Module 1: Engine Operating Principles

Terms and Definitions

- **Accessory** is the component that is not always essential to the operation of the engine. An example would be an air compressor.
- **Bottom dead center (BDC)** is the location of the piston at its lowest point of travel.
- **Clearance volume** is the total space between the cylinder head and the piston at top dead center.
- **Combustion** is burning the air/fuel mixture to produce heat.
- **Companion cylinders** are cylinders whose pistons reach top dead center (TDC) or BDC together.
- **Component** is member of a system; a group of connected parts and/or assemblies often contained within housing and designed to perform a specific but limited function within a system.
- **Compression** is reducing of the volume of the trapped air in the cylinder by pushing the piston upward.
- **Compression ratio** is the ratio of cylinder volume to clearance volume; a measure of how much the air has been compressed. An example is if the cylinder volume is 80 in³ and clearance volume is 5 in³, and the compression ratio is 80:5 or 16:1.
- **Cycle** is a series of events that repeat themselves in a regular sequence.
- **Cylinder volume** is the total space between the cylinder head and the piston at BDC.
- **Displacement** is to move physically out of position or to take the place of.
- **Engine speed** is the crankshaft revolutions per minute (RPM).
- **Firing order** is the sequence in which the cylinders, beginning with number 1 cylinder, deliver their power stroke.
- **Horsepower** is the measurement of an engine’s power.
- **Integral** is formed as a unit with another part.
- **Overspeed** is when an engine exceeds its governed maximum no-load RPMs.
- **Power control** is controlling the engine power by varying the amount of fuel injected into the combustion chamber.
- **Precombustion chamber** is the small cavity in the cylinder head of some diesel engines where fuel ignition and combustion occur.
- **Pump** is the device that transfers fluids or gases using suction or pressure or both.
- **Reciprocating motion** is the movement up-and-down; an example would be a piston.
- **Rotary motion** is movement in a circular manner.
- **Scavenging** is using the intake of fresh air to clear exhaust gases from the cylinder.
- **Stroke** is the distance the piston travels from TDC to BDC or from BDC to TDC.
- **System** is the group of interconnected components or assemblies arranged in such a way that their separate functions work together to accomplish a broader function.
- **Temperature** is the measure of heat intensity.
- **Top dead center (TDC)** is the location of the piston at its highest point of travel.
- **Torque** is the measurement of twisting force.
- **Valve** is a device for sealing the intake or exhaust ports in a cylinder head.
- **Valve overlap** is the period of time, measured in crankshaft degrees, that both the intake and exhaust valves are open; allows for scavenging to occur.
Basic Engine Systems and Their Function

- Lubrication system
  - Reduces friction by providing lubrication around and between moving parts or contact points within the engine
  - Helps transfer heat to cool the engine
  - Cleans the engine by removing contaminants
- The cooling system circulates either air only or air and liquid to transfer heat of combustion and friction away from the engine to prevent engine damage.
- The air intake and exhaust system(s) provides cleaned, pressurized, and cooled air to the engine and then directs exhaust gases to accessory equipment and the atmosphere.
- The fuel system provides fuel storage and delivers fuel to the engine using mechanical and/or electronic components.

- Electrical systems
  - The starting system, which controls and powers the electric motor used to start the engine
  - The charging system, which produces, controls, and monitors the electrical current needed while the vehicle is running; also recharges the storage batteries
  - The electronic-control system electronically monitors and adjusts the operation of various systems (especially fuel) and provides the driver and service technician with information about those systems.
- The engine braking system uses the engine’s power to help slow the vehicle.

Basic Engine Components

- A push tube is the steel rod or tube that transfers reciprocating motion from the valve lifter to the rocker arm.
- A camshaft is the shaft with eccentric lobes that controls valves, and in some designs, also controls the injectors. It is driven by chains, belts, or gears.
- Water pump
- Intake ports on the cylinder line
- A crankshaft gear drives the camshaft gear or idler gear.
- A crankshaft is the main shaft in the engine power train, which, as it is turned by the connecting rods, converts the reciprocating motion of the pistons into a rotary motion.
- A connecting rod connects the piston to the crankshaft and transmits the reciprocating motion to the crankshaft.
- A piston converts heat energy into reciprocating motion.
- An exhaust valve opens a port in the cylinder head to allow the fresh air charge to be drawn into the cylinder.
- An oil pan is a reservoir for the engine oil.

Basic Four-Stroke Engine Components

- Blower
- Valve rocker
- Fuel injector
- A cylinder block is an iron or aluminum alloy casting that houses the cylinders, water and lubrication passages, crankshaft, and in some designs, the camshaft.
- A cylinder head is the machined casing bolted to the top of the cylinder block, sealing the top of the cylinder; it contains coolant passages, injectors, valves, and in some designs, the camshaft.
- A flywheel (in housing) attaches to the end of the crankshaft; it stores momentum, smooths out firing pulses, carries the crankshaft around to the next firing pulse, and provides a starter engagement point.
- A starter is an electric motor used to initiate an engine’s ignition.
Two-Stroke Engine Components

- A push tube is the steel rod or tube that transfers reciprocating motion from the valve lifter to the rocker arm.
- A camshaft is the shaft with eccentric lobes that controls valves, and in some designs, also controls the injectors. It is driven by chains, belts, or gears.
- Intake ports on the cylinder line
- Water pump
- Valve rocker
- Fuel injector
- A cylinder block is the iron or aluminum alloy casting that houses the cylinders, water and lubrication passages, crankshaft, and in some designs, the camshaft.
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- A connecting rod connects the piston to the crankshaft and transmits the reciprocating motion to the crankshaft.
- A piston converts heat energy into reciprocating motion.
- A crankshaft gear drives the camshaft gear or idler gear.
- A crankshaft is the main shaft in the engine power train, which, as it is turned by the connecting rods, converts the reciprocating motion of the pistons into a rotary motion.
- A flywheel (in housing) attaches to the end of the crankshaft. It stores momentum, smoothes out firing pulses, carries the crankshaft around to the next firing pulse, and provides a starter engagement point.
- An exhaust valve opens a port in the cylinder head to allow the fresh air charge to be drawn into the cylinder.
- An oil pan is a reservoir for the engine oil.
- Blower
- Starter
- Gasoline engines are of much lighter construction with extensive use of aluminum and aluminum alloys.
- In diesel engines the fuel is injected directly into the combustion chamber or precombustion chamber.
- In gasoline engines the fuel is mixed with the air charge by carburetion or by fuel injection; the air/fuel mix is then sent through the intake port and into the combustion chamber.

Characteristics of Gasoline and Diesel Engines

- Construction
  - Diesel engines are of heavy cast iron and forged steel construction.
  - Gasoline engines are of much lighter construction with extensive use of aluminum and aluminum alloys.
- Fuel delivery systems
  - In diesel engines the fuel is injected directly into the combustion chamber or precombustion chamber.
  - In gasoline engines the fuel is mixed with the air charge by carburetion or by fuel injection; the air/fuel mix is then sent through the intake port and into the combustion chamber.
- Fuel ignition
  - Diesel engines use compression ignition; high temperature and high pressure cause the fuel to ignite.
  - Gasoline engines use electric spark ignition; spark from spark plugs ignites the fuel.
- Fuel
  - Diesel engines burn a lower grade fuel oil.
  - Gasoline engines burn a highly refined gasoline.
- Intake air
  - With diesel engines, fresh air is taken directly into the combustion chamber.
  - With gasoline engines, fresh air is mixed with fuel first, then brought into the combustion chamber.
- Compression
  - Diesel engines have a high compression ratio (16-22:1) and high pressure (400-600 psi).
  - Gasoline engines have a low compression ratio (7-11:1) and lower pressure (100-160 psi).
Four-Stroke Cycle Process

First stroke: intake
- The intake valve opens.
- Just after the piston reaches TDC, the exhaust valve closes completely.
- The piston moves down, from TDC to BDC, pulling fresh air into the cylinder.

Second stroke: compression
- Just after the piston reaches BDC, the intake valve closes completely. Both valves are now closed.
- The piston moves up, from BDC to TDC, compressing the air charge. As the air charge is compressed, its temperature rises to over 1,000°F.
- Just before the piston reaches TDC, fuel injection begins.

Third stroke: power
- Injected fuel mixes with the superheated air and immediately begins to burn.
- The burning fuel/air mixture produces hot gases. The rapidly expanding gases force the piston down, from TDC to BDC.

Fourth stroke: exhaust
- The piston moves up, pushing out the spent gases through the exhaust valve.
- Just before the piston reaches TDC, the intake valve begins to open.

Two-Stroke Cycle Process

Upstroke: intake/compression
- The piston moves up, from BDC to TDC.
- As the piston moves up the cylinder, the exhaust valves close; cylinder scavenging stops, and the cylinder filling begins.
- The rising piston covers the intake ports, cylinder filling stops, and the piston now compresses the air charge.
- As the air is compressed, its temperature rises to over 1,000°F.
- Just before the piston reaches TDC, fuel injection begins.

Downstroke: power/exhaust
- Injected fuel mixes with the superheated air and immediately begins to burn.
- The burning fuel/air mixture produces hot gases, and rapidly expanding gases force the piston down, from TDC to BDC.
- Before the piston reaches the intake ports, the exhaust valves open.
- Hot exhaust gases begin to pour out of the cylinder.
- The piston continues to BDC, uncovering the intake ports.

Characteristics of Diesel Engines

Two-stroke diesel engine
- Produces a power stroke every crankshaft revolution
- Typically uses a mechanically driven supercharger (blower) for scavenging and cylinder charging
- Creates greater engine heat load than a four-stroke design since the engine fires twice as often
- Has smoother operation since power strokes occur at shorter intervals

Four-stroke diesel engine
- Produces a power stroke every two crankshaft revolutions
- Does not typically use an engine-driven blower to charge the cylinder
- Is more fuel-efficient due to improved valve timing and is more effective scavenging the exhaust gases