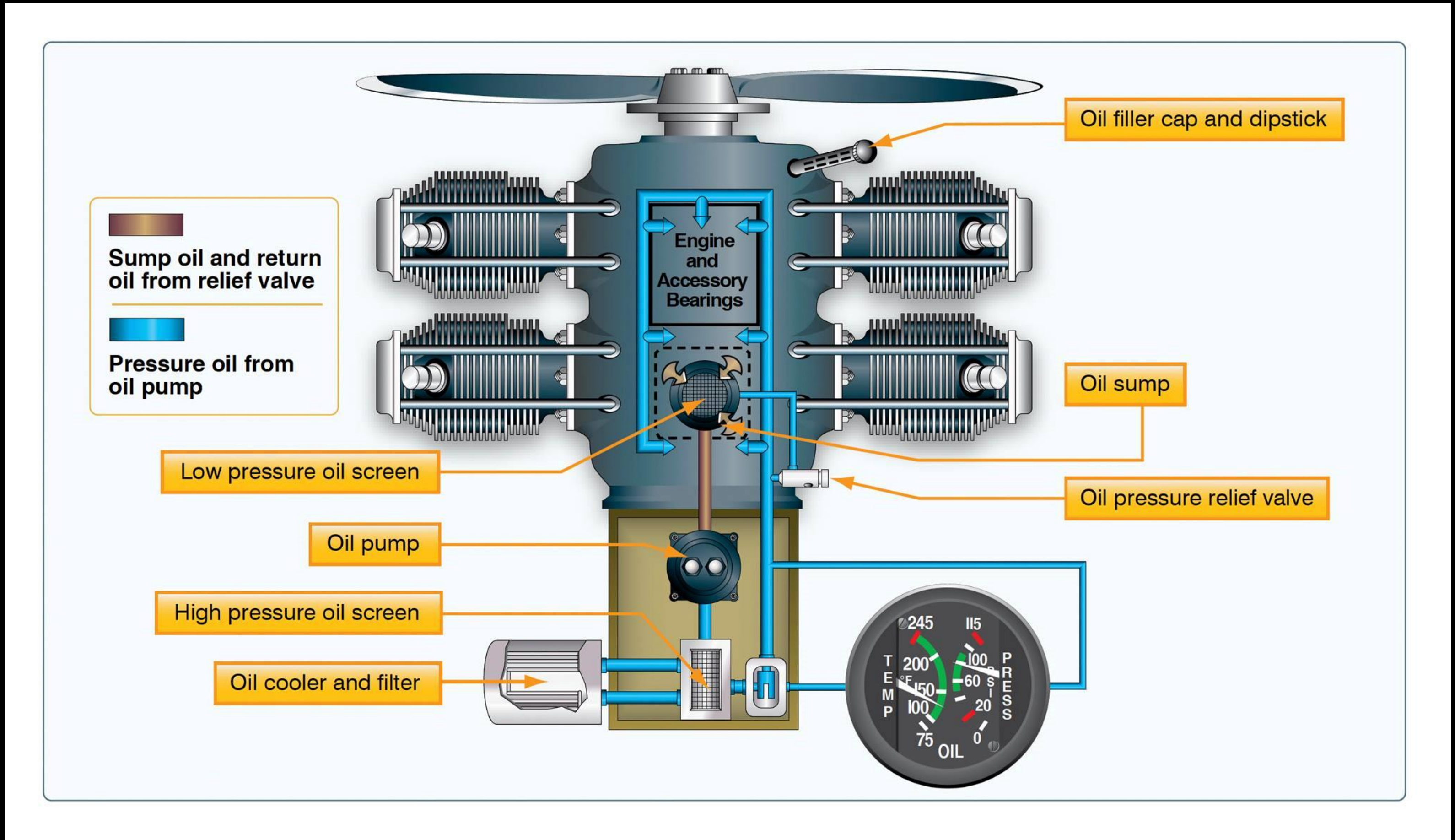
- Lubrication of the engine's moving parts
- Cooling of the engine by reducing friction
- Removing heat from the cylinders
- Providing a seal between the cylinder walls and pistons
- Carrying away contaminants

Oil System Sumps

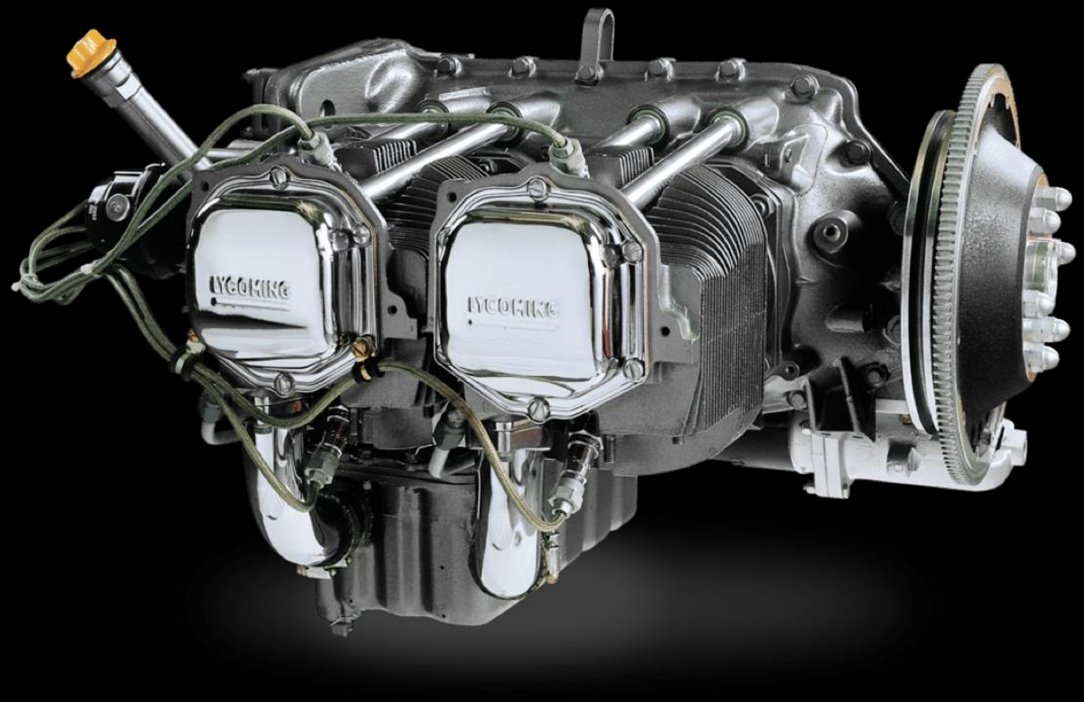
- Reciprocating engines use wet-sump or dry-sump oil systems.
- Wet-sump: Oil located in an integral sump.
- Dry-sump: Oil in a separate tank, circulated by pumps.

Wet-Sump System

- Main component: Oil pump draws oil from the sump and routes it to the engine.
- After passing through the engine, oil returns to the sump.
- Some engines use crankshaft rotation for additional lubrication by splashing oil onto engine parts.

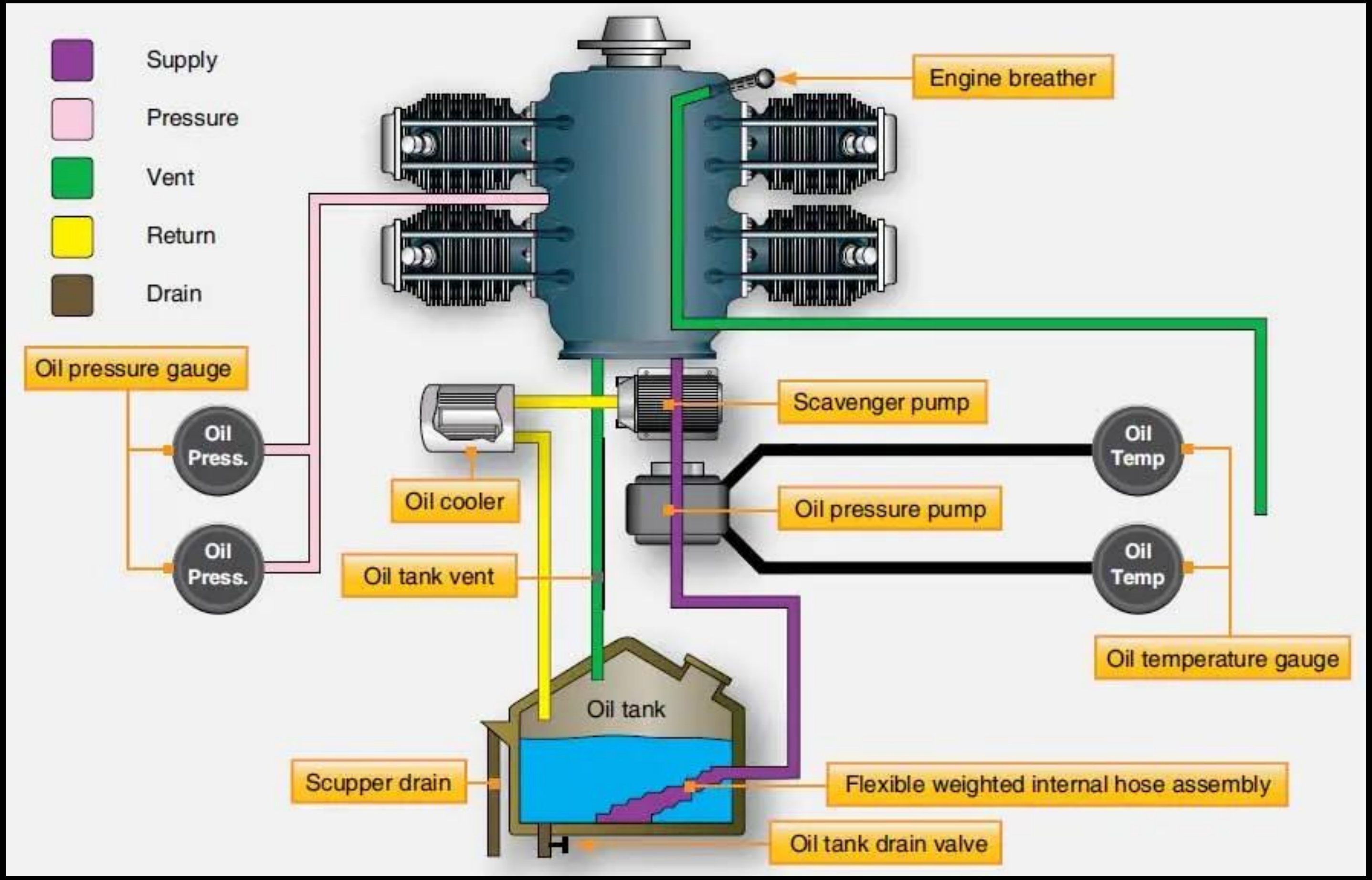


Wet Sump

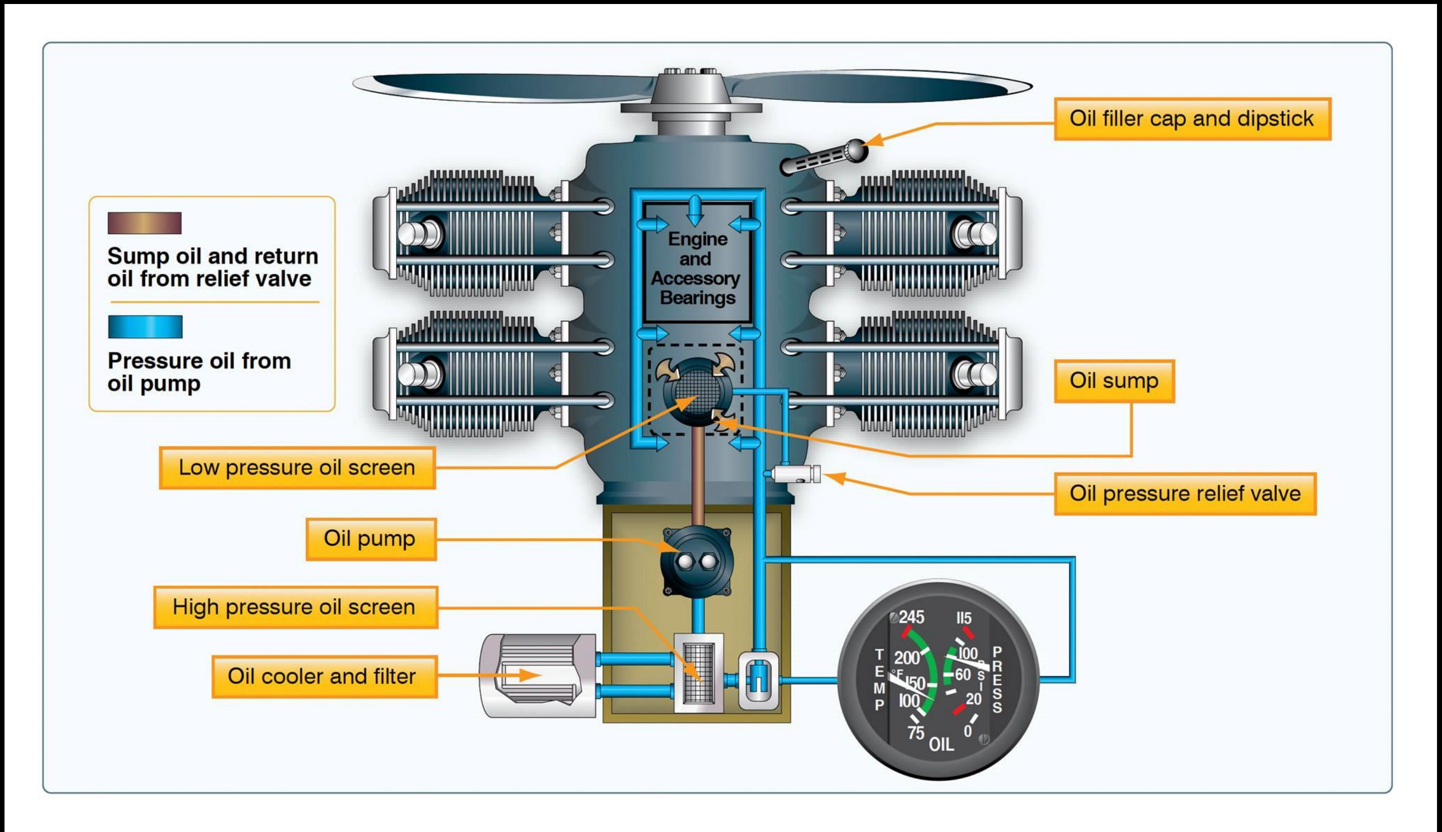


Dry Sump System

- Oil pump provides pressure in a dry-sump system.
- Oil source external to the engine in a separate oil tank.
- Scavenge pumps route oil from various engine locations back to the oil tank.



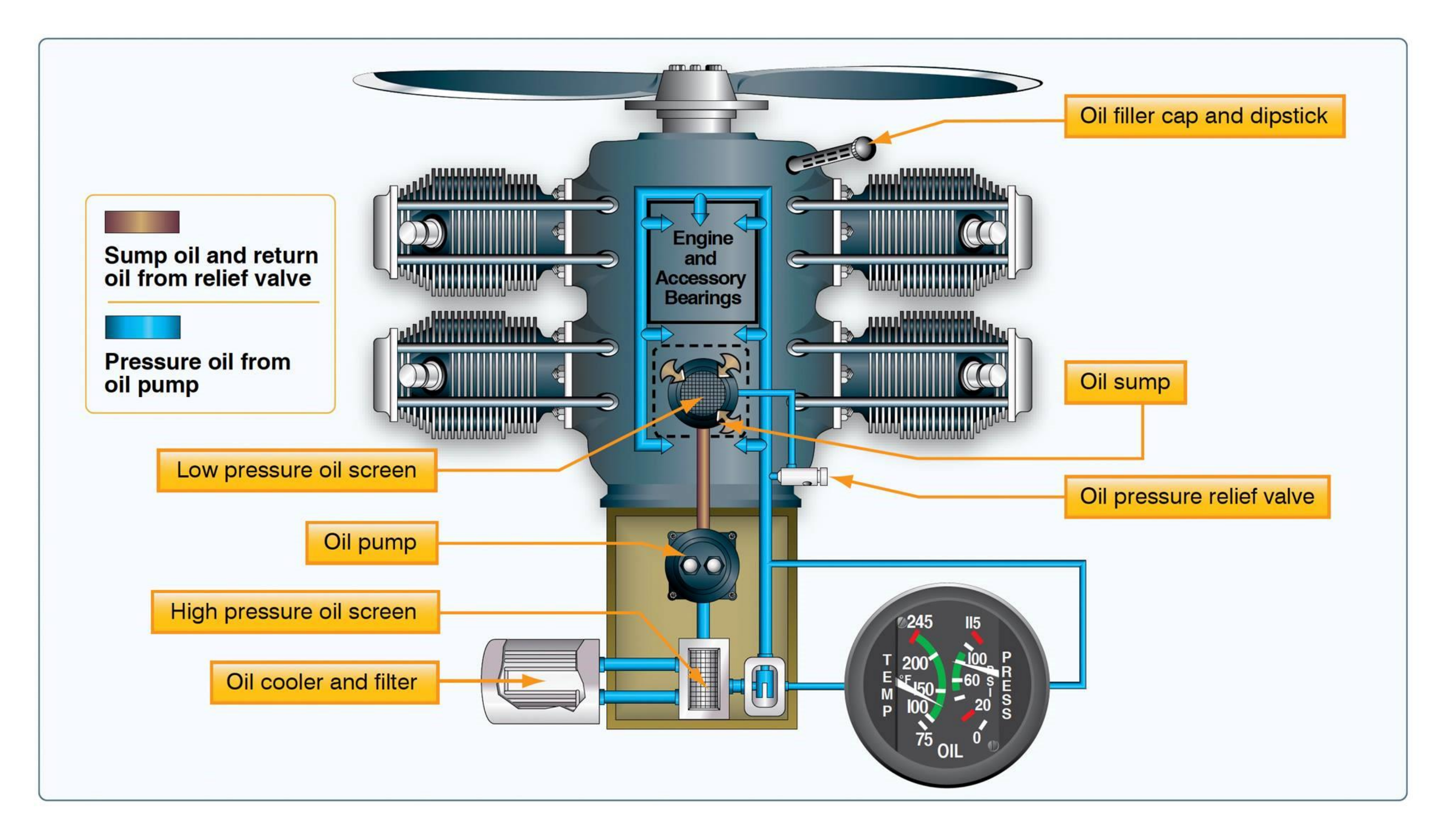
Oil Pressure Gauge



- Oil pressure gauge measures pressure in psi.
- Green range is normal operating pressure, red indicates minimum and maximum.
- Oil pressure indication should be present during engine start.

Oil Temperature Gauge

- Measures the temperature of oil
- Green area shows the normal operating range
- Red line indicates the maximum allowable temperature



Low or Fluctuating Oil Pressure

- After start, adjust to 1,000 RPM and check oil pressure gauge.
- Needle should enter the green arc within 30 seconds.
- Shutdown if not, possible issues include pump failure, leaks, low oil, cold oil, or a stuck relief valve.

Low or Fluctuating Oil Pressure

- Decrease in oil pressure during flight is serious.
- Engine cooling decreases significantly.
- Oil temperature should rise with falling pressure.
- If not, oil pressure gauge may be faulty.
- Best solution: Land ASAP.

High Oil Pressure

- Oil pressure relief valve prevents high pressure.
- Ensures oil doesn't damage engine seals.
- Normal for oil pressure to decrease as engine heats up.

Oil Temperature

- High oil temperature indications may signal a plugged oil line, a low oil quantity, a blocked oil cooler, or a defective temperature gauge
- Low oil temperature indications may signal improper oil viscosity during cold weather operations

Oil Temperature

- Oil temperature changes slowly.
- Takes time to increase after starting a cold engine.
- Check oil temperature periodically, especially in extreme temperatures.

Low Oil Temperature

- In very cold conditions, oil pressure may take 30 seconds to rise.
- Cold oil needs time to circulate properly to prevent engine wear.
- Preheating engines in extreme cold is common to prevent damage during startup.

High Oil Temperature

- Insufficient oil in the engine leads to high oil temperature.
- Excessive temperature can result in oil consumption, power loss, and detonation.
- Internal engine damage may occur, including scoring cylinder walls and damaging pistons, rings, valves, etc.
- Pilot actions include climbing at a higher airspeed, lowering the nose, opening cowl flaps, leveling off, or descending to cool the engine.

Oil Quantity

- Oil filler cap and dipstick are accessible through an engine cowling panel.
- Check oil quantity using the dipstick; add oil if below recommended levels.
- Refer to AFM/POH or placards for correct oil type, weight, and quantity limits.

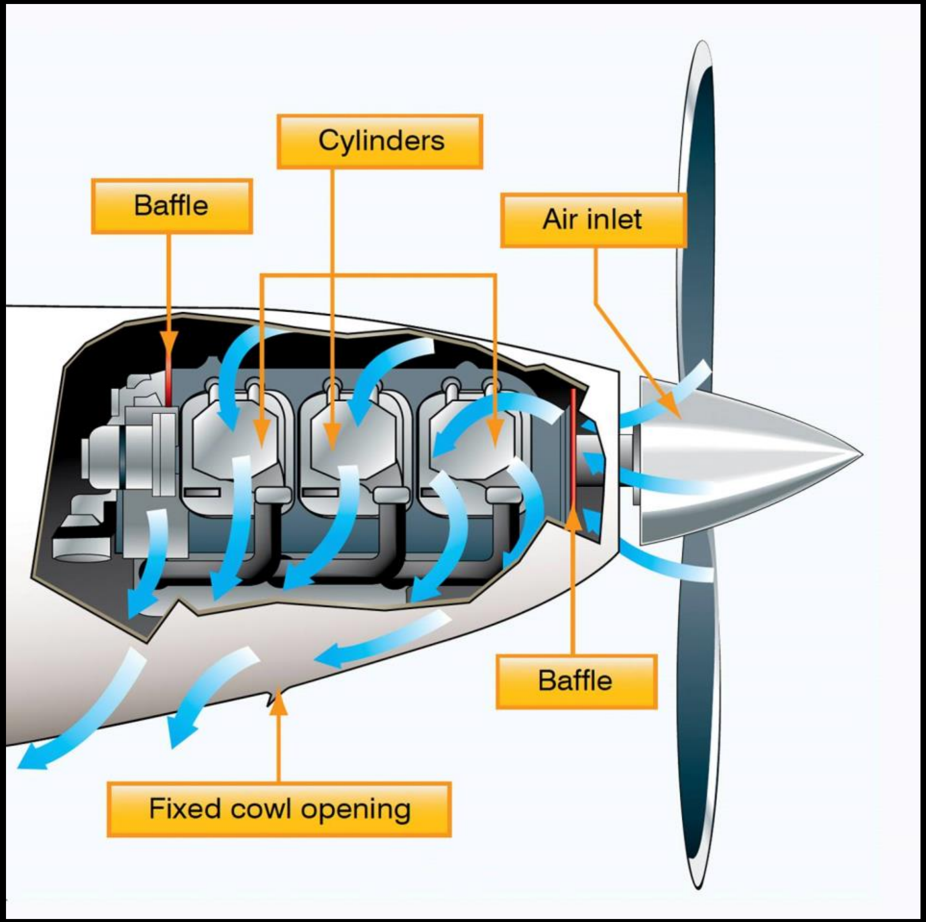
Engine Cooling

- Burning fuel generates intense heat in the cylinders.
- Excess heat must be dissipated to prevent engine overheating.
- High temperatures can cause power loss and serious damage.
- Air cooling is a common method for small aircraft engines.

Cylinder Fins

Air Cooling

- Air cooling involves airflow through front cowling openings.
- Baffles direct air over fins attached to cylinders and engine parts.
- Air absorbs engine heat during this process.
- Hot air is expelled through openings in the lower aft cowling.



Temperature Effects on Engines

- Air-cooling less effective during high-power, low-airspeed operations.
- Operating at higher than designed temperature causes issues.
- Potential consequences: power loss, oil consumption, detonation, and serious engine damage.

Engine Temperature Monitoring

- Gauges aid in avoiding high operating temperatures.
- Engine temperature control by changing airspeed or power output.
- Increasing airspeed or reducing power decreases high engine temperatures.
- Oil temperature gauge provides indirect indication of rising engine temperature.

Excessive Cooling

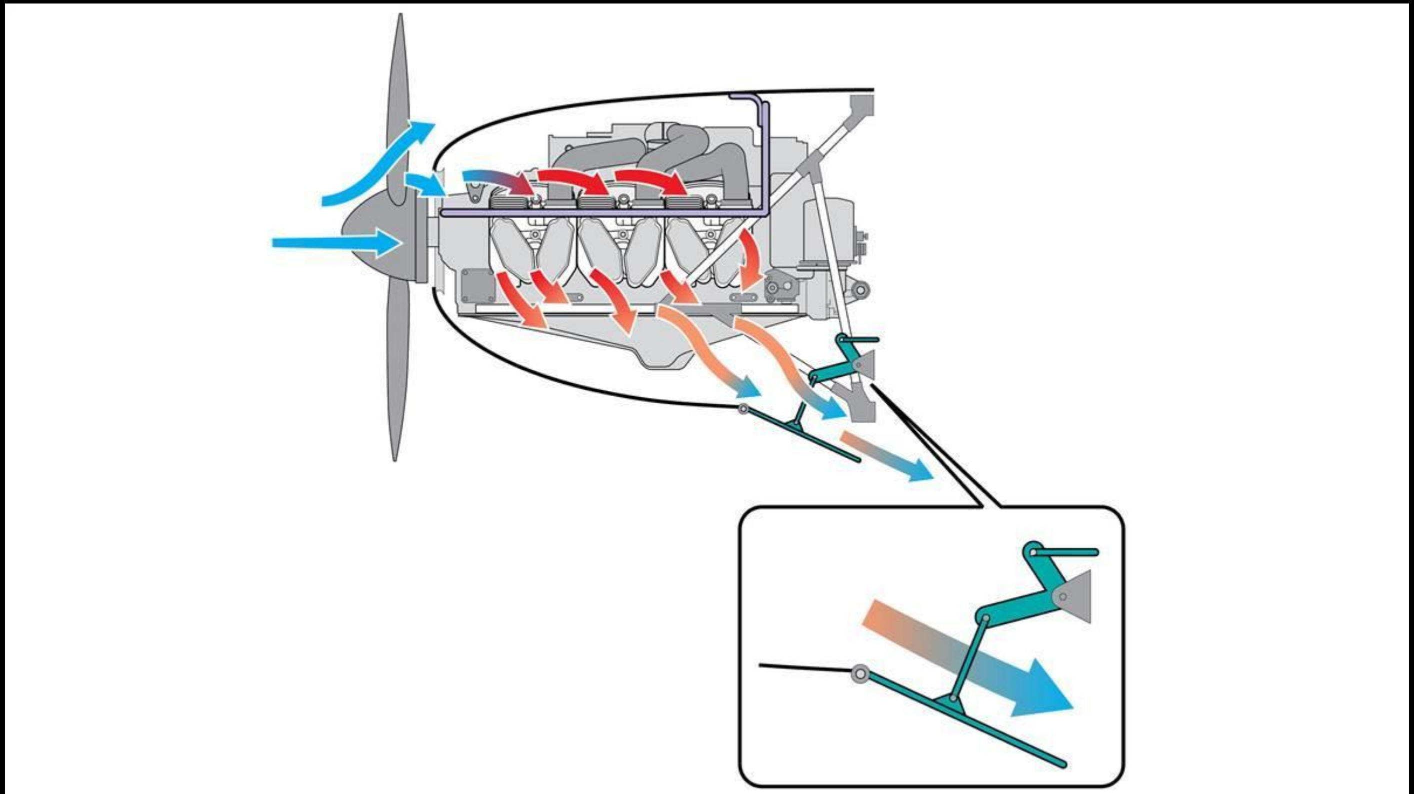
- High-speed descents under low power conditions provide excess air and can shock cool the engine, subjecting it to abrupt temperature fluctuations
- The various metals of the cylinders cool suddenly and at different rates
- Plan your descents to maintain some power to prevent the engine from overcooling
- Prevent the CHT and EGT from decreasing too quickly

Cylinder Head Temperature

- CHT provides direct and immediate cylinder temperature change.
- Green arc indicates normal operating range.
- Red line shows maximum allowable cylinder head temperature.
- To avoid excessive CHT, increase airspeed, enrich fuel-air mixture, and/or reduce power.

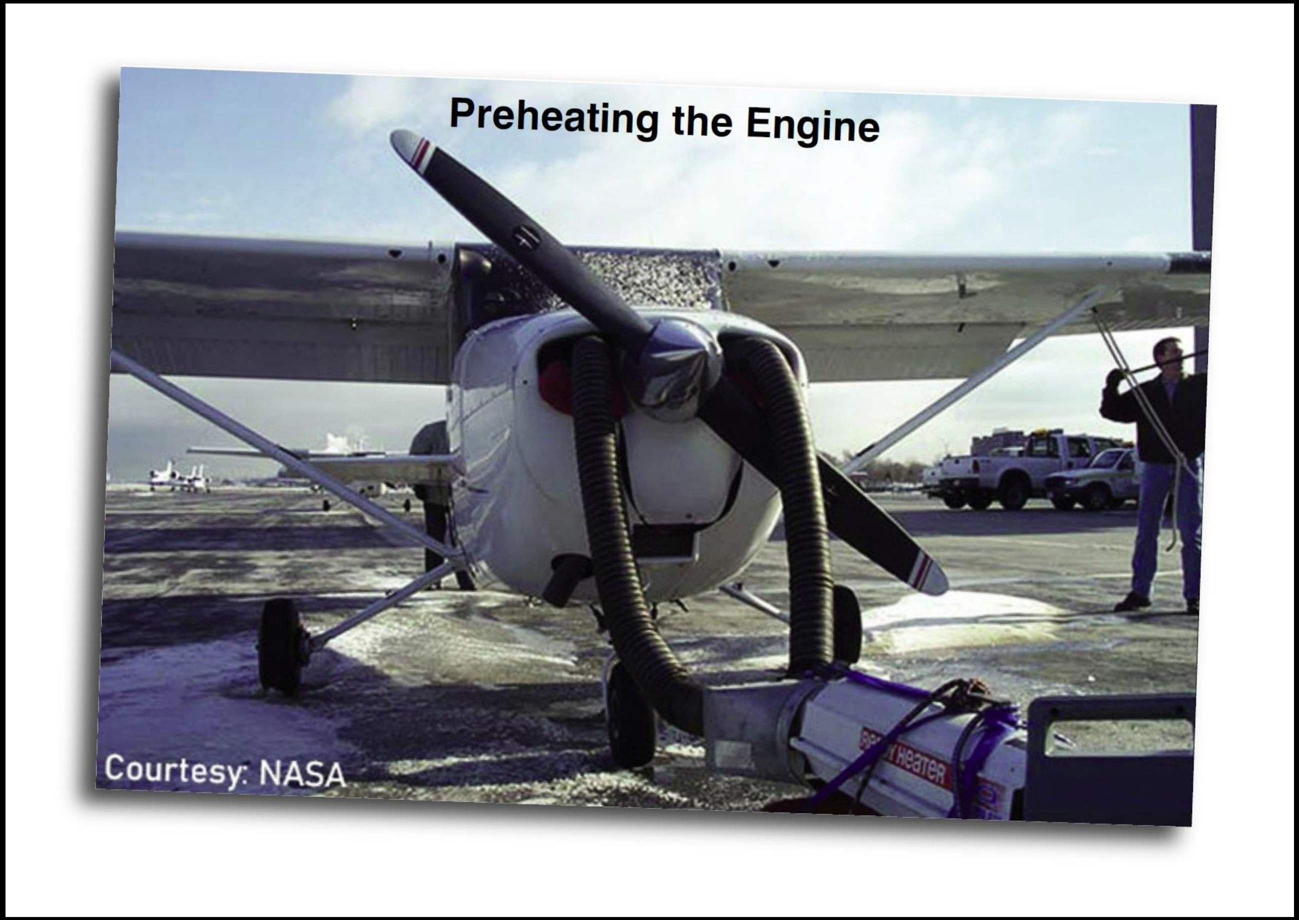
Cowl Flaps

- Cowl flaps are hinged covers over the opening for expelled hot air.
- Closing cowl flaps increases engine temperature.
- Opening cowl flaps decreases engine temperature when it's high.



Fuel Fired Heaters

- Used to pre-heat engine and cabin

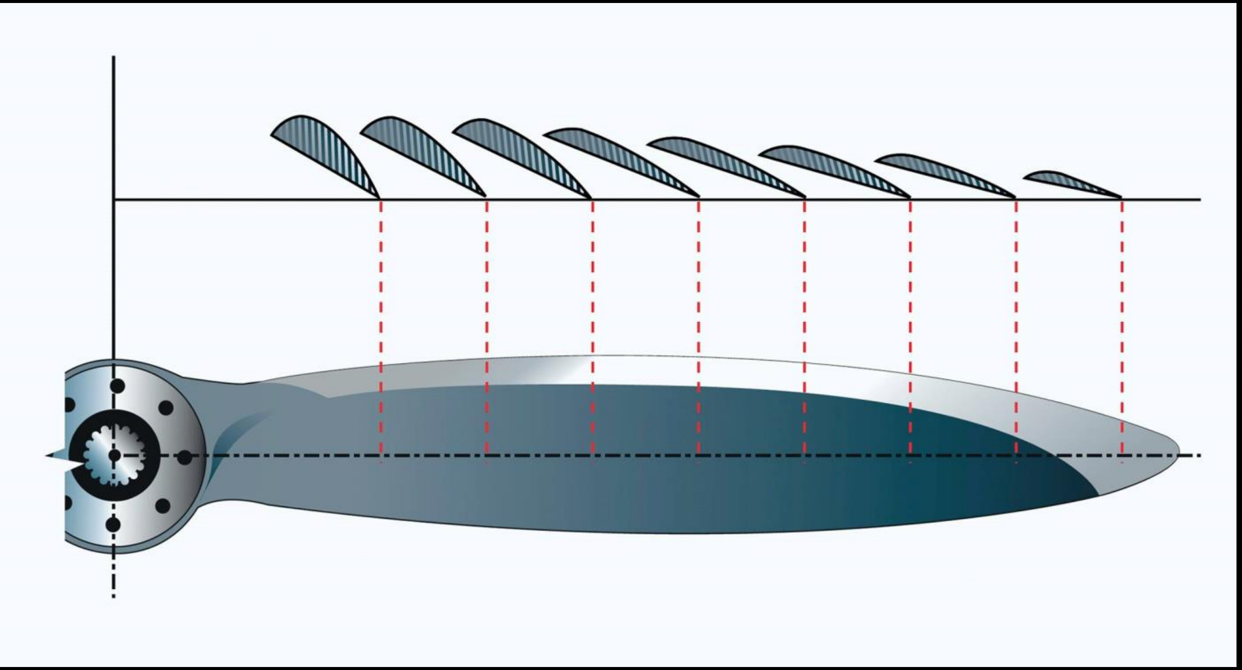


Propellers

- Propeller generates thrust similar to a wing producing lift.
- Induced drag, stalls, and aerodynamic principles apply to the rotating airfoil.
- Engine power rotates the propeller, determining thrust based on airfoil shape, angle of attack, and RPM.

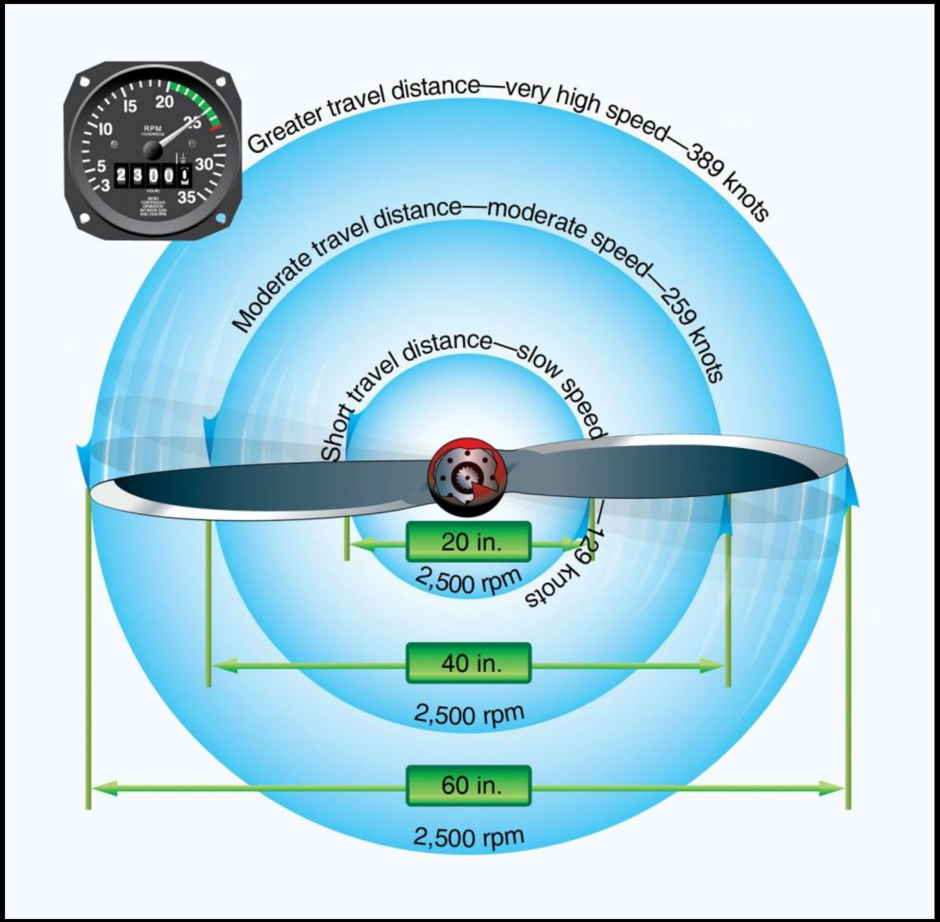
Propeller Twist

- The propeller is twisted to change the blade angle from hub to tip.
- Greatest pitch at the hub, smallest pitch at the tip for uniform lift.
- Twist compensates for the difference in speed along the blade as it rotates.

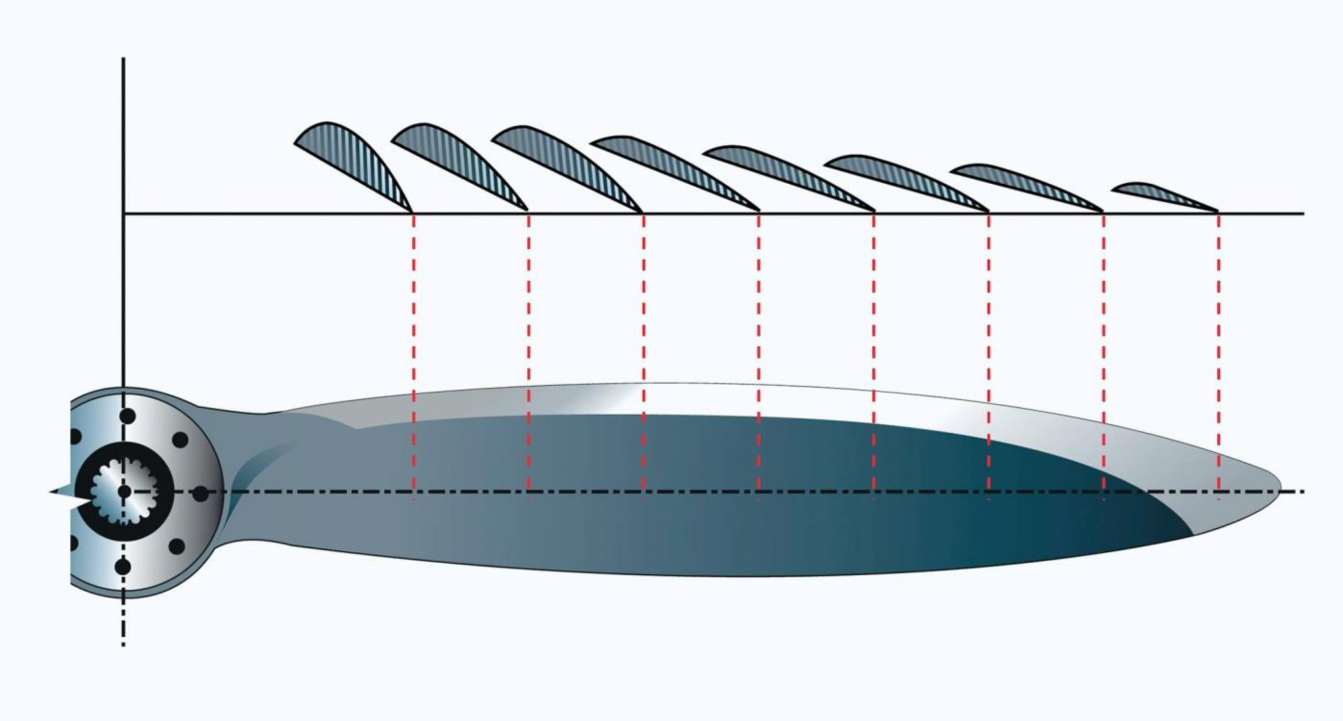


Propeller Twist

- The tip of the blade travels faster than the part near the hub, because the tip travels a greater distance than the hub in the same length of time



Propeller Twist



- Angle of incidence changes from hub to tip for uniform lift.
- Uniform lift prevents inefficiencies and stalls at varying airspeeds.

Types of Propellers

- Small aircraft are equipped with either one of two types of propellers
  - Fixed-pitch or
  - Constant speed

Fixed-Pitch Propeller

- Fixed-pitch propellers have a set blade angle by the manufacturer.
- Efficiency is compromised as it's optimized for specific airspeed and RPM.
- Suitable for applications where low weight, simplicity, and cost are crucial.

Propeller RPM

- Propellers can be mounted directly on the engine crankshaft or on a shaft geared to the crankshaft.
- Direct mounting results in propeller RPM matching engine RPM.
- Geared mounting allows different RPM for the propeller compared to the engine.

Tachometer

- Tachometer indicates engine power in fixed-pitch propeller setups.
- Calibrated in hundreds of RPM.
- Green arc signifies the maximum continuous operating RPM.
- May have additional markings for specific limitations.

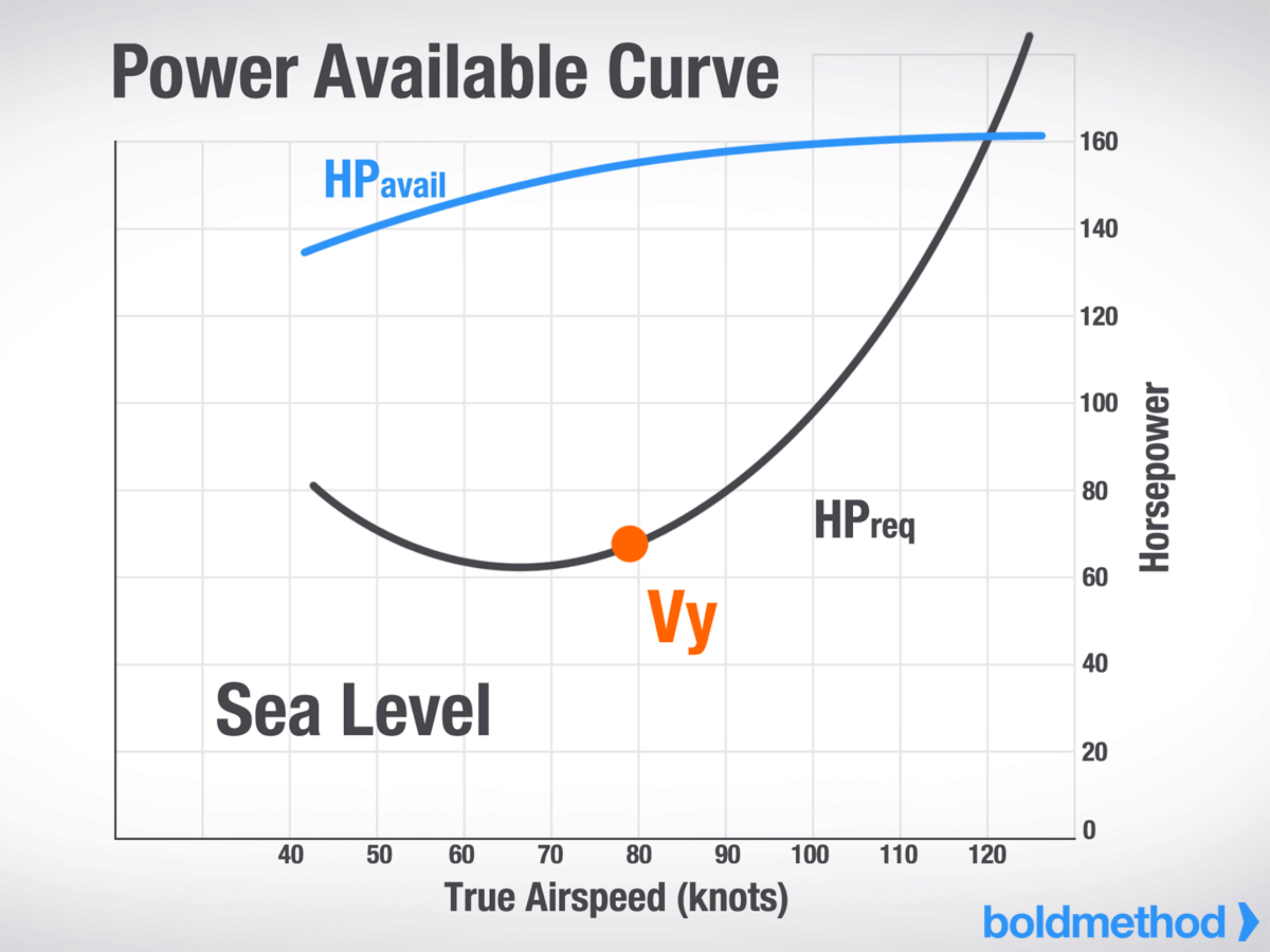
RPM Regulation

- RPM is regulated by the throttle, which controls the fuel/air flow to the engine
- At a given altitude, the higher the tachometer reading, the higher the power output of the engine
- When operating altitude increases, the tachometer may not show correct power output of the engine

RPM Regulation

- For example, 2,300 rpm at 5,000 feet produces less horsepower than 2,300 rpm at sea level because power output depends on air density
  - Power output depends on air density.
- Decrease in air density at higher altitudes reduces engine power.
- Throttle position needs adjustment with changing altitude to maintain the same RPM.
- Higher altitude requires opening the throttle further for the same RPM as at lower altitudes.

RPM Regulation

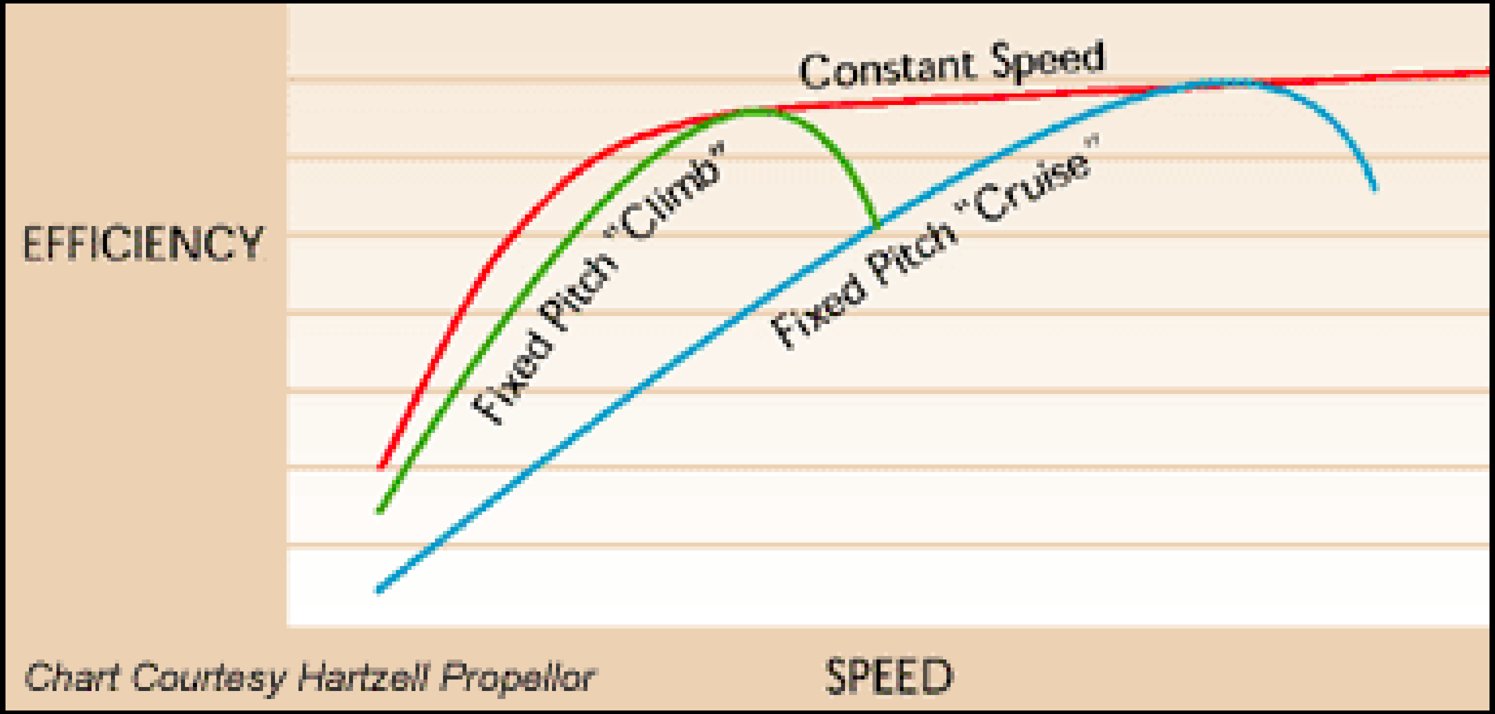


Constant-Speed Propeller

- Constant-speed propeller automatically adjusts pitch to maintain constant RPM.
- Governor ensures constant RPM despite varying air loads.
- Converts a high percentage of brake horsepower (BHP) into thrust horsepower (THP).
- More efficient than other propellers, allowing selection of the most efficient engine RPM for given conditions.

Propeller Efficiency

- Ratio of THP to BHP



Engine Controls

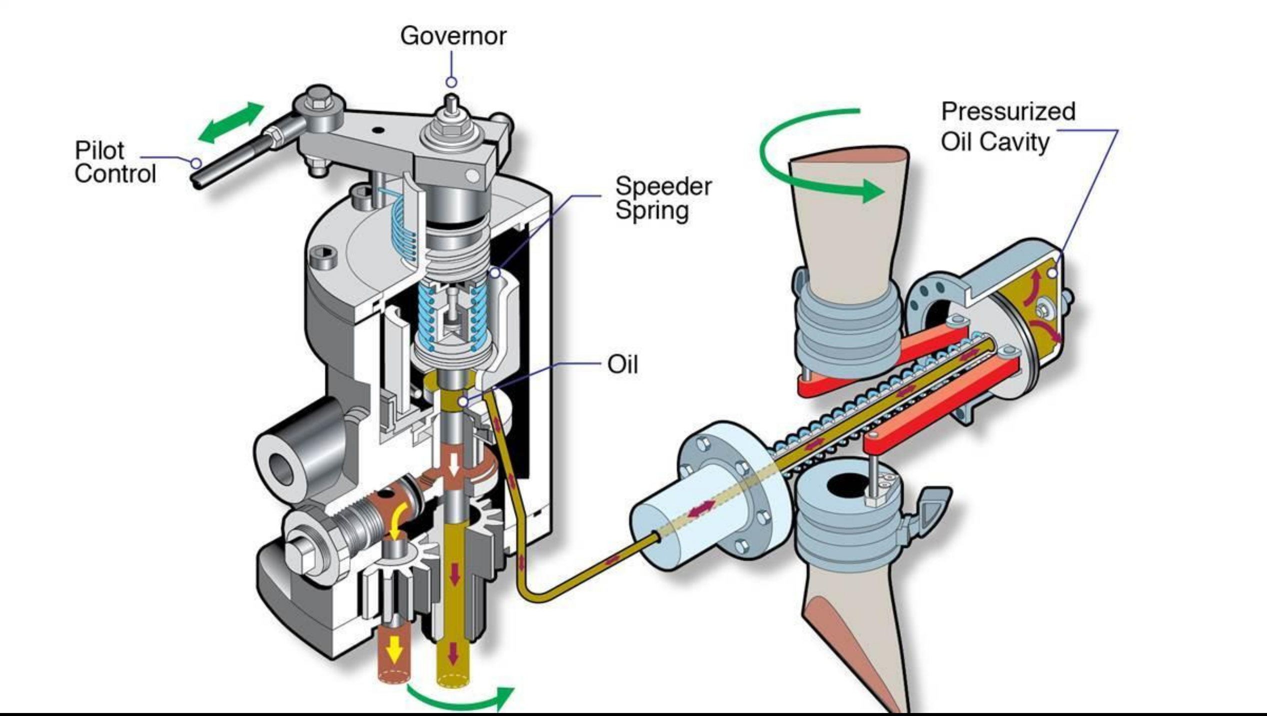
- Constant-speed propeller aircraft has two controls: throttle and propeller control.
- Throttle adjusts power output, registered on manifold pressure gauge.
- Propeller control regulates engine RPM, registered on the tachometer.

Propeller Governor

- Governor adjusts propeller blade angle to maintain selected RPM.
- Increased airspeed or decreased load increases blade angle to maintain RPM.
- Decreased airspeed or increased load decreases blade angle to maintain RPM.

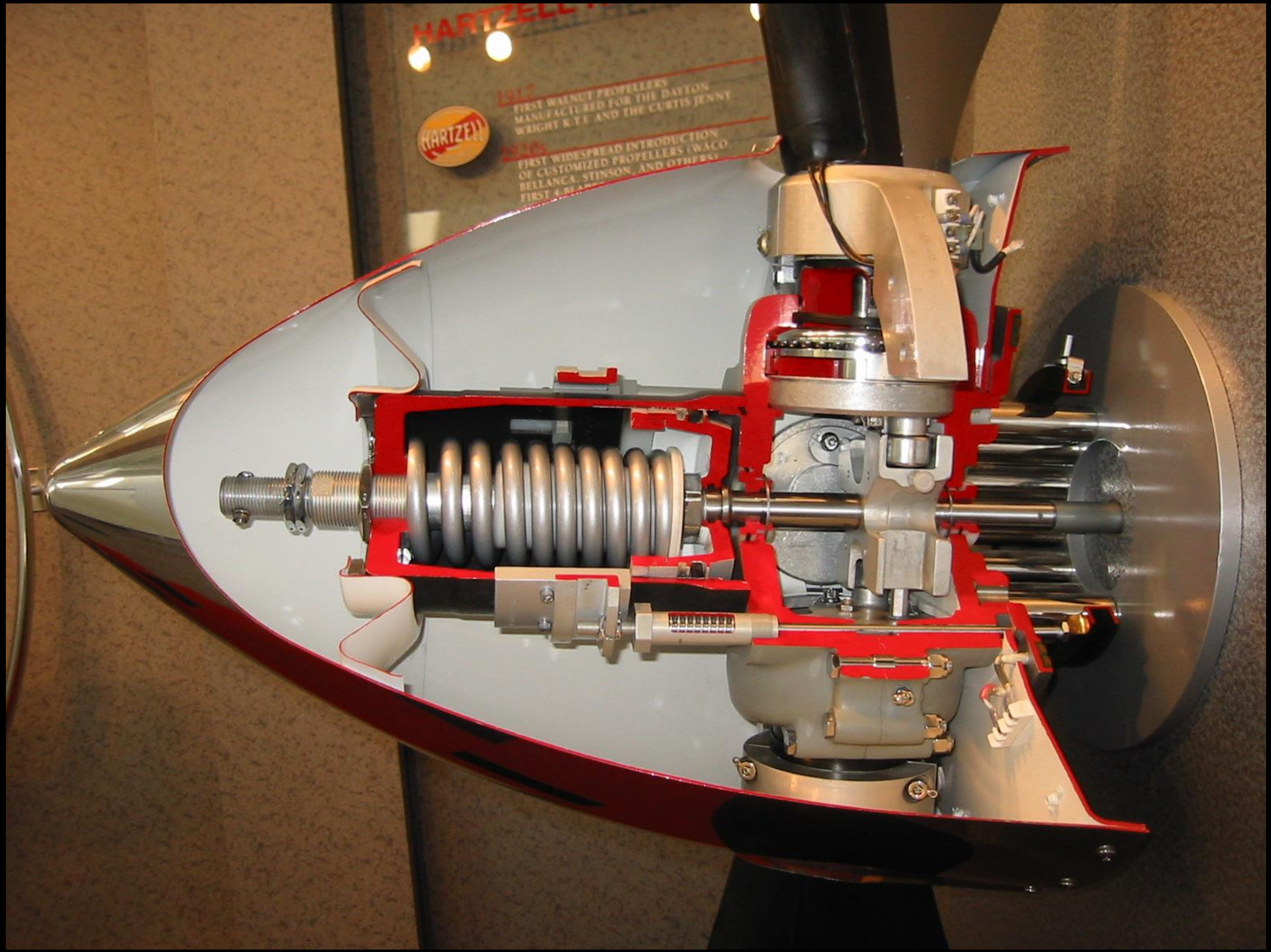
Propeller Governor

- Propeller control sets RPM.
- Oil pressure adjusts blade pitch for more power or efficiency.
- Flatter pitch for takeoff, steeper pitch for efficiency.

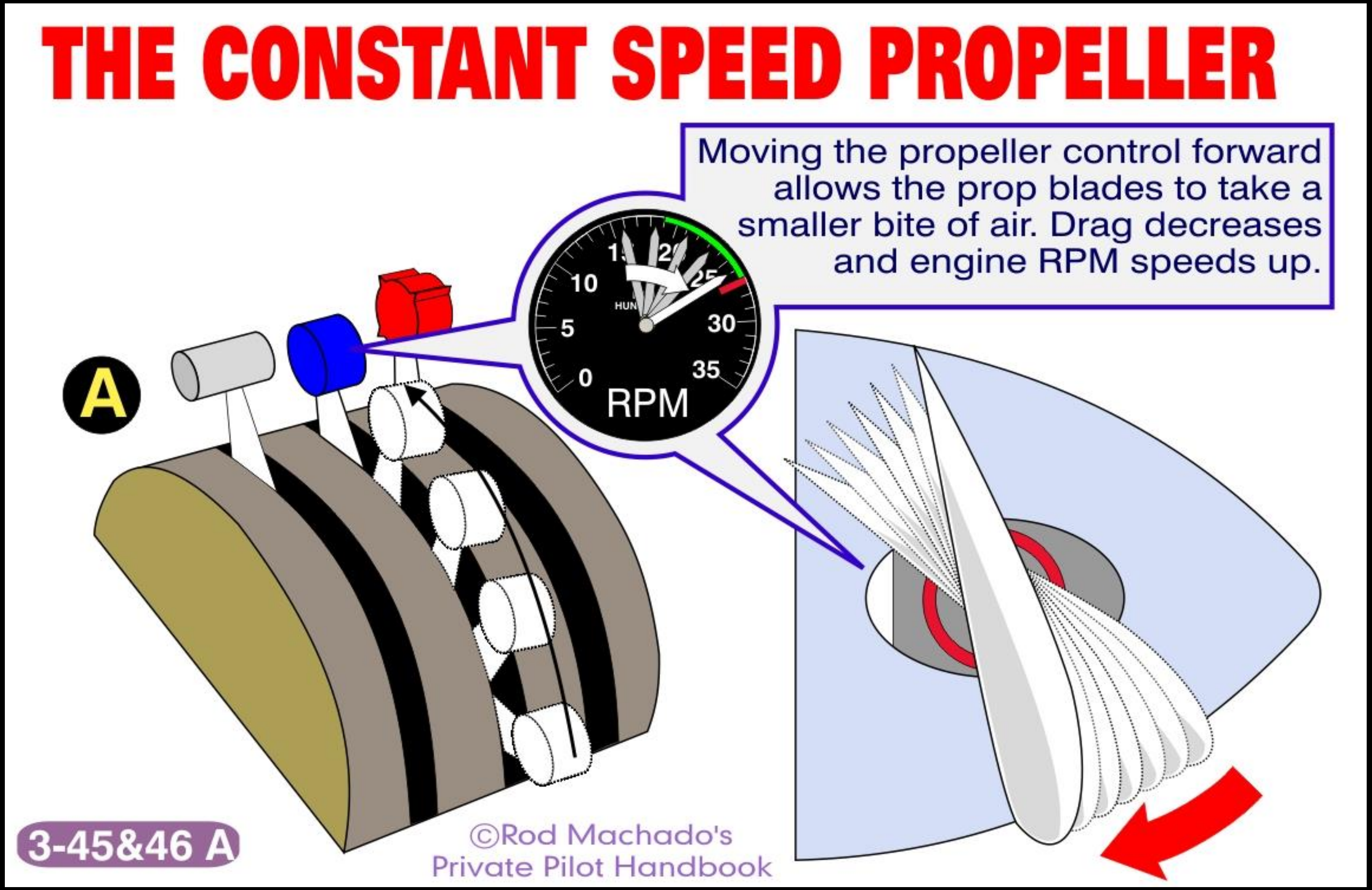


Propeller Operation

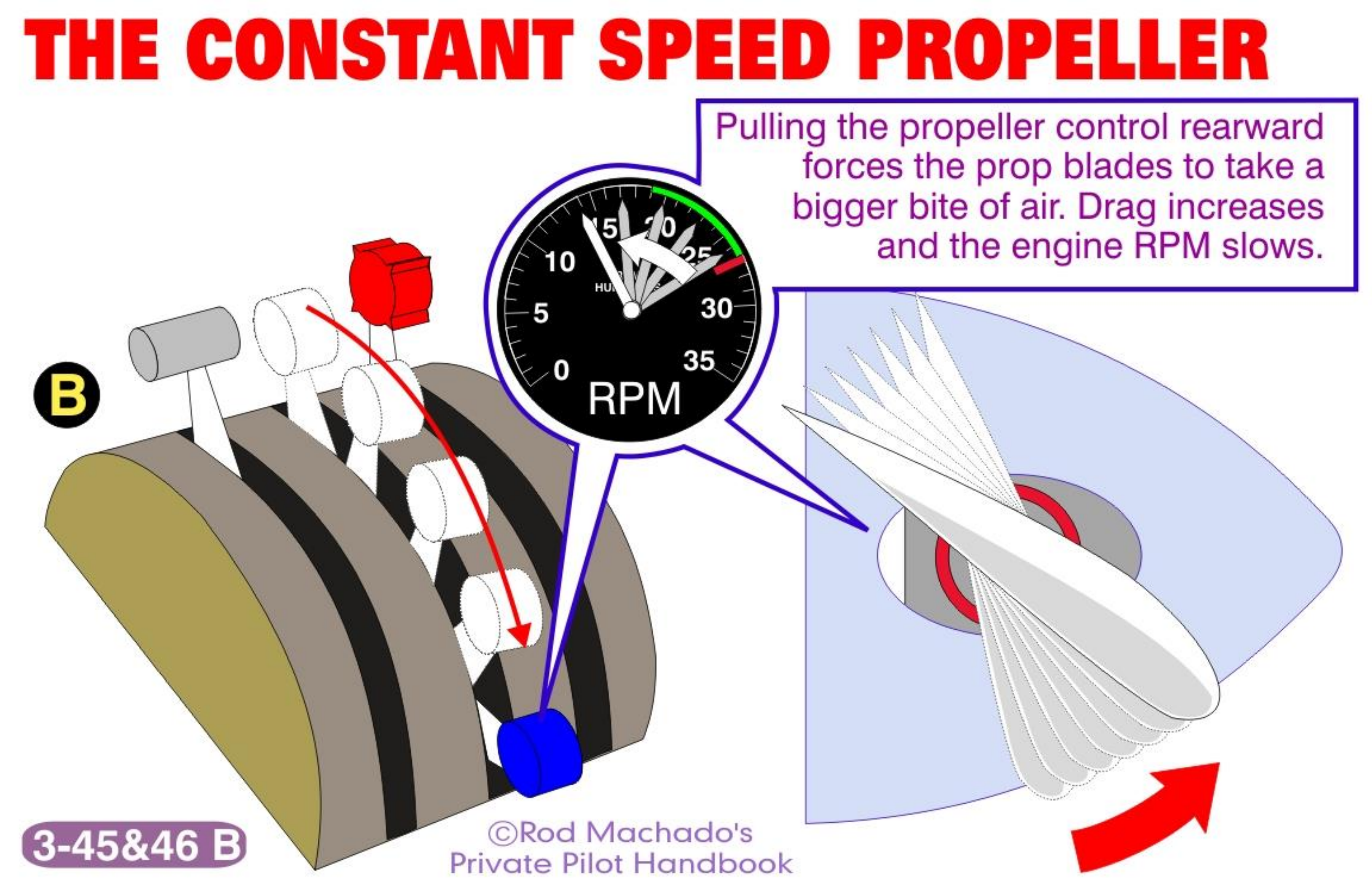
- Engine oil pressure adjusts propeller pitch.
- Moving control aft increases pitch for high power.
- Moving control forward reduces pitch for high RPM.



Propeller Control - Forward

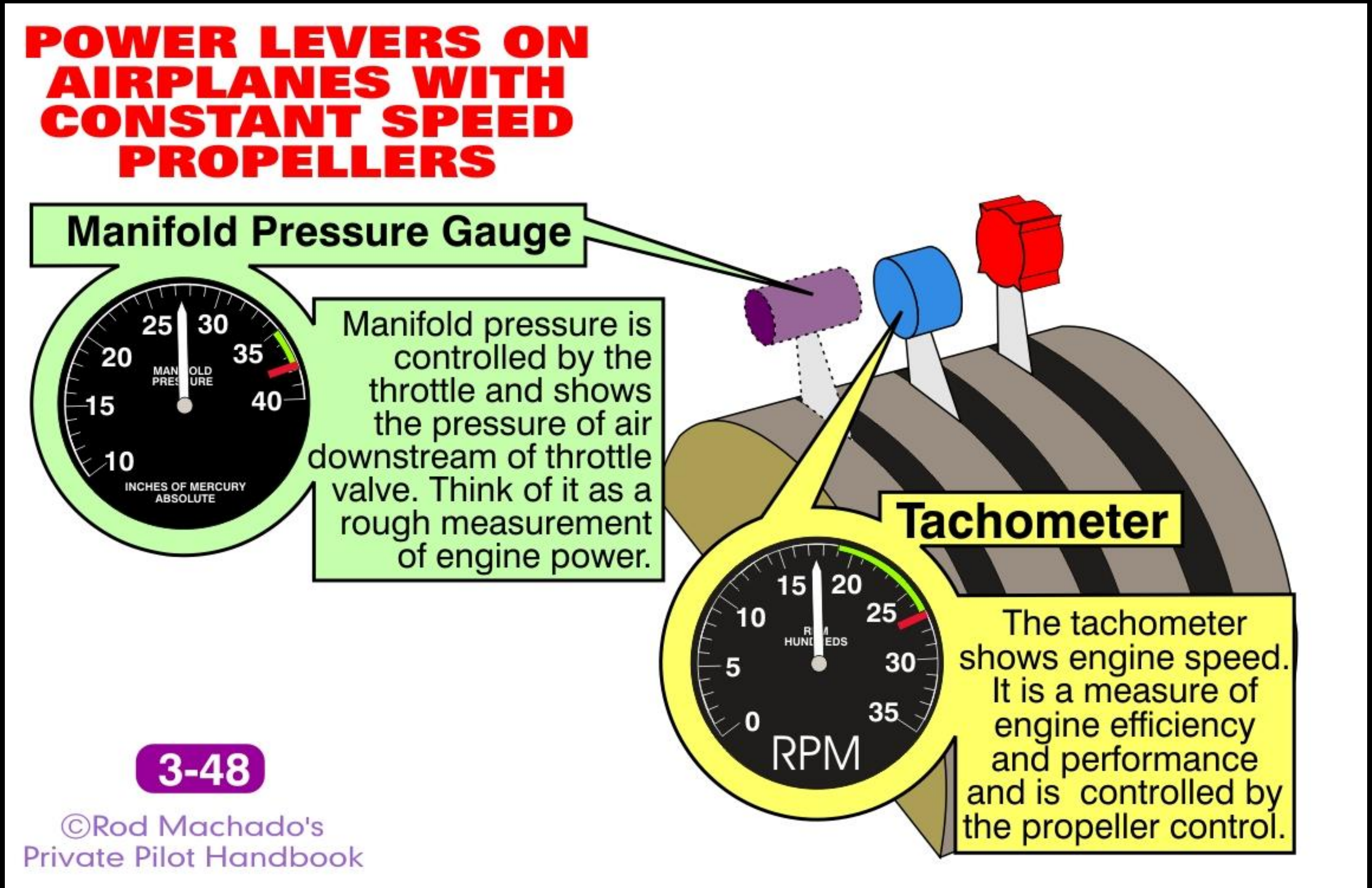


Propeller Control - Aft



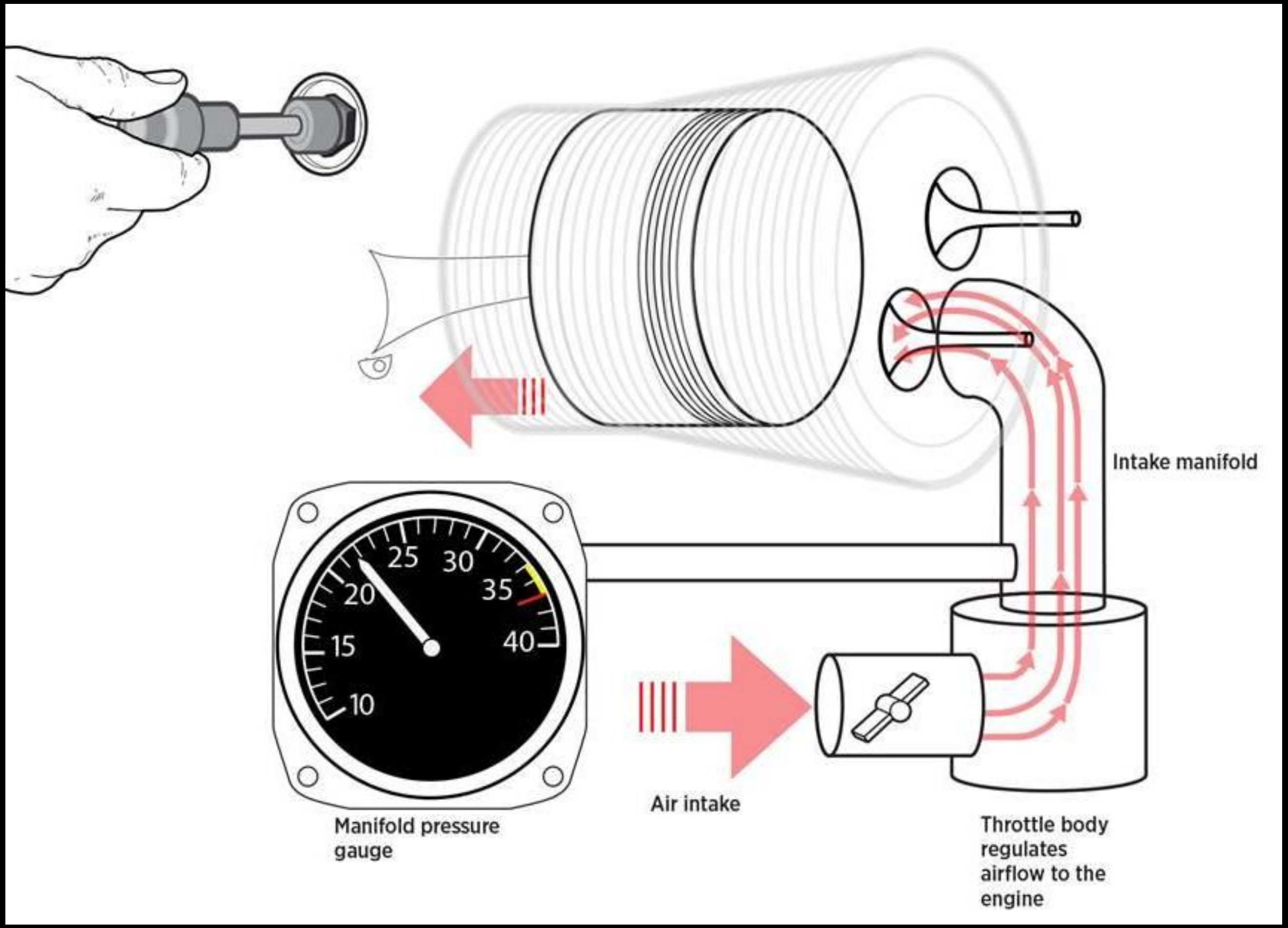
Power Levers

- Power output is controlled by the throttle and indicated by a manifold pressure gauge



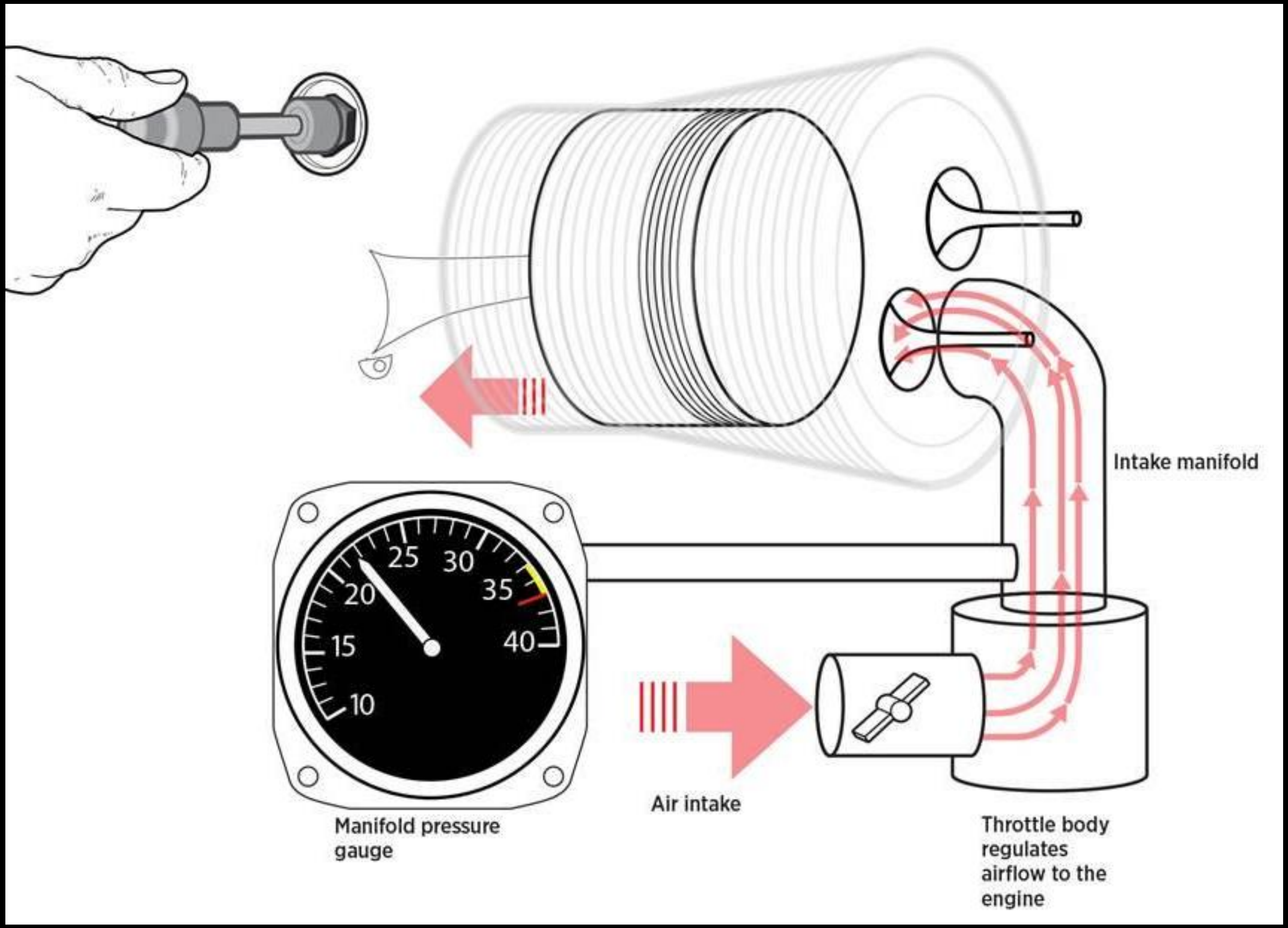
Manifold Pressure

- Gauge measures intake manifold pressure.
- Power relates to fuel-air mixture at constant rpm and altitude.

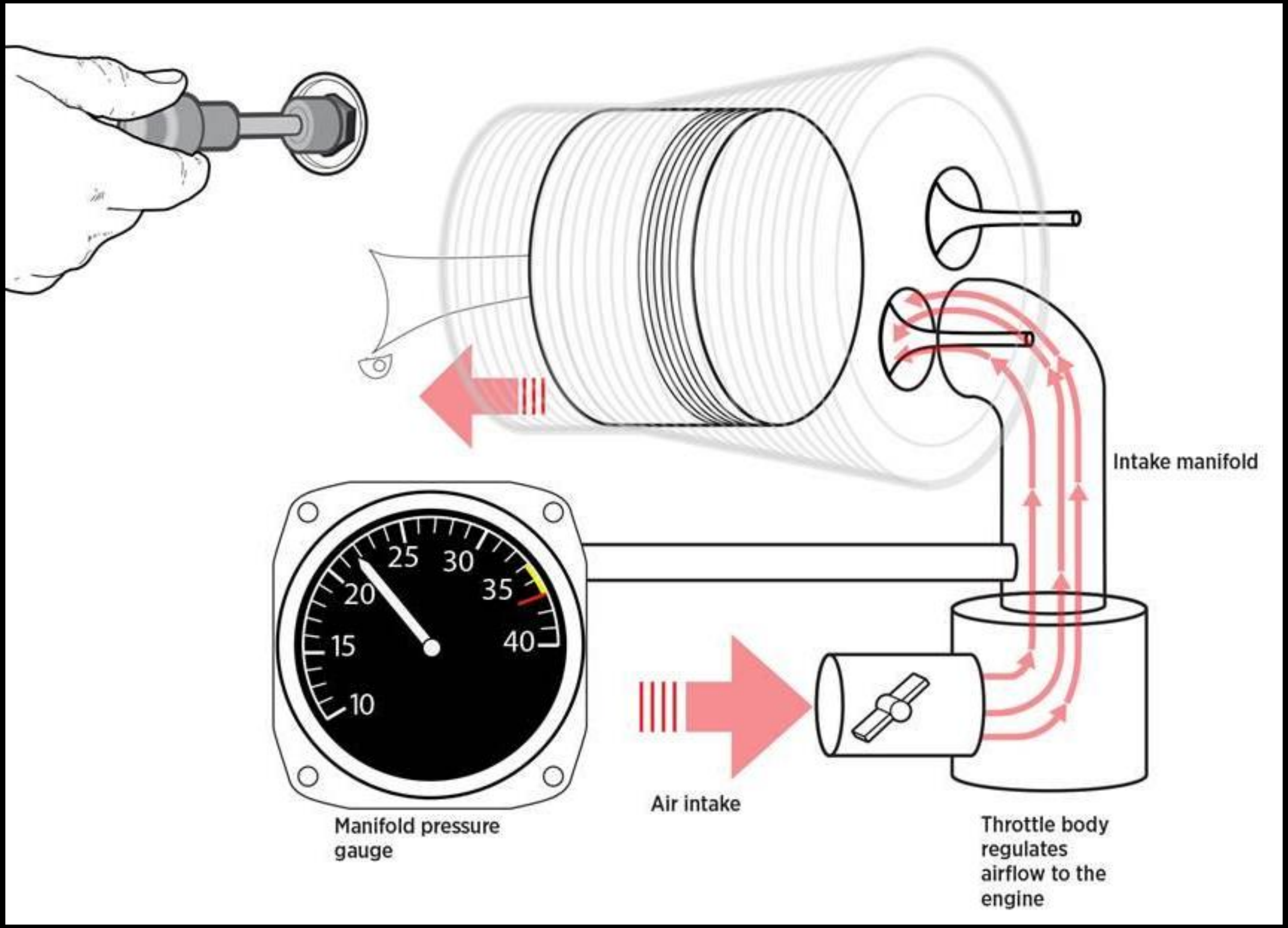


Manifold Pressure

- Gauge shows ambient air pressure when the engine is off. (29.92 if standard day).
- Engine failure/power loss increases MP to ambient pressure at failure altitude.



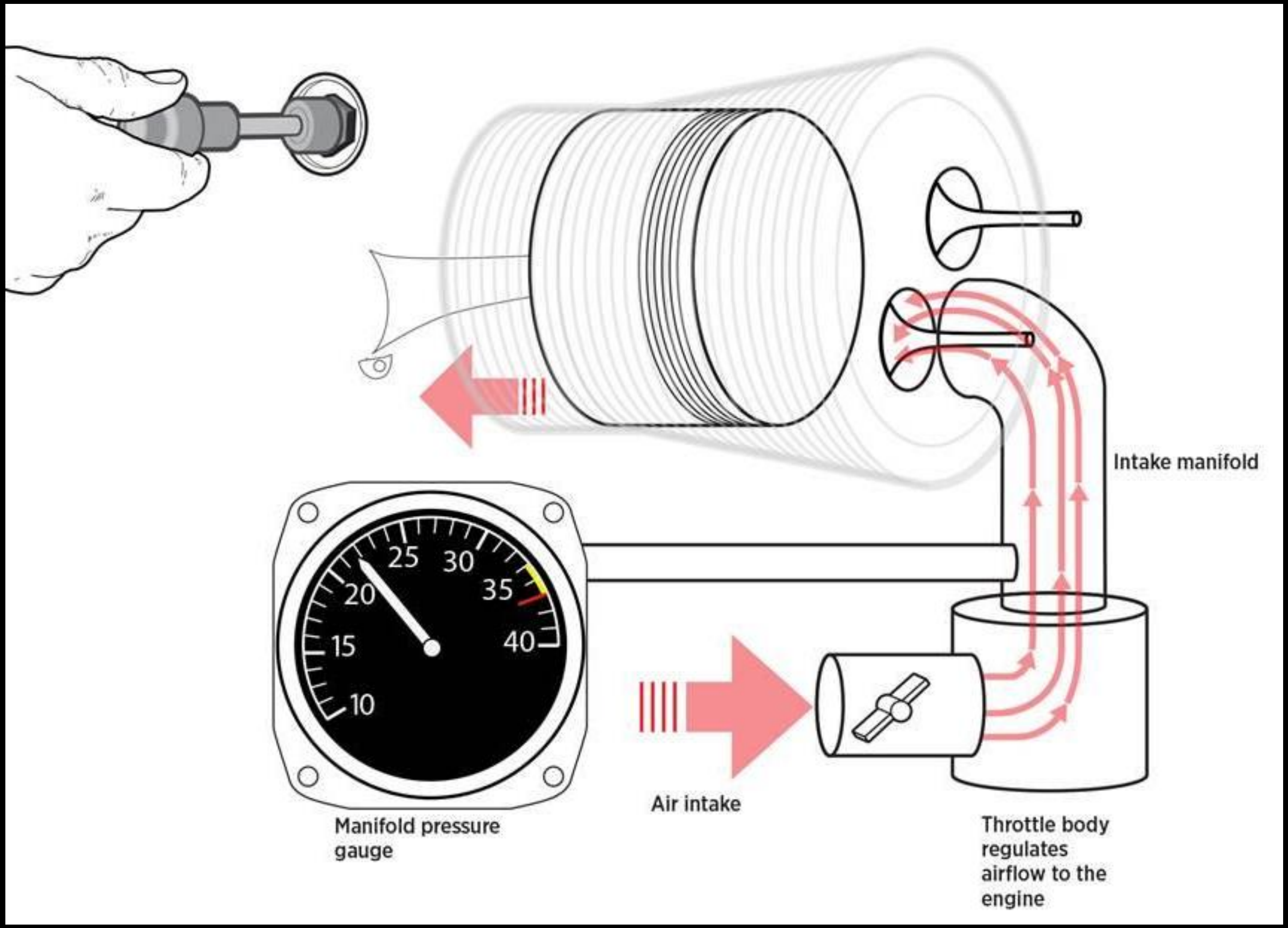
Manifold Pressure



- When the engine is started, the manifold pressure indication decreases to a value less than ambient pressure (i.e., idle at 14 "Hg)

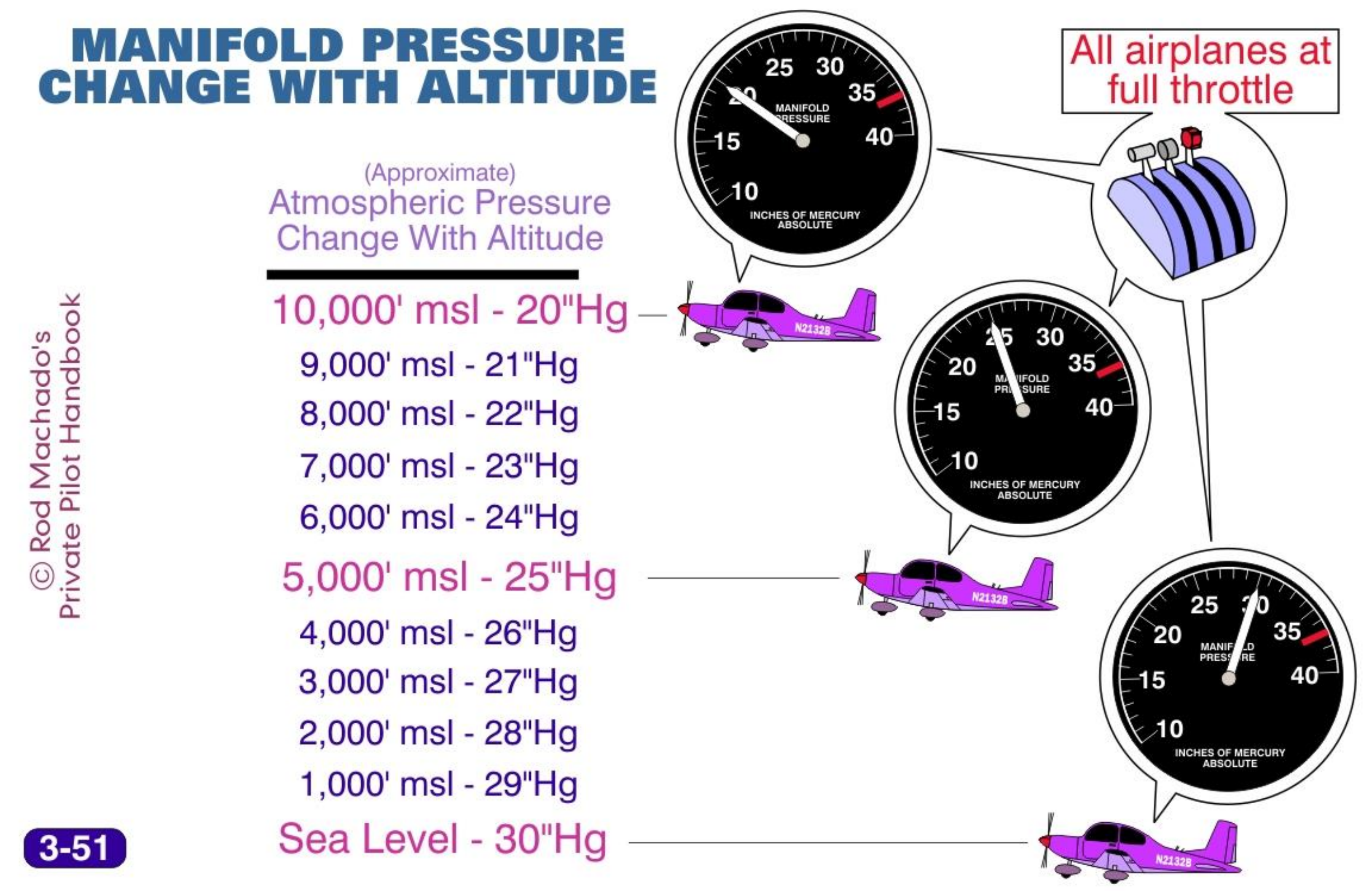
Manifold Pressure

- As the throttle setting is increased, more fuel and air flows to the engine and manifold pressure increases



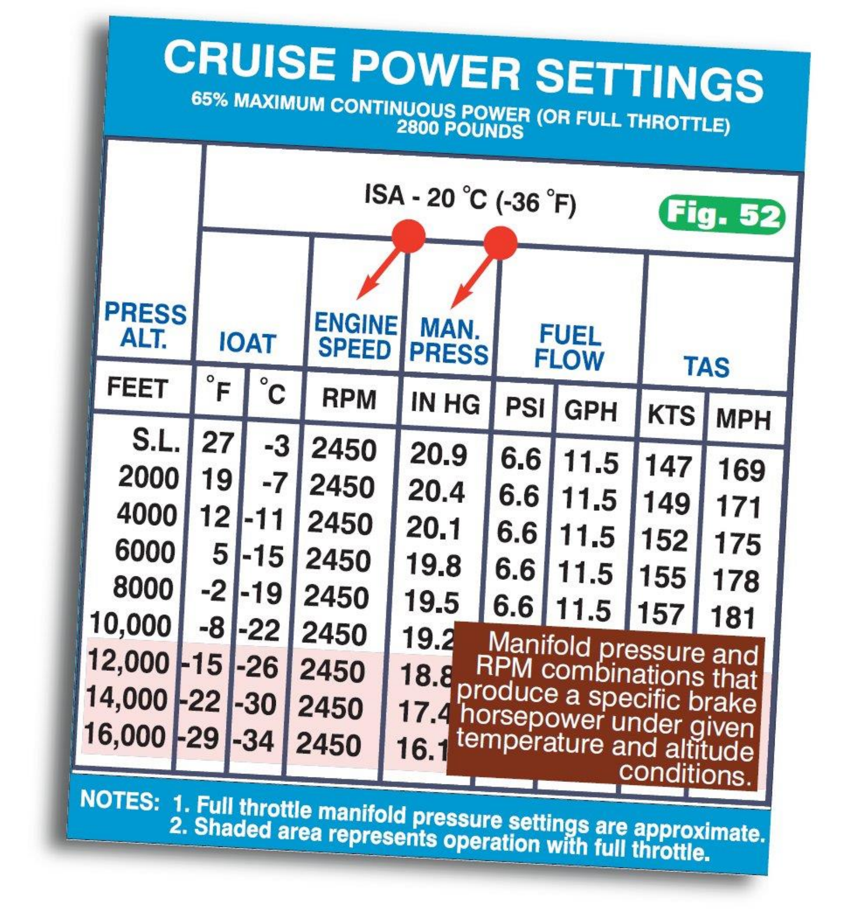
Changes in Manifold Pressure With Altitude

- Air is forced into engine by atmospheric pressure
- Pressure decreases 1”Hg/1000 ft
- Manifold pressure decreases by this amount at full throttle



POH Power Table

- Total power is a mix of manifold pressure and engine RPM.
- Various MP and RPM combinations achieve a specific power setting.
- Fuel use, airspeed, and power percentage vary with different MP and RPM combos.



CRUISE POWER SETTINGS

65% MAXIMUM CONTINUOUS POWER (OR FULL THROTTLE)
2800 POUNDS

ISA - 20 °C (-36 °F)

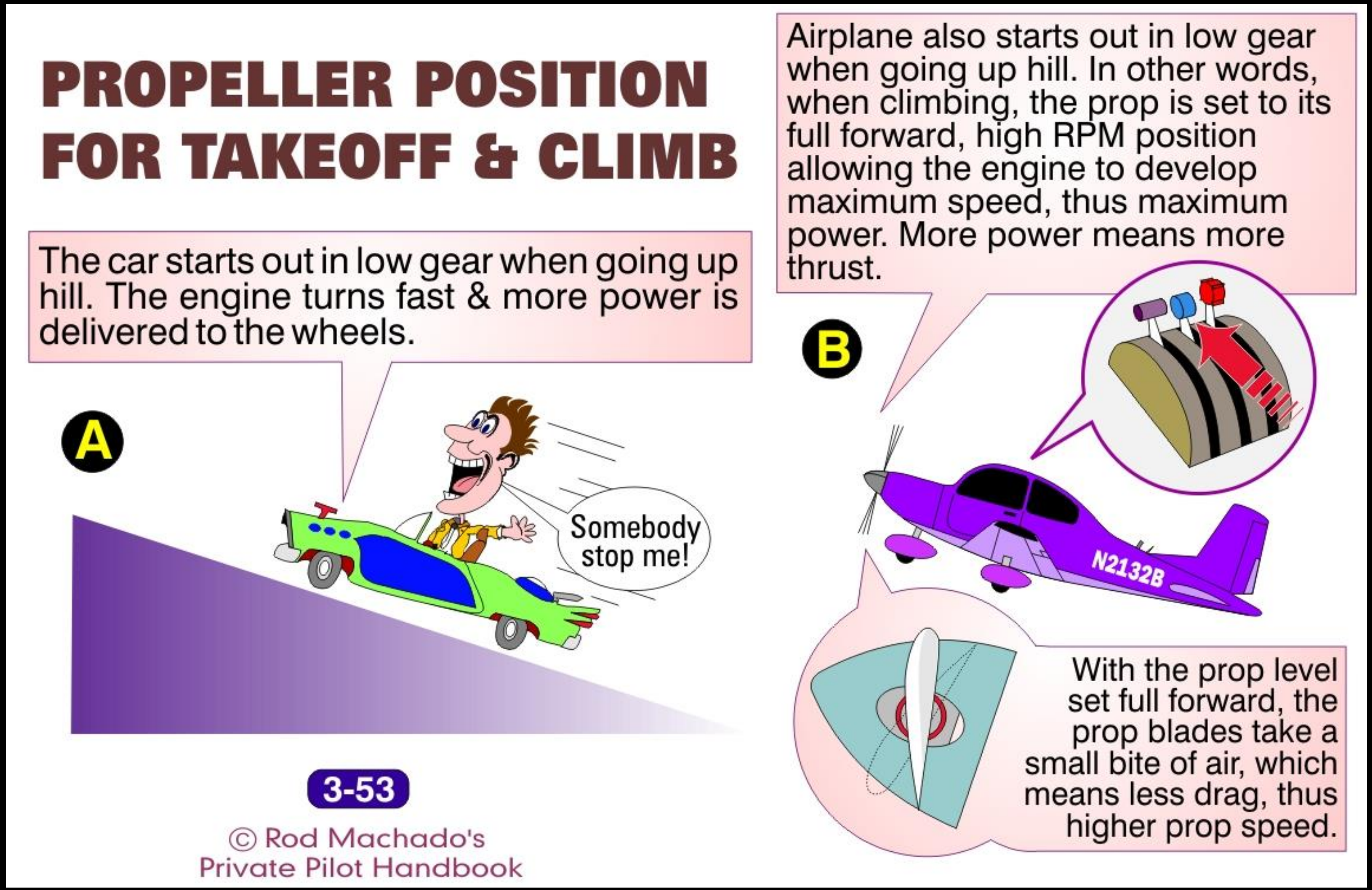
Fig. 52

PRESS ALT.	IOAT		ENGINE SPEED	MAN. PRESS	FUEL FLOW		TAS	
FEET	°F	°C	RPM	IN HG	PSI	GPH	KTS	MPH
S.L.	27	-3	2450	20.9	6.6	11.5	147	169
2000	19	-7	2450	20.4	6.6	11.5	149	171
4000	12	-11	2450	20.1	6.6	11.5	152	175
6000	5	-15	2450	19.8	6.6	11.5	155	178
8000	-2	-19	2450	19.5	6.6	11.5	157	181
10,000	-8	-22	2450	19.2				
12,000	-15	-26	2450	18.8				
14,000	-22	-30	2450	17.4				
16,000	-29	-34	2450	16.1				

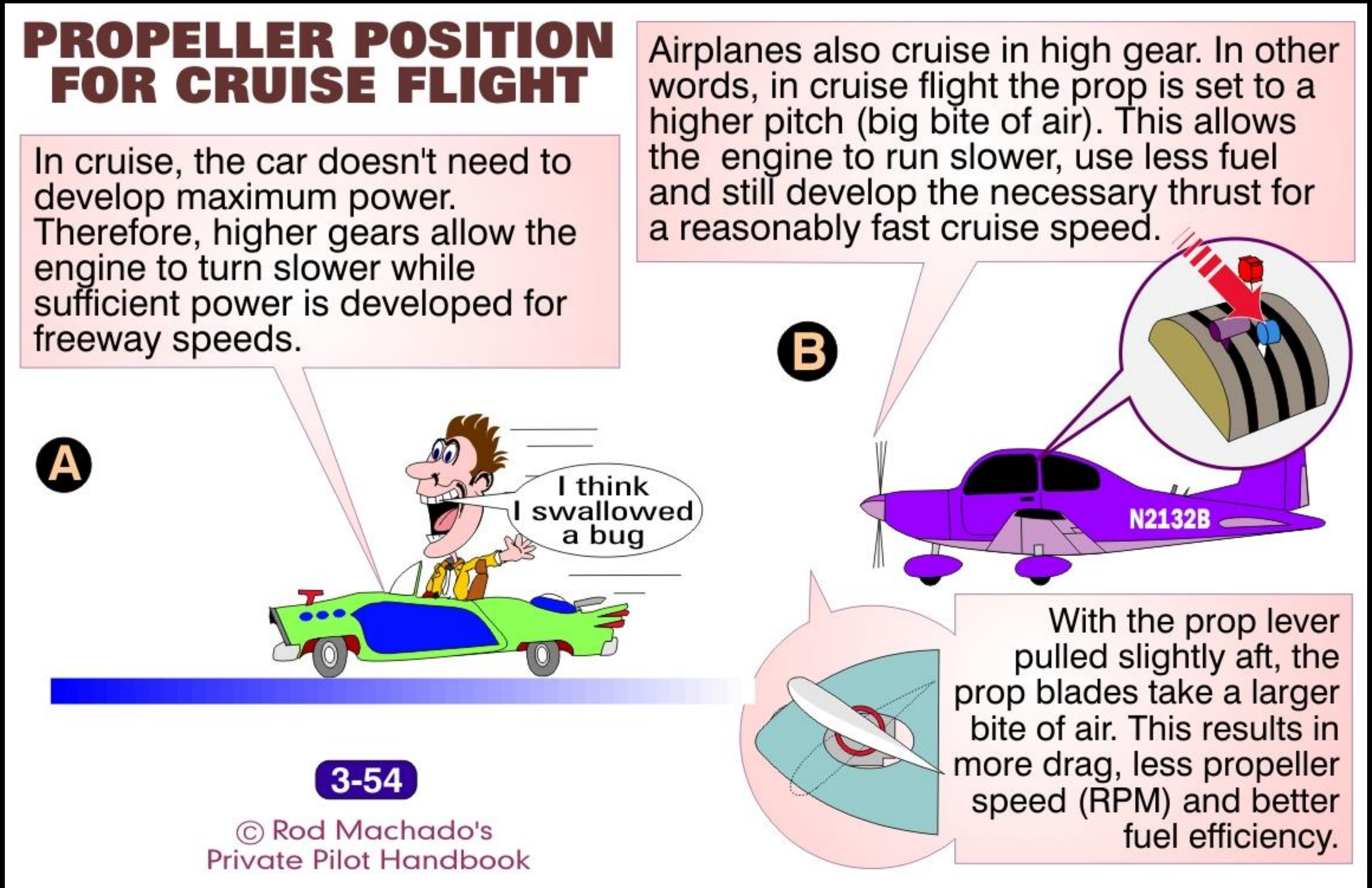
NOTES: 1. Full throttle manifold pressure settings are approximate.
2. Shaded area represents operation with full throttle.

Takeoff & Climb

- Operate the engine at the highest allowable RPM for maximum power.
- During takeoff, set the propeller to lowest pitch (highest RPM).
- Lower pitch reduces drag, maximizing engine RPM and thrust for climbing.



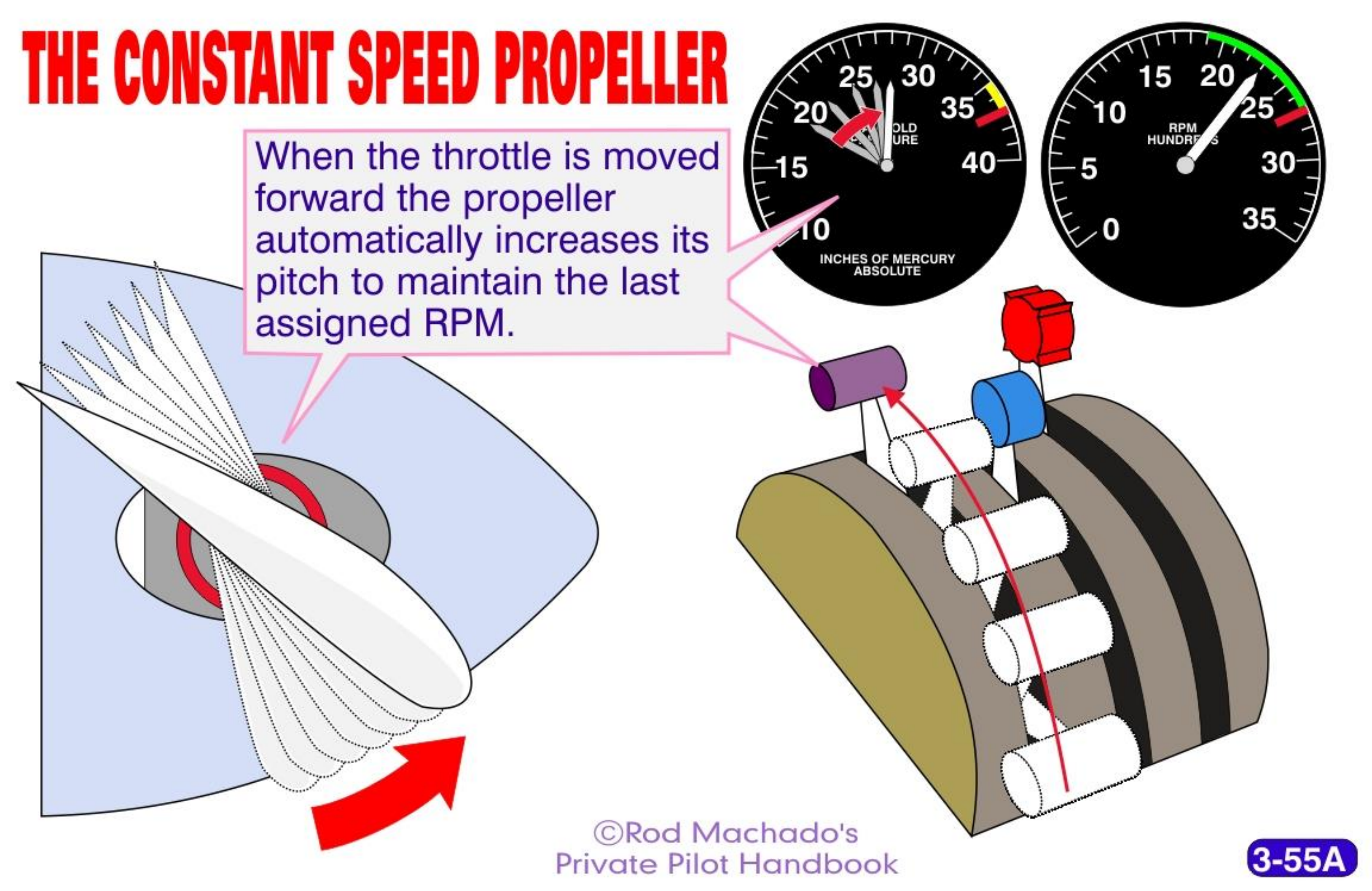
Cruise



- There is no need to develop maximum horsepower during cruise flight
- Objective is to obtain a reasonably fast airspeed while keeping fuel consumption low
- Cruise flight is a tradeoff between high airspeed and low fuel consumption

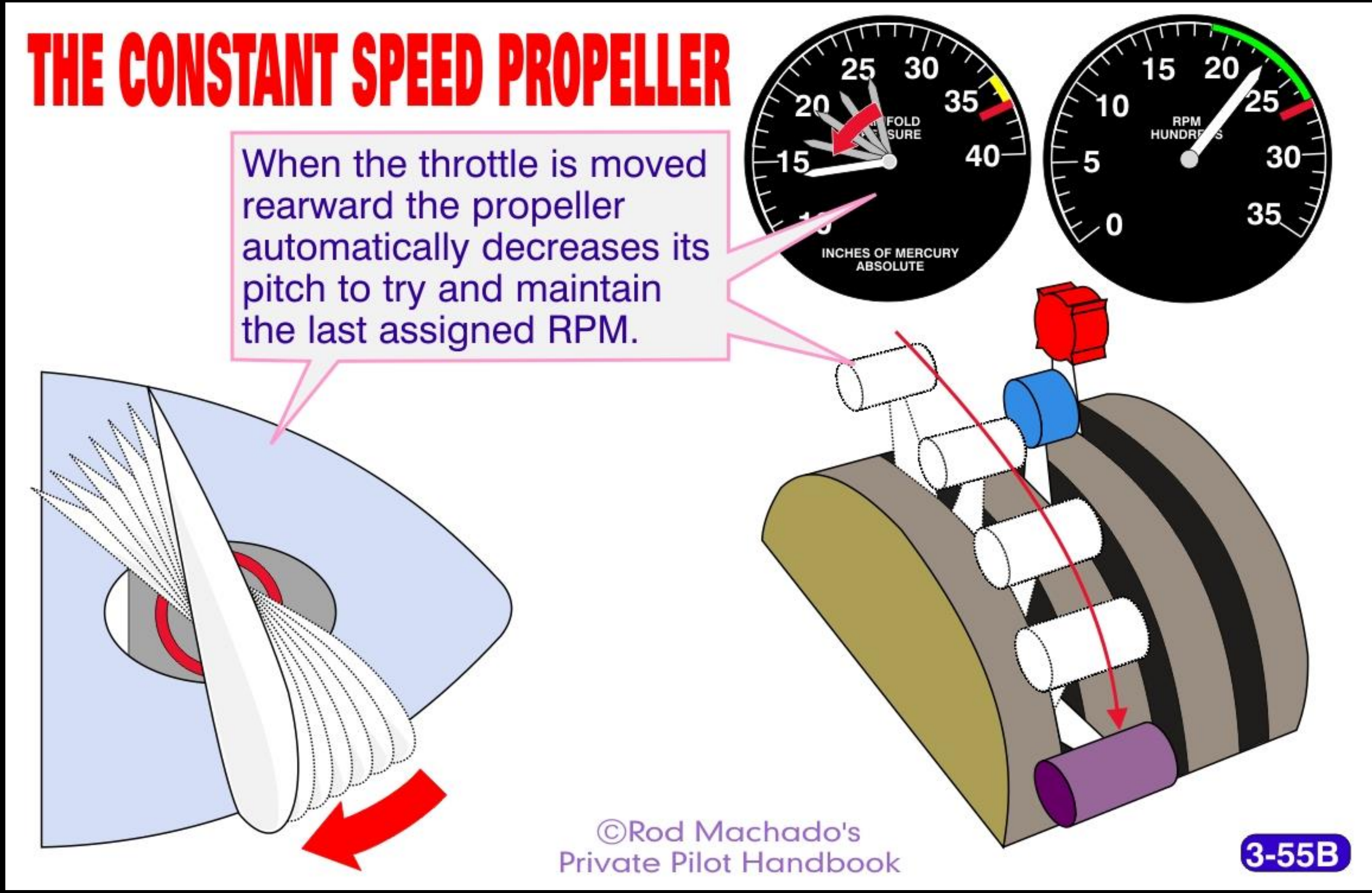
Throttle Moved Forward … RPM Remains Constant

- When power changes are made, the constant speed propeller automatically adjusts its pitch to maintain the propeller speed (last RPM) assigned by the pilot



Throttle Moved Aft …
RPM Remains Constant

- When power changes are made, the constant speed propeller automatically adjusts its pitch to maintain the propeller speed (last RPM) assigned by the pilot



Excessive Manifold Pressure

- Avoid exceeding recommended manifold pressure for a given RPM.
- Excessive pressure can stress cylinders, leading to weakened components and potential engine failure.

Excessive Manifold Pressure

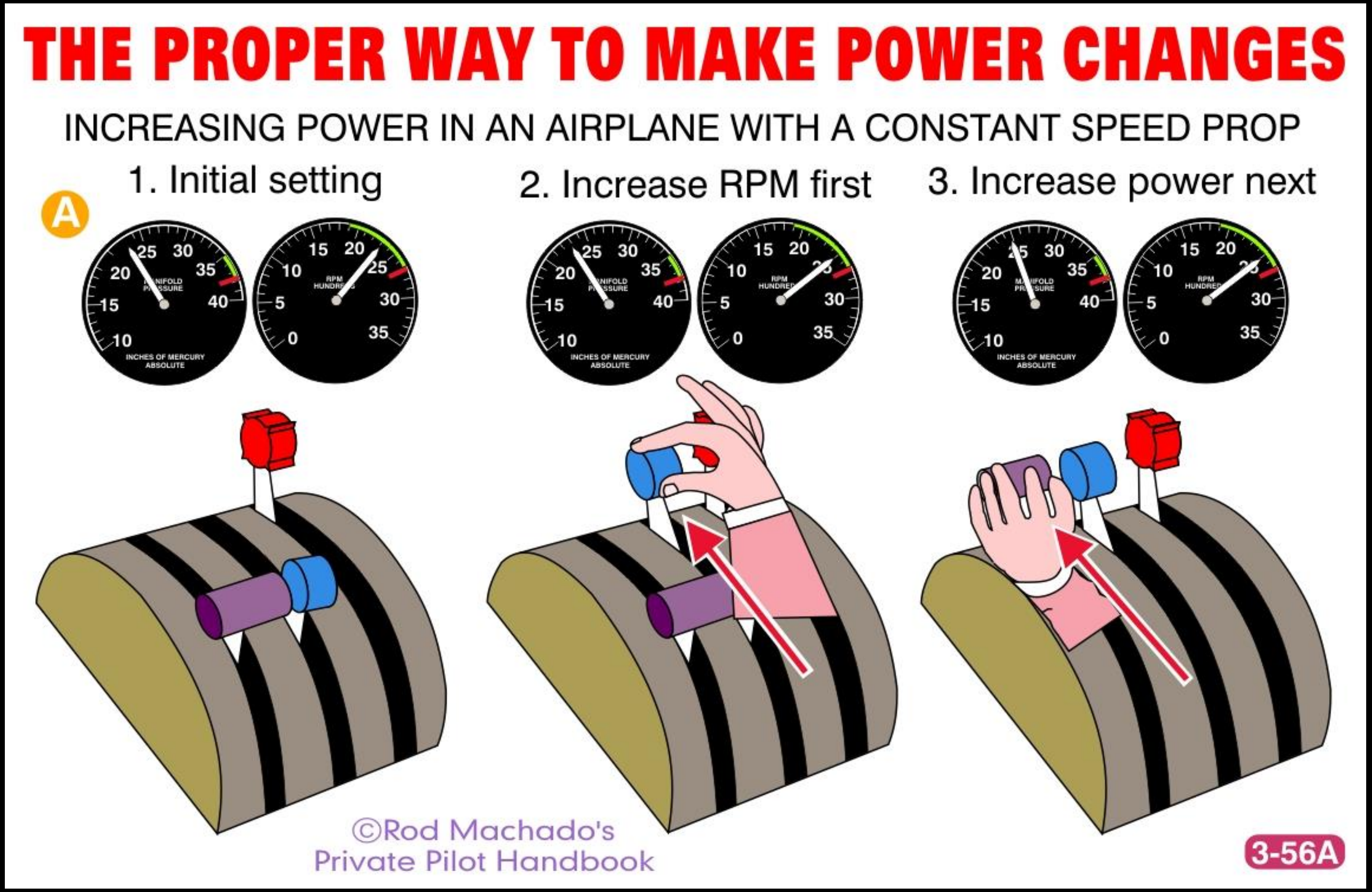
- Constantly monitor RPM, especially when increasing manifold pressure.
- Consult the manufacturer's recommendations for maintaining the proper relationship between manifold pressure and RPM to avoid overstressing cylinders.

Power Changes Prop on Top

- Change power settings in the proper order to avoid engine overstress:
  - Decrease: Reduce manifold pressure before reducing RPM.
  - Increase: Increase RPM first, then manifold pressure.
- Follow the engine and airframe manufacturer's recommendations to prevent wear, fatigue, and damage to high-performance reciprocating engines.

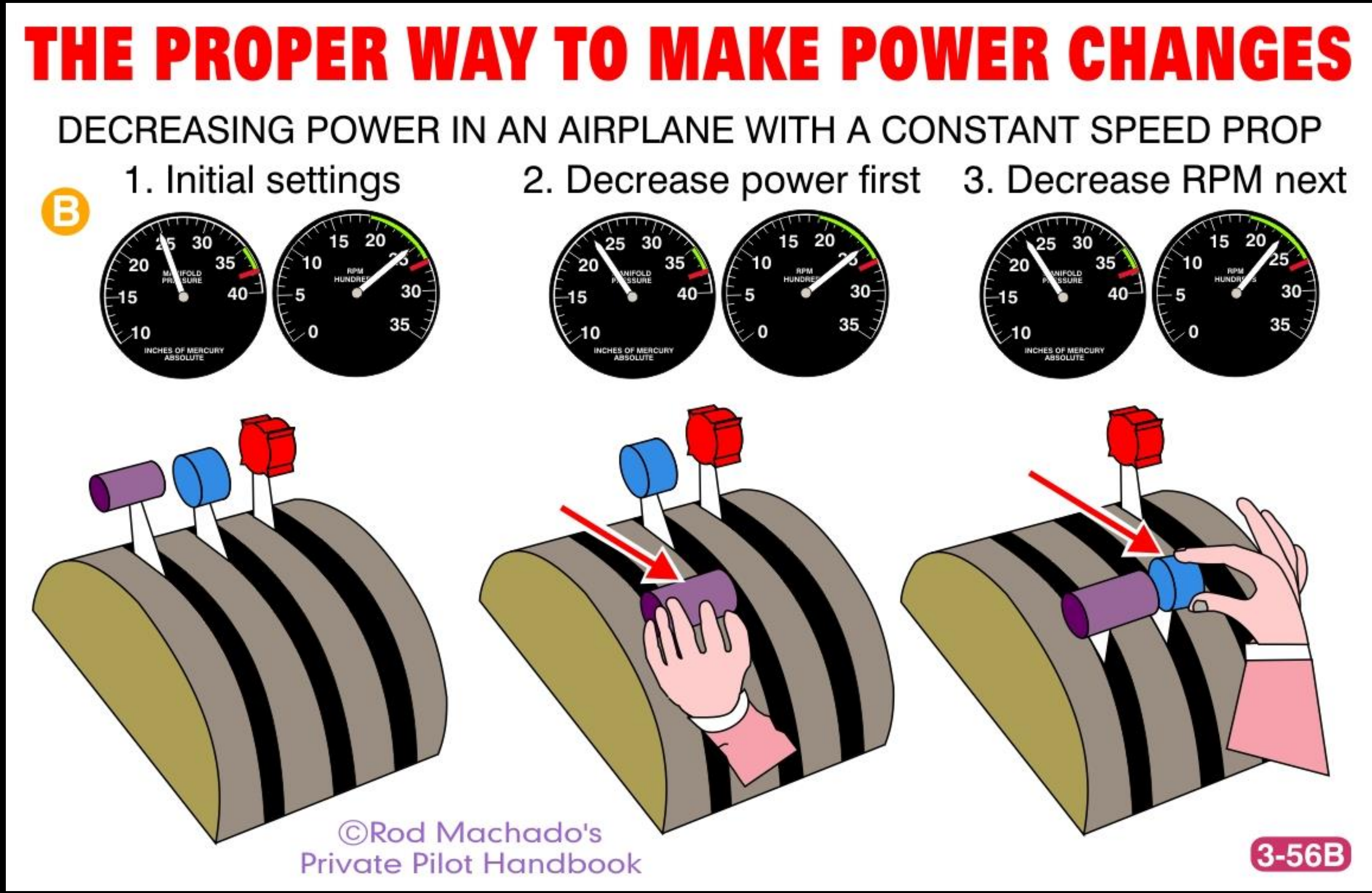
Increasing Power Prop on Top

- 1. Increase prop RPM
  2. Increase throttle



Decreasing Power Prop on Top

- 1. Decrease throttle
  2. Decrease prop RPM



Carb Ice With Constant Speed Propeller

- When carburetor heat is used on an aircraft with a constant-speed propeller and ice is present, a decrease in the manifold pressure is noticed, followed by a gradual increase
- If carburetor icing is not present, the gradual increase in manifold pressure is not apparent until the carburetor heat is turned off

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

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~~

Knowledge Check

While in flight, a falling oil pressure and rising oil temperature indicates which of the following?

A. Leak or lack of oil
B. Excess oil
C. Clogged fuel line leading to hotter engine
D. None of the above

Knowledge Check

While in flight, a falling oil pressure and rising oil temperature indicates which of the following?

A. Leak or lack of oil
B. ~~Excess oil~~
C. ~~Clogged fuel line leading to hotter engine~~
D. ~~None of the above~~