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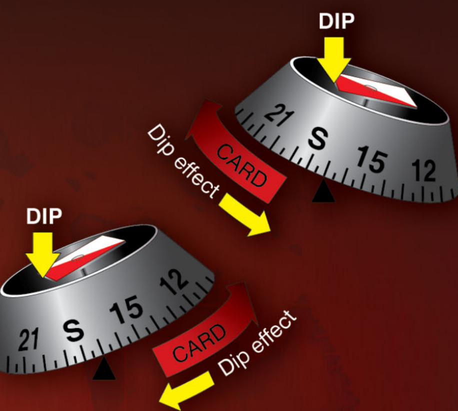
Pilot's Handbook of Aeronautical Knowledge



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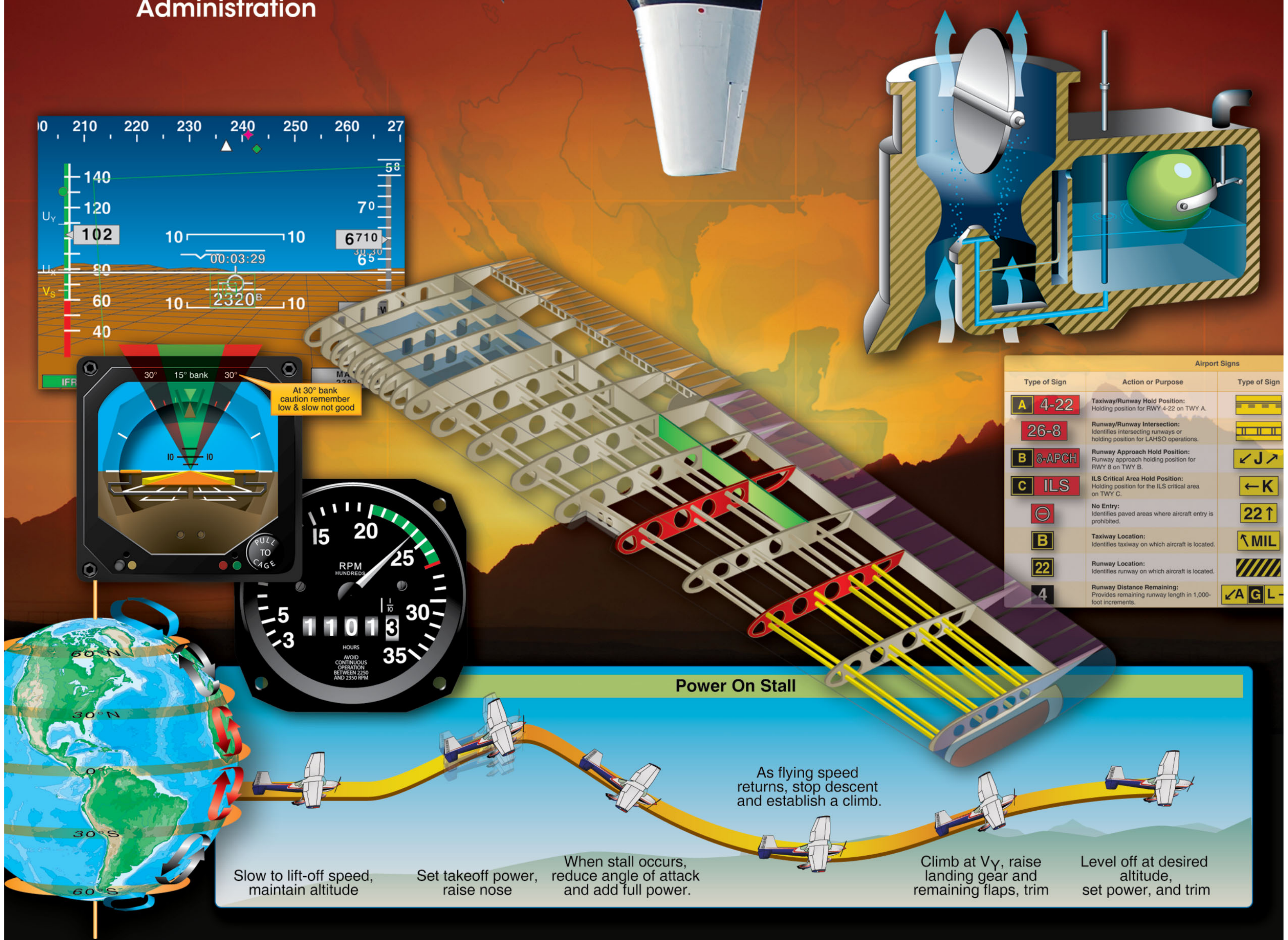

by changing the airspeed or the power output of the engine. High engine temperatures can be decreased by increasing the airspeed and/or reducing the power.

The oil temperature gauge gives an indirect and delayed indication of rising engine temperature, but can be used for determining engine temperature if this is the only means available.

Most aircraft are equipped with a cylinder-head temperature gauge that indicates a direct and immediate cylinder temperature change. This instrument is calibrated in degrees Celsius or Fahrenheit and is usually color coded with a green arc to indicate the normal operating range. A red line on the instrument indicates maximum allowable cylinder head temperature.

To avoid excessive cylinder head temperatures, increase airspeed, enrich the fuel-air mixture, and/or reduce power. Any of these procedures help to reduce the engine temperature. On aircraft equipped with cowl flaps, use the cowl flap positions to control the temperature. Cowl flaps are hinged covers that fit over the opening through which the hot air is expelled. If the engine temperature is low, the cowl flaps can be closed, thereby restricting the flow of expelled hot air and increasing engine temperature. If the engine temperature is high, the cowl flaps can be opened to permit a greater flow of air through the system, thereby decreasing the engine temperature.

Exhaust Systems

Engine exhaust systems vent the burned combustion gases overboard, provide heat for the cabin, and defrost the windscreen. An exhaust system has exhaust piping attached to the cylinders, as well as a muffler and a muffler shroud. The exhaust gases are pushed out of the cylinder through the exhaust valve and then through the exhaust pipe system to the atmosphere.

For 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, in turn, 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.

Exhaust gases contain large amounts of carbon monoxide, which is odorless and colorless. Carbon monoxide 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.

Some exhaust systems have an EGT probe. This probe transmits the EGT to an instrument in the flight deck. The 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. The EGT gauge is highly accurate in indicating the correct fuel-air mixture setting. When using the EGT to aid in leaning the fuel-air mixture, fuel consumption can be reduced. For specific procedures, refer to the manufacturer's recommendations for leaning the fuel-air mixture.

Starting System

Most small aircraft use a direct-cranking electric starter system. This system consists of a source of electricity, wiring, switches, and solenoids to operate the starter and a starter motor. Most aircraft have starters that automatically engage and disengage when operated, but some older aircraft have starters that are mechanically engaged by a lever actuated by the pilot. The starter engages the aircraft flywheel, rotating the engine at a speed that allows the engine to start and maintain operation.

Electrical power for starting is usually supplied by an onboard battery, but can also be supplied by external power through an external power receptacle. 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. 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. *[Figure 7-20]*

When starting an engine, the rules of safety and courtesy should be strictly observed. One of the most important safety rules is to ensure there is no one near the propeller prior to starting the engine. In addition, the wheels should be chocked and the brakes set to avoid hazards caused by unintentional movement. To avoid damage to the propeller and property, the aircraft should be in an area where the propeller will not stir up gravel or dust.

Combustion

During normal combustion, the fuel-air mixture burns in a very controlled and predictable manner. In a spark ignition engine, the process occurs in a fraction of a second. The mixture actually begins to burn at the point where it is ignited

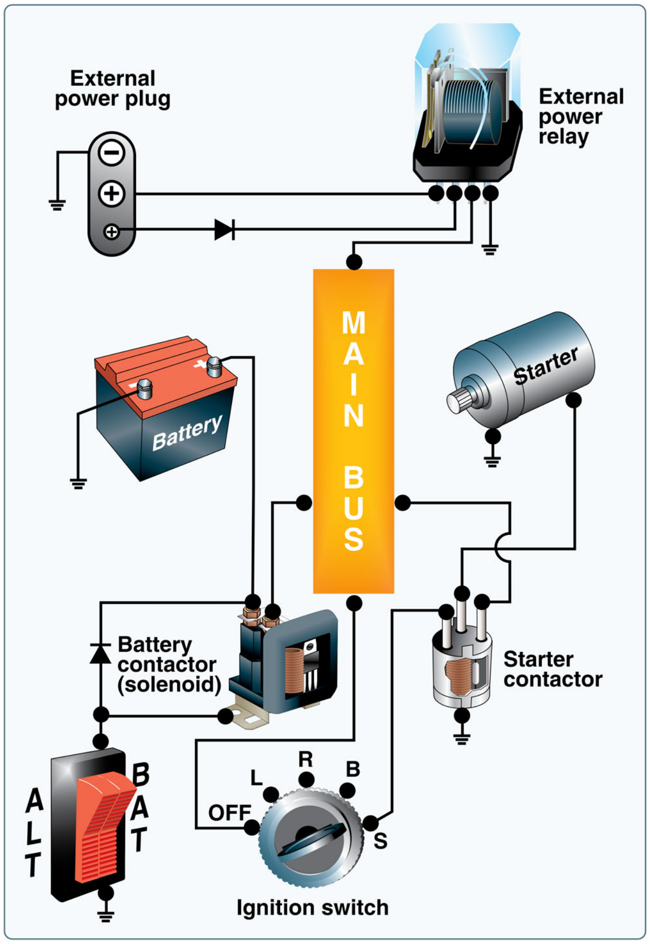

Figure 7-20. *Typical starting circuit.*

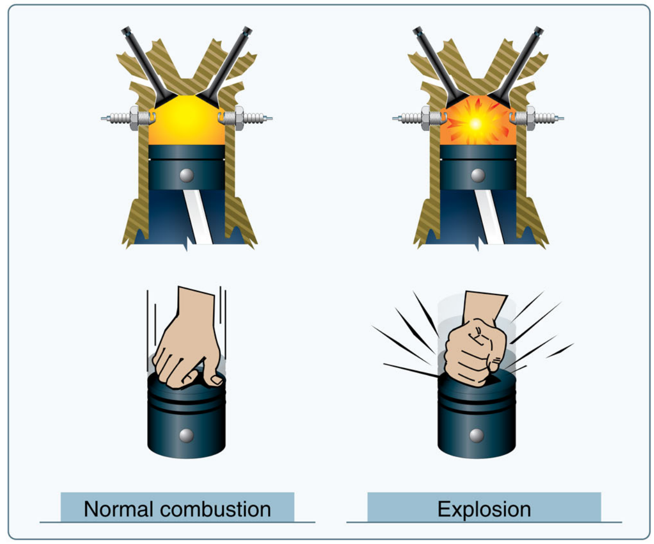

Figure 7-21. *Normal combustion and explosive combustion.*

by the spark plugs. It then burns away from the plugs until it is completely consumed. This type of combustion causes a smooth build-up of temperature and pressure and ensures that the expanding gases deliver the maximum force to the piston at exactly the right time in the power stroke. *[Figure 7-21]* Detonation is an uncontrolled, explosive ignition of the fuel-air mixture within the cylinder's combustion chamber. It causes excessive temperatures and pressures which, if not corrected, can quickly lead to failure of the piston, cylinder, or valves. In less severe cases, detonation causes engine overheating, roughness, or loss of power.

Detonation is characterized by high cylinder head temperatures and is most likely to occur when operating at high power settings. Common operational causes of detonation are:

- Use of a lower fuel grade than that specified by the aircraft manufacturer
- Operation of the engine with extremely high manifold pressures in conjunction with low rpm
- Operation of the engine at high power settings with an excessively lean mixture
- Maintaining extended ground operations or steep climbs in which cylinder cooling is reduced

Detonation may be avoided by following these basic guidelines during the various phases of ground and flight operations:

- Ensure that the proper grade of fuel is used.
- Keep the cowl flaps (if available) in the full-open position while on the ground to provide the maximum airflow through the cowling.
- Use an enriched fuel mixture, as well as a shallow climb angle, to increase cylinder cooling during takeoff and initial climb.
- Avoid extended, high power, steep climbs.
- Develop the habit of monitoring the engine instruments to verify proper operation according to procedures established by the manufacturer.

Preignition occurs when the fuel-air mixture ignites prior to the engine's normal ignition event. Premature burning is usually caused by a residual hot spot in the combustion chamber, often created by a small carbon deposit on a spark plug, a cracked spark plug insulator, or other damage in the cylinder that causes a part to heat sufficiently to ignite the fuel-air charge. Preignition causes the engine to lose power and produces high operating temperature. As with detonation, preignition may also cause severe engine damage because the expanding gases exert excessive pressure on the piston while still on its compression stroke.

Detonation and preignition often occur simultaneously and one may cause the other. Since either condition causes high engine temperature accompanied by a decrease in engine performance, it is often difficult to distinguish between the two. Using the recommended grade of fuel and operating the engine within its proper temperature, pressure, and rpm ranges reduce the chance of detonation or preignition.

Full Authority Digital Engine Control (FADEC)

FADEC is a system consisting of a digital computer and ancillary components that control an aircraft's engine and propeller. First used in turbine-powered aircraft, and referred to as full authority digital electronic control, these sophisticated control systems are increasingly being used in piston powered aircraft.

In a spark-ignition reciprocating engine, the 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. In a compression-ignition engine, the FADEC operates similarly and performs all of the same functions, excluding those specifically related to the spark ignition process.

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.

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 often results in decreased fuel consumption and increased horsepower.

FADEC systems are considered an essential part of the engine and propeller control and may be powered by the aircraft's main electrical system. In many aircraft, FADEC uses power from a separate generator connected to the engine. In either case, there must be 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 is capable of providing all engine and propeller functions without limitations.

Turbine Engines

An aircraft turbine engine consists of an air inlet, compressor, combustion chambers, a turbine section, and exhaust. Thrust is produced by increasing the velocity of the air flowing through the engine. Turbine engines are highly desirable aircraft powerplants. They are characterized by smooth operation and a high power-to-weight ratio, and they use readily available jet fuel. Prior to recent advances in material, engine design, and manufacturing processes, the use of turbine engines in small/light production aircraft was cost prohibitive. Today, several aviation manufacturers are producing or plan to produce small/light turbine-powered aircraft. These smaller turbine-powered aircraft typically seat between three and seven passengers and are referred to as very light jets (VLJs) or microjets. *[Figure 7-22]*

Types of Turbine Engines

Turbine engines are classified according to the type of compressors they use. There are three types of compressors—centrifugal flow, axial flow, and centrifugal-axial flow. Compression of inlet air is achieved in a centrifugal flow engine by accelerating air outward perpendicular to the longitudinal axis of the machine. The axial-flow engine compresses air by a series of rotating and stationary airfoils moving the air parallel to the longitudinal axis. The centrifugal-axial flow design uses both kinds of compressors to achieve the desired compression.

The path the air takes through the engine and how power is produced determines the type of engine. There are four types of aircraft turbine engines—turbojet, turboprop, turbofan, and turboshaft.

Turbojet

The turbojet engine consists of four sections—compressor, combustion chamber, turbine section, and exhaust. The compressor section passes inlet air at a high rate of speed to

Figure 7-22. *Eclipse 500 VLJ.*