***INCOMPLETE***

Nicoletta Fala
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# III.C. Operation of Systems

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| **Objectives** | The student should develop knowledge of the elements related to the systems and their operations as required in the necessary ACS. |
| **Key Elements** | ✈ Powerplant<br>✈ Fuel pump and primer<br>✈ Electrical failure |
| **Elements** | ✈ Primary flight controls and trim<br>✈ Flaps<br>✈ Powerplant and propeller<br>✈ Landing gear<br>✈ Fuel, oil, and hydraulic systems<br>✈ Electrical systems<br>✈ Avionics<br>✈ Pitot static, vacuum pressure, and associated flight instruments<br>✈ Environmental |
| **Schedule** | 1. Discuss objectives<br>2. Review material<br>3. Development<br>4. Conclusion |
| **Equipment** | ✈ White board<br>✈ Markers<br>✈ References |
| **Instructor's Actions** | 1. Discuss lesson objectives<br>2. Present lecture<br>3. Questions<br>4. Homework |
| **Student's Actions** | Participate in discussion<br>Take notes |
| **Completion Standards** | The student has knowledge of and can explain aircraft systems. |
| **References** | C172RG POH<br>FAA-H-8083-25B, *Pilot's Handbook of Aeronautical Knowledge* (Chapter 7) |

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## Instructor Notes

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| **Introduction** | Overview—review objectives and key ideas.<br>Why—understanding of how the aircraft works can lead to improved troubleshooting and problem identification. |
| **Reciprocating engines** | Use process of combustion in cylinders to convert chemical energy into mechanical energy. Two designs: spark ignition, and compression ignition. Both convert linear motion of the cylinder into the rotary motion of the crankshaft—differ in fuel ignition process.<br>Spark ignition engines—use a spark plug to ignite a pre-mixed fuel/air mixture (the ratio of the weight of fuel to the weight of air entering the cylinders).<br>Compression ignition engines—first compress the air in the cylinder, raising its temperature, resulting in automatic ignition when fuel is injected into the cylinder. (jet fuel piston engines) |
| Cylinder arrangement | Radial—row(s) of cylinders arranged in a circular pattern around the crankcase. Favorable power-to-weight ratio.<br>In-line—relatively small frontal area, but low power-to weight ratios; normally limited to four or six cylinders since the rearmost cylinders of air-cooled, in-line engine receive very little cooling air.<br>V-type—provide more horsepower than in-line engines and still retain a small frontal area.<br>Opposed—most popular reciprocating engines in use on smaller aircraft. Always have an even number of cylinders (a cylinder on one side of the crankcase opposes a cylinder on the other side). Air-cooled, usually mounted in a horizontal position on fixed-wing airplanes. High power-to-weight ratios, small frontal area, and allow streamlined installation that minimizes aerodynamic drag. |
| Operating cycle | In a two-stroke engine, the conversion of energy occurs over a two-stroke operating cycle. The intake, compression, power, and exhaust processes occur in only two strokes of the piston. The two-stroke engine has a power stroke upon each revolution of the crankshaft—typically has higher power-to-weight ratio than a comparable four-stroke engine. Limited use due to inherent inefficiency and disproportionate emissions. |

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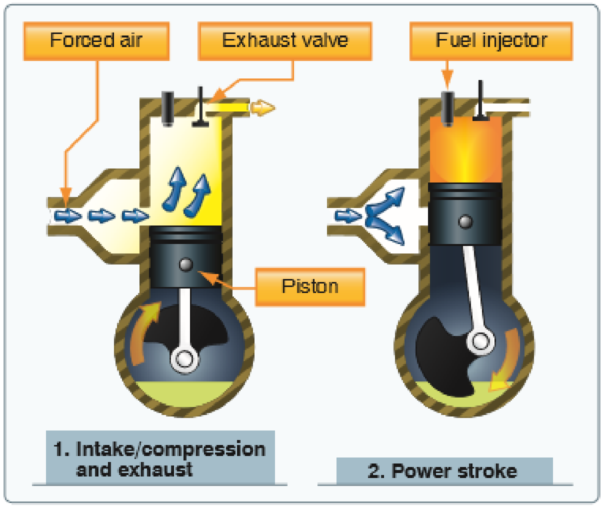


**Figure 7-3.** *Two-stroke compression ignition.*

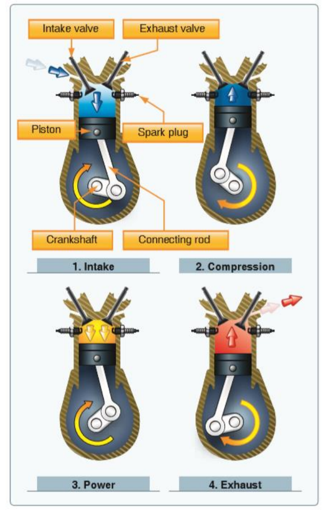


**Figure 7-5.** *The arrows in this illustration indicate the direction of motion of the crankshaft and piston during the four-stroke cycle.*

Four-stroke engines are more common. Main parts of spark ignition reciprocating engine: cylinders, crankcase, accessory/housing.
The cylinders include the intake/exhaust valves, spark plugs, and pistons.
The crankcase includes the crankshaft and connecting rods. The engine accessory housing includes the magnetos, normally.
In the four-stroke operating cycle, the intake, compression, power, and exhaust processes, occur in four separate strokes of the piston.

- The intake stroke—begins as the piston starts its downward travel. The intake valve opens and the fuel-air mixture is drawn into the cylinder.
- The compression stroke—begins when the intake valve closes and the piston starts moving back to the top of the cylinder. This phase of the cycle is used to obtain a greater power output from the fuel-air mixture once it is ignited.
- The power stroke—begins when the fuel-air mixture is ignited, which causes a pressure increase in the cylinder and forces the piston downward, away from the cylinder head. This creates the power that turns the crankshaft.
- The exhaust stroke—begins when the exhaust valve opens and the piston starts to move toward the cylinder head again; used to purge the cylinder of burned gases.

The four-stroke cycle occurs several hundred times each minute. In a four-cylinder engine, each cylinder operates on a different stroke. Precise timing of the power strokes in each cylinder maintains continuous rotation of the crankshaft.

Method of cooling

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**Propeller**

A rotating airfoil that is subject to all aerodynamic principles. Provides necessary thrust to pull/push the aircraft through the air.
Engine power used to rotate the propeller—turning propeller generates thrust.

Amount of thrust produced depends on the shape of the airfoil, the angle of attack of the propeller blade, and the revolutions per minute of the engine.

Propeller twist—the blade angle changes from hub to tip, with the greatest angle of incidence (highest pitch) at the hub and the smallest angle of incidence (smallest pitch) at tip. As the blade rotates, the various portions of the blade rotate at different speeds—the tip is faster than the hub. Changing the angle of incidence produces uniform lift throughout the blade length.

**Fixed-pitch propeller**

Fixed blade angle set by manufacturer. Achieves best efficiency only at a given combination of airspeed and rpm, making the propeller idea at neither cruise nor climb. Used for weight savings, cost savings, and simplicity.

Climb propeller—lower pitch, therefore less drag, resulting in higher rpm and more horsepower capability. Increases performance during takeoffs and climbs but decreases performance during cruise.
Cruise propeller—higher pitch, therefore more drag, resulting in lower rpm and less horsepower capability. Decreases performance during takeoffs and climbs but increases efficiency during cruise.

Propeller usually mounted on shaft, which may be an extension of the engine crankshaft. In the fixed-pitch propeller case, the rpm of the propeller would be the same as the crankshaft rpm. Sometimes the propeller is mounted on a shaft geared to engine crankshaft, in which case the propeller rpm is different than that of the engine.

Indicator of engine power—tachometer. Gives a direct indication of engine/propeller rpm, regulated by the throttle, which controls fuel-air flow to the engine.

**Adjustable-pitch propeller**

Ground-adjustable propeller. Propeller blades can be adjusted on the ground (with the engine not running) but not in flight.

**Constant-speed propeller**

Controllable-pitch propeller with automatically varied pitch, controlled in flight by a governor that maintains constant rpm despite varying air loads. Converts a high percentage of brake horsepower (BHP) into thrust horsepower (THP) over a wide range of rpm/airspeed combinations. More efficient than other propellers—allows selection of most efficient engine rpm for given conditions.

Throttle controls power output--indicated by manifold pressure gauge. The gauge measures the absolute pressure of the fuel-air mixture inside the intake manifold—a measure of manifold absolute pressure. At a constant rpm and altitude, the amount of power produced is directly related to the fuel-air mixture being delivered to the combustion chamber. When the engine is not running, the manifold pressure gauge indicates ambient air pressure. Engine failure/power loss indicated on gauge as an increase in manifold pressure to ambient air pressure at the altitude where the failure occurred.

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The propeller control regulates engine rpm, which regulates propeller rpm (registered on tachometer).
Once the pilot selects a specific rpm, the governor automatically adjusts the propeller blade angle as necessary to maintain the selected rpm. An increase in airspeed or decrease in propeller load will cause the propeller blade angle to increase as necessary to maintain the selected rpm. A reduction in airspeed or increase in propeller load will cause the propeller blade angle to decrease.

***Need example and figure here!

Propeller's constant-speed range—defined by the high and low pitch stops; the range of possible blade angles for a constant-speed propeller. Governor can maintain a constant engine rpm as long as the propeller blade angle is within the constant-speed range/not against either pitch stop. If the propeller blades contact a pitch stop, the engine rpm will increase or decrease appropriately with changes in airspeed and propeller load.

To avoid overstressing the cylinders, be constantly aware of the rpm, especially when increasing the manifold pressure. For any given rpm, there is a manifold pressure that should not be exceeded. If manifold pressure is excessive for a given rpm, the pressure within the cylinders could be exceeded, placing undue stress on the cylinders. If repeated too frequently, the stress may weaken the cylinder components and cause engine failure.
Make power adjustments in the proper order—
- To decrease power settings, reduce manifold pressure, then reduce rpm.
- To increase power settings, increase rpm first, then increase manifold pressure.

To prevent damage to radial engines, minimize operating time at maximum rpm and manifold pressure, and avoid operation at maximum rpm and low manifold pressure.

## Induction systems

Induction system—brings air from outside, mixes it with fuel, and delivers the fuel-air mixture to the cylinder, where combustion occurs.
Intake port—at front of engine cowling, from where outside air enters the induction system. Air filter inhibits dust/foreign object entry. Alternate source of air available in case the filter becomes clogged—usually from inside the engine cowling, where it bypasses the clogged air filter.

Two common types:
- Carburetor system—mixes fuel and air in the carburetor before delivering the mixture to the intake manifold.
- Fuel injection system—mixes fuel and air immediately before entry into each cylinder, or injects fuel directly into each cylinder.

### Carburetor systems

Two types of aircraft carburetors—float-type, and pressure-type.

Float-type carburetors are most common. Include idling, accelerating, mixture control, idle cutoff, and power enrichment systems.

Outside air first flows through air filter (at air intake). Filtered air flows into the carburetor and through a venturi. Low pressure area created in the venturi forces the fuel to flow through a main fuel jet located at the throat. The fuel flows into the airstream where it is mixed with the flowing air. Fuel-air mixture drawn through intake manifold into the combustion chambers, where it is ignited. A needed attached to a float that rests on fuel within the float chamber opens and closes an opening at the bottom of the carburetor bowl—level of fuel in float chamber controls position of float, which meters the amount of fuel entering the 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.

**(Pitot-)static system**

Three instruments operate on the static system.
- Airspeed indicator
- Altimeter
- Vertical speed indicator

Pitot tube mounted on outboard left wing—provides ram air pressure for the airspeed indicator. Heated through a heating element controlled with pitot heat in the cockpit. Activated by a rocker arm switch, protected by a circuit breaker.

Two static ports—located on the sides of the fuselage (one on each side); provide static air pressure for the altimeter and the vertical speed indicator. Alternate static pressure source located beneath panel—activated by push-pull knob, causes a momentary rise in airspeed, altitude, and vertical speed, because of the lower pressure in the cabin.

Airspeed indicator

Sensitive differential pressure—measures and promptly indicates the difference between pitot (impact/dynamic pressure) and static pressure. Static pressure introduced into airspeed case—pitot pressure introduced into a diaphragm. Pitot pressure expands/contracts one side of the diagram, attached to the indicating system which drives the mechanical linkage and airspeed needle.
Limitations/range markings:
- White arc—flap operating range
- Green arc—normal operating range
- Yellow arc—caution range
- Red line—never exceed speed

C172RG: KIAS units used
Position error at high angle of attack and during slips and skids.

Airspeeds
- Indicated airspeed (IAS)
- Calibrated airspeed (CAS)—indicated airspeed corrected for position error
- Equivalent airspeed (EAS)—calibrated airspeed corrected for compression of air at a particular altitude
- True airspeed (TAS)—calibrated airspeed corrected for density effects
- Groundspeed (GS)—true airspeed corrected for winds aloft

### Altimeter

Measures the height of the aircraft above a given pressure level. Aneroid barometer—opening leads to a sealed case that measures static pressure. Series of sealed diaphragms (aneroid wafers) expand and contract in response to the changing static pressure—mechanically linked to the altitude needle. They expand when climbing, due to a loss of pressure within the instrument, and contract when descending, due to a gain in pressure within the instrument.

Calibration knob sets altimeter to current barometric pressure—displayed in Kolesman window.
Station pressure—pressure read at any airport.
Altimeter setting—station pressure corrected to sea level.

Altitudes

- Indicated altitude—shown on altimeter
- True altitude (MSL)—actual altitude above sea level
- Absolute altitude (AGL)—actual height above the terrain below
- Pressure altitude—indicated altitude corrected for non-standard pressure
- Density altitude—pressure altitude corrected for non-standard temperature (affects aircraft performance)

Altimeter errors

- As the airplane enters an area of lower pressure, the altimeter will read lower than actual if setting not adjusted.
- As the airplane enters an area of higher pressure, the altimeter will read higher than actual if setting not adjusted.
- "High to low, look out below; low to high, clear the sky."

### Vertical speed indicator

Static air enters a chamber with a calibrated leak. As air pressure flows in and out, it moves a diaphragm that is connected to an indicator needle by mechanical linkages. Calibrated to read climbs/descents in fpm.

Two types of information displayed:

- Instantaneous trend—immediate indication of increase/decrease in aircraft's rate of climb/descent; usually takes about 6-9 seconds to settle.
- Rate information—stabilized rate of change in altitude

### Errors

If the pitot tube is blocked but the drain hole is open—airspeed will indicate zero. Ram air cannot enter the pitot system. Air already in system vents through the drain hole—remaining pressure drops to ambient air pressure. The airspeed indicator senses no difference between ram and static air pressure.
Pitot tube and drain hole are blocked—airspeed indicator acts like an altimeter (increase in airspeed during climb, decrease in airspeed during descent). Pressure in pitot tube is trapped. Static port still unblocked—change in static pressure noted on airspeed indicator.
Static port blocked—airspeed will read lower above the altitude where the blockage occurred, and higher below the altitude where the blockage

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| | occurred. The VSI and altimeter will freeze immediately once the blockage occurs. |
| **Gyroscopic instruments** | Three instruments<br>✈ Turn coordinator<br>✈ Heading indicator<br>✈ Attitude indicator |
| Gyroscopic principles | Spinning objects that are rigid in space will resist any forces applied on them. A freely or universally mounted gyroscope is free to rotate in any direction about its center of gravity. |
| *Rigidity in space* | A gyroscope will remain in a fixed position in the plane in which it is spinning. The axis of rotation will always point in a constant direction. |
| *Precession* | The gyroscope tilts or turns in response to a deflective force. The reaction of this force occurs at a point that is 90° later in the direction of rotation from the point at which it was applied.<br>This allows the gyroscope to determine the rate of turn, by sensing the amount of pressure created by the change in direction. Precession rate inversely proportional to the speed of the rotor and proportional to the deflective force. |
| Power source | ✈ Electric<br>✈ Pressure<br>✈ Vacuum—the system spins the gyroscope by drawing a stream of air against the rotor vanes to spin the rotor at high speeds. Typically consist of an engine-driven vacuum pump, relief valve, air filter, gauge, and tubing. If the suction pressure is too low, the instrument indications may be unreliable. |
| Turn indicators | Two types of indicators<br>✈ Turn-and-slip indicator—shows only the rate of turn (degrees per second) and coordination.<br>✈ Turn coordinator—shows rate of turn, rate of roll, and coordination<br><br>Inclinometer—depicts yaw. In straight and level flight, the force of gravity forces the ball to rest in the lowest part of the tube (centered between reference lines). If the aerodynamic forces are unbalanced, the ball moves away from the center of the tube. To maintain coordinated flight, keep the ball centered. |
| Attitude indicator | Consists of a miniature aircraft and horizon bar that show the attitude of the aircraft. The relationship of the miniature aircraft to the artificial horizon is the same as that of the real aircraft to the actual horizon.<br>Gives instantaneous indication of even small changes in attitude.<br>Adjustment knob—pilot can move miniature aircraft up/down to align it with the horizon bar as appropriate to suit the pilot's line of vision.<br>Most realistic flight instrument on panel—indications are close approximations of actual attitude. |

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| | Limitations:<br>Maximum bank 100°<br>Maximum pitch 60° |
| Heading indicator | Mechanical instrument designed to facilitate the use of a magnetic compass. Operation depends upon the principle of rigidity in space.<br>Adjustment knob to align with magnetic compass—susceptible to precession. |
| AHRS | Attitude and Heading Reference System<br>Electronic flight displays use solid-state laser systems instead of free-spinning gyros—capable of flight at any altitude without tumbling. AHRS sends attitude information to PFD, which generates pitch/bank information of attitude indicator. Heading information is derived from a magnetometer. |
| **Magnetic compass** | Required by 14 CFR 91.205 for VFR and IFR flight. Magnetic piece of material (usually iron-containing metal) which attracts and holds lines of magnetic flux. Has two poles: north, and south. Opposite poles attract, like poles repel.<br><br>Two small magnets attached to metal float inside a bowl of clear compass fluid (similar to kerosene). Graduated scale (the card) marked with cardinal direction letters is wrapped around the float—can be viewed through a glass window. The magnets align with the Earth's magnetic field—the pilot reads the direction on the scale.<br><br>Jewel-and-pivot type mounting—hardened steel pivot in float's center rides inside a spring-loaded hard glass jewel cup. The buoyancy of the float takes most of the weight off the pivot; the fluid damps the oscillation of the float/card. The mounting allows the float freedom to rotate and tilt. The rear of the compass case is sealed with a flexible diaphragm or metal bellows, to prevent damage and leakage of fluid as a result of temperature changes (causing the fluid to expand/contract).<br><br>Compensator assembly—mounted on the top or bottom of the compass to allow aviation maintenance technician to create a magnetic field inside the compass housing that cancels the influence of local outside magnetic fields. This can correct for deviation error. Two shafts can rotate one or two small compensating magnets. |
| Magnetic compass induced errors | ✈ Variation<br>✈ Deviation<br>✈ Magnetic "dip" error<br>✈ Oscillation error |
| *Variation* | The difference between the true and magnetic north measured in an angular distance. Also known as declination.<br>True Course + Variation = Magnetic Course |

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| *Deviation* | Electrical current flowing through aircraft components, in nearby wiring, or any magnetized part of the structure, create local magnetic fields within the aircraft that conflict with the Earth's magnetic field and cause compass error. Not affected by geographic location, but differs for each heading.<br>"Swinging the compass"—maintenance task that can minimize deviation. Any error that cannot be removed is recorded and placed in a cardholder.<br>Magnetic Course + Variation = Compass Course |
| *Magnetic "dip" error* | The magnets within the compass align with the Earth's magnetic flux lines. Near the poles, they dip (tilt) the float/card assembly.<br>The float is balanced with a small dip-compensating weight, which dampens the effect of dip when operating in the middle latitudes of the northern hemisphere. This causes a northerly turning error and an acceleration error.<br><br>Northerly turning error—<br>The compass initially indicates a turn in the opposite direction the aircraft is turning when turning to a heading of East or West from the North. This error is due to the vertical component of the Earth's magnetic field which pulls the north-seeking end of the magnet toward the Earth.<br>When turning to a heading of East of West from the South, the compass turns in the same direction as the aircraft is turning, but at a faster rate.<br><br>Acceleration error—<br>The dip correction weight causes the end of the float/card assembly marked N (the south-seeking end) to be heavier than the opposite end. When the aircraft is on a heading of East or West, the float is level, as the effects of the magnetic dip and the weight are approximately equal.<br>When accelerating on a heading of East or West, the compass will indicate a turn to the North. When decelerating on a heading of East or West, the compass will indicate a turn to the South. As the aircraft stabilizes, the card wings back to its original indication. |
| *Oscillation error* | Combination of all other errors. Results in the compass card swinging back and forth around the heading flown. When trying to set the gyroscopic heading indicator to agree with the magnetic compass, use the average indication between the swings. |
| Vertical card magnetic compass | Eliminates confusion and errors caused by a traditional wet compass. The dial is rotated by a set of gears from the shaft-mounted magnet. |

Airspeed indicator only instrument that uses pitot and static

Va approximate by multiplying bottom number on green arc by two (will be within +/- 4 kts)

Standard rate turn remove the last digit from the airspeed and add a 5 to it. 100 knots on indicated, 15 degrees will be standard rate

PPL ACS discusses crosswind landing speeds and adding factors

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Six pack, ALPA T

Angle of bank indicators have different indications—pay attention

Type certificate data sheet to find specific information on numbers and such (differential ailerons etc)
http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/cb2bfe3bb96650ff86257ed2006aa7b5/$FILE/3A17_Rev_47.pdf

C172RG—add flaps, nose pitches up

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**CFI PTS**

**Objective:** To determine that the applicant:

1. Exhibits instructional knowledge of the elements of airport/seaplane base runway and taxiway signs, markings, and lighting, by describing:
a. Identification and proper interpretation of airport/seaplane base, runway, and taxiway signs and markings, with emphasis on runway incursion avoidance.
b. Identification and proper interpretation of airport/seaplane base, runway, and taxiway lighting, with emphasis on runway incursion avoidance.

2. Exhibits instructional knowledge of common errors related to airport/seaplane base, runway and taxiway signs, markings, and lighting, by describing:
a. Failure to comply with airport/seaplane base runway and taxiway signs and markings.
b. Failure to comply with airport/seaplane base runway and taxiway lighting.
c. Failure to use proper runway incursion avoidance procedures.

3. Demonstrates and simultaneously explains airport/seaplane base runway and taxiway signs, markings, and lighting, from an instructional standpoint.

4. Analyzes and corrects simulated common errors related to airport/seaplane base runway and taxiway signs, markings, and lighting.

**PPL/CPL ACS**

**Objective:** To determine that the applicant:

1. Exhibits knowledge of the elements related to airport, runway, and taxiway operations, with emphasis on runway incursion avoidance.
2. Properly identifies and interprets airport/seaplane base, runway, and taxiway signs, markings, and lighting.