

# **Powerplants and Propellers**

## **Objective**

To understand the basics of a reciprocating engine and a propeller and how it produces thrust in the airplane.

## **Why do we need to know about the engine?**

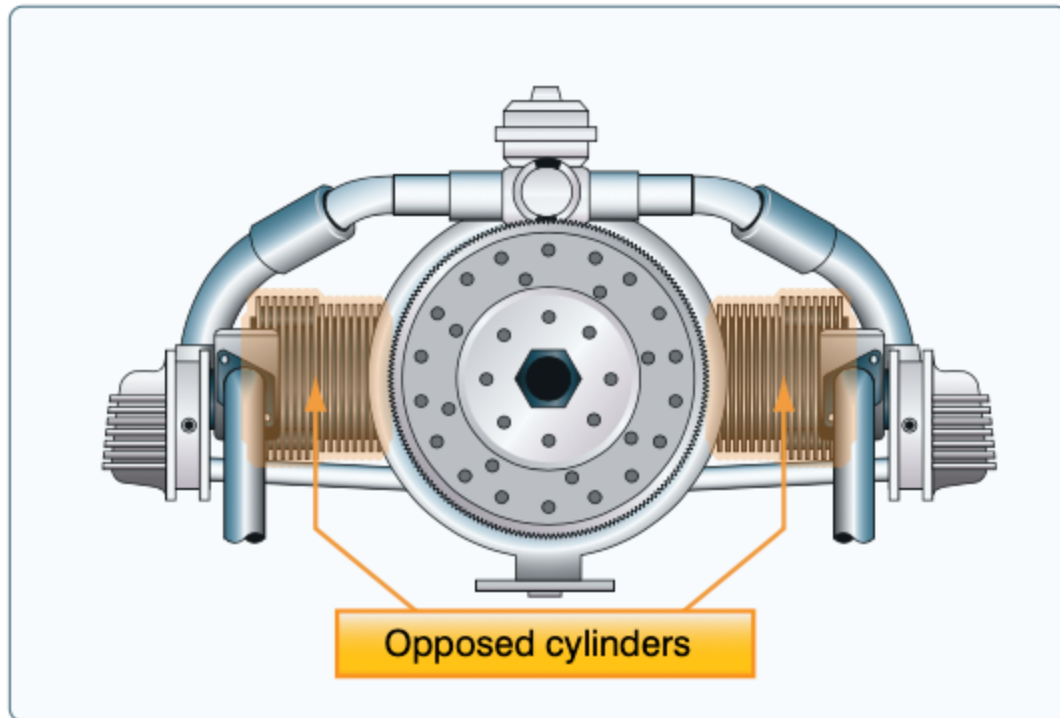
We want an intuitive understanding of how an engine operates to use the engine controls effectively, troubleshoot issues as they arise, and take good care of our aircraft's engine.

# Overview

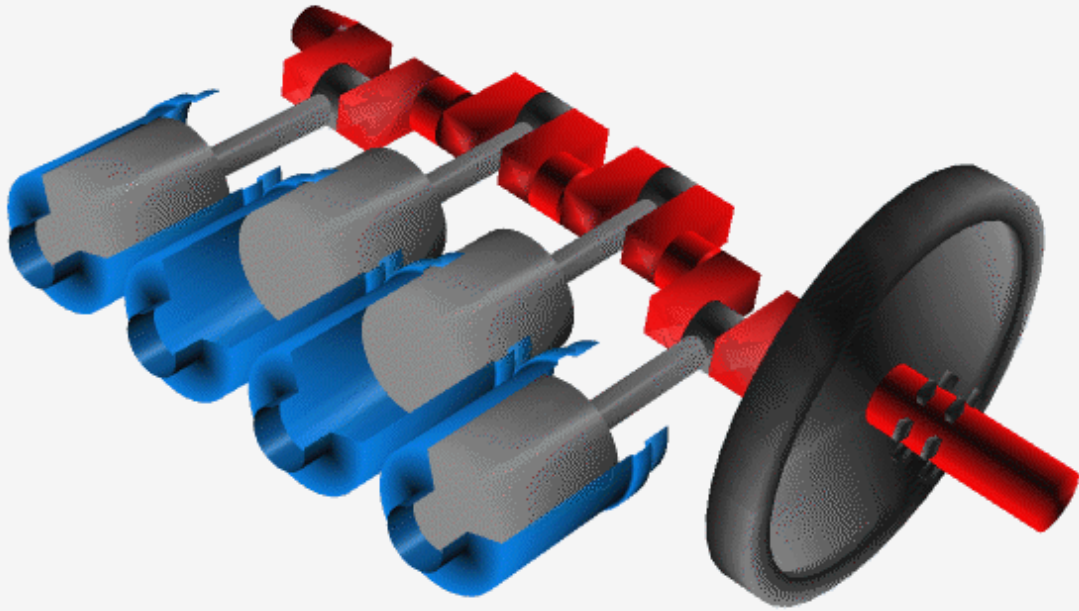
- Reciprocating engines principles
- Engine instrumentation (RPM, manifold pressure)
- Ignition system and magnetic
- Induction system and carburetors
- Turbochargers
- Fixed-pitch propellers
- Constant-speed Propellers

## Reciprocating Engines

- Most light airplane engines are 4- or 6-cylinder, horizontally-opposed, air-cooled

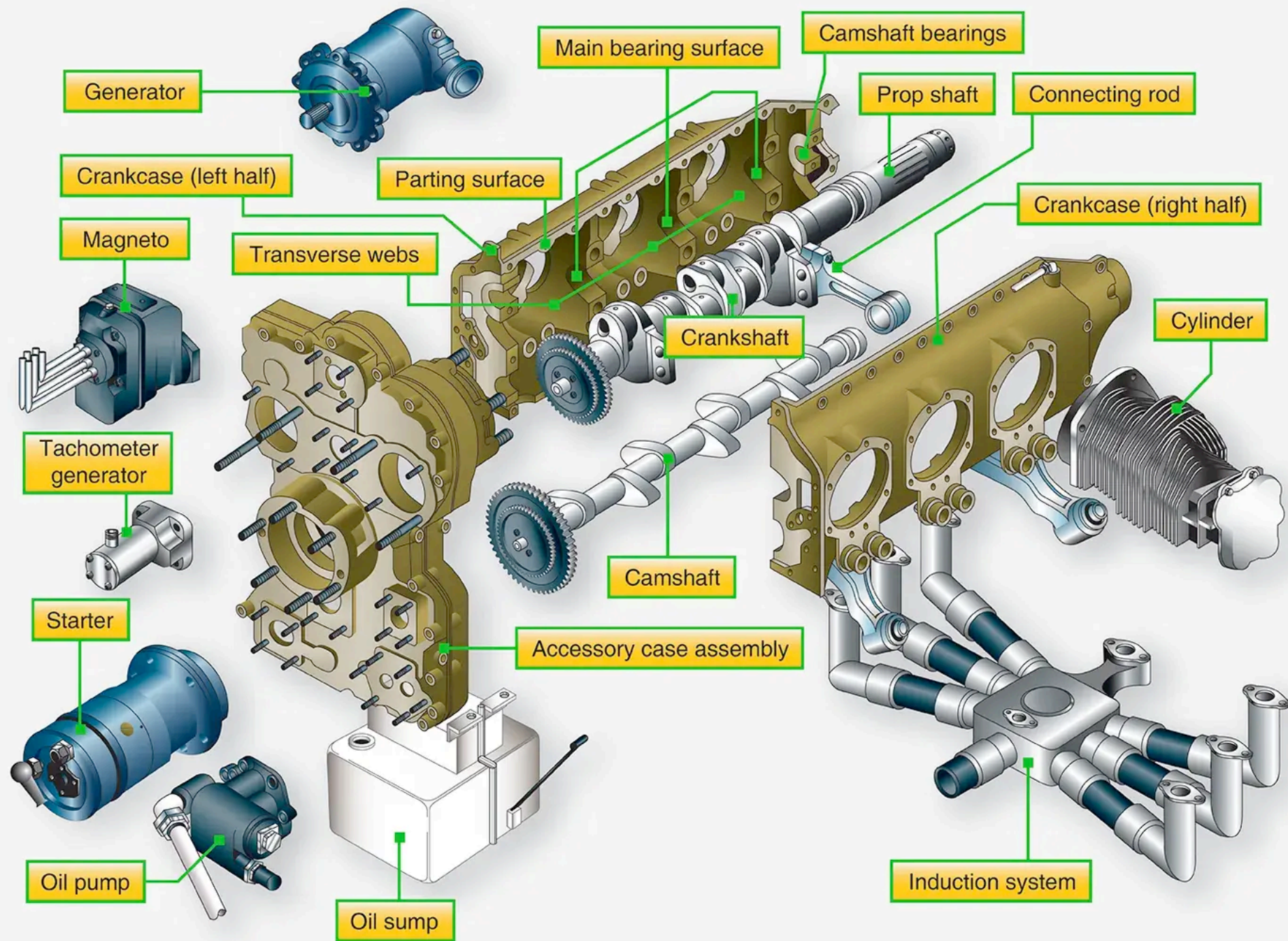




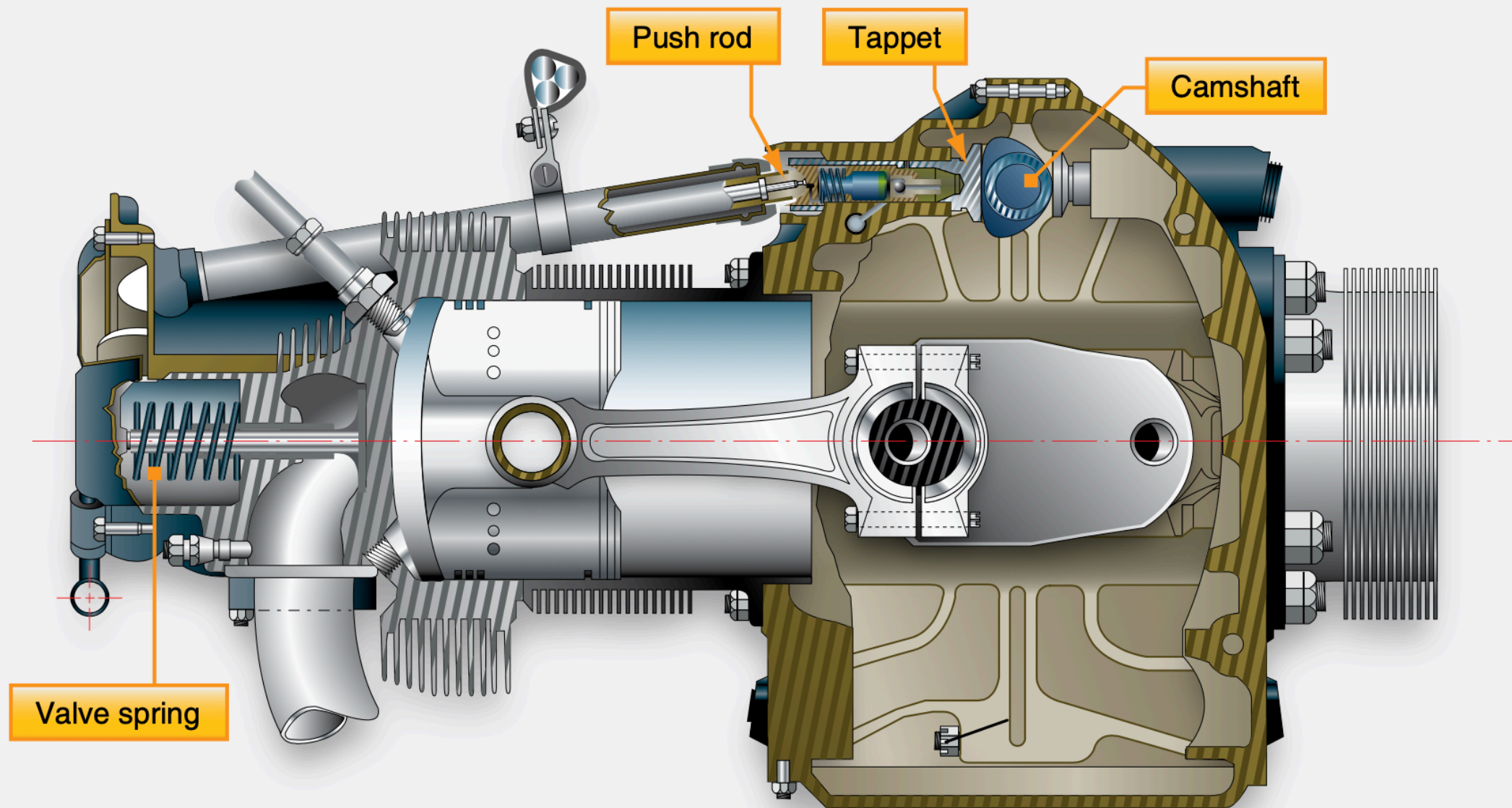


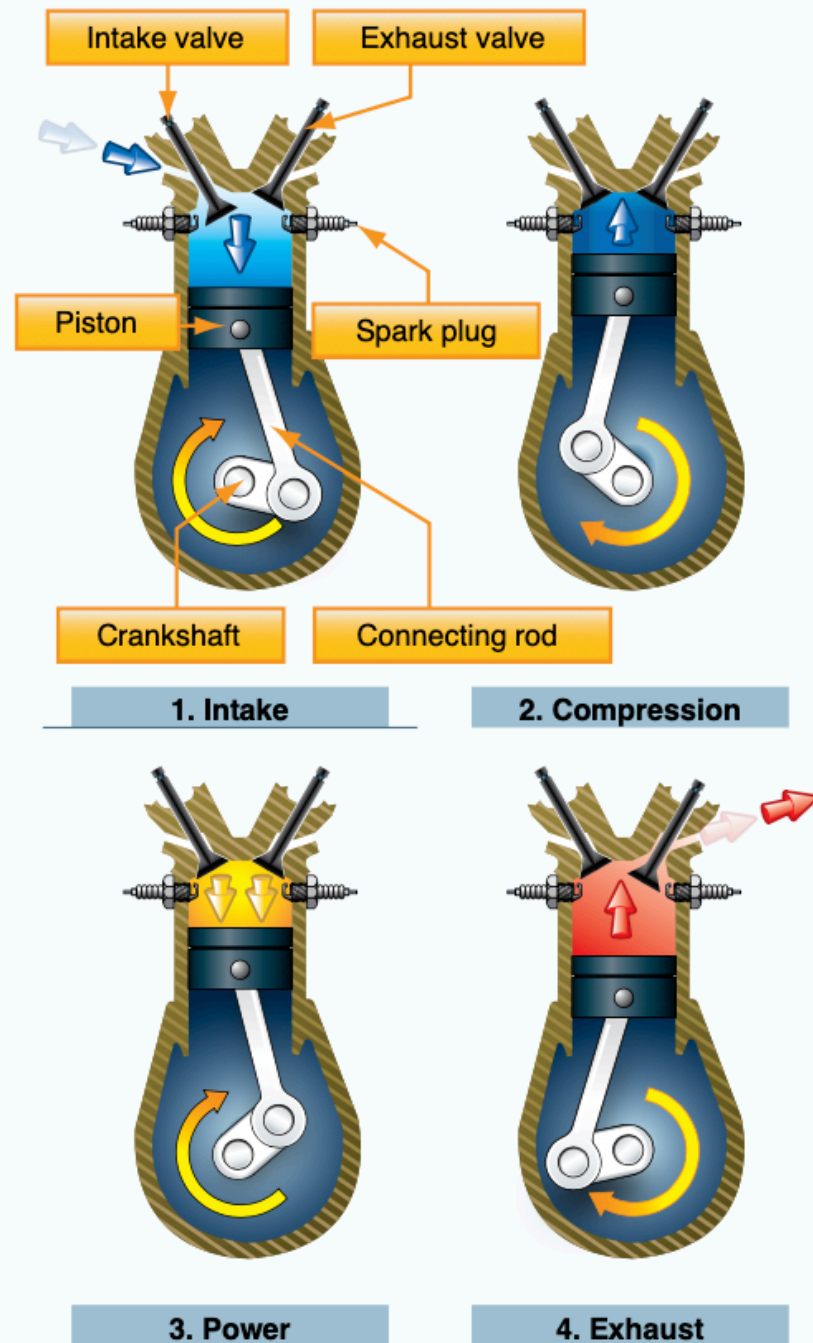
## Cylinders

- Cylinders produce controlled explosions that drive the crankshaft
- The crankshaft then drives the propeller









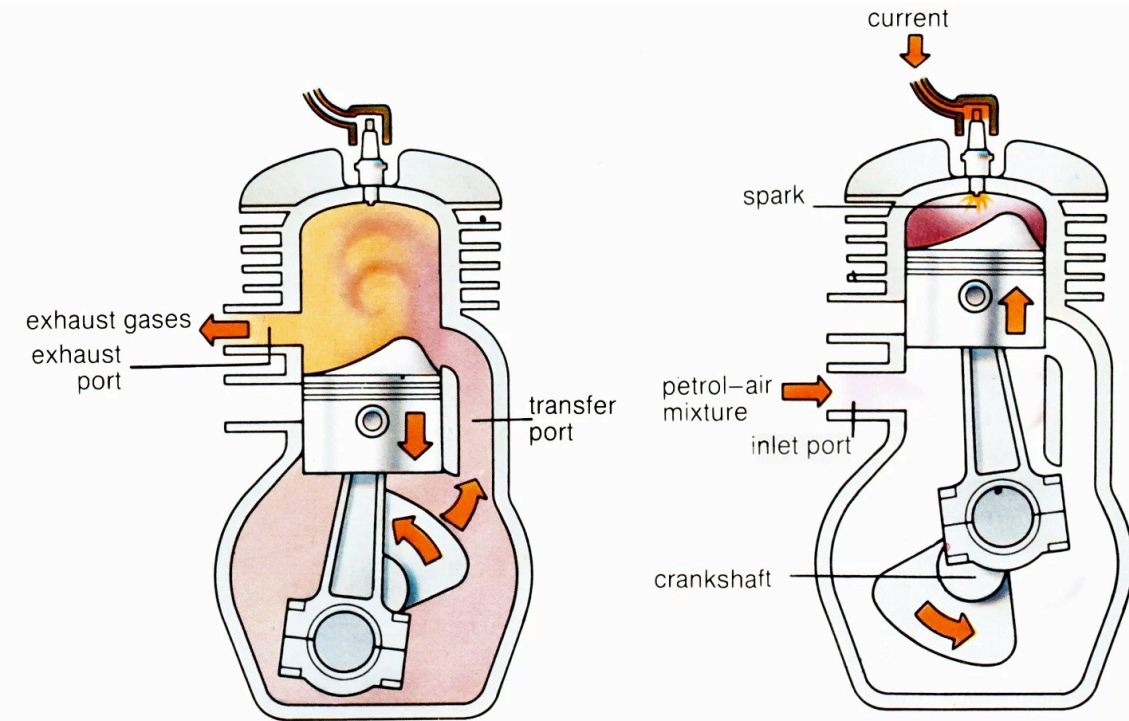
## The Power Cycle (4-stroke engine)

- 4 strokes of an engine
  - Intake: Fuel/air sucked in
  - Compression: Fuel/air is compressed
  - Combustion: Spark plugs ignite fuel/air mixture
  - Exhaust: Exhaust gasses are expelled
- Each cylinder makes two up/down movements for a power cycle
- Each cylinder is a different part of this cycle at any point



# Crankshaft and Camshaft





## 2-stroke Engines

- 2-stroke engines perform a power cycle on each stroke
- Available on some light aircraft

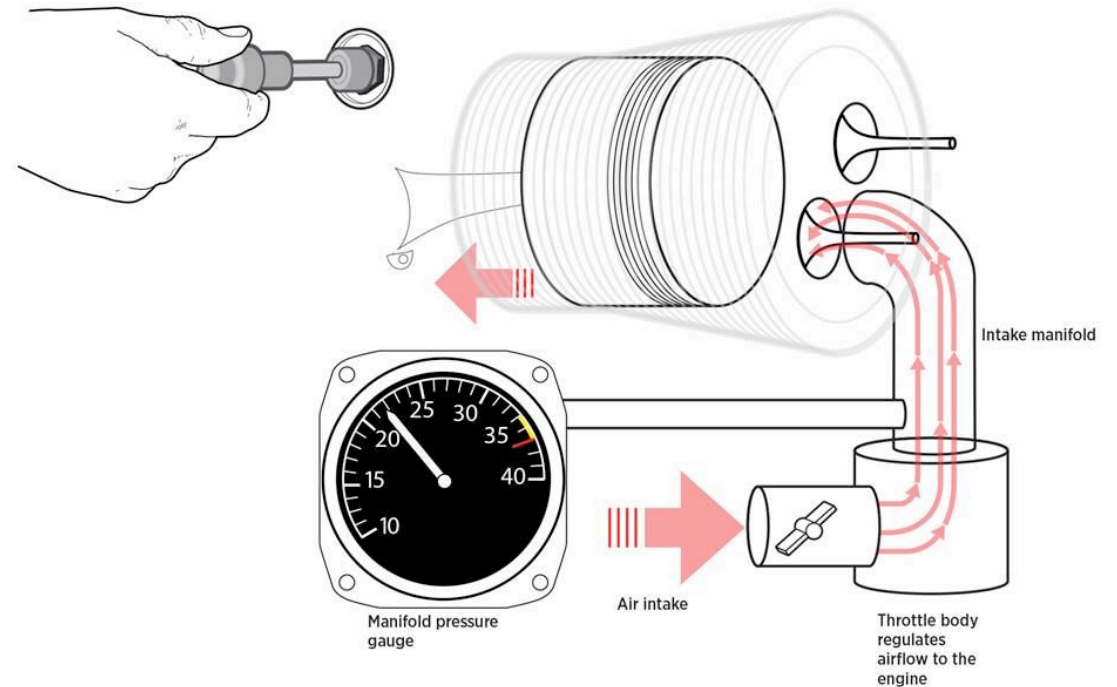


## Tachometer: Engine RPM

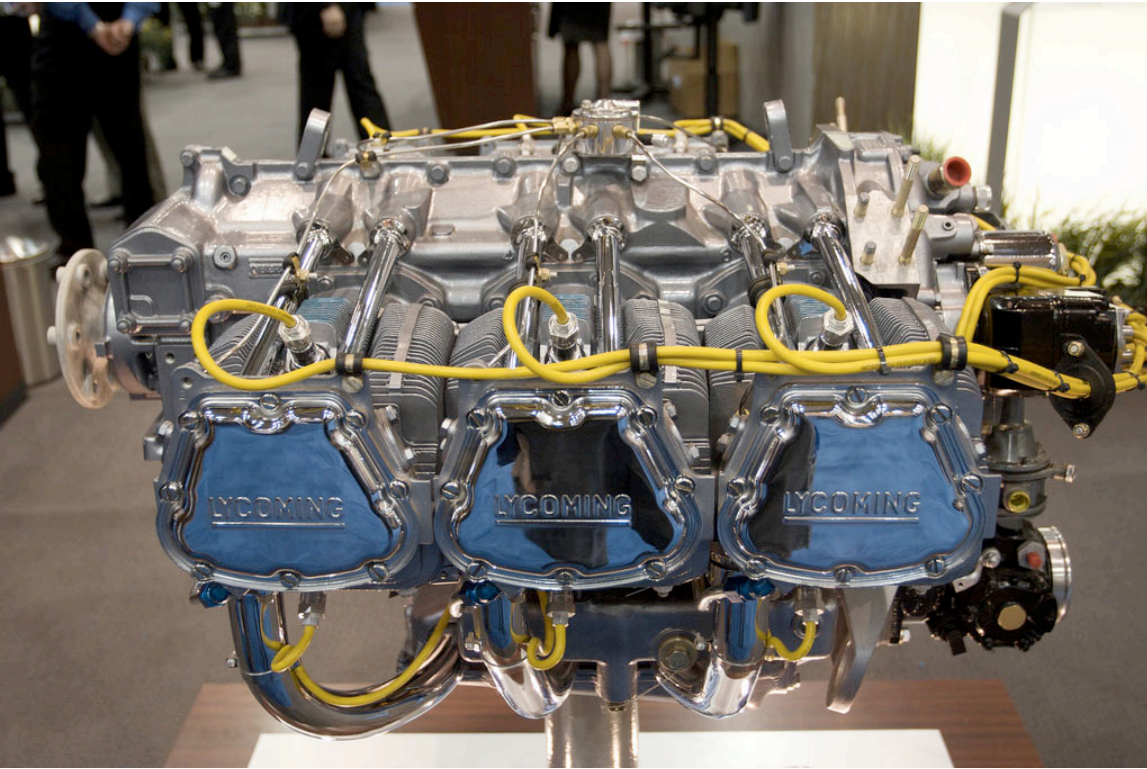
- Primary indication of power on a fixed-pitch propeller
- Indicates hundreds of RPM
- Green indicates normal operating range
- Red line should never be exceeded
- RPM output can change with altitude

# Manifold Pressure: Engine Power

- Partial vacuum of the engine "sucking in" air
- Primary power indication with a constant-speed propeller
- Reads ambient pressure when engine is off



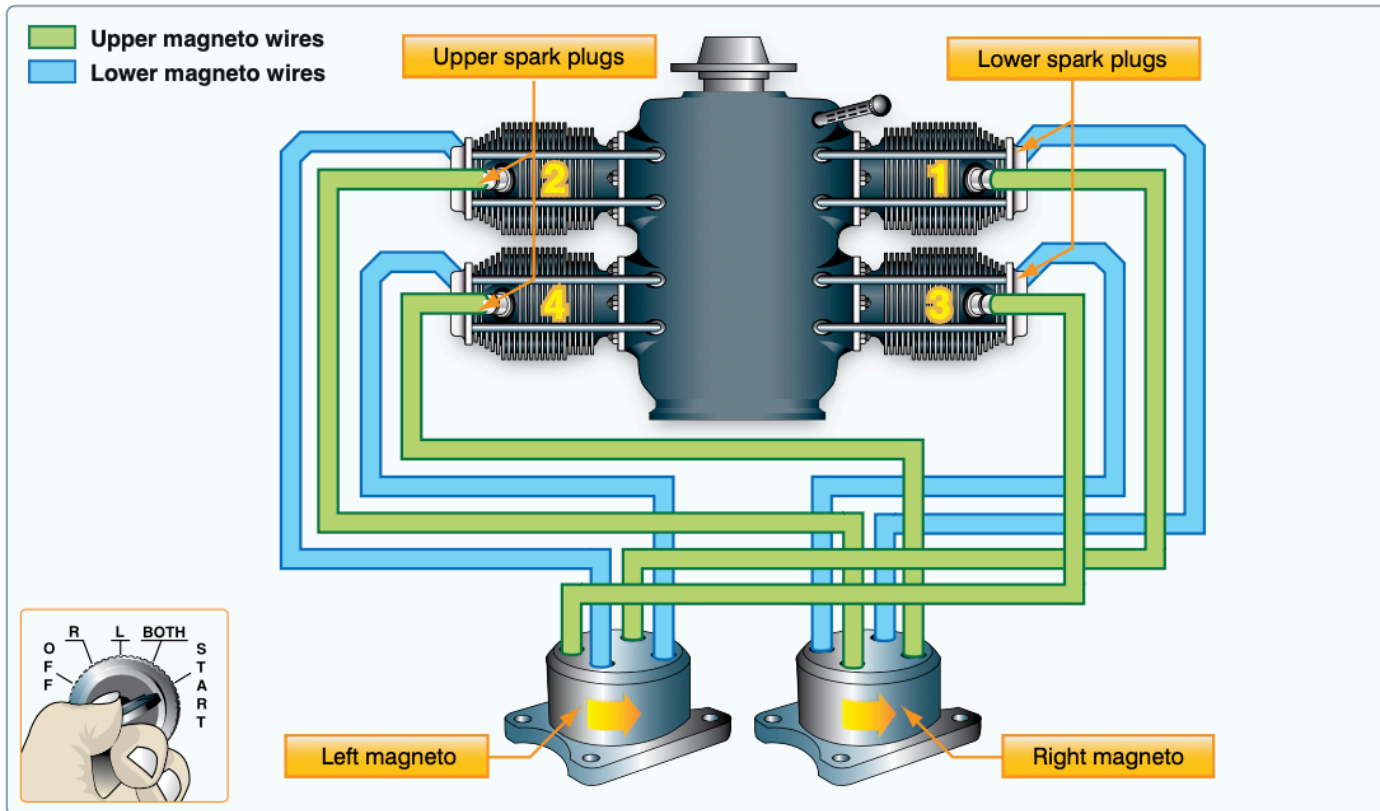




## Ignition System

- Provides the spark which ignites the fuel/air mixture
- Usually driven by magnetos, small generators which generate electrical current
- Magnetos are driven directly from the engine, independent of the electrical system

# Dual-Magneto Systems



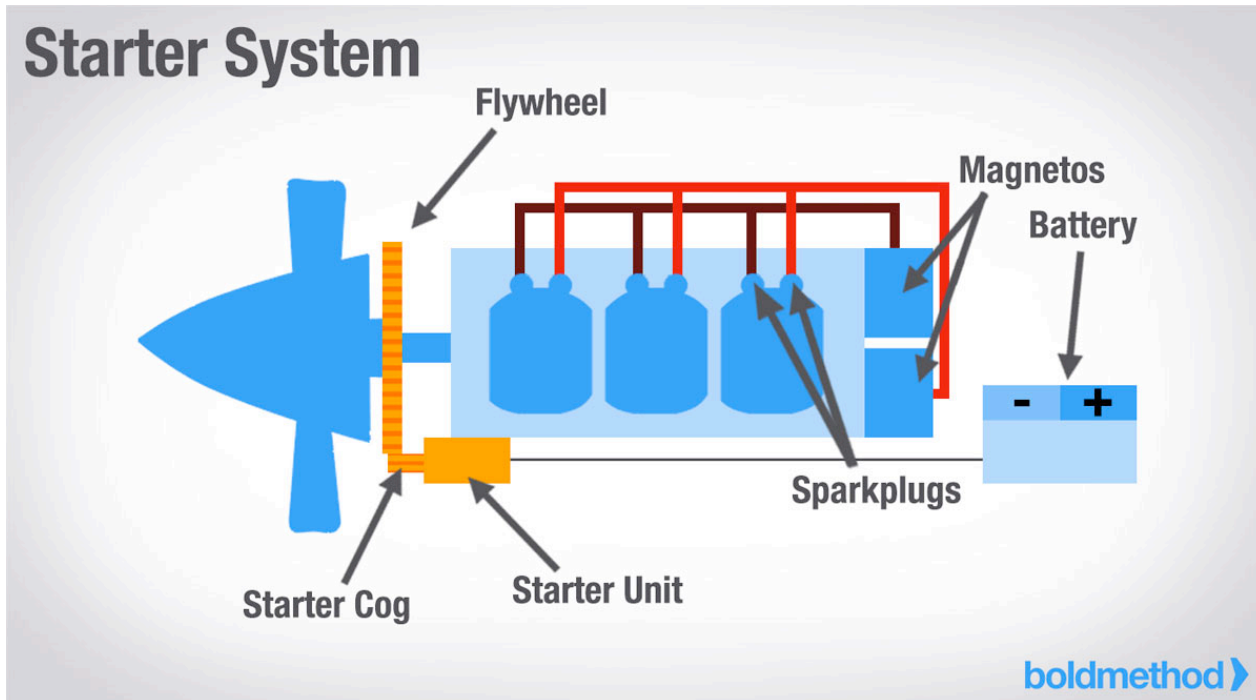
- Two sets of spark plugs in each cylinder, one from each magneto
- Magnetos can be selected independently
  - Both magnetos results in better burning of the fuel/air mixture
  - One magneto has a slightly lower power output



## Spark Plugs

- Current wants to jump the gap between leads
- Dual-magnetos will have two spark plugs per cylinder
- Leaded gasoline can leave lead deposits on the spark plugs

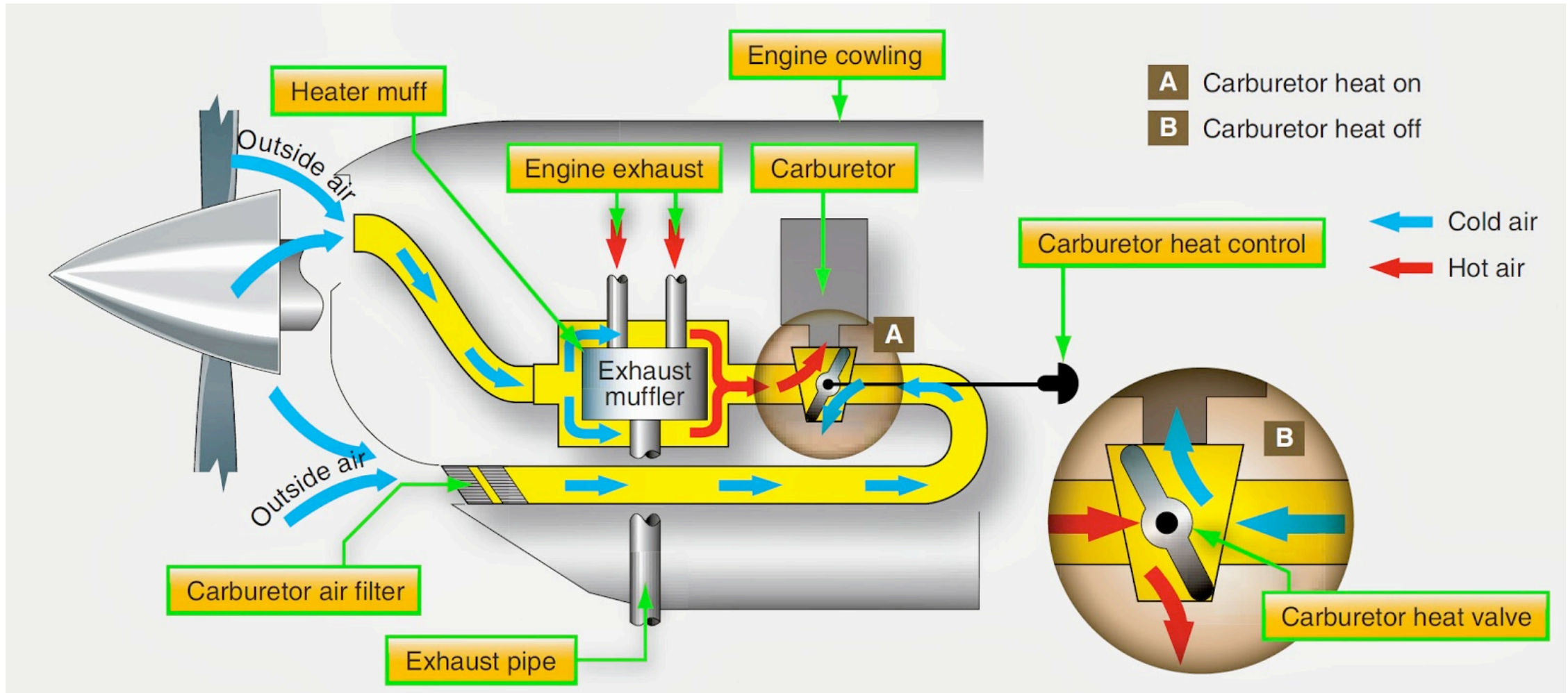
# Starter Systems



- Key engages a starter cog, which turns a flywheel
  - Once the engine starts, starter cog retracts
- Most starters are low-duty electric motors
  - Don't crank for long periods, allow for cooldown between attempts

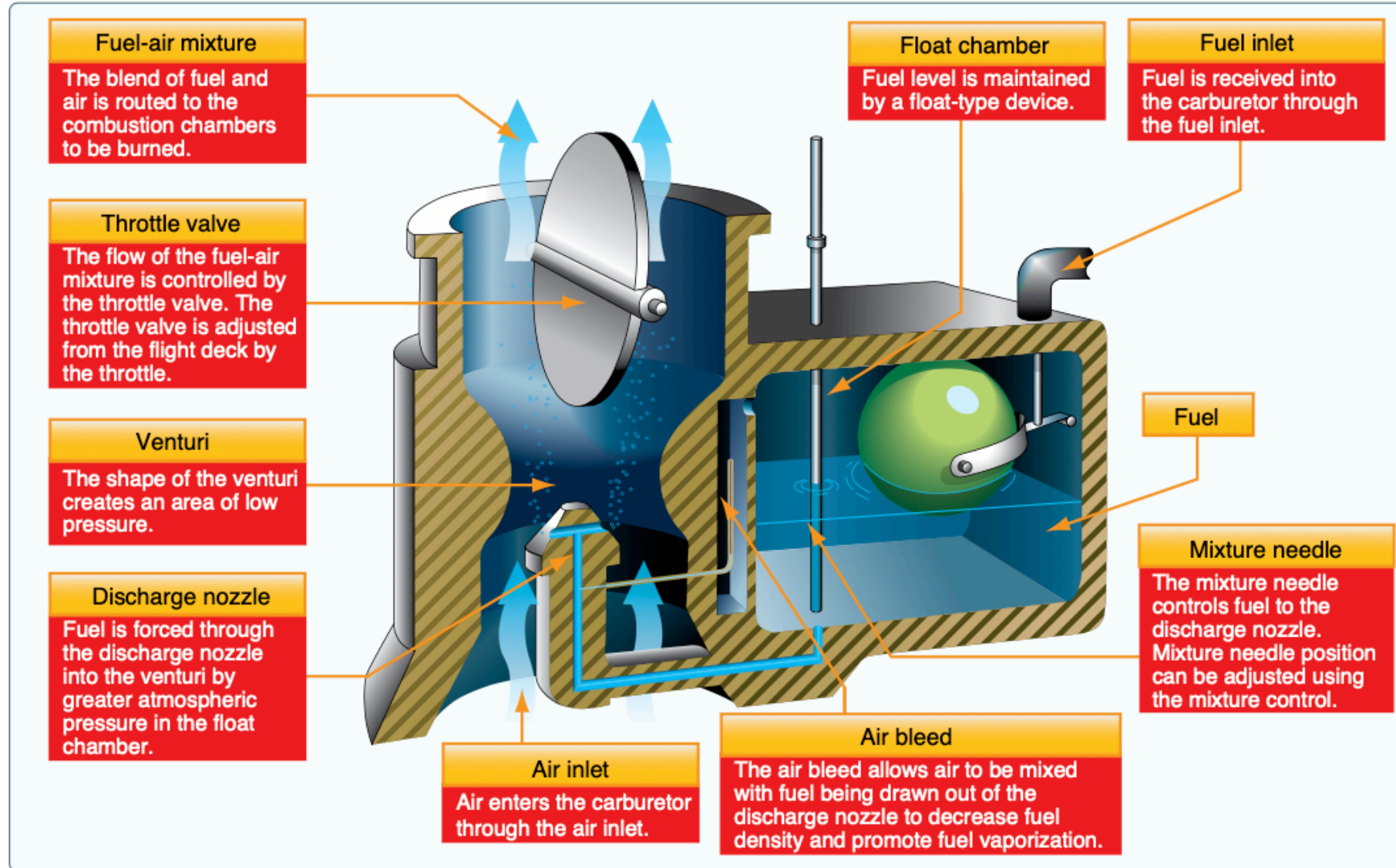


# Induction System: Gets air into the engine



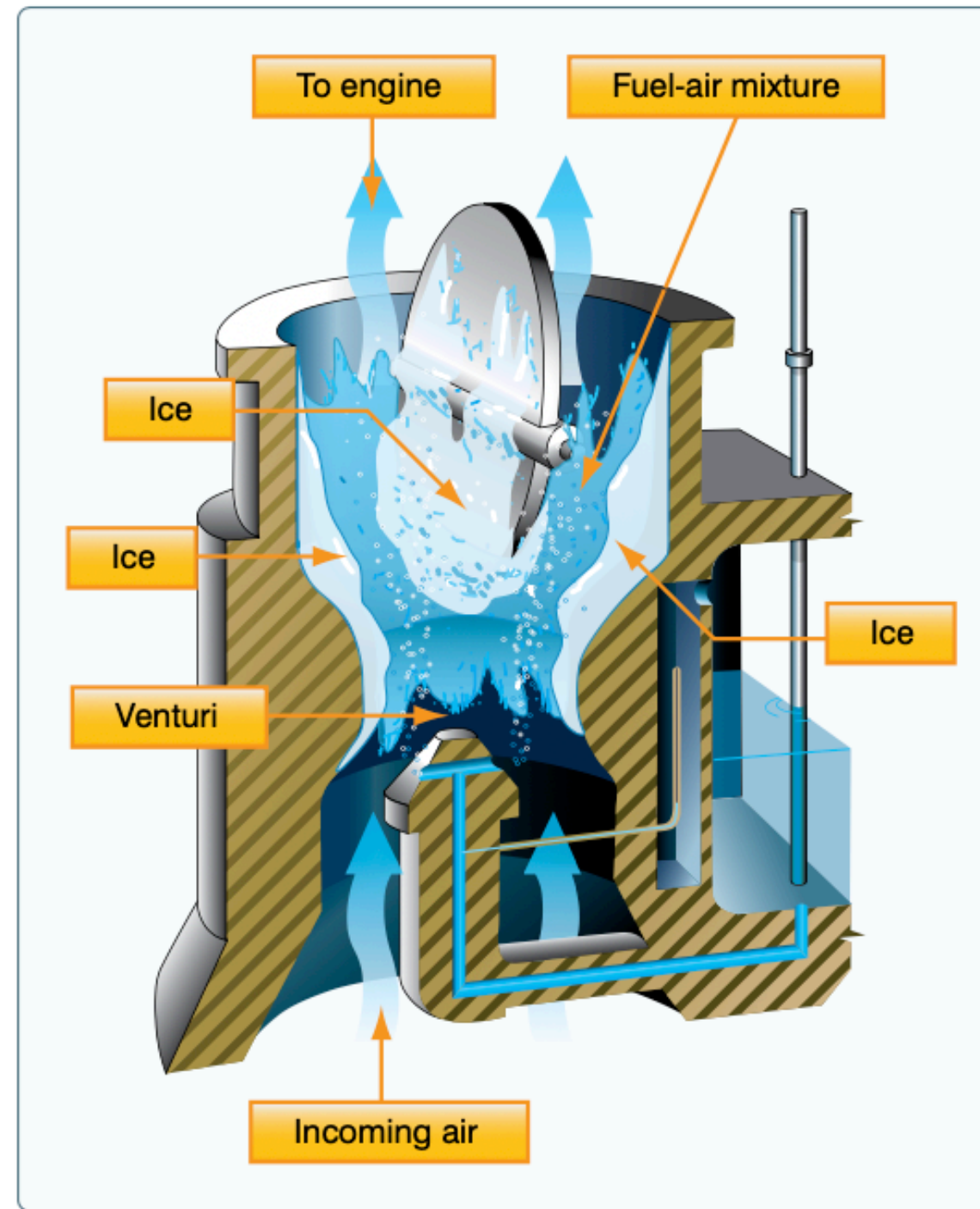
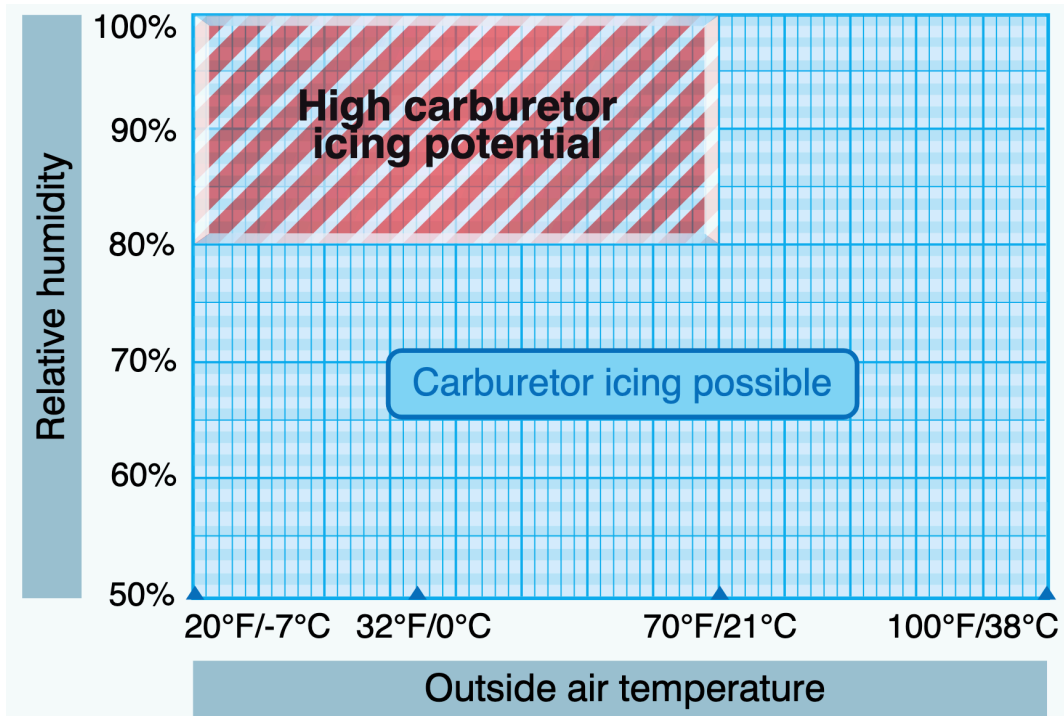


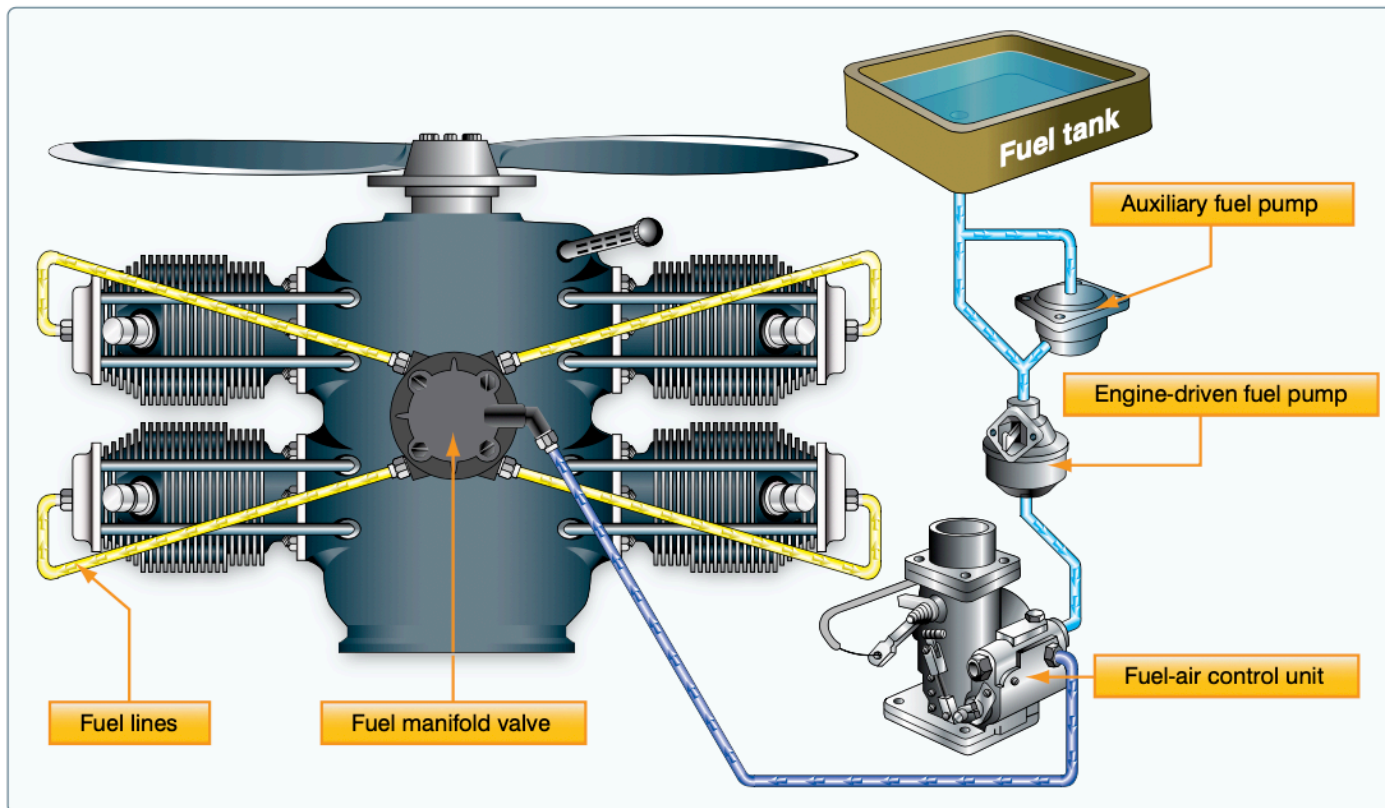
# Carburetor



# Carburetor Icing

- Acceleration of air + vaporization of fuel drastically cools the air
- Carburetor heat is used to combat this





## Fuel Injection

- Alternative to carburetor
- Fuel is mixed in a manifold just before entering the cylinder
- Relies on a fuel pump for continuous fuel pressure
- Produces more even cylinder temperatures

### **Sealing**

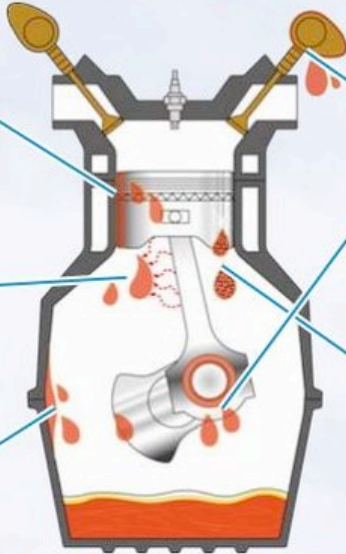
The oil seals gaps, preventing the escape of gases.

### **Cooling**

The oil absorbs heat, preventing overheating and burning of parts.

### **Rust Prevention**

The oil helps to prevent rust and corrosion.



### **Lubrication**

The oil allows the moving parts to slide smoothly, reducing friction and wear.

### **Cleaning**

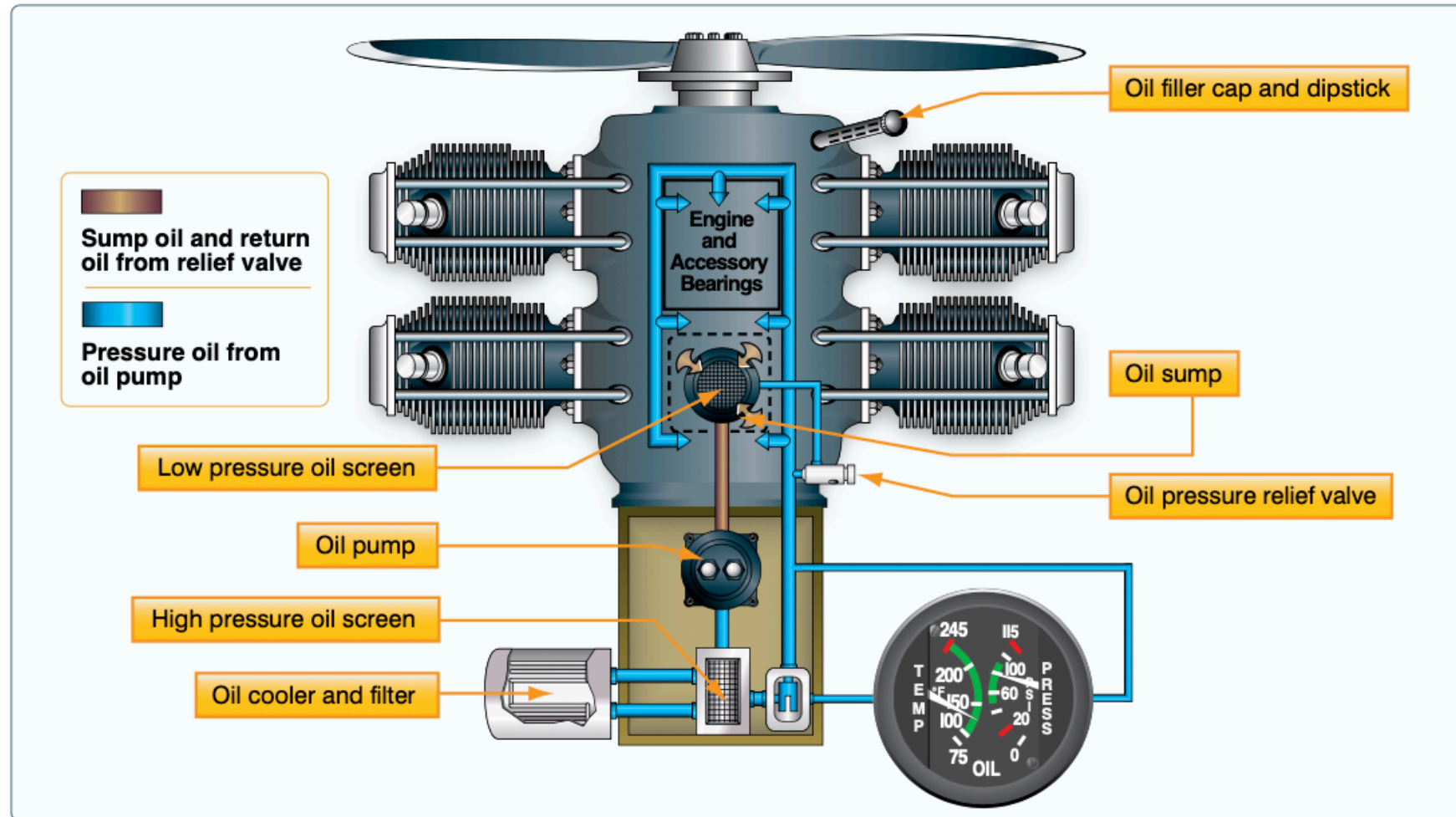
The oil picks up and disperses soot, sludge, etc., cleaning the engine.

## Engine Oil System

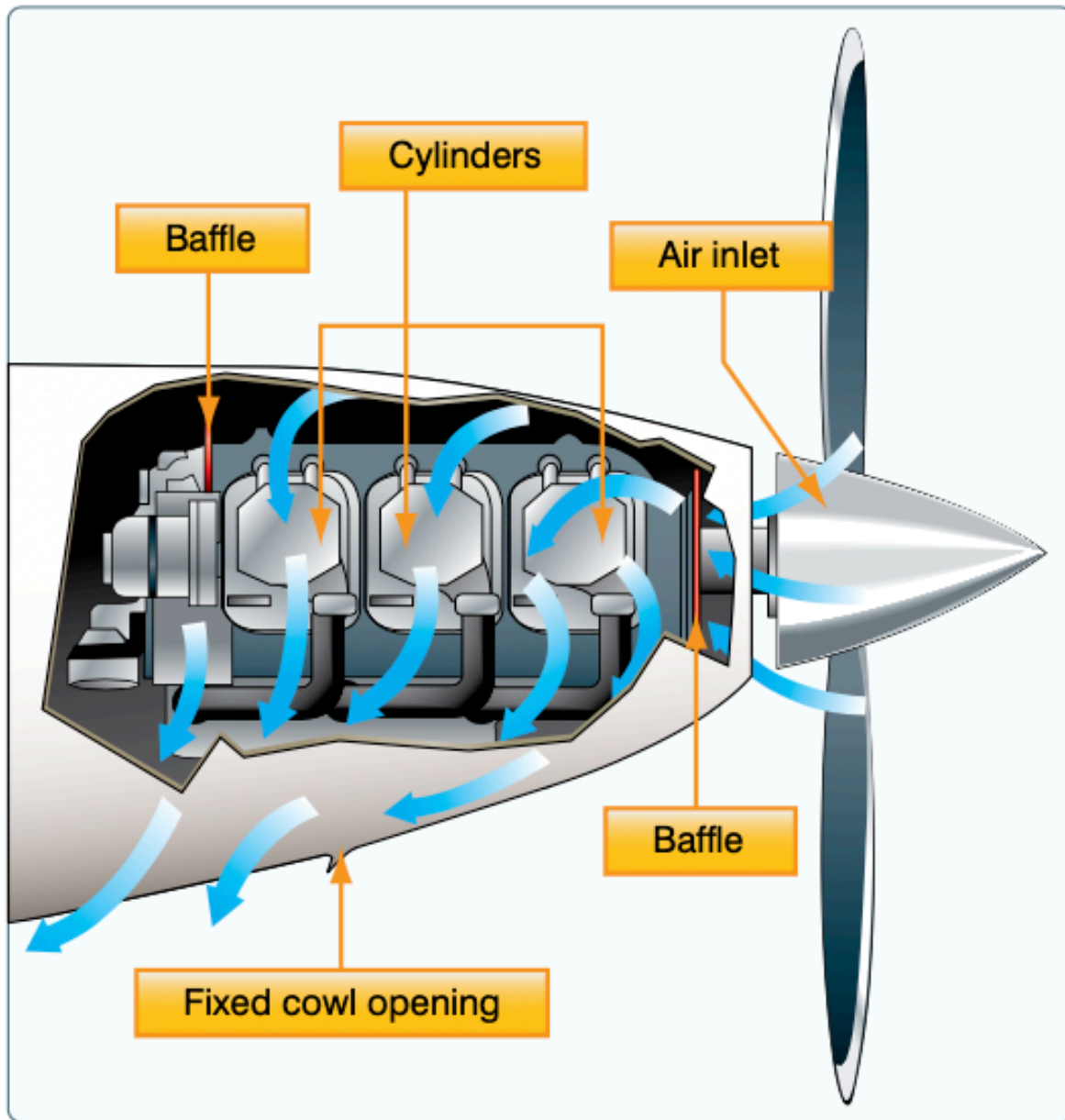
- Lubricates, cools, cleans, seals engine components
- Also prevents rust
- Lubricates the crankshaft, pushrods, cylinder heads



# Types of Oil Systems: Dry or Wet Sump



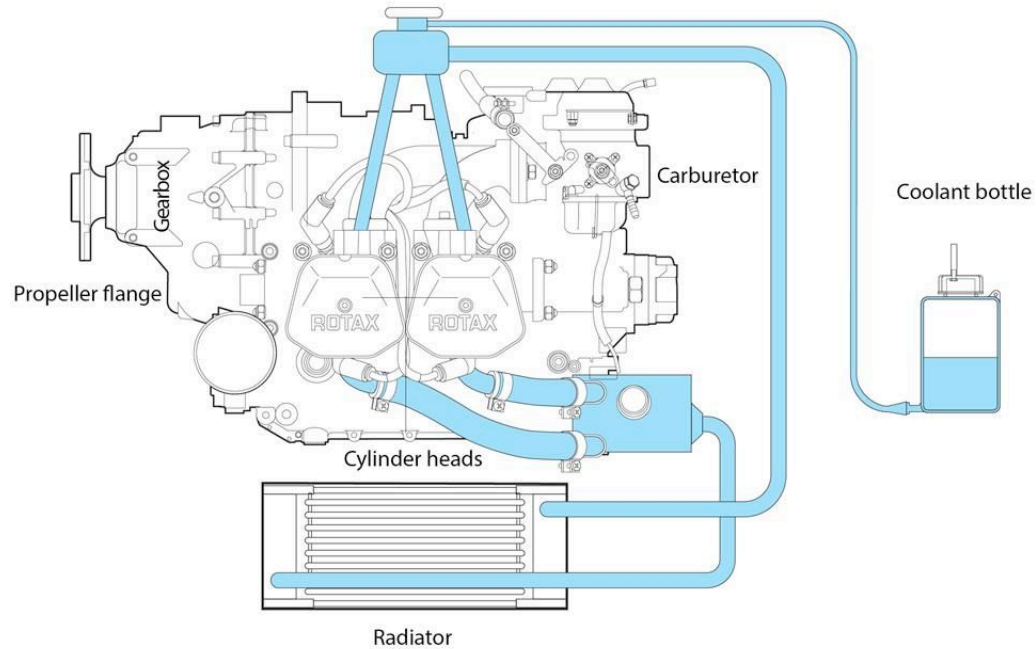




## Engine Cooling: Air Cooling

- Air-cooling through baffles
- Oil cooler at the front of the airplane

**Figure 7-19.** *Outside air aids in cooling the engine.*



## Engine Cooling: Liquid Cooling

- Coolant is circulated through the engine and absorbs heat
- Coolant is passed through a radiator to expel heat energy
- Similar to a car's radiator

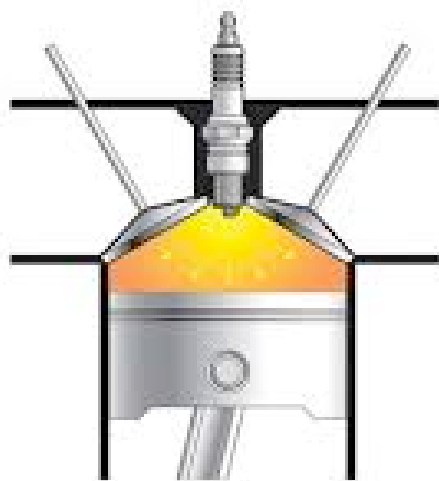
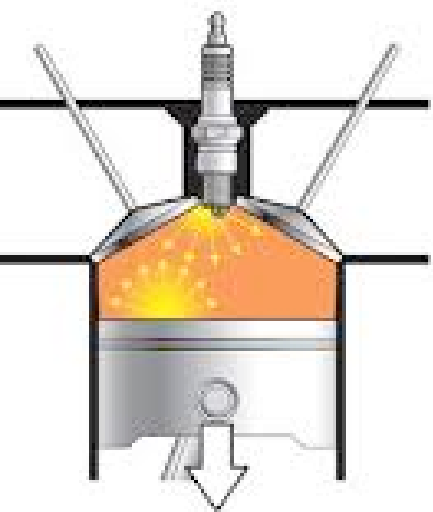


Normal combustion

Explosion

## Detonation

- Detonation: Uncontrolled, explosive ignition of the fuel-air mixture within the cylinder
- May happen with:
  - Lower fuel grade
  - Excessively lean mixture / high power
  - Low RPM / high power



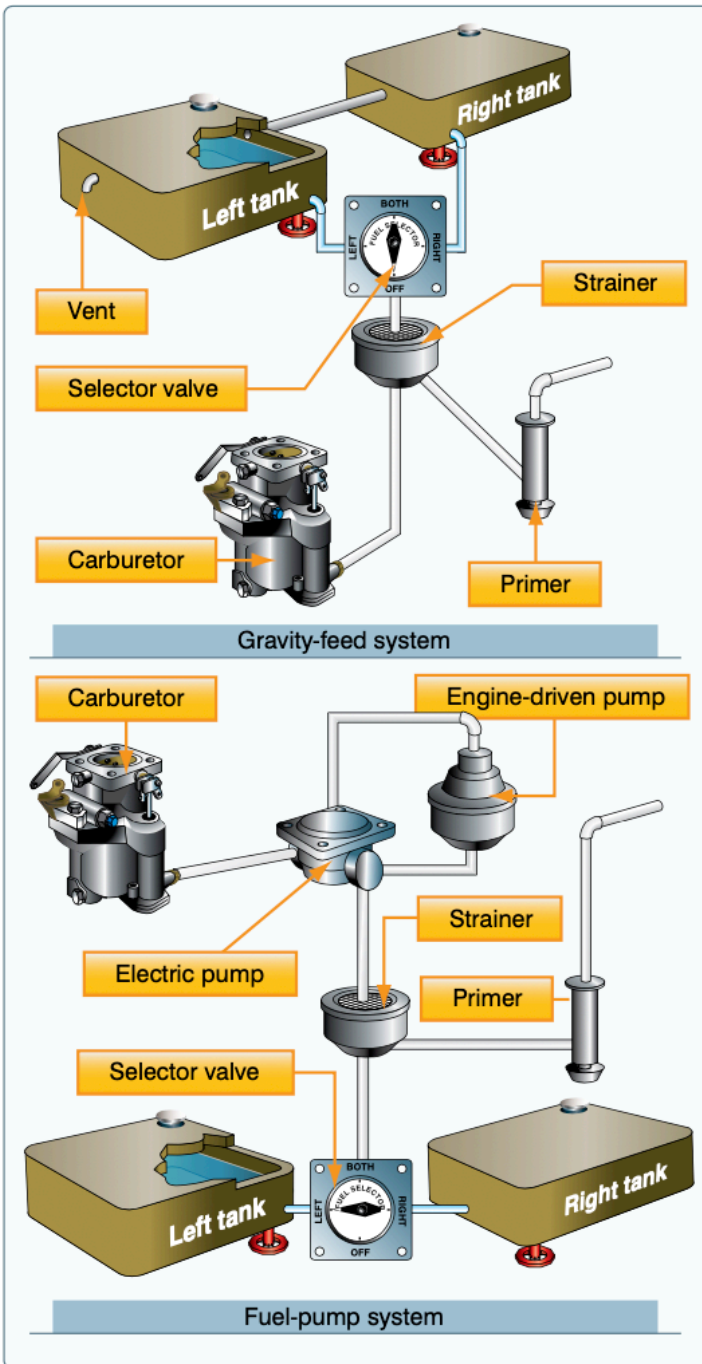
## Pre-Ignition

- Occurs when the fuel-air mixture ignites prior to the engine's normal ignition time
- Carbon build up and create hot spot in the combustion chamber
- Can cause damage since the cylinder is being pushed on the compression stroke

## **Preignition and Detonation Remedy**

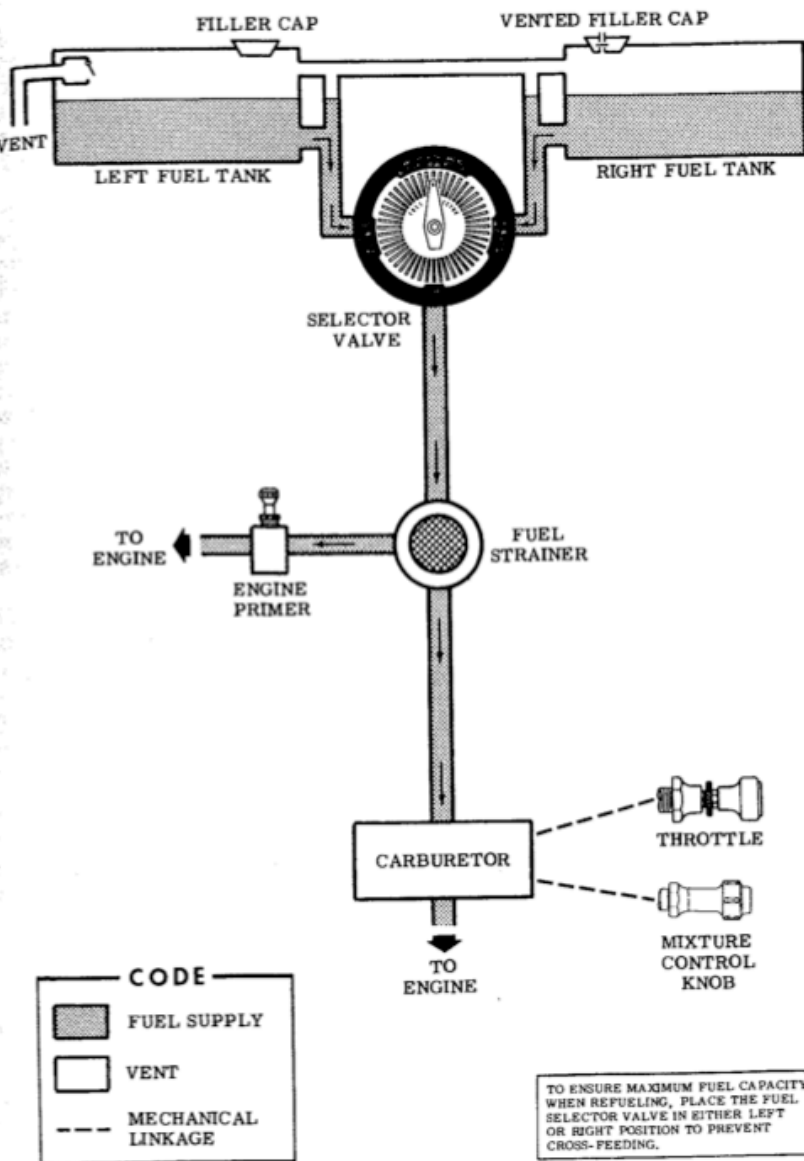
- Engine running rough, but we may not know which one
- Lower power
- Open cowl flaps and shallow climb angle
- Enrichen mixture to enhance cooling





## Fuel System

- High-wing airplanes are usually gravity-fed
- Low-wing airplanes have a fuel-pump system
  - Electrical pump and an engine-driven pump
- Fuel tanks: Wet wings vs wing tanks or bladders



## Fuel System (cont.)

- Fuel primer is used to draw fuel into the cylinders prior to starting
- Fuel selector valves
  - High-wing airplanes may have a "both" option
  - Low-wing airplanes often do not, must be switched periodically
- Running a fuel tank dry may cause vapor lock and impurities to enter the engine

Figure 7-6. Fuel System (Standard and Long Range)

# Fuel Sumps

- Fuel sumps and drains are usually present
  - At the lowest point on each tank
  - At the lowest point in the system

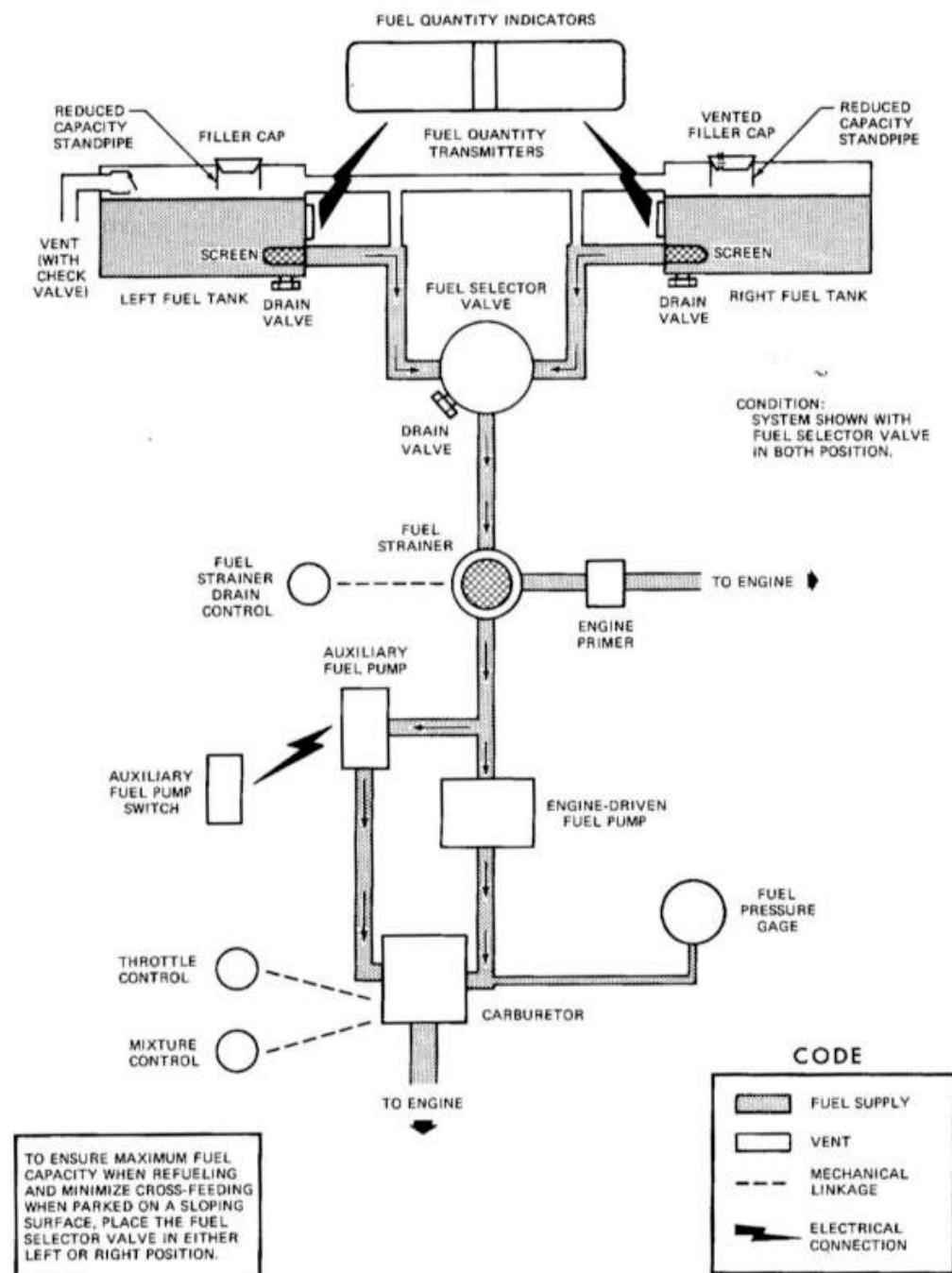
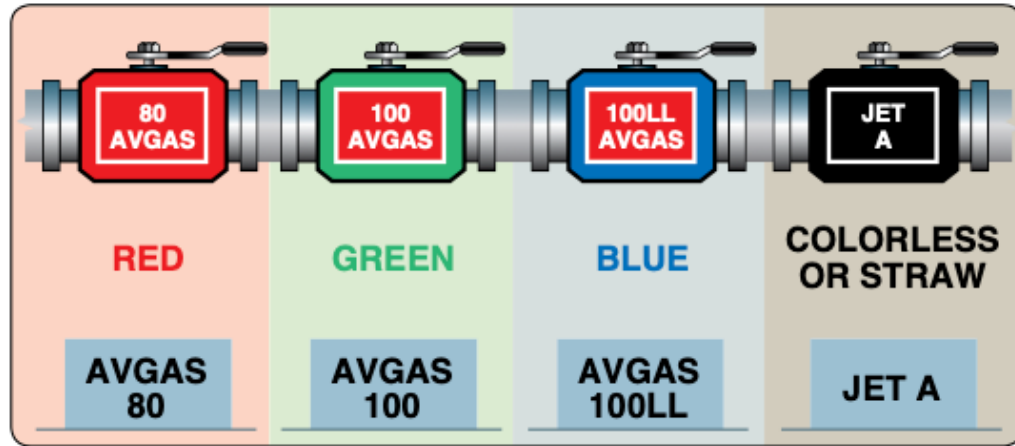


Figure 7-5. Fuel System

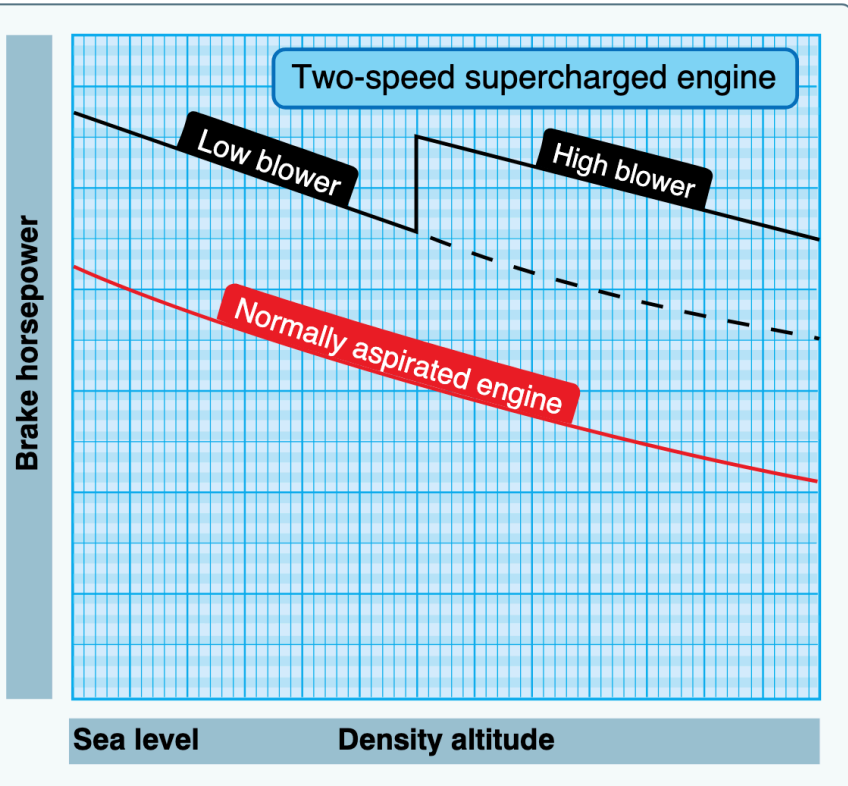
# Fuel Grades



- AVGAS 80 and 100 aren't available
- Can never mix JET-A and AVGAS
- 100UL is an unleaded variety now available - colored yellow
- Automobile gasoline may also be available (mogas)



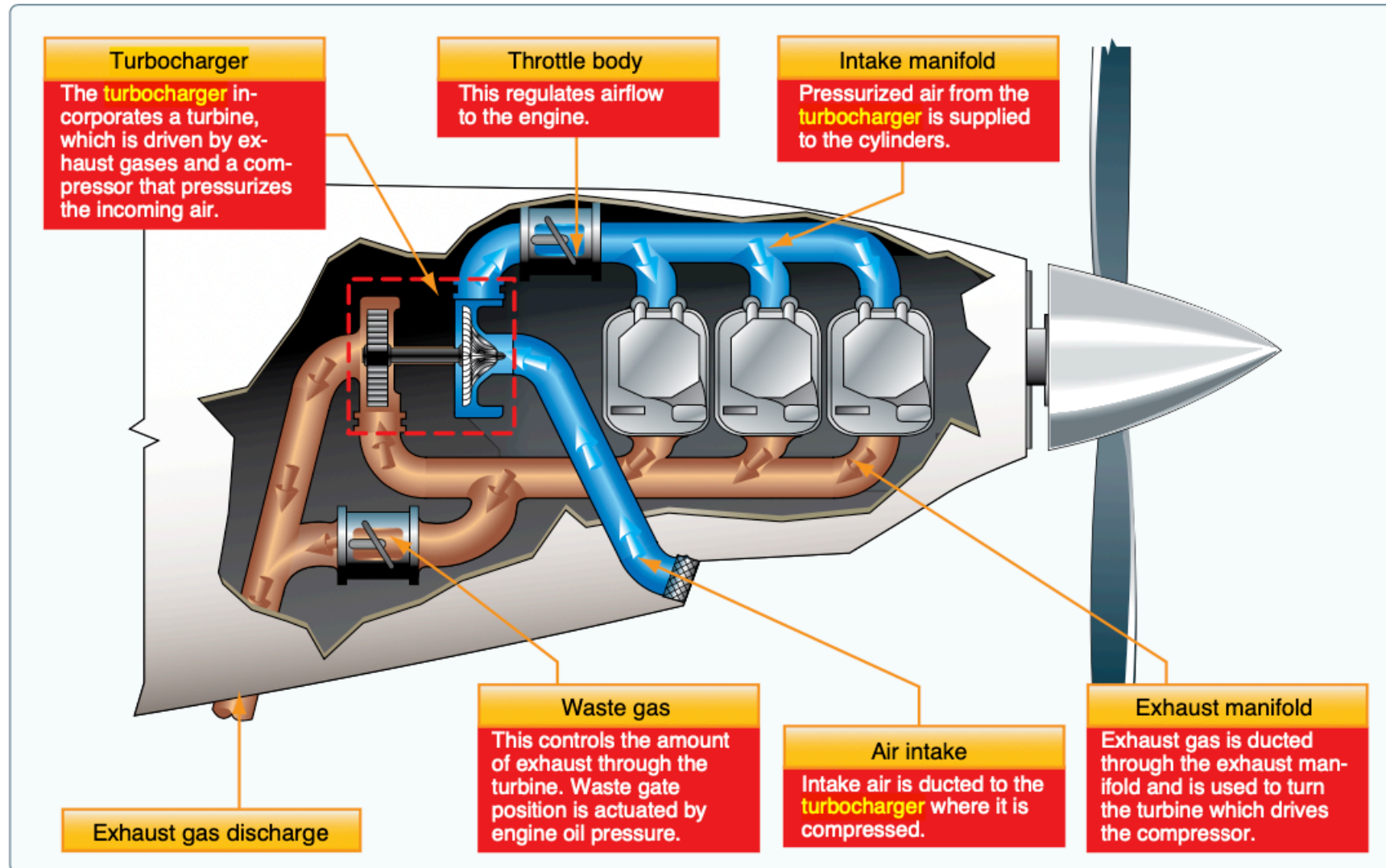
# Turbochargers and Superchargers



- Normally-aspirated engines lose horsepower as they climb into thinner air
- Boosting intake air pressure can maintain horsepower, burning more fuel
- Turbonormalization: Boosting to sea-level pressure
- Turboboosting: Boosting to more than sea-level
- They are especially useful when flying high

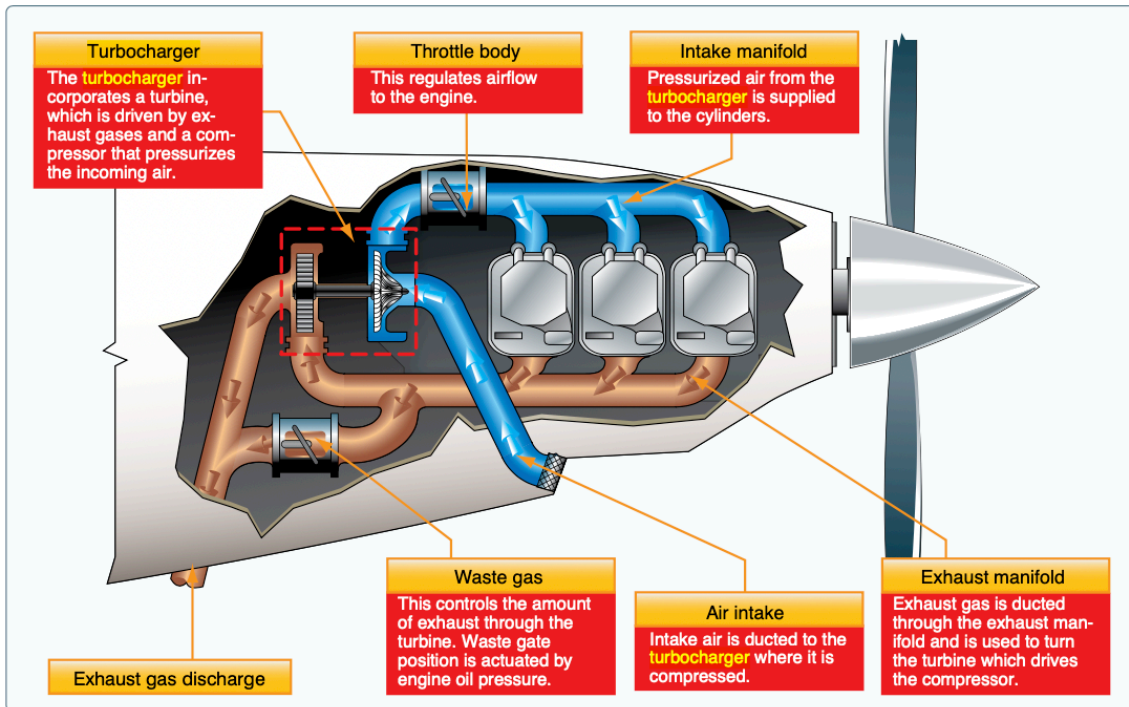


# Turbocharger Operation



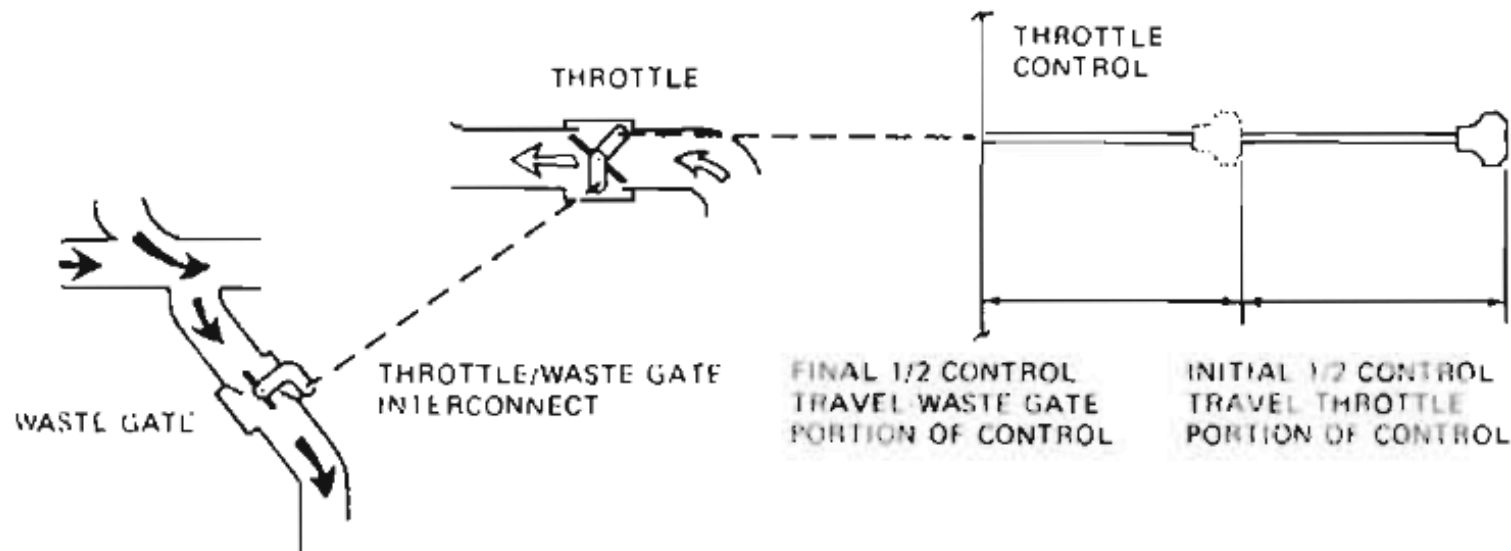
# Turbo Wastegate

- Controls how much exhaust is vented into the turbine
- Wastegate slowly closes as you climb, meaning more pressure and constant power
- At the critical altitude the wastegate is completely closed, no more boost

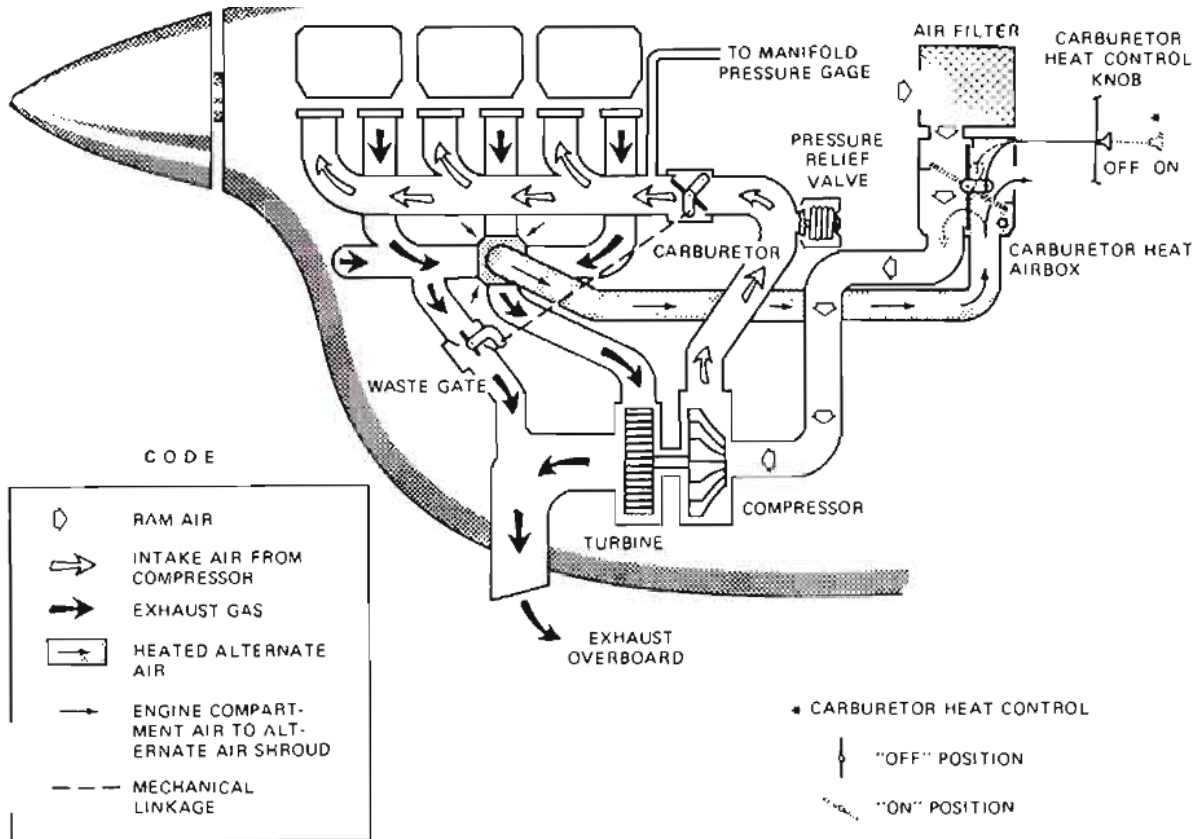


# Wastegate Control

- Different airplanes have different wastegate control mechanisms
  - Some airplanes open/close automatically to maintain a give manifold pressure
  - Manual wastegates are common on aftermarket turbochargers
  - The T182 is mechanically linked to the throttle
    - Need to be careful not to overboost

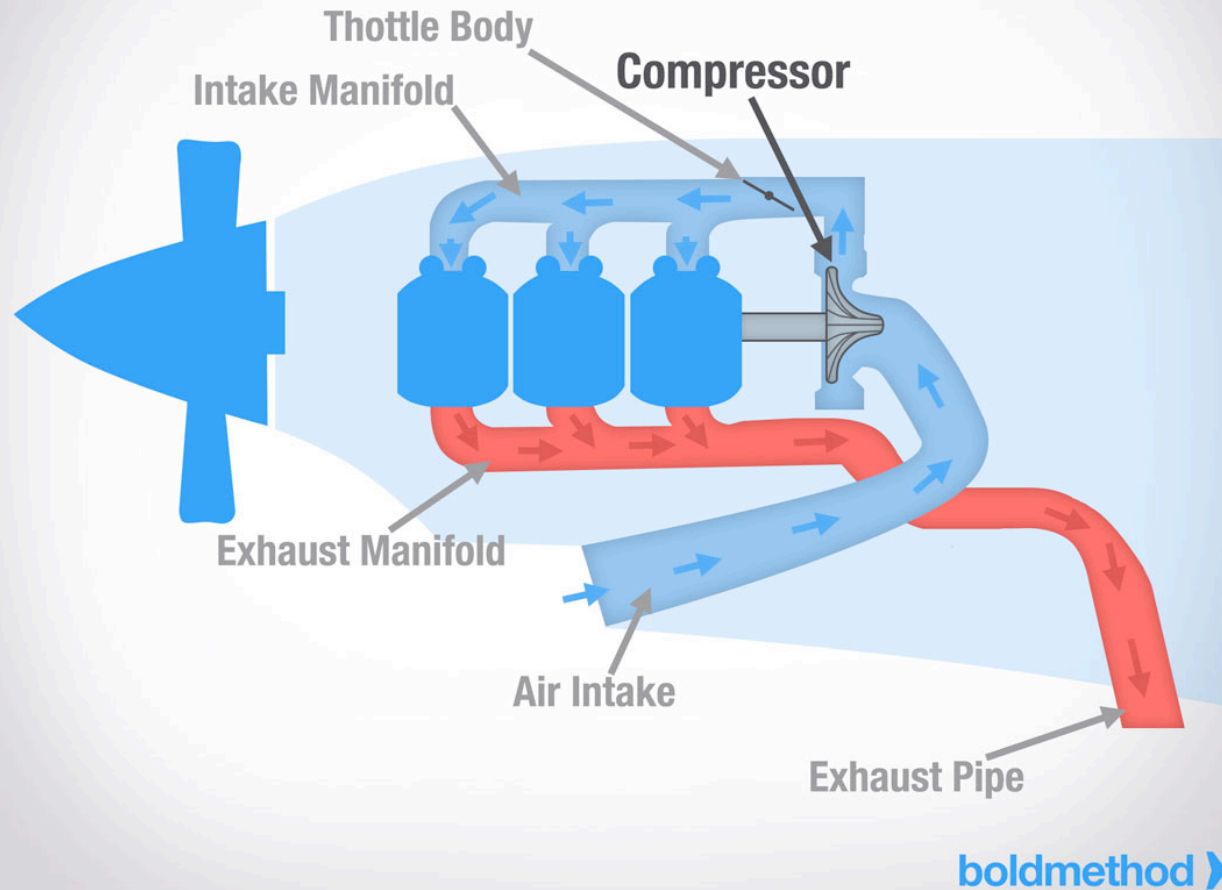


# Turbo Failures



- Failure of the turbine/compressor
  - Engine essentially because a normally-aspirated engine with constricted airflow
- Failure of the wastegate
  - May fail open, closed, or partially open
  - Need to modulate throttle to prevent over boosting
- Turbo cooldown
  - Allow for the RPM bearing temperature to equalize

# Supercharger Diagram



## Supercharger Operation

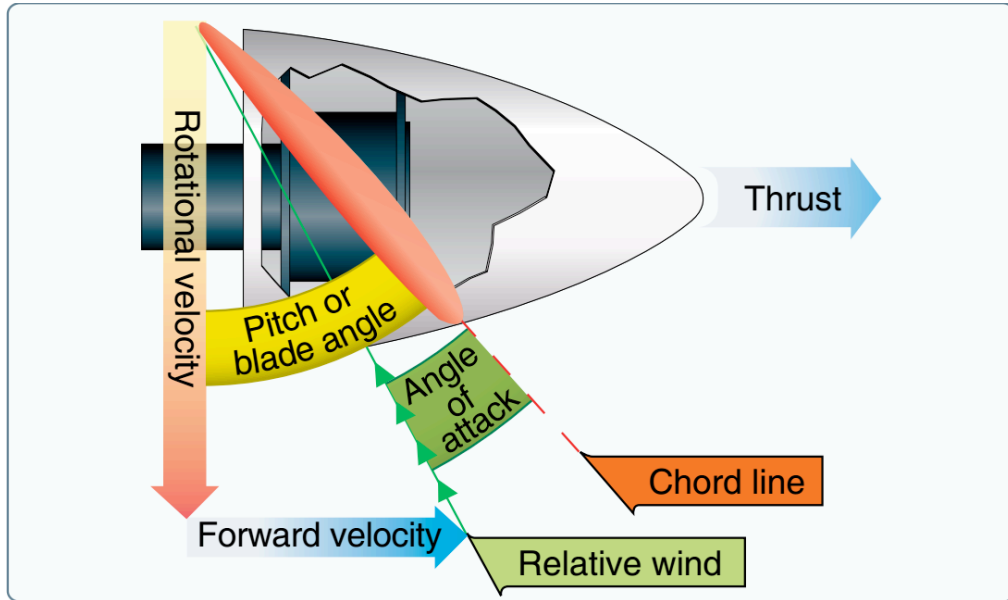
- Same principle as turbochargers, but different energy source
- Compressor is driven by the engine directly, not from the exhaust



# Propellers

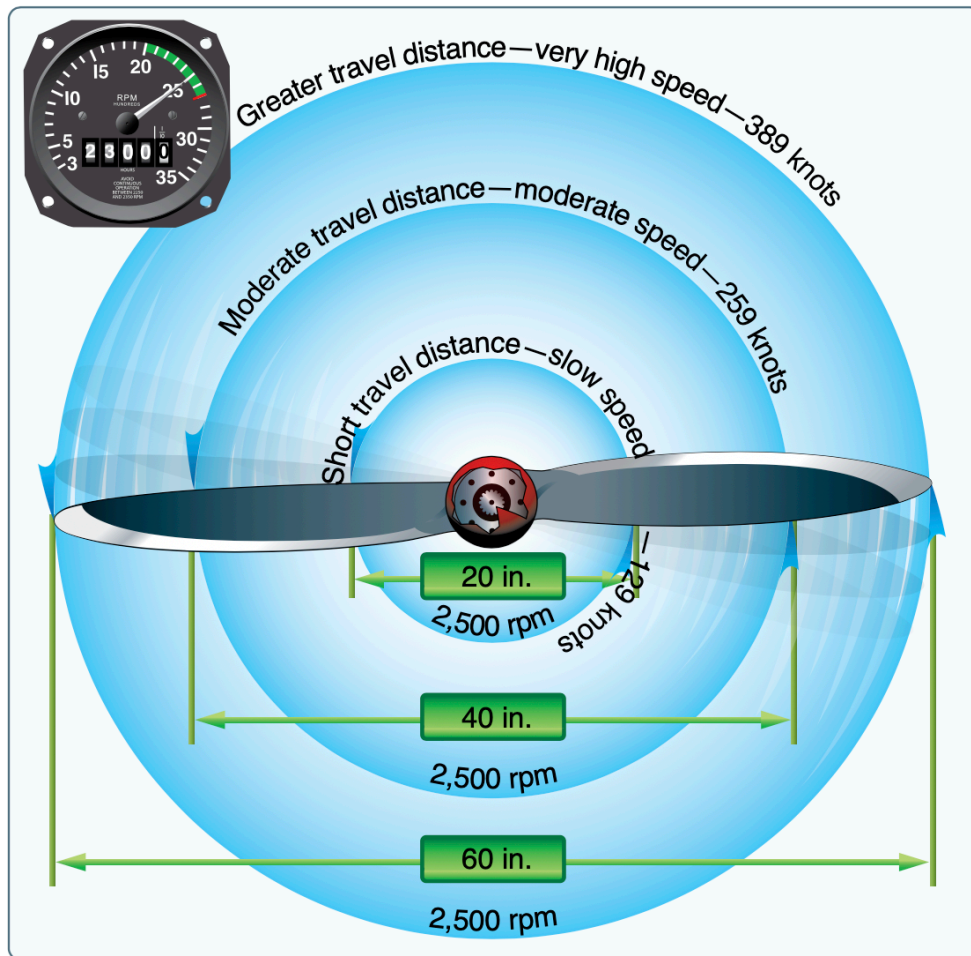
# Rotating airfoils

- Subject to angle of attack, stalls (exceeding critical AoA)

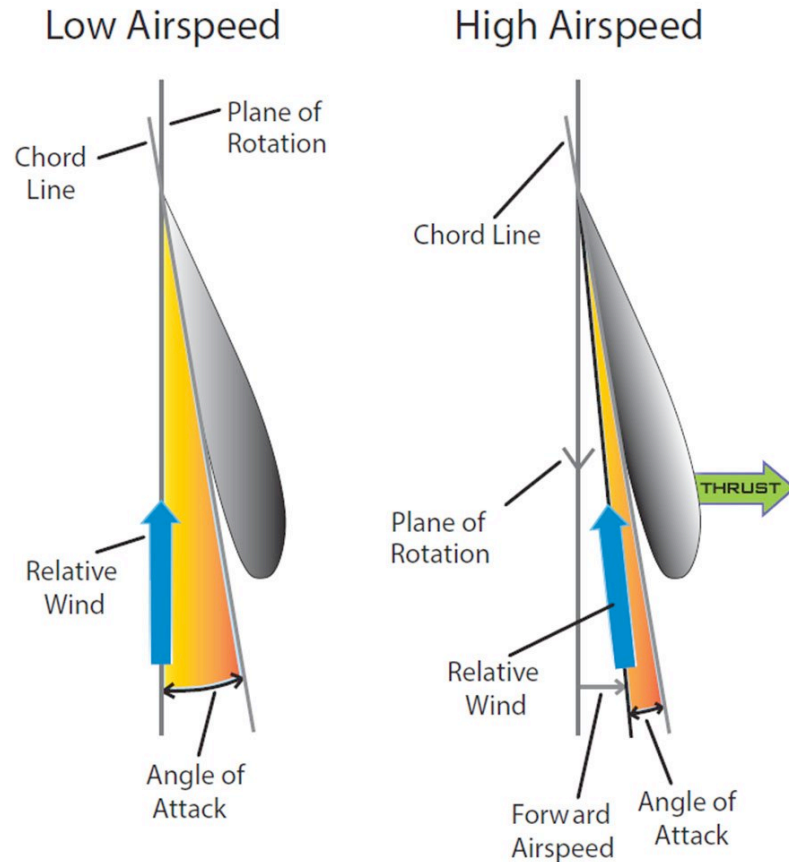


# Propeller Twist

- The propeller area near the hub is spinning slower than the tip



# Fixed-pitch propellers



- Propellers are calibrated for a single speed
  - High/fine pitch: Small "bite" of air
  - Low/coarse pitch: Big "bite" of air
- Corollary to gears on a bike: Climb prop is a low gear, cruise prop is a high gear
- A climb prop has lower pitch, less drag:
  - More RPM, horsepower, which increases takeoff and climb performance
- A cruise prop has a higher pitch, more drag:
  - Less RPM, bigger "bite" of air, but increased efficiency

# Ground-Adjustable Propeller

- Some airplanes have "adjustable" pitch propellers, which can be adjusted on the ground





# Variable-Pitch Propellers

- What if we could vary the prop angle in flight?
- Variable-pitch propellers allow us to dynamically set the blade angle
  - Constant-speed propellers automatically vary the pitch of the propeller to maintain an given RPM

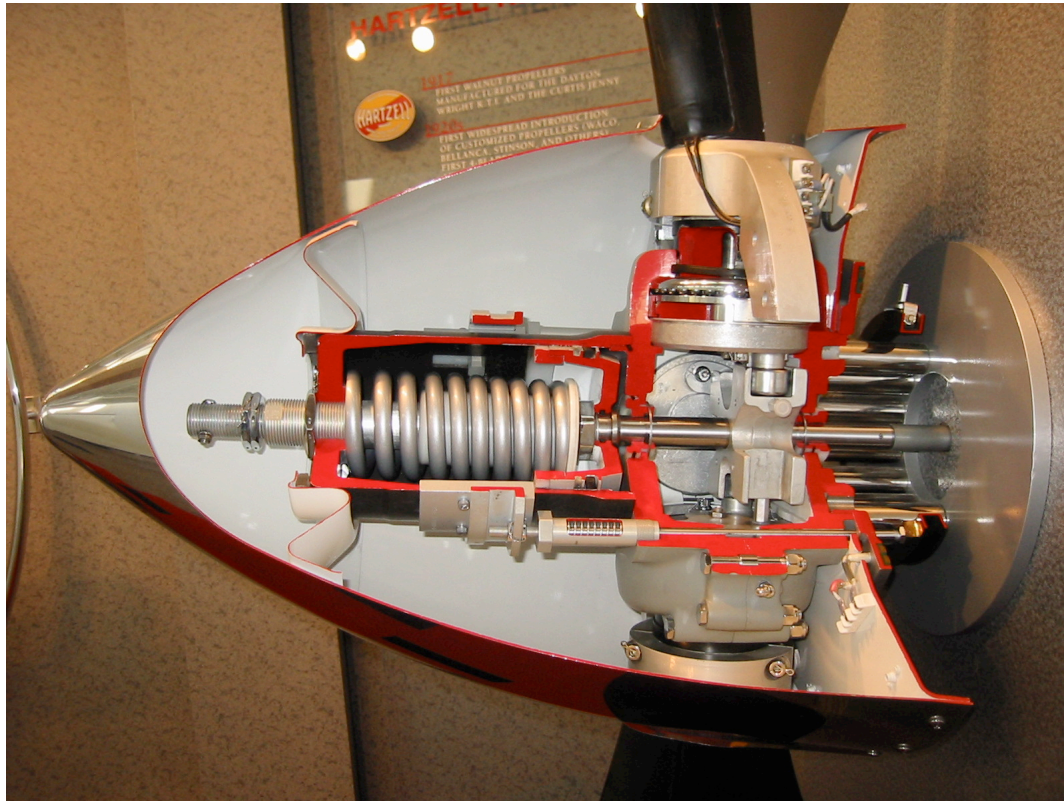


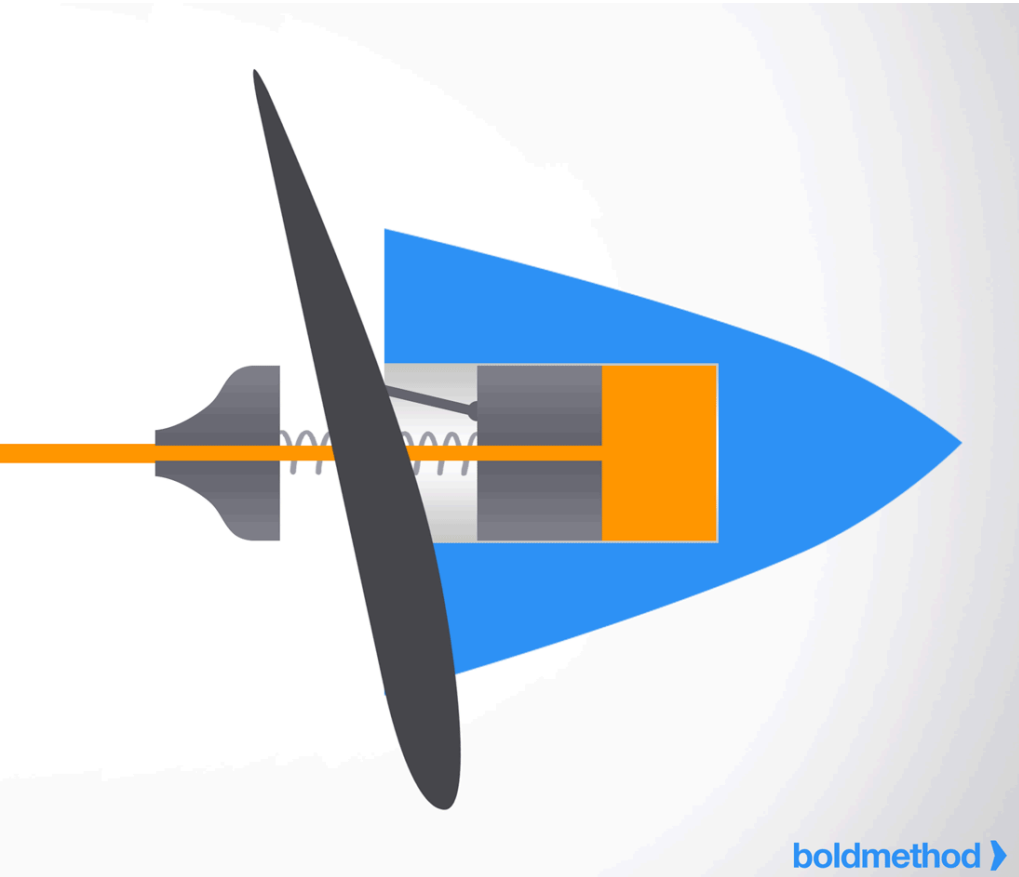
## Constant-Speed Propellers

- Effect of pitch on RPM
  - A "finer" or large pitch of a propeller increases RPM
  - A "coarser" or smaller pitch of the propeller decreases RPM

# Propeller Governor

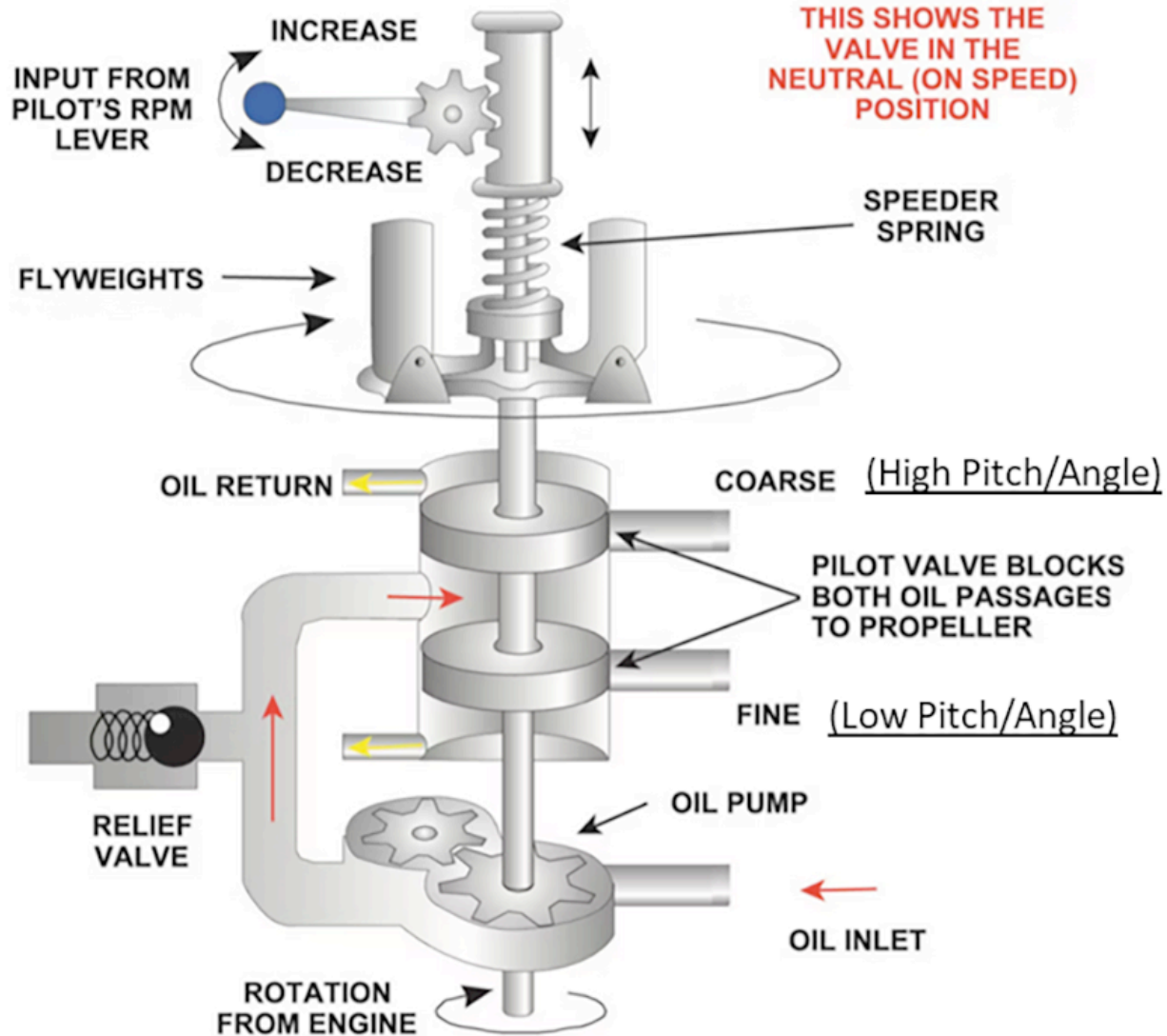
The propeller governor controls the pitch of the propeller to maintain a pilot-selected RPM





## Constant-Speed Prop Operation

- Engine oil is boosted into the propeller hub assembly
- A spring is tensioned to hold the prop in the full fine or large pitch setting
- Engine oil must work against this to coarsen the blade
  - The engine oil forces a piston which changes the angle of the blade



## Governing Oil Pressure

Oil pressure is governed by a set of fly-weights, tuned to a specified RPM

- Prop spins faster: flyweights move outward, more oil is forced into the blade angle piston
- Prop spins slower: flyweights fall inward and less oil is allowed to enter the blade angle piston

# Constant-Speed Prop Usage



- When increasing power: Increase prop first, then engine power
- When decreasing power: Decrease power first, then decrease prop
- Always change RPM slowly and smoothly



# Constant-Speed Prop Failures

- Loss of oil pressure
  - Propeller should fail in the high pitch position (high RPM)
- Prop control linkage failure
  - May get stuck at a particular RPM setting
  - Modulate with engine power to prevent overspeed

# Constant-Speed Prop Pros/Cons

- Pros
  - Better performance at high altitudes
  - Better performance for climb and cruise
- Cons
  - Complexity, risk of failure
  - Weight
  - Maintenance

# Summary

- 4-stroke engine on most light aircraft
- RPM and manifold pressure are our primary indications
- Magnetos are self-contained electrical systems that power the spark plugs
- The induction system gets air into the engine
- Turbochargers: Help us maintain sea-level pressure and high altitude
- Fixed-pitch propellers are common on most trainers
- Constant-speed propellers are used for efficiency in cruise and climb

## **Knowledge Check**

Will the engine run if the master switch is off?

## **Knowledge Check**

What effect would low oil pressure have on a constant-speed prop?

## Knowledge Check

Two airplanes take off at sea level. One has a normally aspirated 150 H.P. engine, the other has a turbo-normalized 150 H.P. engine.

Which one will produce more power?



## Knowledge Check

You come out to the airplane one morning and notice your fuel sump is completely clear, but not blue. What should you suspect?

## Knowledge Check

You come out to the airplane one morning and notice your fuel sump is completely clear, but not blue. What should you suspect?