Engines

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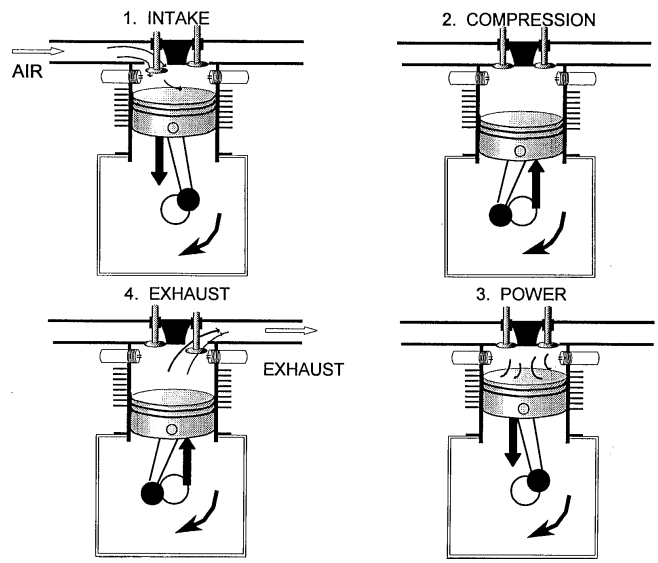
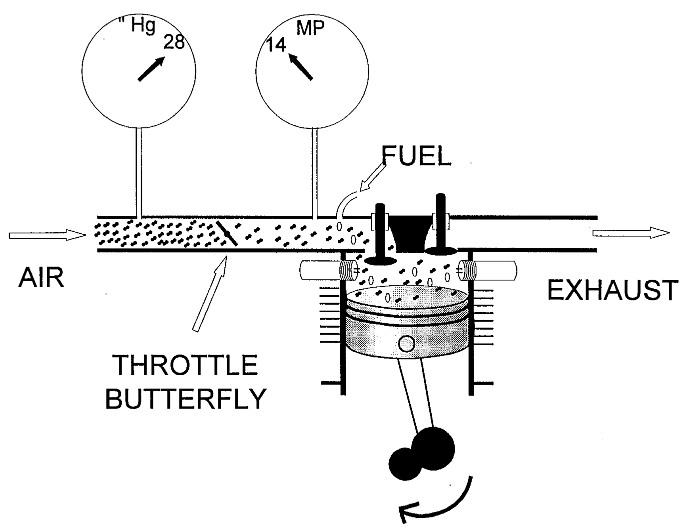
Piston Engine Fundamentals



- Most airplane piston engines are *four-stroke* engines. The four strokes are:
  - *Intake* – the piston moves down, sucking air and fuel in through the intake manifold
  - *Compression* – the piston moves up, compressing the air and fuel mixture
  - *Power* – The spark plug(s) fire, causing the fuel/air mixture to burn and the piston to move down from the resulting expansion of the air
  - *Exhaust* – The piston moves up, pushing the air out through the exhaust manifold
- Unlike in a car, the ignition spark is generated by a *magneto*, an early 20th century device that does not require any external power source. Thus, the operation of an airplane engine is independent of the airplane's electrical system (alternator and battery).
- **Airplane engines have two magnetos, and two spark plugs in each cylinder (one per magneto). This provides redundancy in the event of a magneto failure, but also allows the fuel to burn more evenly resulting in higher performance.**
- **Before takeoff, a *magneto check* is performed during which each magneto is disconnected one at a time to make sure the other magneto and associated spark plugs are operating properly**

Throttle, Manifold Pressure, RPM, and Propellers



- Air is not forced into the cylinder. Instead, the vacuum caused by the intake stroke draws air into the cylinder.
- The *throttle* controls the amount of air admitted into the cylinder, and thus the amount of power produced
- The part of the intake system that is exposed to outside air will be at the outside air pressure
- The part of the intake system that is exposed to the cylinder vacuum will vary pressure depending on how open the throttle valve is
  - When the throttle is open, the pressure will be similar to the outside air pressure
  - When the throttle is closed, the pressure will be very low because of the high vacuum from the cylinder intake stroke
- In an airplane with a fixed-pitch propeller,

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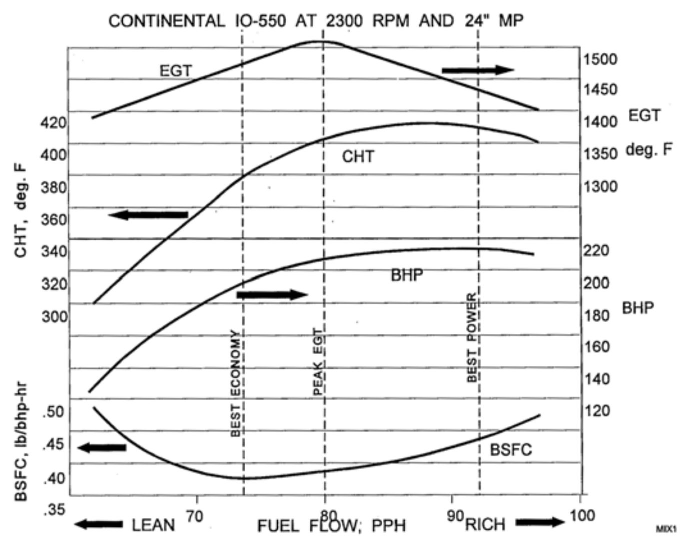
engine power is measured by propeller RPM because more power directly translates into higher RPM

- A *constant-speed* propeller uses a set of weights, springs, and oil pressure to change the pitch of the propeller to maintain a constant RPM
    - o The propeller pitch is increased (more "bite" out of the air, and more drag) to keep the engine at the same RPM when more power is applied
    - o The propeller pitch is decreased to keep the engine at the same RPM when less power is applied
- **The advantage of a constant-speed propeller is that it allows efficient operation at a range of airspeeds**
- The RPM is set by the pilot using the propeller control in the cockpit
- A constant RPM can be maintained as long as sufficient engine power is maintained. If too little power is available, then even the flattest propeller pitch will not allow the RPM to be maintained.
- Because RPM is now constant, another way must be found to measure engine power
- The *manifold pressure gauge* measures the pressure between the throttle valve and the cylinder, and is an indirect measurement of the amount of air going into the cylinder
- **In an engine with a constant-speed propeller, the throttle controls engine power which is read on the manifold pressure gauge, and the propeller control controls engine RPM which is read on the tachometer**
- **When operating with high manifold pressure (high power) and low RPM, excessive stress may be placed on the cylinders. Thus the pilot must be careful to avoid this situation.**

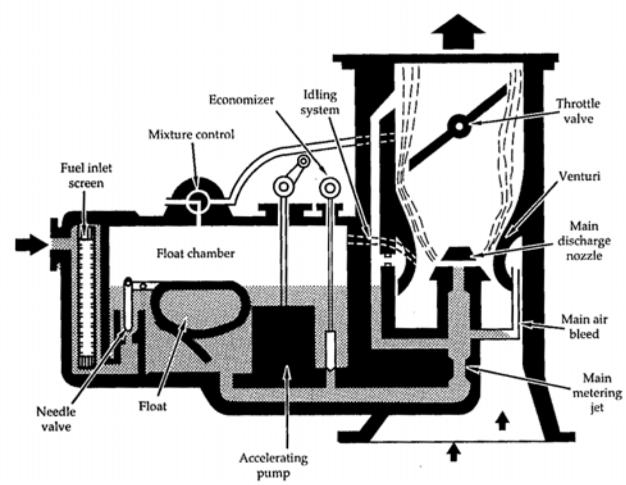
Mixture



- For perfect combustion (all fuel and air is used) there is a *stoichiometrically correct* ratio of air to fuel, which is about 15 to 1 by weight
- The *throttle* controls the amount of *air* admitted to the engine, which indirectly controls the amount of fuel because the fuel is drawn in by the passage of air
- The *mixture control* controls the amount of *fuel* admitted to the engine and is used to adjust the ratio of fuel to air (the "mixture")
- To shut down the engine, the mixture is reduced to its "idle cutoff" position, which starves the engine of fuel
- Adding additional fuel relative to the amount of air is called *enriching*, and removing fuel is called *leaning*
- The mixture must be adjusted manually under various circumstances
    - o The perfect 15:1 ratio will cause the highest engine temperatures
    - o **Additional fuel beyond the perfect 15:1 ratio will cause a cooling effect on the engine as the unburned fuel absorbs heat and carries it out the exhaust. Thus is the engine is getting too hot, a richer mixture may help.**
    - o At higher altitudes, the air is less dense and the mixture must be leaned to prevent a significant excess of fuel compared to the amount of air available (which the volume of air in the cylinder is the same, the number of air molecules is less). Thus the mixture must be leaned as the airplane is climbed, and enrichened as the airplane is descended.
    - o **When taking off from a high-altitude airport, a full-rich mixture control may cause too rich a mixture and a rough running engine. In this case, the mixture must be leaned before takeoff.**
- Various mixture settings will provide different advantages:
    - o *Peak EGT* (see below) occurs when the fuel/air mixture is perfectly 15:1
    - o *Best power* is usually found at about 100-125 degrees F cooler (richer mixture) than peak EGT (15:1 ratio)
    - o *Best economy* is usually found somewhat leaner than peak EGT, but with many engines it is not permitted to operate lean of peak EGT, so the best economy can be found at peak EGT

Fuel Supply Systems

Carburetors



- A *carburetor* is a mechanical device that mixes fuel and air to supply to the intake valves in the piston cylinders
- **A carburetor works on the Bernoulli principle, just like a wing – a constricted throat (a "venturi") causes a low static pressure which draws fuel from a float chamber**
- The purpose of the float chamber is to have a local reservoir of fuel in case the flow of fuel from the wing tanks is interrupted
- Carburetors are prone to the formation of *carburetor ice* because the air being expanded after the venturi, combined with the vaporization of fuel, causes a dramatic drop in temperature
- **Carburetor ice can form any time the outside temperature is between 20 degrees F and 70 degrees F when the humidity is high**
- *Carburetor heat* redirects hot exhaust air into the carburetor to raise the temperature and eliminate the carburetor ice
- **In an airplane with a fixed-pitch propeller, the formation of ice results first in a loss of engine RPM followed by engine roughness**
- In an airplane with a constant-speed propeller, the formation of ice results in a drop in manifold pressure followed by engine roughness
- **When ice is present, applying carburetor heat will first result in a further drop in RPM (or manifold pressure) as the lower density hot air is admitted to the engine, followed by a gradual increase in RPM (or manifold pressure) as the ice melts**
- **In general, because of the lower density hot air, the use of carburetor heat will cause a reduction in engine performance and an enriching of the fuel/air mixture (less air for the same amount of fuel)**

Fuel Injection

- Fuel injection is a more modern system to provide a fuel/air mixture to the cylinders
- Fuel and air are carefully metered and admitted to each cylinder in precise doses
- **Fuel injected engines are less prone to icing than carburetor-based engines because there is no venturi to cause the formation of ice.**
- They are, however, still susceptible to impact icing (which covers the air intake on the cowl)

Engine Temperatures and Oil System

- **Airplane engines are cooled by the flow of air through the cowling, and by the flow of oil through the engine.** There is no water or radiator like there is in a car.
- Non-turbocharged engines have three basic ways to indicate engine temperature:
  - Oil temperature: This is an FAA-required instrument in all piston-powered airplanes. In many airplanes this is the only indication of engine temperature.
  - Exhaust Gas Temperature (EGT): This gauge measures the temperature of the gas in the exhaust manifold. This is an optional instrument that may help with mixture control

    - Cylinder Head Temperature (CHT): This gauge directly measures the temperature of one or more of the cylinders. This is an optional instrument that directly indicates engine temperature and is important for controlling temperatures.
- Turbocharged engines add a Turbine Inlet Temperature (TIT) gauge
- High engine temperatures may be caused by:
    - **Insufficient air cooling (e.g. high power and low airspeed, especially on the ground or during a climb)**
    - **Low oil level**
    - **Excessively lean mixture with high power**
- **Excessive engine temperature may cause loss of power, excessive oil consumption, and possible internal damage**
- An oil pressure gauge is also an FAA-required instrument in all piston-powered airplanes
- A low oil pressure will usually be accompanied by a high oil temperature
- If these indications do not agree, one of the gauges may be broken

Fuel

- Fuel for airplane piston engines ("AvGas") has a slight lead content and is octane rated just like auto gas
- Most airplanes require, and most airports supply, 100 octane low-lead ("100LL")
- Some airplanes also take 80 octane low-lead, or 100 octane full-lead, but these fuels are much more difficult to find
- AvGas and jet fuel is color coded:
    - 80 – red
    - 100LL – blue
    - 100 – green
    - Jet-A – colorless
- **If the required fuel is not available, fuel of the next *higher* octane may be used (although this doesn't work if you need 100 octane!)**
- **The use of fuel with a lower octane rating than required may result in excessive engine temperatures and detonation**
- Water may collect in a fuel tank through humidity or leaks in the fuel caps
- Water is more dense than AvGas and will sink to the bottom of the tank
- Before the first flight of the day, and after each refueling, the sumps in each tank should be drained to check for the presence of water
- **It is considered good operating practice to fill the tanks after the last flight of the day to remove air and prevent the condensation of moisture as temperatures fall at night**
- In high-wing carburetor-equipped aircraft, the fuel is usually gravity-fed
- In low-wing aircraft, or any aircraft with fuel injection, an engine-driven fuel pump is required to bring the fuel to the engine
- **If the engine-driven fuel pump fails, an electric backup pump may be used**

Engine Problems

- ***Preignition* is the early burning of fuel before the spark from the spark plug and will result in engine roughness**
- Preignition is caused by an excessively hot cylinder or a hot spot in the cylinder, such as a glowing carbon deposit
- *Detonation* is the explosive, uncontrolled burning of fuel instead of the normal control burning
- Detonation is equivalent to hitting the top of the piston with a hammer instead of pushing on it
- **Detonation is usually caused by the use of the wrong grade of fuel**
- **If detonation is suspected, the engine should be cooled by increasing airflow over the engine**

Engine Starting

- The starting procedure for each engine is different and should be taken from the airplane manual
- **After starting the engine, the RPM should be adjusted to the appropriate idle setting (usually 1000 RPM) and the engine gauges checked for proper reading**
- **When hand-propping an engine, it is vital that a competent pilot be inside the cockpit to maintain control of the airplane**

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