AIRCRAFT TECHNICAL BOOK COMPANY

B2

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

PROPULSION

14

EASA 2023-989 COMPLIANT

Update notices for this book will be available online at www.actechbooks.com/revisions.html
If you would like to be notified when changes occur, please join our mailing list at www.actechbooks.com

VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2016.02	Module creation and release.
002	2017.11	Format updates and minor type corrections.
003	2019.04	Fine tuned Submodule content sequence based on Appendix-A. Updated layout and styling.
003.1	2023.04	Inclusion of Measurement Standards for clarification, page iv. Minor appearance and format updates.
004	2024.12	Regulatory update for EASA 2023-989 compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 004 are:

14.1 *Construction and Operation of APUs* - topic added.
14.1 *Construction and Operation of Piston Engines* - topic added.
14.1 *Construction and Operation of Hybrid Engines* - topic added.
14.2 *Cylinder Head Temp, Coolant Temp, Vibration Measurement* - topics added.
14.3 *Propeller Systems* - complete submodule added.
All submodule review questions edited and replaced.

PROPULSION

TABLE OF CONTENTS

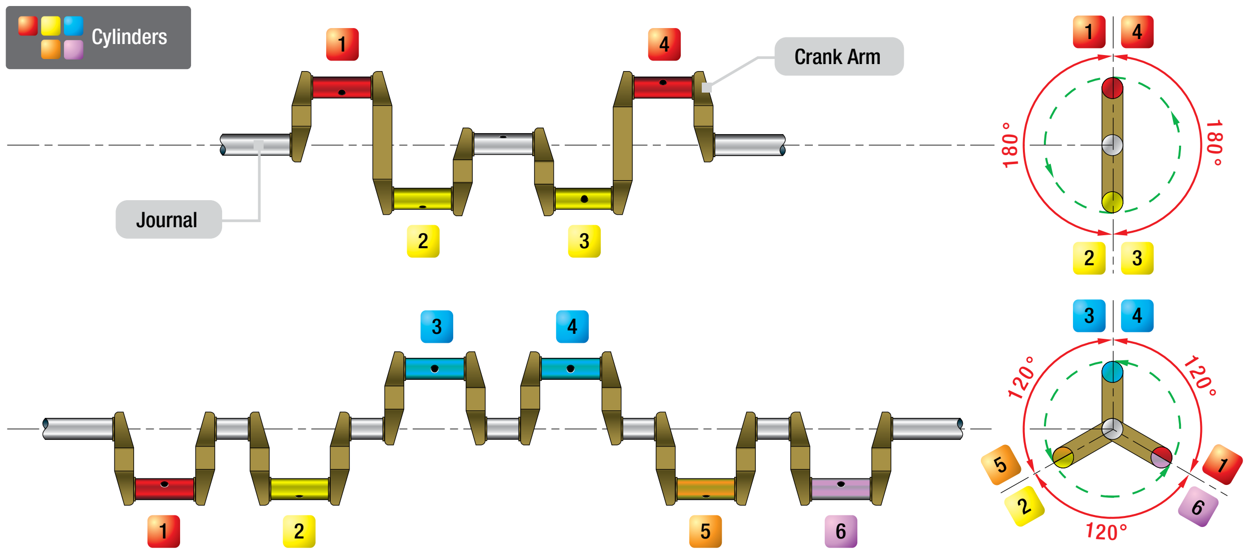

Figure 1-9. Four and six cylinder solid crankshafts.

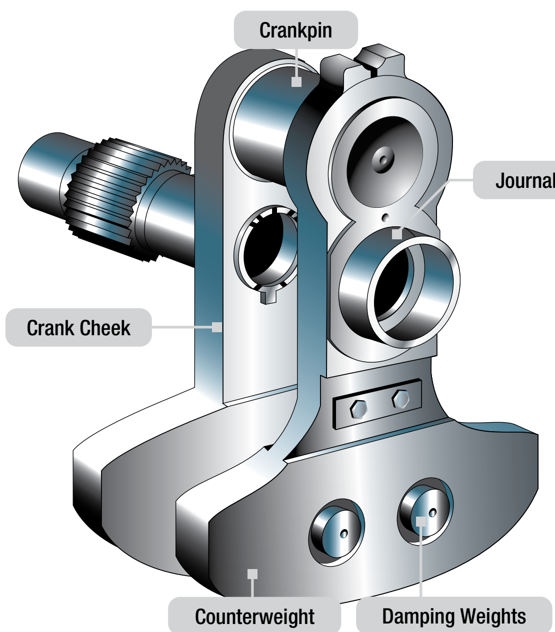

Figure 1-10. Single throw radial engine crankshaft.

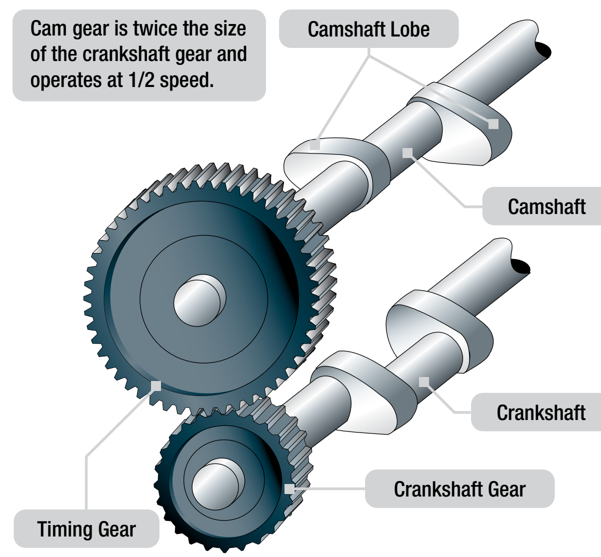

Figure 1-11. Cam drive mechanism opposed type aircraft engine.

direction, it causes the crankshaft to rotate. The outer surface is hardened by nitriding to increase its resistance to wear. The crankpin is usually hollow. This reduces the total weight of the crankshaft and provides a passage for the transfer of lubricating oil.

On some engines, a passage is drilled in the crank cheek to allow oil from the hollow crankshaft to be sprayed on the cylinder walls. The crank cheek connects the crankpin to the main journal. In some designs, the cheek extends beyond the journal and carries a counterweight to balance the crankshaft.

CAMSHAFT

The valve mechanism of an opposed engine is operated by a camshaft. The camshaft is driven by a gear that meshes with another gear attached to the crankshaft as shown in **Figure 1-11**. The camshaft always rotates at one half the crankshaft speed. As the camshaft revolves, its lobes cause transmitting forces to open and close the valve as illustrated in **Figure 1-12**.

SUMPS

Piston engines have sumps that are used as part of the oil system. The sumps are located at the low point of the engine and are used to collect oil circulating through the engine. Depending on where the lubricating oil for the engine is stored will determine whether the engine is a wet sump or a dry sump.

Wet sump engines use the sump as the storage tank for the oil. Oil departs the oil sump, passes through the engine, and returns to the oil sump. Because the oil remains in the engine, with the exception that it may travel to a remote oil cooler, the engine is classified as a wet sump design.[**Figure 1-13**]

By contrast, dry sump engines store their oil in a remote tank. Generally speaking, dry sump engines have oil quantities that are comparatively large. In such instances, it would not be practical to keep those quantities of oil within the engine. A scavenge oil pump is used to transfer the oil from the dry sump to the oil tank. Normally, the oil returning to the oil tank from the sump passes through an oil cooler.

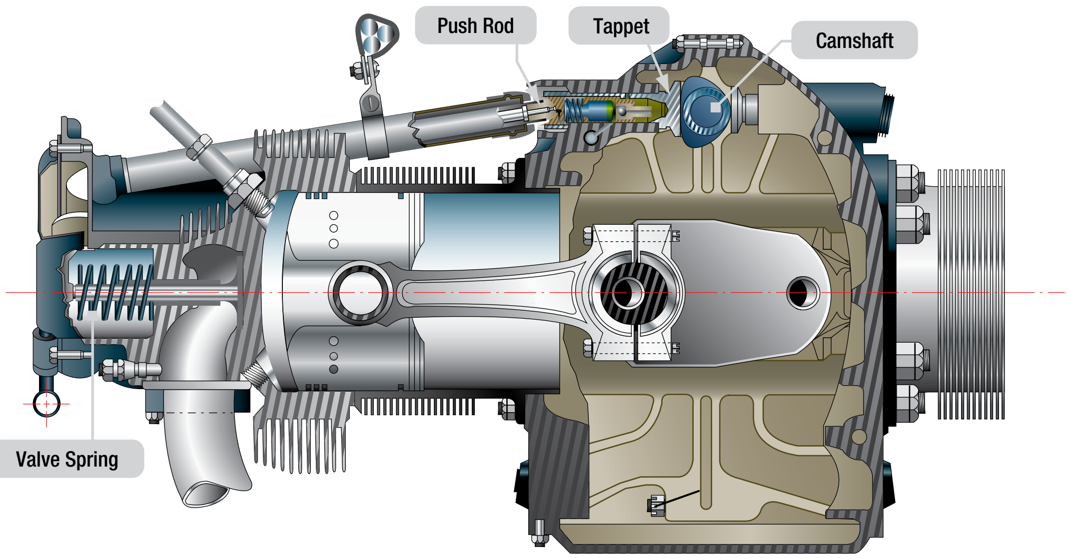

Figure 1-12. Valve operating mechanism (opposed engine).

Figure 1-13. Wet sump engine.

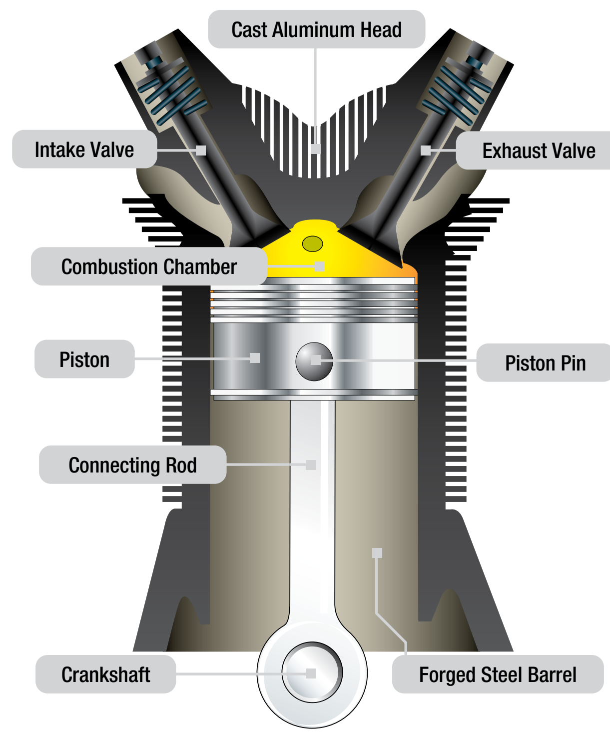

Figure 1-14. Cutaway view of the cylinder assembly.

ACCESSORY SECTION

The accessory (rear) section usually a cast construction of either aluminum alloy or magnesium. The accessory case provides a means for mounting the accessories such as magnetos, carburetors, fuel, oil, vacuum pumps, starter, generator, tachometer drive, etc., in the various locations as required. Other adaptations consist of a casting and a separate cover plate on which the accessory mounts are arranged. Accessory drive shafts are mounted in suitable arrangements that are carried out to the mounting pads. In this manner, the various gear ratios can be arranged to give the proper drive speed to magnetos, pumps, and other accessories to obtain their correct timing.

CYLINDER AND PISTON ASSEMBLIES

CYLINDERS

The cylinder provides a combustion chamber where the burning and expansion of gases take place, and it houses the piston and the connecting rod. As illustrated in **Figure 1-14**, each cylinder is an assembly of two major parts: cylinder head and cylinder barrel. The majority of the cylinders used are constructed in this manner using an aluminum head and a steel barrel.

CYLINDER HEADS

The purpose of the cylinder head is to provide a barrier for combustion of the fuel/air mixture and to give the cylinder more heat conductivity for adequate cooling.

The intake and exhaust valve ports are located in the cylinder head along with the spark plugs and the intake and exhaust valve actuating mechanisms.

After the cylinder head is cast, the spark plug bushings, valve guides, rocker arm bushings, and valve seats are installed. Spark plug openings may be fitted with bronze or steel bushings that are pressed or screwed into the openings. Valve guides are pressed into other openings in the cylinder head to provide guides for the valve stems. The valve seats are circular rings of hardened metal that protect the relatively soft metal of the cylinder head from the hammering action of the valves as they open and close.

The cylinder heads of air cooled engines are subjected to extreme temperatures; and so it is necessary to provide adequate cooling fin area and to use metals that conduct heat rapidly. Because of the difference in temperature in the various sections of the cylinder head, it is necessary to provide more cooling fin area on some sections than on others. The exhaust valve region is the hottest part of the internal surface; therefore, more fin area is provided around the outside of the cylinder head in this section.

CYLINDER BARRELS

The cylinder barrel is made of a steel alloy forging with the inner surface hardened to resist wear of the piston and the piston rings that bear against it. This hardening is usually done by exposing the steel to ammonia or cyanide gas while the steel is very hot. The steel soaks up nitrogen from the gas. As a result of this process, the metal is said to be nitrided. As the cylinder barrels wear due to use, they can be repaired by chroming. This is a process that plates chromium on the surface of the cylinder barrel and brings it back to new standard dimensions.

In some instances, the barrel has threads on the outside surface at one end so that it can be screwed into the cylinder head. Cooling fins are machined as an integral part of the barrel and have limits on repair and service.

PISTONS

The piston is a cylindrical member that moves back and forth within the cylinder. [**Figure 1-15**] It acts as a moving wall within the combustion chamber. As the piston moves down in the cylinder, it draws in the fuel/air mixture. As it moves upward, it compresses the charge and the expanding gases then force the piston downward. This force is transmitted to the crankshaft through the connecting rod. On the return upward stroke, the piston forces the exhaust gases from the cylinder and the cycle repeats.

PISTON CONSTRUCTION

The majority of aircraft engine pistons are machined from aluminum alloy forgings. Cooling fins are provided on the inside of the piston for greater heat transfer to the engine oil.

Grooves may be machined around the piston to accommodate the compression rings and oil rings. **Figure 1-15** reveals a piston with three ring grooves. The compression rings are installed in the uppermost grooves and the oil control rings are installed below them. An additional oil scraper ring is installed at the base of some pistons to prevent excessive oil consumption.

PISTON PINS

The piston pin joins the piston to the connecting rod as illustrated in **Figure 1-14**. It is a hardened tube of nickel steel. In modern aircraft engines it is a full floating type, so called because the pin is free to rotate in both the piston and in the connecting rod bearing. The piston pin must be held in place to prevent its ends from scoring the cylinder walls. A plug of relatively soft aluminum in the pin end provides that good bearing surface against the cylinder wall.

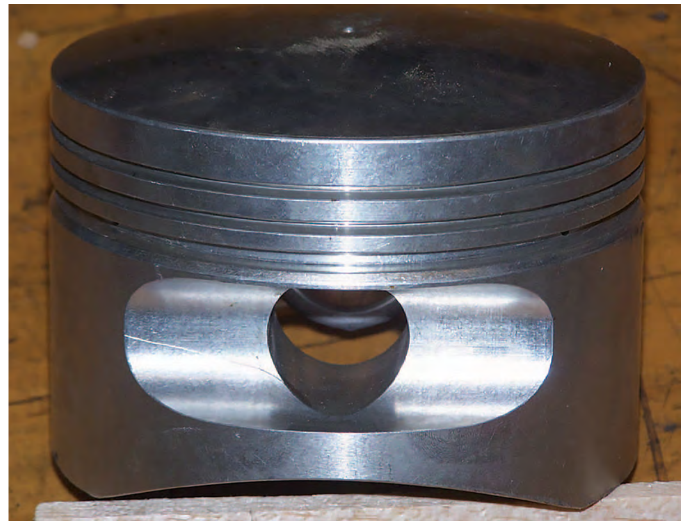

Figure 1-15. A piston.

PISTON RINGS

Most piston rings are made of high grade cast iron. Then they are split so that they can be slipped over the outside of the piston and into the ring grooves of the piston wall. Since their purpose is to seal the clearance between the piston and the cylinder wall, they must fit the cylinder wall snugly enough to provide a gas tight fit.

COMPRESSION RING

Compression rings minimize the escape of combustion gases past the piston. They are placed in the ring grooves immediately below the piston head. Most aircraft engines use two compression rings.

OIL CONTROL RINGS

Oil control rings are placed in the grooves immediately below the compression rings and above the piston pin bores. Oil control rings regulate the thickness of the oil film on the cylinder wall. If too much oil enters the combustion chamber, it burns and leaves a coating of carbon on the chamber walls, the piston head, spark plugs and the valve heads. This carbon can cause the valves and rings to stick. In addition, the carbon can cause spark plug misfiring or excessive oil consumption.

OIL SCRAPER RING

An oil scraper ring is installed in the groove at the bottom of the piston skirt. The scraper ring retains the surplus oil above the ring on the upward piston stroke, and this oil is returned to the crankcase by the oil control rings on the downward stroke.

CONNECTING RODS

The connecting rod is the link that transmits forces between the piston and the crankshaft. While several types of connecting rods exist, the Plain type shown in **Figure 1-16** is used in all inline and opposed engines. The large end of the rod that attaches to the crankpin is fitted with a cap and a two piece bearing. The bearing cap is held on the end of the rod by bolts or studs. To maintain proper fit and balance, connecting rods should always be replaced in the same cylinder and in the same relative position.

VALVES

The fuel/air mixture enters the cylinders through the intake valve ports, and burned gases are expelled through the exhaust valve ports. The head of each valve opens and closes these cylinder ports. Valves are typed by their shape and are called either mushroom or tulip. [**Figure 1-17**]

VALVE CONSTRUCTION

Valves are subjected to high temperatures, corrosion, and stresses; thus, the alloy in the valves must be able to resist all these factors. Because intake valves operate at lower temperatures than exhaust valves, they can be made of chromic nickel steel. Exhaust valves are usually made of cobalt chromium steel because of its greater resistant. The valve head has a ground face that forms a seal against the ground valve seat in the cylinder head when the valve is closed.

The valve stem acts as a pilot for the valve head and rides in the valve guide installed in the cylinder head. [**Figure 1-18**] The valve stem is surface hardened to resist wear. The neck is the part that forms the junction between the head and the stem. A machined groove on the stem near the tip receives the stem keys. These stem keys form a lock ring to hold the valve spring retaining washer in place, as seen in **Figure 1-19**.

Some intake and exhaust valve stems are hollow and partially filled with metallic sodium. This material is used because it is an excellent heat conductor. The motion of the valve circulates the liquid sodium, allowing it to carry away heat from the valve head to the cylinder head and the cooling fins. Under no circumstances should a sodium filled valve be cut open. Exposure of the sodium in these valves to the outside air results in fire or explosion with possible personal injury.

VALVE OPERATING MECHANISM

For a piston engine to operate properly, each valve must open at the correct time, stay open for the required length of time, and close at the proper time. Intake valves are opened just before the piston reaches top dead center on the exhaust stroke, and exhaust valves remain open after top dead center as the cylinder begins its intake stroke. The timing of the valves is controlled by the valve operating mechanism and is referred to as the valve timing.

The valve lift (distance that the valve is lifted off its seat) and the valve duration (length of time the valve is held open) are both determined by the shape of the cam lobes. [**Figure 1-20**]

The lobes are machined on each side of the cam to permit the rocker arm to be eased into contact with the valve tip.

Figure 1-16. Plain-type connecting rod and cap assembly.

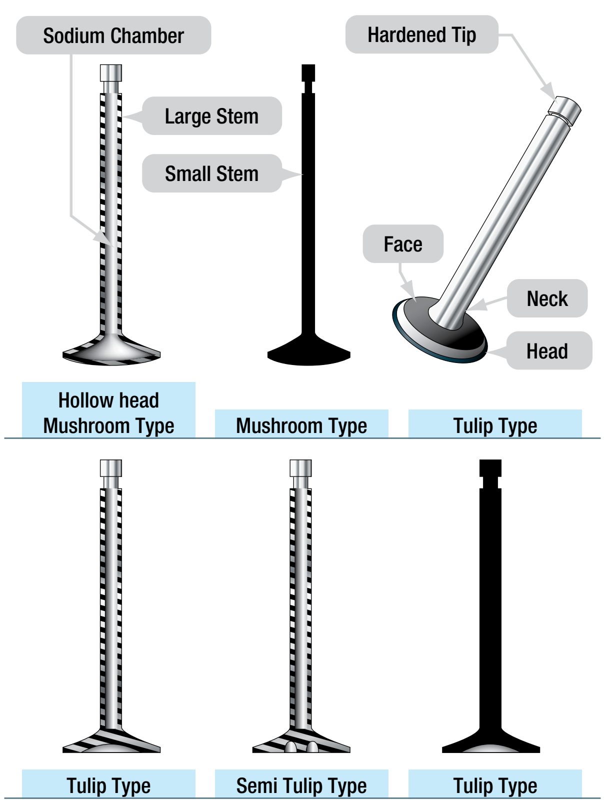

Figure 1-17. Type of valves.

Figure 1-18. View of cylinder head showing valve seats, valve guides, and spark plug holes.

Figure 1-19. Valve installation showing valve tip, valve springs, valve spring cap, and valve stem keepers.

The valve operating mechanism consists of a camshaft equipped with lobes that work against a cam follower as shown in **Figure 1-12**. The tappet pushes a push rod, actuating a rocker arm, which in turn opens the valve. Springs, which slip over the stem of the valves and are held in place by a retaining washer closes each valve.[**Figure 1-21**]

TAPPETS/LIFTERS

The function of tappet is to convert the rotational movement of the camshaft into piston motion and to transmit this motion to the push rod, rocker arm, and then to the valve tip, opening the valve at the proper time. While some older engines have used solid tappets, most aircraft engines today use hydraulic tappets/lifters.

Hydraulic tappets automatically keep the valve clearance at zero when the engine is running, eliminating the necessity for valve clearance adjustments. A typical hydraulic tappet assembly is shown in **Figure 1-22**.

When the intake or exhaust valve is closed, the face of the tappet is on the cam. The plunger spring lifts the plunger so that its outer end contacts the push rod, exerting pressure against it. As the plunger moves outward, a ball check valve moves off its seat. Oil flows in and fills the chamber. As the camshaft rotates, it pushes the tappet body outward against the push rod.

PUSH RODS

The push rod transmits the lifting force from the tappet to the rocker arm. A hardened steel ball is pressed into each end of the tube. One ball end fits into the socket of the rocker arm [**Figure 1-23 and 1-24**]. The other rides on the tappet. The push rod is enclosed in a tubular housing that extends from the crankcase to the cylinder head, referred to as push rod tubes.

ROCKER ARMS

The rocker arms transmit the lifting force from the cams to the valves. Rocker arm assemblies are supported by a combination of bearings which serves as a pivot. Generally, one end of the arm rides against the push rod and the other bears on the valve stem. The arm may have an adjusting screw for adjusting the clearance between the rocker arm and the valve stem tip. The screw can be adjusted to the specified clearance to make certain that the valve closes fully.

Figure 1-20. Cam lobe.

Figure 1-21. Inner and outer valve springs, valve spring cap, and valve stem keepers.

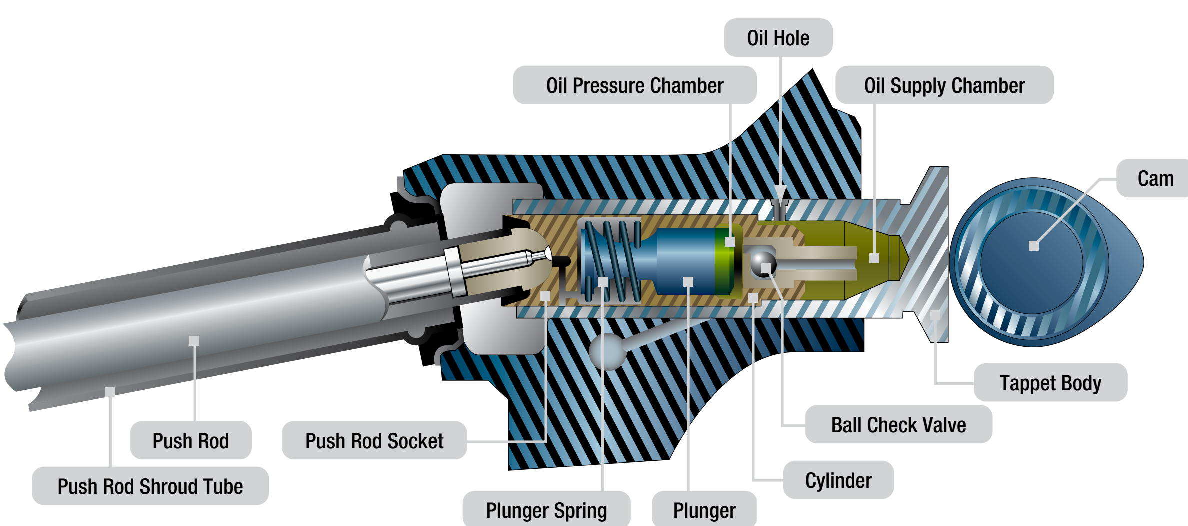

Figure 1-22. Illustration of zero-lash hydraulic lifter.