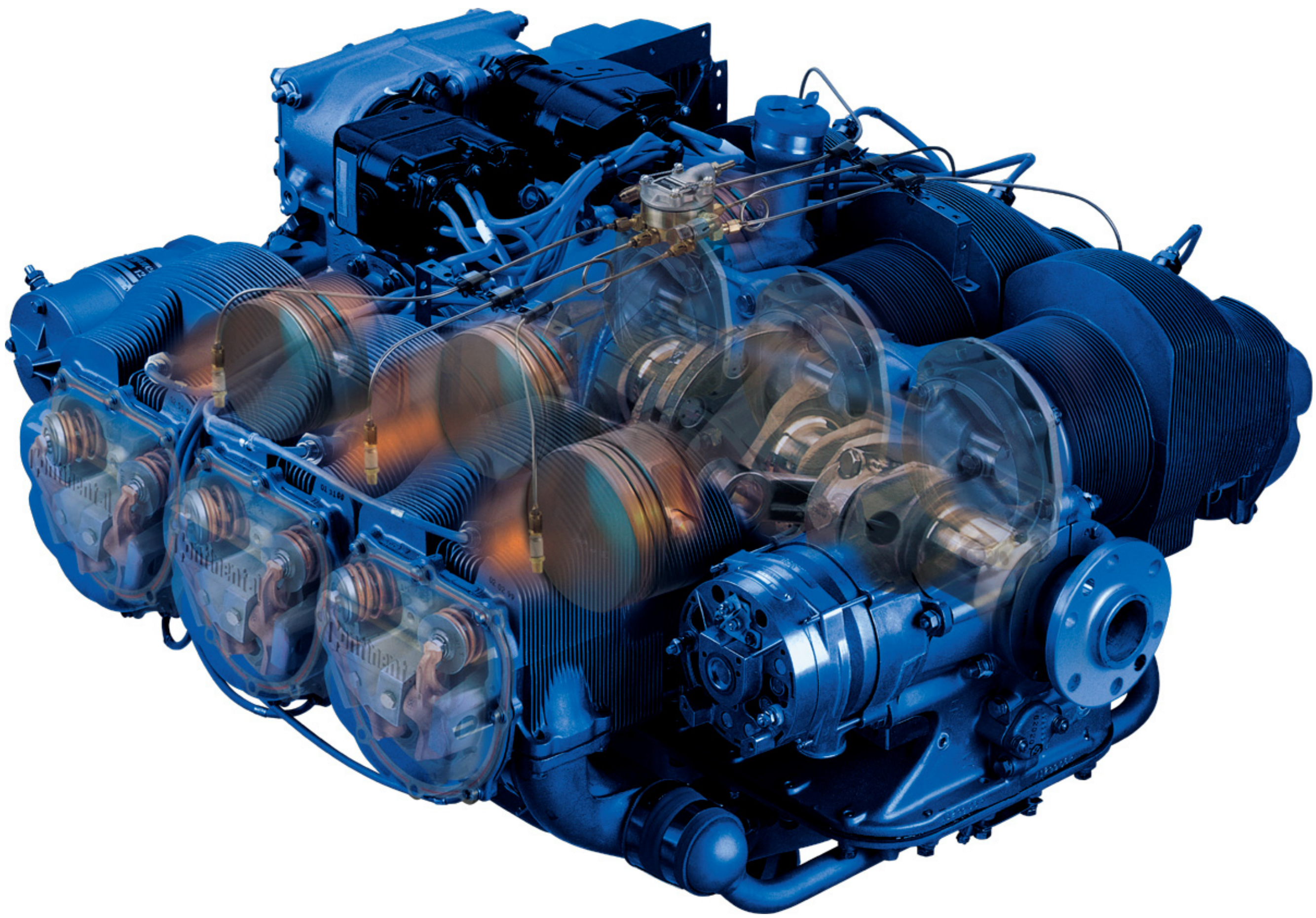
STUDENT TEXT BOOK

AVIATION TECHNICIAN ADVANCED TRAINING PROGRAM

CONTINENTAL ENGINE THEORY



Teledyne Continental Motors, Inc.

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PURPOSE

This Student Text Book has been designed for use by students attending the Aviation Technician Advanced Training Program training course conducted by Teledyne Continental Motors. The material in this book contains general theory of operation on the engine's major subsystems. Being general in nature, the theory is not all encompassing, but rather designed to refresh the technician with the internal combustion engine designs of the Continental® Aircraft Engine. It is important that you, the student, understand you must always refer to the most current authorized Engine or Aircraft Manufacturer's Service Manuals whenever servicing a specific engine. **This Student Text Book is authorized for training purposes only do not use on the job.**

TABLE OF CONTENTS

Chapter One

Introduction to Continental® Engine Designs

CHAPTER 1 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Identify the categories of engine models.

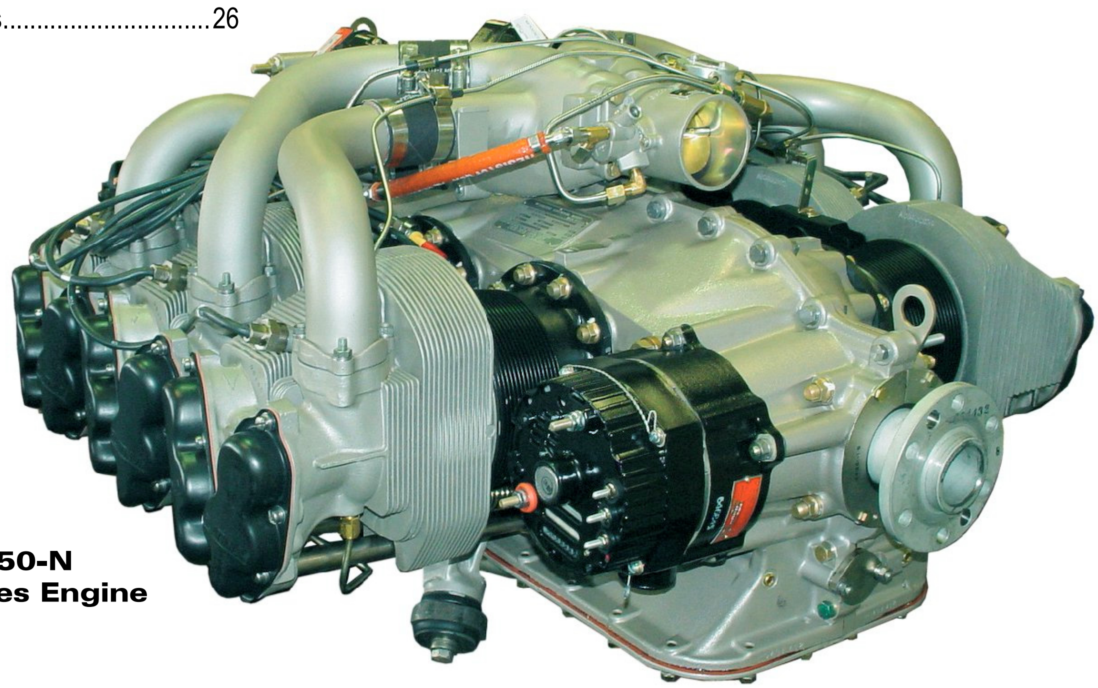
② Describe the difference between the engine model and the spec.

③ Describe the current line-up of engines produced by Teledyne Continental Motors.

③ Identify the different performance features of Continental Aircraft engines.

⑤ Describe the various subscriber services available on the TCMLINK system.

⑥ Describe the procedures for properly accessing service information using the TCMLINK system.



The IO-550-N Platinum Series Engine

GENERAL INTRODUCTION

The information in this student textbook is for training purposes only and should never be used on the job. It is designed to provide you with general information on engines produced by Teledyne Continental Motors. Always refer to the instructions published by the aircraft, engine or component manufacturer when performing maintenance, preventive maintenance or overhaul. Any technical discrepancies found in this material should be addressed to:

TELEDYNE CONTINENTAL MOTORS
Attention: Training Department
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In this chapter we will introduce these engine models and identify their basic operating parameters. We will then introduce the TCMLINK® Information Services program in order that you may make use of this program through the conduct of your studies in this text

A general description and explanation of terms and designators used in this industry should be covered before we get into the more detailed descriptions of the various engine designs produced for the general aviation fleet.

4 Cylinder Models - O-200, IO-240 & the new IOF-240 FADEC Engine.

6 Cylinder Models - O-300, IO-360, TSIO-360, O-470, IO-470, IO-520, TSIO-520, GTSIO-520, IO-550, the IOF-550 FADEC Engines and TSIO-550 and TSIOL-550.

Each engine bears an identification plate (data plate) on which are stamped engine model, specification serial number, ignition timing, Type Certificate number and production certificate number for that particular engine, together with the engine serial number.

Teledyne Continental Motors manufactures engines ranging from the small O-200 carbureted engine, to the TSIOL-550 turbocharged liquid cooled fuel injected engine for high altitude performance.

Variations to the basic engine type have been introduced to suit customer requirements. Variations such as Turbocharged, Fuel Injection and Gear Reductions provide diverse capabilities to meet many customer requirements. The latest of these new engine technologies to come on line is the FADEC system, which consists of electronic controls for the engine’s fuel injection and ignition systems. The new FADEC system will be discussed in detail in chapter eight.

Originally, engines were identified by series, rated horsepower and specification such as C-90-8. Currently engines are identified by series, type cubic inch displacement, model and specification number. See Figure 1-1.

EXPLANATION OF TERMS

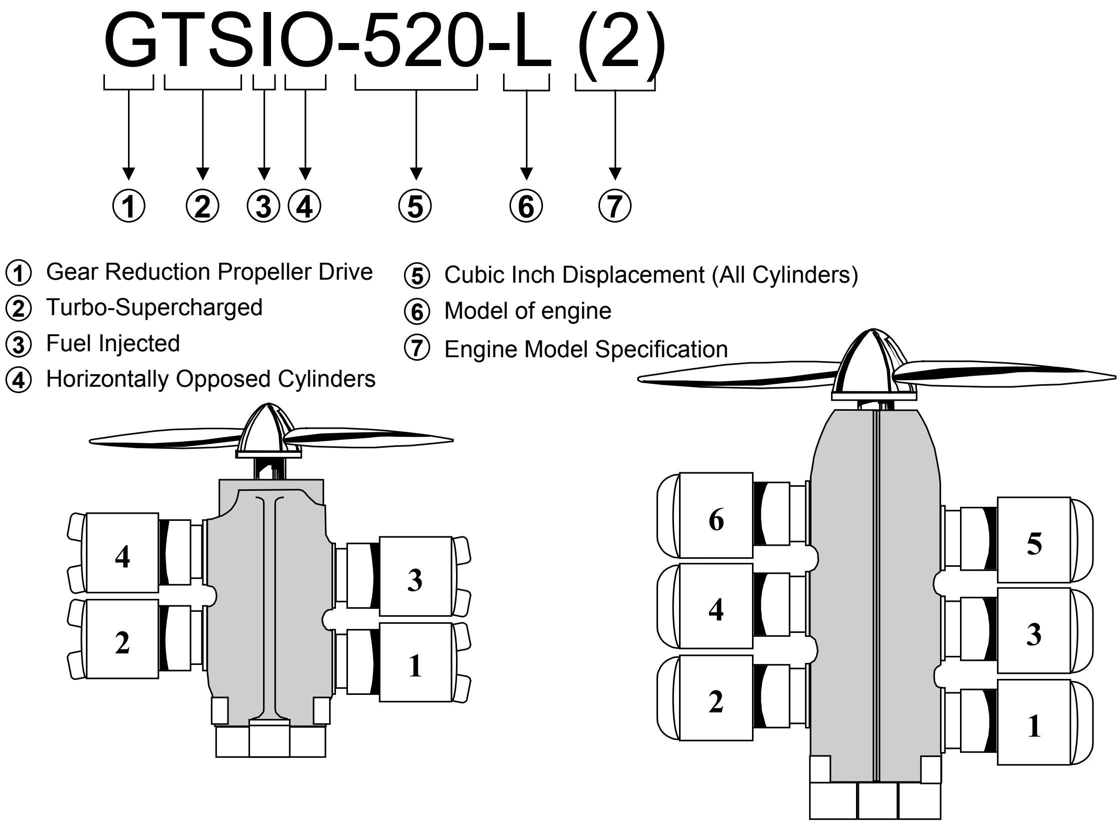


Figure 1-1. Engine Designations and Numbering

The crankshaft end of the engine, to which the propeller is fitted, is called the FRONT, the end where the magnetos are mounted being called the REAR. The right-hand and left-hand sides are defined when viewed from the REAR.

The cylinders are numbered 1 - 4 (1 - 6), commencing from the right rear as shown in figure 1-1. Propeller rotation is clockwise, or counter-clockwise, when viewed from the rear of the engine. Direction of rotation of crankshaft, camshaft and internal gears is referenced as viewed from the rear. Rotation of accessories is referenced as viewed from the drive end of the accessory. All internal drive train components are referenced from the rear forward. For example, the number #1 main journal on the crankshaft is the rear main journal.

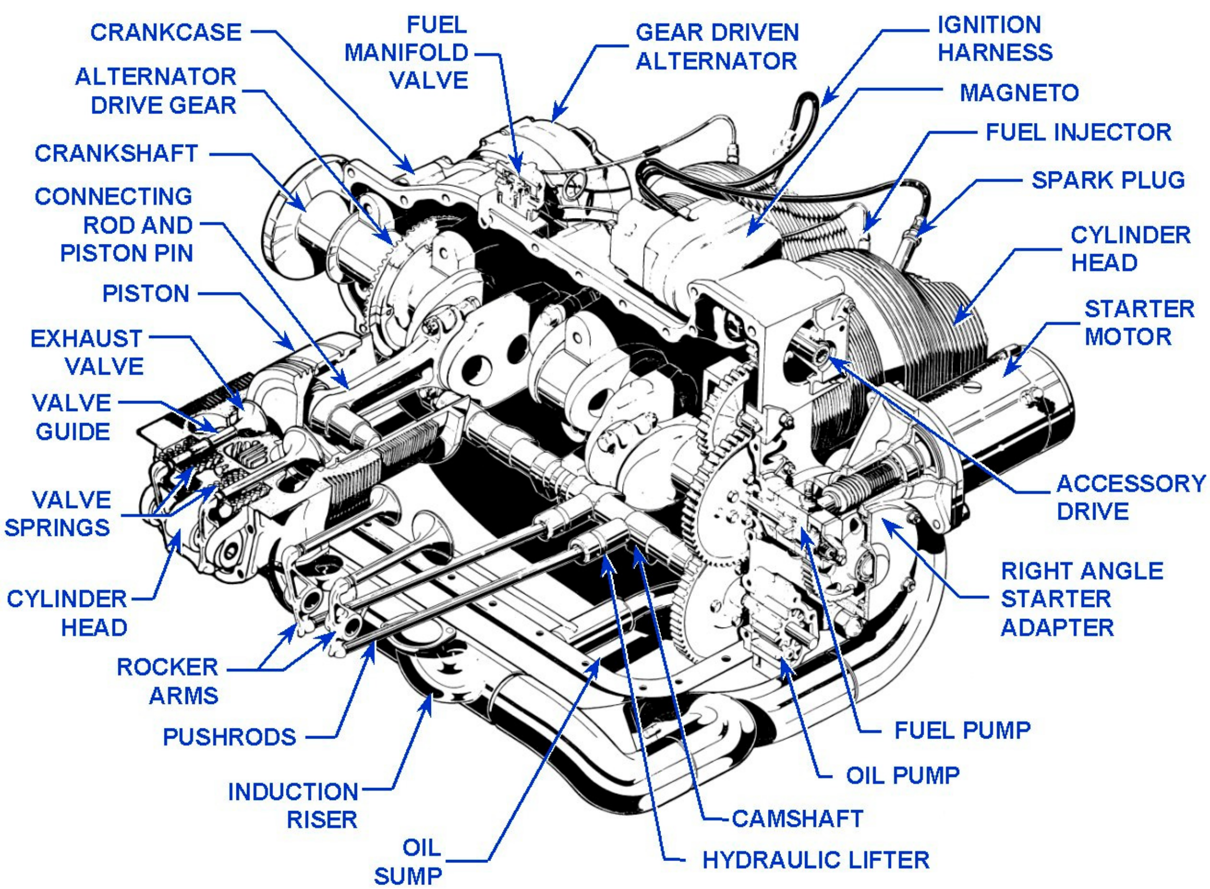
In the above figure, you see the designator for the GTSIO-520-L (2) explained. This engine may be referred to as a **G**ear reduced, **T**urbo-**S**upercharged Fuel **I**njected, Horizontally **O**pposed engine with a **520** cubic inch displacement. It is model suffix **L** dressed out as a spec **2** engine. The engine model (L) may be and quite often is different both externally and internally from other models of the same family grouping. The spec number (2) denotes how the engine is dressed out. For example, what type of magnetos, the starter and alternator voltage rating (12v or 24v), just to name a few of the various accessories.

There are many new additions to the designators that should also be introduced and further explained. You will encounter engines that have a TSIO-360 designator, which may also accompanied by the LTSIO-360. The "L" in front of the family grouping indicates the engine is left hand or (counterclockwise) rotation when viewed from the rear of the engine. An engine designation with an "L" suffix after the TSIO family grouping indicates Liquid Cooled. Example, the TSIOL-550-C is a turbocharged, fuel injected, horizontally opposed, liquid cooled engine with a 550 cubic inch displacement.

An "F" suffix following the engine family designator denotes the engine is equipped with FADEC electronic engine controls. The PowerLink FADEC series engines will be covered in book three of this series.

The power delivered by these engines per pound of weight is achieved by using carefully selected high strength materials, by ongoing improvements in design calculated to make the optimum use of these high quality materials, and by very close control of critical dimensions, surface finishes, heat treatment methods and hardening processes. Careful work has produced more rugged engines than could be built by less exacting methods. However, no amount of ruggedness built into an engine will enable it to withstand neglect and serious misuse or mistreatment. Overheating, neglect, inferior fuels and lubricants will seriously affect engine performance, particularly when the specific power rating is high and each part must be free to function properly in order to withstand the imposed loads with minimum wear. These considerations are mentioned here in order to emphasize the necessity of using the manufacturer's specified gasoline and oil and the importance of keeping the fuel, oil and air filters clean. Always use the octane rated fuel specified, and if not available, use the next highest rated fuel.

Keeping the engine clean will facilitate optimum cooling for air-cooled designs. Dirty and clogged cylinder cooling fins will restrict airflow and hinder proper cooling. Also insure that the aircraft manufacturer's installed baffles are in proper working condition.



200 & 240 SERIES ENGINES

Figure 1-2. O-200 Engine Model

The 200 Series engines consist of the O-200 the IO-240 and IOF-240 engine models. The O-200 which is referenced if Figure 1-2 above is the first engine we will discuss. The O-200-A/B is a four cylinder carbureted engine producing 100 brake horsepower and has a crankshaft speed of 2750 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders have an overhead valve design. The cylinders have updraft intake inlets and downdraft exhaust outlets mounted on the bottom of the cylinder.

The O-200-A/B engines have a 201 cubic inch displacement achieved by using a cylinder design with a 4.06 inch diameter bore and a 3.88 inch stroke. The dry weight of the engine is 170.18 lbs. without accessories. The weight of the engine with installed accessories is approximately 215 lbs. The engine is provided with four integral rear engine mounts. A crankcase breather port is located on the 1-3 side of the crankcase forward of the number 3 cylinder.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, oil pressure relief valve, pressure oil screen mounted on the rear of the accessory case and pressure instrumentation. A fitting is provided at the 1-3 side of the crankcase for oil pressure measurement. The oil sump capacity is 6 quarts maximum.

The O-200-A/B induction system consists of an updraft intake manifold with the air intake and throttle mounted below the engine. Engine manifold pressure is measured at a port located on the 2-4 side of the intake air manifold.

The O-200-A/B is equipped with a Carburetor that meters fuel flow as the cockpit throttle and mixture controls are changed.

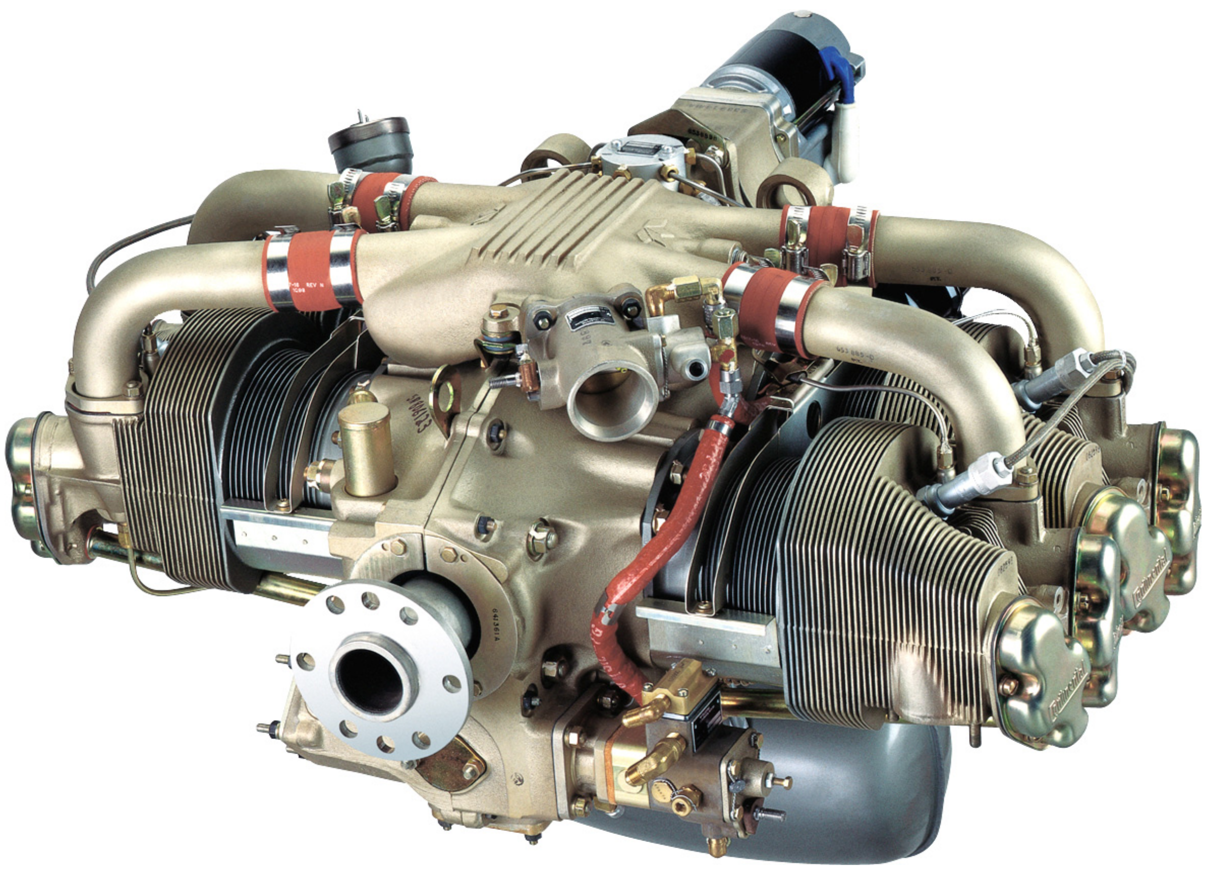


Figure 1-3. IO-240-B Series Engine

The IO-240-B is a four cylinder fuel injected engine producing 125 brake horsepower and has a crankshaft speed of 2800 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders are cross flow design having overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The IO-240-B engine has a 240 cubic inch displacement achieved by using a cylinder design with a 4.438 inch diameter bore and a 3.875 inch stroke. The dry weight of the engine is 205 lbs without accessories. The average weight of the engine with installed accessories is approximately 250 lbs.

The engine is provided with four integral rear mounts. A crankcase breather port is located on the right crankcase half forward of cylinder #3. Intercylinder baffles are supplied to direct airflow across the underside of the cylinder as well as the topside to maintain uniform cooling. A port is located on the bottom side of the cylinder head for use with an AS234 or equivalent bayonet thermocouple using an AS236 or equivalent adapter. Cylinder fuel drains are also located on the bottom of the cylinder, tapped into the intake chamber.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, oil cooler adapter, oil sump, full flow oil filter airframe supplied remote mounted oil cooler, oil pressure relief valve, and pressure instrumentation. The removable hydraulic tappets, pushrod ends and rocker arm bearings are lubricated by the engine's main oil pressure system.

The oil cooler adapter incorporates a vernatherm valve to allow oil flow into the engine in the event of an oil restriction occurring in the external oil cooler and during cold starting. A fitting is provided at the oil cooler adapter on the rear of the 2-4 side crankcase for oil pressure measurement. The oil sump capacity is 6 US quarts. When the engine is at a 10° nose up, or 10° nose down attitude, only 3.0 quarts are available for use.

The IO-240-B induction system consists of a tuned overhead plenum intake manifold with the air throttle mounted above the engine. Engine manifold pressure is measured at a port located in the intake air manifold.

The IO-240-B is equipped with a TCM Continuous Flow Fuel injection system that meters fuel flow as a function of engine speed, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port.

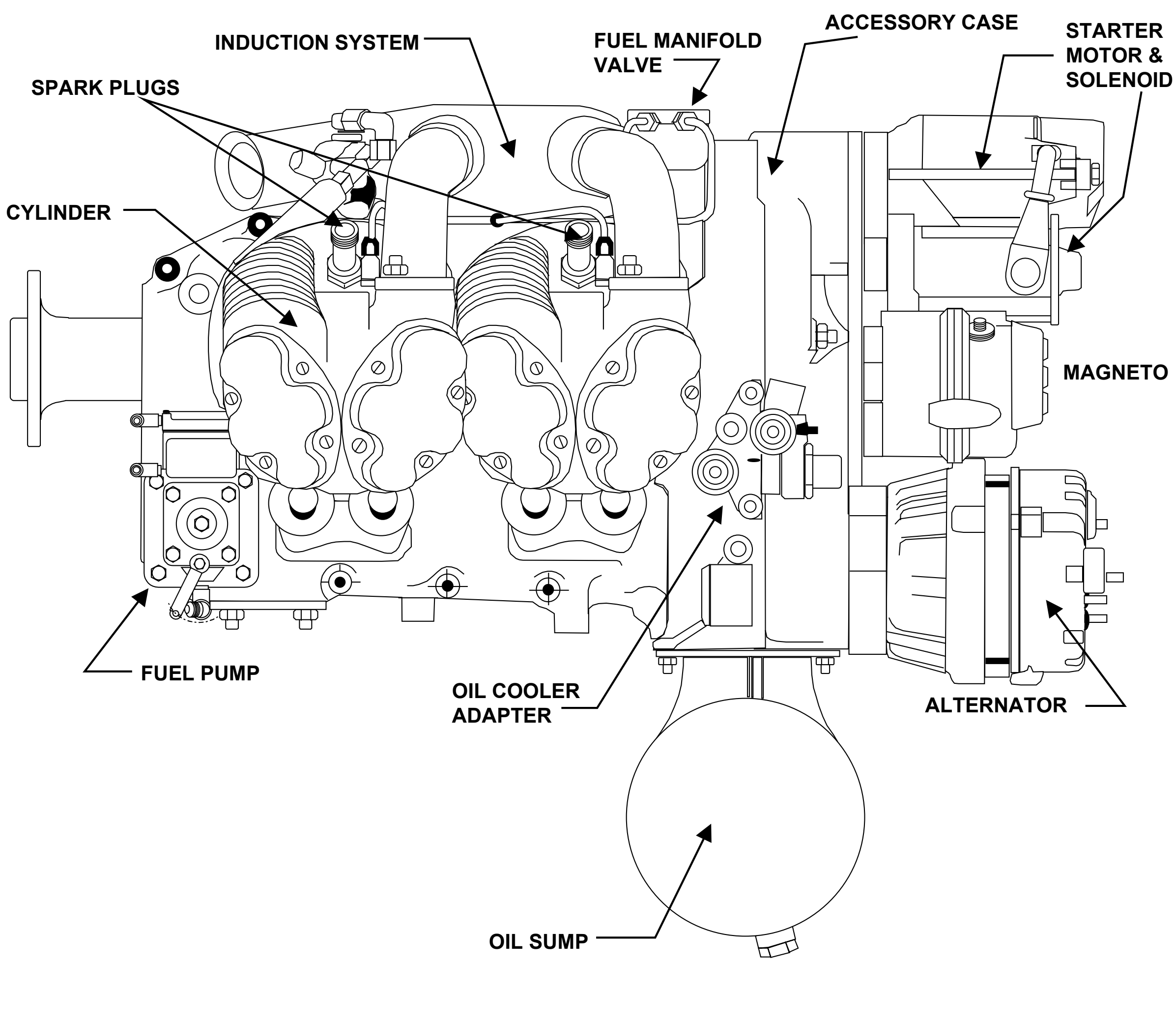


Figure 1-4. IO-240-B Engine Side View

360 SERIES ENGINES

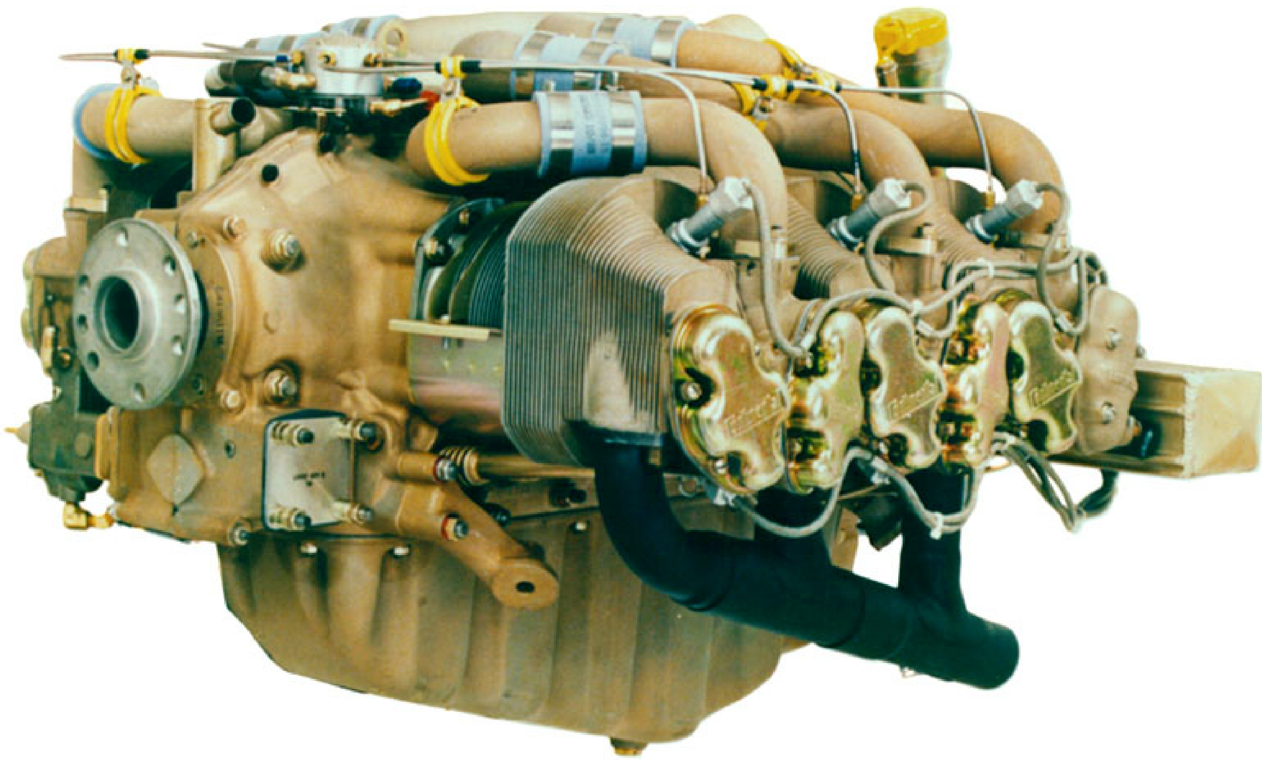


Figure 1-5. IO-360-ES Series Engine Model

This description will refer in general, to all naturally aspirated IO-360 engines. The IO-360 series engines are six cylinder fuel injected air cooled engines producing the following horsepower ratings:

ENGINE MODEL	RATED MAX. CONT. BHP	MAX RPM
IO-360- J, JB, K, KB	195 BHP	2600 RPM
IO-360-C, CB, D, DB, ES, G, GB, H, HB	210 BHP	2800 RPM

The engine has horizontally opposed air cooled cylinders. The engine cylinders are cross flow design having overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The IO-360 Series engines have a 360 cubic inch displacement achieved by using a cylinder design with a 4.438 inch diameter bore and a 3.875 inch stroke. The IO-360-D, DB, H, HB, J, JB, K, KB engine's dry weight is 327.25 lbs. without accessories. The IO-360-C, CB, G, GB engine's dry weight is 331.25 lbs. without accessories.

The engine is provided with four dyna-focal mounts. A crankcase breather port is located on the 1-3-5 side of the crankcase forward of the number 5 cylinder. A threaded port is located on the bottom side of the cylinder head for use with an AS234 or equivalent bayonet thermocouple using an AS236 or equivalent adapter. Cylinder fuel drains are also located on the bottom of the cylinder, tapped into the intake chamber.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation. The removable hydraulic tappets, pushrod ends and rocker arm bearings are lubricated by the engine's main oil pressure system.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F. The oil cooler adapter incorporates a vernatherm valve to allow oil flow into the engine in the event an oil restriction occurs in the oil cooler and during cold starting.

A fitting is provided between the #2 & #4 cylinder on the 2-4-6 side crankcase for oil pressure measurement. The oil sump capacity ranges from 8 to 10 US Quarts based on the engine model. When the engine is at a 25° nose up or down attitude, only 7.0 quarts are available for use.

The IO-360 Series induction system consists of a tuned overhead runner with the air throttle mounted above the engine. Engine manifold pressure is measured at the port located in the intake air manifold.

The engine is equipped with a TCM Continuous Flow multi-nozzle fuel injection system. This system meters fuel flow in proportion to engine RPM, throttle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each of the cylinder intake ports.

The crankshaft flange has six bolt holes, two dowel pins and a center pilot extension which has provisions for the hydraulic propeller control oil and is supplied internally from the governor drive pad. The crankshaft is also equipped with pendulum type torsional damper weights.

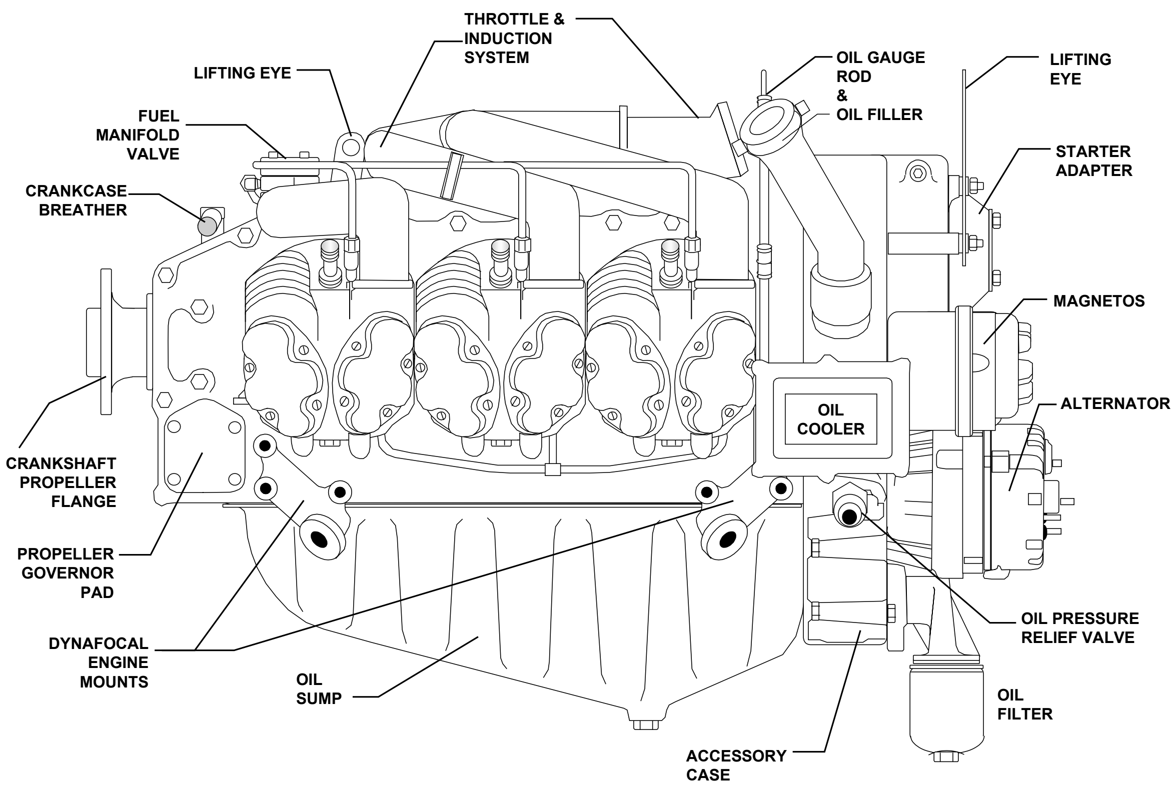


Figure 1-6. IO-360-ES Engine Side View

470 SANDCAST SERIES ENGINES

Figure 1-7. O-470 Series Engine

The O-470 model engines are six cylinder carbureted engines producing between 225 - 240 brake horsepower and have crankshaft speeds ranging between 2400 - 2600 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders have an overhead inclined valve design. The cylinders have updraft intake inlets and downdraft exhaust outlets mounted on the bottom of the cylinder head.

The O-470 model has a 471 cubic inch displacement achieved by using a cylinder design with a 5.00 inch diameter bore and a 4.00 inch stroke. The O-470 weighs in at a dry weight of 385.66 lbs. without accessories. The weight of the engine with installed accessories is approximately 425 lbs.

The engine is provided with four engine bed mounts. A crankcase breather port is located on the 2-4-6 side of the crankcase top surface located forward of the number 6 cylinder.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, oil pressure relief valve, oil cooler, removable pressure oil screen mounted on the oil pump and pressure instrumentation. A fitting is provided between the #2 & #4 cylinder on the left crankcase half for oil pressure measurement.

The oil sump capacity is 12 US Quarts. The minimum quantity at 15° nose down attitude is 4.00 quarts and when 30° nose up there is 5.50 quarts of useable oil for lubrication.

The oil cooler is mounted forward of the #5 cylinder on the 1-3-5 side of the crankcase. The oil cooler incorporates a vernatherm valve to allow oil flow into the engine in the event an oil restriction occurs in the external oil cooler and during cold starting. A fitting located in the oil gallery between the #2 and #4 cylinder on the 2-4-6 side of the crankcase is provided for oil pressure gauge connection. The removable hydraulic tappets, pushrod ends and rocker arm bearings are lubricated by the engine's main oil pressure system.

The induction system consists of an updraft runner type induction with the air intake and carburetor mounted below the engine. Engine manifold pressure is measured at the port located on the rear of the induction tube where it mounts to the carburetor.

The O-470 is equipped with a Float type Carburetor that meters fuel flow as the cockpit throttle and mixture controls are changed.

The IO-470 engine models are six cylinder fuel injected engines that produces 260 brake horsepower and have a crankshaft speed ranging to 2700 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders have an overhead inclined valve design. The cylinders have updraft intake inlets and downdraft exhaust outlets mounted on the bottom of the cylinder head.

The IO-470 engine has a 471 cubic inch displacement achieved by using a cylinder design with a 5.00 inch diameter bore and a 4.00 inch stroke. The dry weight of the engine is 426.06 lbs. without accessories. The average weight of the engine with installed accessories is approximately 455 lbs.

The engine is provided with four engine bed mounts. A crankcase breather port is located on the 2-4-6 side of the crankcase forward of the number 6 cylinder.

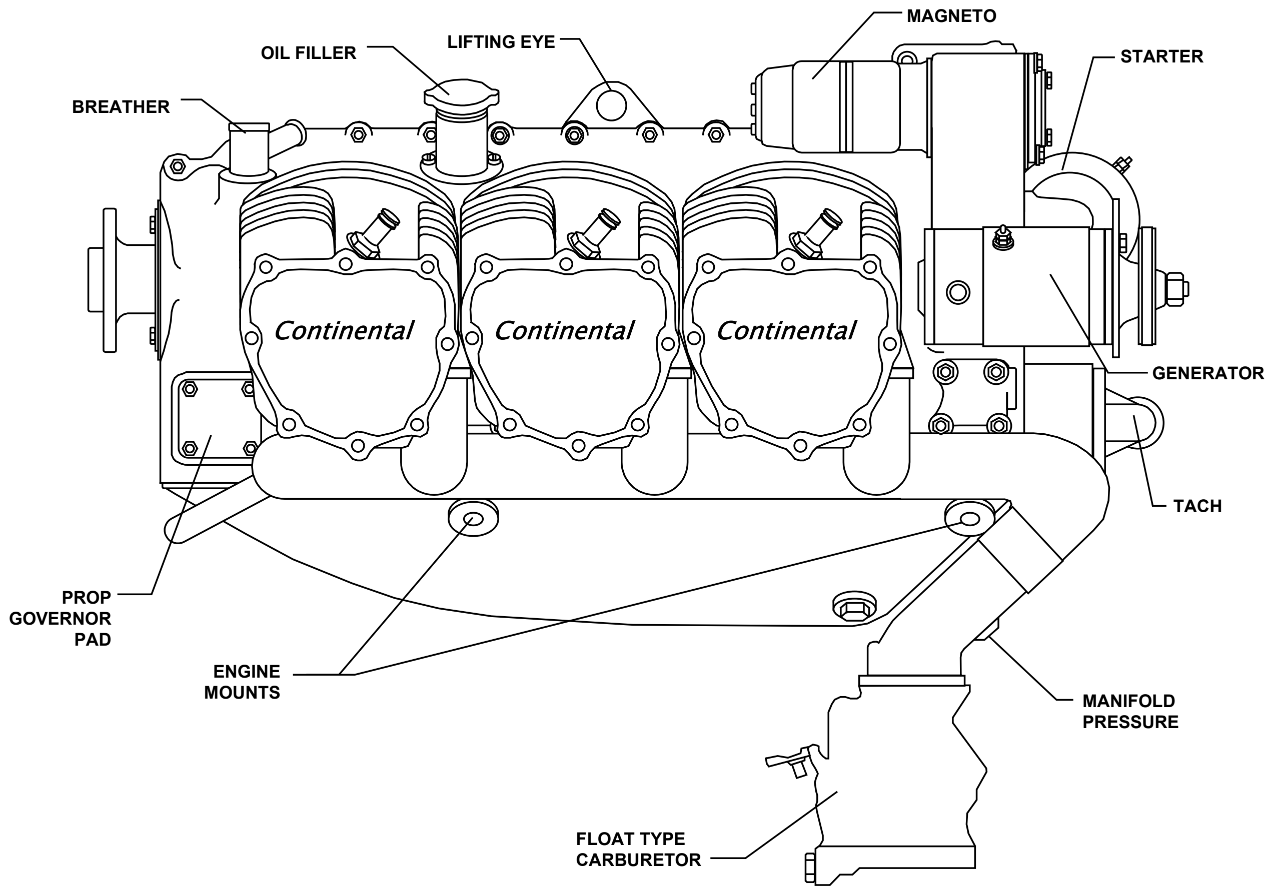
The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, oil pressure relief valve, oil cooler, removable pressure oil screen mounted on the rear of the crankcase and pressure instrumentation.

The oil sump capacity is 12 US Quarts. With a 30° nose up attitude there are 5.50 quarts of available oil and when at a 15° nose down attitude there is 4.00 quarts of useable oil.

The oil cooler is mounted forward of the #5 cylinder on the 1-3-5 side of the crankcase. The oil cooler incorporates a vernatherm valve to allow oil flow into the engine in the event an oil restriction occurs in the external oil cooler and during cold starting. A fitting located in the oil gallery between the #2 and #4 cylinder on the 2-4-6 side of the crankcase is provided for oil pressure gauge connection.

The IO-470-D induction system consists of an updraft runner type induction with an engine mounted throttle. Engine manifold pressure is measured at a port located on the 1-3-5 side induction tube where it mounts to the throttle.

The IO-470-D is equipped with a TCM Continuous Flow Fuel Injection system that meters fuel flow as a function of engine RPM, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port. A fuel drain is provided at the lowest part of the induction runners located at the rear of the engine and one located on the induction balance tube in the front of the engine.



O-470-U

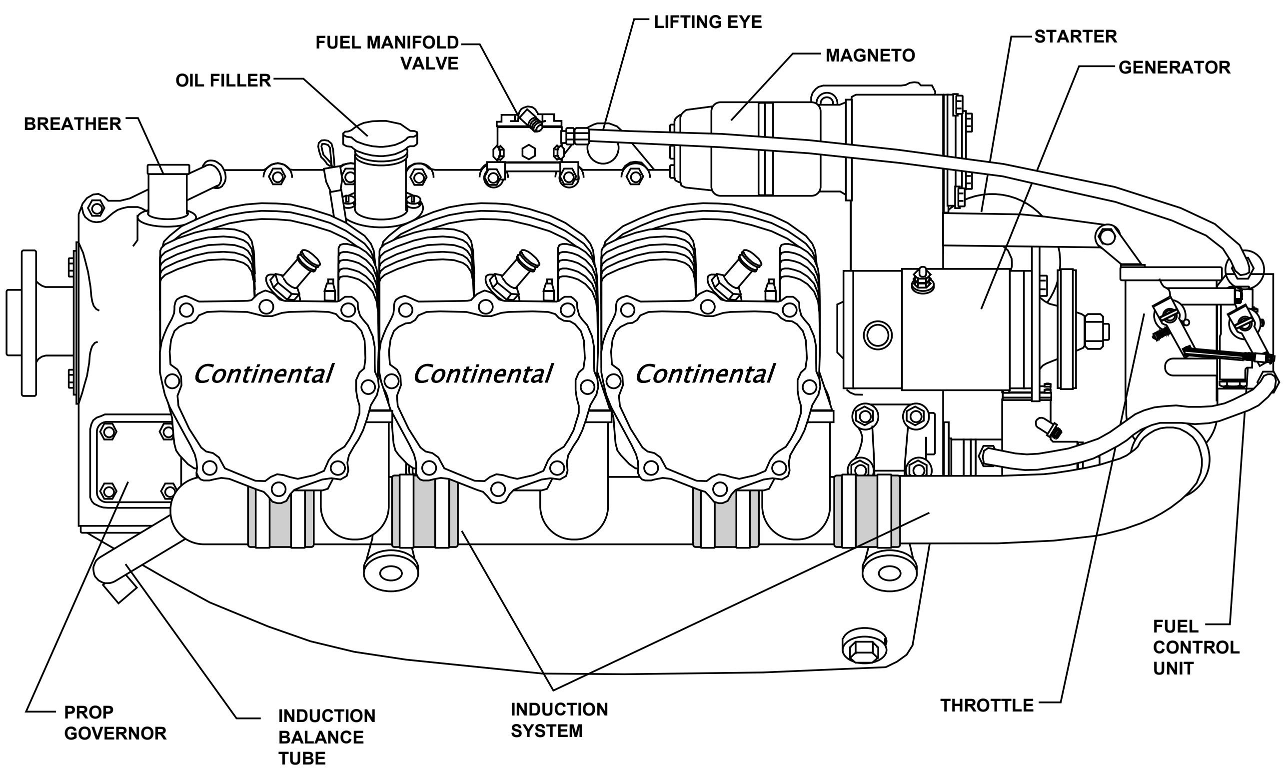


Figure 1-8. O-470-U & IO-470-L Engine Side Views

IO-520 & IO-550 ENGINES

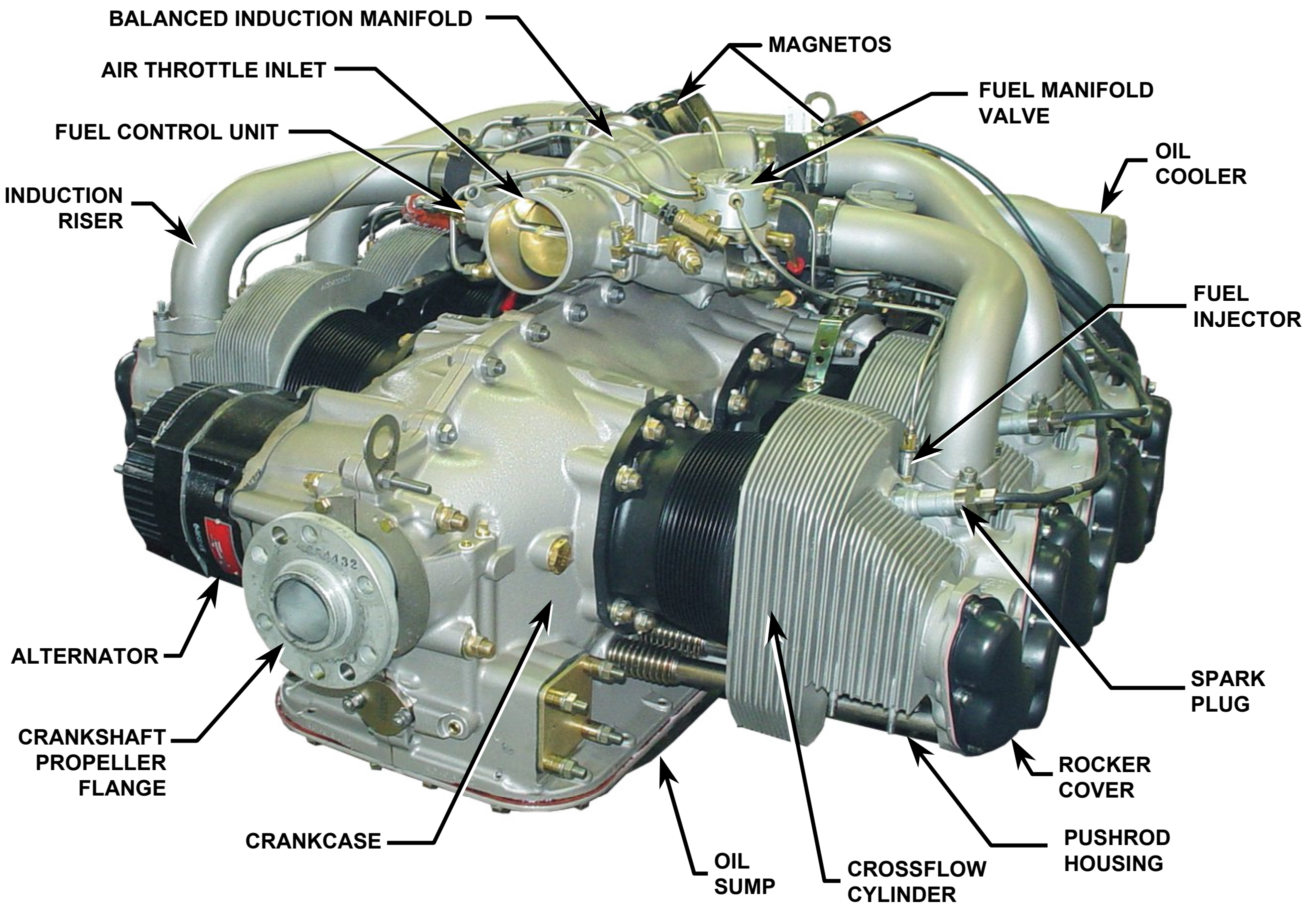


Figure 1-9. IO-550 Engine Series

Our newest in the IO-550 lineup of engine models is the IO-550-N. Typically, the IO-520 models produce horsepower in the 285 brake horsepower (bhp) range where the IO-550 engines produce horsepower up to 310 bhp. The IO-550-N is a six cylinder fuel injected air cooled engine producing 310 brake horsepower and has a crankshaft speed of 2700 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders are cross flow design having overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The IO-550-N engines have a 550 cubic inch displacement achieved by using a cylinder design with a 5.25 inch diameter bore and a 4.25 inch stroke. The engine enclosure is of the Permold series crankcase design. The dry weight of the engine is 412.0 lbs. without accessories. The average weight of the engine with installed accessories is approximately 467 lbs.

The engine is provided with four dyna-focal engine mounts. A crankcase breather port on the oil filler neck is located on the 2-4-6 side of the crankcase between the #2 and #4 cylinder. Intercylinder baffles are supplied to direct airflow across the underside of the cylinder as well as the top side air to maintain uniform cooling. A threaded port is located at the bottom side of the cylinder head for use with a bayonet thermocouple.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F.

The oil cooler is mounted on the rear of the 2-4-6 side of the engine and incorporates a vernatherm valve to provide oil by-pass to the engine in the event of an oil restriction, and provides bypass during cold starting. A fitting is provided at the oil cooler on the rear of the 2-4-6 side of the crankcase for oil pressure measurement.

The oil sump capacity is 8 US Quarts. When the engine is at a 16° nose up attitude, only 5.0 quarts are available or when at a 10° nose down attitude, only 4.5 quarts are available for use.

The IO-550-N induction system consists of a balanced overhead intake manifold with the air throttle mounted above the engine. Engine manifold pressure is measured by a port located in the intake air manifold.

The IO-550-N is equipped with a TCM Continuous Flow Fuel injection system that meters fuel flow as a function of engine speed, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port.

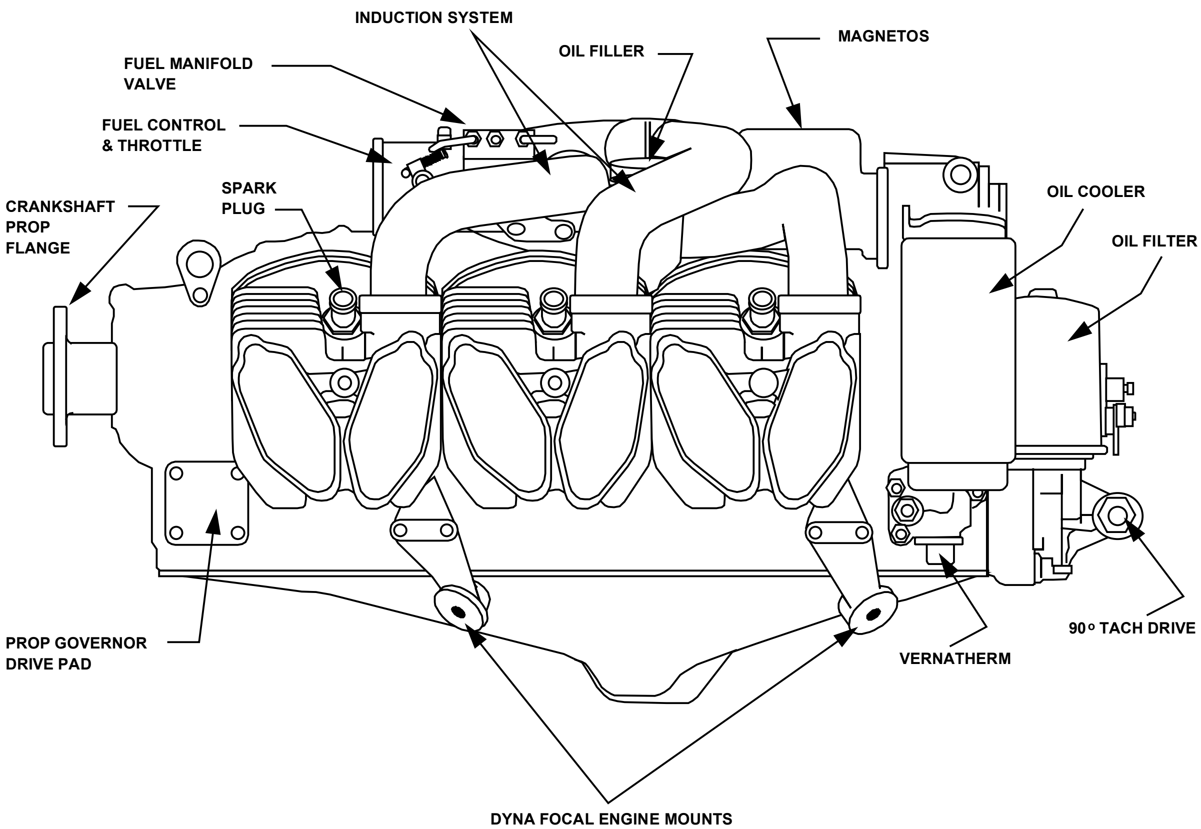


Figure 1-10. IO-550-N Engine Side View

TURBOCHARGED 360 SERIES ENGINES

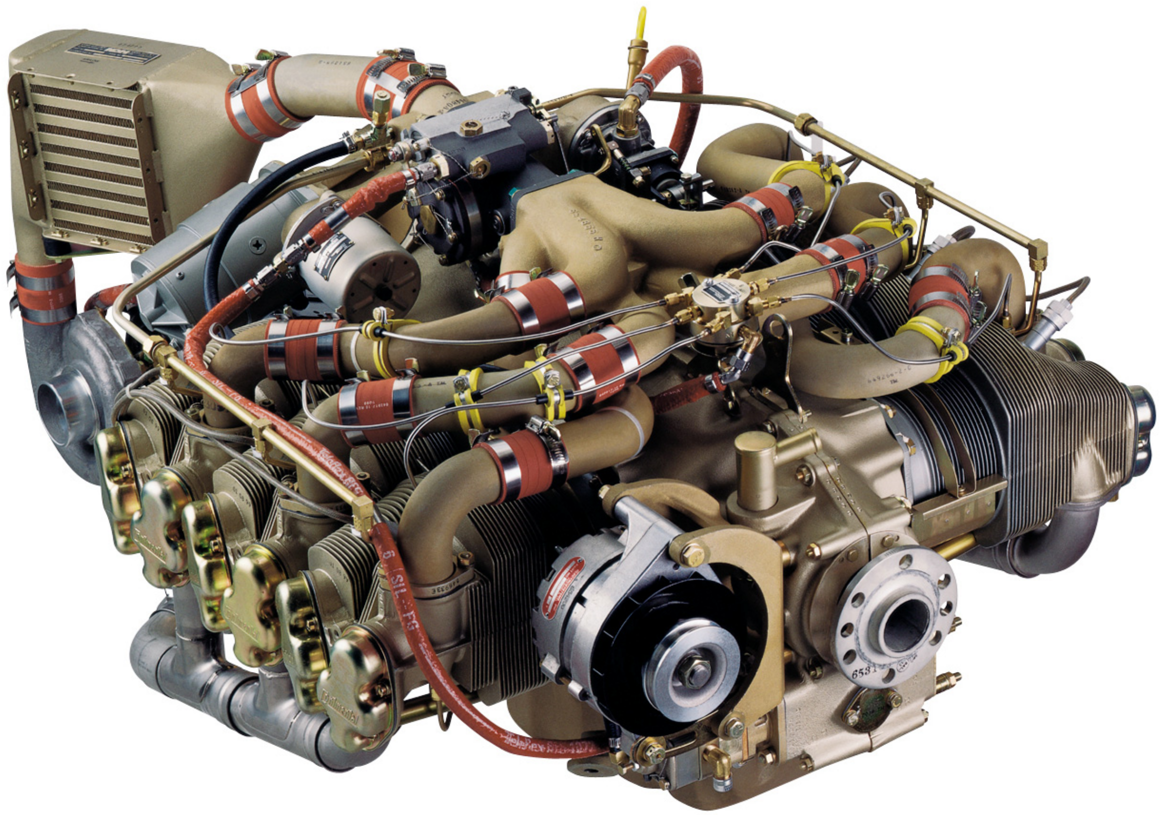


Figure 1-11. TSIO-360-RB Engine

The L/TSIO-360-RB engine is an air cooled turbocharged fuel injected engine producing 220 brake horsepower at a maximum crankshaft speed of 2600 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders are cross flow design having overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The L/TSIO-360-RB engines have a 360 cubic inch displacement achieved by using a cylinder design with a 4.438 inch diameter bore and a 3.875 inch stroke. The dry weight of the engine is 327.50 lbs. without accessories. The average weight of the engine with accessories is approximately 410 pounds.

The engine is provided with four dyna-focal mounts. A crankcase breather port is located on the 1-3-5 side of the crankcase forward of the number 5 cylinder. A threaded port is located at the bottom of the cylinder head for use with an AS234 or equivalent bayonet thermocouple using an AS236 or equivalent adapter.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F. The oil cooler adapter incorporates a vernatherm valve to allow oil flow into the engine in the event of an oil restriction occurring in the oil cooler and during cold starting.

A fitting is provided between the # 2 & #4 cylinder on the 2-4-6 side crankcase for oil pressure measurement and for supplying pressure oil to the turbocharger housing.

The oil sump capacity is 8 US Quarts. When the engine is at a 26° nose up attitude or 18° nose down attitude, only 5.0 quarts are available for use.

The L/TSIO-360-RB induction system consists of a tuned overhead runner with the air throttle mounted above the engine. Engine manifold pressure is controlled by the throttle plate and measured at a port located in the intake air manifold.

Maximum air temperature at the air throttle inlet shall not exceed 280°F at maximum rated continuous horsepower or at maximum rated cruise.

The engine is equipped with a TCM Continuous Flow fuel injection system. This system meters fuel flow in proportion to engine RPM, turbocharger compressor discharge pressure, and throttle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port. Cylinder fuel drains are located on the bottom of each cylinder and are gang connected to a common fitting on each side of the engine.

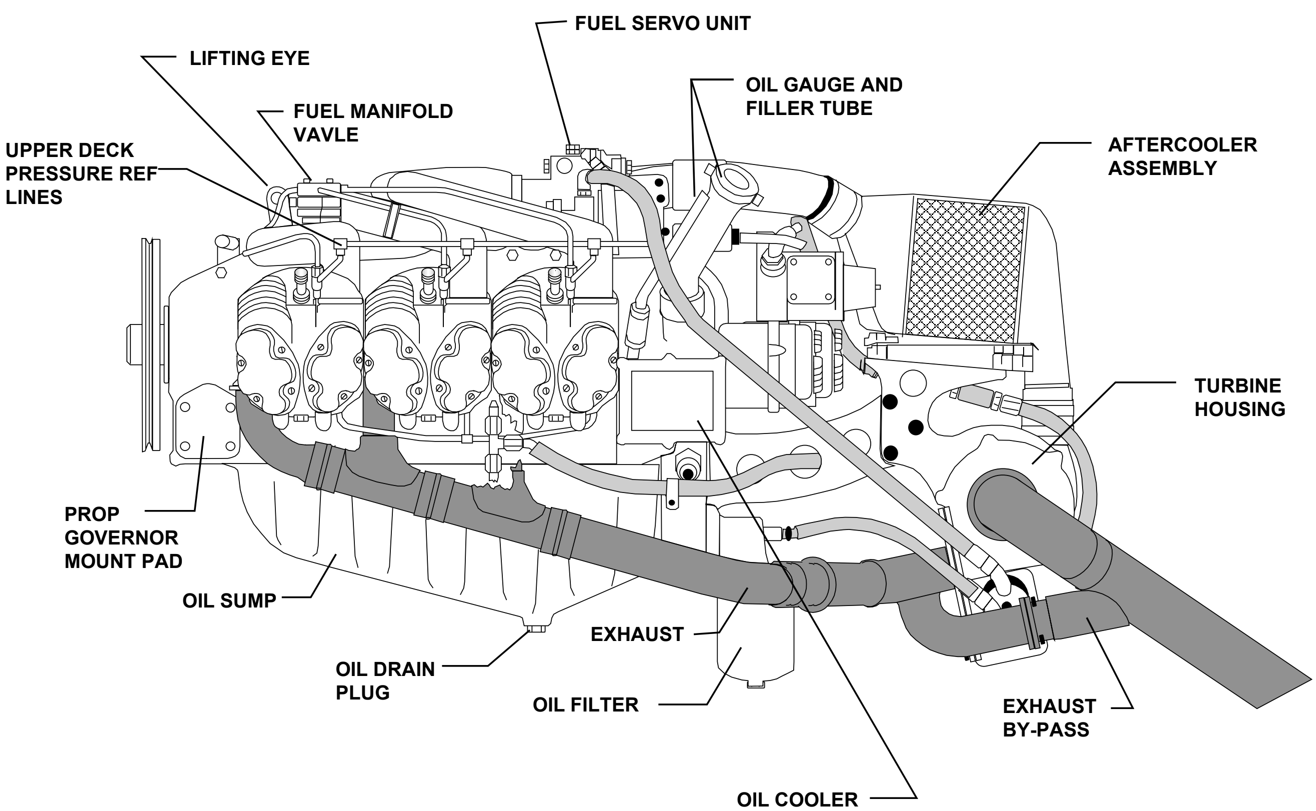


Figure 1-12. TSIO-360-RB Engine Side View

GTSIO-520 SERIES ENGINES

Figure 1-13. GTSIO Series Engine

The GTSIO-520-N is a geared six cylinder fuel injected, turbocharged engine producing 375 brake horsepower and has a crankshaft speed of 3350 RPM and a propeller speed of 2233 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders are crossflow design and incorporate overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The GTSIO-520-N engines have a 520 cubic inch displacement achieved by using a cylinder design with a 5.25 inch diameter bore and a 4.00 inch stroke. The dry weight of the engine is 486 lbs. without accessories. The average weight of the engine with installed accessories is approximately 598 lbs.

The engine is provided with four engine mounts designed for dyna-focal mounting. A crankcase breather port is located on the 1-3-5 side of the crankcase forward of the #5 cylinder. Each cylinder head is configured with a . threaded port, located near the bottom side of the cylinder head for use with a bayonet thermocouple. Cylinder fuel drains are also located on the bottom of the cylinder, tapped into the intake chamber.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F.

The oil cooler is mounted on the left crankcase half behind the #2 cylinder. A vernatherm valve allows oil flow into the engine if an oil restriction occurs in the external oil cooler and during cold starting. A fitting is provided on the 2-4-6 crankcase side, tapped off the oil gallery between the # 2 and # 4 cylinder for oil pressure gauge connection and to supply pressure oil to the turbocharger.

The oil sump capacity is 13 US Quarts. When the engine is at a 16° nose up or nose down attitude, 9 quarts are available for use.

The GTSIO-520-N induction system incorporates a balanced port design downdraft induction. Engine manifold pressure is controlled by the throttle plate and is measured by a port located at the propeller end of the induction manifold.

Maximum air temperature at the intake manifold shall not exceed 300° F at maximum rated continuous horsepower or 200°F at maximum allowable cruise power.

The exhaust system is furnished by the aircraft manufacturer. The turbocharger turbine is driven by exhaust gases and drives the compressor by means of a common shaft. The turbocharger compressor supplies compressed air to the induction system to maintain sea level performance at higher altitudes where lower air density would cause a decrease in engine performance.

The GTSIO-520-N is equipped with a TCM Continuous Flow Fuel injection system that meters fuel flow as a function of engine speed, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port.

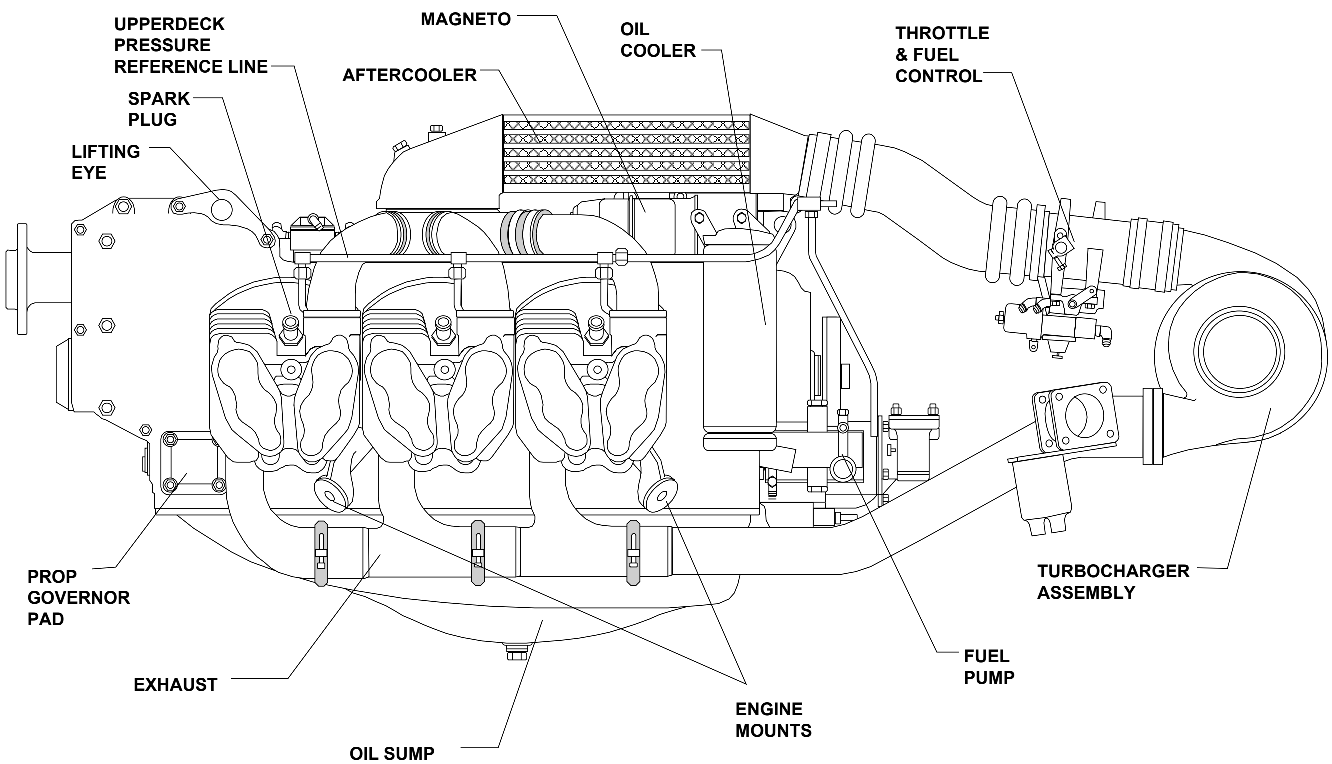


Figure 1-14. GTSIO-520-N Engine Side View

TSIO-550 SERIES ENGINES

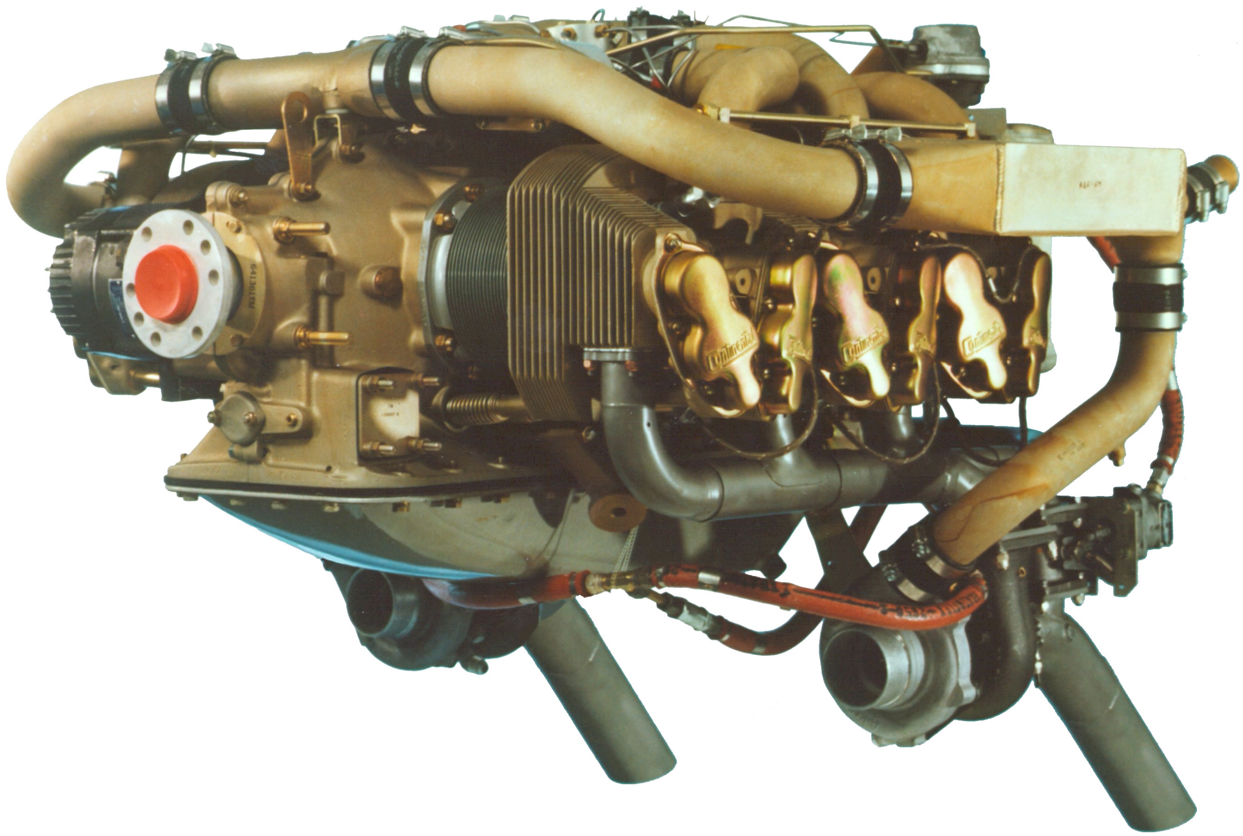


Figure 1-15. TSIO-550-E Model Engine

The TSIO-550-E is a six cylinder fuel injected, turbocharged engine producing 350 brake horsepower and has a crankshaft speed of 2700 RPM. The engine has horizontally opposed air cooled cylinders. The engine cylinders are cross flow design having overhead inclined valves. The cylinders have downdraft intake inlets mounted on the top of the cylinder head and downdraft exhaust outlets located on the bottom of the cylinder.

The TSIO-550-E engines have a 550 cubic inch displacement achieved by using a cylinder design with a 5.25 inch diameter bore and a 4.25 inch stroke. The engine enclosure is of the Permold series crankcase design. The dry weight of the engine is 442.10 lbs. without accessories. The average weight of the engine with installed accessories is approximately 570 lbs.

The engine is provided with four engine mounts designed for a focalized bed mount. A crankcase breather port is located on the oil filler neck on the 2-4-6 side of the crankcase between #2 and #4 cylinder. A threaded port is located on the bottom of the cylinder head for use with a bayonet thermocouple.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F.

The oil cooler is mounted on the left crankcase half behind the #2 cylinder. A vernatherm valve allows oil flow into the engine if an oil restriction occurs in the external oil cooler and during cold starting. A fitting is provided on the rear of the oil cooler for oil pressure gauge connection and for supplying pressure oil to the turbocharger housing.

The oil sump capacity is 12 US Quarts. When the engine is at a 20° nose up attitude 7.5 quarts are available and when at a 14.5° nose down attitude, 6.5 quarts are available for use.

The TSIO-550-E incorporates a downdraft balanced port induction system with an engine mounted throttle body. Engine manifold pressure is controlled by the throttle plate and is measured at the .125 - 27 NPTF port located on the induction manifold near the throttle.

The TSIO-550-E incorporates dual turbochargers and dual aftercoolers. The exhaust bypass for the turbine sections are connected to a single exhaust wastegate that is controlled by a sloped controller.

The TSIO-550-E is equipped with a TCM Continuous Flow Fuel injection system that meters fuel flow as a function of engine speed, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port. Fuel drains are provided at the bottom of each cylinder.

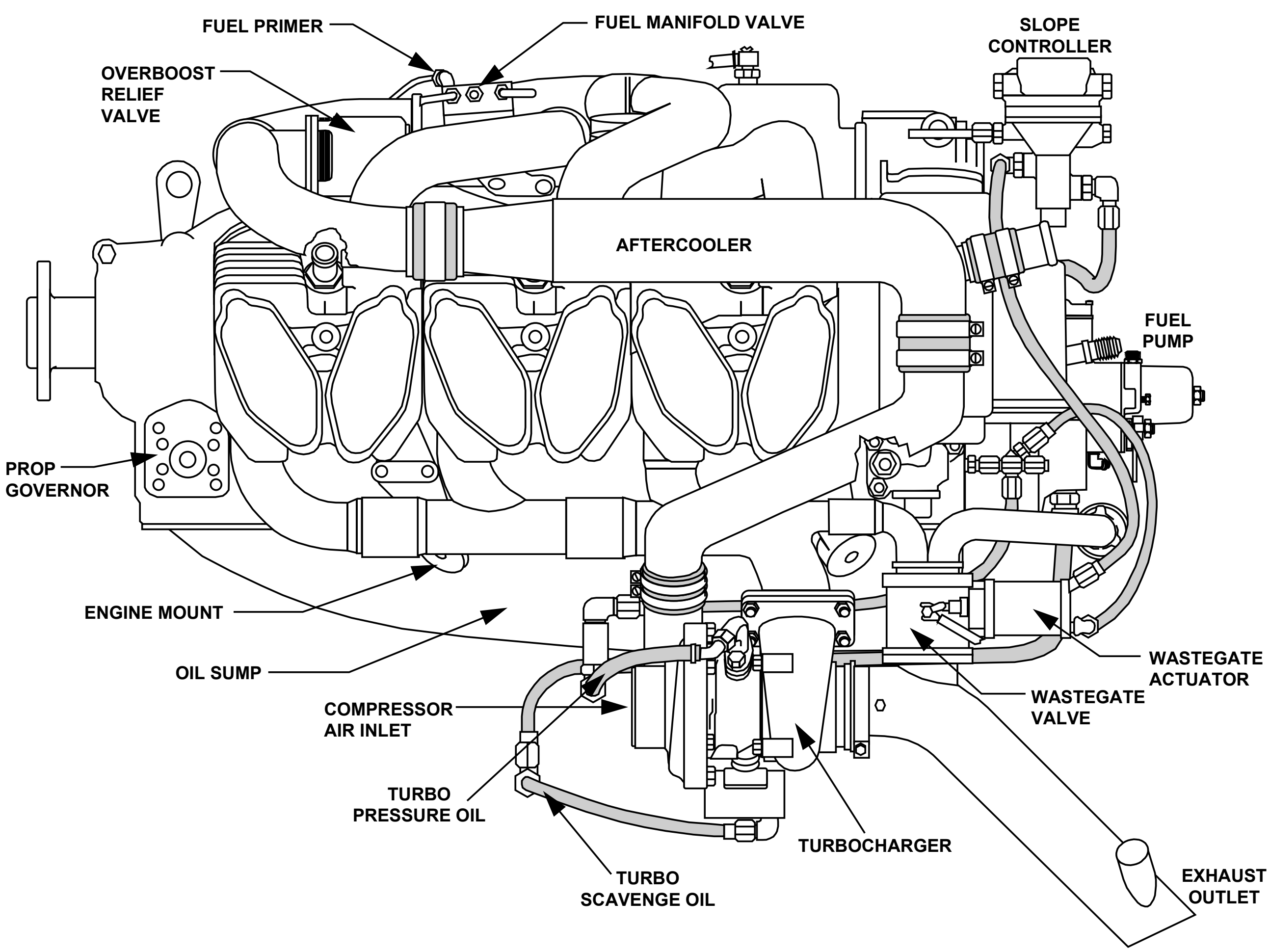


Figure 1-16. TSIO-550-E Engine Side View

TSIOL-550 SERIES ENGINES

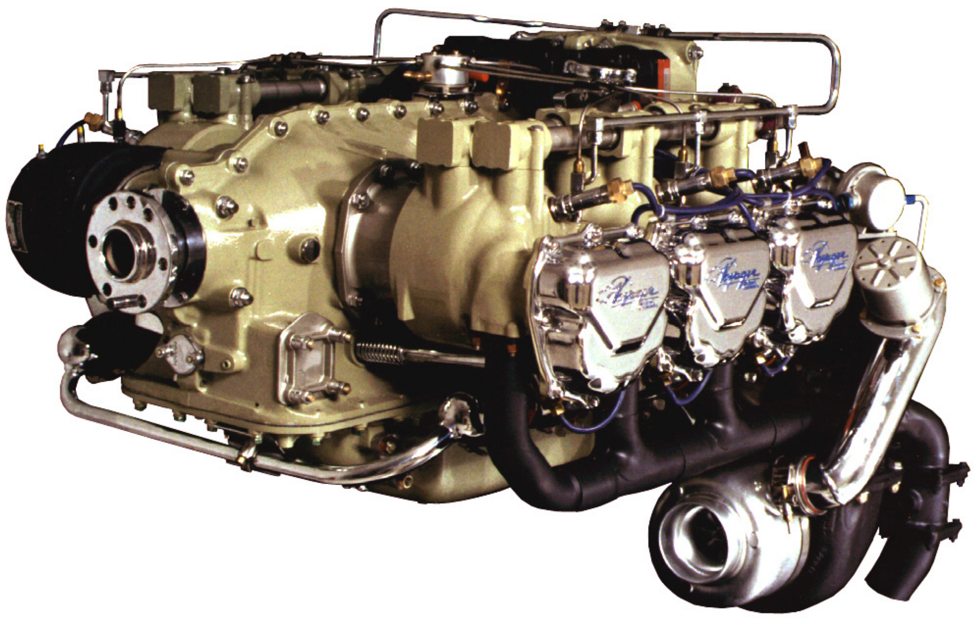


Figure 1-17. TSIOL-550-A Engine (Liquid Cooled)

The TSIOL-550-C is a liquid cooled, six cylinder, fuel injected, turbocharged engine producing 350 brake horsepower and has a crankshaft speed of 2600 RPM. The engine has horizontally opposed liquid cooled cylinders. The engine cylinders have overhead inclined valves. The cylinders have updraft intake inlets and downdraft exhaust outlets mounted on the bottom of the cylinder head.

The TSIOL-550-C engines have a 550 cubic inch displacement achieved by using a cylinder design with a 5.25 inch diameter bore and a 4.25 inch stroke. The engine enclosure is of the Permold series crankcase design. The dry weight of the engine is 415.40 lbs. without accessories. The average weight of the engine with installed accessories is approximately 552 lbs.

The engine's liquid coolant system includes a gear driven pump which supplies coolant to the cylinder heads by means of a runner type manifold mounted on top of each of the cylinders. Each cylinder heads includes a coolant jacket. Coolant flows through the cylinder heads and returns to an engine mounted reservoir through a parallel runner type manifold. Coolant is then directed to a remote mounted radiator before being returned to the coolant pump.

The engine is provided with four engine mounts designed for a focalized bed mount. A crankcase breather port is located on the oil filler neck on the 2-4-6 side of the crankcase between #2 and #4 cylinder.

The engine lubrication system is a wet sump, high pressure oil system. The engine lubrication system includes the internal engine driven pressure oil pump, engine mounted oil cooler, oil sump, full flow oil filter, oil pressure relief valve, and pressure instrumentation.

The oil filter should be a 20 micron filter incorporating a by-pass valve set to open at 12-16 psi at a flow of 70 lbs./minute using SAE 50 oil at maximum oil temperature of 240°F.

A remote mounted oil cooler is use on this engine design. A vernatherm valve allows oil flow into the engine if an oil restriction occurs in the external oil cooler and during cold starting. A fitting is provided on the oil cooler adapter for oil pressure gauge connection and for supplying pressure oil to the turbocharger housing.

The oil sump capacity is 12 US Quarts. When the engine is at a 20° nose up attitude 7.5 quarts are available and when at a 14.5° nose down attitude, 6.5 quarts are available for use.

The TSIOL-550-C incorporates an updraft induction runner system with an aircraft mounted turbo-compressor and throttle body. Engine manifold pressure is controlled by the throttle plate and is measured by a port located on the aftercooler outlet.

The TSIOL-550-C is equipped with a TCM Continuous Flow Fuel injection system that meters fuel flow as a function of engine speed, throttle angle and mixture control angle. The metered fuel is fed to continuous flow air bled injector nozzles located at each cylinder intake port. Fuel drains are provided at the bottom of each cylinder.

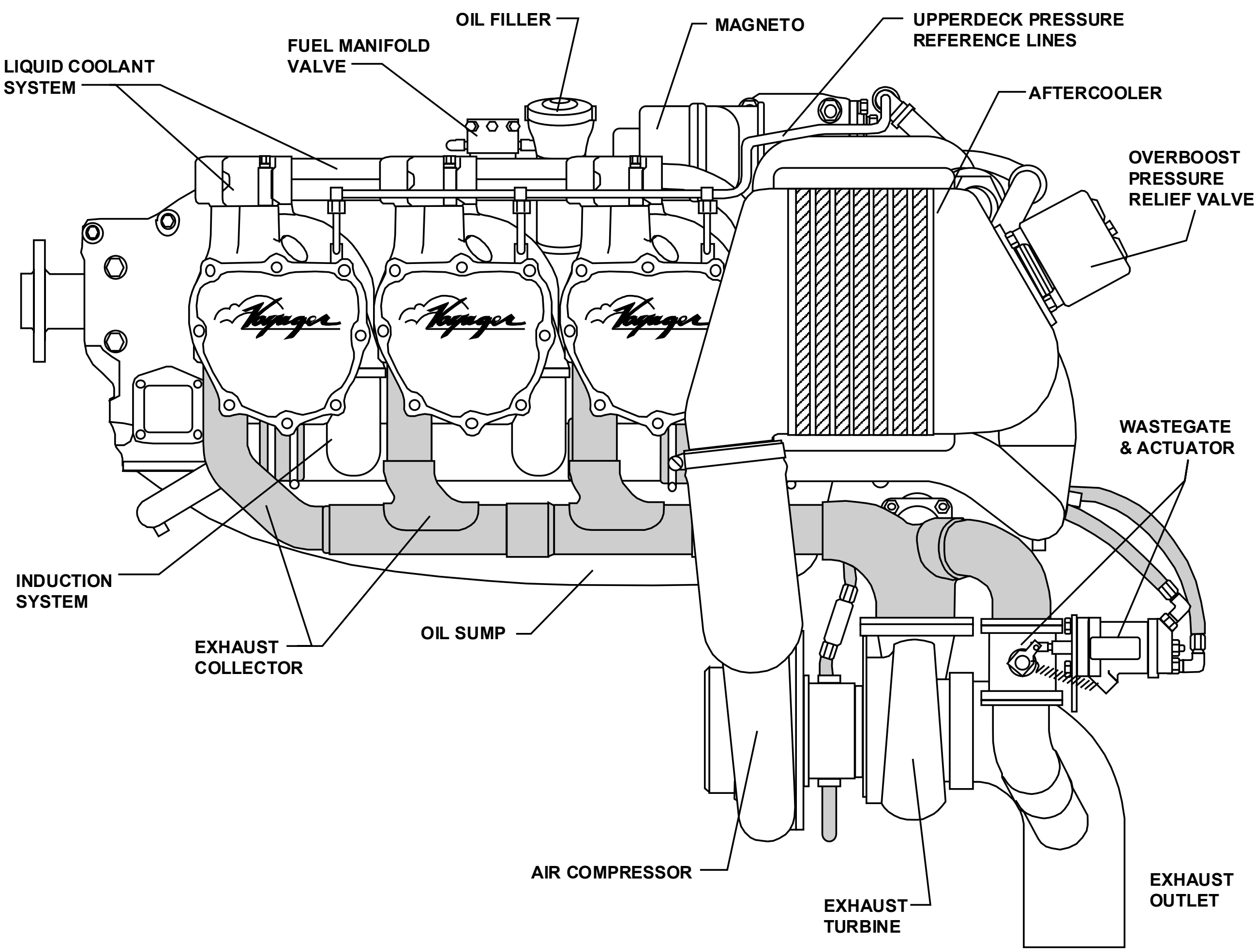


Figure 1-18. TSIOL-550-C Side View

TCMLINK GLOBAL SERVICES NETWORK

Information Services is the aircraft mechanics direct link to TCM. This service provides engine specific parts listings, TCM engine and ignition service bulletins, FAA Airworthiness directives, access to technical briefs, scheduled maintenance checklists, a distributor locator, a troubleshooting guide and engine serial number data base search, part supersede history search and Maintenance & Overhaul manuals. Our web site gives you 24-hour, year round access from anywhere you can plug into a telephone. You have received a complimentary subscription to this web based service and will also receive a quarterly mailing of the off-line CD ROM. The TCMLINK Information Services User Guide has been sent as part of this mailing and you should study the guide to learn how to make the most of using this service. Sections of this text will refer you to the web site to locate service information.

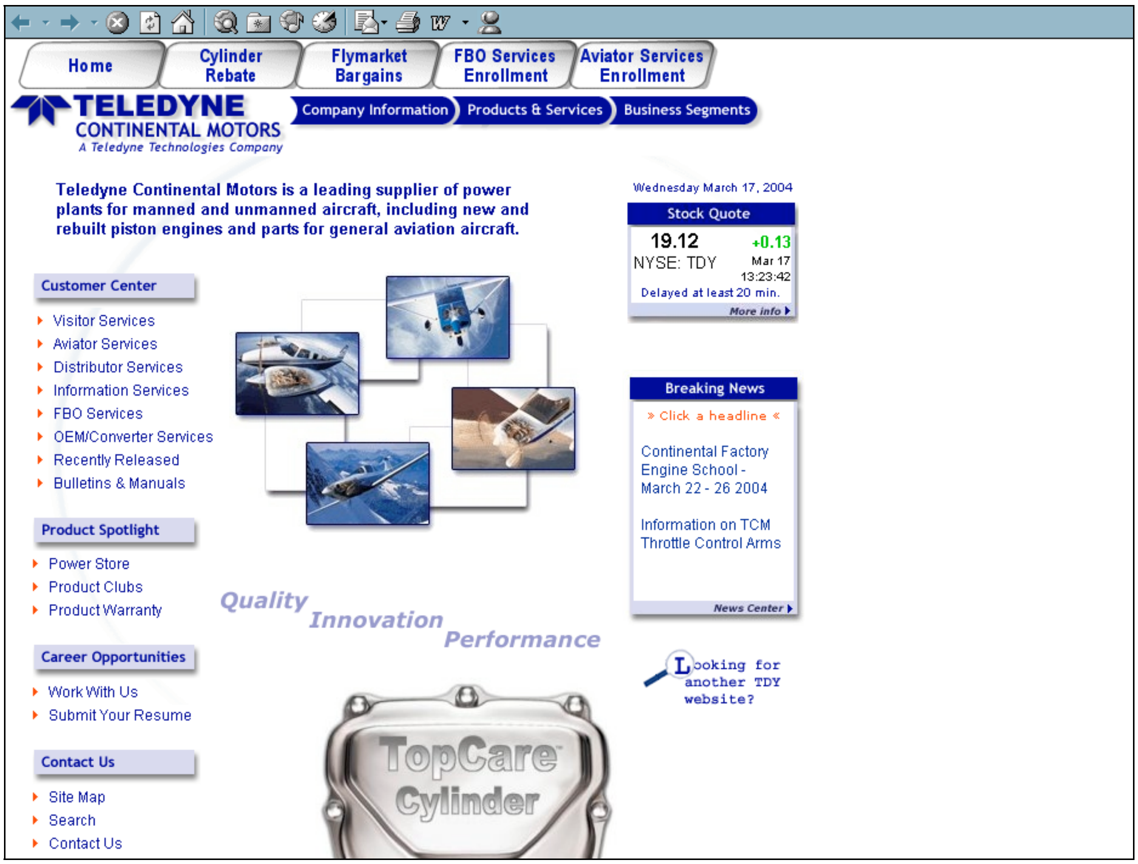


Figure 1-19. TCMLINK Front Page

In the next few paragraphs, we will discuss the features and benefits of the TCMLINK Information Services program. There are many subscriber services programs available from this web site. We will first provide an introduction to all of the main customer service subscriber services that are available from www.tcmlink.com.

Come to TCMLINK® and let us help you serve your Continental Powered customer's needs.

TCMLINK
GLOBAL SERVICES NETWORK

TCMLINK AVIATOR SERVICES

Figure 1-20. The Aviator Services Screen

There are currently thousands of Continental Powered Aircraft owner's signed up to take advantage of this free service. The Aviator Services program has been designed with the owner in mind. This program will provide the same feature benefits of the Information Services program with the exception of the Electronic Illustrated Parts catalog, which for the Aviator member is tailored specifically to the engine or engines that they own. This program is free of charge to the owner of a Continental Powered Aircraft for as long as they own the engine. The available menu items can be seen on the left side of the screen shown in Figure 1-19.

Among the many menu features, this program tailors the customer service requirements by engine serial number reported by the owner at the time they register for this free service. The Service Bulletins and Airworthiness Directives that need to be complied with are readily available for study. This service even permits the owner to perform on-line Oil Analysis and has a feature that permits them to graphically analyze the particle contaminants in their engine oil for trend analysis.

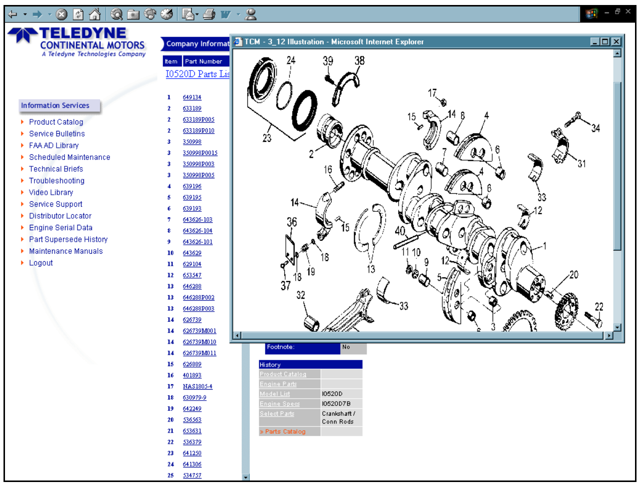
TCMLINK FBO SERVICES

Figure 1-21. FBO Services Screen.

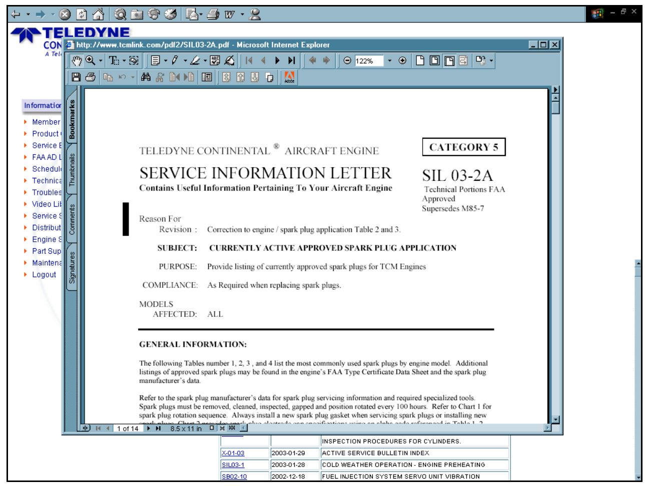
The TCMLINK FBO Services program provides fixed base operators with the ability to access complete Continental Service instructions regarding our complete product line up. The FBO using this program can also directly "LINK" to the Aviator Service member whenever they come in for maintenance. If the servicing FBO finds a need to order a part for the Aviator customer, they simply access the parts catalog via the Aviator's membership number and they then have the assurance that they are looking up and ordering the correct part for the customer. A glance at the menu items will show the wealth of service information available to the FBO Services member.

TCMLINK INFORMATION SERVICES

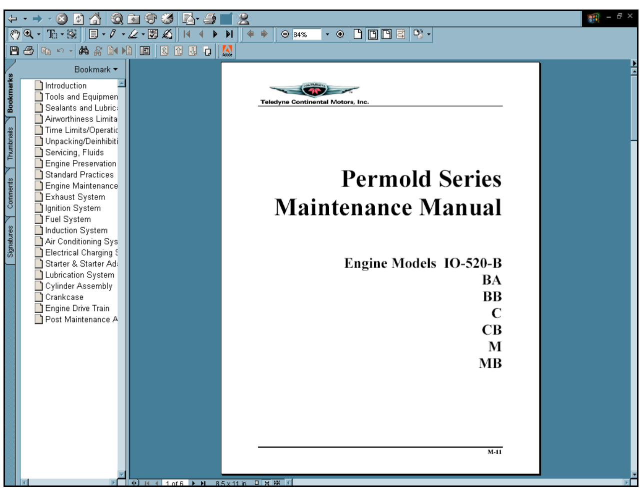
They say that a picture is worth a thousand words, well here's a few thousand for you. There are a few screen captures below that shows the information availability through this powerful web based service. The same data is also available off-line by using the CD ROM, however it is important to note that the CD ROM data is only as up to date as every 90 days whereas the web based system is "real time." These screen captures are designed to introduce you the many features available to the program you will be using throughout this course of study. The accompanying user guide will show you how to make the most of these features.



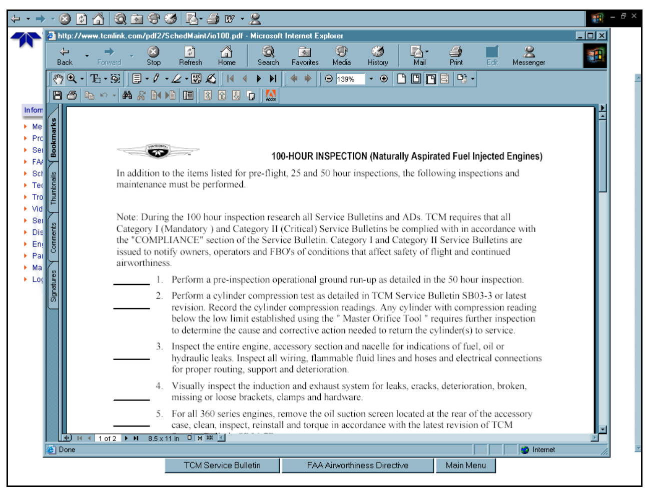
Electronic Illustrated Parts Catalog



Service Bulletins & FAA ADs



Maintenance & Overhaul Manuals



Scheduled Maintenance Checklists

Shown above are screen captures that illustrate just a few of the features of the TCMLINK Information Services program. Among others are Technical Briefs, Troubleshooting, Distributor Locator, Engine Serial Data and Parts Supersede History. Please take the time to sign on and follow the instructions of the User Guide to learn more about how this program will assist you in servicing the needs of your Continental Powered Customer.

SUMMARY

In this chapter we have introduced our main line-up of current production engines that we manufacture. It is important to remember that Continental Motors currently manufactures over 100 different engines and specs them out over 1,100 different ways. What you have seen here are just a few of the more popular engines in use around the world. There are many different models in each of the families of engines.

On the following pages you will be challenged to discover more about the different designs of the engines produced by Teledyne Continental Motors, Inc. using our web based service information program. You will see just how much information is available to you by trying some of the exercises. So log on to the Information Services program with Member ID# and Password that was assigned to you when you received this instructional series package.

KEY TERMS TO REMEMBER

Terminology	Description
A.B.C.	After Bottom Center
ADMP	Absolute Dry Manifold Pressure
Approx.	Approximately
A.T.C.	After Top Center
Bar.	Barometric
B.B.C.	Before Bottom Center
B.H.P.	Brake Horsepower
BSFC	Brake Specific Fuel Consumption
BSOC	Brake Specific Oil Consumption
B.T.C.	Before Top Center
C.A.R.	Civil Air Regulations
C.G.	Center of Gravity
c.f.m.	Cubic Feet Per Minute
C.H.T.	Cylinder Head Temperature
CW	Clockwise Rotation
CCW	Counter-clockwise Rotation
°C	Degrees Celsius
°F	Degrees Fahrenheit
°	Degrees of Angle
Dia.	Diameter
EGT	Exhaust Gas Temperature
FAA	Federal Aviation Administration
Fig.	Figure (Illustration)
Front	Propeller End of Engine
Ft.	Foot or Feet
F.T.	Full Throttle
FT-LBS	Foot Pounds Torque
G.P.M.	Gallons Per Minute
gms	Grams
Hex	Hexagon
H_2O	Water
Hg.	Mercury
hr.	Hour
I.D.	Inside Diameter or Inner Diameter
In lbs	Inch Pounds Torque

Terminology	Description
in. (")	Inches
Left Side	Side on which No's 2, 4 and 6 cylinders are located.
Lbs.	Pounds
Lockwire	Soft steel wire used to safety connections, etc.
Man.	Manifold or Manometer
MAP	Manifold Pressure
Max.	Maximum
Min.	Minimum
N.P.T.	National Pipe Thread (Tapered)
N.R.P.	Normal Rated Power
N.C.	National Course (Thread)
N.F.	National Fine (Thread)
O.A.T.	Outside Air Temperature
O.D.	Outside Diameter
oz.	Ounce
PPH	Pounds Per Hour
Press.	Pressure
p.s.i.	Pounds Per Square Inch
PSIA	Pounds Per Square Inch Absolute
PSID	Pounds Per Square Inch Differential
PSIG	Pounds Per Square Inch Gauge
Rear	Accessory End of Engine
Right Side	Side on which No's 1, 3 and 5 cylinders are located
R.P.M.	Revolutions Per Minute
Std.	Standard
TBO	Time Between Overhaul
T.C.D.P.	Turbocharger Deck Pressure
T.D.C.	Top Dead Center
Temp.	Temperature
Torque	Force x lever arm (125 ft.-lbs. torque = 125 lbs. Force applied one ft. from bolt center or 62-1/2 lbs.2 ft. from center)
100LL	100 Octane Low Lead Fuel
1-3-5	Cylinder numbering right side of engine (rear to front)
2-4-6	Cylinder numbering left side of engine (rear to front)
30'	Thirty minutes of angle (60' equal one degree)

GENERAL ENGINE THEORY EXERCISES

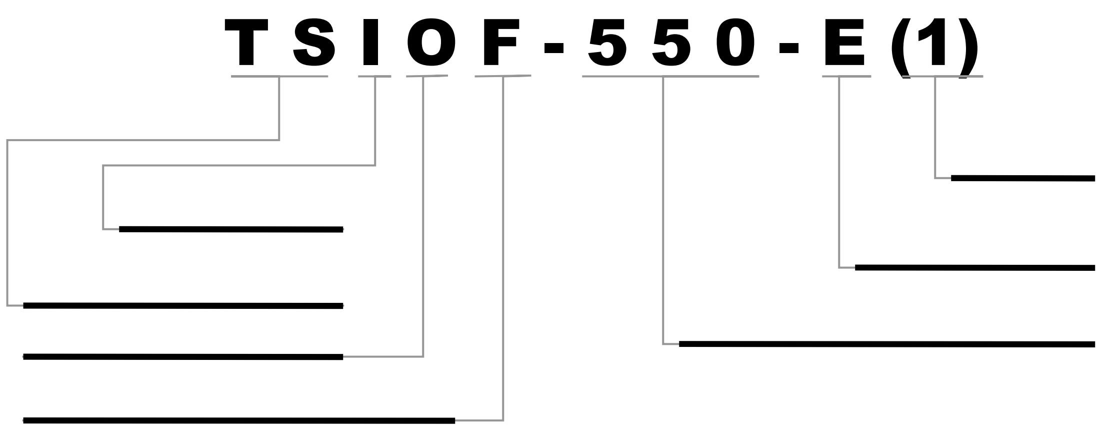
1. Using the table below, fill in the horsepower ratings for the engines listed.

Model	O200A	IO240B	IO360ES	IO550N	GTSIO520N	TSIO550E
BHP Rating						

2. List the cylinder bore and stroke dimensions for the IO360 series engines. ______________________

3. When servicing the GTSIO-520-N engine oil, how many quarts are added to fill the sump to maximum capacity?______________________

4. Fill in the details pertaining to the engine designator listed in the figure below.



5. Follow the instructions to access required information for the engines listed below.

   a. Access the www.tcmlink.com web page and click on the **Visitor Services** menu item.

   b. Click on the **Engine Spec Sheets** menu item. The screen will refresh with a **Select Model:** drop down selection box.

   c. Chose the engine models listed below to fill out the details. You can check your work with the X30659 Engine Specifications Ready Reference Guide supplied with this course.

   IO-240-B Oil Sump Capacity ______________

   IO-360-ES Ignition Timing _______________

   IO-470-L Brake Horsepower _______ BHP @ ________ RPM

   IO-520-BB Brake Horsepower _______ BHP @ ________ RPM

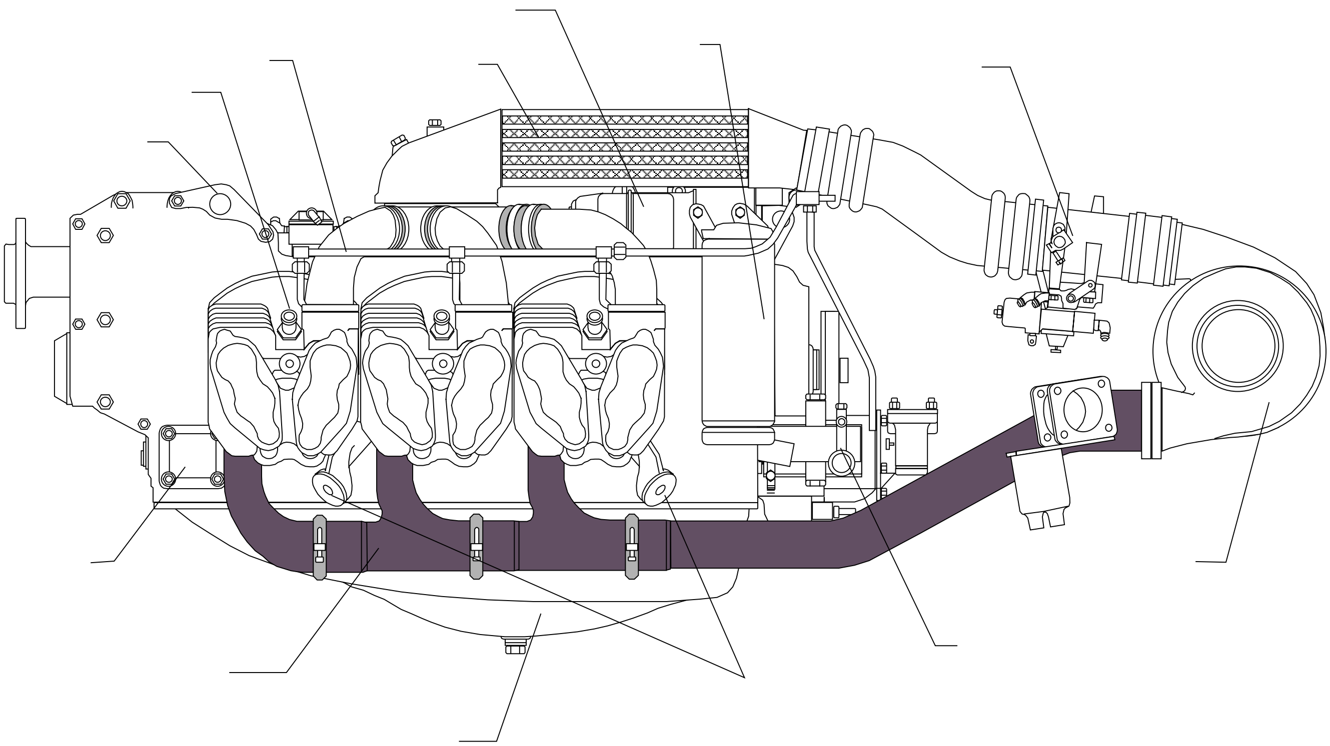
   IO-550-N Brake Horsepower _______ BHP @ ________ RPM

   IO-550-B Oil Sump Capacity ______________

   TSIO-360-SB Manifold Pressure Limit ______ in. hg.

   TSIO-550-E Compression Ratio ____________

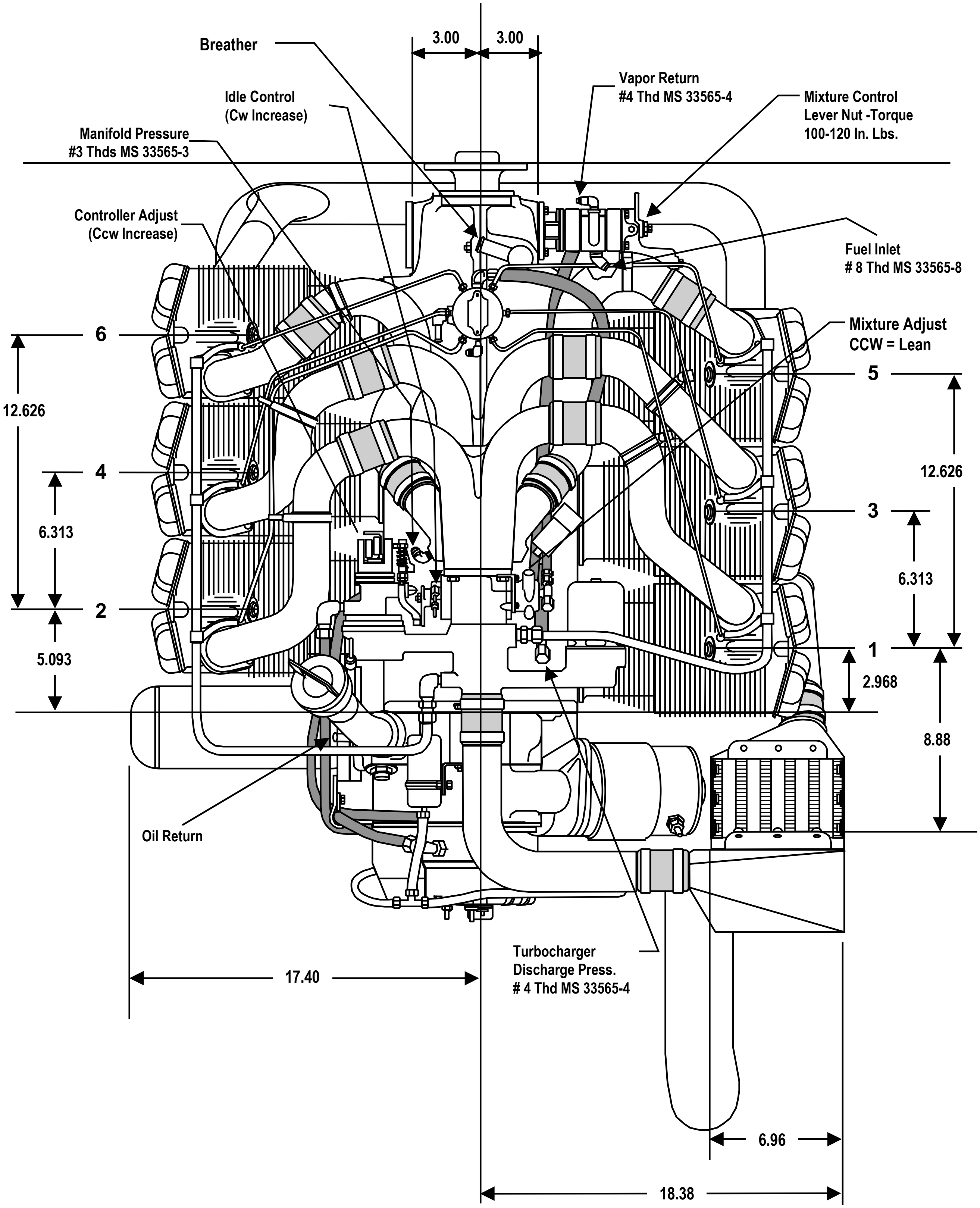
6. Refer to the engine callout tab section in this book to assist you in filling in the blanks on the figure below.



GTSIO-520-N

7. Sign on to your Information Services account provided with your purchase and access the Service Bulletins menu. Choose the **Search by Key Word in Subject** and enter the word *"Lubricants"* in the text entry field. Identify the Service Bulletin number and the subject matter title of the bulletin below.

____



Sample Installation Diagram - TSIO-360-SB Engine

Chapter Two

Crankcases

CHAPTER 2 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Describe the functional purposes of the machined surfaces of the crankcase halves.

② Describe the fundamental purposes of the accessory sections of the crankcase

③ Describe the differences between the Sandcast & Permold designs.

④ Identify the materials required when assembling the crankcase halves.

⑤ Describe the procedures for properly torquing the crankcase halves.

⑥ Using the TCM LINK Information Services CD ROM, identify the Service Bulletins relating to crankcases.

O-200 100 BHP Four Cylinder Engine

INTRODUCTION

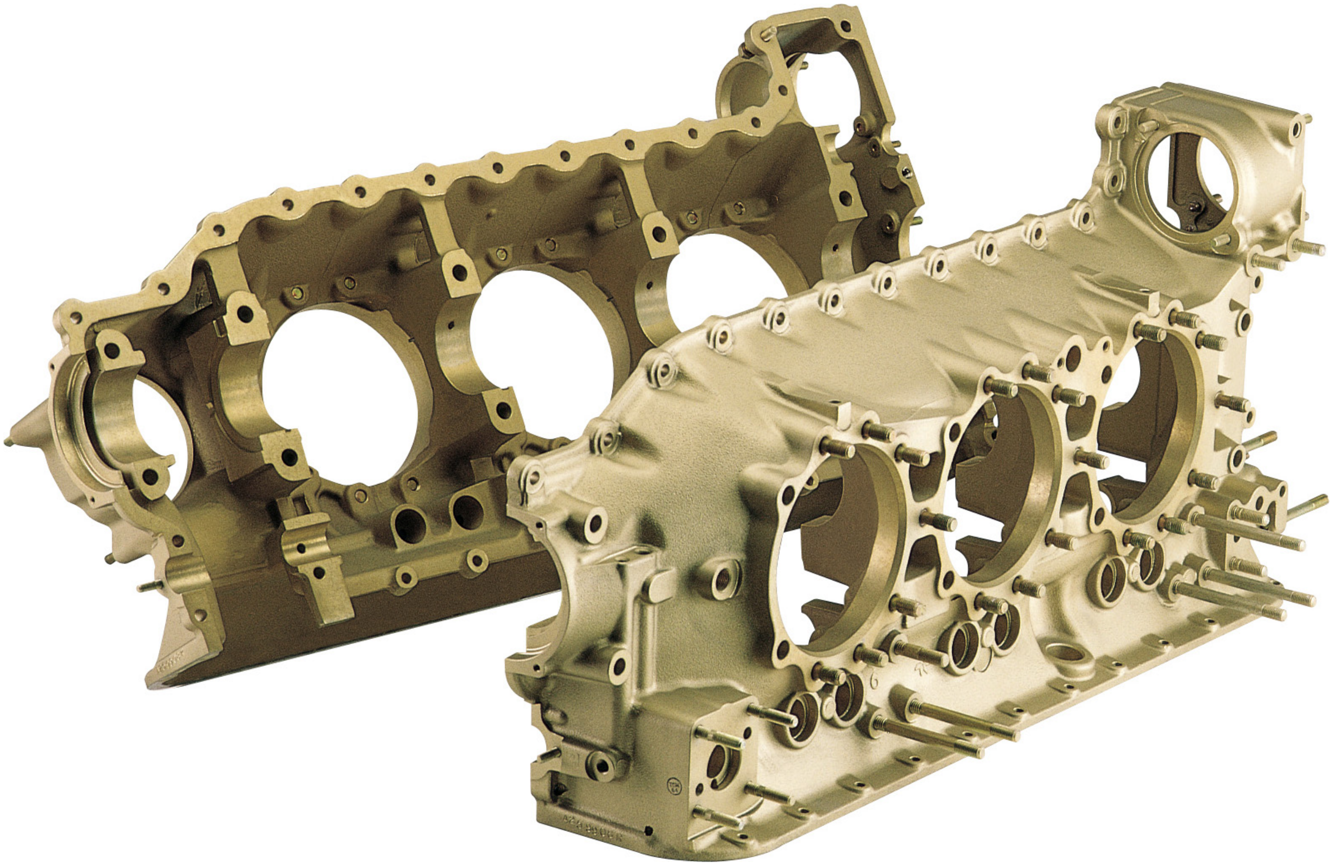


Figure 2-1. Permold Series Aerospace Quality Crankcase

CRANKCASE GENERAL DESCRIPTION

Think of the crankcase as the main housing for the engine. It is the backbone of the engine, and it's integrity is critical to the engine's longevity. The crankcase provides a tight enclosure that houses all internal drive train components and has machined oil galleries for lubrication. The crankcase is sufficiently rigid to provide support for the crankshaft, camshaft and bearings. It also provides surfaces for mounting the cylinders as well as all other external engine mounted components such as the oil and fuel pumps, induction and exhaust systems, magnetos, starter motor and starter adapter (on 6 cylinder models), alternator and oil cooler. For external component locations refer to Figure 2-3 for an external top & side view drawing of the IO-550-N model engine. Aircraft supplied accessories such as a propeller governor, vacuum pumps and standby alternators can also be mounted to the engine.

Two aluminum alloy castings are joined along the vertical center plane to form the complete crankcase. The individual castings (with studs and inserts) are referred to as the "left crankcase half" and "right crankcase half". The two halves are sealed together on the vertical split line with silk thread that forms a gasket. An oil sump is attached to the bottom of the joined crankcase halves at the sump flange mount area and sealed with a paper type gasket.

Cylinder mounting pads on the left crankcase are farther forward than the corresponding pads on the right crankcase to permit each connecting rod to work on a separate crankpin. There are six studs and two through bolts for attaching the cylinders with the exception of the "C" series engines and the O-200 and O-300 series engines. The 520 and 550 series engine crankcases are machined for a 7th stud located at the horizontal center line of the cylinder bore, between the cylinders, forward of number five cylinder and aft of number 2 cylinder.

Interior cast bosses are precision line bored with the two case halves assembled and torqued, to form the bearing surfaces for the camshaft and main bearing saddles that will house precision tri-metallic crankshaft main bearing inserts. Guides are bored through lateral bosses at the main oil transfer galleries to support the hydraulic valve lifters.

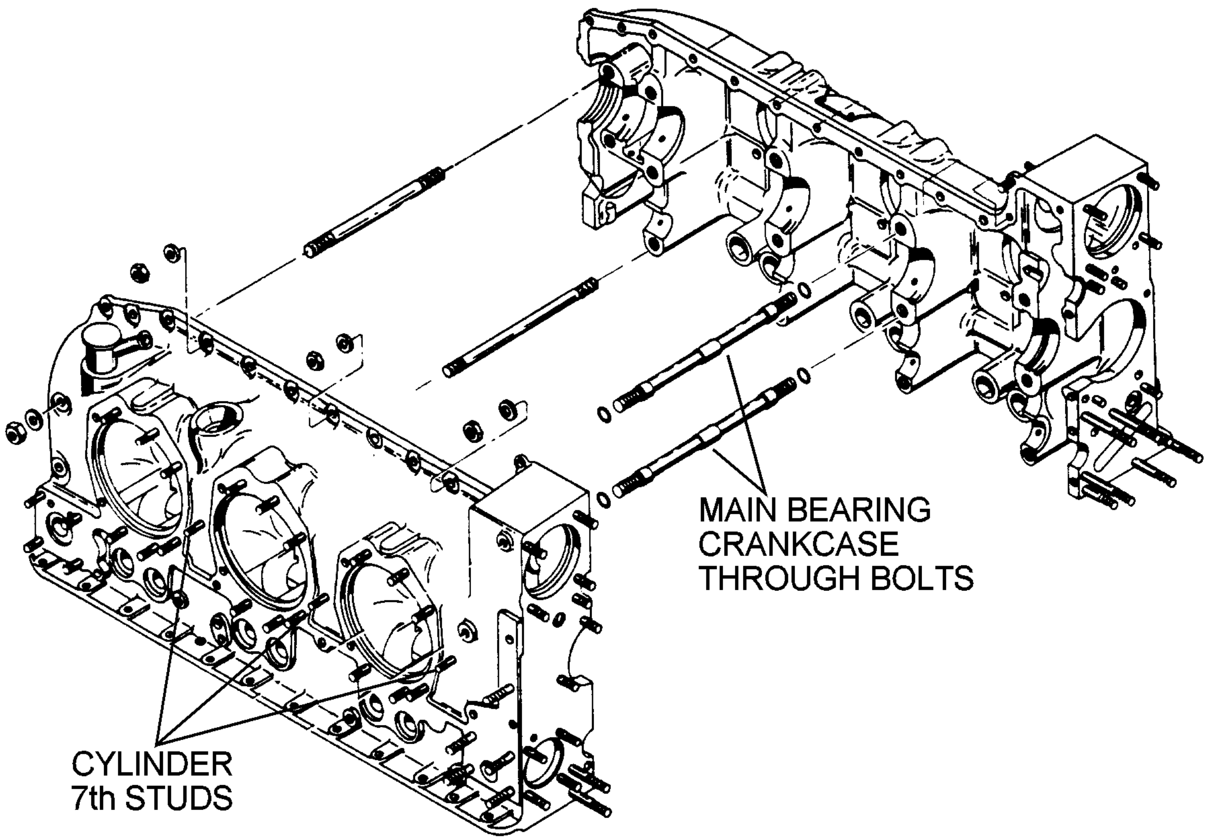
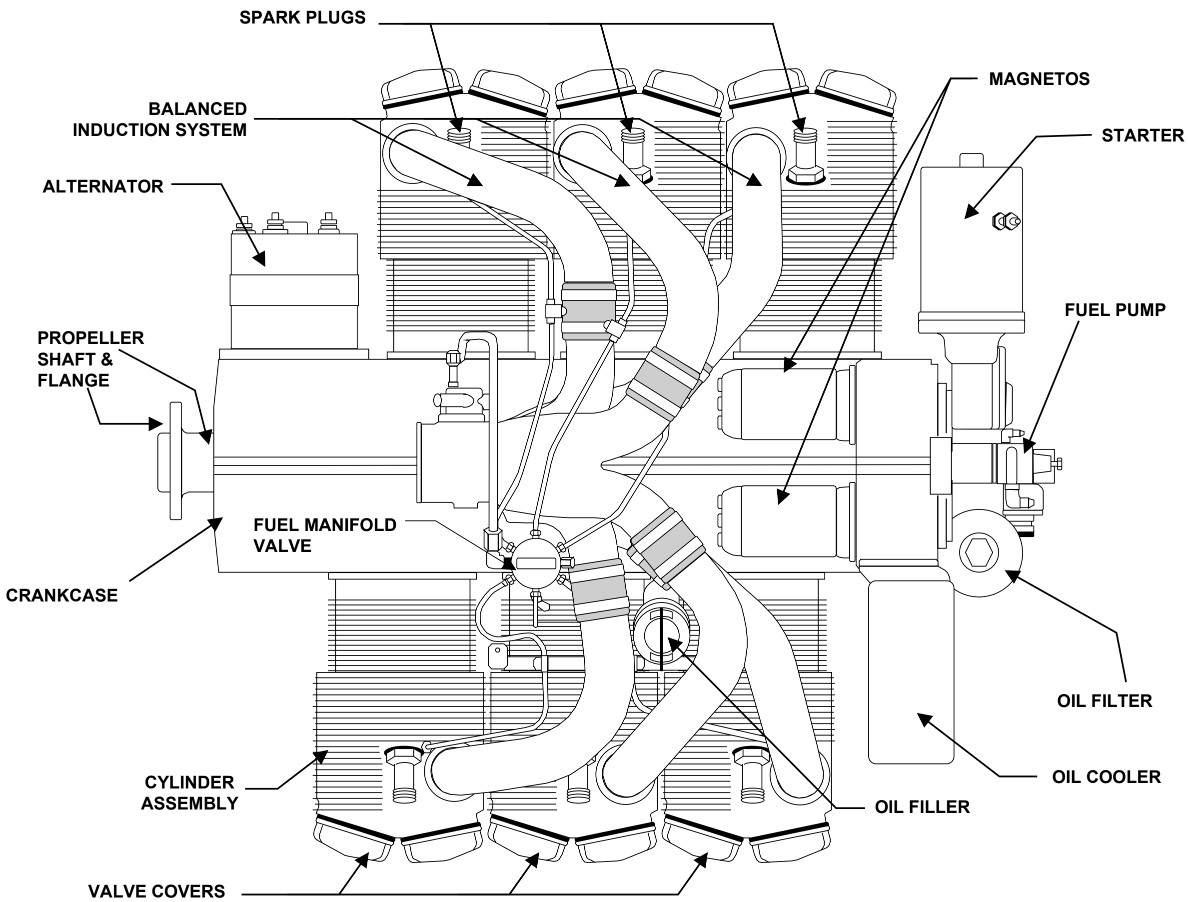


Figure 2-2. Crankcase with Through Bolt Locations Shown

Two through bolts run through each of the cylinder mounting pads and are fitted through solid aluminum inside the crankcase extending all the way the through the crankcase to the other side. The through bolts that are used at these attach points for the cylinders are inserted just above and below the crankshaft main bearing saddles. You will notice in figure 2-2, the through bolts and oil sealing "O" rings that fit over the shouldered area in the center of the bolt.

These through bolts serve to hold the crankcase together at the crankshaft main bearing saddles. This just happens to be where the greatest forces and stresses to the crankcase are applied by the power pulses developed within the engine cylinders.

More will be discussed on the importance of the crankcase through bolts later in this chapter.



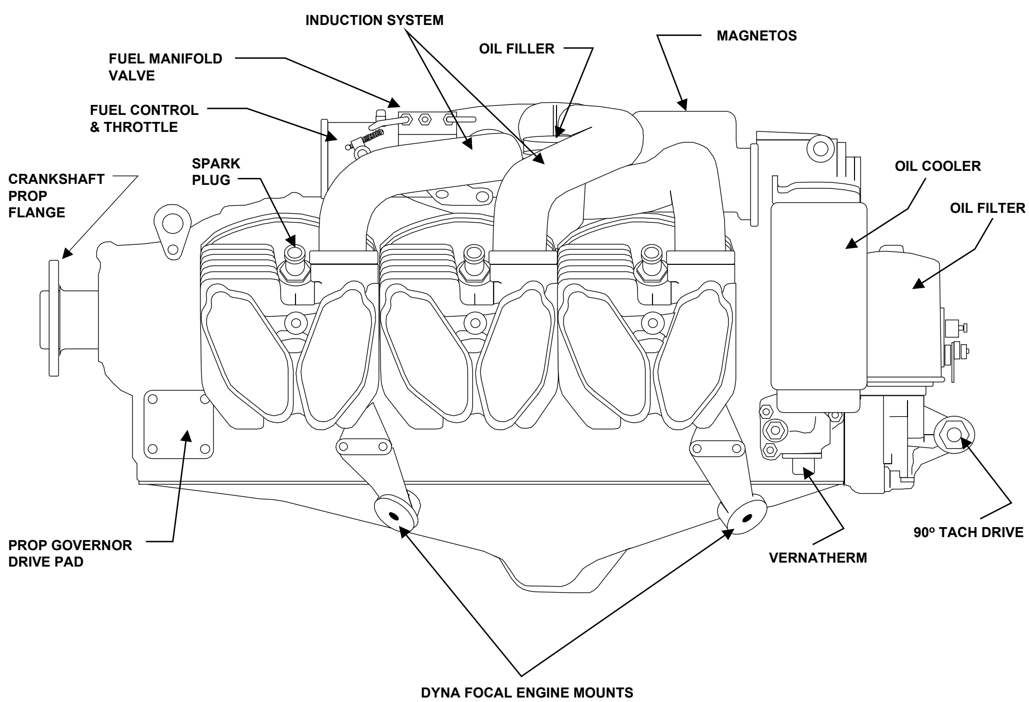


Figure 2-3. IO-550-N External Component Location Diagrams

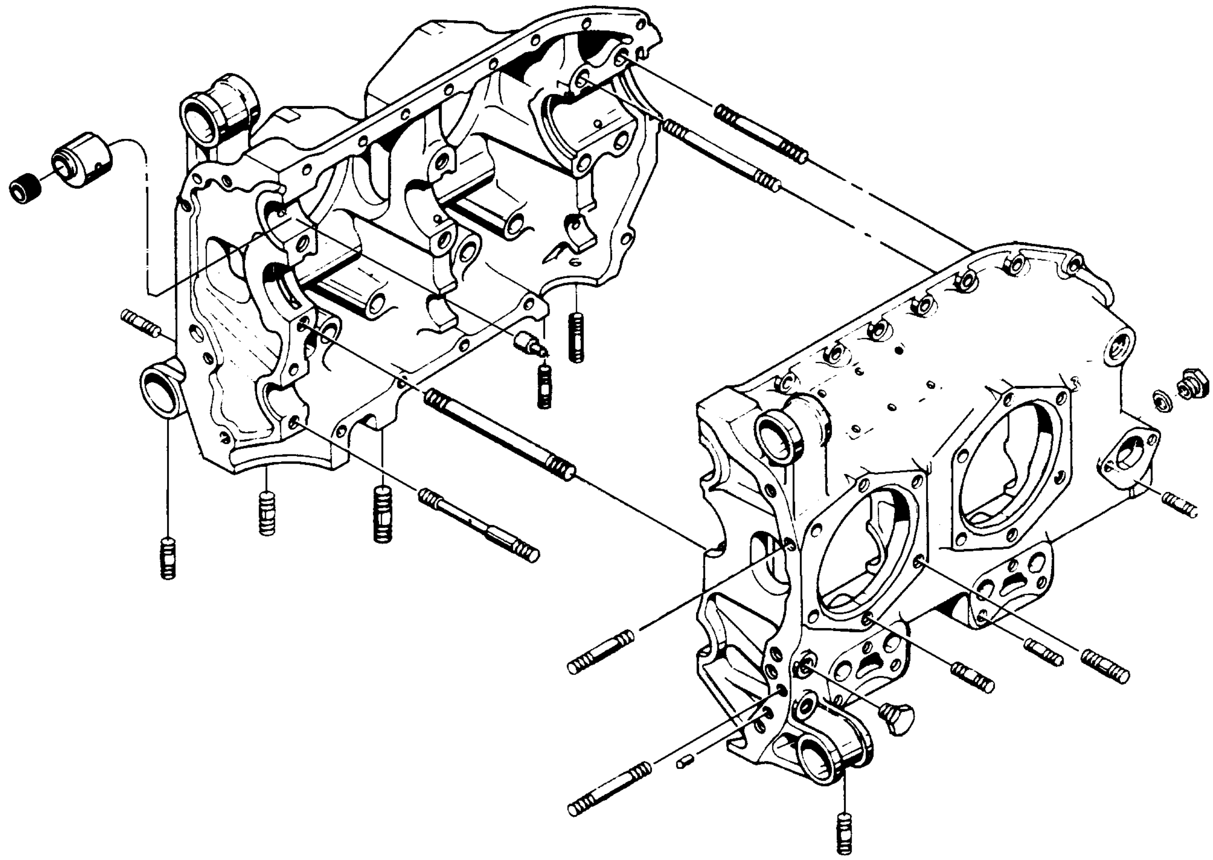
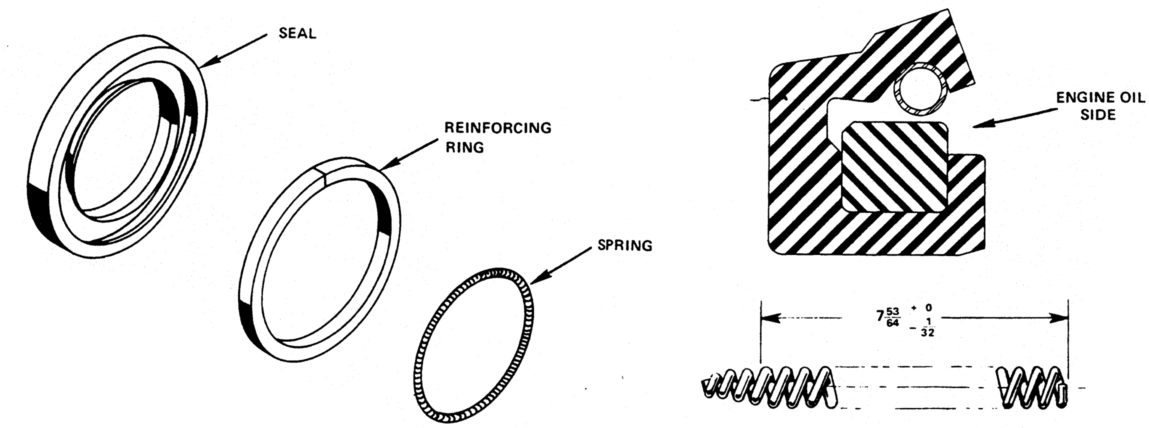


Figure 2-4. O200 Crankcase Exploded View



A three piece neoprene oil seal (for O-200, IO-240 and IO-360 models) fits over the crankshaft and is seated in a machined recess in the front of the assembled crankcase halves. A helical spring inserted into the oil seal provides tension to maintain seal contact with the crankshaft. Depending on the diameter of the propeller mount flange, some engines use a split seal while other engine models use a seal without a split. Service Bulletin M76-4 provides correct installation information for these seals. The larger 470, 520 and 550 engine models use a single piece seal rather than the split type seal.

CRANKCASE DETAILED DESCRIPTIONS

240 - SERIES ENGINES

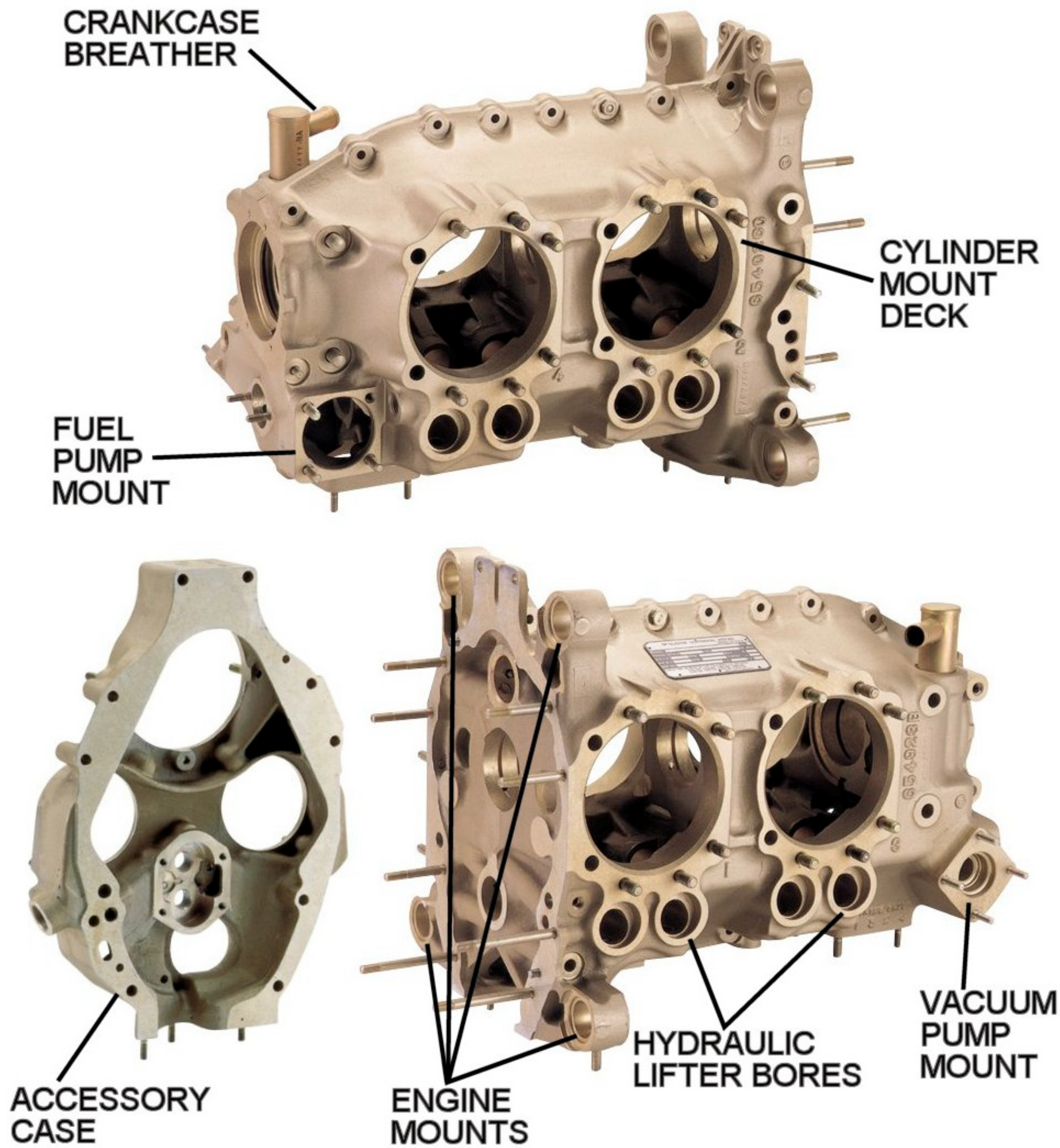


Figure 2-5. IO-240-B Engine

On the left crankcase half provisions are made to mount the engine driven fuel pump and an oil cooler adapter, which allows for installation of a remote mounted oil cooler. The engine driven fuel pump mounts forward of number 4 cylinder, while the oil cooler adapter mounts aft of number 2 cylinder. Provisions to measure engine oil pressure are provided at the oil cooler adapter.

The right crankcase half accommodates a breather adapter that is pressed into a machined boss at the front of the crankcase half on the upper surface. An accessory drive pad for mounting a vacuum pump is located forward of number 3 cylinder. The accessory drive and engine driven fuel pump share a common drive shaft that is driven by a camshaft bevel gear.

At the rear of each crankcase half are 2 cast bosses that are machined to provide four engine mounts. The IO-240 series engine accessory case is mounted on the rear of the left and right crankcase halves. The rear of the accessory case is machined to provide mounting surfaces for the engine starter, gear driven alternator, oil filter adapter, tachometer drive adapter and two magnetos. On the right side of the accessory case, a machined boss is provided for an oil pressure relief valve assembly.

The interior of the accessory case contains a machined oil pump cavity, oil galleries and oil pressure relief valve seat. The engine oil sump attaches to the lower surface of the crankcase and accessory case at the rear of the engine.

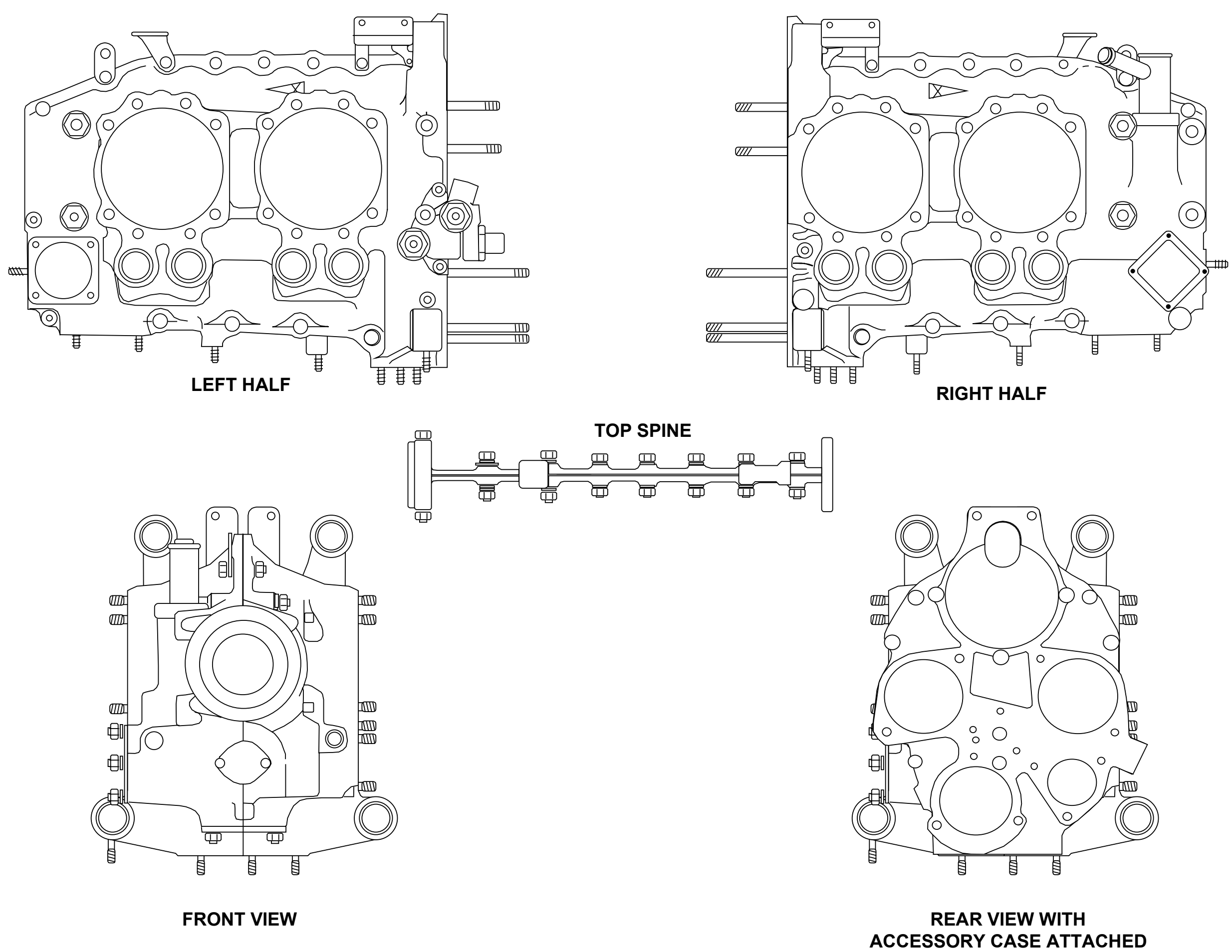


Figure 2-6. IO-240-B Crankcase Sectional Views

360 SERIES

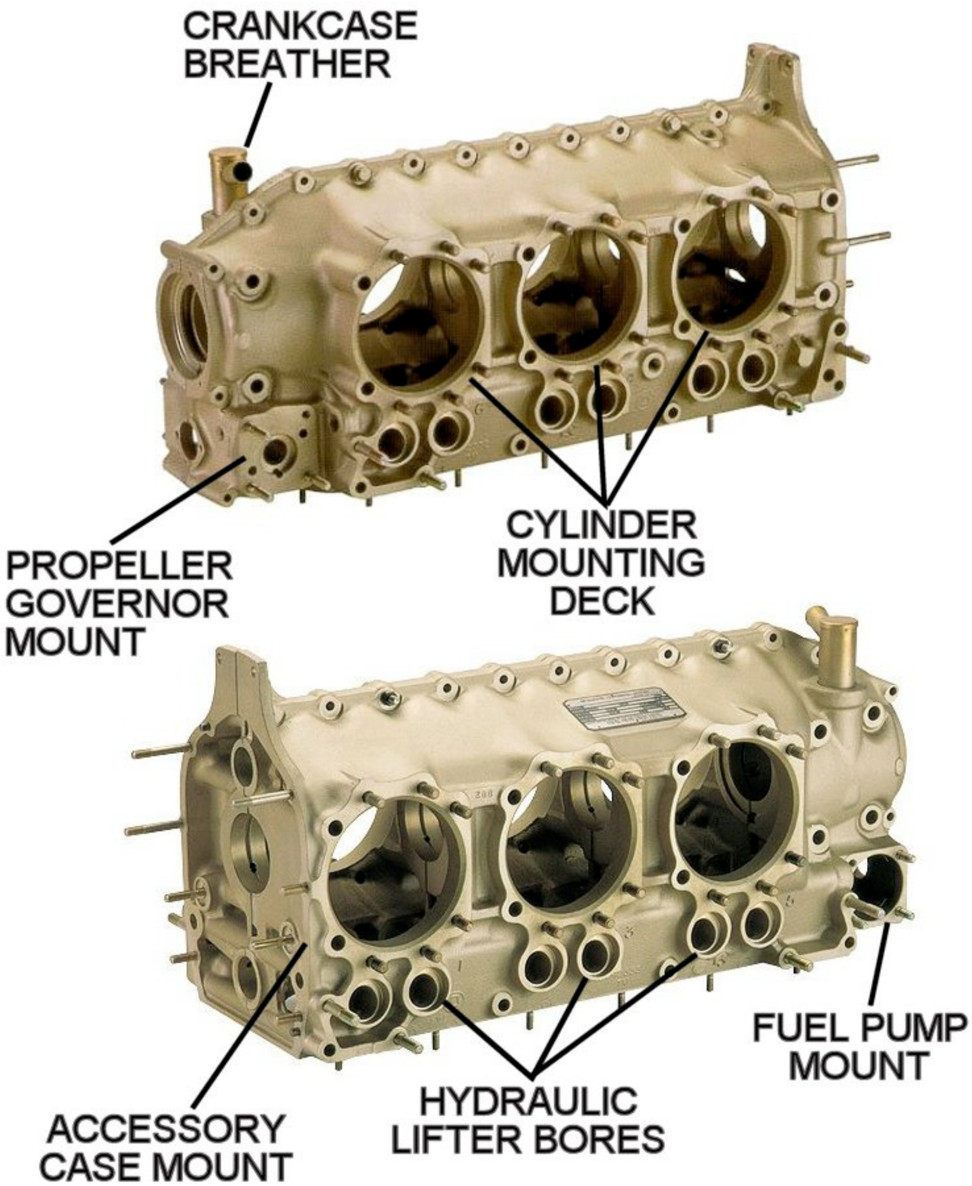


Figure 2-7. 360-Series Crankcase

On the left crankcase half an accessory drive pad forward of number the 6 cylinder accommodates the propeller governor. The engine oil cooler, and combination oil cooler adapter and left rear engine mount leg are attached to the crankcase aft of number 2 cylinder. A drilled and tapped hole located between number 2 and 4 cylinders provides access to engine oil pressure for either turbocharger lubrication or for reference to engine oil pressure.

The engine driven fuel pump is mounted on the right crankcase half forward of the number 5 cylinder. This fuel pump on the right crankcase half shares a common drive shaft with the propeller governor that is driven off the camshaft bevel gear. The cast aluminum oil sump attaches to the lower surface of the crankcase halves and the rear of the accessory case when assembled.

As can be seen from the top view in figure 2-8, the IO-360-ES model incorporates a balanced induction system, which provides optimum air flow into each cylinder across a large operational range. The result is a much smoother and more efficient running engine when coupled with the downdraft style cylinders.

The accessory case attaches to the rear of the crankcase. The accessory case provides machined surfaces for mounting the engine starter adapter, alternator, oil filter adapter (or installation of an oil screen), tachometer drive adapter and the left and right magneto. On the side of the accessory case a machined boss is provided for installing an oil pressure relief valve.

The oil pressure relief valve is located on the left side of the accessory case on all IO and TSIO-360's. On LTSIO-360 engines the relief valve is located on the right side of the accessory case. The interior of the accessory case contains a machined cavity for the engine driven oil pump, oil galleries and oil pressure relief valve seat.

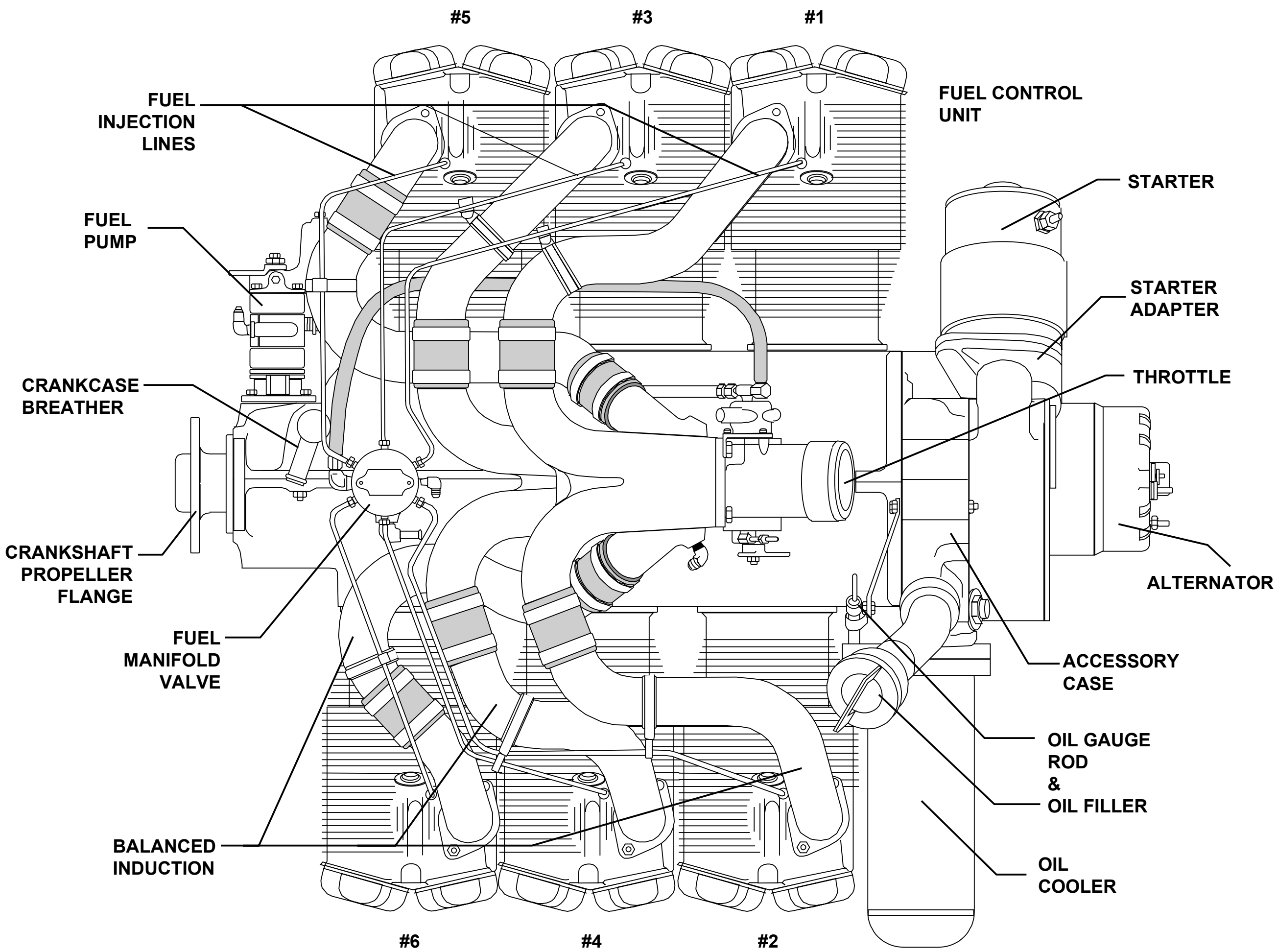


Figure 2-8. IO-360-ES Top View

470/520/550 SANDCAST SERIES ENGINES

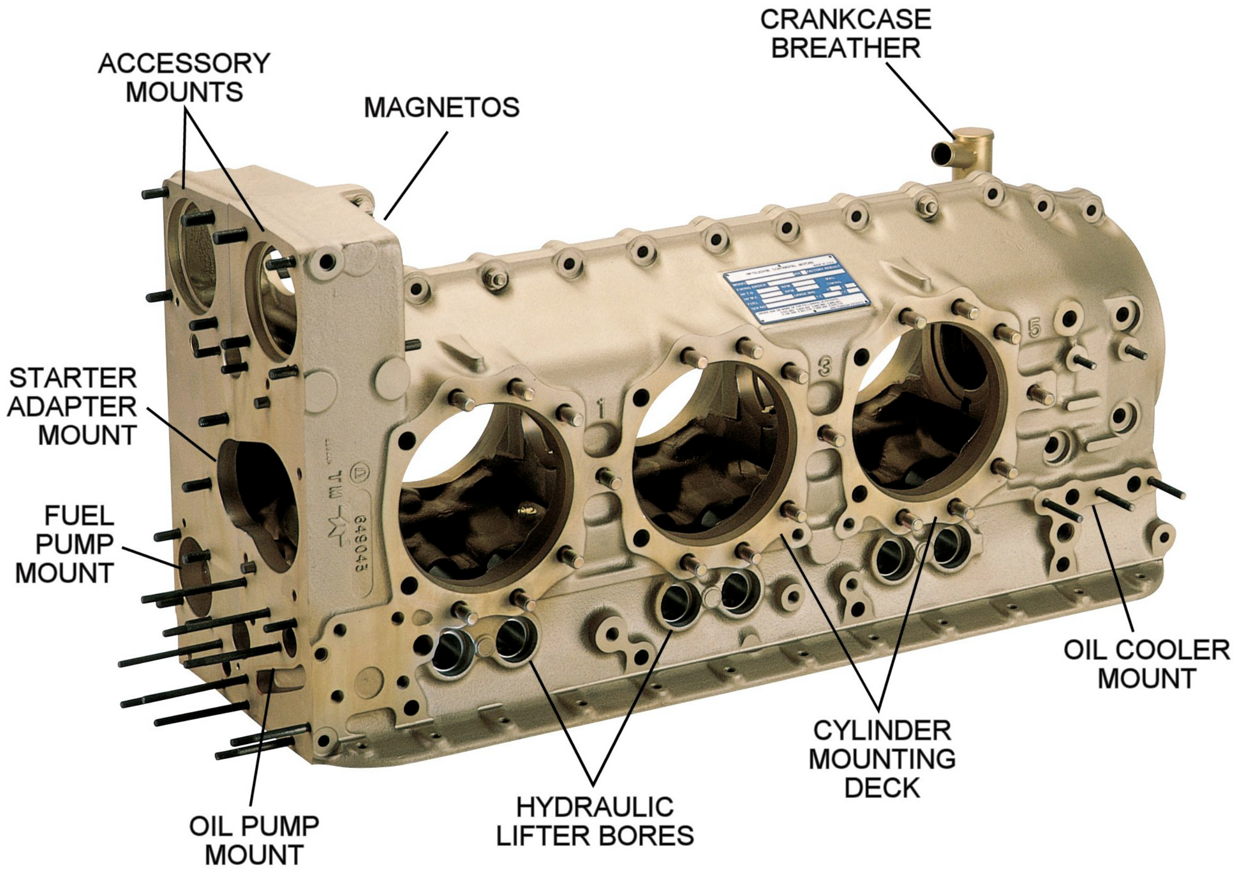
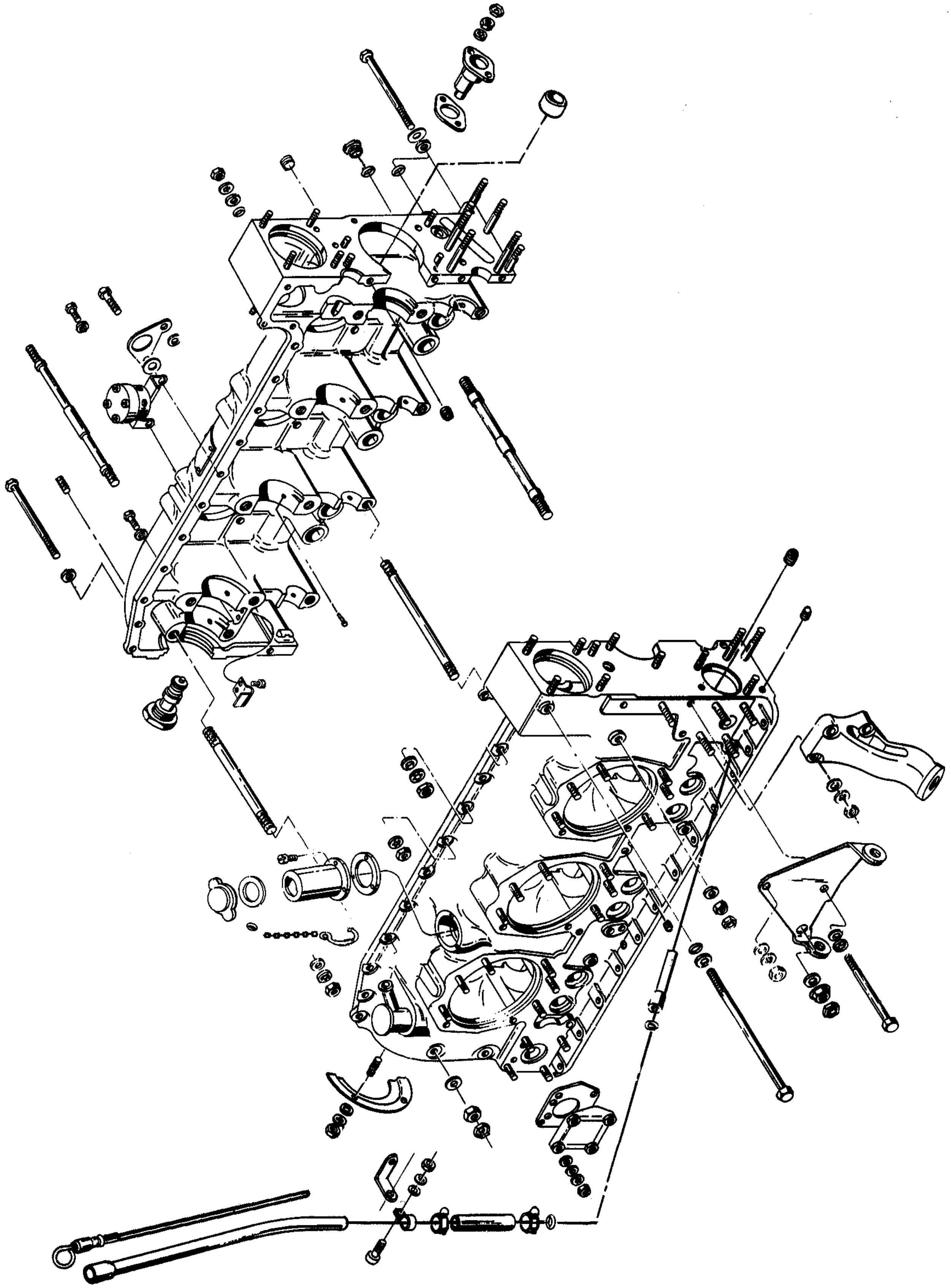


Figure 2-9. Sandcast Series Crankcase

On the left crankcase half, forward of number 6 cylinder an accessory drive pad is provided for installation of the propeller governor. A combination alternator and engine mount leg attaches to the crankcase aft of number two cylinder. The crankcase interior is ventilated by a breather tube that is pressed into the left crankcase half upper surface forward of number 6 cylinder. An oil filler tube is attached to the upper surface of the left crankcase half above the number 4 and 6 cylinder.

On the right crankcase half ahead of number 5 cylinder an oil cooler adapter plate and oil cooler are mounted. On aircraft using remote mounted oil coolers a special adapter is mounted in this area. On the front face of the right crankcase half a machined taped hole is provided for either an oil temperature control valve (vernatherm) or special plug, depending on oil cooler application. The rear main bearing saddle aft face is machine bored for installation of the starter adapter shaft gear needle bearing.

The accessory section is an integral part of the crankcase casting. Magnetos are mounted on the front face of the accessory section above number 1 and 2 cylinders. Accessory drive pads located on the rear face of the accessory section share a common drive with the magnetos. The oil pump is externally mounted on the lower right side of the accessory section. The starter adapter mounts above the oil pump assembly. The engine driven fuel pump is mounted on the lower left side and is driven off the camshaft. The oil sump is attached to the bottom of the assembled crankcase.



520/550 PERMOLD SERIES ENGINES

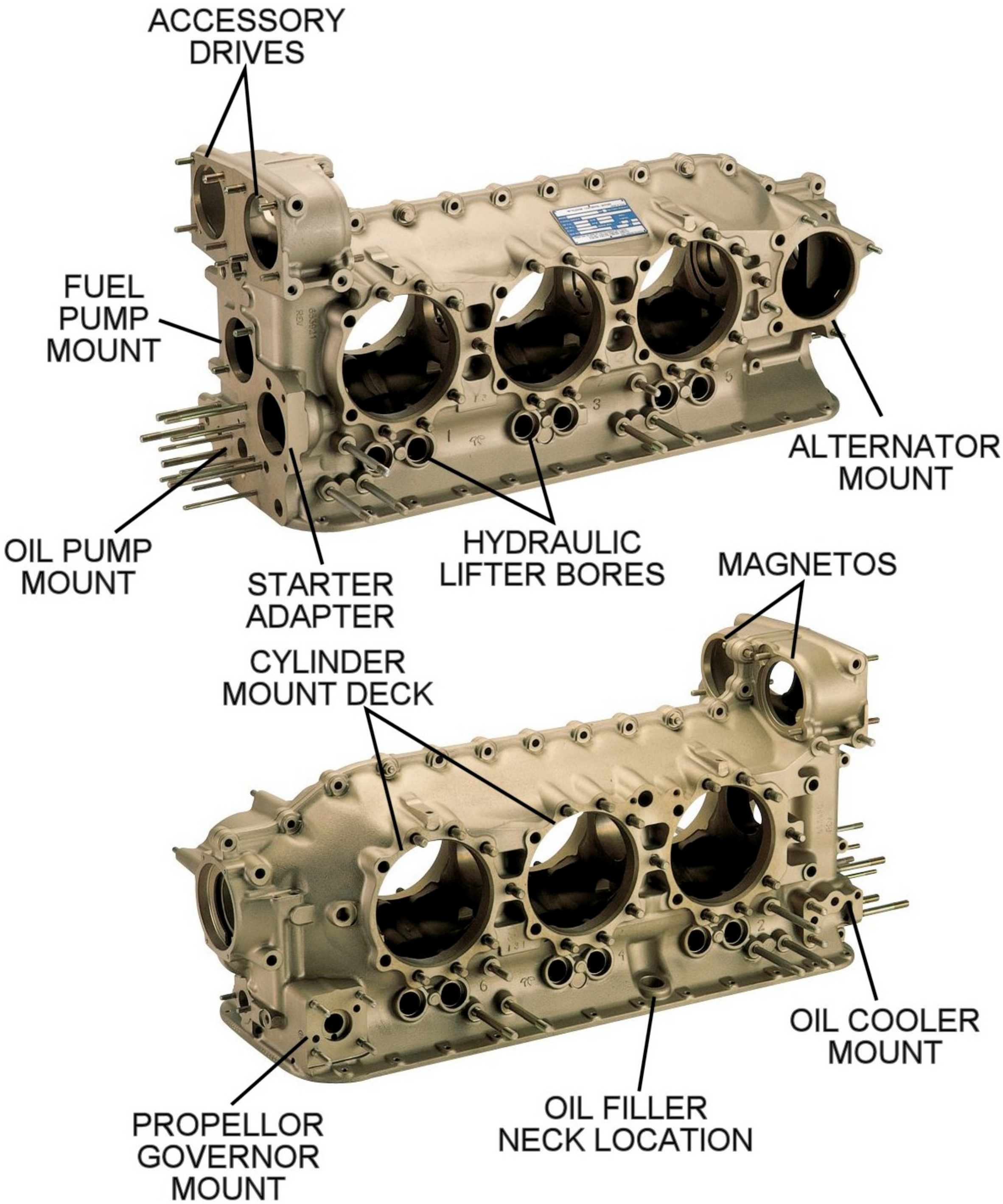


Figure 2-10. 520/550 Permold Series Crankcase Photo View

The propeller governor mount pad is located on the left crankcase half forward of number 6 cylinder. The combination engine oil filler tube and crankcase breather is mounted to the crankcase between the number 2 and 4 cylinder location at the sump flange mount. The engine oil cooler is mounted aft of cylinder number 2.

An alternator mount pad is provided on the right crankcase half forward of number 5 cylinder. The aft face of the rear main bearing saddle is bored for installation of the starter adapter shaft gear needle bearing.

The accessory section is an integral part of the crankcase casting. Magnetos are mounted on the front face of the accessory section above number 1 and 2 cylinders. Accessory drive pads located on the rear face share a common drive with the magnetos. The engine oil pump assembly is mounted just above the oil sump across both crankcase halves. The engine driven fuel pump mounts at the center of the accessory section across the split line between left and right crankcase half. Permold engine fuel pumps are driven by the crankshaft.

Depending on aircraft application the permold series engines utilize either a cast aluminum or extruded aluminum oil sump attached to the bottom of the assembled crankcase.

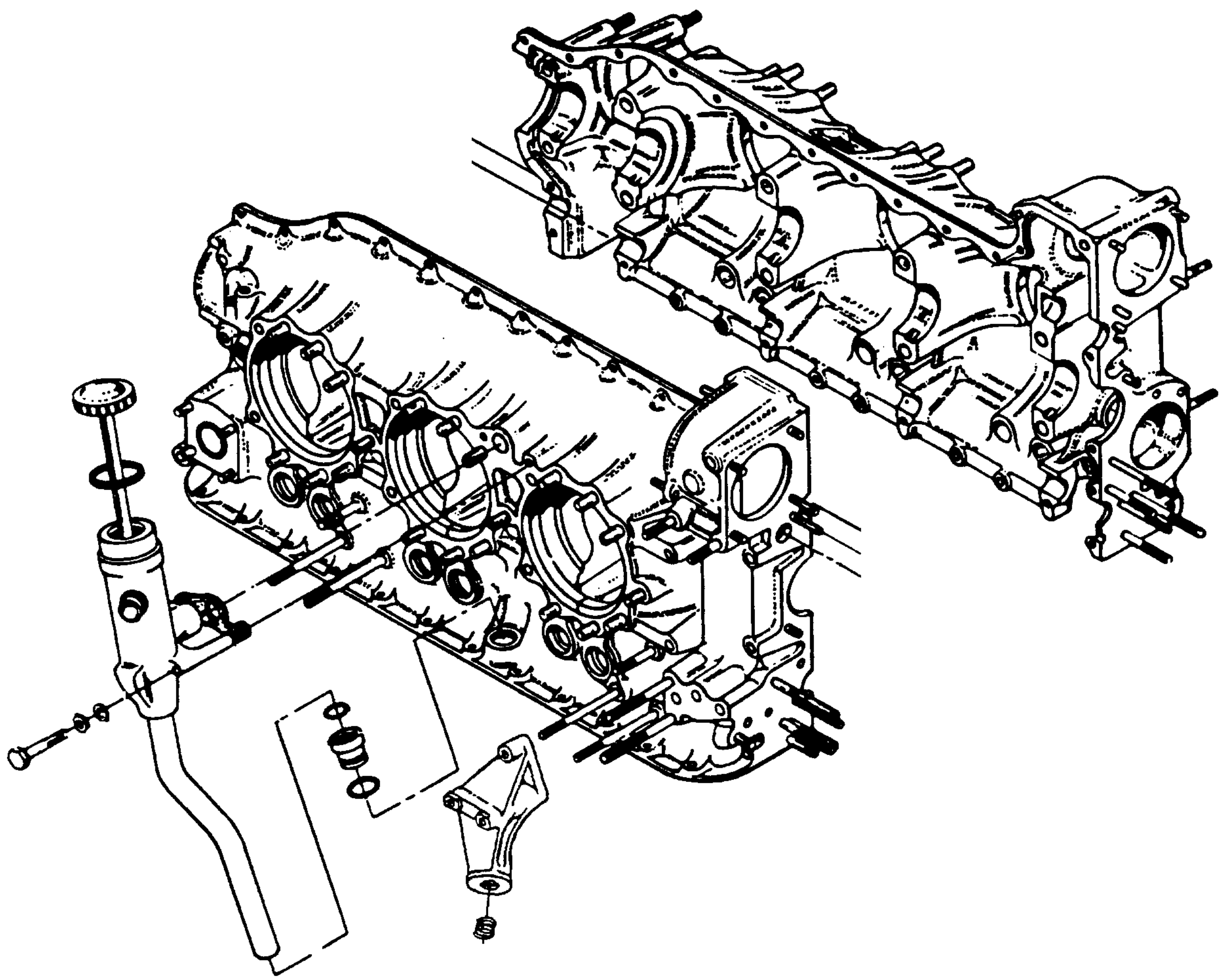


Figure 2-11. 520/550 Permold Series Crankcase Exploded View

GTSIO-520 SERIES ENGINES

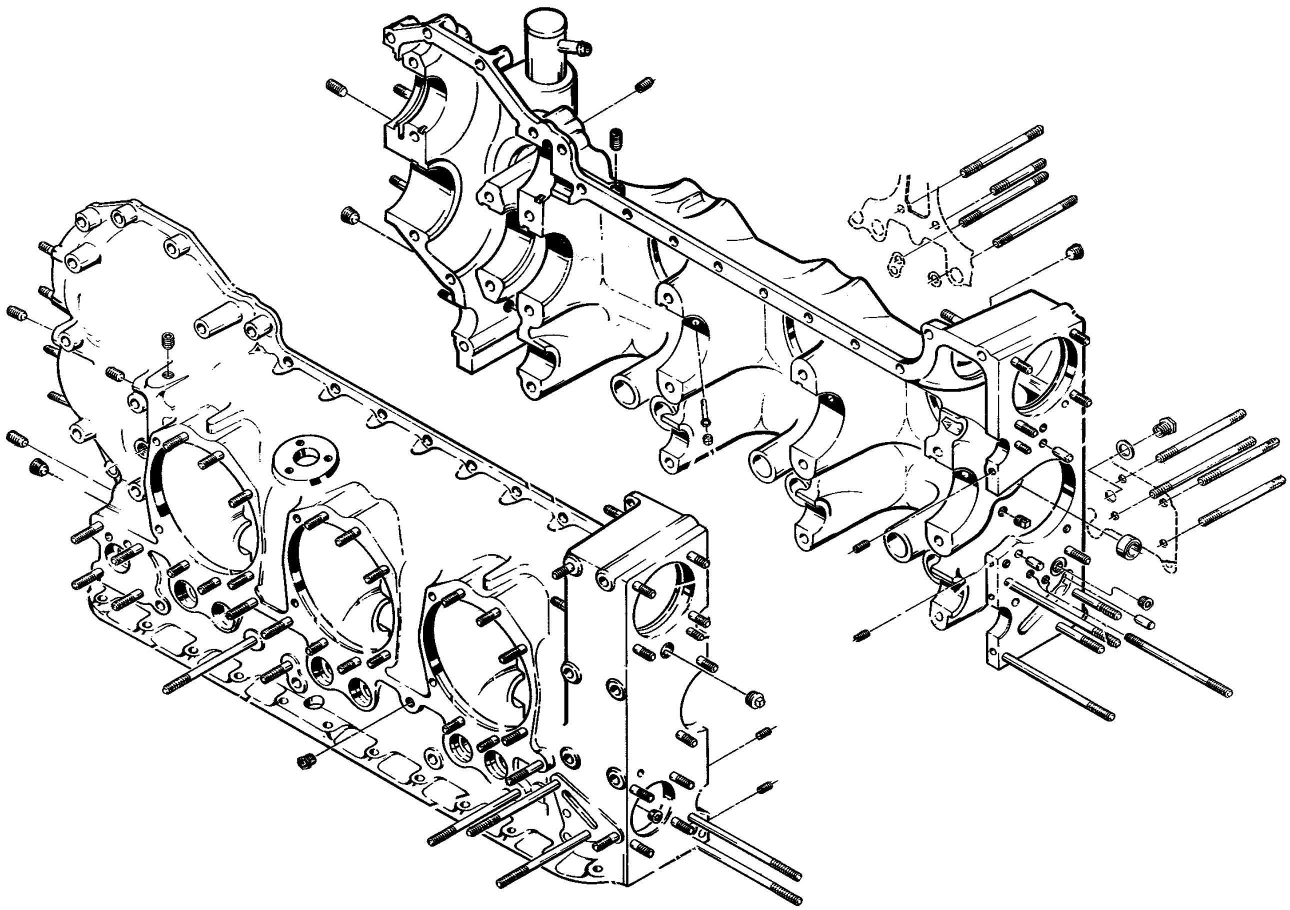


Figure 2-12. GTSIO Series Crankcase Exploded View

The GTSIO series engines incorporate a spur type reduction gear. The reduction gear or bowl gear requires that the front of the crankcase to have a “hump” to provide an enclosure.

On the left crankcase forward of number 6 cylinder an accessory drive pad is provided for installation of the propeller governor. The oil filler is mounted above the number 4 and 6 cylinders and is connected to the crankcase breather adapter in the right crankcase. The engine oil cooler is mounted aft of cylinder number two.

On the right crankcase an alternator drive pad is located forward of number 5 cylinder. The engine interior is vented by a breather adapter pressed into the crankcase “hump” above and between number 5 cylinder and the alternator.

The accessory section is an integral part of the crankcase casting. The magnetos are mounted on the front face of the accessory section above number 1 and 2 cylinders. Accessory drive pads on the rear face share a common drive with the magnetos. The starter adapter and oil pump are mounted on the right crankcase. The engine driven fuel pump is mounted on the left crankcase and is driven by the camshaft.

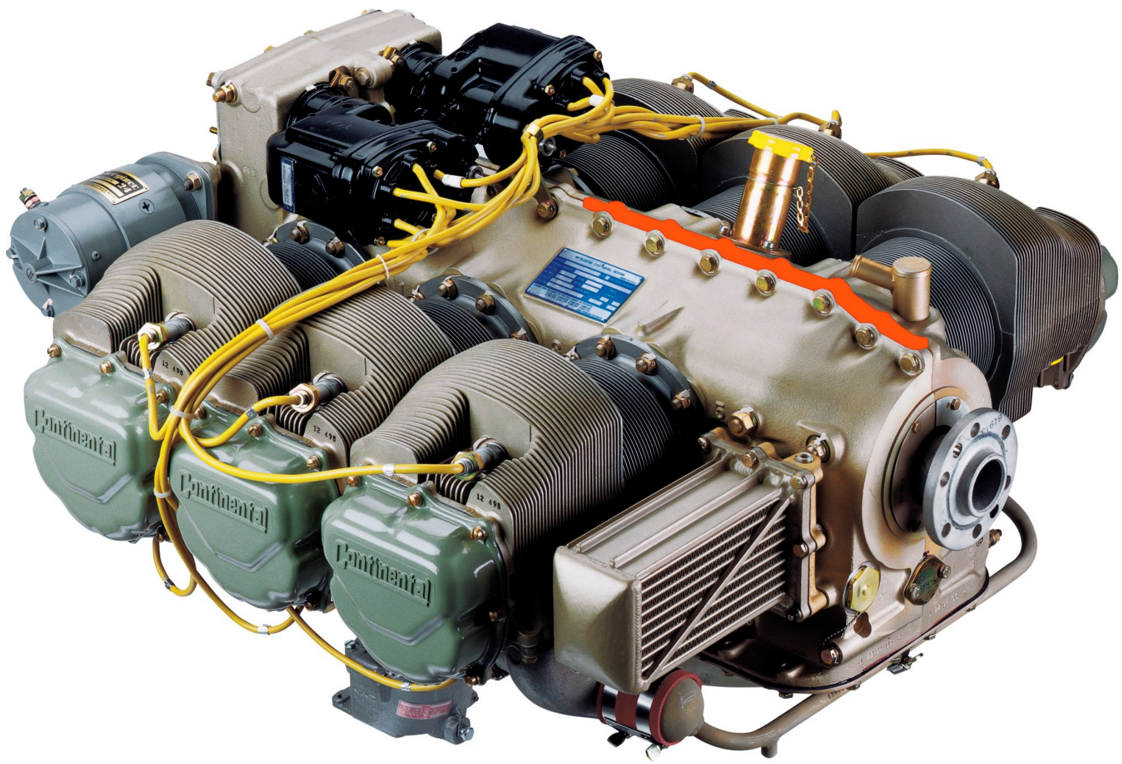


Figure 2-13. Sealant Applied to Backbone of Crankcase (Highlighted in Red)

The above figure illustrates that a sealant has been applied to the top of the engine at the crankcase backbone. The sealant is shown in red so that it can be readily seen in the photograph.

So here's the dilemma; you're doing an annual inspection on a customer's aircraft and during the engine portion of the inspection you spot the sealant. A study of the logbook reveals the engine has 1100 hours since new and 50 hours ago, the customer squawked the engine was leaking oil from the backbone area. The other shop that did the maintenance wrote up the fix as follows:

> *During annual inspection of engine, repaired customer complaint that engine was leaking oil at the top of the backbone. Corrective action: Loosened backbone bolts and flushed with solvent. Applied sealant to top of crankcase backbone and re-torqued backbone bolts.*

Was this in fact a corrective action? If you answered yes, are you sure? Let's examine this scenario a little more closely. What could cause the case to begin leaking all of a sudden? In order for us to discover this phenomenon, we must first understand how the case halves are sealed.

The split line of the two case halves are joined together and sealed with a silk thread which acts as the gasket. Silk thread is used because it will never "wick" oil. It also provides a minimal interface between the machined parting surfaces. The silk thread is installed at engine buildup in accordance with the most current version of SIL99-2, which details that the left crankcase surface be lightly coated with Aviation Permatex® or Loctite® 30516. This surface coating acts provides a tacky surface to hold the string in place during assembly. Once the crankcase is properly torqued, the string will remain permanently fixed for the lifetime of the engine.

Now back to the question; what can cause the crankcase backbone to develop a leak? The string has begun to move. What can cause the string to move in between the crankcase parting surfaces? The crankcase is moving. Let's take a look back a little further in the engine logbook to see if at some time in the past, a cylinder was removed.

Performed an engine top overhaul replacing all six cylinders at customer request.

The logbook reveals that 200 hours prior to the leak, a cylinder top overhaul was performed. This can be an indicator that the engine cylinders when installed, were not properly torqued. Recall that the cylinders attach to the crankcase mounting deck with two through bolts per cylinder. Those through bolts are the attach points that also hold the crankcase together just above and below the crankshaft main bearing saddles. This is a highly stressed area of the crankcase due to the movement and loads placed on the crankshaft that are induced by the power pulses of the cylinders.

When the cylinders are installed and the through bolts are torqued to 800 inch pounds, the through bolts are stretched approximately 14 thousandths of an inch in length. It is this amount of stretch that provides the sufficient clamping load to hold the two crankcase halves together without allowing movement. If the cylinders are incorrectly installed, that is, with insufficient torque, the crankcase halves can begin to move against each other causing fretting. This fretting will eventually cause a loss of material between the two surfaces. The cylinder through bolt torque across the crankcase will begin to relax and the situation feeds itself to such a point where the crankcase halves are moving enough to cause the silk thread to begin to "walk" to a backbone bolt location or even deteriorate. This will promote a leak that usually shows itself at the top of the crankcase backbone.

This leads us to the critical part of the entire matter. In the reciprocating engine, there are rapidly accelerating and decelerating forces created by the piston during it's travel inside the cylinder. At the moment the piston stops and reverses travel, there is a pull on the connecting rod journal of the crankshaft. This force pulls on the crankshaft and on one side of the crankcase. If the crankcase through bolts are not properly torqued, and the clamping load on the crankcase is not sufficient, the two crankcase halves can begin to move against each other over time.

Once this movement occurs, the loss of crankcase clamping load can eventually cause crankshaft main bearing movement because of loss of main bearing crush. Main bearing crush is a term that identifies "locking" the bearing steel back against the main bearing boss that is machined into the crankcase.

If the crankcase torque has deteriorated to a point where movement is sufficient to case the silk thread to move, it is possible then, that the case movement is severe enough to permit the crankshaft main bearings to begin shifting as well. The main bearings for the crankshaft can shift ***Laterally***, where the main bearing has shifted into the radius of the main journal causing direct metal to metal contact.

A lateral movement will cause the direct metal-to-metal contact that the oil can no longer provide a protective film of lubrication against friction. This will super heat the local area and breach the nitride layer of the crankshaft causing ladder cracks to form. These cracks will eventually give way to stress riser and the result is catastrophic, with the crankshaft breaking in two.

Getting back to the crankcase leaking scenario addressed by Figure 2-13, we can now see what could cause such a leak on a "high-time" engine. If you see a situation such as this, be sure to research the log book and then perform the following check before determining that you can return the engine to service.

Crankcase Through-Bolt Inspection and Re-Torque Procedure

To inspect the crankcase through-bolts:

1. Remove one spark plug (the most accessible) from each cylinder.
2. Attach a spring scale to the propeller blade approximately 6 inches in from the tip.
3. Rotate the propeller in the normal direction of rotation via the attached scale and record the pounds required to rotate the propeller. (Normally around 10 pounds)
4. Also check for evidence of end play by holding opposite propeller blades as close to the hub as possible and move the crankshaft fore and aft to assure the crankshaft has end play.

Warning

Use extreme caution in the area of the propeller while performing this check.

5. To re-torque the through-bolts:

a. Gain access to the crankcase through bolt nuts. With a cylinder base wrench, loosen the through bolt nuts and back them off approximately 1/2 inch.

b. Liberally lubricate the exposed through bolt threads and the nuts with clean 50 weight engine oil.

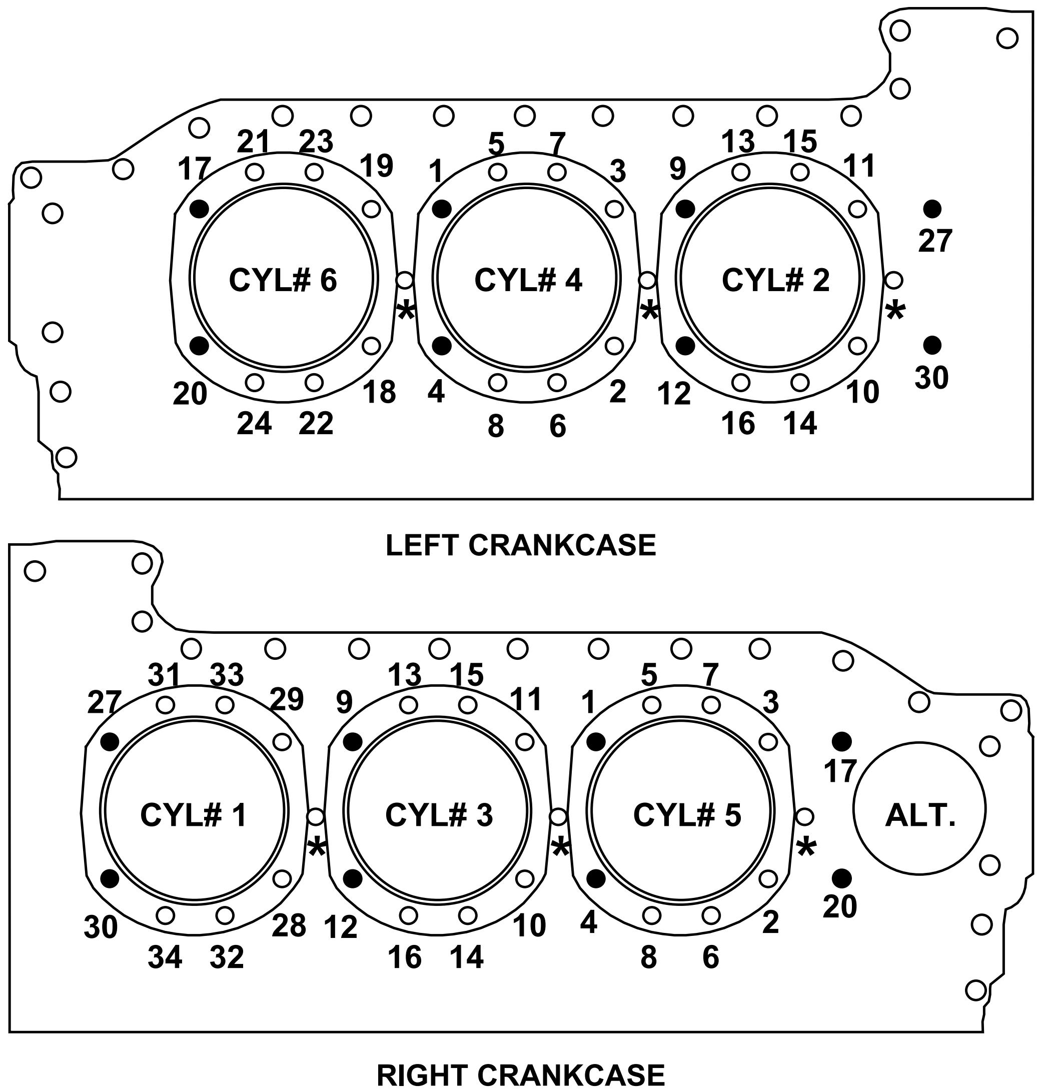
c. Using the torque sequence shown in Figure 2-14, torque the nuts to a preliminary torque, then repeat the final torque as specified in the applicable overhaul manual for the engine you are working on. It will be necessary to have someone retain the opposite nuts to prevent through-bolt rotation.

NOTE: Torque the 7th stud nut last.

d. Verify that the through-bolt nuts on both sides of the engine are torqued.

6. Repeat steps 1 through 4 above and record the pounds required to rotate the propeller. If after torquing the through-bolts per step 5a-d, the effort (in pounds) required to rotate the propeller is more than the previously recorded amount, or if there is no evidence of crankshaft endplay, it is very likely that the crankshaft main bearings have moved due to insufficient through bolt torque. This torque is required to clamp the left and right crankcase halves together.

If through-bolt torquing is insufficient, the engine must be torn down and inspected and repaired as necessary in accordance with procedures in TCM's Overhaul Manuals.



● DESIGNATES CRANKCASE THROUGH BOLTS - CRANKCASE THROUGH BOLT THREADS & NUTS MUST BE LUBRICATED WITH CLEAN 50 WT AVIATION OIL AND TORQUED SIMULTANEOUSLY

* TORQUE 7TH STUD NUT LAST

520/550 PERMOLD & LIQUID COOLED CYLINDER TORQUE SEQUENCE

Figure 2-14. Through Bolts on Permold Series Crankcase (Black Circles)

The above figure illustrates the **"MAIN"** through bolt location on a Permold series engine crankcase. You should be able to notice, for example through bolts 17 & 20 on the right crankcase attach at the cylinder #6 position on the left crankcase. Take a moment to study the relationship of the through bolts from the right to the left half.

There are eight through bolts that do most of the work in keeping the two crankcase halves together and keep the two halves from moving. These through bolts clamp the two halves together at the crankshaft main bearing boss areas.

CRANKCASE INSPECTIONS

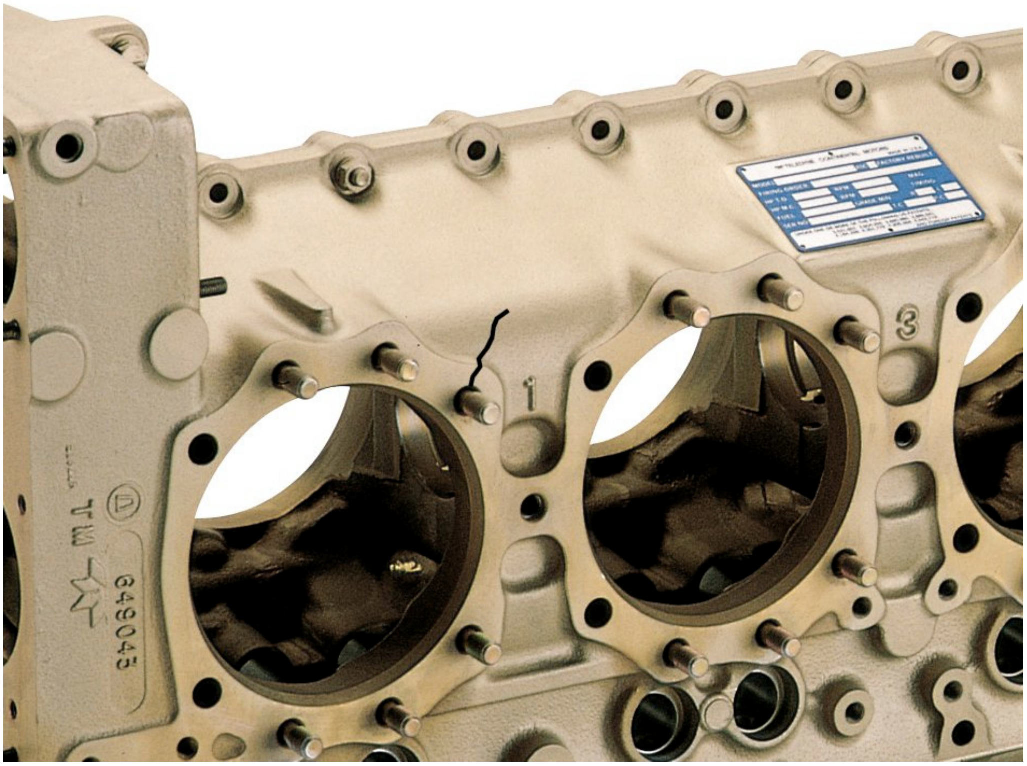


Figure 2-15. Inspecting Crankcase for Cracks

The crankcase should be given a through physical and visual inspection for leaks or any signs of cracks in the case material. Check the engine applicable Maintenance Manual as well as Service Bulletin M90-17 for Crankcase Inspection Criteria. This type of crack is considered in the non-critical area of the crankcase and under certain conditions specified in M90-17, could be permitted to continue in service. It should be noted that, while a crack in this area may be considered allowable for continued operation, it will eventually propagate further to a point where it will exceed the allowable criteria for continued operation and then must be considered as no longer airworthy.

SUMMARY

In this chapter we discussed the crankcases of the IO-240, 360, & the 470/520/550 Sandcast series of engines and the 520/550 Permold series engines. The geared GTSIO-520 series engines were also discussed. While this discussion is not all encompassing when regarding the TCM product line, this discussion represents a broad range of engine models. We also discussed the internal components of the drive train to emphasize the crankshaft and camshaft designs of the various model engines. The lubrication systems of these engines will be discussed in the next chapter.

KEY TERMS

Corrosion
Deterioration of a metal surface usually caused by oxidation of the metal.

Fretting
Fretting refers to damage of contact surfaces. This damage is induced under load and in the presence of repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage where surface materials have transferred.

Damage can occur at the interface of two highly loaded surfaces which are not designed to move against each other. The most common type of fretting is caused by vibration.

Gallery
A passageway in the engine or subcomponent. Generally one through which oil is flowed.

Galling or Scuffing
Excessive friction between two metal surfaces resulting in particles of the softer metal being torn away and literally welded to the harder metal.

Sump
The lowest part of a system. The main oil sump on a wet sump engine contains the oil supply. It is usually attached to the bottom of the engine crankcase.

Torque
Twisting moment or leverage, stated in pounds-foot (or pounds-inch).

Viscosity
The characteristic of a liquid to resist flowing. Regarding oil, high viscosity refers to thicker or "heavier" oil while low viscosity oil is thinner. Relative viscosity is indicated by the specific "weight" of the oil such as 30 "weight" or 50 "weight". Some oils are specified as multiple-viscosity such as 10W30. In such cases, this oil is more stable and resists the tendency to thin when heated or thicken when it becomes cold.

EXERCISES

1. Explain where the accessory drive pad is located on the IO-240 Series Engine. ________________

    ____

    ____

2. Where is the oil pump located on the IO-240 Series Engine?
    a. Left Crankcase half
    b. Right Crankcase half
    c. In the Accessory Case
    d. In the Oil Sump

3. The Crankshaft main journals, rod journals and crankshaft cheeks are numbered from __________

    ____

4. Select the Service Bulletin that contains the authorized gasket materials when building up the two crankcase halves.
    a. SIL02-2A
    b. SIL99-2A
    c. SIL99-1
    d. SIL98-9A

5. Using the TCMLINK CD or Information Services on the web site, access SB96-7B Torque Limits and identify the correct torque value for the 12 point through bolt nuts when torquing cylinders onto the IO520 Series crankcase.
    a. 490 – 510 in lbs
    b. 590 – 610 in lbs
    c. 690 – 710 in lbs
    d. 790 – 810 in lbs

6. When performing a top overhaul, which cylinder is to be installed first on a 520/550 permold series crankcase?
    a. Cylinder #1
    b. Cylinder #4
    c. Cylinder #2
    d. Cylinder #3

7. Where is the Oil Cooler located on a 520 Sandcast engine?___________________________________

____

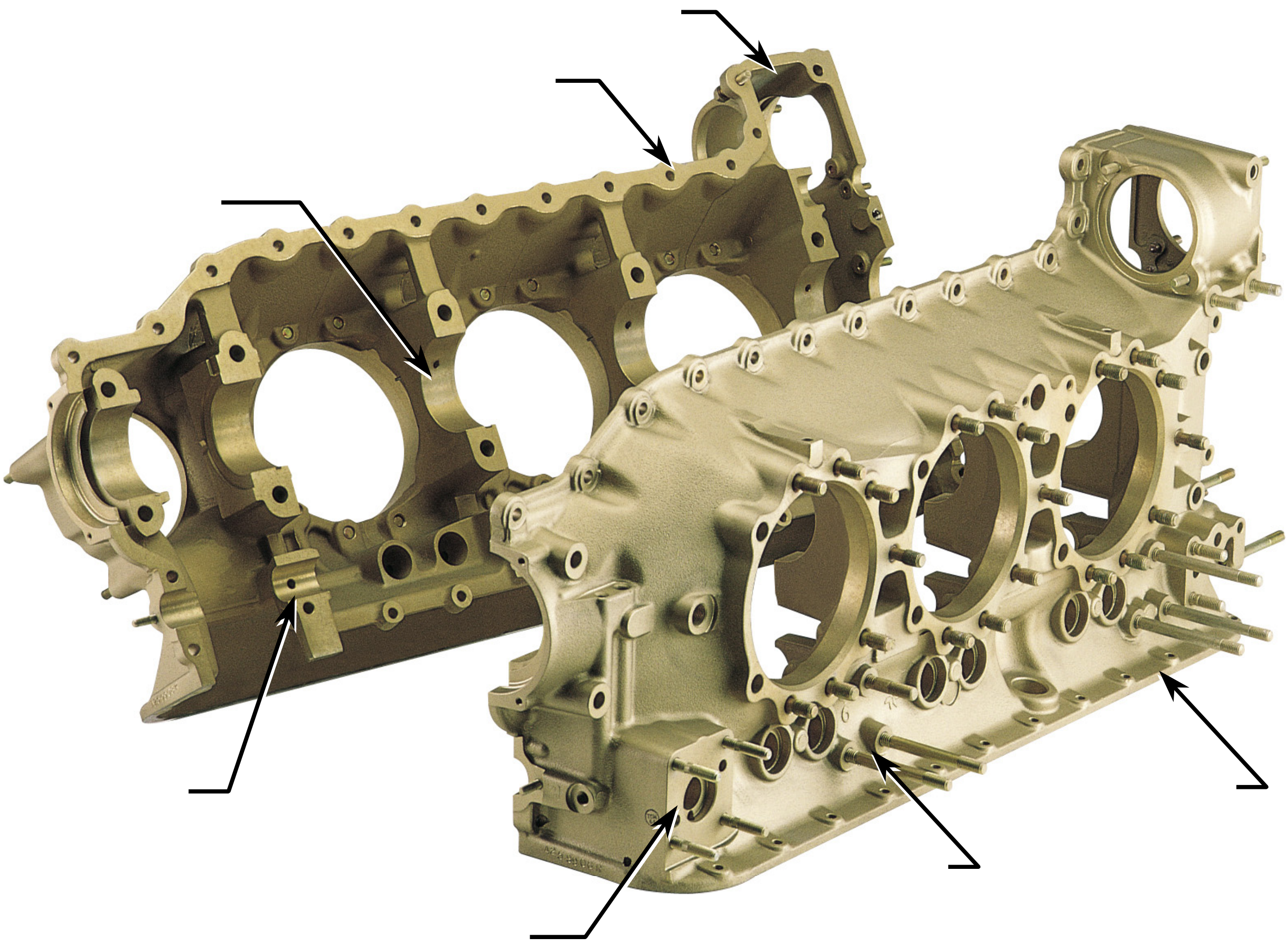
____

8. Where is the alternator located on a 550 Permold engine? ___________________________________

____

____

Label the sections of the crankcase identified by arrows.



Chapter Three

Internal Engine Drive Train Components

CHAPTER 3 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Describe the machining processes for the crankshaft.

② Describe the fundamental purposes of the nitride process.

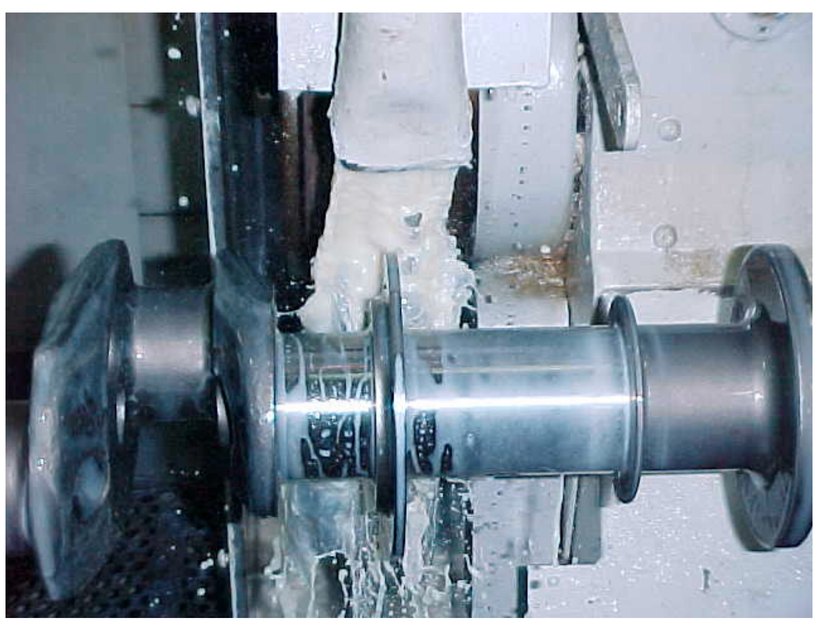
③ Describe the purposes of the counterweight dampers.

④ Identify the task knowledge procedures for correct installation of counterweights.

⑤ Identify the task knowledge procedures for crankshaft seal installation.

⑥ Describe the machining processes for the camshafts.

⑦ Identify inspection procedures using Service BulletinSB00-3A.



Crankshaft Machining - One of hundreds of Crankshaft machining operations.

ENGINE DRIVE TRAIN COMPONENT GENERAL DESCRIPTION

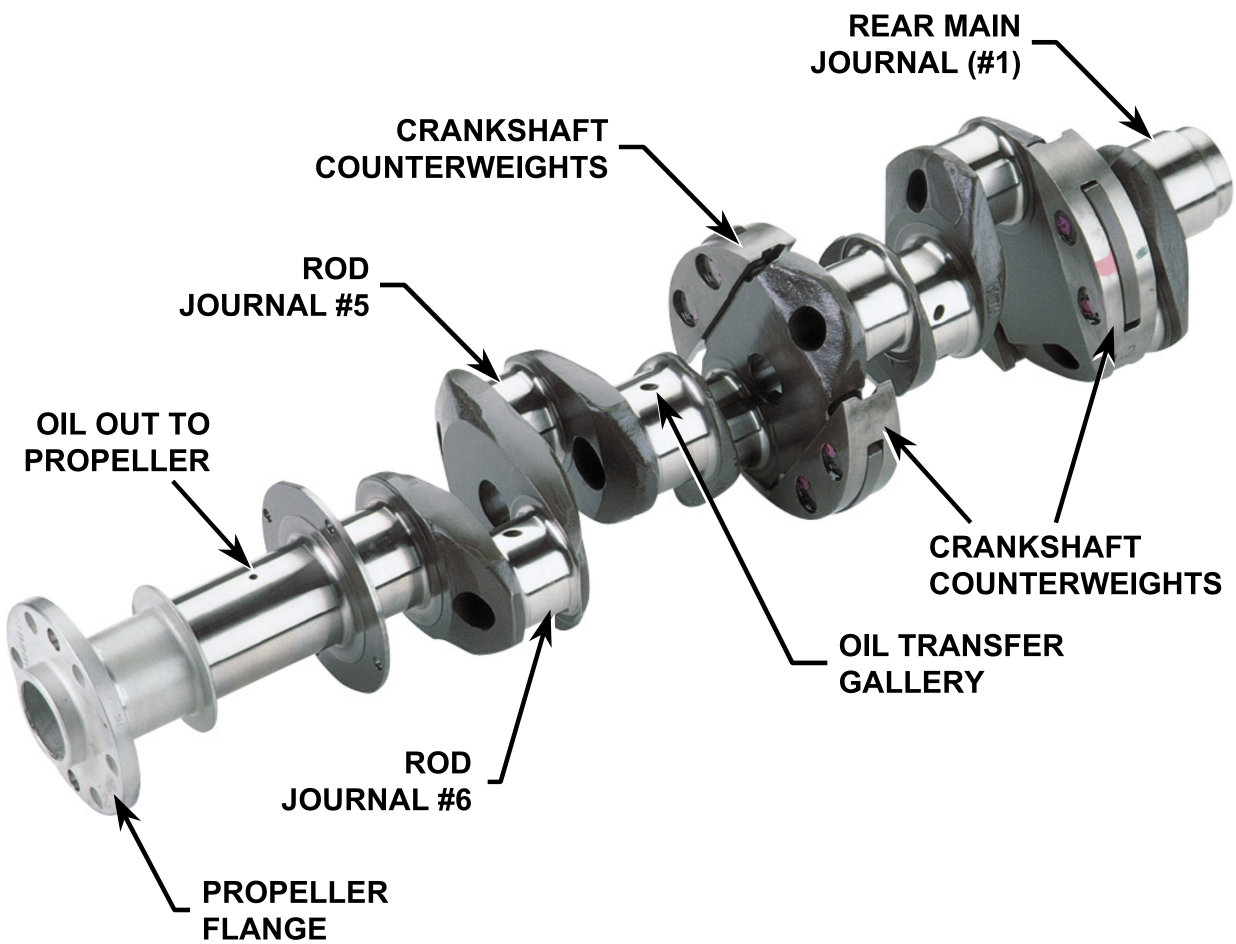


Figure 3-1. 550 Engine Series Crankshaft

Crankshaft - The crankshaft main journals, rod journals and crankshaft cheeks are numbered from the rear of the crankshaft forward. Crankshafts are balanced to ¾ oz. inches calculated on a 2 inch radius and at a rotational speed of 600 R.P.M. The crankshafts are balanced at this low speed because the greater centrifugal forces produced by higher rotational speeds actually throw off the balance.

The crankshaft gear is heated to facilitate installation. The gear is indexed on the crankshaft by a dowel, secured by machine bolts and safety wired.

A neoprene oil seal, a split retainer ring, and helical spring are seated in a machined bore at the front of the crankcase. The helical spring installed inside the oil seal lip provides tension to maintain seal contact with the crankshaft during operation and prevents oil from exiting this area.

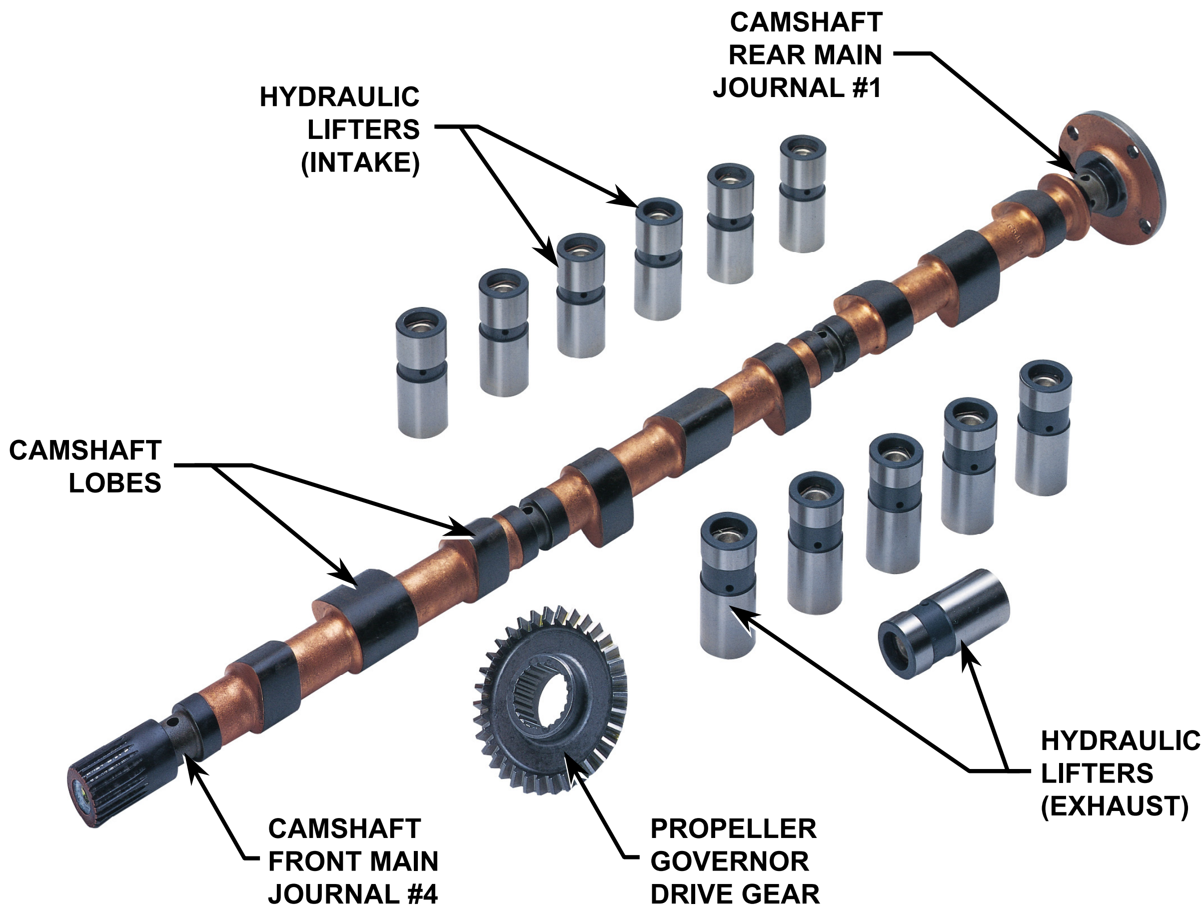


Figure 3-2. 550 Engine Series Camshaft & Lifters

Camshaft - The camshaft is machined from an aircraft quality steel forging. Main journals and cam lobes ground and hardened. The steel surface area of the cam lobes are carburized for additional hardness and wear resistance while the shaft is masked with copper to prevent hardening of this area. During manufacture, the lobes are also coated with a manganese phosphate coating (black areas) to resist rust and lower friction during the initial hours of engine operation. The rear flange of the camshaft has four unequally spaced bolt holes to secure the cam gear to the camshaft and insure proper positioning, locating the gears timing mark in relation to the cam lobes. Valve opening and closing is synchronized with piston position by timing the camshaft and crankshaft gears.

Hydraulic Lifter - The hydraulic lifter performs two functions. First, it provides an interface between the camshaft lobe and the remaining valve train. Hydraulic valve lifters ride on the eccentric cam lobes opening and closing the intake and exhaust valves mechanically via push rod tubes and rocker arms. This allows conversion of the cam lobe profile into a linear movement for actuation of the intake and exhaust valves. Secondly, the hydraulic mechanism inside the lifter maintains zero clearance between the valve and it's actuating components.

The lifter body is made of cast iron with the face being "chilled" during casting. The chilled cast iron face has areas of extremely hard wear resistant material, iron carbides, surrounded by a softer matrix of iron. This combination provides excellent wear characteristics under high contact stress situations such as the cam-lifter interface. The face of the lifter is also manganese phosphate coated for the same reasons as the cam lobes.

The loads on the lifter are a result of the force of the cam lift against the valve springs and the inertia of the components. This load transfers between the cam face and the lifter face over a small area with some sliding occurring between the two surfaces. High contact stresses are generated and are countered by use of very hard materials with splash oil present to reduce friction. The face of the lifter has a small curvature or crown, and the cam lobe has a slight taper. This results in the contact point being off-center of the lifter and causes the lifter to rotate during operation, avoiding single point contact between the lifter and the camshaft lobe.

The interface between a cam lobe and lifter is intended to wear to some degree as the engine operates. This is similar to the piston ring / cylinder wall interface that must seat together for proper operation and wear over time. The manganese phosphate will quickly wear off in loaded areas of the cam lobe and the lifter face. Normal wear may take the form of a bright shiny uniform wear surface, with a circular pattern visible on the lifter face. Damage to the lifters is often referred to as “galling” or “spalling”. Localized areas may show signs of spalling or galling in service due to various operating conditions. Some level of such conditions will frequently be found at overhaul. Note that this wear material as with all other normal wear material will be collected by the oil and trapped in the oil filter element or screen.

200 SERIES ENGINES

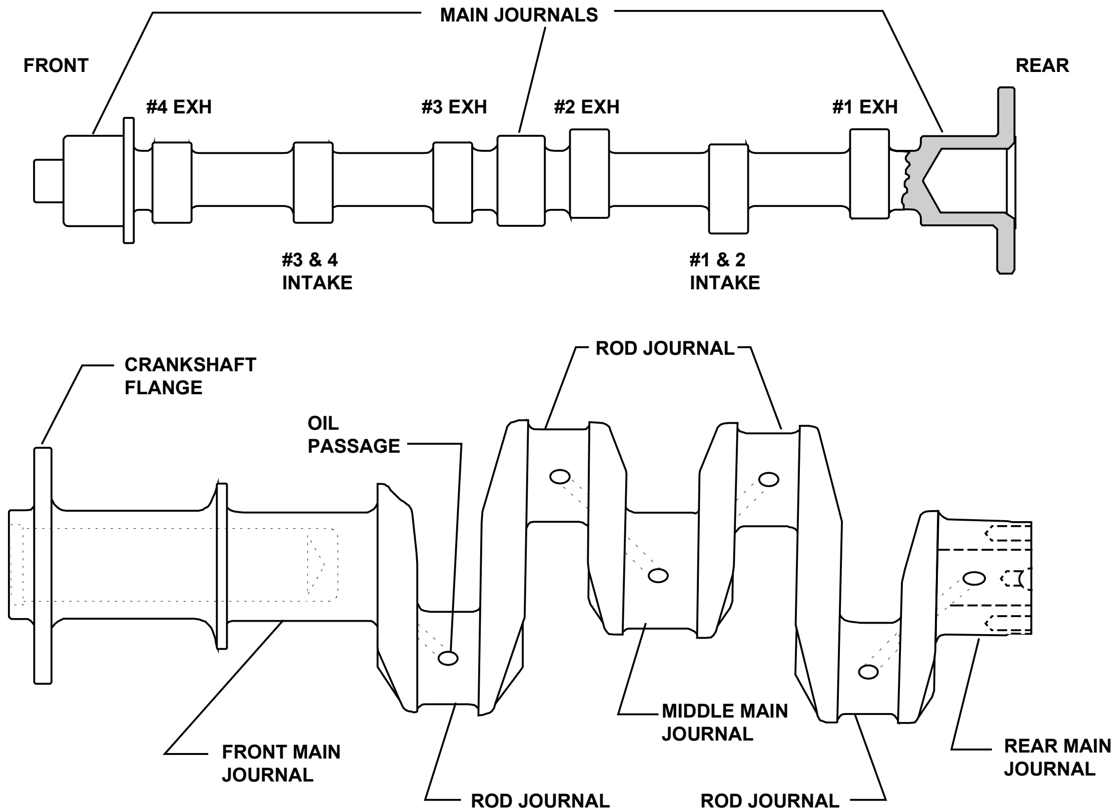


Figure 3-3. O200/IO-240 Crankshaft & Camshaft

Crankshaft - The crankshaft has three main journals running in tri-metallic bearings supported by the main bearing saddles. Four crankshaft rod journals, spaced 180 degrees apart provide attachment of the connecting rods. These 4 cylinder engine crankshafts are not machined to incorporate counterweights.

Camshaft -There are 6 cam lobes, 2 shared intake lobes and 4 individual exhaust, and three main bearing journals. The camshaft is supported by the camshaft bearing journals that are precision line bored in the crankcase.

A front mounted bevel gear is secured to the camshaft and drives the fuel pump driven gear, which drives the accessory drive gear through a common shaft.

360 SERIES ENGINES

COMPONENT DESCRIPTION

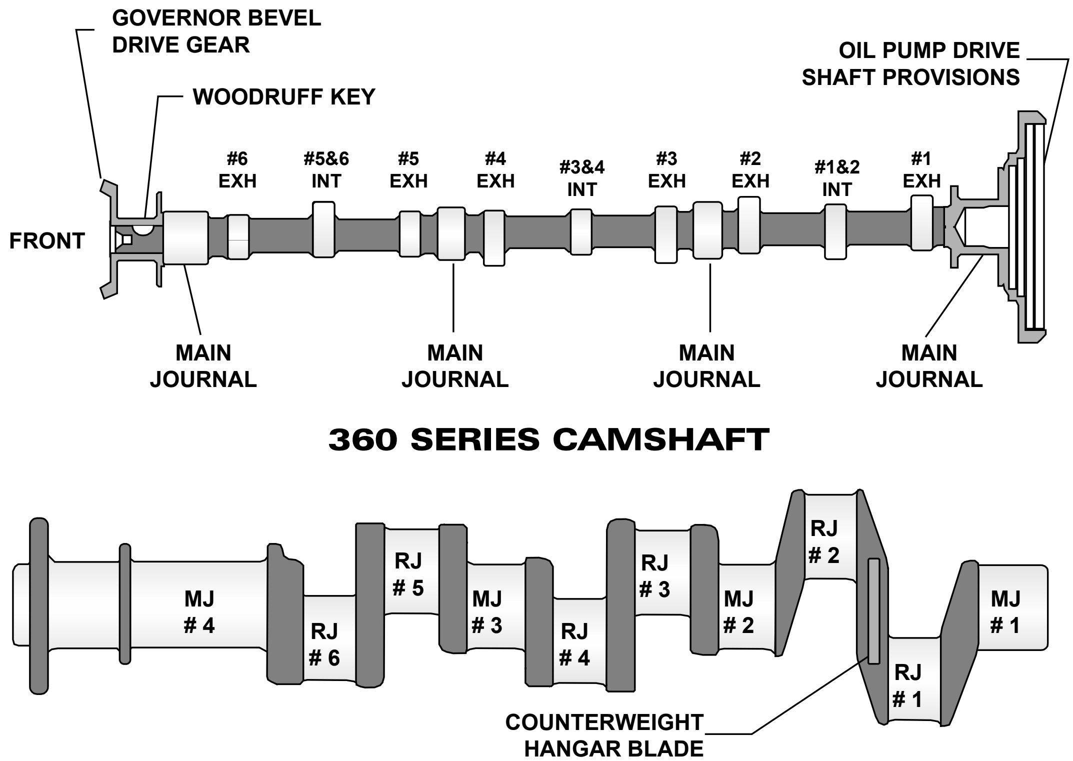


Figure 3-4. 360 Series Crankshaft & Camshaft

Crankshaft - The crankshaft has four, machined, main journals which are supported by precision bearing inserts in each of the four bearing saddles machined in the crankcase. Six machined rod journals provide attachment of the connecting rod assemblies. Counterweights are installed on the #2 crankshaft cheek hanger.

Camshaft - The aircraft quality steel forging is machined on four main journals, nine cam lobes and the gear mount flange at the rear of the camshaft. There are 3 shared intake lobes and 6 individual exhaust lobes.

The rear mounted camshaft gear has internal teeth for driving the oil pump gear and if installed a gear driven alternator or generator. The front mounted, keyed bevel gear drives the governor drive bevel gear which drives the fuel pump through a splined shaft.

470/520/550 SANDCAST SERIES ENGINES

COMPONENT DESCRIPTION

Crankshaft - The crankshaft has five, machined, main journals supported within the crankcase by precision tri-metallic bearing inserts installed in each of the crankcase main bearing saddles. Six, machined, rod journals provide for attachment of the connecting rod assemblies.

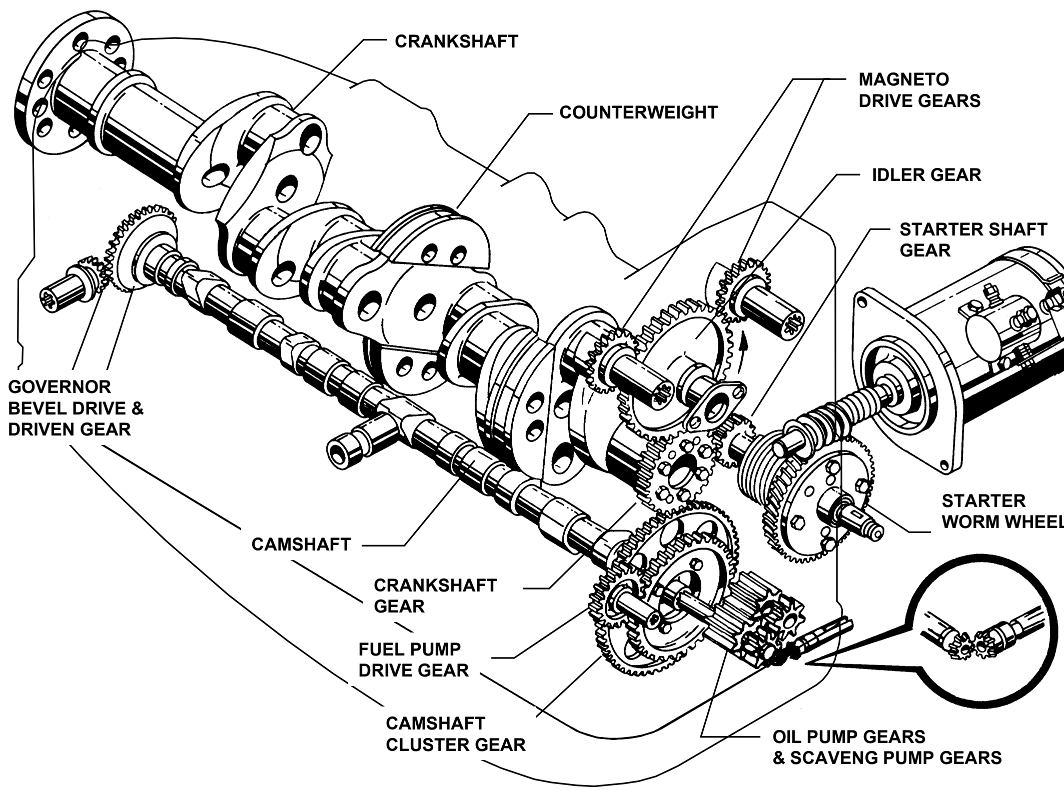


Figure 3-5. Sandcast Drive Train Schematic

Counterweights are installed on the number 2 and number 5 crankshaft cheek hangers. Torque from the crankshaft is transmitted by the crankshaft gear directly to the idler gear and the camshaft gear. The idler gear, rotating in a counterclockwise direction, drives the magneto drive gears. Optional accessories mounted on the upper rear of the crankcase are driven by internal splines of magneto drive gears. The fuel pump drive gear is driven by the camshaft cluster gear. The splined end of the oil pump drive gear mates with the internal splines of the camshaft gear and transmits torque to the oil pump driven gear. The governor drive bevel gear is keyed to the camshaft and meshes with and drives the governor driven bevel gear.

A “V” belt sheave attached to the extended starter adapter shaft gear is fitted with a “V” belt that drives the alternator drive sheave.

Camshaft - The camshaft is made of aircraft quality steel. The forging is machined on four (4) main journals, nine cam lobes. There are 3 shared intake cam lobes and 6 individual exhaust cam lobes.

Idler Gear - The Idler gear assembly rotates within the crankcase supported at its front end by a crankcase bushing and a support pin bushing at its rear. The idler gear is driven directly by the crankshaft. The idler gear drives the left and right magneto accessory drive gears.

520/550 PERMOLD SERIES ENGINES

COMPONENT DESCRIPTION

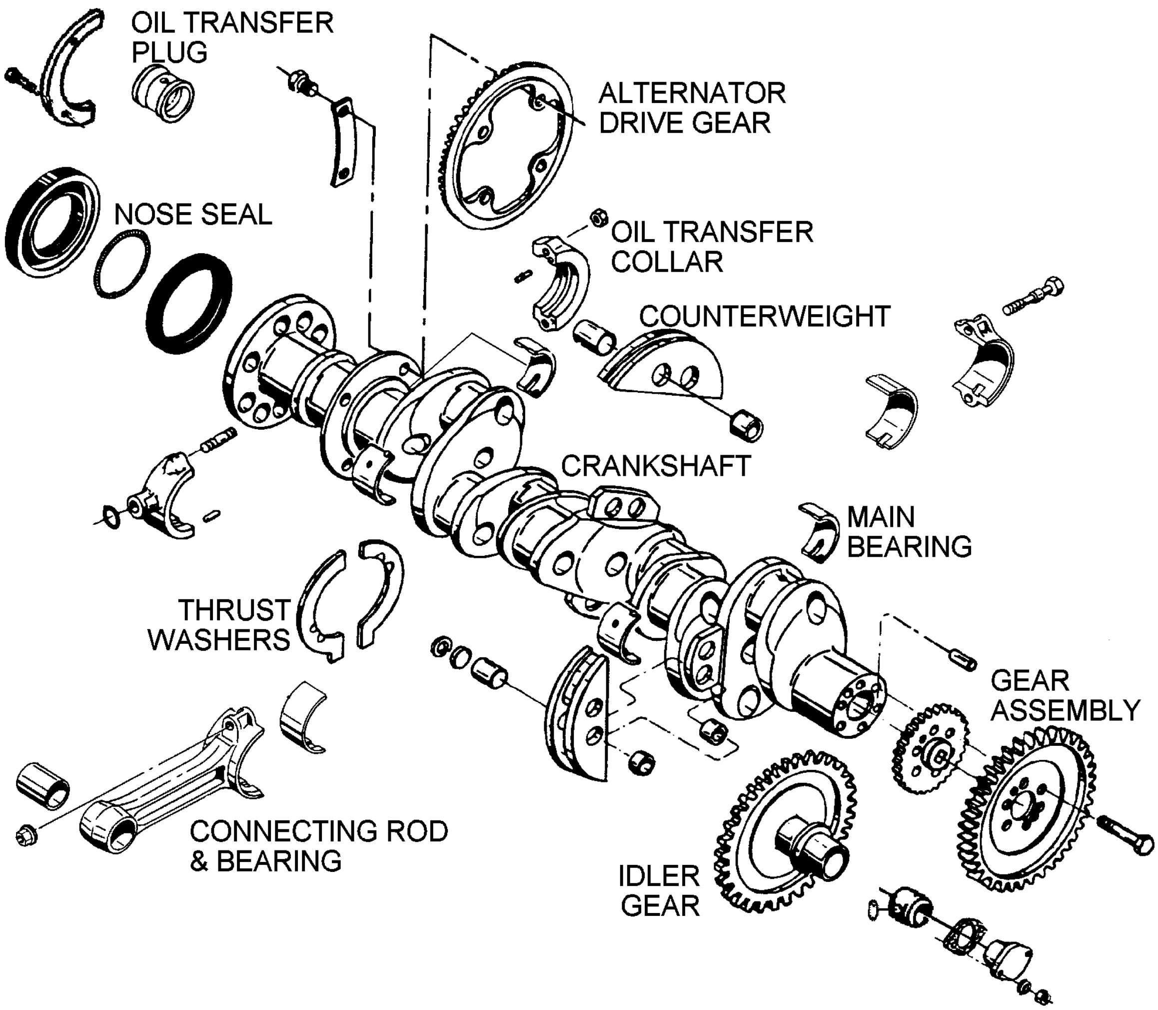


Figure 3-6. Permold Series Crankshaft

Crankshaft - The crankshaft has five, machined, main journals supported within the crankcase by precision tri-metallic bearing inserts installed in each of the crankcase main bearing saddles. Six, machined, rod journals provide for attachment of the connecting rod assemblies.

A flange is machined at the front of the crankshaft, between the number 4 and 5 main journals. The flange has four drilled and tapped holes that are used to attach the alternator drive face gear. The bolts are safetied using lock tabs.

Camshaft - The camshaft is made of aircraft quality steel, with four main journals and nine camshaft lobes, 3 shared lobes for the intake valves (1 & 2, 3 & 4, 5 & 6) and 6 individual lobes for the exhaust valves. The center-line of the camshaft is drilled to provide an oil gallery. The four (4) main journals are drilled to intersect the gallery in the camshaft to provide a path for oil flow through the engine.

The camshaft gear incorporates internal splines to drive the engine oil pump. A front mounted, keyed bevel gear drives the propeller governor drive bevel gear.

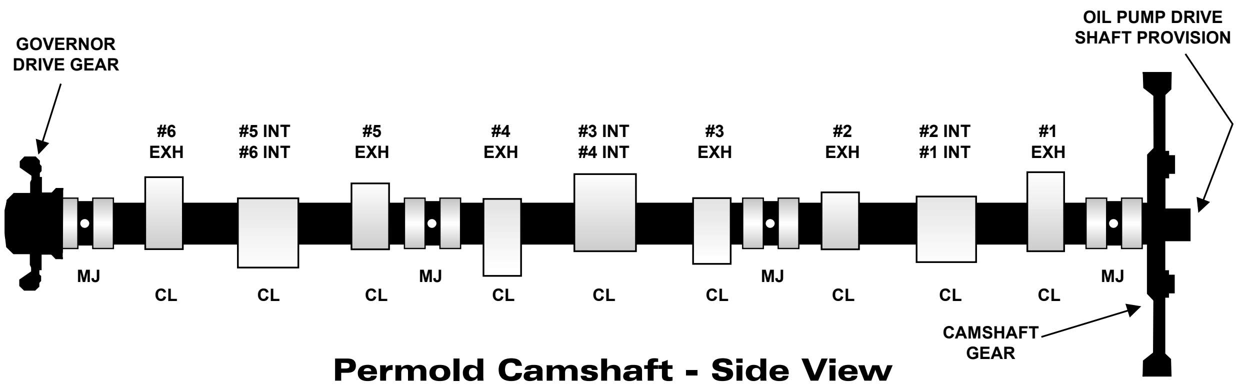


Figure 3-7. Permold Series Camshafts

Idler Gear - The Idler gear assembly rotates within the crankcase supported at its front end by a crankcase bushing and a support pin bushing at its rear. The idler gear is driven directly by the crankshaft. The idler gear drives the left and right magneto accessory drive gears.

GTSIO-520 SERIES ENGINES

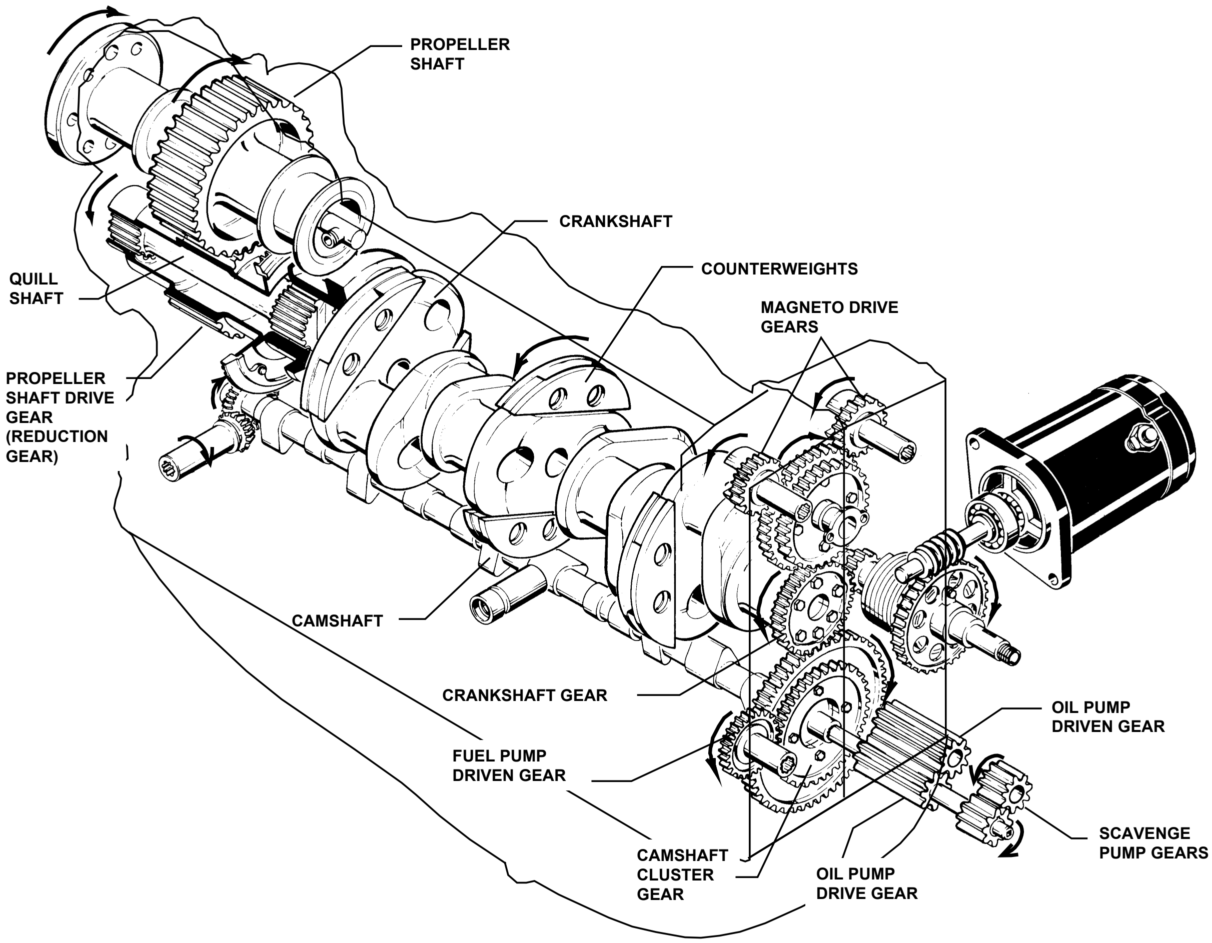


Figure 3-8. Engine Drive Train Schematic - Geared Engines

When starting the engine, torque is transmitted from the electric starter motor to the right angle drive starter adapter. As the worm shaft rotates, it turns the worm-wheel. The clutch spring mounted on the worm-wheel hub, is tightened to grip the drum of starter adapter shaft gear. The starter adapter shaft gear is meshed with the crankshaft gear and turns the crankshaft. After engine start the spring returns to its normal position allowing the shaft gear to rotate freely in the starter adapter housing. A Viscous Damper is keyed and secured to the starter adapter shaft as it exits the rear of the housing.

Torque from the crankshaft is transmitted to the idler gear, camshaft gear and propeller reduction (bowl) gear.

The idler gear, rotating in a clockwise direction, drives the magneto drive gears. Optional accessories mounted on the upper rear of the crankcase are driven by internal splines of magneto drive gears.

The fuel pump drive gear is driven by the camshaft cluster gear. The splined end of t he oil pump drive gear mates with the internal splines of the camshaft gear and transmits torque to the oil pump drive gear. The governor drive bevel gear is keyed to the camshaft and meshes with and drives the governor drive bevel gear.

COMPONENT DETAILED DESCRIPTION

Crankshaft: - The crankshaft is machined from a steel forging with 4 main bearing journals and 6 crankpin (connecting rod) journals. The front of the crankshaft is splined on the I.D. to accommodate a reduction gear quill shaft. The crankshaft gear is installed on the rear main journal, located by a dowel pin and secured by machine bolts and safetied.

There are 3 sets of counterweights, installed on counterweight hangers located on number 2, 5 and 8 crankshaft cheek.

Quill Shaft - The quill shaft is splined on both ends. The rear of the quill shaft mates with internal splines in the crankshaft, while the front of the quill shaft mates with internal splines in the propeller shaft drive gear. The quill shaft connects the propeller drive gear with the crankshaft.

Propeller Shaft Drive Gear - The propeller shaft drive gear is located forward of the crankshaft. The alternator drive (face) gear is attached to a machined flange that has 4 drilled and taped holes. The alternator drive gear is secured with machine bolts and safetied by lock plates.

Propeller Shaft - The propeller shaft is located above the crankshaft. The front and rear journals ride in tri-metallic bearing inserts installed in bearing saddles.

A synthetic rubber oil seal with a reinforcing ring and helical spring is seated in a machined recess in the crankcase. The helical spring is seated in the seal's lip and provides tension to maintain contact with the crankshaft.

Camshaft - The camshaft is made of aircraft quality steel. The forging is machined on four (4) main journals, nine cam lobes. There are 3 shared intake cam lobes and 6 individual exhaust cam lobes.

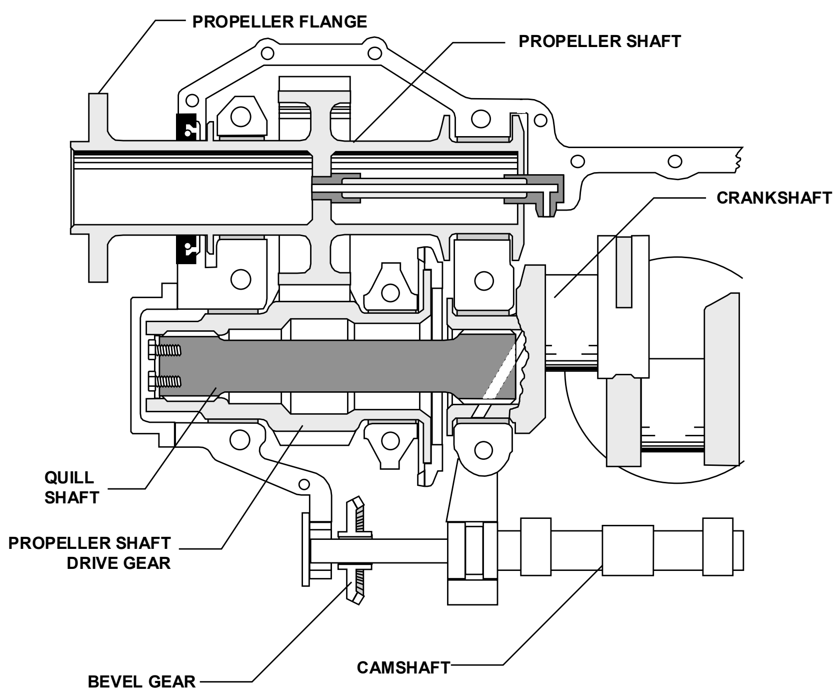


Figure 3-9. GTSIO Series Engines Reduction Gear Diagram

Idler Gear - The Idler gear assembly rotates within the crankcase supported at its front end by a crankcase bushing and a support pin bushing at its rear. The idler gear is driven directly by the crankshaft. The idler gear drives the left and right magneto accessory drive gears.

STARTER ADAPTERS COMPONENT DESCRIPTION

360 SERIES ENGINE MODELS

The 360 series engines utilize a starting system that employs an electric starter motor mounted on a right angle drive adapter. As the starter motor is electrically energized, the adapter worm shaft and gear engage the starter shaftgear by means of a spring and clutch assembly. As the shaftgear rotates, it in turn rotates the crankshaft gear and crankshaft. After engine start, the clutch spring disengages from the shaftgear.

The 360 series engines can be equipped with an accessory drive adapter and freon compressor mounting brackets. The accessory drive adapter has provisions for installing a sheave on an extended shaft.

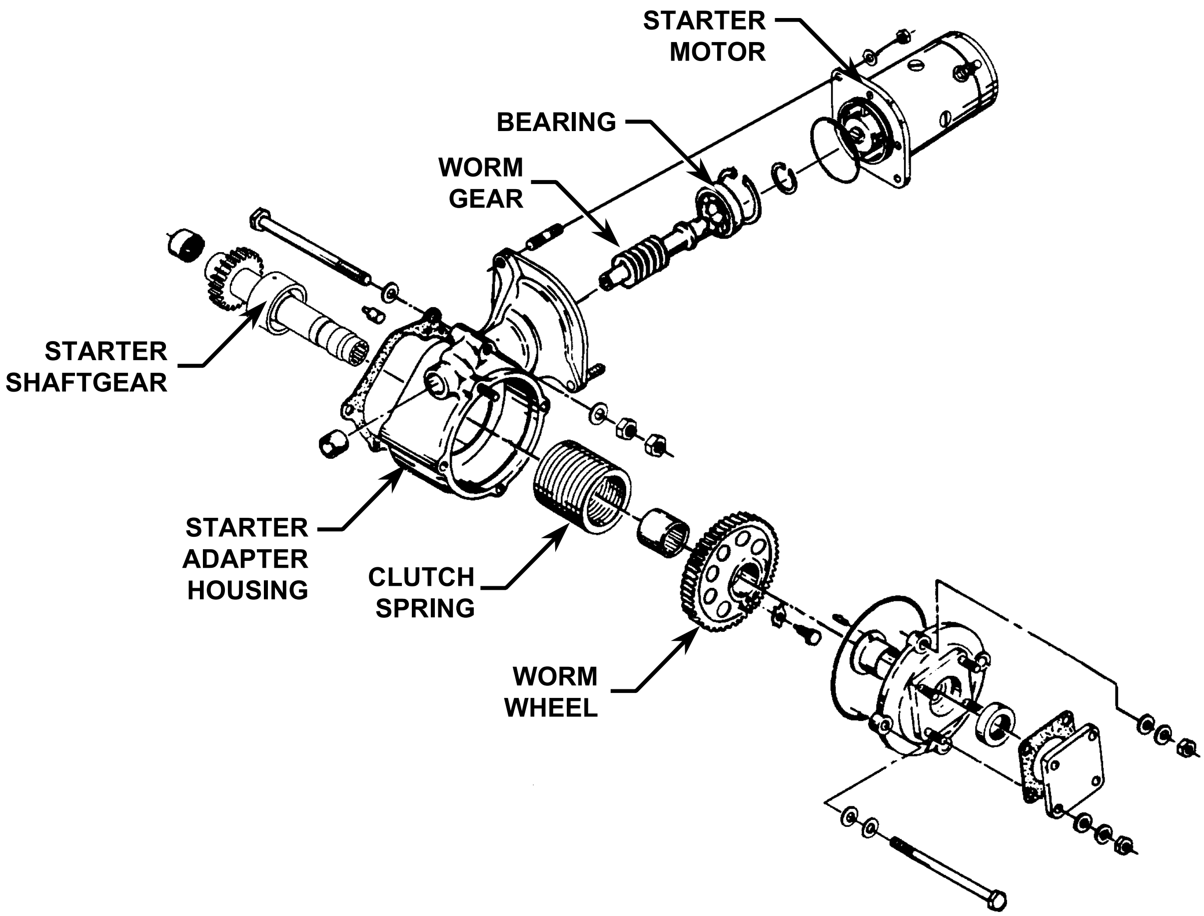


Figure 3-10. 360 Series Starter Adapter Exploded View

Starter Adapter - The starter adapter assembly uses a worm drive gear shaft and worm gear to transfer torque from the starter motor to the clutch assembly. The shaft is supported in the housing at the starter end by a ball bearing and retaining ring, the opposite end is supported by a needle bearing pressed into the adapter housing. As the worm gear rotates the worm wheel and clutch spring, the clutch spring is tightened around the drum of the starter shaftgear. As the shaftgear turns, torque is transmitted directly to the crankshaft gear. The starter shaftgear is supported at the adapter cover by a pressed in ball bearing, and is supported at the opposite end by a needle bearing in the crankcase. The 360 series engines starter adapter rotates the crankshaft in a clockwise direction.

SANDCAST SERIES STARTER ADAPTERS

The starter adapter assembly uses a worm drive gear shaft and worm gear to transfer torque from the starter motor to the clutch assembly. The shaft is supported in the housing at the starter end by a ball bearing and retaining ring. The opposite end is supported by a needle bearing pressed into the adapter housing. As the worm gear rotates the worm wheel and clutch spring, the clutch spring is tightened around the drum of the starter shaftgear. As the shaftgear turns, its torque is transmitted directly to the crankshaft gear. The starter shaftgear is supported at the adapter cover by a pressed in ball bearing, and is supported at the opposite end by a needle bearing pressed into the 3-3-5 crankcase half. New style starter adapter shaftgears do not have a knurled drum. The new style adapter also uses a new style clutch spring, worm wheel and worm gear drive shaft assembly. The new style starter adapter housing does not use a clutch spring sleeve.

New style starter adapters part number 643259 will exhibit varying degrees of resistance to propeller rotation in the direction opposite of normal engine cranking rotation. This is caused by the light friction which is required to initiate clutch engagement in the cranking mode and is considered normal. Removing the starter motor may reduce resistance when rotating propeller opposite direction of normal rotation.

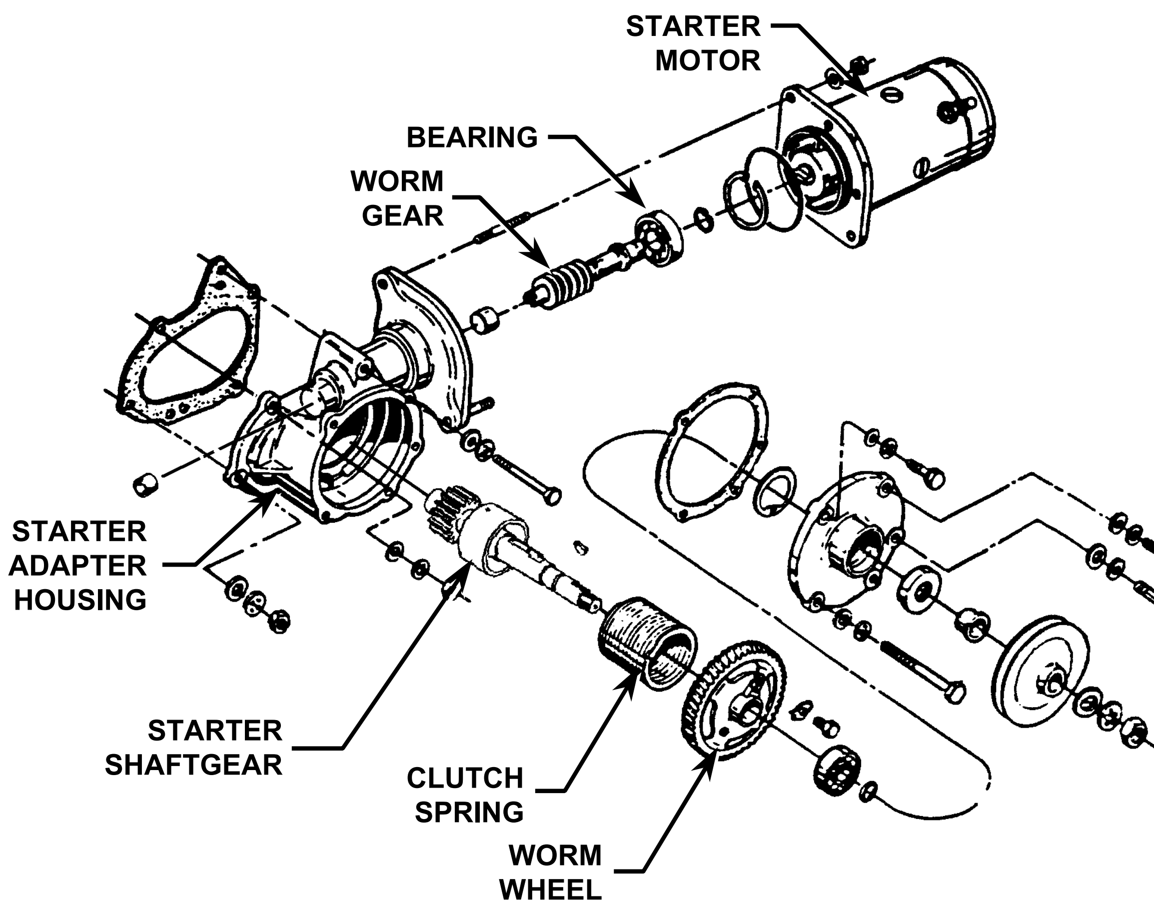


Figure 3-11. Sandcast Series Starter Adapter Exploded View

PERMOLD SERIES STARTER ADAPTERS

The Permold Series engines utilize a starting system that employs an electric starter motor mounted on a right angle starter drive adapter. The right angle drive adapter serves to shorten engine overall length. As the starter motor is electrically energized, the adapter worm shaft and gear engage the starter shaftgear by means of a spring and clutch assembly. As the shaftgear rotates, it in turn rotates the crankshaft gear and crankshaft. When the engine starts and accelerates, the gripping action of the clutch spring is relieved, disengaging the shaftgear from the worm shaft and electric starter motor.

The starter adapter assembly uses a worm drive gear shaft and worm gear to transfer torque from the starter motor to the clutch assembly. The shaft is supported in the housing at the starter end by a ball bearing and retaining ring, the opposite end is supported by a needle bearing pressed into the adapter housing. As the worm gear rotates the worm wheel and clutch spring, the clutch spring is tightened around the drum of the starter shaftgear. As the shaftgear turns, its torque is transmitted directly to the crankshaft gear. The starter shaftgear is supported at the adapter cover by a pressed in ball bearing, and is supported at the opposite end by a needle bearing pressed into the 3-3-5 crankcase half.

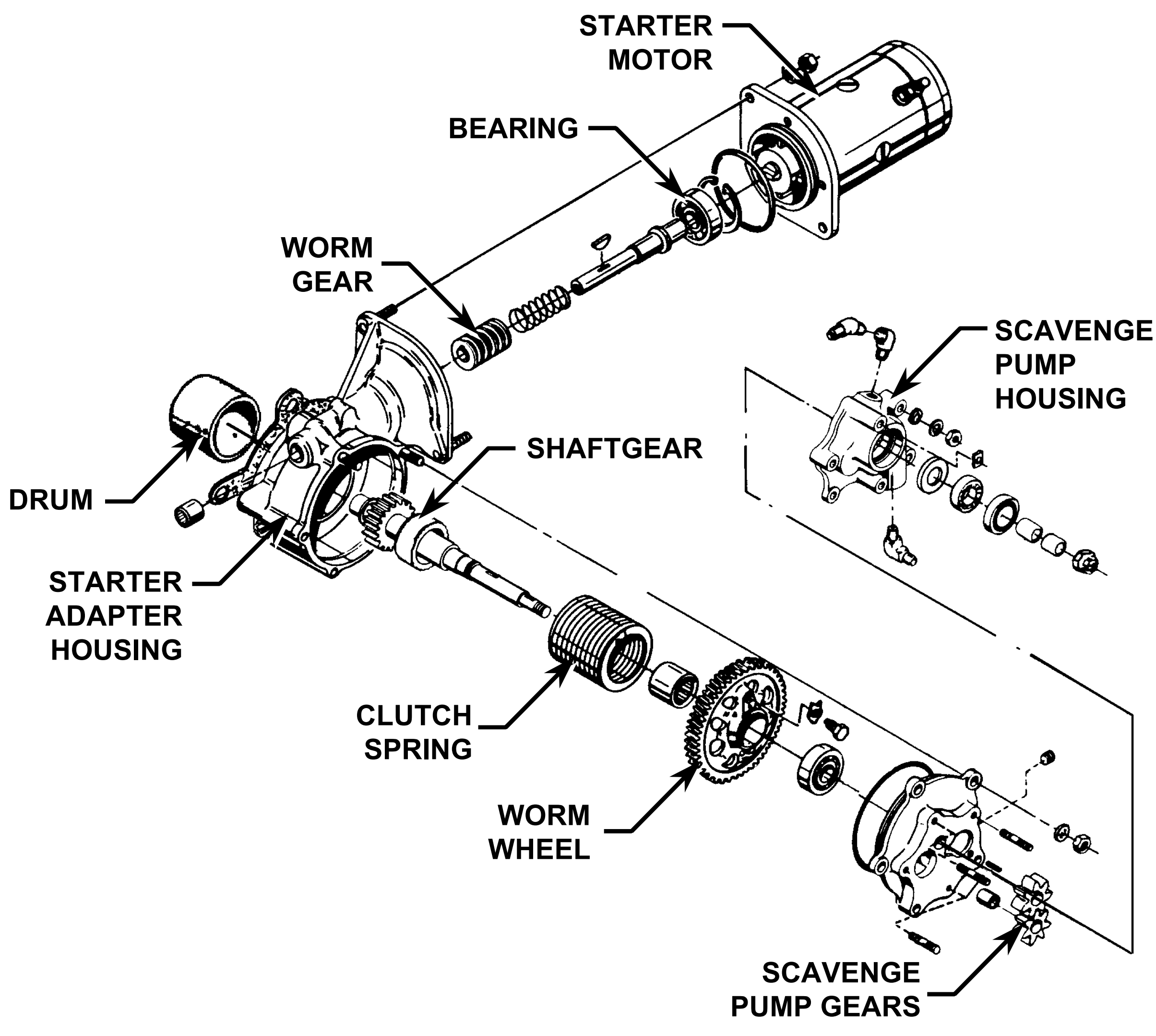


Figure 3-12. Permold Series Starter Adapter Exploded View

CRANKSHAFT COUNTERWEIGHTS

Counterweight assemblies are supplied in matched pairs with the bushings installed. Maximum weight difference between counter-weights installed on opposing counterweight hangers on the same crankshaft cheek must not exceed 2 grams.

The counterweight order number designates the vibration frequency the counterweight is absorbing. If a vibration frequency occurs six times per revolution, the counterweight is designated a 6th order counterweight. Similarly, if a vibration occurs five times per revolution, the counteracting counterweight is designated a 5th order counterweight. Counterweight order, i.e.; 6th order, is determined by the diameter of the counterweight pin.

The figure below is an extract from SB00-3A, which details the correct processes for installation of counterweight assemblies with their retaining plates and snap rings. When these procedures are followed the counterweight will remain permanently fixed to the crankshaft.

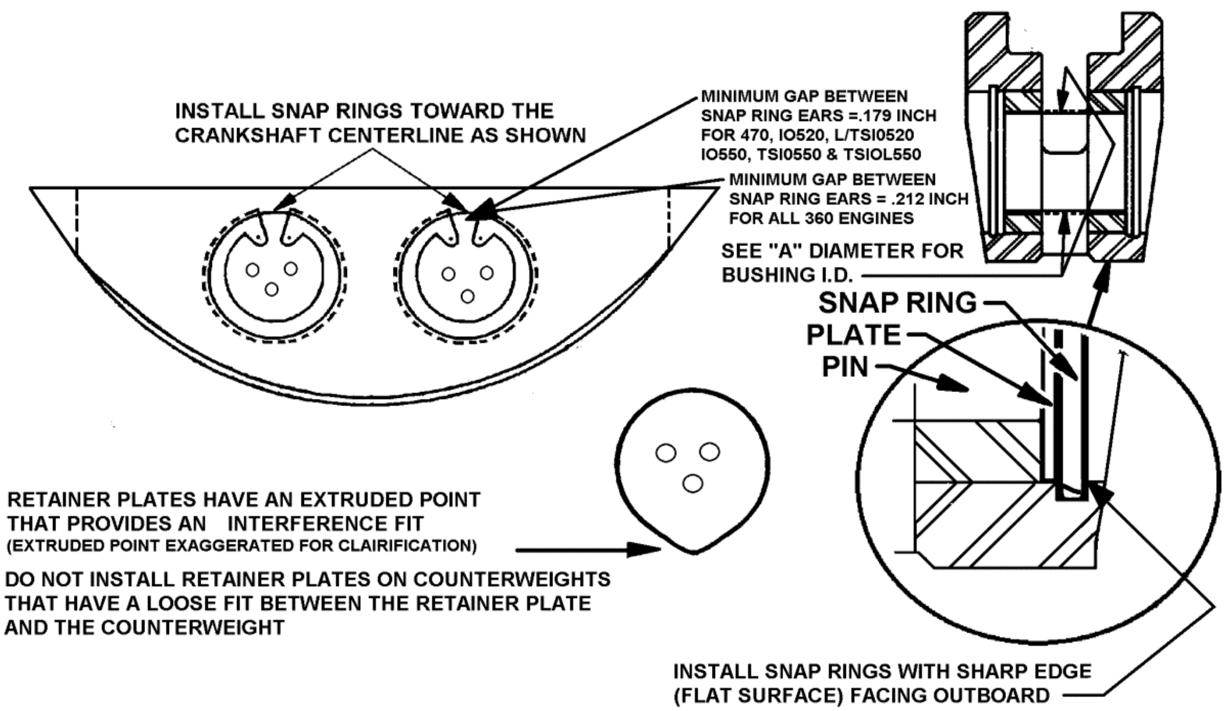


Figure 3-13. Counterweight Installation

CONNECTING RODS

The connecting rods are made of aircraft quality steel. The connecting rod large diameter end, which attaches to the crankshaft crankpin or rod journal, is fitted with a cap and two (2) piece bearing. The bearing cap is held to the main rod by special bolts and nuts.

A split steel backed bronze bushing is pressed into the piston pin end and machined for a precision fit. Weight variation of connecting rods in opposing bays, Example: #1 and #2 connecting rods, is limited to 1/2 ounce/14 grams.

NOTE: Some Older models use castelated nut with cotter pin

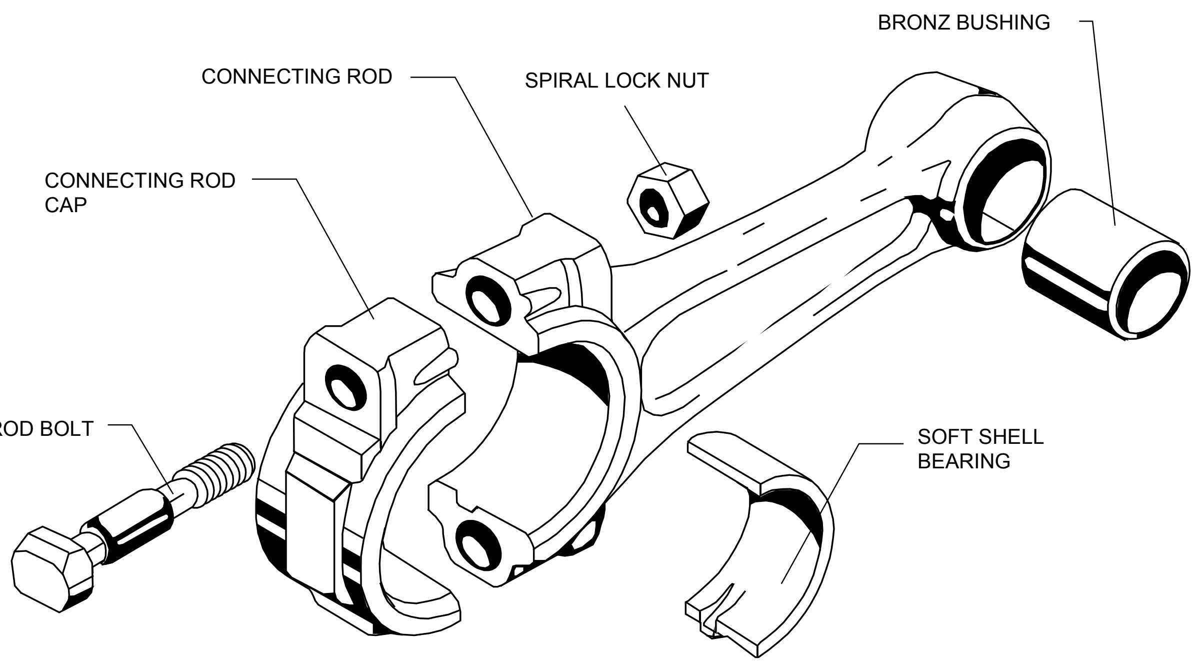


Figure 3-14. Connecting Rod

The figure below is an extract from SB00-3A, which details the inspection criteria for connecting rods.

WARNING
FAILURE TO COMPLY WITH THESE SPECIFICATIONS AND INSTRUCTIONS WILL RESULT IN ENGINE MALFUNCTION AND STOPPAGE.

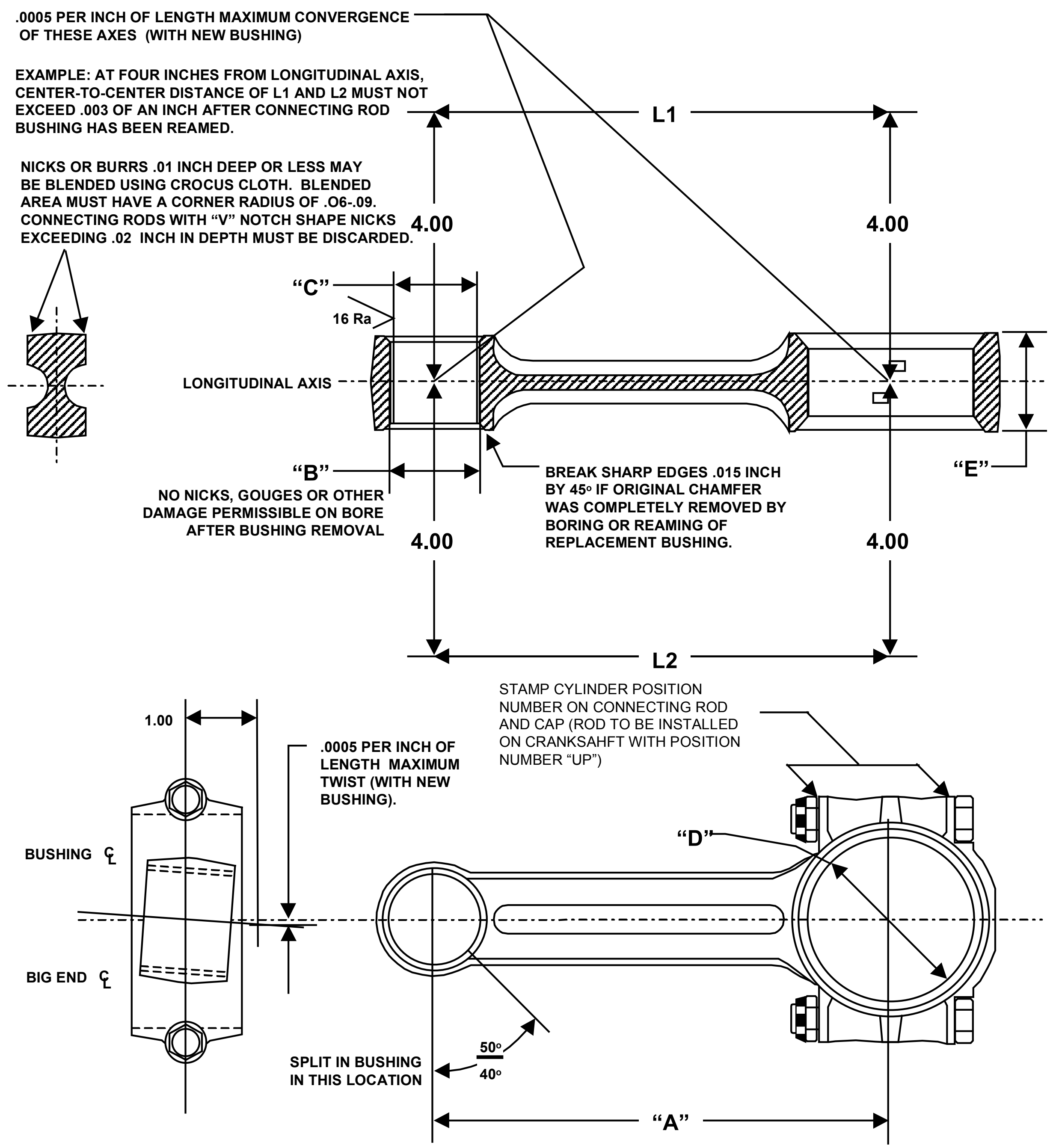


Figure 3-15. Connecting Rod Inspection Criteria

SUMMARY

In this chapter we discussed the internal components of the drive train to emphasize the crankshaft and camshaft designs of the various model engines. The starter adapters were also discussed for the six cylinder engine models that incorporate this design. The lubrication systems of these engines will be discussed in the next chapter.

KEY TERMS

BHP — Brake Horsepower. The power actually delivered to the engine propeller shaft. It is so called because it was formerly measured by applying a brake to the power shaft of an engine. The required effort to brake the engine could be converted to horsepower - hence: "brake horsepower".

Corrosion — Deterioration of a metal surface usually caused by oxidation of the metal.

Four Cycle — Short for "Four Stroke Cycle." It refers to the four strokes of the piston in completing a cycle of engine operation (Intake, Compression, Power and Exhaust). In a four stroke engine the camshaft turns at half crankshaft speed in order that all valve timing for all cylinders can be satisfied in one cam revolution.

Gallery — A passageway in the engine or subcomponent. Generally one through which oil is flowed.

Galling or Scuffing — Excessive friction between two metal surfaces resulting in particles of the softer metal being torn away and literally welded to the harder metal.

Overspeed — When an engine has exceeded its rated revolutions per minute.

Propeller Load Curve — A plot of horsepower, fuel flow, or manifold pressure versus RPM through the full power range of one engine using a fixed pitch propeller or a constant speed propeller running on the low pitch stops. This curve is established or determined during design and development of the engine.

Propeller Pitch — The angle between the mean chord of the propeller and the plane of rotation.

Run Out — Eccentricity of wobble of a rotating part.

TBO — Time Between Overhauls. Usually expressed in operating hours.

T.D.C. — Top Dead Center. The position in which the piston has reached the top of its travel. A line drawn between crankshaft rotation axis, through the connection rod and axis and the piston pin center would be straight line. Ignition and valve timing are stated in terms of degrees before or after TDC.

Torque — Twisting moment or leverage, stated in pounds-foot (or pounds-inch).

REVIEW EXERCISES

1. The Crankshaft main journals, rod journals and crankshaft cheeks are numbered from ______

   ____

2. What does a 6th order counterweight designate?

   a. The design number of the counterweight

   b. The number of cylinders installed on an engine

   c. The number of counterweights that must be installed

   d. The vibration frequency the counterweight is designed to absorb

3. List the primary difference between a Sandcast and a permold camshaft installed on six cylinder engines.

   ____

   ____

4. What is the purpose of the Idler Gear on GTSIO-520 engines? __________________________

   ____

   ____

5. What type of hardening process is used on the crankshaft?

   a. Nitride

   b. Carburize

   c. Tuftride

   d. Temper

6. Explain why the camshaft has a copper plated shaft surface applied before hardening? _____

   ____

7. Which service bulletin covers the inspection criteria for crankshaft counterweights and connecting rods?

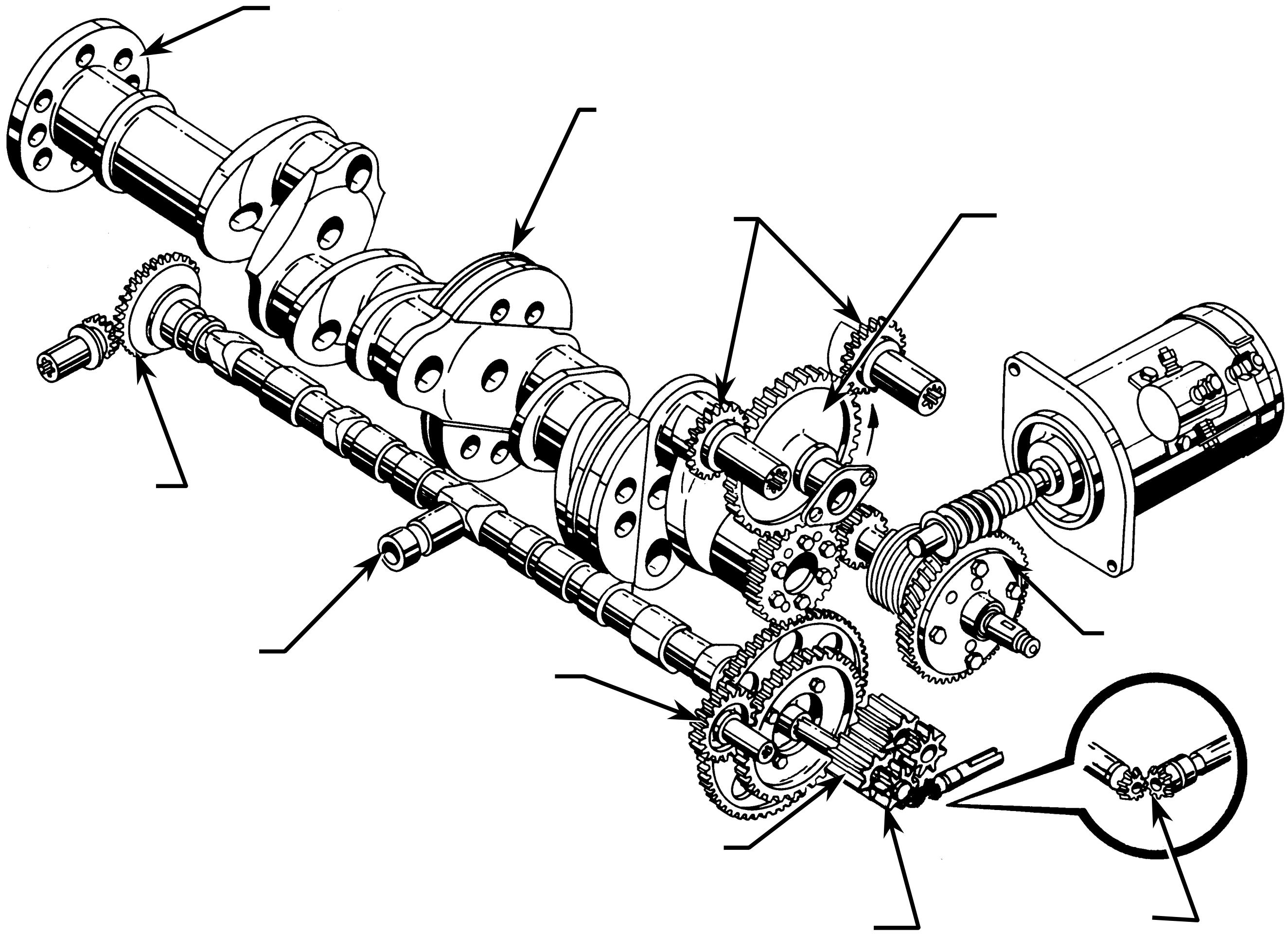
   a. SB03-3

   b. SIL99-2A

   c. SID97-2B

   d. SB00-3A

8. Referring to the figure below, identify the components called out by arrows.



Chapter Four

Lubrication Systems & Components

CHAPTER 4 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

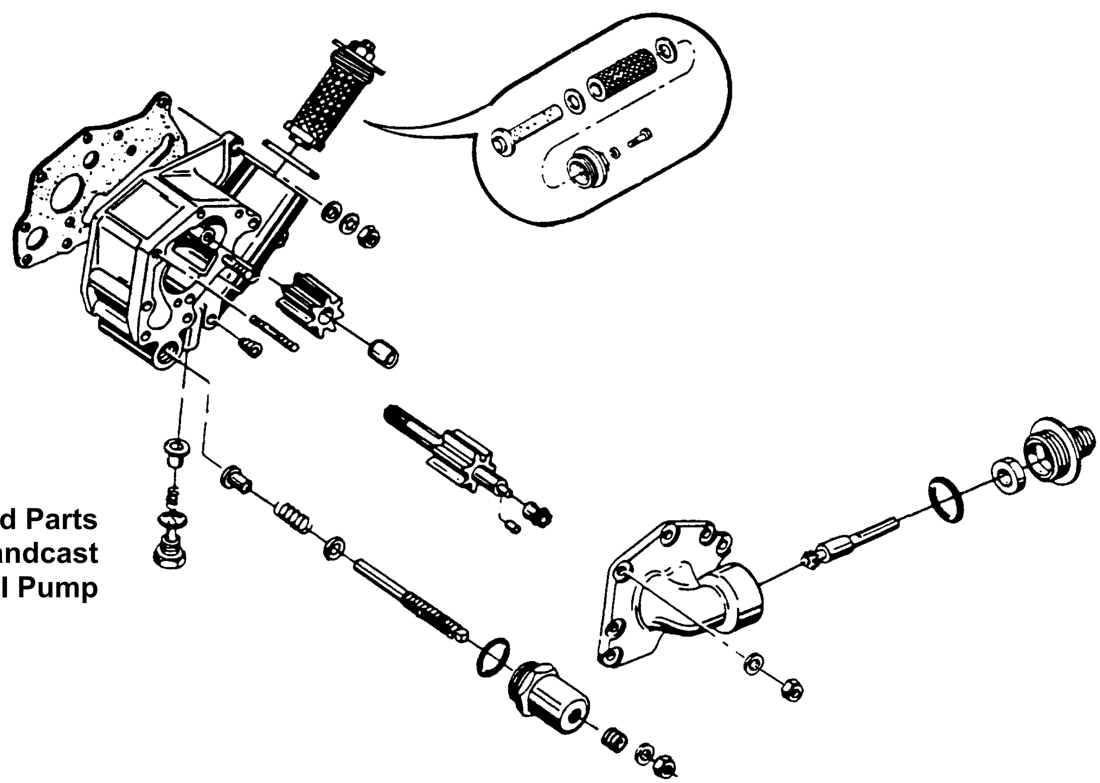
① Describe the processes for lubricating the engine.

② Identify the Oil pressure requirements for Continental engine designs.

③ Describe the fundamental purposes of the Oil Cooler.

④ Describe the fundamental purposes of the Vernatherm.

⑤ Describe the fundamental purposes of the Oil Pumps.



Exploded Parts view of a Sandcast Series Oil Pump

LUBRICATION SYSTEM DESCRIPTION
240 SERIES ENGINES

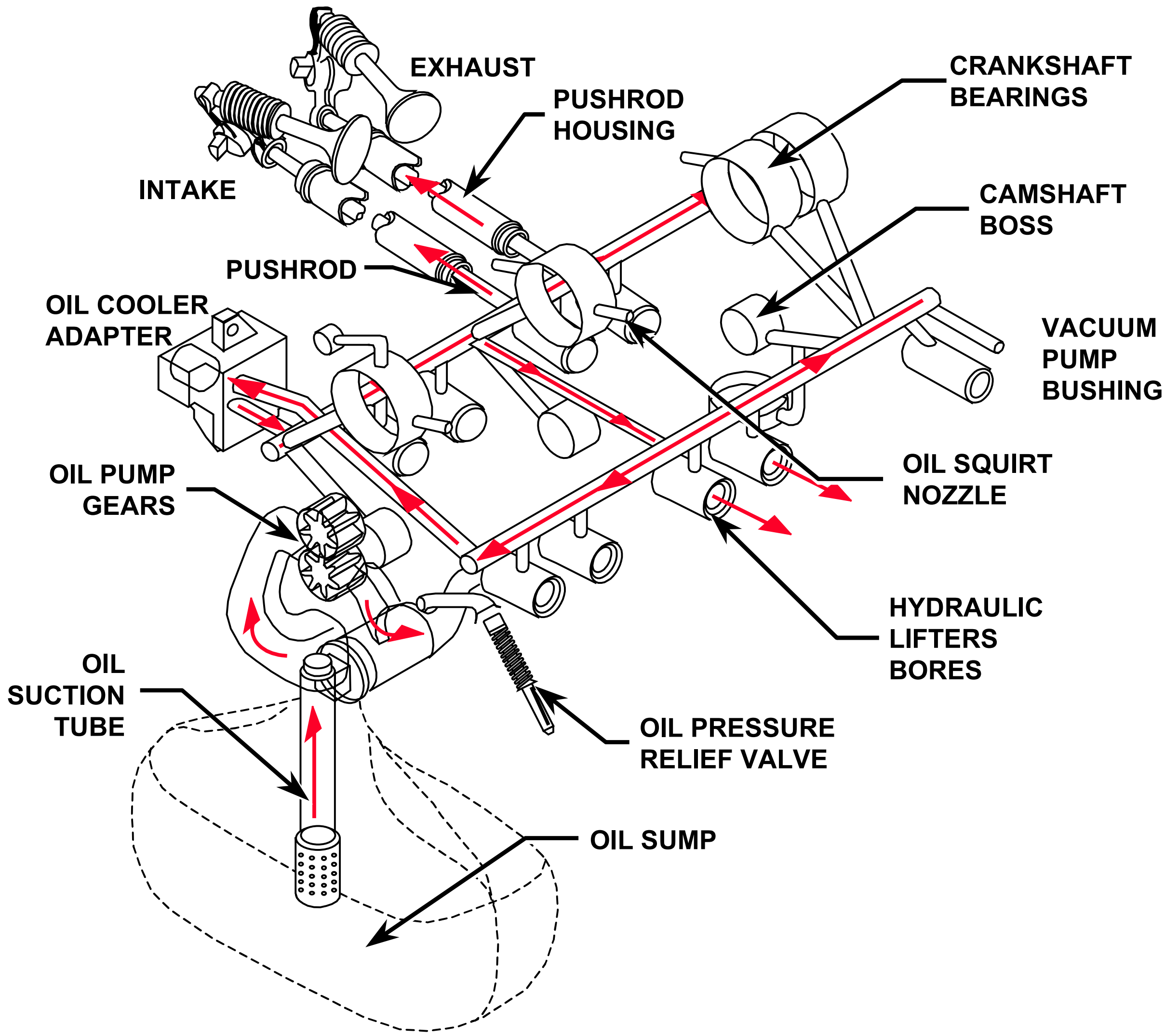


Figure 4-1. IO-240 Series Oil Schematic.

The engine oil supply is contained in the sump. Oil is drawn from the sump through the oil suction tube by the engine driven, gear type oil pump. Oil flows around the chambers between the gear teeth, emerging from the outlet port to flow through the passages in the accessory case. The outlet from the accessory case aligns with a drilled passage in the crankcase. This passage together with an intersecting passage drilled across the crankcase allows oil to flow to the oil cooler adapter. From the adapter, oil flows to the airframe supplied oil cooler to the oil screen or oil filter. The oil returns back to the adapter and then into the left hand oil gallery. The oil flows forward through the oil gallery across the crankcase through the passages connected by the camshaft front journal groove and into the right hand oil gallery. This lubricates the camshaft front bearing. This gallery is blanked off at the rear of the crankcase by the accessory case.

The oil pressure relief valve is located on the right hand lower side of the accessory case. It's passages are connected to the oil pump outlet passage. The valve opens when the pump pressures exceed the adjusted limit and oil is directed back to the sump.

An oil passage drilled from the vacuum pump adapter to the left hand crankcase passage provides an oil feed for lubricating the adapter bushing. Oil drainage from the bushing is returned to the crankcase cavity through two oil passages just above the oil seal seat. If a vacuum pump is installed, an external oil return line must be provided to return the oil from the vacuum pump to the tapped hole in the crankcase.

Two passages drilled in the right hand oil gallery feed oil to the crankshaft front main bearing. Two drilled passages from the left hand oil gallery feed oil to the center and rear main bearings. The left hand oil gallery also feeds the camshaft center and rear bearings. A portion of the crankshaft main bearing oil, flows through the crankshaft web passages to the crankpins. The oil film formed in the big end bearings is continually replenished, the oil being forced to spray from their ends fills the case interior with a mist. Oil sprayed onto the cylinder walls is scraped back into the case by the piston rings. The small end bearings and cylinder walls are lubricated and cooled by the spray. The gears in the accessory case are similarly lubricated by spray (mist) from the main and rear camshaft bearings.

Piston cooling is aided by a jet of pressurized oil which squirts from nozzles installed in the main bearing bores to the underside of the pistons.

Oil is supplied to the hydraulic lifters through oil holes in the crankcase. These holes align with the groove in the body of the tappet. From the tappet sockets the oil flows through the hollow pushrods to the rocker arm passages to lubricate the rocker bushings. The valve stems are lubricated by an oil spray (mist) from the rockers. The oil returns to the crankcase from the rocker boxes through the pushrod tubes, then back to the sump through the open center of the oil sump mounting flange.

Oil Pump - The positive displacement oil pump consists of two meshed gears that revolve inside the oil pump housing machined in the accessory case. An oil pump cover is secured to the housing using 4 bolts, safetied with tab washers.

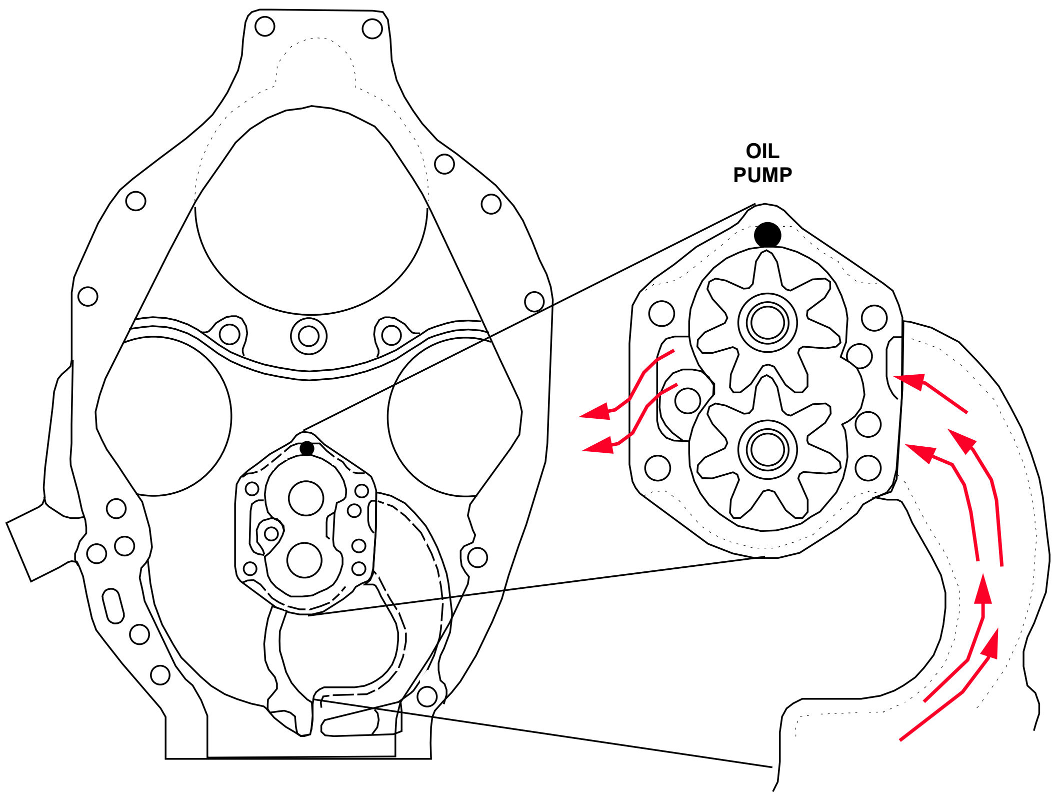


Figure 4-2. IO-240 Oil Pump

The camshaft drives the oil pump drive gear, which drives the oil pump driven gear. The oil pump driven gear is supported by a shaft pressed into the accessory case and secured by the oil pump cover.

The oil pump drive gear shaft is supported by bushings pressed into the crankcase and oil pump cover plate. The oil pump drive gear shaft incorporates provisions to drive a mechanical tach.

During engine operation the oil pump drive gear turns (looking from the rear of the engine forward) counterclockwise, this drives the driven gear in a clockwise direction. The two gears turning create a suction that draws oil from the sump, through the oil suction tube to the pump gears. The oil is then forced around the outside of the gears and directed through a gallery to the oil pressure relief valve and oil screen or filter.

The oil pressure relief valve limits oil pressure to a predetermined value. This insures adequate lubrication to the engine and its accessories at high engine RPM. From the oil pressure relief valve oil flows through galleries in the crankcase to the various parts of the engine that require lubrication.

Oil Cooler Adapter - The oil cooler adapter attaches to the left side of the crankcase, aft of number 2 cylinder. The adapter allows the use of a remote mounted oil cooler. The adapter also incorporates a bypass valve that allows oil flow in the event that the cooler becomes restricted.

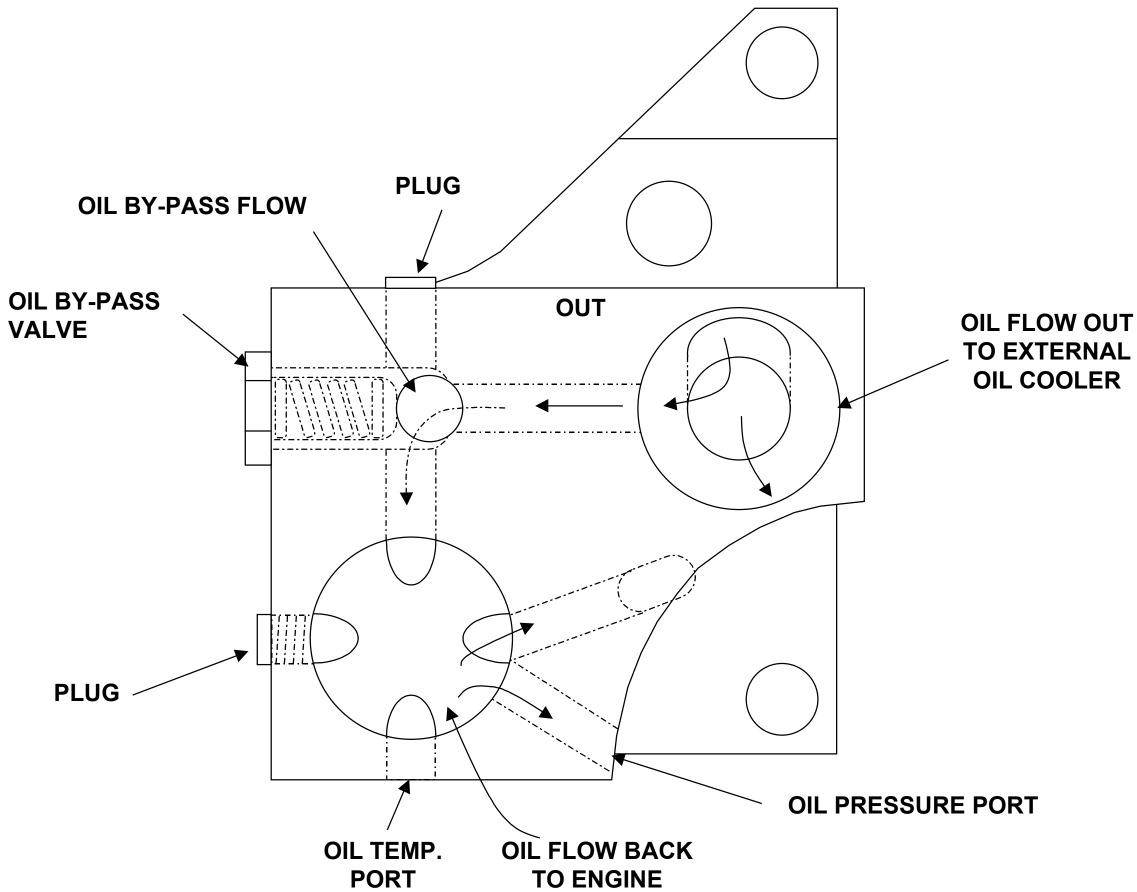


Figure 4-3. IO-240 Oil Cooler Adapter

360 SERIES ENGINES

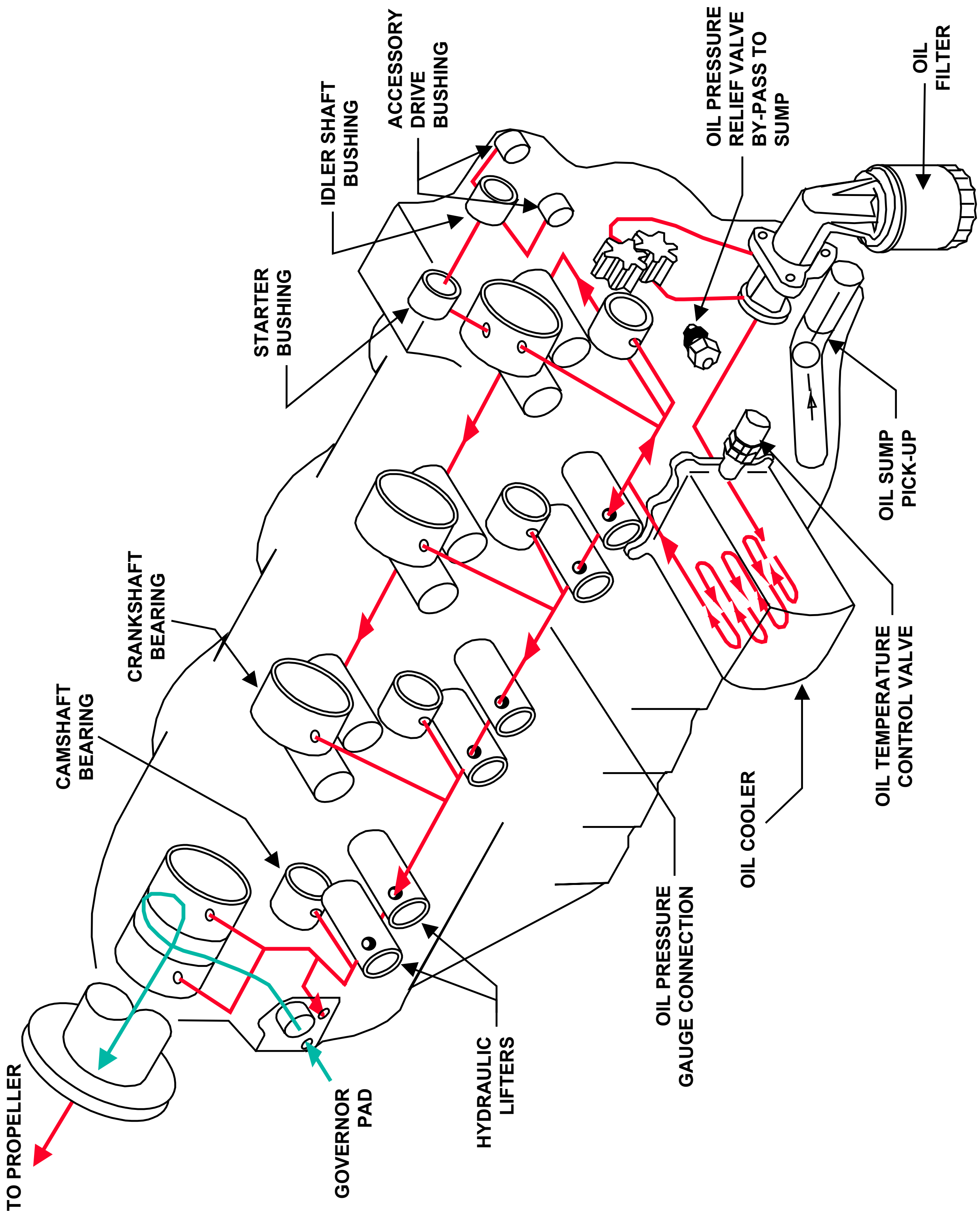


Figure 4-4. IO-360 Series Oil System Schematic

The engine oil supply is contained in the oil sump. Oil is drawn from the sump through the oil suction tube to the intake side of the engine driven, gear type, oil pump. From the outlet side of the pump, oil passes to an oil pressure relief valve installed in the oil gallery in the accessory case. The valve opens when the pump pressures exceed the adjusted limit and oil is directed back to the oil sump. From the pressure relief valve the oil flows to a full flow oil filter.

From the oil filter oil is directed through a gallery to the oil cooler. The oil cooler incorporates an oil temperature control valve. Oil passing through the oil temperature control valve cavity is directed either through the oil cooler core or by-passes the oil cooler core depending on the oil temperature to the left crankcase gallery. In this manner, engine oil temperature is maintained within the normal operating range.

Oil passages off the left main gallery direct oil flow to the camshaft journals, the right main gallery and hydraulic valve tappet bosses. Oil flow is also directed upward to each of the crankshaft main bearings and forward to the propeller governor pad. Oil from the rear crankshaft main bearing is directed upward to the starter shaft gear bushing. On turbocharger models, oil flow is tapped off the left main oil gallery between the #2 and #4 cylinders and directed to the turbocharger through various hoses, fittings and a check valve to the turbocharger bearings. Oil pressure connection is also tapped from this fitting. The oil from the turbocharger is collected through various hoses, fittings and a check valve by the oil scavenge pump where it is returned to the engine oil sump.

From the propeller governor, lubricating oil is directed through a crankcase gallery to the front main bearing where it is directed to the interior of the crankshaft. Oil then travels through a transfer plug installed in the crankshaft to the variable pitch propeller. Hydraulic valve tappets transfer oil from the main oil galleries to the cylinder head through the hollow pushrods to a drilled oil passage in the rocker arms. Oil exiting the rocker arms lubricates the valve stems, springs and rotocoils. The oil then falls to the lower rocker cavity and returns to the crankcase and sump through the pushrod housings.

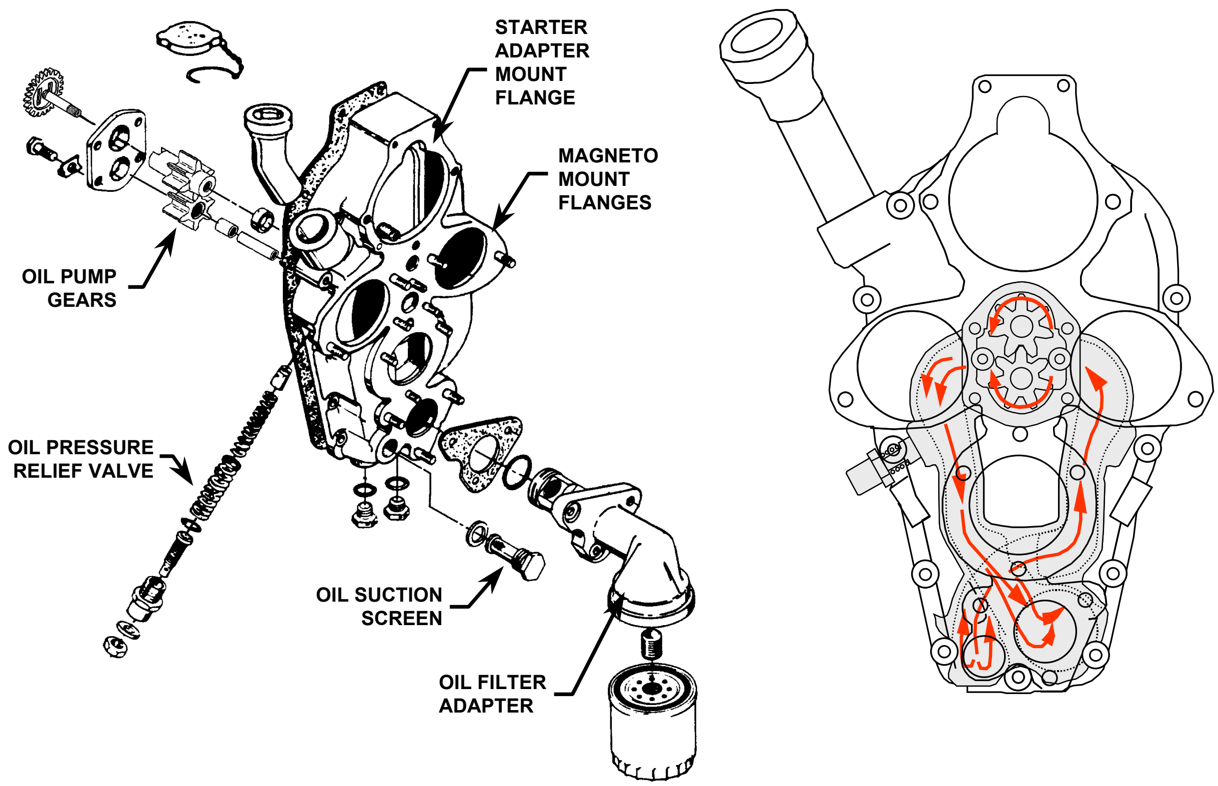


Figure 4-5. IO-360 Series Accessory Case and Oil Pump

Oil Pump - The oil pump is a positive displacement pump that consists of two meshed steel gears that revolve inside the oil pump cavity machined in the accessory case.

The camshaft drives the oil pump drive gear, which drives the oil pump driven gear. The oil pump driven gear is supported by a shaft pressed into the accessory case and supported by the oil pump cover plate. The oil pump drive gear shaft is supported by bushings pressed into the accessory case.

As the engine starts rotating the oil pump drive gear turns (looking from the rear of the engine forward) counterclockwise, this drives the driven gear in a clockwise direction. The two gears turning create a suction that draws oil from the sump, through the oil suction tube to the oil pump gears. The oil is then forced around the outside of the gears and directed through a gallery to the pressure relief valve and oil filter.

An adjustable oil pressure relief valve regulates oil pressure within the specified limits. This insures adequate lubrication to the engine and its accessories at all speeds.

Oil Cooler and Oil Temperature Control Valve - Oil flowing from the oil filter enters the oil cooler inlet, oil temperature control valve cavity. When the oil is below normal operating temperature, the oil temperature control valve (vernatherm) is open allowing oil to flow through the by-pass portion of the oil cooler adapter. Oil flowing through the by-pass flows past the oil temperature control valve and out to the crankcase left main oil gallery.

When oil temperature reaches 168°F-172°F the oil temperature control valve closes and the oil flows through the cooler core. As the oil flows through the cooler core cooling air fins between the core oil passages dissipate heat from the oil maintaining normal operational oil temperatures.

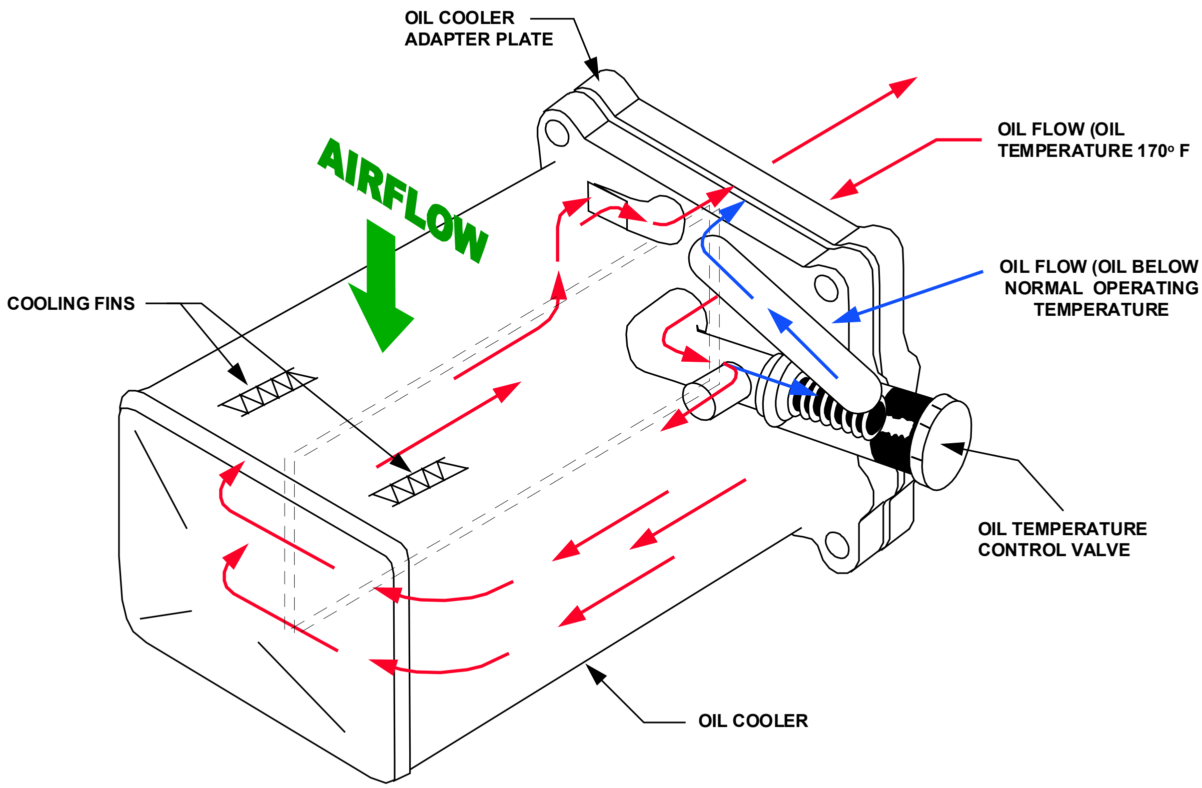


Figure 4-6. IO-360 Series Oil Cooler

Oil Sump - The oil sump is cast aluminum. The sump is attached to the crankcase flange with 14 nuts, washers and lock washers. The oil sump assembly incorporates a tapped drain plug boss. The drain plug boss has provisions for safety wiring of the oil drain plug.

Oil Suction Tube - The oil suction tube is threaded into the oil sump and sealed to the accessory case by the accessory case gasket. Oil flows from the sump through the oil suction tube to the accessory case oil suction screen cavity.

Oil Suction Screen – The Oil suction screen should be removed and cleaned at annual or 100 hour inspection intervals. Since this type of oil screen is situated horizontally, the screen can begin to collect impurities, which over time can restrict the flow of oil from the sump to the oil pump. This can cause degraded oil flow to the engine and as a result lowered oil pressure indications on the aircraft oil pressure gauge. This type of horizontal removable screen is employed on all IO360, TSIO360 and LTSIO360 engine models. The earlier C125, C145 and O300 engines also incorporated this type of removable oil screen.

470/520/550 - SANDCAST SERIES ENGINES

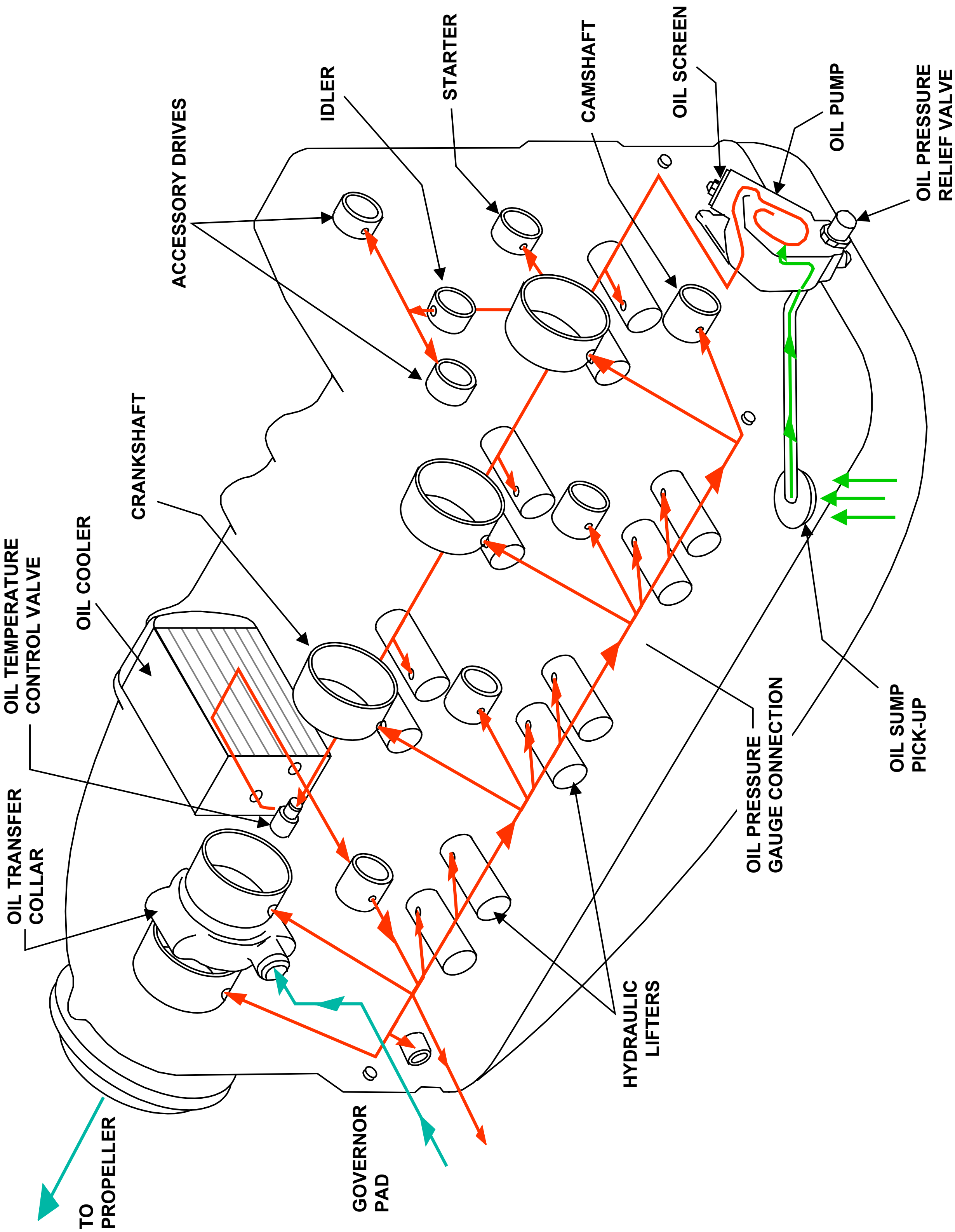


Figure 4-7. 470/520/550 Sandcast Series Engine Oil System Schematic

The engine oil supply is contained in the oil sump. The oil is drawn from the sump through the oil suction tube to the intake side of the engine driven, gear type, oil pump. From the outlet side of the pump, oil is directed to the integral oil filter screen chamber. An oil by-pass valve is incorporated in the oil pump housing in the event that the filter becomes clogged. An oil pressure relief valve is incorporated in the oil pump housing. The pressure relief valve opens when pump pressures exceed the adjusted limit. When the pressure relief valve opens, oil is directed back to the intake side of the oil pump gears.

From the oil filter discharge port, oil is directed through a crankcase passage to the right crankcase oil gallery. Right side tappets, tappet guides and valve mechanisms are lubricated by passages leading off this gallery. An oil temperature control valve is located at the front end of the right gallery to regulate oil temperature within limits.

When the oil reaches a temperature high enough to require cooling, the oil temperature control valve expands and blocks the passage, directing oil flow through the oil cooler. From the oil temperature control valve cavity, oil is directed to the camshaft passage. A groove around the front of the camshaft directs oil to the front camshaft bearing and left crankcase oil gallery. Left side tappets, tappet guides and valve mechanisms are lubricated by passages leading off this gallery.

Hydraulic valve tappets transfer oil from the main oil galleries to the cylinder overhead. Oil flows through the hollow push rods to a drilled oil passage in the rocker arms. Oil that flows through and exits the rocker arms lubricates the valve stems, springs, rotocoils and retainers. The oil then falls to the lower rocker cavity returning to the crankcase and sump through the push rod housings.

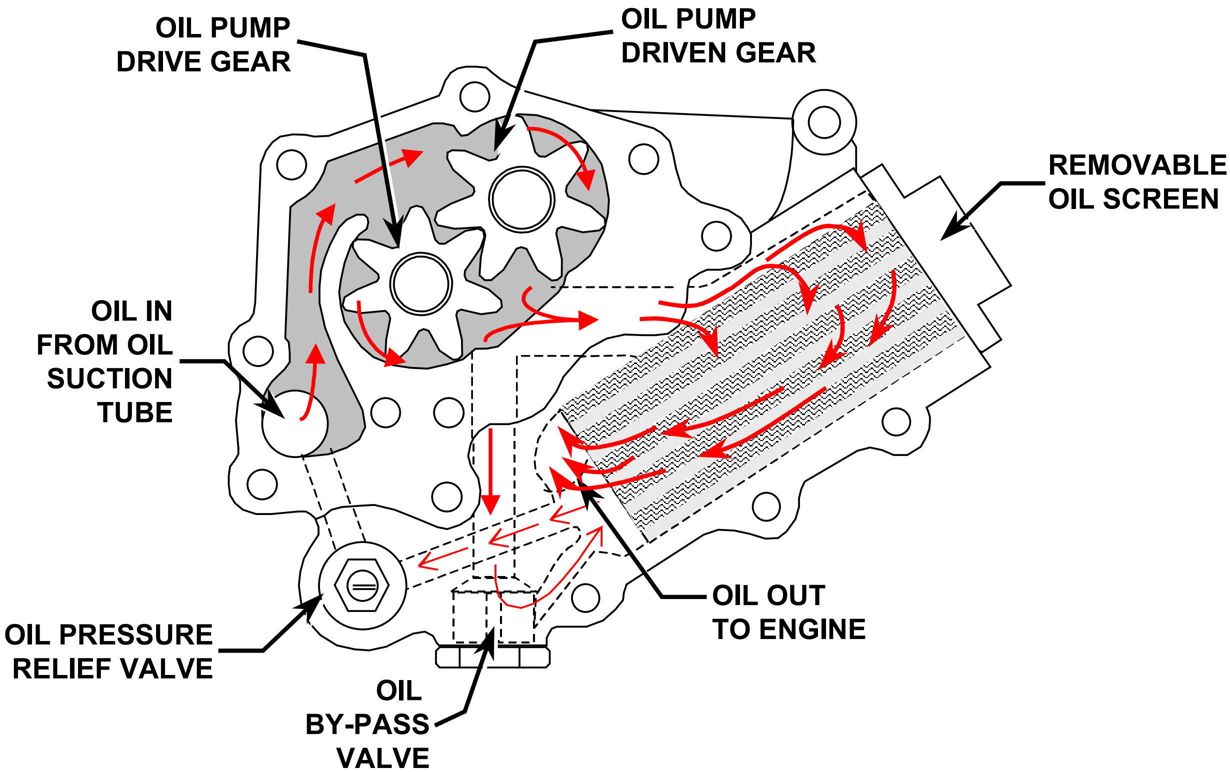
Lubricating oil is directed to the governor drive gear and propeller governor through passages off the left main gallery. Oil is channeled through a discharge port to the crankshaft oil transfer collar and crankshaft interior.

Oil then travels through a transfer plug installed in the inside diameter of the crankshaft and flows to the variable pitch propeller.

Oil from the left main crankcase gallery is also directed upward through crankcase oil passages to the crankshaft main bearings. Oil flow from the rear crankshaft main bearing flows to the starter shaft gear bushing and idler gear bushing. Oil is directed upward from the idler gear bushing to both accessory drive bushings.

Oil lubricating the crankshaft main journals is directed through the upper main bearing oil holes, through crankcase passages to oil squirt nozzles that spray oil onto the underside of the pistons. This oil spray aids in lubrication and heat dissipation. Oil falls from the pistons through the crankcase cavity back to the oil sump.

Figure 4-8. Crankshaft Main Bearing Set



Early Style Sandcast Series Oil Pump

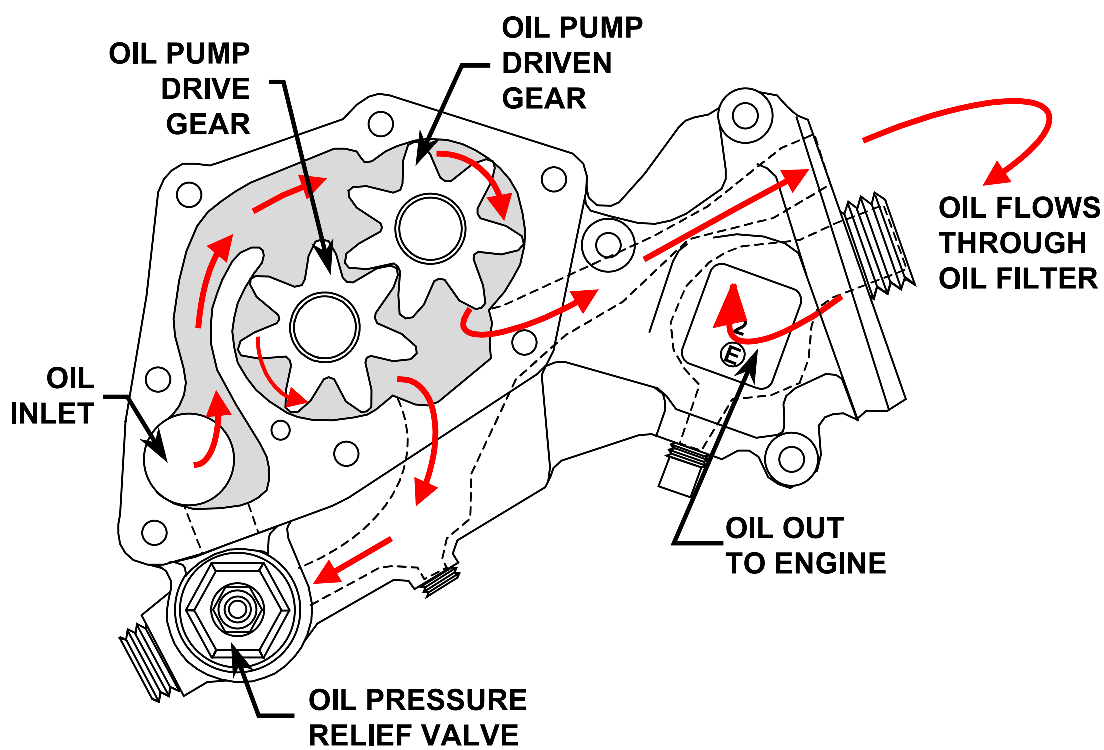


Figure 4-9. Early & New Style Sandcast Series Oil Pump Design

Oil Pump - The positive displacement oil pump consists of two meshed gears that revolve inside the pump housing cavity. The clearance between the oil pump cavity and oil pump gear teeth is small.

A by-pass is installed in the early style oil pump housing to allow an alternate route for the oil in the event the oil filter element becomes clogged. During normal operation oil flows from the oil pump to the oil filter housing and filter element. The oil is then directed through the element, down through a passage in the oil pump housing and out to the right crankcase main oil gallery.

The oil pressure relief valve limits oil pressure to a predetermined value. This insures adequate lubrication to the engine and its accessories at high engine RPM. Oil pressure is adjusted by turning the oil pressure relief valve adjusting screw.

The camshaft drives the oil pump drive gear. The oil pump drive gear drives the oil pump driven gear. The oil pump driven gear is supported by a shaft pressed into the oil pump housing. The oil pump drive gear shaft is supported by the tach drive housing on one end and the oil pump housing at the opposite end. The oil pump drive gear has a tachometer drive gear attached to its end which drives a tachometer shaft gear inside the tach drive housing for either electrical or mechanical tachometers.

As the engine starts rotating, the oil pump drive gear turns (looking from the rear of the engine forward) counterclockwise. The counterclockwise rotation of the drive gear causes the driven gear to turn in a clockwise direction. The rotating gears create a suction that draws oil from the sump through the oil suction tube to the pump gear inlet. The oil is then forced around the outside of the gears and directed through a passage to the oil filter. Oil flow through the filter element is directed out to the right crankcase main oil gallery and to an oil passage leading to the oil pressure relief valve. Oil that flows past the pressure relief valve is directed through a passage back to the inlet side of the oil pump gears.

Standard Oil Cooler and Oil Temperature Control Valve - Oil flowing from the oil pump enters the right crankcase oil gallery where it is directed forward to the oil temperature control valve (vernatherm). When the oil is below normal operating temperature the oil temperature control valve (vernatherm) is open allowing oil to by-pass the oil cooler. When oil temperature reaches 180°F the oil temperature control valve expands blocking oil flow. Oil flow is then re-directed through the oil cooler core. As the oil flows through the cooler core, cooling air fins between the core oil passages dissipate excess heat from the oil maintaining normal operational oil temperatures. Oil then flows from the cooler out to the camshaft and crankshaft left main oil gallery.

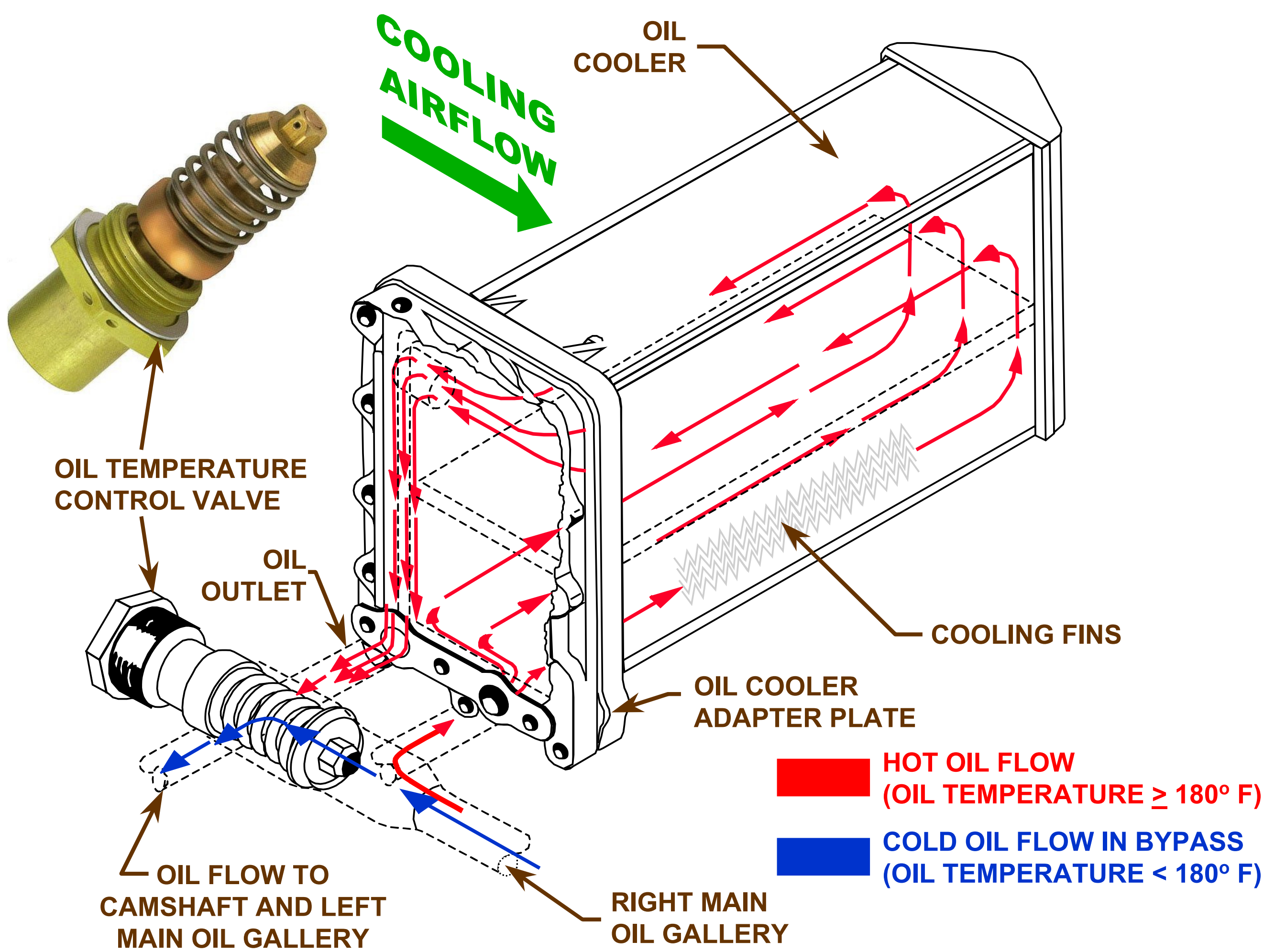


Figure 4-10. Sandcast Series Oil Cooler

Non-Congealing Oil Cooler and Oil Temperature Control Valve - The non-congealing oil cooler incorporates a de-congealing tube located in the center of the cooler core. The de-congealing tube and oil passages in the oil cooler adapter plate allow oil by-pass flow when the oil temperature is below normal operating temperature. An oil temperature control valve is installed in the oil cooler adapter plate. A special plug is installed in the crankcase oil temperature control valve boss. The special plug directs oil flow to the oil cooler plate and cooler by-pass. As normal operating oil temperature occurs, the oil temperature control valve expands blocking oil flow through the by-pass. Oil flow is then directed through the cooler core.

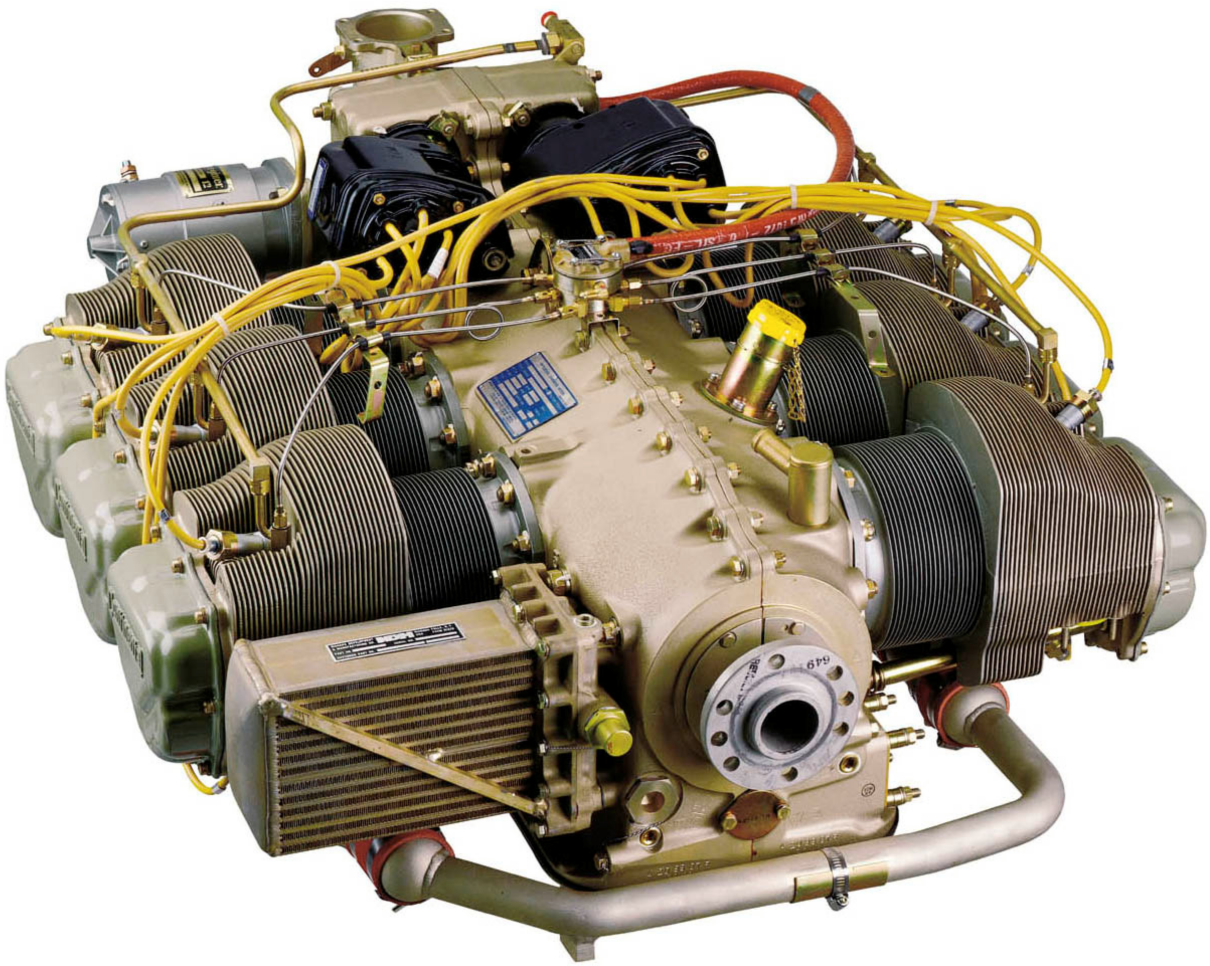


Figure 4-11. TSIO-520 Engine With De-Congealing Oil Cooler

520/550 - PERMOLD SERIES ENGINES

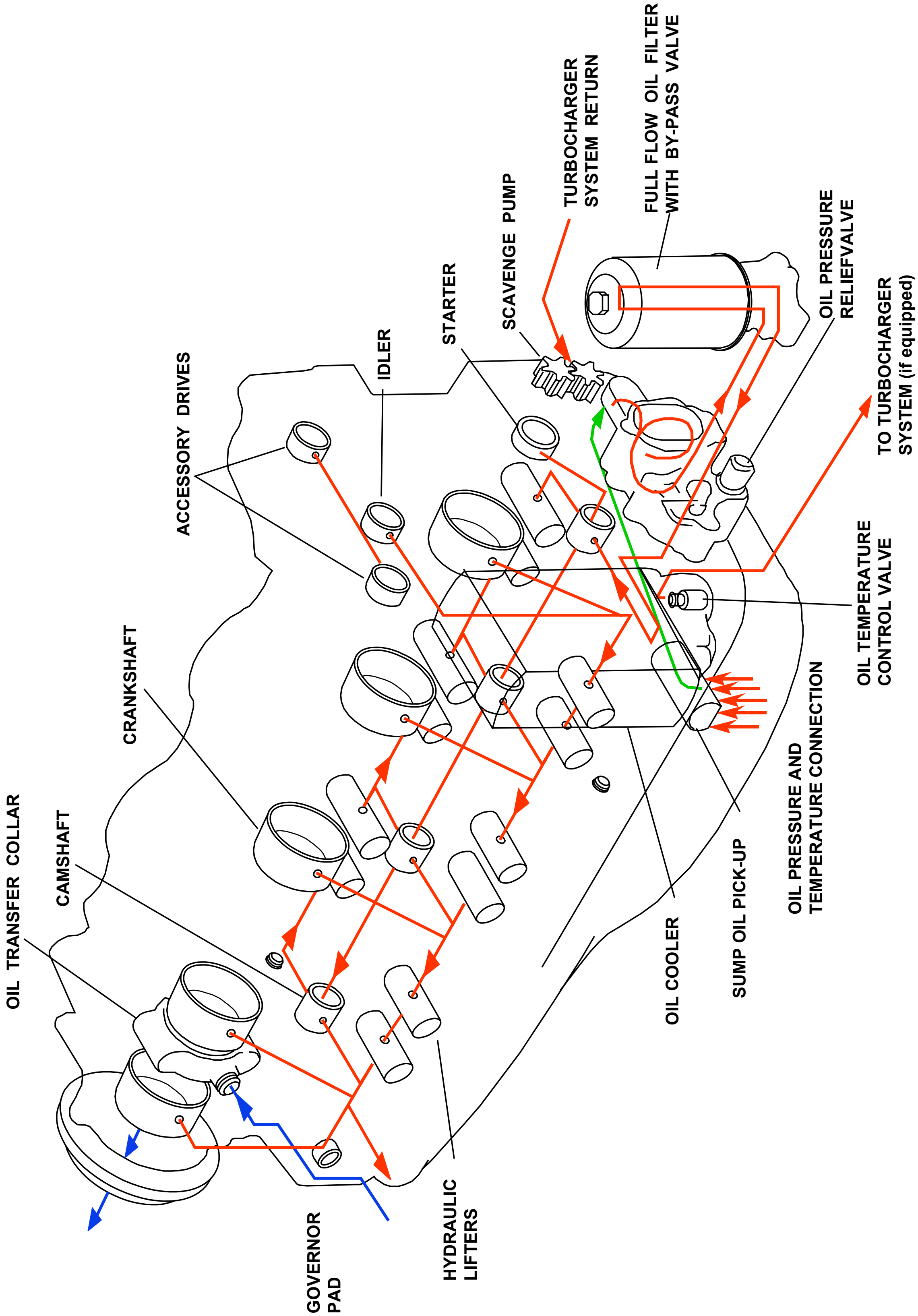


Figure 4-12. 520/550 Permold Series Oil System Schematic

The engine oil supply is contained in the oil sump. The oil is drawn from the sump through the oil suction tube to the intake side of the engine driven, gear type, oil pump. From the outlet side of the pump, oil is directed to the full flow, replaceable oil filter. A by-pass valve is incorporated in the oil filter. An oil pressure relief valve is incorporated in the oil pump housing. The valve opens when the pump pressures exceed the adjusted limit and oil is directed back to the intake side of the oil pump gears.

From the oil filter discharge port, oil is directed through a crankcase passage to the oil cooler. In addition to facilities for oil pressure, the oil cooler incorporates an oil temperature control valve. Oil passing through the oil temperature control valve cavity is directed either through the oil cooler core or through the oil cooler by-pass to the crankcase passage at the rear of the camshaft depending on the oil temperature. In this manner engine oil temperature is maintained at 180°F.

Oil entering the engine is directed to the hollow camshaft, which serves as the engine main oil gallery. Grooves and drilled holes in the camshaft are located so as to afford proper lubrication through a system of orifices to the main bearings, hydraulic valve tappets, idler gear bushing, accessory drive gear bushings and the starter drive gear bearing.

Oil leaving the camshaft interior at the front of the crankcase is directed to the left main crankcase gallery, from there it is directed upward through crankcase oil passages to the main thrust bearing and to the governor drive gear.

From the governor drive gear, lubricating oil is directed from the left main gallery through drilled crankcase passages and oil transfer collar to the crankshaft. Oil then travels through a transfer plug installed in the inside diameter of the crankshaft and is routed to the variable pitch propeller. Hydraulic valve tappets transfer oil from the main oil galleries to the cylinder overhead through the hollow pushrods to a drilled oil passage in the rocker arms. Oil exiting the rocker arms lubricates the valve stems, springs and rotocoils. The oil then falls to the lower rocker cavity and returns to the crankcase and sump through the pushrod housings.

Oil from the left main crankcase gallery is also directed upward through crankcase oil passages to the crankshaft main bearings and idler gear bushing. Oil is directed upward from the idler gear bushing to both accessory drive bushings. Oil lubricating the crankshaft mains is directed through the upper main bearing oil holes, through crankcase passages to oil squirt nozzles that spray oil onto the underside of the pistons for heat dissipation and lubrication. Oil falls from the pistons through the crankcase cavity back to the oil sump.

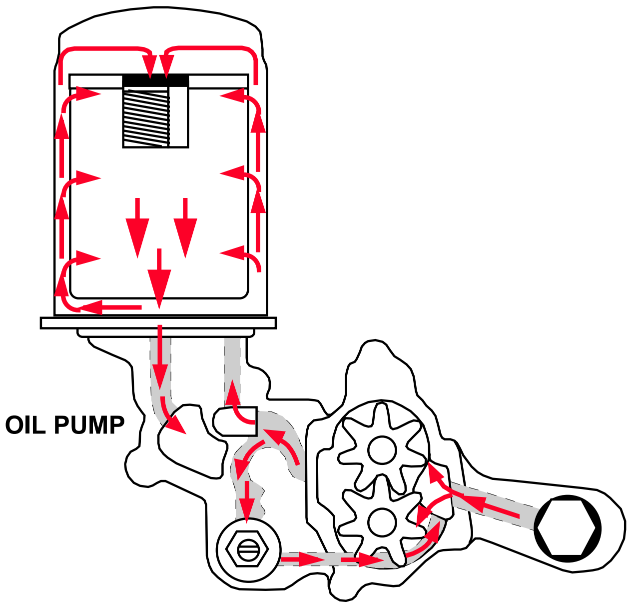


Figure 4-13. Permold Series Oil Pump

Oil Pump - The positive displacement oil pump consists of two meshed gears that revolve inside the pump housing cavity. The clearance between the oil pump cavity and oil pump gear teeth is small.

The camshaft drives the oil pump drive gear, which drives the oil pump driven gear. The oil pump driven gear is supported by a shaft pressed into the oil pump housing.

The oil pump drive gear shaft is supported by the tach drive housing on one end and the oil pump housing at the opposite end. The oil pump drive gear has a tachometer drive gear attached to its end which drives a tachometer shaft gear inside the tach drive housing for either electrical or mechanical tachometers.

As the engine starts rotating, the oil pump drive gear turns (looking from the rear of the engine forward) counterclockwise, this drives the driven gear in a clockwise direction. The two gears turning create a suction that draws oil from the sump, through the oil suction tube to the pump gears. The oil is then forced around the outside of the gears and directed through a gallery to the oil filter adapter and pressure relief valve.

Oil that flows past the pressure relief valve is directed through a passage back to the inlet side of the pump gears. The oil pressure relief valve limits oil pressure to a predetermined value, this ensures adequate lubrication to the engine and its accessories at high engine RPM. Oil pressure is adjusted by turning the oil pressure relief valve adjusting screw.

The oil filter incorporates a by-pass in the event the filter element becomes clogged. During normal operation oil flows from the by-pass to an area between the oil filter housing and filter element. The oil is then directed through the element and down to a gallery in the filter adapter through a passage in the oil pump housing and out to the engine.

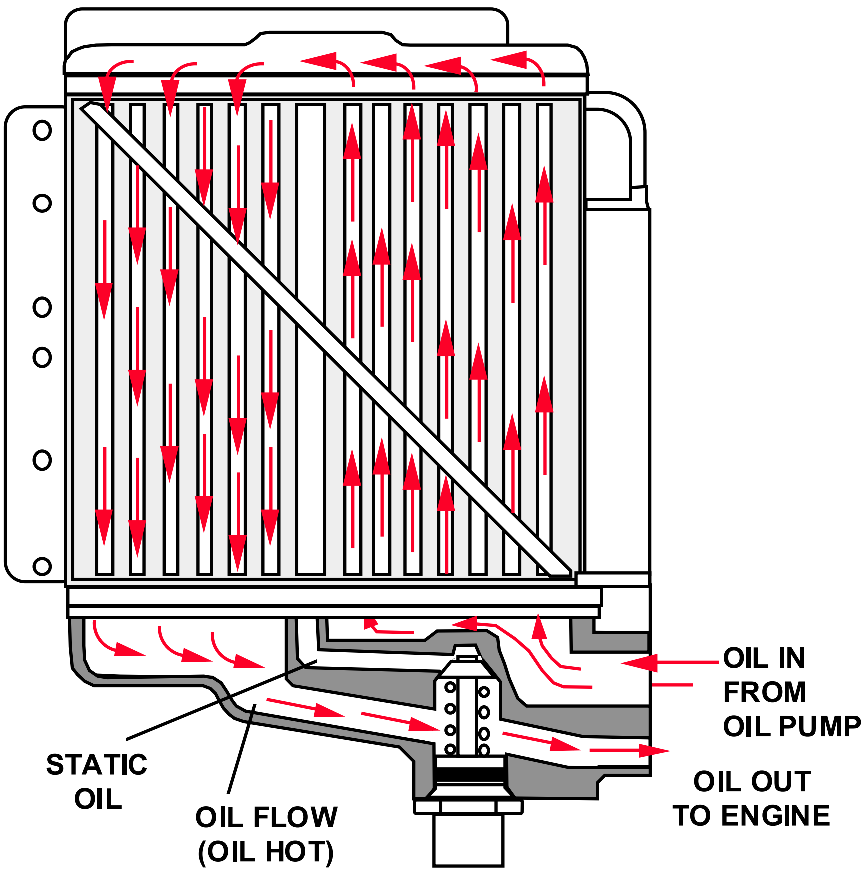


Figure 4-14. Permold Series Oil Cooler

Oil Cooler And Oil Temperature Control Valve - Oil flowing from the oil pump enters the oil cooler inlet where it is directed upward through the cooler core by the cast oil gallery. When the oil is below normal operating temperature, the oil temperature control valve (vernatherm) is open allowing oil to flow through the center by-pass portion of the cooler. Oil flowing through the by-pass flows past the oil temperature control valve and out to the crankcase main oil galleries and camshaft.

When oil temperatures reach 180°F the oil temperature control valve closes changing the oil flow path from flow through the by-pass to oil flow through the outer cooler core. As the oil flows through the cooler core cooling air fins between the core oil passages dissipate excess heat from the oil maintaining normal operational oil temperatures.

GTSIO SERIES ENGINES

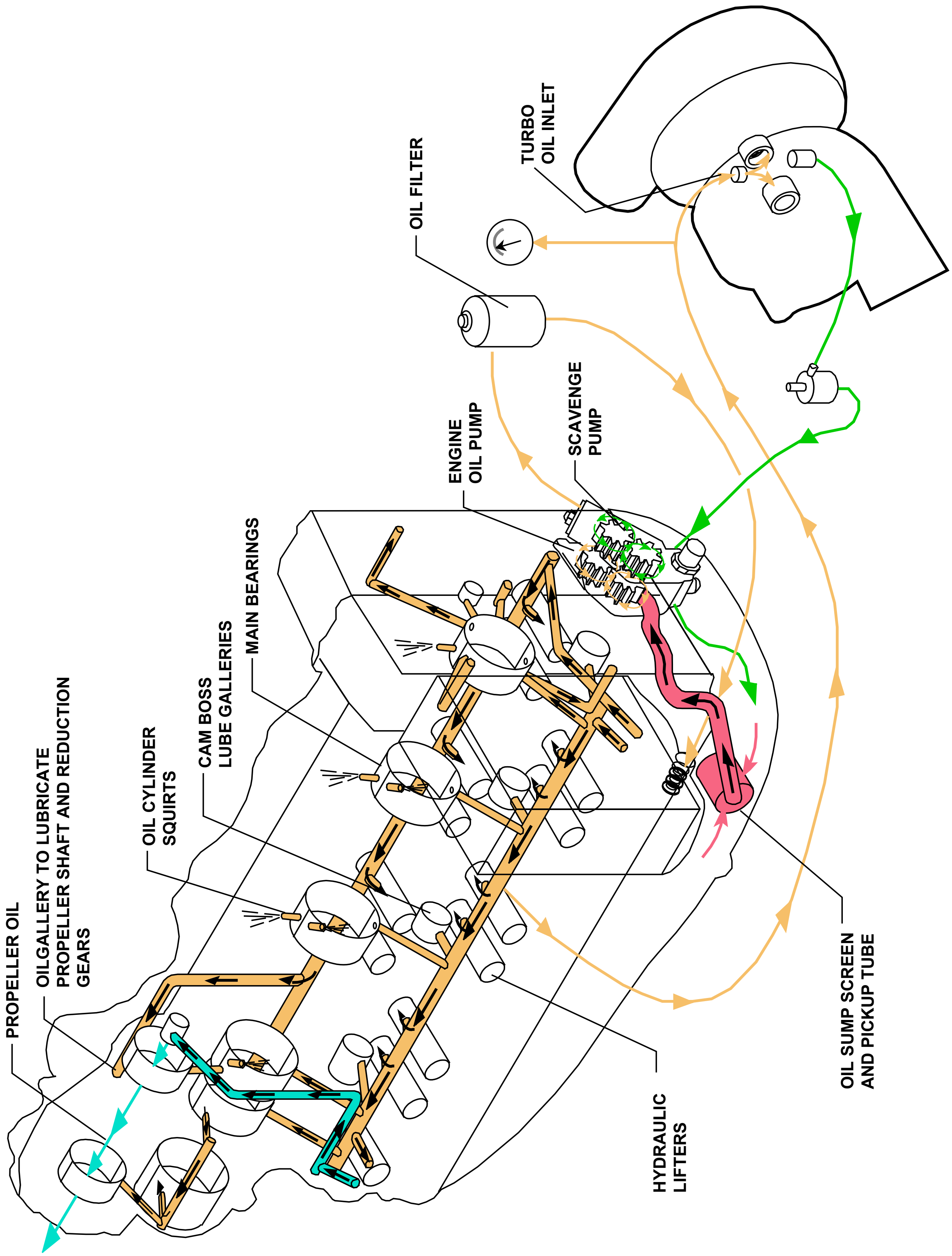


Figure 4-15. GTSIO-520 Series System Oil Schematic

The engine oil supply is contained in the oil sump. The oil is drawn from the sump through the oil suction tube to the intake side of the engine driven oil pump. An oil pressure relief valve is incorporated in the oil pump housing. The pressure relief valve opens when pump pressures exceed the adjusted limit. When the pressure relief valve opens, oil is directed back to the inlet side of the oil pump gears. From the outlet of the pump oil is directed through external lines to a remote mounted oil filter adapter. Oil then travels through external lines to the inlet of the oil cooler.

When the oil reaches a temperature high enough to require cooling, the oil temperature control valve expands and blocks the passage, directing oil flow through the oil cooler. Oil exits the oil cooler and is directed down the left crankcase gallery and is also directed across the accessory section of the crankcase to the right crankcase gallery.

The oil traveling down the left crankcase half lubricates the crankshaft main bearings, the main bearing bosses for the camshaft and feeds lubricating oil to the hydraulic lifter bosses for the left side. The crankshaft bearing bosses provide oil squirts for spraying lubricating oil to the cylinder walls and the back of the pistons. The front end of the left crankcase oil gallery provides an oil outlet to the propeller governor and to the rear main bearing for the propeller driver gear. The propeller driver gear rear main bearing feeds oil to a gallery that directs oil to the front main bearing for the propeller driver gear and directs oil to the front main bearing for the propeller shaft.

The front main crankshaft bearing directs oil to a gallery, which feeds oil to the rear main bearing of the propeller shaft. The crankshaft rear main bearing provides exits to galleries in the accessory case for providing lubricating oil to the accessory drive gears.

Oil traveling to the right crankcase gallery provides lubricating oil to the right side hydraulic lifter bosses. The front of the gallery directs oil up near the top of the right crankcase half to a squirt in the crankcase to provide lubricating oil to the propeller driver gear and the propeller shaft assembly.

Oil is tapped off of the left crankcase half gallery between the # 2 and # 4 cylinders to a tee connector fitting. This fitting will provide oil to the turbocharger components and for oil pressure gauge connection.

Pressurized oil is directed to the center section of the turbocharger housing to lubricate and cool the turbo/compressor shaft. Oil is scavenged from the bottom of the center section of the turbocharger housing through an air/oil separator back through the scavenge pump and is directed back to the oil sump.

Oil Pump - The positive displacement oil pump consists of two meshed gears that revolve inside the pump housing cavity. The clearance between the oil pump cavity and oil pump gear teeth is small.

The camshaft drives the oil pump drive gear. The oil pump drive gear drives the oil pump driven gear. The oil pump driven gear is supported by a shaft pressed into the oil pump housing. The oil pump drive gear has a tachometer drive gear attached to its end, which drives a tachometer shaft gear inside the tach drive housing.

As the engine starts rotating, the oil pump drive gear turns (looking from the rear of the engine forward) clockwise. The clockwise rotation of the drive gear causes the driven gear to turn in a counterclockwise direction. The rotating gears create a suction that draws oil from the sump through the oil suction tube to the pump gear inlet. Oil that flows past the pressure relief valve is directed through a passage back to the inlet side of the oil pump gears.

The oil pressure relief valve limits oil pressure to a predetermined value. This ensures adequate lubrication to the engine and its accessories at high engine RPM. Oil pressure is adjusted by turning the oil pressure relief valve adjusting screw.

A by-pass is installed in the oil pump housing to allow an alternate route for the oil in the event the oil filter element becomes clogged. During normal operation oil flows from the oil pump to the oil filter housing and filter element. The oil is then directed through the element, down through a passage in the oil pump housing and out to the right crankcase main oil gallery.

SUMMARY

This chapter covered the lubrication systems for the various Continental engine designs, with differences being discussed between the Sandcast and permold series for the 520 & 550 engine models. In these discussions we detailed the flow of oil following oil lubrication system schematic diagrams. We also discussed the various designs of oil pumps with illustrations to include the earlier and later style Sandcast oil pumps and the permold series oil pumps.

KEY TERMS

Cavitation — Formation of partial vacuums in a flowing liquid as a result of the separation of its part.

Gallery — A passageway in the engine or subcomponent. Generally one through which oil is flowed.

Galling or Scuffing — Excessive friction between two metal surfaces resulting in particles of the softer metal being torn away and literally welded to the harder metal.

Heat Soaked — Prolonged exposure of an object to hot temperature so that its temperature throughout approaches that of ambient.

Oil Temperature — A thermostatic unit to divert oil through or around the oil Control Valve cooler, as necessary, to maintain oil temperature within desired limits.

Scavenge Pump — A pump (especially an oil pump) to prevent accumulation of liquid in some particular area.

Sump — The lowest part of a system. The main oil sump on a wet sump engine contains the oil supply.

Vernatherm Valve — A valve which directs oil flow into the oil cooler or bypasses the oil cooler directly into the engine during cold starting in order to maintain control of oil temperatures. The vernatherm will also bypass the oil cooler in the unlikely event that an oil restriction occurs.

Viscosity — The characteristic of a liquid to resist flowing. Regarding oil, high viscosity refers to thicker or "heavier" oil while low viscosity oil is thinner. Relative viscosity is indicated by the specific "weight" of the oil such as 30 "weight" or 50 "weight". Some oils are specified as multiple-viscosity such as 10W30. In such cases, this oil is more stable and resists the tendency to thin when heated or thicken when it becomes cold.

1. Which temperature range will close the Oil Temperature Control Valve for the 360 series engines?

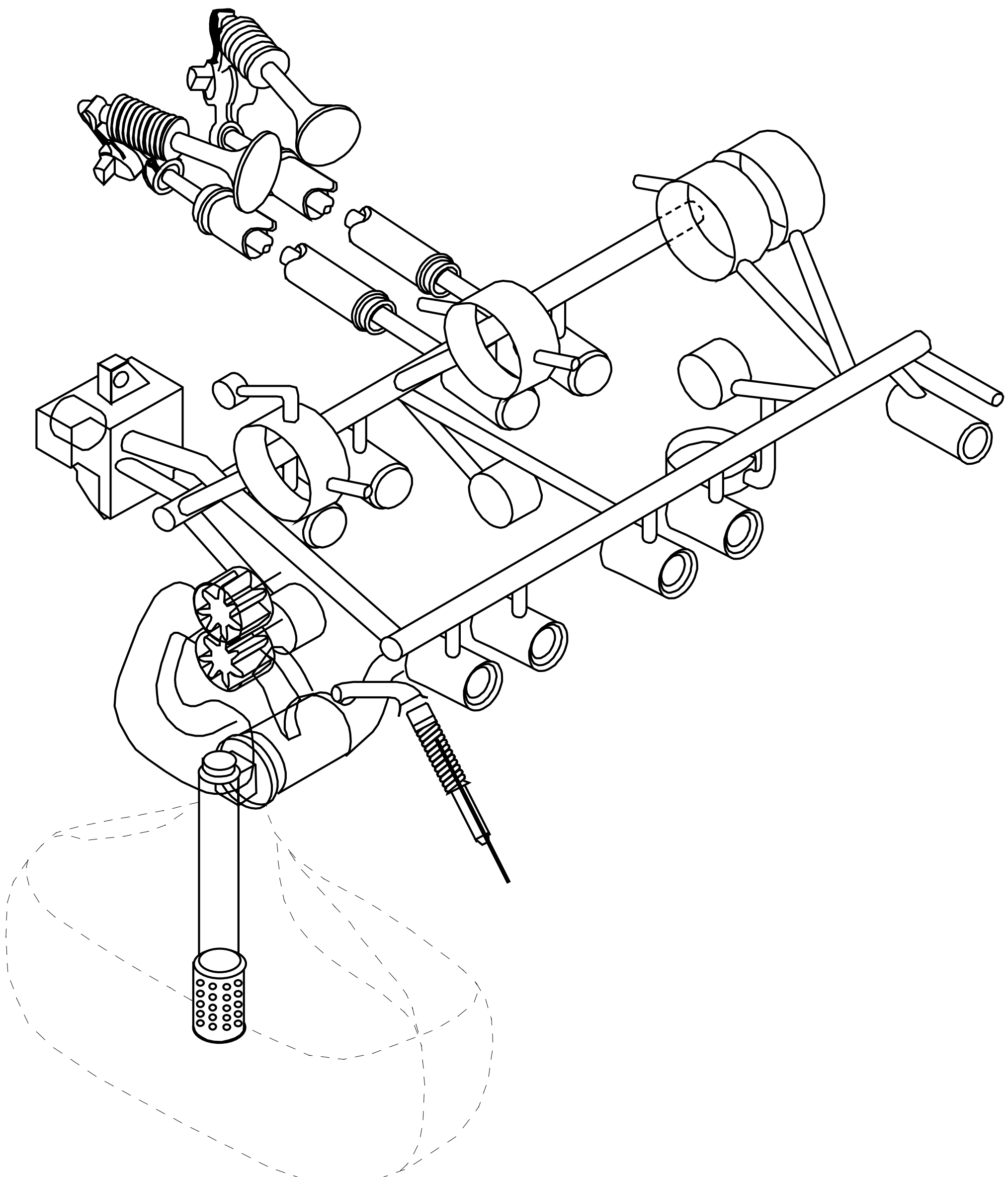
   ____

   ____

   How about for the 520/550 Series Engines? ____________________________

   ____

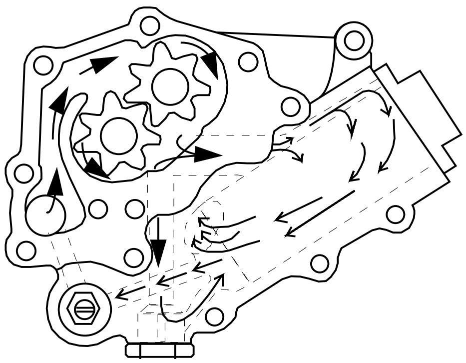
2. Which engine is shown in the oil schematic below? ____________________ Using the diagram below trace the direction of oil flow through the system.



3. What engine component drives the oil pump drive gear on the 360 series engine?

   ____

4. Label the 3 oil pumps shown in the diagram below.



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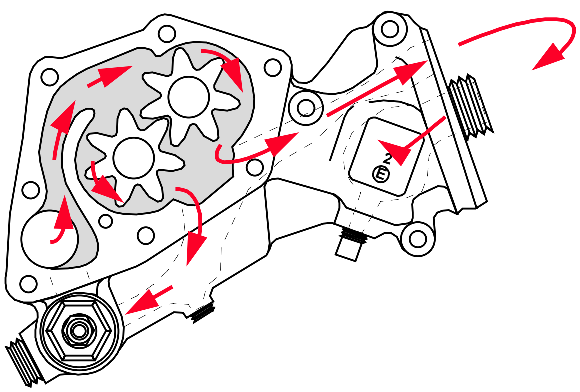

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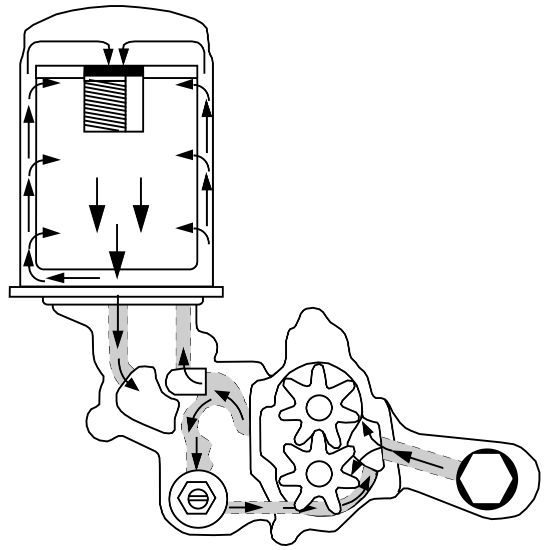

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5. Using the TCMLINK CD ROM or the Information Services web site program identify the Service Bulletin which lists the Sealants, Lubricants and Adhesives authroized by TCM. ________________

Chapter Five

Continental Engine Cylinder Designs

CHAPTER 5 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

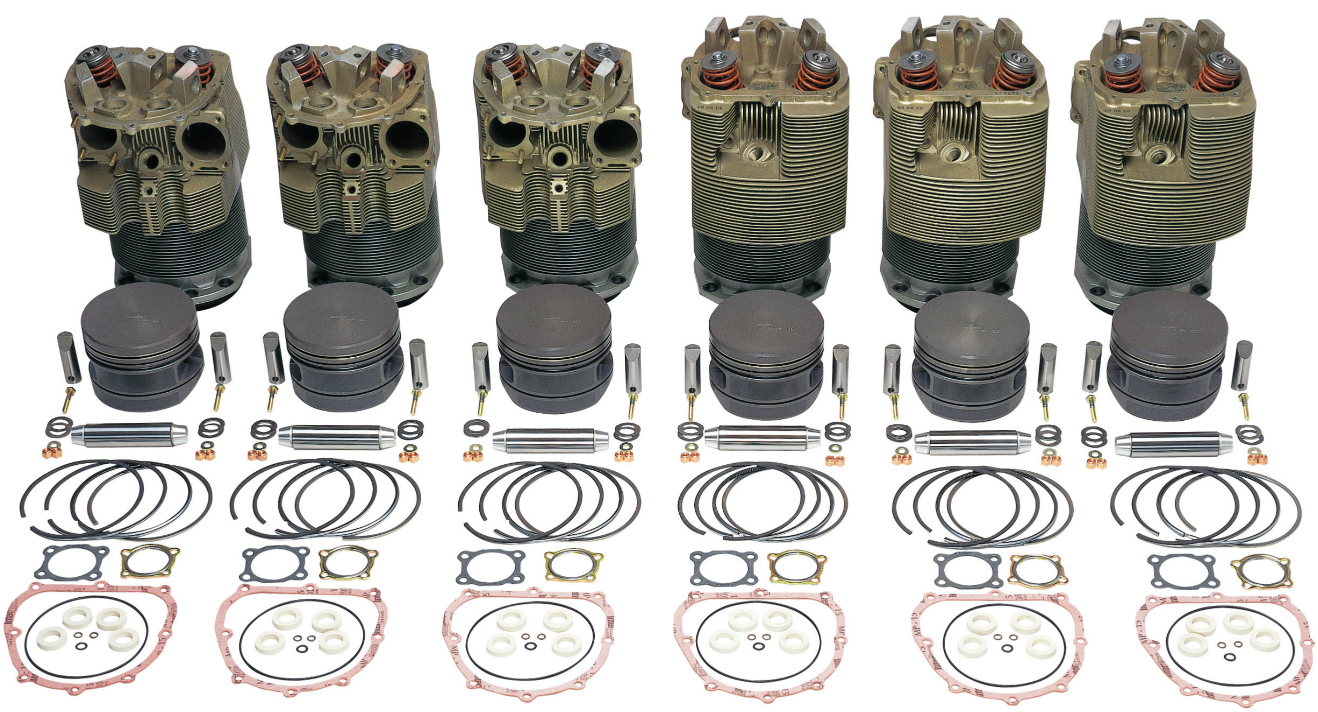
① Identify the different cylinder designs

② Identify the processes employed in manufacturing the Continental Cylinder

③ Describe the effect on combustion with differing fuel/air ratios applied

④ Describe the functional operation of the components which make up the cylinder

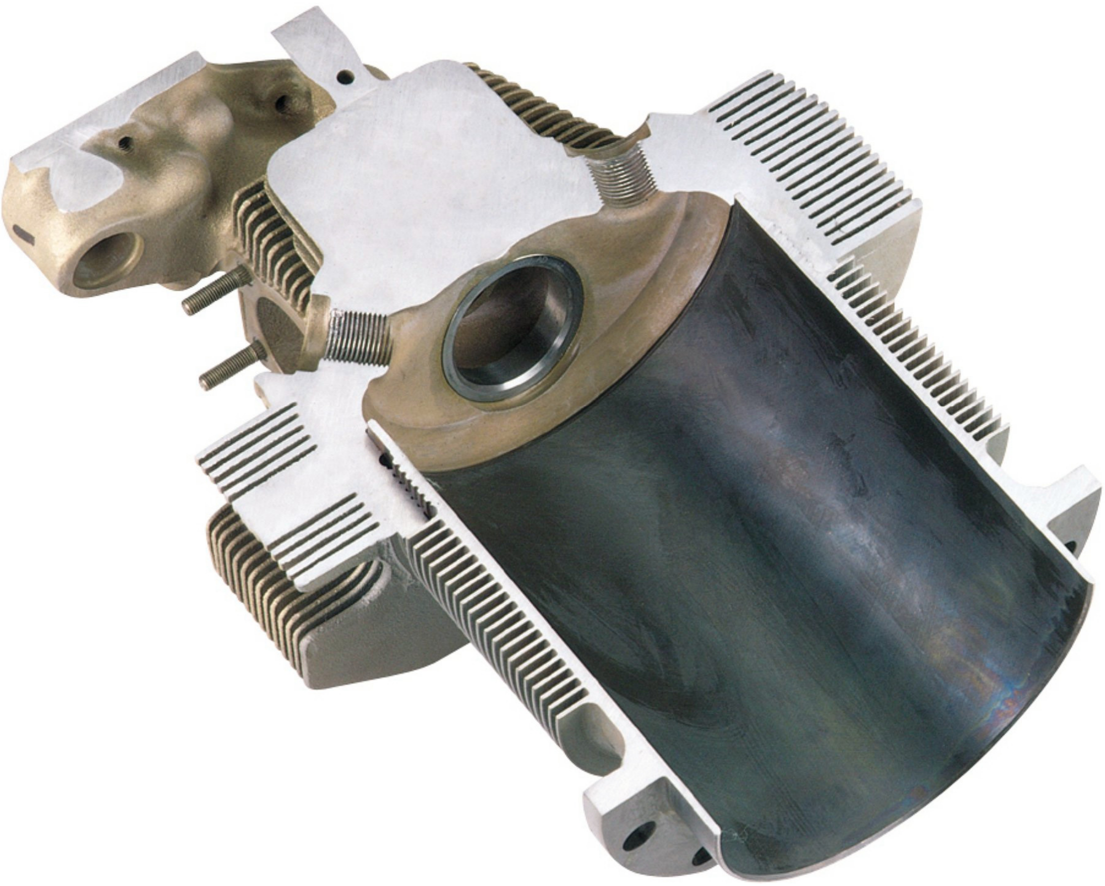
⑤ Describe the functional operation of the components which make up the cylinder valve train



TopCare® Cylinder Overhaul Kit

INTRODUCTION TO CONTINENTAL CYLINDER DESIGNS

The following information in this chapter will provide you with an understanding of the cylinder designs for Teledyne Continental Motors engines. The theory will also explain the dynamics involved in the combustion process that takes place inside the cylinder.



The TopCare® cylinder on Continental engines are engineered and designed to make use of carefully selected high strength materials. Continental Motors has produced a cylinder product that is very strong while keeping the weight of the product to a minimum through the process of ongoing improvements in design calculated to make the optimum use of these high quality materials. Our manufacturing facility has been engineered to monitor very close control of critical dimensions, surface finishes, heat treatment and hardening processes. This careful work has produced more rugged engine cylinder designs than could be built by less exacting methods. However, no amount of ruggedness built into an engine cylinder will enable it to withstand neglect and serious misuse or mistreatment. Overheating, neglect, inferior fuels and lubricants will seriously affect performance longevity, particularly when the specific power rating is high and each part must be free to function properly in order to withstand the imposed loads with minimum wear. These considerations are mentioned here in order to emphasize the necessity of using the manufacturer's specified gasoline and oil and the importance of keeping the fuel, oil and air filters clean. Always use the octane rated fuel specified, and if not available, use the next highest rated fuel. Proper fuel management techniques will be discussed later on in this chapter.

Keeping the engine clean will facilitate optimum cooling for these air-cooled cylinder designs. Dirty and clogged cylinder cooling fins will restrict airflow and hinder proper cooling. Also insure that the aircraft manufacturer's installed baffles are in proper working condition.

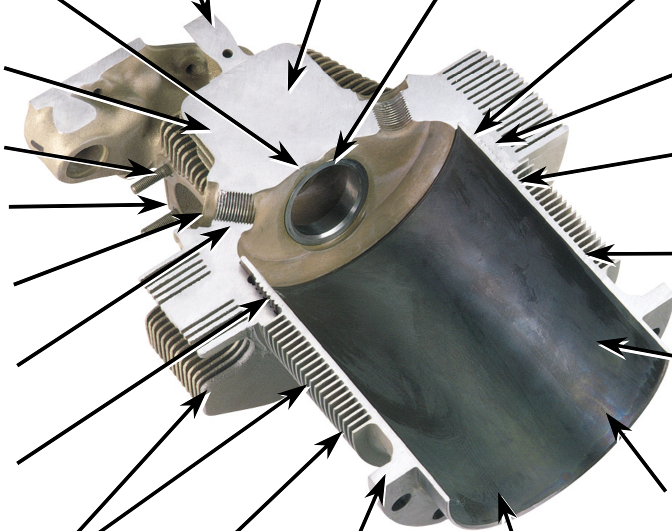


Figure 5-1. Photo showing TopCare Cylinder Engineering

Cylinder barrel hardness is critical to controlling wear. But let's examine the phrase "through-hardened barrel." Cylinder barrel manufacturing typically starts with an Aircraft Quality SAE 4140 steel forging which is heat treated to raise the base metal hardness by a process commonly known as "through-hardening."

For over 65 years TCM barrels have been made from through hardened steal forgings. Certainly not a novel concept. These barrels worked well when properly machined and honed in lower power engines. With turbocharging, higher output and higher duty cycle engines, the additional wear resistance processes of nitriding was added to TCM's cylinder production.

TopCare cylinder barrels spend an additional 40 hours in our high temperature nitriding furnace to case harden the bores of our barrels even further. When finished, the barrel bore surface has over 40% higher surface hardness (based on Rockwell C scale comparison) than competitive barrels. The nitriding process not only produces a deep layer of high hardness, but it also enhances high temperature hardness and strength.

Nitriding is a process that requires specialized equipment. Furnaces that heat the barrels to 940°F in an ammonia atmosphere for 40 hours are required to achieve the exceptional hardness desired. Nitriding is not just for initial wear. The nitriding process hardens the barrel to a significant depth, allowing extended service life by grinding oversize without losing the benefits of the process.

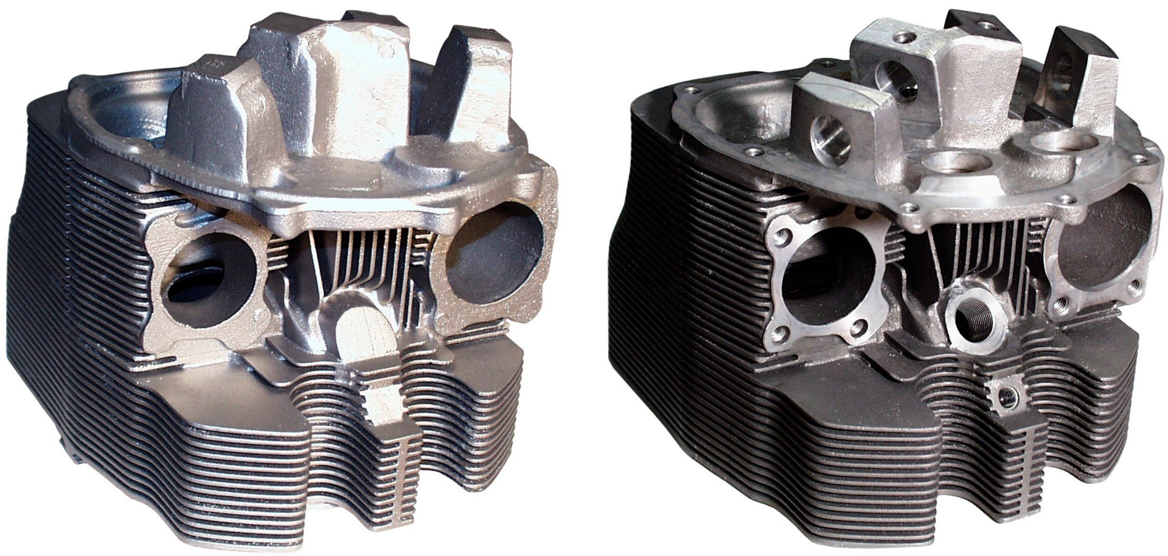


Figure 5-2. Cylinder Head Casting and Machined Product

The engineering of cylinder heads demands premium material specifications to withstand the rigors of high temperatures combined with high stresses. The engineers at Continental Motors have developed a proprietary material specification to meet these conditions based on years of development and experience.

The TopCare sand-cast aluminum cylinder head material specification is 40% higher strength than the conventional AMS 4220 material spec for aluminum. Our proprietary specification has always tailored the material properties to provide the highest thermal fatigue strength available.

Terms like Sand, Investment and Permanent describe the types of casting processes. The investment cast process can produce a great "cosmetic finish," but control of critical metal cooling rates in the investment process is more difficult than with the other processes and, if the cooling rate is not controlled, undesirable properties can result.

Continental uses a special combination of sand castings and permanent mold castings more accurately called "semi-permanent mold casting." The geometry of the cylinder head makes it a natural for this process and using it actually results in better material properties in critical areas of the cylinder head. The permanent mold tool in the critical internal dome area is water cooled to allow control of the aluminum cooling rate during casting. Exceptional material elongation and strength result in the most needed area. In addition, the rougher surface texture formed on the exterior of the cylinder by the sand mold process promotes more effective cylinder cooling.

TCM has precise grinding equipment to create the desired size and shape of the bore and the desired choke in the very hard nitrided bore surface. With the shape established, the hone pattern is the next step. The two-stage hone process is done to create a hone pattern that breaks in quickly, but retains lubrication for long life. This unique two-step cylinder wall honing system first introduces deep oil retaining grooves in the cylinder wall, followed by a second stage that creates a plateau system which helps to quickly seat the piston rings during initial engine operation without eliminating the deeper scratches. Designed and tested by Continental Motors, the two-step hone process is 100% inspected by computer based tools to assure that every TopCare cylinder meets our exacting standards.

Every TopCare cylinder provided is inspected at a computerized inspection station that provides an exceptional view of the hone pattern and calculates a number of characteristics. This equipment permits process development and control far better than any "magic touch" technique and takes the mystery out of the process.

The power demands placed upon your piston aircraft engine require the use of high strength steels, such as Aircraft Quality SAE 4140 that can rust if not protected. Many issues can affect cylinder life, like fuel leaning practices, improper fuel or incorrect fuel injection adjustment, inactivity, cold starting and corrosion from inactivity, just to name a few. Inactivity which, permits rust formation, is perhaps the biggest threat to the health of your engine, especially if your flight hours are irregular or less than 100 hours per year. Rust can begin to form in your engine almost overnight from the cycling of ambient temperature extremes, even with hangared aircraft. Prevention requires that the engine be flown regularly, for long enough, to get oil temperatures high enough to remove latent moisture from the engine. This will typically involve one hour of flight at oil temperatures of 170° - 200°F.

Continental has incorporated a manganese phosphate coating (shown in figure 5-1) in its TopCare cylinder bores to protect the cylinder barrel through the initial break-in period. The coating is specifically designed to provide rust protection during the first hours of operation. The benefits of the phosphate coating in the TopCare cylinder can be dramatic.

Heavy rust pits on cylinder barrel fins can lead to problems in highly stressed areas. TCM barrels are bronze plated underneath the painted surface exterior to help protect the outside from the harsh environment of your engine compartment. Aluminum surfaces are alodined to help them to resist corrosion in that same hostile environment. After the plating and the alodine, the paint is then applied. Ring locked exhaust studs help avoid cylinder damage during exhaust system servicing.

The piston skirt area must carry high loads during operation. The piston has carefully designed amounts of taper from ring land to skirt, and is slightly oval to provide a consistent bearing surface. Small "scallops" are incorporated in the machining of the surface to assist with oil retention. But sometimes that is not enough.

A lot of cylinder wear can occur in the period just after the engine has started but before warm oil flow starts. That is why it is always necessary to pre-heat on extremely cold days and to allow your engine to warm up prior to take-off to avoid scuffing. To assist with scuffing protection TCM pistons have graphite coatings applied to the load bearing area of the piston skirt.

For the higher output engines, TCM TopCare Pistons feature Ni-Resist iron inserts for additional durability in the highest load and temperature top ring area.

CYLINDER COOLING

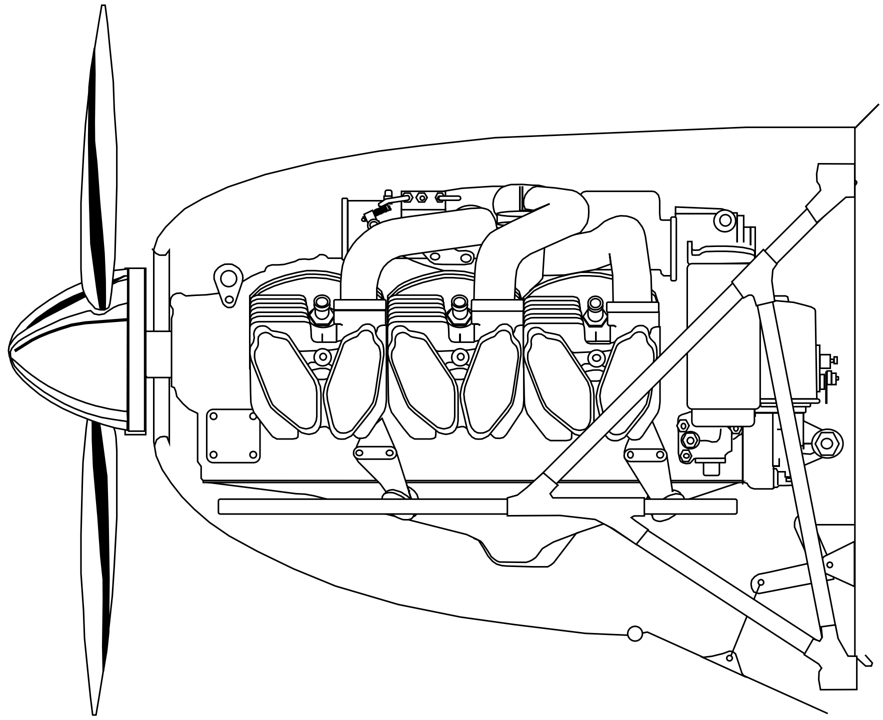


Figure 5-3. Tightly Cowled Engine Compartment

Since most of the Continental engine models are of the air cooled cylinder design, a discussion on cooling airflow is necessary. Cylinder cooling is accomplished by transferring heat from the cylinder barrel and head cooling fins to the surrounding airflow. Airframe engine cowling and engine/airframe supplied baffles and baffle seals direct cooling airflow close and evenly around the cylinders. Controlling airflow in this manner contributes to uniform cylinder temperatures. Cooling airflow is generated by air from the propeller and ram air induced by the aircraft's forward movement. This airflow is regulated by the size of the cooling air inlets and outlets. Increasing or decreasing outlet size with the use of airframe cowl flaps changes airflow and is used as an aid in controlling engine operating temperatures.

An important difference between the radial engines of yesterday and the horizontally opposed engines of today is cooling. The early radial engines were velocity cooled and had little, if any, baffling. Even though velocity cooling did not provide uniform air flow around the entire cylinder, it was satisfactory for the low compression ratios and low rpm's of those early engines. In that environment, the excess heat from the cylinder barrels and heads could be effectively removed without baffles and seals under the cowling.

With performance improvements such as more horsepower, greater efficiency, and improved reliability, velocity cooling could not meet the cooling requirements of later radial and horizontally opposed engines. Soon, cowlings were placed around the engines and engine cooling improved. And pressure cooling was born.

As the aircraft industry matured, greater emphasis was placed on reducing drag, and engine cowlings became more streamlined. Streamlining often resulted in less space inside the cowling making engine cooling more difficult.

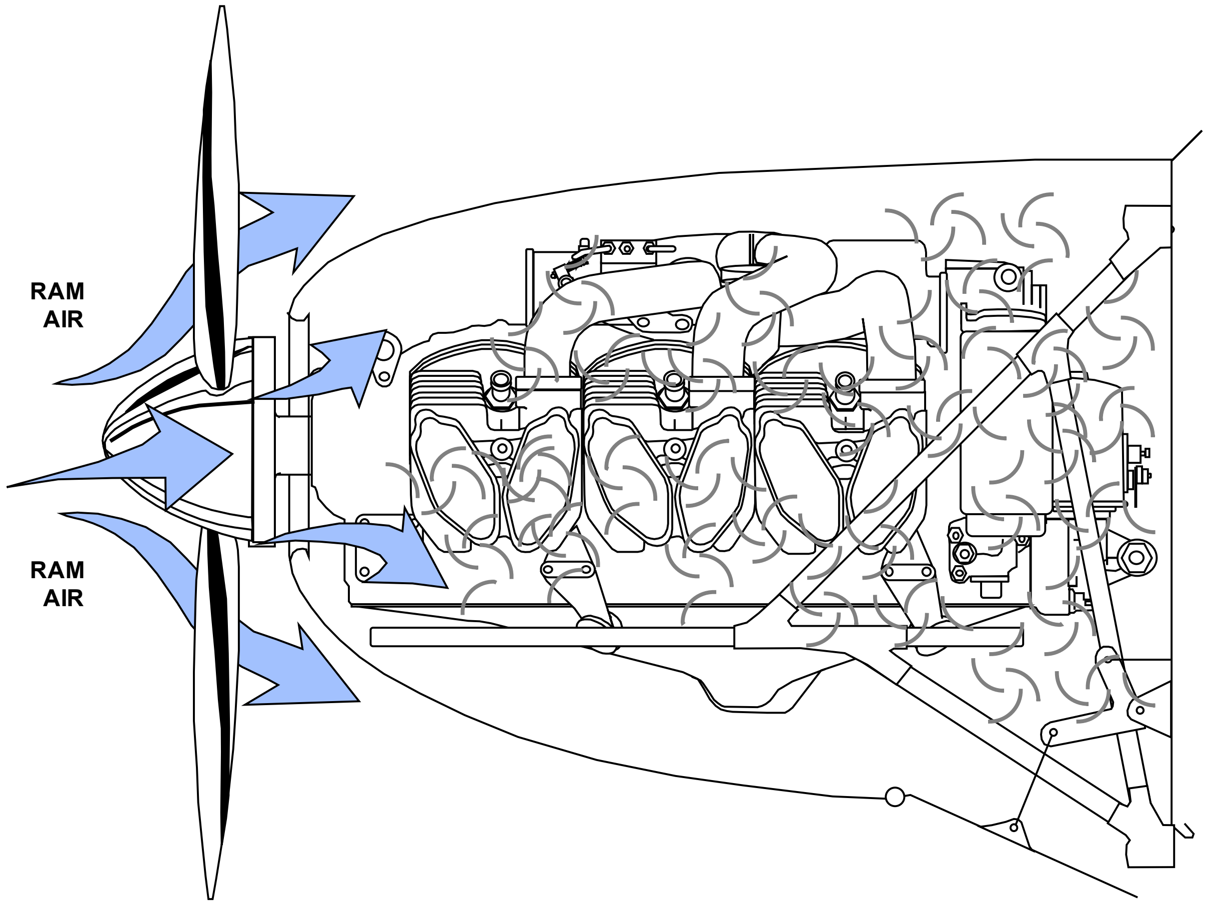


Figure 5-4. Airflow Without Baffles

Figure 5-4 illustrates a typical airflow pattern around an engine cowling that has no baffles or seals. You can see how the air piles up inside the cowling and how the flow is restricted. This pileup occurs because there is no pressure differential inside the cowling. A pressure differential can be created by channeling the airflow around the engine with baffles and seals rather than letting the air back up and get hotter.

Baffling installed on today's engines is a result of extensive development by the airframe manufacturer. Wraparound baffles now guide cooling air all around the cylinder heads and barrels. Other baffles channel cooling air into oil coolers and cooling ducts for accessories. Cooling efficiency is enhanced with seals along the cowling edges to minimize air leakage between the cowling and the baffling.

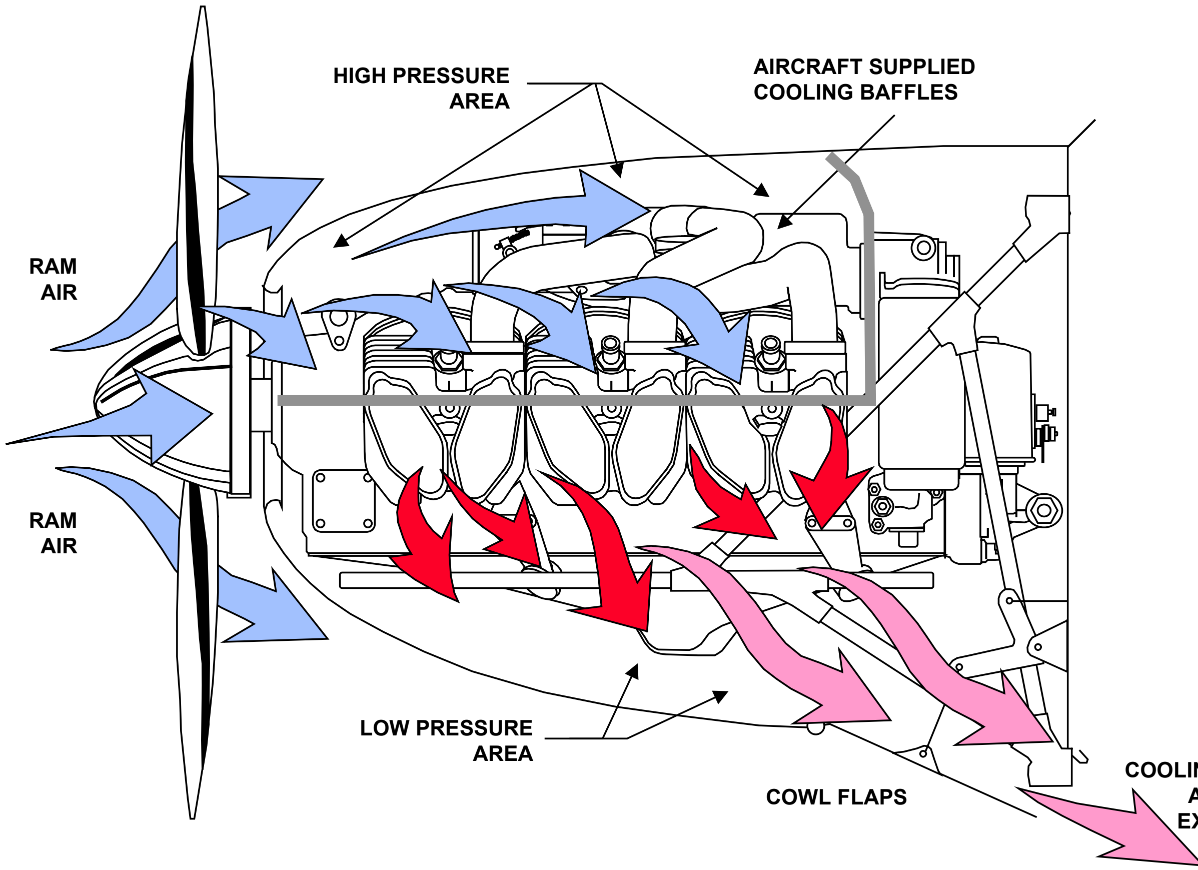


Figure 5-5. Cooling with Installed Baffles

Aircraft manufacturers put a lot of time and effort into designing engine cowlings and the baffles, seals, and cowl flaps that provide cooling air to the engine. However, the very best cooling system is soon no better than the maintenance it receives in the field. The most neglected areas are the seals and the inter-cylinder baffles.

The seals play a critical role in maintaining a pressure differential in the engine cowling. If a seal is missing, damaged, or out of position, differential pressure will be reduced and engine cooling will suffer. Remember: the seals are not there just to reduce the transfer of engine vibration to the airframe. They are an integral part of the engine cooling system and they must be properly installed, positioned and maintained.

Figure 5-5 illustrates the cooling airflow pattern that results from the pressure differential created by properly designed, installed and maintained baffles and seals.

> **NOTE: IT IS IMPORTANT TO UNDERSTAND THAT THE PRESSURE DIFFERENTIAL IN THE COWLING IS SMALL AND SLIGHT IRREGULARITIES IN THE BAFFLES CAN EASILY HAVE AN ADVERSE AFFECT ON ENGINE COOLING.**

Another less discussed aspect of cylinder cooling is maintaining the proper ratio of fuel to air. Too lean of a fuel mixture can cause cylinder temperatures to soar.

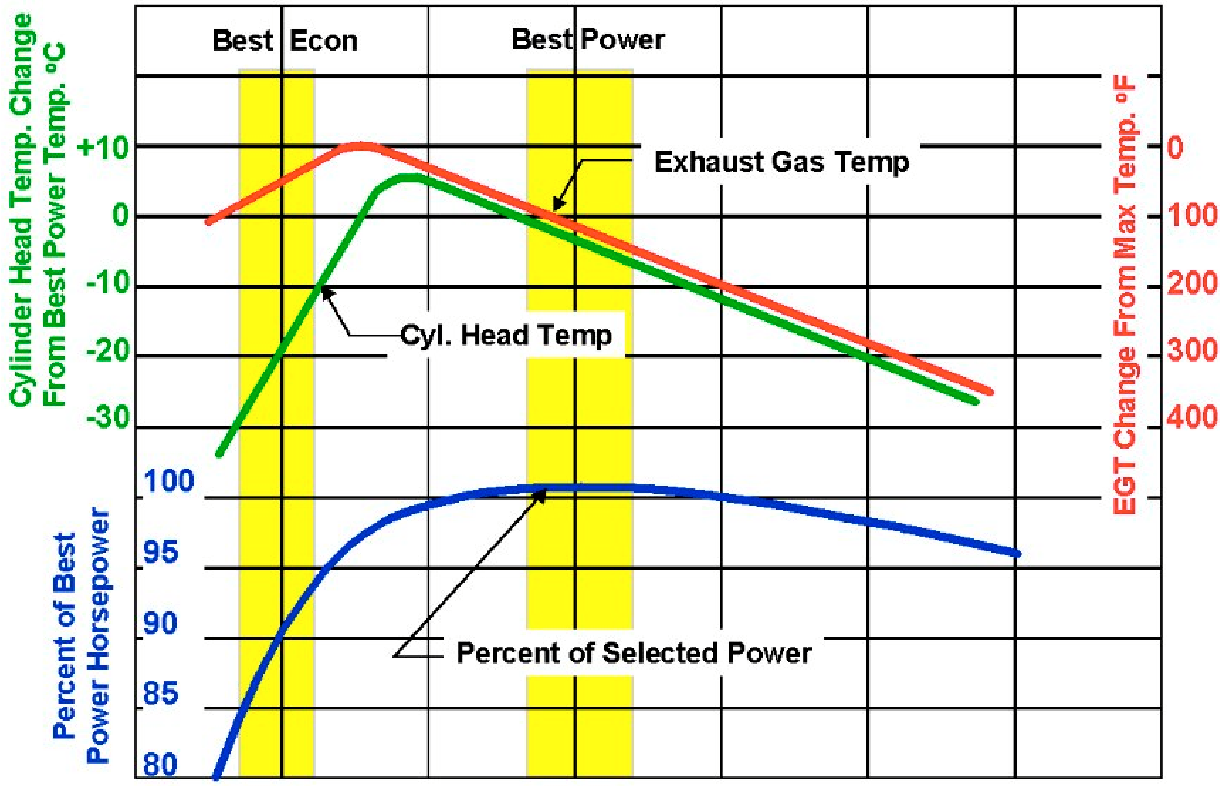


Figure 5-6. Fuel Management Chart

During high power and slow speed aircraft operations, the fuel/air mixture must be rich to supplement air cooling. Enriched fuel flow is a powerful way of controlling combustion temperatures and, therefore cylinder, piston and ring temperatures.

The highest combustion temperatures occur near the ideal fuel/air ratio of about one part of fuel for 15 parts of air. Combustion temperatures drop on both the lean side and rich side of this point. However, on the lean side of peak, the reduction in power with leaning is rapid and lean misfire occurs on many engines about 100° F lean of peak. On the rich side, power is very stable with changes in fuel flow. This characteristic allows the engine to obtain rated power with rich mixtures where the combustion temperatures are substantially reduced. This additional fuel at takeoff is required to maintain control of cylinder structure and oil cooling.

In cruise, operating rich mixtures reduces combustion temperatures and should be used to control engine temperatures. For normal operation, it is good practice that mixtures be controlled so that the hot cylinder is 75° to 100° F rich of peak at cruise settings.

In addition, rapid temperature changes should be avoided. Warm-up and cool down periods at the start and end of flights are also recommended.

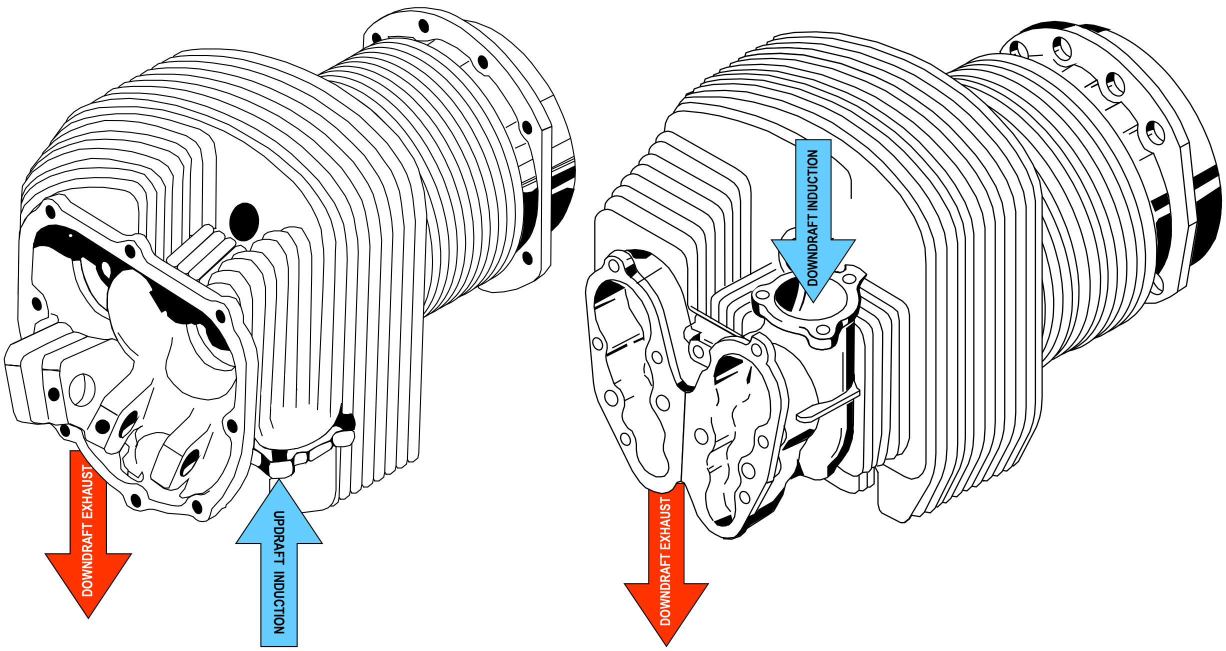


Figure 5-7. Comparison between Updraft and Cross-flow Cylinders

The amount of exhaust a cylinder can eliminate on the exhaust stroke and the amount of fresh air that it can draw in for a given intake stroke is a function of efficiency in developing power in a cylinder. To improve exhaust gas scavenging, the intake valve begins to open just before the exhaust valve closes at the top of the exhaust stroke. When the piston reaches top dead center, there is still a little space between the top of the piston and the cylinder combustion chamber dome. It is not possible for the piston to push out any further gases at this point. Opening the intake valve at this precise time aids in venting the remaining exhaust gases out of the cylinder by reducing the resistance of the gas to flow out.

The earlier cylinder design incorporates updraft induction / down draft exhaust. This cylinder uses the valve overlap that we just discussed, however you see from the figure above (left cylinder), the induction air must make a “U-turn” to assist in exhaust gas scavenging. This “U-turn” causes the airflow to change direction during the scavenging process. The cylinder on the right in the above figure incorporates downdraft induction airflow and from this you can see the airflow does not have to change directions and therefore provides greater efficiency in scavenging the exhaust gases. The result is more fresh air on the intake stroke an improved power pulse and greater efficiency.

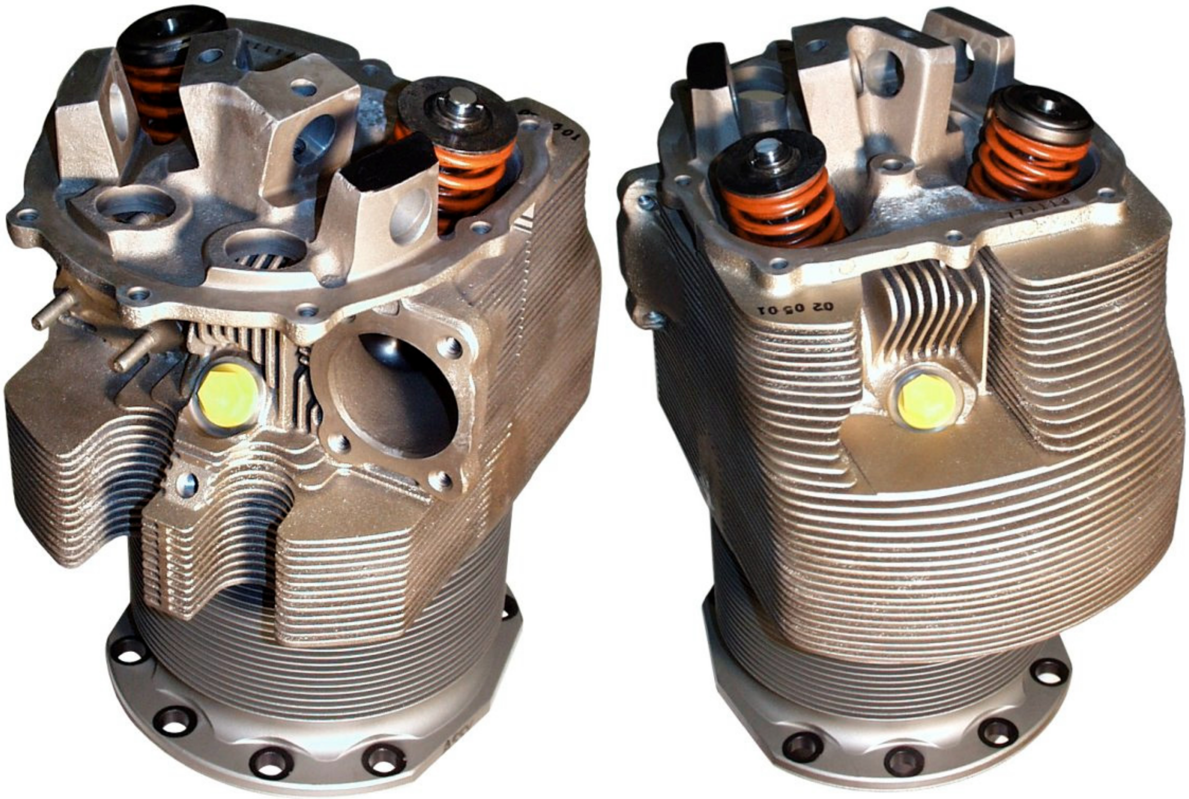
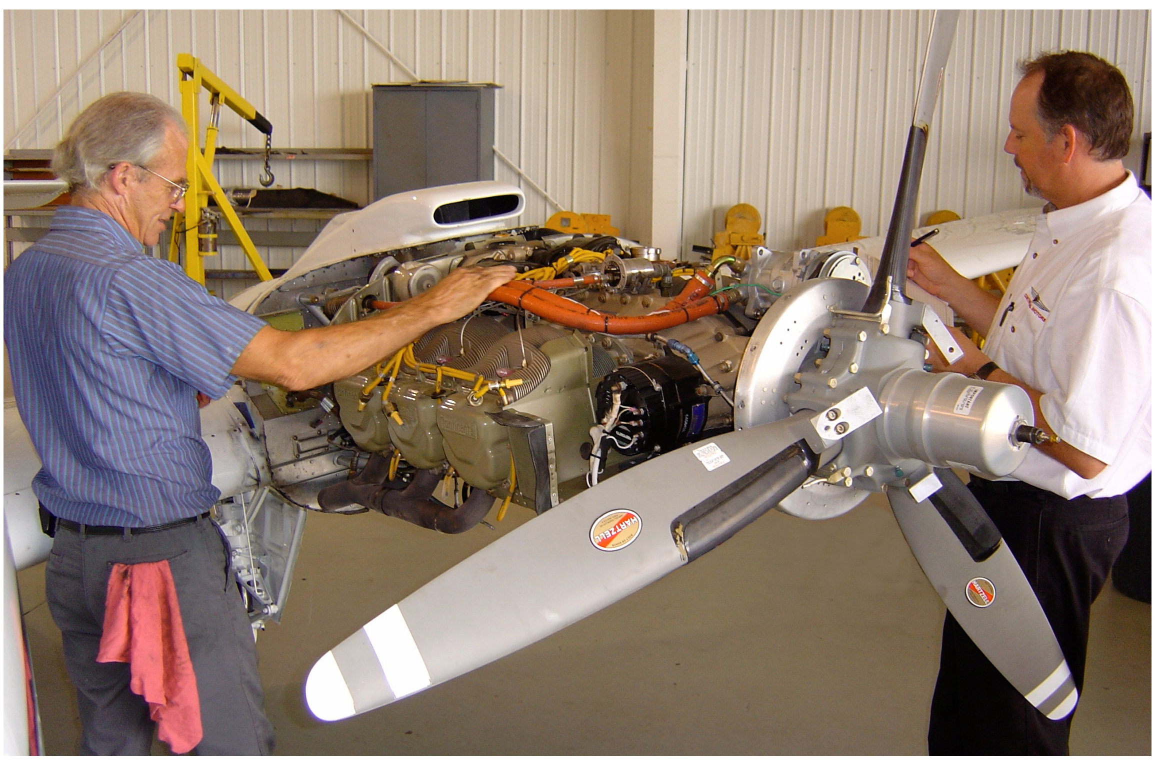


Figure 5-8. Updraft style 550 Cubic Inch Cylinder Views



Inspecting Cylinders During an Annual Inspection

240/360 SERIES ENGINES

CYLINDERS, PISTONS AND OVERHEAD DRIVE TRAIN

The cylinders, pistons and overhead drive train are the portion of the engine that develop power. The cylinder combustion chamber provides a controlled area for burning fuel/air mixture and converting that heat energy into mechanical energy. Aviation fuel and air are drawn into a cylinder during the intake stroke, compressed by the piston during the compression stroke and then ignited by a high intensity spark produced across the spark plug electrode air gap during the power stroke. As the mixture is ignited, the expanding gases force the piston to move inward toward the crankshaft.

This inward motion acting on the connecting rod and crankshaft throw is converted into circular or rotary motion by the crankshaft. As the crankshaft throw rotates past half of one revolution, the connecting rod and piston start moving outward on the exhaust stroke toward the cylinder head. During this movement, the exhaust valve begins to open allowing the burned mixture (exhaust) to escape. Momentum from the crankshaft forces the piston toward the cylinder head in preparation of the next intake stroke event.

Proper mechanical timing between the crankshaft and camshaft allows the intake and exhaust valves to open and close in synchronization with piston position in all six cylinders.

Proper magneto internal timing and magneto to engine mechanical timing allow precise spark plug ignition during the piston's compression stroke.

CYLINDER ASSEMBLY DETAILED DESCRIPTION

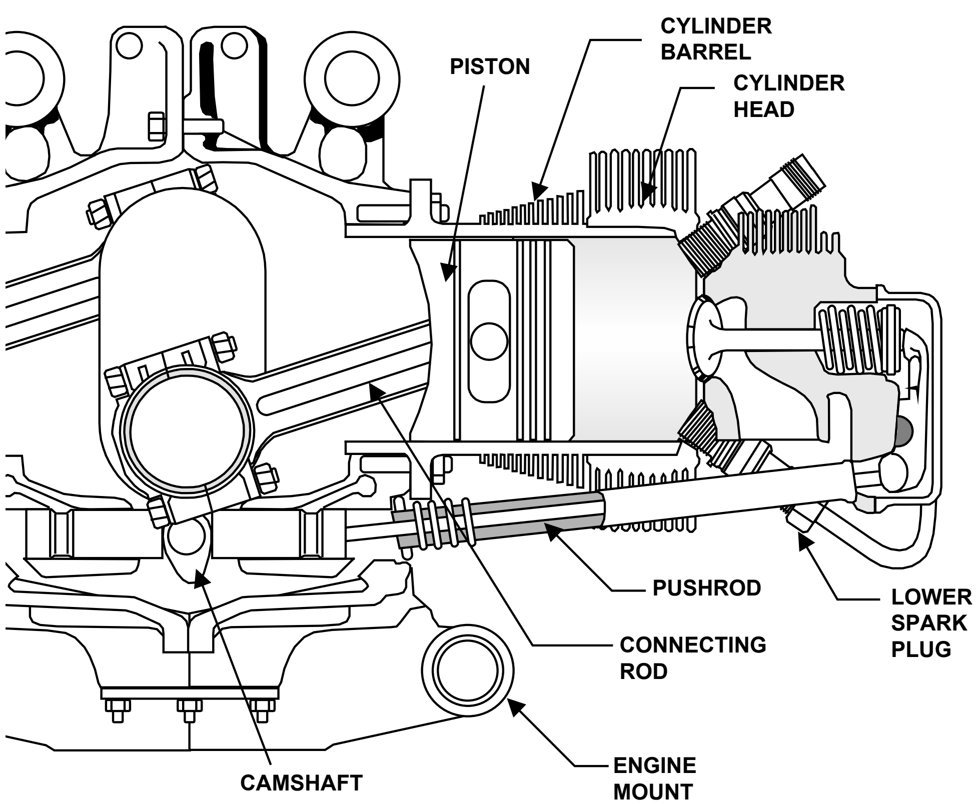


Figure 5-9. IO-240-B Cylinder Drive Train Schematic

Cylinder, Valve Guides, Valves, Rotocoils - The cylinder head is of the crossflow design where intake ports are top mounted to incorporate downdraft style induction. The exhaust ports are mounted on the bottom of the head to incorporate downdraft exhaust. The externally finned aluminum alloy head castings are heated and valve seat inserts installed before the head is screwed and shrunk onto an externally finned steel alloy barrel to make the permanent head and barrel assembly.

The cylinder barrel is nitrided for wear resistance. The cylinder barrel has cooling fins and come in both the straight barrel fin and tapered barrel fin design. The newer production design engines come with the tapered barrel fin. The taper reduces the fin area in the lower barrel area where there is less heat to dissipate. The primary design rational is weight reduction, approximately 1 lb. per barrel.

Intake and exhaust valve guides are pressed into the heated cylinder assembly. Special helical coil thread inserts are installed in upper and lower spark plugs holes. Exhaust valve faces are Stellite No. 6 and stem tips are hardened. Valve stems are solid. Rotocoil assemblies retain the two concentric springs surrounding each valve and are locked to the stems by tapered, semi-circular keys, which engage grooves around the stems. The controlled rotating action of this type retainer helps to prevent burning and eroding of the valve and valve seat. Valve rocker covers are stamped sheet steel and cadmium plated.

Valve Rockers, Shafts, Pushrods and Housings (Overhead Drive Train) - Valve rockers are steel forgings with hardened sockets, rocker faces and pressed in bronze bushings. They have a drilled oil passage for lubrication. The rocker shafts are held in place on the rocker bosses by retainers, locking tab washers and bolts. Pushrods are constructed of steel tubes and pressed-in, hardened, forged steel ball ends, which are center drilled for oil passages. The pushrod housings are beaded steel tubes. The bead at the cylinder end retains a gasket. The bead at the crankcase end retains a heavy spring, washer, packing ring and second washer.

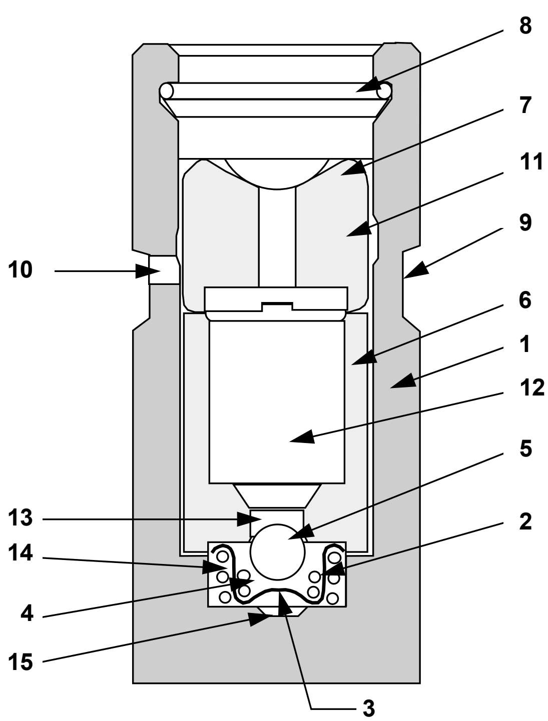


Figure 5-10. Hydraulic Lifter

Hydraulic Tappet - The barrel type hydraulic valve tappet consists of a steel body (1), an expanding spring (2), a check valve assembly (3, 4 and 5), a plunger (6), a socket (7) for pushrod end, and a retaining ring (8). A groove (9), around outside of the body picks up oil from the crankcase supply hole. From the exterior groove oil is directed to the interior body groove (11) through hole (10) and from the interior groove through the hole to the reservoir (12). Oil is withheld from reservoir (14) by check valve ball (5) which is supported by a spring (4) in the housing (3). The check valve is opened by outward motion of the plunger under pressure of the expanding spring whenever a clearance occurs in the valve train. Thus the body reservoir is kept full of oil which transmits lifting force from the body of the plunger. The plunger and socket are selectively fitted to the body to permit a calibrated leakage so the lifter will readjust its effective length after each cycle while the cylinder valve is closed to return "lash" in valve train to zero. The barrel type hydraulic tappets may be removed and replaced without complete disassembly of the engine.

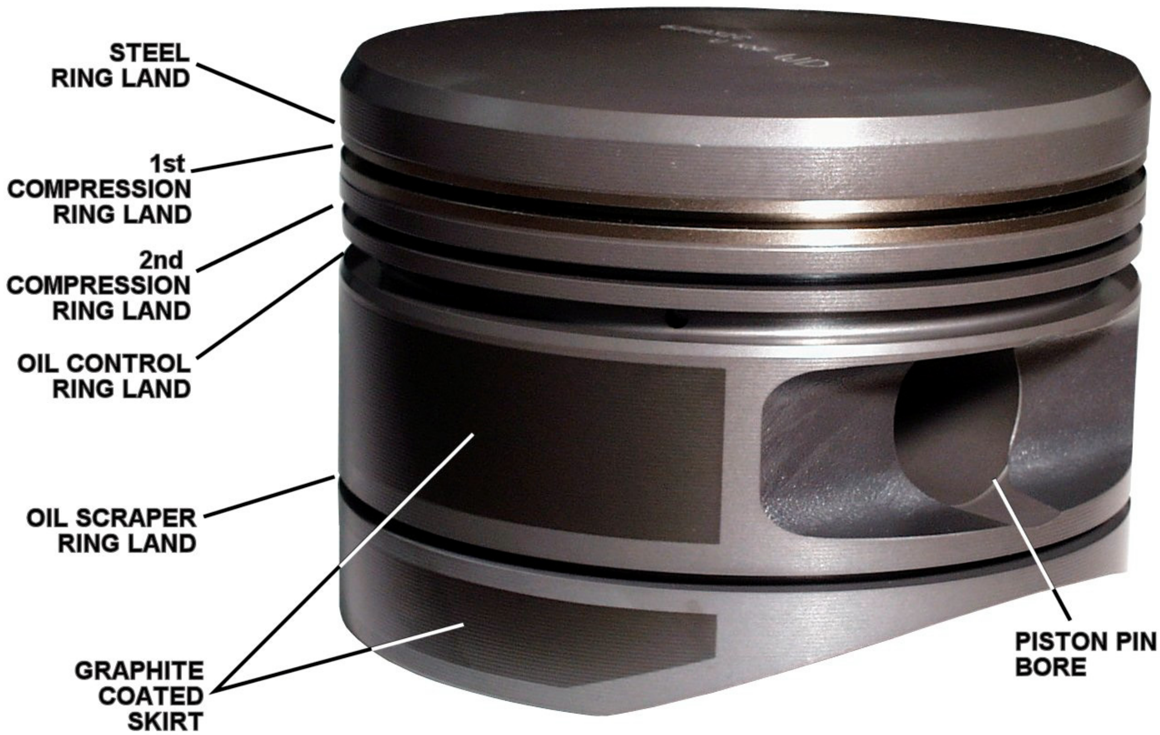


Figure 5-11. Coated Piston

Piston - Pistons are aluminum alloy castings with a steel insert cast into the top ring groove. The skirts are solid and have cylindrical relief cuts at the bottom. Pistons have three ring grooves above the pin hole and one ring groove below. Compression rings are installed in the top, and second grooves. The groove below the pin hole contains an oil scraper. A center grooved and slotted oil control ring is installed in the third groove which has six oil drain holes to the interior. Weight differences are limited to 1/2 ounce or 14.175 grams in opposing bays. Piston pins are full floating with permanently pressed-in aluminum end plugs.

470/520/550 SERIES – UPDRAFT & GT SERIES CROSSFLOW DESIGNS

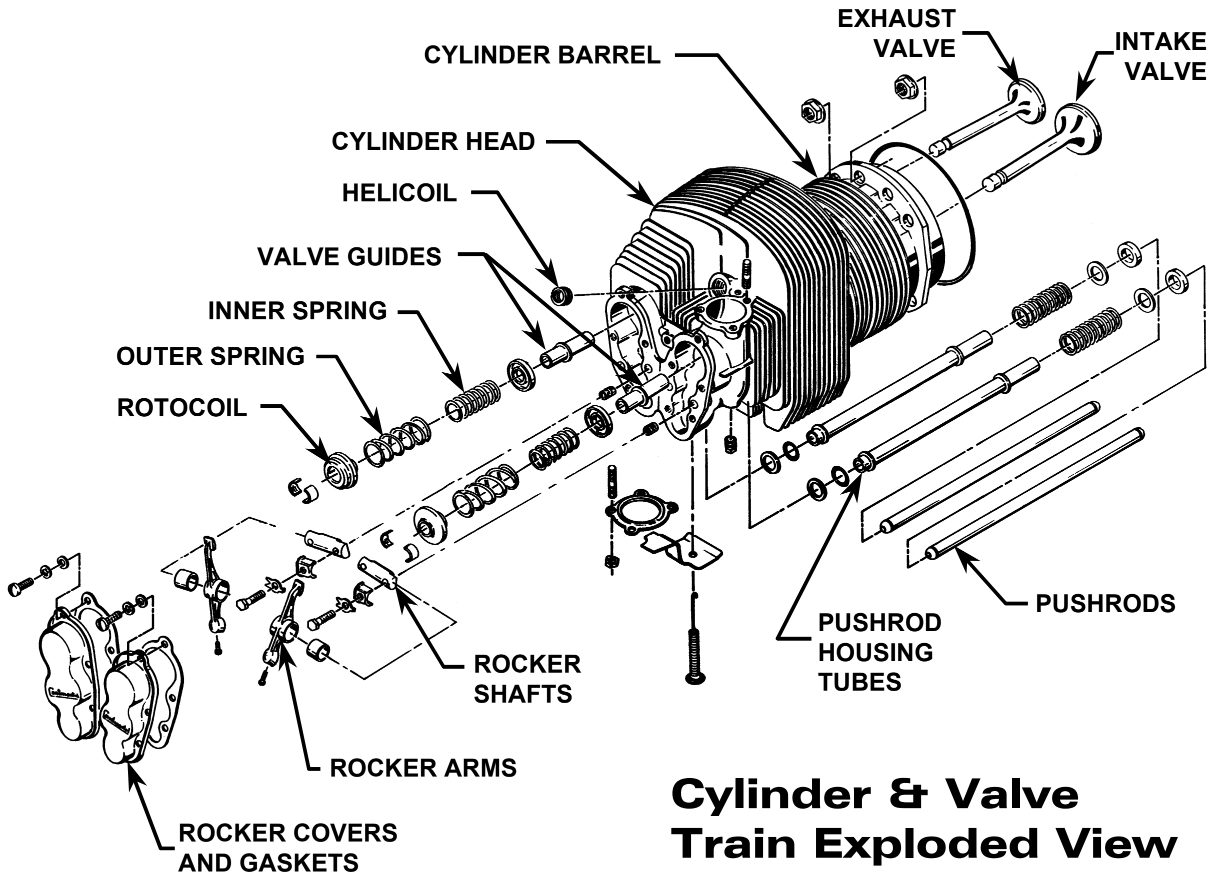


Figure 5-12. 550 Cross Flow Style Cylinder Exploded View

CYLINDERS, PISTONS AND OVERHEAD DRIVE TRAIN

The cylinders, pistons and overhead drive train are the portion of the engine that develop power. The cylinder combustion chamber provides a controlled area for burning fuel/air mixture and converting that heat energy into mechanical energy. Aviation fuel and air is drawn into a cylinder during the intake stroke, compressed by the piston during the compression stroke and then ignited by a high intensity spark produced across the spark plug electrode air gap during the power stroke. As the mixture is ignited, the expanding gases force the piston to move inward toward the crankshaft.

This inward motion acting on the connecting rod and crankshaft throw is converted into circular or rotary motion by the crankshaft. As the crankshaft throw rotates past half of one revolution, the connecting rod and piston start moving outward on the exhaust stroke toward the cylinder head. During this movement, the exhaust valve begins to open allowing the burned mixture (exhaust) to escape. Momentum from the crankshaft forces the piston toward the cylinder head in preparation of the next intake stroke event.

Proper mechanical timing between the crankshaft and camshaft allows the intake and exhaust valves to open and close in synchronization with piston position in all six cylinders.

CYLINDER ASSEMBLY DETAILED DESCRIPTION

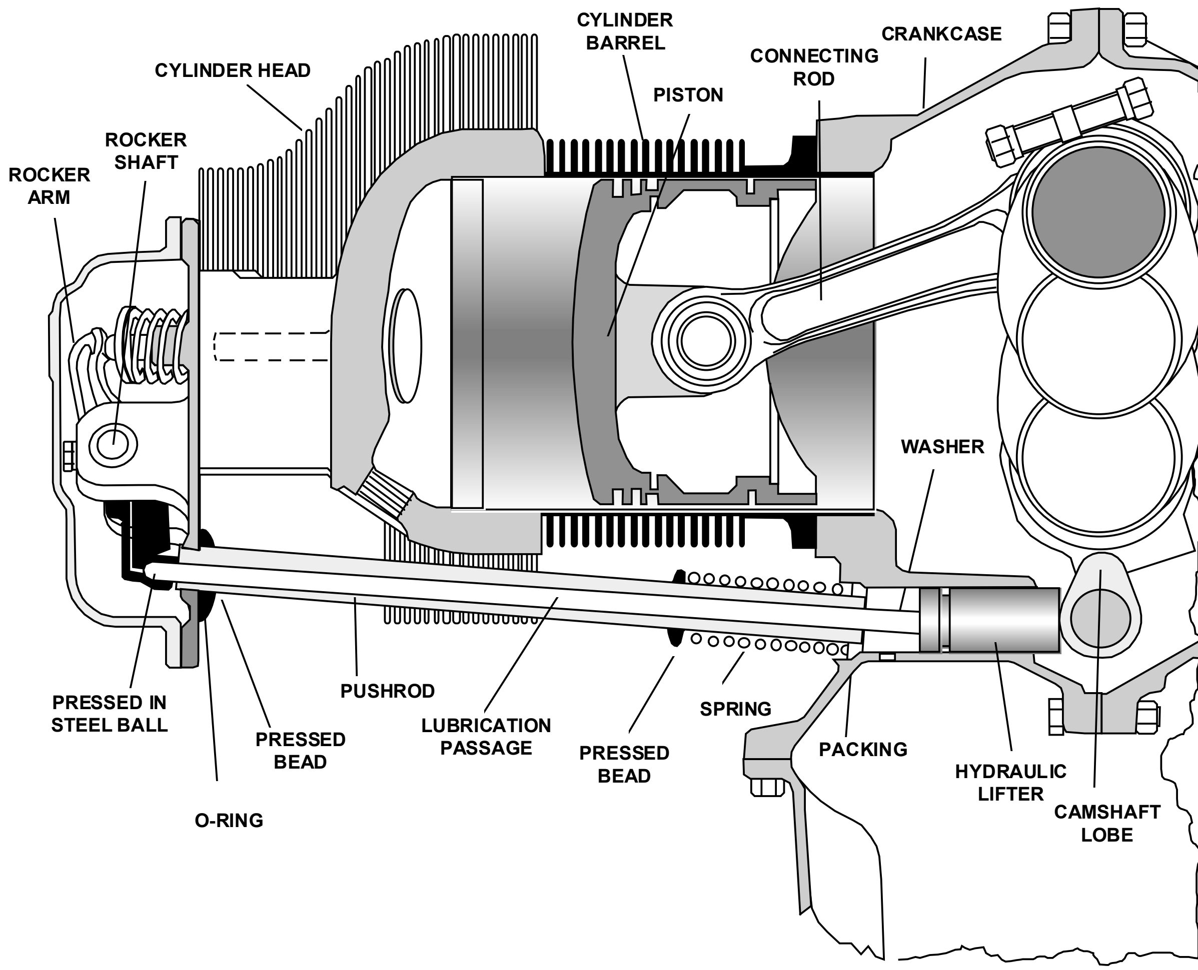


Figure 5-13. Engine Cutaway Detailing Cylinder Assembly

Cylinder, Valve Guides, Valves, Rotocoil and Retainer - The standard cylinder head design incorporates updraft intake and downdraft exhaust ports located below the cylinder as installed. This standard design is incorporated on a large number of 470, 520, & 550 series engines. The standard style cylinder comes in straight valve and inclined valve designs. The straight valve designs are used primarily in some the 470 series engines with the exception of the L/IO-520-P and the TSIO-520-AE.

The GT series cylinder head is of the crossflow design where intake ports are top mounted to incorporate downdraft style induction. The exhaust ports are mounted on the bottom of the head to incorporate downdraft exhaust. The GT style cylinder is used on the GTSIO-520 series engines, the TSIO-520-BE the IO-550-G & N and the TSIO-550 Series engines.

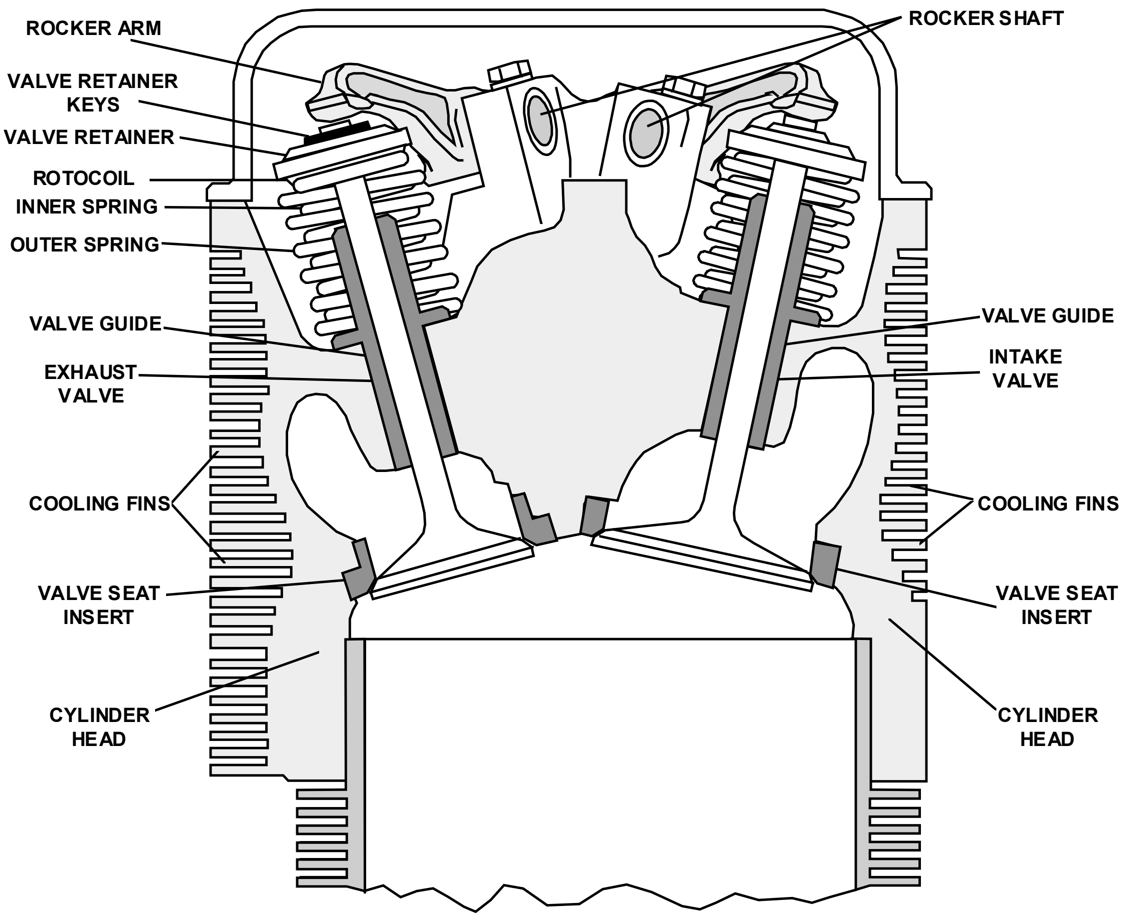


Figure 5-14. Detail of Cylinder Overhead Valve Train

The externally finned aluminum alloy head castings are heated and valve seat inserts installed before the head is screwed and shrunk onto an externally finned steel alloy barrel to make the permanent head and barrel assembly. The cylinder barrel is nitrided for wear resistance. Intake and exhaust valve guides are pressed into the heated cylinder assembly. Special helical coil thread inserts are installed in upper and lower spark plug holes. Exhaust valve faces are Stellite No. 6 and stem tips are hardened. Valve stems are solid. A rotocoil assembly retains the two concentric springs surrounding the exhaust valve and is locked to the exhaust valve stem by tapered, semi-circular keys that engage grooves around the stem. The controlled rotating action of this type retainer helps to prevent burning and eroding of the valve and valve seat. A retainer retains the two concentric springs surrounding the intake valve and is locked to the intake valve stem by tapered, semi-circular keys which engage grooves around the stem. Valve rocker covers are painted die-cast aluminum.

Valve Rockers, Shafts, Pushrods and Housings (Overhead Drive Train) - Valve rockers are steel forgings with hardened sockets, rocker faces and pressed in bronze bushings. They have a drilled oil passage for lubrication. The rocker shafts are held in place in the rocker bosses by washers and retaining bolts. Pushrods are constructed of steel tubes and pressed-in, hardened, forged steel ball ends, which are center drilled for oil passages. The pushrod housings are beaded steel tubes. The bead at the cylinder end retains a washer, packing ring and second washer. The bead at the crankcase end retains a heavy spring, washer, packing ring and second washer.

9 Inch Rigid Borescope for Cylinder Inspections

SUMMARY

In this chapter we discussed the complexities of the combustion chamber, requiring the best of engineering and manufacturing processes in use today to produce the TopCare cylinder. We then began with an in-depth discussion on cylinder cooling and baffling requirements. We discussed the importance of maintaining differential pressure using ram airflow and cylinder baffles and cowl flaps and completed the discussion with maintaining proper fuel/air mixtures. We then discussed the functions of the components in cylinder assemblies for the 240, 360 and 520/550 series engines.

KEY TERMS

Four Cycle — Short for "Four Stroke Cycle." It refers to the four strokes of the piston in completing a cycle of engine operation (Intake, Compression, Power and Exhaust).

Heat Soaked — Prolonged exposure of an object to hot temperature so that its temperature throughout approaches that of ambient.

Lean Limit Mixture — The leanest mixture approved for any given power condition. It is not necessarily the leanest mixture at which the engine will continue to operate.

Manifold Pressure — Pressure as measured in the intake manifold down-stream of the air throttle. Usually measured in inches of mercury.

Octane Number — A rating which describes relative anti-knock (detonation) characteristics of fuel. Fuels with greater detonation resistance than 100 octane are given performance ratings.

Overhead Valves — An engine configuration in which the valves are located in the cylinder head itself.

Overspeed — When an engine has exceeded its rated revolutions per minute.

Rocker Arm — A mechanical device used to transfer motion from the pushrod to the valve.

T.D.C. — Top Dead Center. The position in which the piston has reached the top of its travel. A line drawn between crankshaft rotation axis, through the connection rod and axis and the piston pin center would be straight line. Ignition and valve timing are stated in terms of degrees before or after TDC.

Thermal Efficiency — Regarding engines, the percent of total heat generated which is converted into useful power.

1. Cooling airflow is critical to maintaining the engine cylinder temperatures. What other engine subsystems greatly assist in preventing the cylinders from overheating? ____________________

____

____

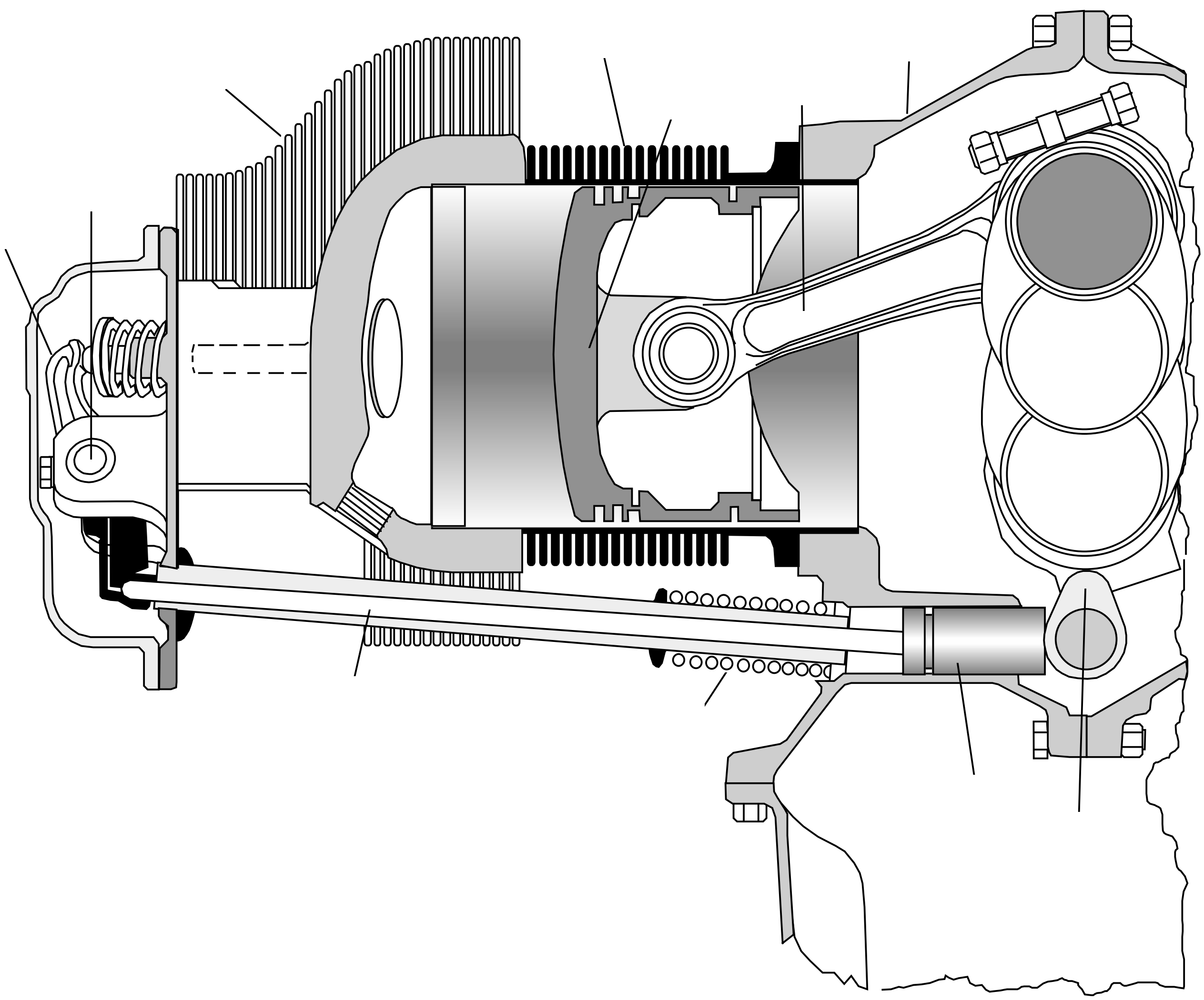
2. What is the name of the process applied to the cylinder barrel to resist wear? _______________

____

3. What is the weight difference between matching pistons in opposing cylinders? ____________

____

4. Referring to the Cylinder Assembly sectional diagram below label all components pointed to.



7. In the diagram shown above, trace the path through which oil travels to the valve train.

8. List the new cylinder and piston enhancements that were brought about by the TopCare® program.
____
____
____

9. Describe the forces on components that cause the valves to rotate? ____________________
____
____

10. What component controls valve rotation? ______________________________________
____

What is the reason for doing this? ____
____

11. Which service bulletin lists the latest piston and cylinder fit specifications? ____________

At what depth would you measure for the "X" diameter on a 5.25" cylinder? ___________
____

INTENTIONALLY

LEFT

BLANK

Chapter Six

Continental Continuous Flow Fuel Injection

CHAPTER 6 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Identify the Components which comprise the Fuel Injection System.

② Describe the functional operation of the components in the Fuel Injection System.

③ Identify the root cause of fuel injection faults by given symptoms.

④ Identify the Service Bulletin required for setting up the fuel injection system.

⑤ Describe the task knowledge procedures for setting up the fuel injection system.

Setting up the Fuel Injection System

INTRODUCTION

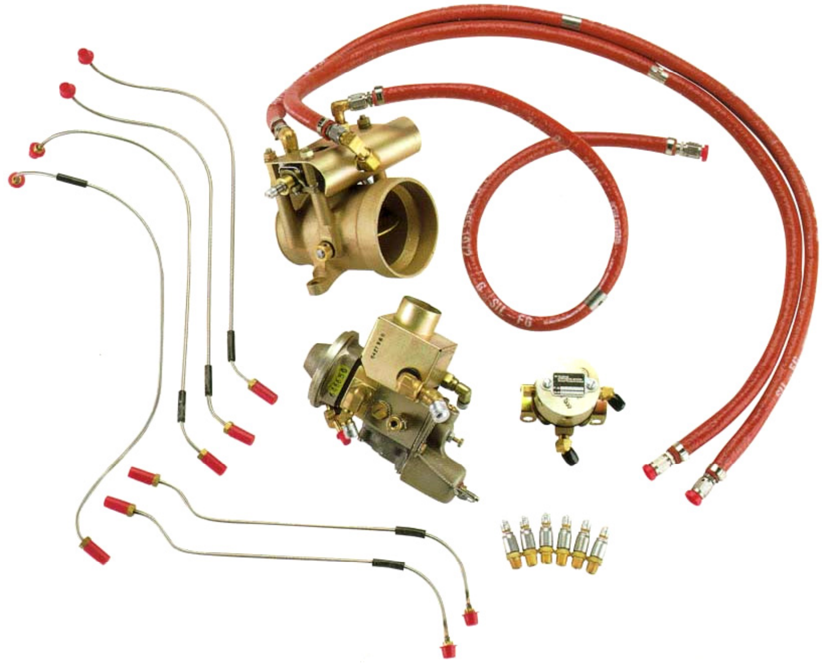


Figure 6-1. Photo of the IO550B engine model Fuel Injection System Components

The Continental Continuous Flow Fuel Injection system has been designed to be a very affective system at delivering the correct amount of fuel to each individual cylinder as power demands change within the engine. Over the past several decades this system has gained worldwide acclaim for being a very reliable system, a very safe and redundant system. One of the least understood items about this fuel injection system is that it is also a very simple system to understand and maintain. The fuel injection system will have to be adjusted when one of the following situations occurs:

The fuel injection system will have to be adjusted when a new, rebuilt, or overhauled engine is installed into the aircraft. This is due to the little understood fact that the fuel pump has been designed to be pressure inlet sensitive. This means that the fuel pump outlet capacity will change as the inlet pressure to the pump varies. If the engine is installed into a high wing aircraft with a positive head pressure on the inlet fuel line to the pump the outlet of the fuel pump will be greater. Likewise if installed into a low wing aircraft with a negative inlet pressure to the fuel pump, the outlet flow and pressure from the fuel pump will be less.

The fuel injection system should have calibrated gauges connected to perform an operational verification of the system flow and pressure parameters during 100 Hour or annual inspections. If the engine is operated throughout the year where extreme climate changes occur, you may find the Idle Mixture rise will vary. Do not simply adjust the Idle Mixture rise. You must connect calibrated gauges to the system and perform a complete operational verification. Operational verification of the system with calibrated gauges is also required whenever a system component is replaced. Even if standard fuel injector nozzles are replaced with tuned fuel injection nozzles.

The Continental® Engine that is equipped with the TCM Continuous Flow Fuel Injection System has many advantages over the standard carbureted engine. Improved metering of fuel and even distribution to each cylinder will improve horsepower with the same fuel consumption. Engines that are Fuel Injected are free from the fuel vaporization icing that can occur with a carburetor.

COMPONENT IDENTIFICATION

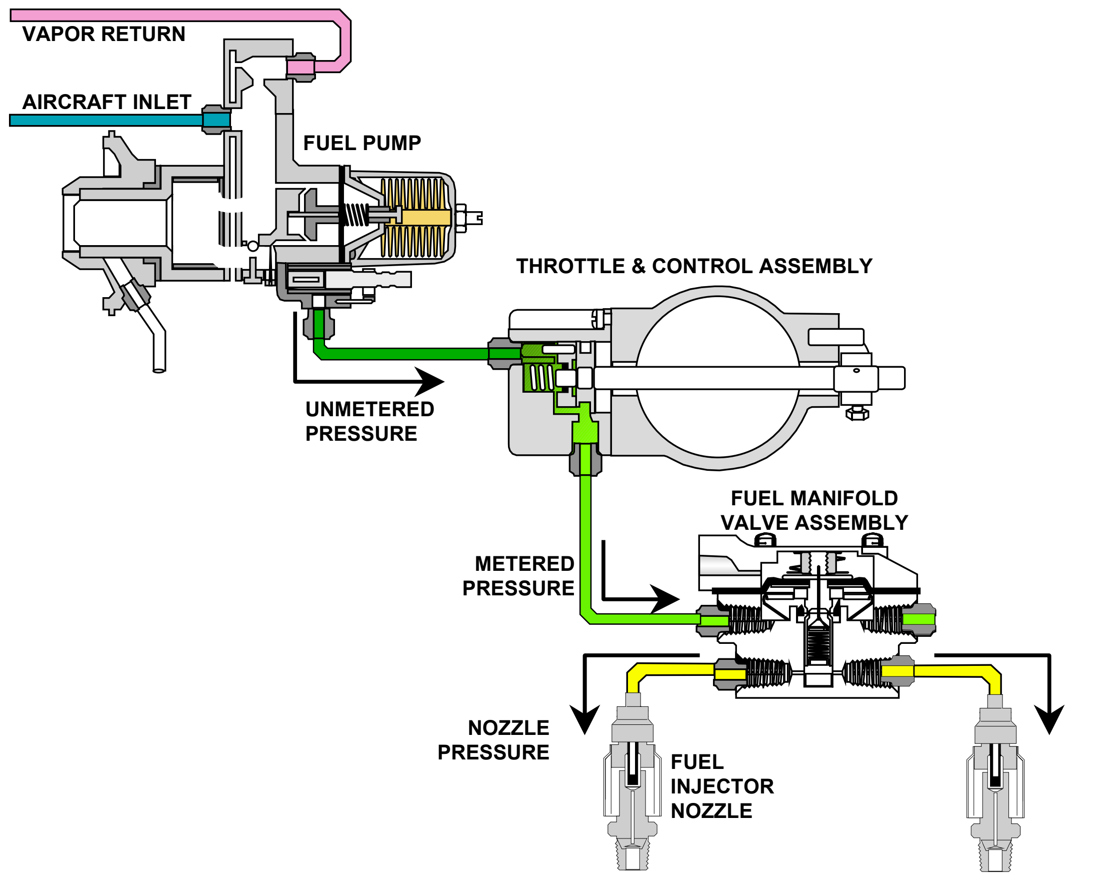


Figure 6-2. Continental Continuous Flow Fuel Injection System Basic Diagram

The Continental Continuous Flow Fuel Injection System has only four basic systems. The Fuel Injection Pump, the metering unit, the fuel manifold valve and the injector nozzle.

- The Fuel Injection Pump is a positive displacement, vane type pump. Being engine driven, its output volume and pressure vary with engine RPM. It is the only continual moving part in the fuel injection system. The primary functions of the fuel injection pump include supplying fuel under pressure to the rest of injection system and performing certain metering functions. Since the fuel pump is engine driven, the fuel pump outlet pressure and flow will vary with engine rpm. As engine rpm increases, the outlet fuel flow and pressure will increase.

- The Fuel Metering unit correctly proportions the fuel to air mixture and the amount of fuel to flow as engine requirements are changed at the throttle.

- The Fuel Manifold Valve equally distributes fuel flow to all of the engine cylinders by dividing the metered fuel flow equally between the number of nozzles in the system. It also serves as a positive idle cut-off valve whenever the engine is shut down.

- The Fuel Injector Nozzle is responsible for atomization and subsequent vaporization of the raw metered fuel. The nozzle sprays fuel continuously into the intake chamber of the engine cylinder head. There is no timing involved. Heat from the cylinder head quickly accomplishes vaporization of the atomized fuel. Much more complete vaporization of the fuel and cooler running intake valves are two more examples of the superiority of continuous flow fuel injection.

FUNCTIONAL COMPONENT DESCRIPTION

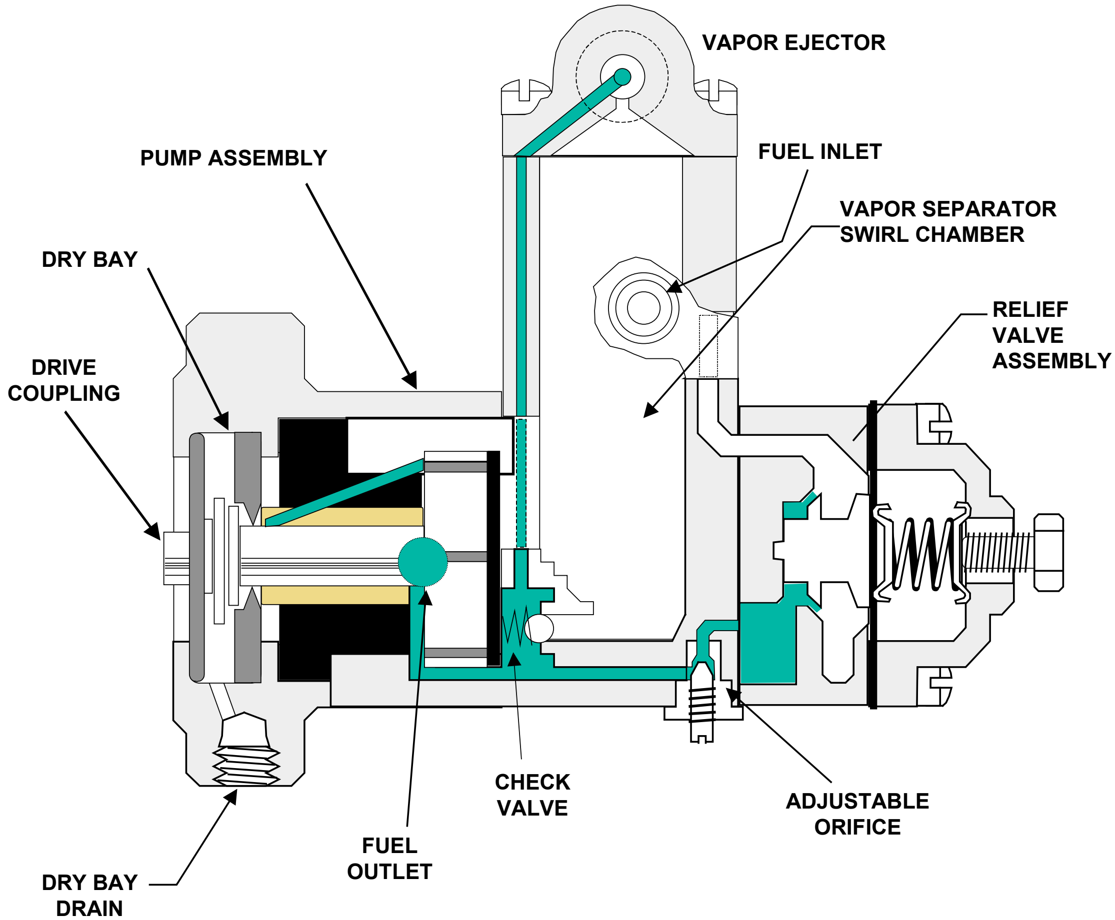


Figure 6-3. Typical Naturally Aspirated Fuel Pump

Fuel Pump - Since the fuel pump must deliver more fuel than the engine can use, a return line will be necessary to recirculate the excess fuel. The recirculation path will reduce the fuel pump output pressure so an orifice in the return line develops the pressure and allows the pump to maintain excess capacity. The faster the pump runs, the greater will be its output. Because the orifice in the fuel return line remains fixed, any increase in pump output will also increase pump output pressure. Since the pump is driven by the engine, the pump's output will be in direct proportion to engine RPM.

The fuel pump will actually meter fuel in direct proportion to engine RPM. The fixed orifice in the return fuel path plays an important role in fuel metering. Should the orifice become partially or completely restricted, excessive output pressure will result and upset the balance of proper fuel metering and subsequent fuel flow.

The fuel injection pump must provide adequate fuel flow and pressure at low engine speed as well as the higher ranges. Remember the output pressure of this pump will vary with engine speed. Therefore, at idle speeds the output will be considerably less. The orifice that worked for us at the higher speeds will not be able to maintain the outlet fuel pressure in the low to idle speed range.

By adding a small relief valve in series with the adjustable orifice, we can now have sufficient outlet pressure in the idle range, and without disturbing the relationship of the orifice to output pressure in the higher engine RPM ranges. This relief valve is adjustable and its adjustment is important. When set too high, excessive pressure and flow will occur at idle and throughout the entire range of engine speeds.

A vapor separator tower is also added to the fuel injection pump and inlet fuel enters near the top of the tower. The fuel enters a cylindrical chamber inside the tower. The swirling action created in this cylindrical chamber tends to centrifuge the liquid fuel causing the vapors to rise to the top of the separator tower. This process helps to insure that only liquid fuel will reach the vanes of the fuel pump. A vapor jet and return line is added to the top of the separator tower. Fuel rushing through the small orifice in the jet actually creates a small low pressure and as a result, will perform a pumping action. It will transfer any vapors and excess fuel back to the aircraft fuel tank from which the fuel was pumped.

A by-pass check valve is added. The aircraft's fuel system incorporates an electric fuel pump for starting, ground checking, and possible emergencies. For example, when priming before starting, fuel under pressure from the electric pump enters the injection pump in the usual manner. When the injection pump is at rest, the fuel by-passes the vane portion of the pump by way of the by-pass check valve to reach the metering unit.

When fuel under pressure is being supplied by the auxiliary electric pump all of the other circuits of the injection pump continue to function. Fuel is passing through the adjustable orifice, the relief valve is functioning, the vapor ejector is at work, and fuel under pressure is leaving the injection pump for the mixture control and Fuel Metering unit.

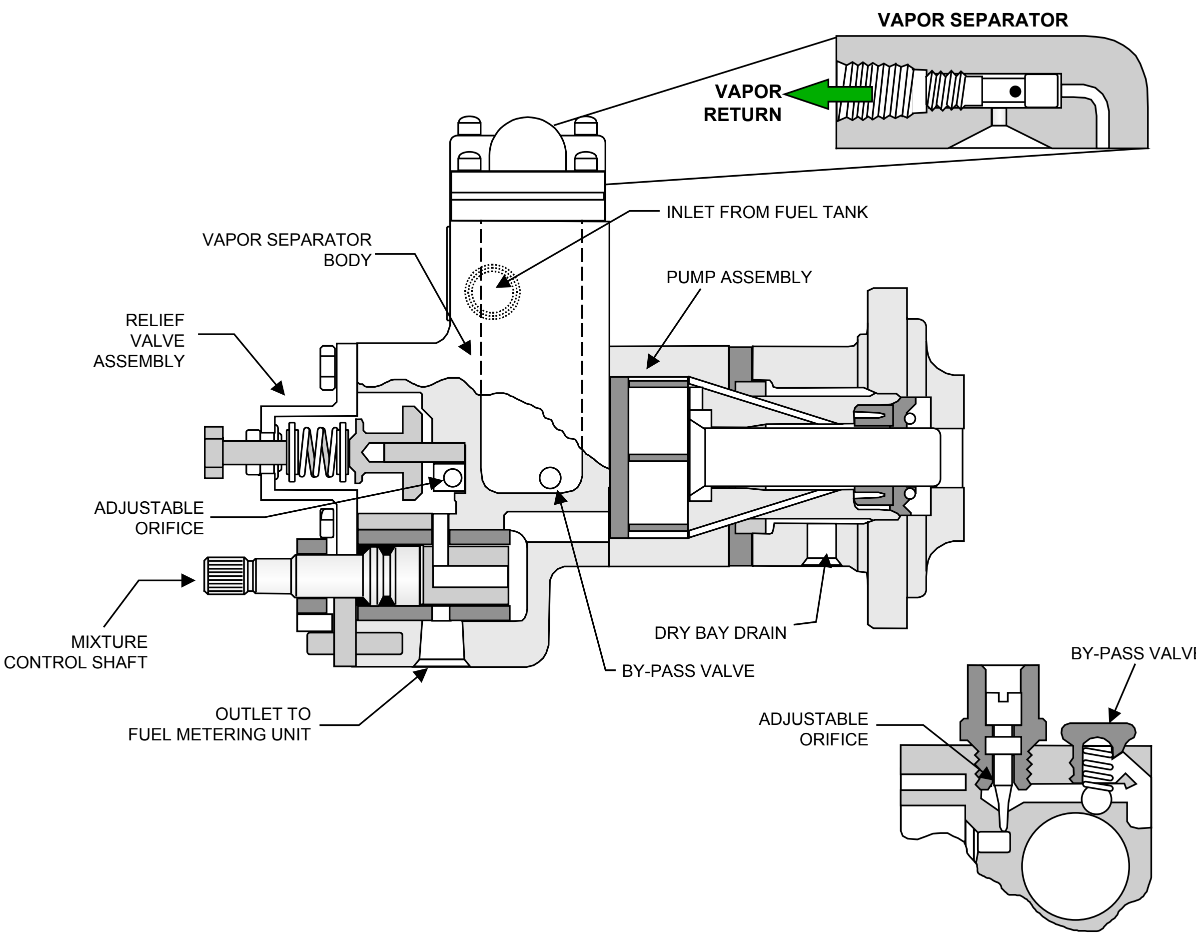


Figure 6-4. Fuel Pump with Integral Mixture Control

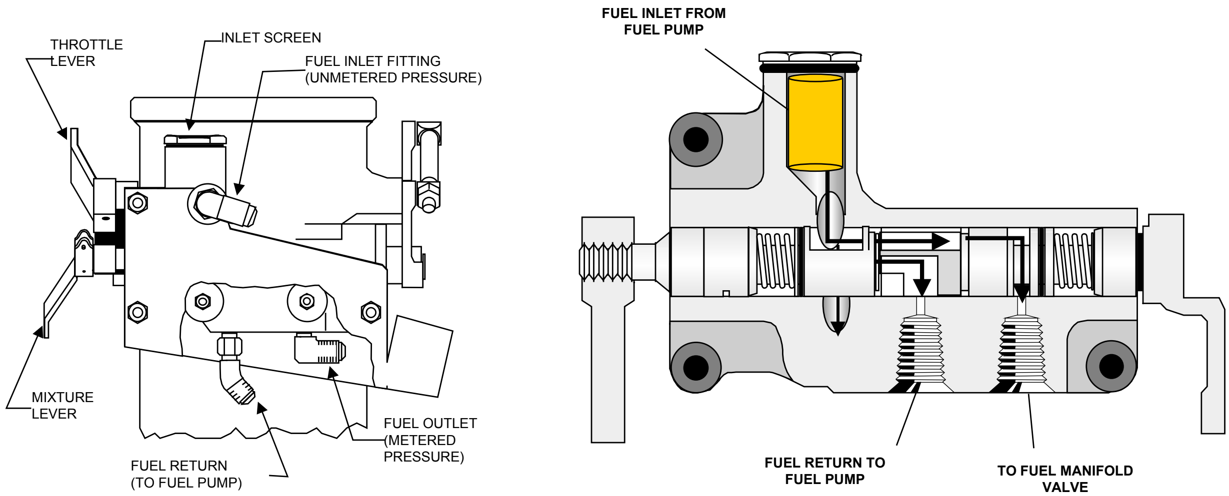


Figure 6-5. Typical Fuel Control Unit

Fuel Control Unit - The fuel leaves the injection pump and travels through fuel lines to the Fuel Control unit. The fuel enters the control unit through a fuel screen where it is filtered. The filtered fuel advances into the mixture control valve. With the mixture control in the IDLE CUT-OFF position, all of the fuel entering the control unit will return to the fuel pump. When in the FULL RICH position most of the fuel is passing to the throttle control valve. A small amount will still pass through the return system. The throttle control valve is linked directly to the air throttle and moves in direct proportion to the air throttle. The mixture ratio will remain constant through all movement of the throttle.

On some Continental fuel injection systems, the mixture control is designed into the injection pump. When moved away from the FULL RICH position, the mixture control reduces the pump outlet pressure thus dropping the flow through the Fuel Control Unit. The end result to the cylinders in terms of mixture ratio will be the same as with the other type mixture control built into the Fuel Control unit.

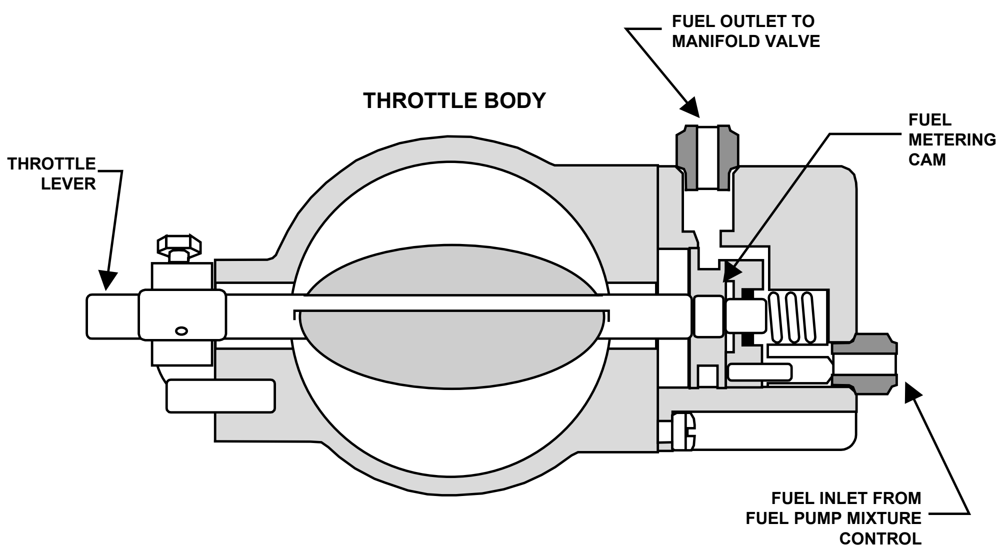


Figure 6-6. Fuel Control Unit

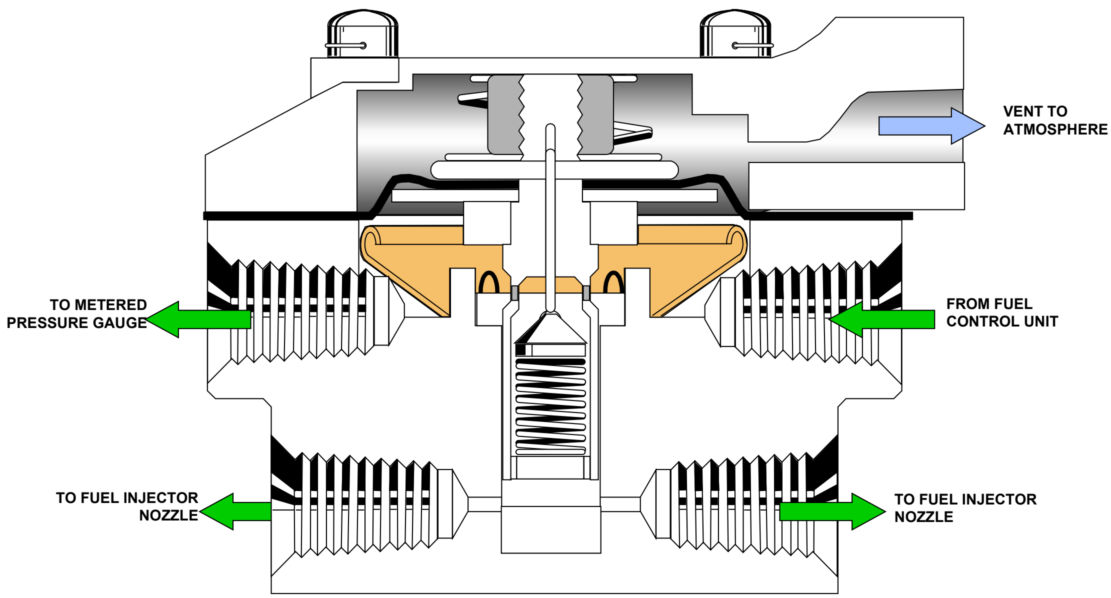


Figure 6-7. Fuel Manifold Valve

Fuel Manifold Valve - The third component in our continuous flow fuel injection system is the fuel manifold valve. This valve serves two basic functions, each of which will be explained separately. The first function of this valve is to provide positive fuel cut-off between the Fuel Control unit and the nozzles during engine shutdown and when the injection system is not in operation. Referring to Figure 6-7, you can see the diaphragm that is attached to the top of the valve to create two separate chambers. The spring serves to counteract the force of fuel pressure acting on the opposite side of the diaphragm. The upper chamber is vented to atmosphere while the lower chamber interacts with fuel under pressure from the metering unit. This positive fuel pressure will open the cut-off valve and permit fuel to flow. A valve rated at 4 PSI will actually begin to open at approximately 3.2 PSI. It will be fully open at 4 PSI. Fuel entering the lower chamber under pressure pushes the diaphragm and attached valve up. This action uncovers the entrance ports in the valve permitting fuel to flow into the interior of the valve and out the distributor ports to the nozzles.

Placing the mixture control in the IDLE CUT-OFF position will stop the flow of fuel to the manifold valve. Once fuel flow has stopped, the closing spring will push the plunger down into its bore, sealing off the distributor ports at the bottom and coming to rest against the cut-off seal at the top of the bore. This action provides a double seal and therefore positive cut-off to the nozzles.

Notice the function of the atmospheric vent. Each time the valve opens (engine start), or closes (engine shutdown), this upper chamber must be able to breathe. If this vent should become obstructed, the valve will not operate properly. The vent must always be open and facing away from the ram air entering the cowling.

The second function is simply to provide equal fuel flow to all nozzles at all speeds and power settings. The bottom portion of the manifold valve contains the outlet ports. Fuel lines of equal length connect these ports to the injector nozzles. This is the distributing function of the manifold valve.

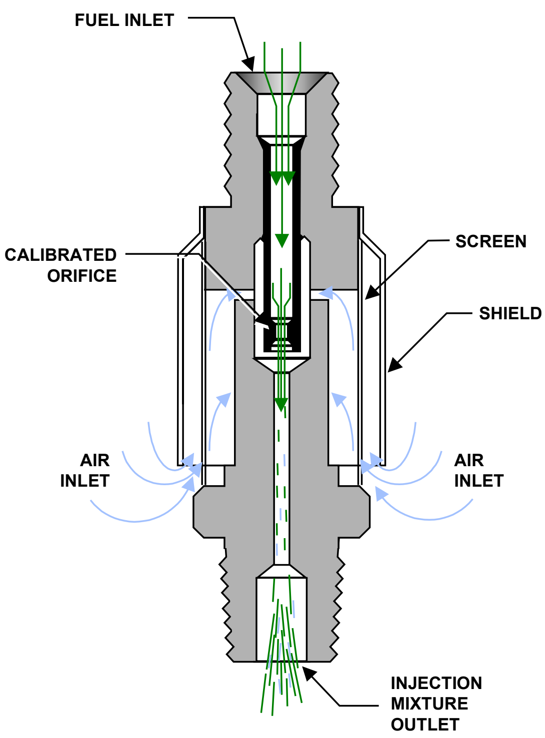


Figure 6-8. Fuel Injector Nozzle

Fuel Injector Nozzle - The basic nozzle consists of a fuel inlet for the line from the manifold valve. Drilled air openings are provided for the entrance of ambient air. A calibrated orifice assures that nozzles in the engine will flow exactly the same amount of fuel to each cylinder.

A screen fitted to the nozzle filters the ambient air entering the nozzle to mix with fuel and begin the process of atomization. A shroud is fitted over the outside of the filter screen to protect the screen from any possible damage.

At idle speed, fuel enters the nozzle from the manifold valve and ambient air enters at much greater pressure than existing manifold pressure. The liquid fuel is broken up and the first stage of vaporization begins. At higher operating engine speeds, much more fuel will pass through the nozzle. Less ambient air is entering the nozzle due to a lower differential between ambient and manifold pressure. At higher engine speeds a much greater volume of air is entering the cylinders, and considerably more fuel is passing through the nozzles. The greater the flow through the nozzle, the better it will atomize. Therefore under high nozzle flow considerably less air is needed for internal mixing in the nozzle, and vaporization of the injected fuel will occur much quicker from the high heat of the cylinder heads.

The injector air openings serve more than to just improve atomization of the fuel. At low speed, low fuel flow conditions, the high manifold vacuum created during the intake stroke would suck the fuel out of the nozzles and upset proper operation of the manifold valve. The air bleeds in the nozzles prevent this from happening. Should these air bleeds or their air filter screens become obstructed with dirt, erratic and rough low speed engine operation will surely result.

Fuel Systems with Fuel Pump Integral Mixture Control

Certain engine models are equipped with a newer style fuel pump that incorporates the mixture control in the pump itself. The engine models that are equipped with this style of fuel system are listed as follows: The IO240, IO/TSIO/LTSIO360, and all downdraft induction IO550 series engines.

The fuel injection system is a simple, low pressure system that injects fuel into the intake valve port in the cylinder head. It is designed for ready adaptation on engines of widely varying power ratings, displacement and number of cylinders. There are four basic elements in the fuel injection system: the fuel pump, fuel metering unit, fuel manifold valve and fuel nozzles. Fuel flows from the fuel pump to the fuel metering unit. The fuel then flows from the fuel metering unit to the fuel manifold valve where it is distributed to the four fuel injector nozzles.

FUEL INJECTION SYSTEM COMPONENT DETAILED DESCRIPTION

Fuel enters the fuel pump at the swirl well of the vapor separator. Here, vapor is separated by a swirling motion so that only liquid fuel is fed to the pump. The vapor is drawn from the top center of the swirl well by a small pressure-jet of fuel and is fed into the vapor return line. This line carries the vapor back to the fuel tank. There are no moving parts in the vapor separator, and the only restrictive passage is used in connection with vapor removal. Thus, there is no restriction of main fuel flow.

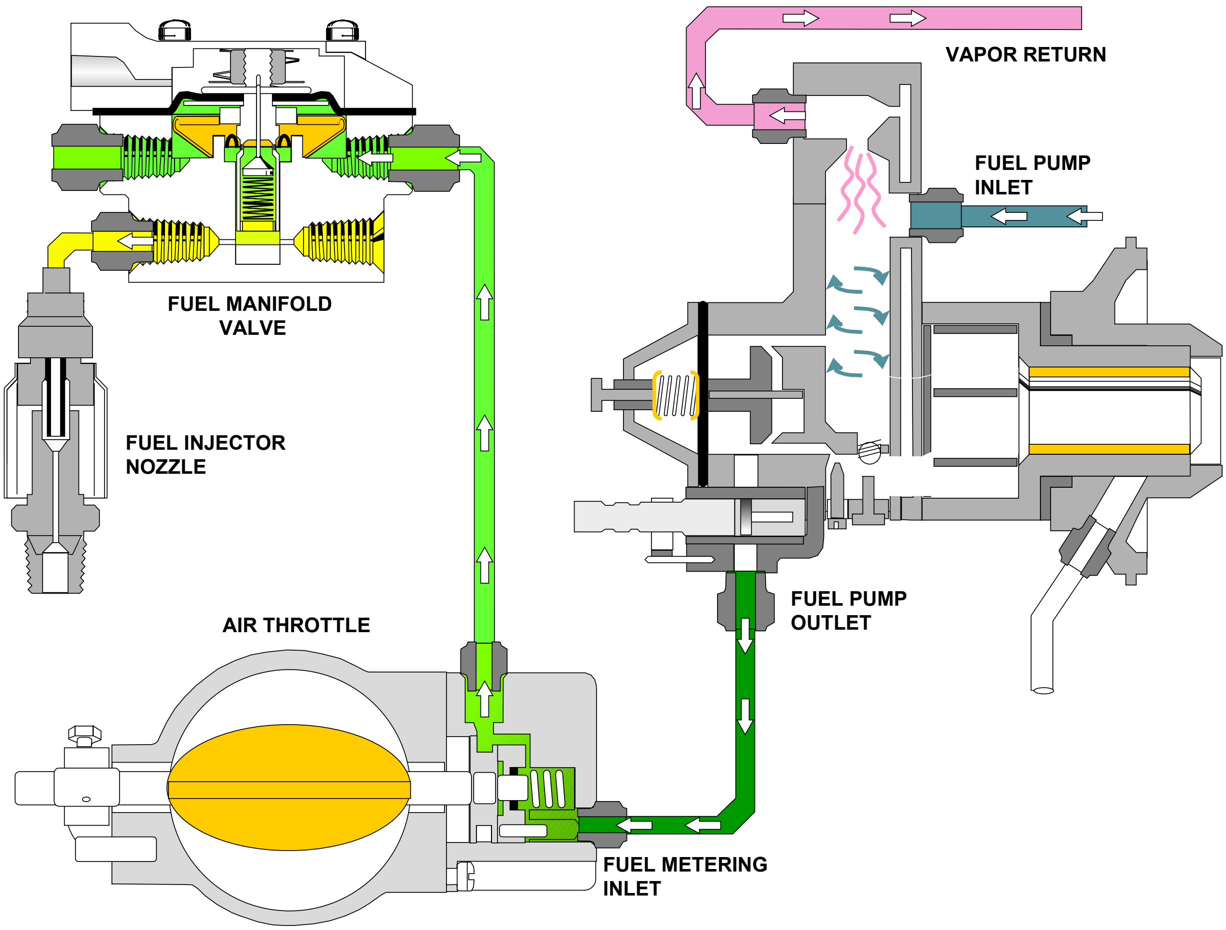


Figure 6-9. IO-240, IO-360 (Except ES) IO-550-G & N Fuel Injection System Schematic.

Ignoring the effect of altitude or ambient air conditions for the moment, the use of a positive displacement, engine-driven pump means that changes in engine speed affect total pump flow proportionally. The fuel pump provides greater capacity than is required by the engine. Thus, a recirculation path is provided.

The fuel pump incorporates a mixture control valve that routes fuel, through the recirculation path, back to the vapor separator swirl chamber when the mixture control lever is placed in the idle cutoff position. In the idle cutoff position, fuel is not allowed to exit the pump outlet. The recirculation path is blocked in the full rich position. When the mixture control is placed in the full rich position, fuel exits the fuel pump outlet. If the mixture control is placed in an intermediate position fuel flows through the pump outlet and the recirculation path.

By arranging a calibrated adjustable orifice and relief valve in the recirculation path, the pump delivery pressure is maintained proportional to engine speed. These provisions assure proper pump pressure and delivery for all engine operating speeds.

A check valve is provided so that boost pressure to the system can by-pass the engine driven fuel pump during engine starting. This feature also aids in the suppression of vapor formation during high ambient temperature conditions. The check valve permits use of the airframe auxiliary fuel boost pump, in the unlikely event of an engine driven fuel pump malfunction.

Throttle and Fuel Metering Unit - The function of this assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the air manifold inlet. The throttle valve controls the flow of air to the engine as positioned by the cockpit throttle control lever.

Fuel enters the fuel metering unit and passes to the metering cam. The rotary metering cam has a cam-shaped edge that mates with the fuel metering plug. The position of the cam at the fuel metering plug calibrated orifice controls fuel flow to the fuel manifold valve and fuel nozzles.

The fuel mixture is controlled by the manual mixture control lever in the cockpit which is connected to the mixture control valve in the fuel pump.

Fuel Metering Unit - The throttle body has a machined boss for attachment of the metering unit housing and a bushed bore for the throttle shaft. The throttle shaft is threaded on one end for attachment of a lever and has a lever throttle stop. The opposite end has a metering cam. The metering cam is located flush against a spring loaded metering plug. The metering plug has a drilled calibrated orifice that provides fuel passage from the fuel inlet to fuel outlet, depending on the throttle shaft and metering cam position. Fuel flow through the fuel metering plug calibrated orifice is controlled by the position of the eccentric cam connected to the throttle shaft and the adjusted position of the fuel metering plug. An idle mixture adjustment screw is located in the metering valve housing which slightly rotates the fuel metering plug changing flow clearance between the metering plug fuel passage and eccentric cam.

Fuel Manifold Valve - The fuel manifold valve body contains a fuel inlet, a diaphragm chamber and outlet ports for fuel lines to the individual nozzles. The spring loaded diaphragm carries a plunger in the central bore of the manifold body. The diaphragm is enclosed by a vented cover which retains the diaphragm loading spring. When the plunger is down in the body bore, fuel passages to the nozzles are closed off. The plunger is drilled for passage of fuel from the diaphragm chamber to its base and the valve within the plunger. As fuel flow increases pressure overcomes diaphragm spring tension causing the plunger to move to the open position and fuel flows from manifold valve outlets through fuel lines to the fuel nozzle assemblies.

Fuel Nozzle - The fuel discharge nozzle is located in the cylinder head. The nozzle outlet is screwed into the tapped fuel nozzle hole in the cylinder head. The nozzle body has a drilled central passage with a counterbore at each end. The lower end is the fuel outlet. The upper bore contains a removable jet for calibrating the nozzles. Near the top, radial holes connect the upper counterbore with the outside of the nozzle body for air admission. These holes enter the counterbore above the orifice and draw outside air through a cylindrical screen fitted over the nozzle body which keeps dirt and foreign material out of the interior of the nozzle. A press-fitted shield is mounted on the nozzle body and extends over the greater part of the filter screen, leaving an opening near the bottom. This provides both mechanical protection and an air path.

Nozzles are calibrated in several ranges and all nozzles furnished for one engine are of the same range identified by a letter stamped on the hex of the nozzle body.

470, 520 & 550 SERIES ENGINES NATURALLY ASPIRATED FUEL SYSTEM DESCRIPTION

Fuel flows from the fuel pump to the fuel control unit. The fuel then flows from the fuel control unit to the fuel manifold valve where it is distributed to the six fuel injector nozzles.

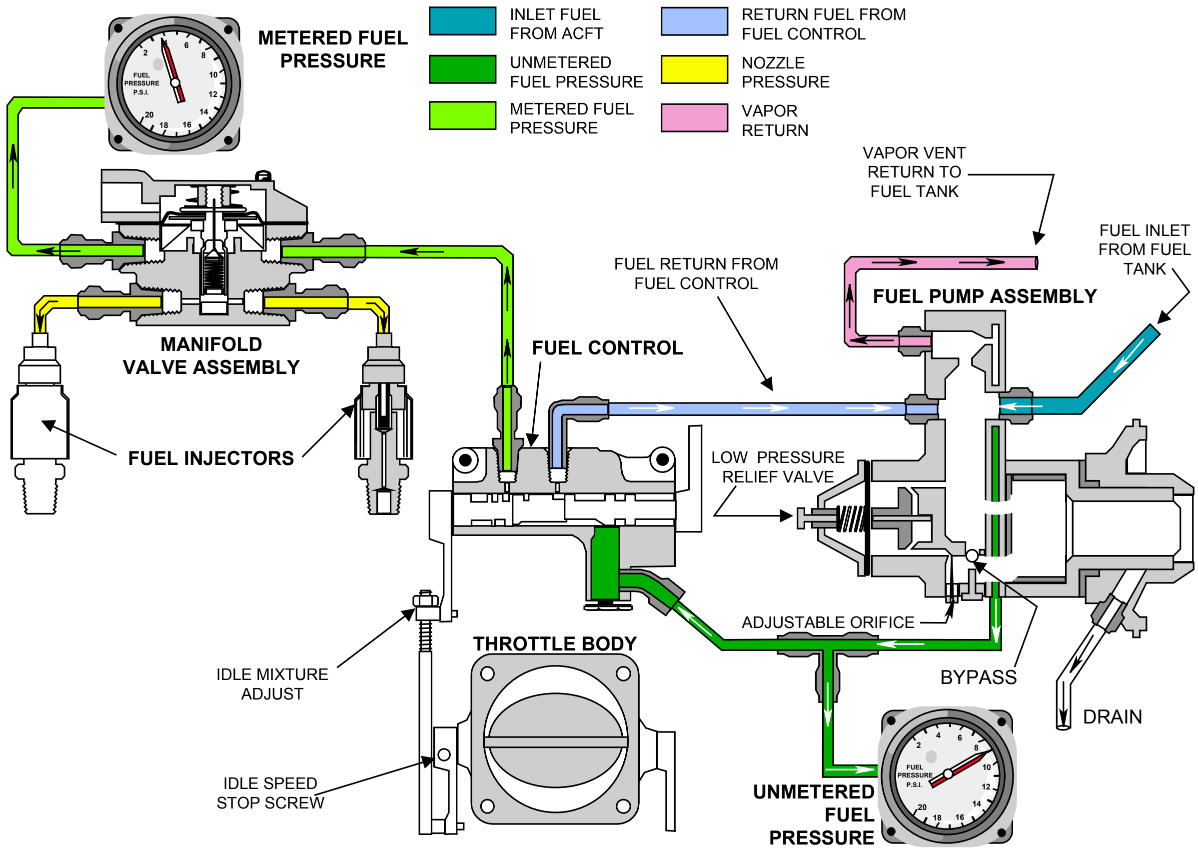


Figure 6-10. Typical Naturally Aspirated Fuel Injection System Schematic

Fuel Pump - Fuel enters the fuel pump at the swirl well of the vapor separator. Here, vapor is separated by a swirling motion so that only liquid fuel is fed to the pump. The vapor is drawn from the top center of the swirl well by a small pressure-jet of fuel and is fed into the vapor return line. This line carries the vapor back to the fuel tank. There are no moving parts in the vapor separator, and the only restrictive passage is used in connection with vapor removal. Thus, there is no restriction of main fuel flow.

Ignoring the effect of altitude or ambient air conditions for the moment, the use of a positive displacement, engine-driven pump means that changes in engine speed affect total pump flow proportionally. The fuel pump provides greater capacity than is required by the engine. Thus, a recirculation path is provided.

By arranging a calibrated adjustable orifice and relief valve in this path, the pump delivery pressure is maintained proportional to engine speed. These provisions assure proper pump pressure and delivery for all engine operating speeds.

A check valve is provided so that aircraft boost pump pressure to the system can by-pass the engine driven fuel pump during engine priming and starting. This feature also aids in the suppression of vapor formation during high ambient temperature conditions. The check valve permits the use of the aircraft auxiliary fuel boost pump should the engine driven fuel pump fail.

Air Throttle and Fuel Control Unit - The function of this assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the air manifold inlet. The throttle valve controls the flow of air to the engine as positioned by the cockpit throttle control lever.

Fuel enters the fuel control unit through a strainer and passes to the metering valve. The rotary metering valve has a cam shaped edge across the fuel delivery port. The position of the cam at the port controls fuel flow to the fuel manifold valve and fuel nozzles. The fuel mixture is controlled by the manual mixture control lever in the cockpit that is connected to the fuel control unit mixture control valve.

NOTE...FUNCTION OF THE THROTTLE, MOUNTING OF THE FUEL CONTROL UNIT AND LINKAGE CONNECTION BETWEEN THE THROTTLE AND FUEL CONTROL UNIT ARE THE SAME ON THE VARIOUS IO-520 SANDCAST SERIES ENGINE MODELS. HOWEVER, THE THROTTLE BODIES USED ON THE DIFFERENT ENGINE MODELS ARE PHYSICALLY DIFFERENT.

Fuel Control Unit - The fuel control body is made of SAE 88 Brass. The fuel metering shaft and mixture control shaft are made of stainless steel. The metering valve is located at one end and the mixture control valve is located at the other end of the control valve central bore. The valves ride in bushings and are sealed against leakage by o-rings. Loading springs force the valve ends against a fixed plug installed in the center of the central bore. This bronze plug has one passage that mates with the fuel return port and one passage that connects the mixture control valve chamber with the metering valve chamber. O-rings seal this plug in the central bore. Each valve includes a groove which forms a fuel chamber. The contoured end face of the mixture control valve aligns with the passages in the metering plug to regulate the fuel flow from the fuel chamber. A control lever is installed on the mixture control valve shaft for connection to the cockpit mixture control. In the metering valve, a cam shaped cut is made on the outer part of the end face. A control lever on the metering valve shaft is connected to the air throttle valve shaft with linkage. The fuel return port in the control body connects to the return passage of the metering plug and alignment of the mixture control valve face with this passage determines the amount of fuel returned to the fuel pump. A removable plug at the fuel inlet port includes a filter screen to prevent admittance of foreign debris.

Fuel Manifold Valve - The fuel manifold valve body contains a fuel inlet, a diaphragm chamber and outlet ports for fuel lines to the individual nozzles. The spring loaded diaphragm carries a plunger in the central bore of the manifold body. The diaphragm is enclosed by a vented cover which retains the diaphragm loading spring. When the plunger is down in the body bore, fuel passages to the nozzles are closed off. The plunger is drilled for passage of fuel from the diaphragm chamber to its base and the valve within the plunger. As fuel flow increases pressure overcomes diaphragm spring tension causing the plunger to move to the open position and fuel flows from manifold valve outlets through fuel lines to the fuel nozzle assemblies.

Fuel Nozzle - The fuel discharge nozzle is located in the cylinder head. The nozzle outlet is screwed into the cylinder head tapped fuel nozzle hole. The nozzle body has a drilled central passage with a counterbore at each end. The lower end is the fuel outlet. The upper bore contains a removable jet for calibrating the nozzles. Near the top, radial holes connect the upper counterbore with the outside of the nozzle body for air admission. These holes enter the counterbore above the orifice and draw outside air through a cylindrical screen fitted over the nozzle body which keeps dirt and foreign material out of the interior of the nozzle. A press-fitted shield is mounted on the nozzle body and extends over the greater part of the filter screen, leaving an opening near the bottom. This provides both mechanical protection and an air path.

Nozzles are calibrated in several ranges and all nozzles furnished for one engine are of the same range identified by a letter stamped on the hex of the nozzle body.

TURBOCHARGED ENGINE FUEL INJECTION SYSTEM

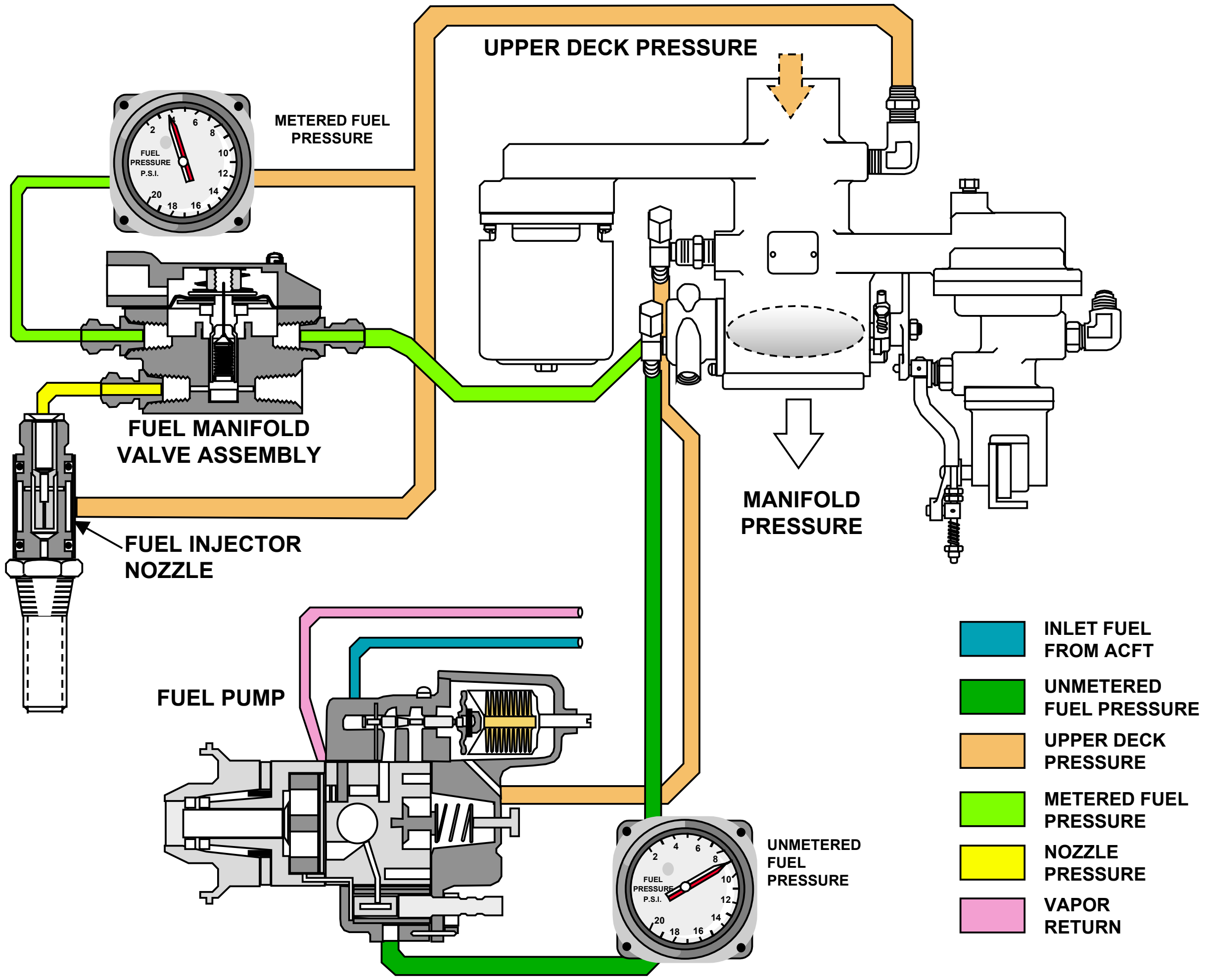


Figure 6-11. Typical Turbocharged Fuel Injection Schematic Diagram

The fuel injection system is of the multi-nozzle, continuous-flow type which controls fuel flow to match engine requirements. Any change in air throttle position, engine speed, deck pressure, or any of these combinations will cause changes in fuel pressure in the correct relation to the engine requirements.

The fuel pump is a single stage, vane-type pump and performs well at high altitude and at low inlet condition. It is driven directly by the engine and its flow rate depends on engine RPM. An aneroid unit is incorporated as an integral part of the pump and functions to increase pump output during high manifold pressure operation. The fuel pump delivers liquid fuel to the fuel-metering unit.

The fuel metering unit/air throttle controls the amount of intake air admitted into the intake manifold and meters the proportionate amount of fuel to the fuel manifold valve.

Some of the fuel injection systems utilize a primer diverter valve that directs fuel flow to the engine priming nozzle rather than the fuel manifold when energized for cold start operation.

The manifold valve receives fuel from the metering unit. When fuel pressure reaches approximately 3.2 psi, the valve in the manifold valve opens and flows fuel through the six ports in the manifold valve (one port for each nozzle line). The manifold valve also serves to provide a positive cutoff of fuel to the cylinder when the engine is shut down.

The injector nozzle lines connect the manifold valve to the six fuel injector nozzles and deliver fuel to the nozzles. The injector nozzles (one per cylinder) are "air bleed" type fuel nozzles that direct fuel directly into the intake port of the cylinder. When the engine is running, a continuous stream of fuel flows into the intake chamber and enters the cylinder combustion chamber when the intake valve opens.

Since the size of the fuel nozzle jets are fixed, the amount of fuel flowing through them is determined by the pressure drop across the jet. For this reason, fuel flow may be accurately determined by measuring the pressure at the manifold valve, and deck pressure fed to the nozzle “air bleed” chamber.

All of the items described above are interdependent on each other to meter the correct amount of fuel according to the power being developed by the engine.

Fuel Pump - Fuel enters the fuel pump at the swirl well of the vapor separator. Here, vapor is separated by a swirling motion so that only liquid fuel is fed to the pump. The vapor is drawn from the top center of the swirl well by a small pressure-jet of fuel and is fed into the vapor return line. This line carries the vapor back to the fuel tank. There are no moving parts in the vapor separator, and the only restrictive passage is used in connection with vapor removal. Thus, there is no restriction of main fuel flow.

Ignoring the effect of altitude or ambient air conditions for the moment, the use of a positive displacement, engine-driven pump means that changes in engine speed affect total pump flow proportionally. The fuel pump provides greater capacity than is required by the engine. Thus, a recirculation path is provided.

The fuel pump incorporates a mixture control valve that routes fuel, through the recirculation path, back to the vapor separator swirl chamber when the mixture control lever is placed in the idle cutoff position. In the Idle Cutoff position, all fuel is diverted from the pump outlet and is recirculated back into the vapor separator chamber. When the mixture control is placed in the full rich position, fuel exits the fuel pump outlet. If the mixture control is placed in an intermediate position fuel flows through the pump outlet and the recirculation path.

A relief valve and variable orifice regulate fuel pump outlet pressure in proportion to engine speed and turbocharger compressor discharge pressure (upper deck pressure).

The fuel pump utilizes an aneroid, which controls a metering rod assembly that assists in controlling fuel flow. The aneroid housing is referenced to upper deck pressure. The aneroid bellows expands when the air pressure surrounding it decreases. As the aneroid expands it moves the rod increasing the size of the orifice opening. An increased amount of fuel flows through the orifice to a recirculation path. This decreases fuel flow from the fuel pump to the fuel metering unit. When upper deck pressure is greater, the aneroid bellows collapses and restricts the amount of fuel permitted to internally recirculate, thus providing a greater outlet to the rest of the fuel injection system.

A check valve is provided so that boost pressure to the system can by-pass the engine driven fuel pump during engine starting. This feature also aids in the suppression of vapor formation during high ambient temperature conditions. The check valve permits use of the aircraft auxiliary fuel boost pump, in the unlikely event of an engine driven fuel pump malfunction.

Throttle and Fuel Metering Unit - The function of this assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the air manifold inlet. The throttle valve controls the flow of air to the engine as positioned by the cockpit throttle control lever.

The throttle body has a machined boss for attachment of the metering unit housing and a bushed bore for the throttle shaft. The throttle shaft is threaded on one end for attachment of a lever and has a lever throttle stop. The opposite end has a metering cam. The metering cam is located flush against a spring loaded metering plug. The metering plug has a drilled calibrated orifice that provides fuel passage from the fuel inlet to fuel outlet, depending on the throttle shaft and metering cam position. Fuel flow through the fuel metering plug's calibrated orifice is controlled by the position of the eccentric cam connected to the throttle shaft and the adjusted position of the fuel metering plug. An idle mixture adjustment screw is located in the metering valve housing which slightly rotates the fuel metering plug changing flow clearance between the metering plug fuel passage and eccentric cam.

Fuel enters the fuel metering unit and passes to the metering cam. The rotary metering cam has a cam-shaped edge that mates with the fuel metering plug. The position of the cam at the fuel metering plug calibrated orifice controls fuel flow to the fuel manifold valve and fuel nozzles.

The fuel mixture is controlled by the manual mixture control lever in the cockpit which is connected to the mixture control valve in the fuel pump.

Fuel Nozzle - The fuel discharge nozzle is located in the cylinder head. The nozzle outlet is screwed into the tapped fuel nozzle hole in the cylinder head. The nozzle body has a drilled central passage with a counterbore at each end. The lower end is the fuel outlet. The upper bore contains a removable jet for calibrating the nozzles. Near the top, radial holes connect the upper counterbore with the outside of the nozzle body for air admission. An air shroud is mounted on the nozzle extending over the nozzle body. The nozzle shroud is sealed to the nozzle body using o-rings. The nozzle shrouds are referenced to upper deck pressure. Nozzles are calibrated in several ranges and all nozzles furnished for one engine are of the same range identified by a letter stamped on the hex of the nozzle body.

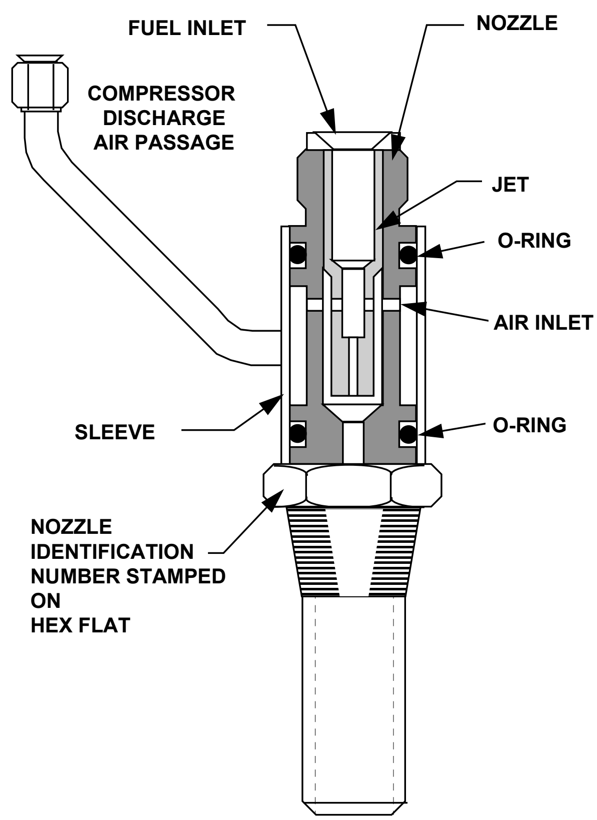
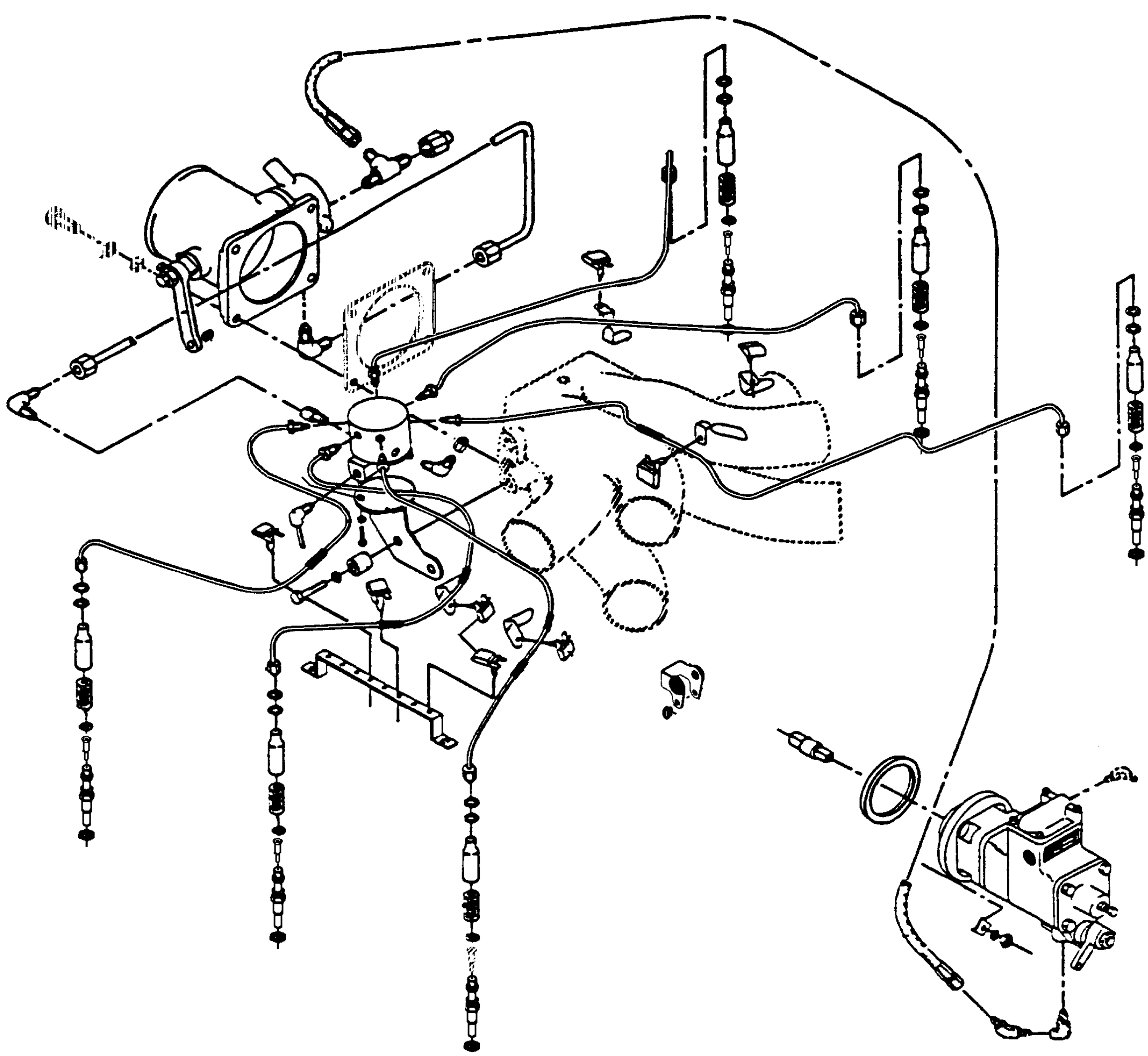


Figure 4-14. Turbo Fuel Injector Nozzle

SUMMARY

Fuel Injection Systems can be difficult to maintain and adjust if not clearly understood. The TCM Continuous Flow Fuel Injection System is a fairly simple and straight forward system. In this chapter we covered the fundamentals of each of the components which make up the fuel injection system. We then discussed in further detail the functions of the Fuel Pump - to provide constant fuel pressure that corresponds to engine speed and to provide certain metering functions. Following this, we covered the functions of the fuel metering unit as it is controlled at either the throttle body or as it is sometimes attached to the fuel pump on some engine models. Next we discussed the two main functions of the Fuel Manifold Valve; 1) to evenly distribute fuel to all of the injector nozzles and 2) to provide a positive IDLE CUT-OFF of fuel flow. We then discussed how the Fuel Injector Nozzle performed its function of fuel atomization to aid in vaporization. After the principles were discussed each of the fuel injection systems were covered for certain 240, 360, and 470/520/550 engine models as well as a turbocharged engine.



IO-550-N Fuel Injection System Components Exploded View

KEY TERMS

ALTERNATE AIR SYSTEM	Should the inlet to the Air Induction system become blocked, the alternate air system is designed to open providing air flow into the engine cylinders to prevent air starvation.
ANEROID METERING ROD	This rod is positioned by the aneroid and regulates fuel pump output pressure based on ambient pressure or turbocharger discharge pressure.
FUEL CONTROL UNIT	A mechanically controlled valve that meters the amount of fuel based on throttle position.
FUEL MANIFOLD VALVE	A device that distributes metered fuel flow to the individual cylinder fuel injector nozzles. It also serves as a positive idle cut-off valve whenever the engine is shut down.
FUEL METERING UNIT	Controls the amount of fuel flow to the Manifold valve assembly based on throttle position.
FUEL PRESSURE REGULATOR	A device that regulates full power fuel pressure without restricting maximum fuel pressure at lower power settings.
FUEL PUMP	A positive displacement, vane type engine driven pump that produces outlet fuel pressures that are proportional to engine speed. It is the only continual moving part in the fuel injection system.
FUEL PUMP ADJUSTABLE ORIFICE	This adjustment allows the mechanic to set the fuel pump pressure at **FULL POWER**.
FUEL PUMP - ALTITUDE COMPENSATING	This fuel pump contains an aneroid that is vented to atmospheric pressure. It controls a metering rod to provide **AUTOMATIC** leaning by reducing or decreasing fuel pump pressure as altitude increases.
FUEL PUMP - ANEROID EQUIPPED	A fuel pump containing an aneroid that is vented to turbo-charger discharge pressure (upper deck pressure). The aneroid controls a metering rod that varies outlet fuel pressure as turbocharger discharge pressure. changes.
FUEL PUMP BY-PASS CHECK VALVE	Located in the engine driven fuel pump. Permits fuel from the aircraft boost pump to flow to the fuel control unit for engine starting.
FUEL PUMP INLET HOSE	Provides a path for fuel from the aircraft to the inlet of the engine driven fuel pump.
FUEL PUMP LOW PRESSURE RELIEF VALVE	Adjustment located on the rear of the engine driven fuel pump that regulates fuel pump pressure at idle speed.
FUEL PUMP VAPOR EJECTOR	Located at the top of the inlet chamber. Fuel being returned to the aircraft flows through the vapor ejector.
FUEL STRAINER	Normally, a fine wire mesh screen required to filter contaminants from the aircraft fuel supply prior to entering the engine driven fuel pump.

FULL RICH	Position of the mixture control that is required for Take off and full power settings. This setting provides the maximum ratio of parts fuel to parts air. (See Mixture Control)
IDLE CUTOFF	Position of the mixture control that will virtually shut off the flow of fuel to the engine. (See Mixture Control)
IDLE MIXTURE ADJUSTMENT	Adjustment setting that alters the metering plate position and thereby leans or enriches the mixture setting at idle.
IDLE SPEED STOP SCREW	An adjustment for setting the minimum idle speed.
MANIFOLD PRESSURE	The pressure in the induction system pressure normally measured in inches of mercury (Hg). Standard day atmospheric pressure at sea level is 29.92 inches Hg.
METERED PRESSURE	Pressure of the fuel in pounds per square inch at the manifold valve.
MIXTURE CONTROL	Control that allows the fuel/air ratio to be changed.
NATURALLY ASPIRATED	A non boosted engine. Utilizes atmospheric pressure for combustion.
THROTTLE	The air throttle controls the flow of air to the engine, depending on the position of the throttle control lever in the aircraft cockpit. Fuel control units are attached to the throttle control to permit the flow of fuel to be controlled by the throttle control.
TURBOCHARGER	An exhaust gas driven turbine which drives a compressor to increase air pressure to the engine inlet for the combustion process. This process provides sea level performance at higher altitudes.
UNMETERED PRESSURE	Pressure of the fuel in pounds per square inch (PSI) at the outlet of the engine driven fuel pump or inlet of the fuel control unit.
UPPER DECK PRESSURE	Upper Deck Pressure is also referred to as turbocharger compressor discharge pressure. This is the pressure in inches of mercury in the induction system after the turbocharger compressor and before the throttle plate.
Vapor Lock	A condition in which the proper flow of a liquid through a system is disturbed by the formation of vapor. Any liquid will turn to vapor if heated sufficiently. The amount of heat required for vaporization will depend on the pressure exerted on the liquid.
Volatility	The tendency of a liquid to vaporize.

EXERCISES

Matching Exercise

1. Match the Fuel Injection System component with its definition by placing the letter next to the definition in the blank space provided by the bearing condition.

_______1.	Fuel Pump By-pass Check Valve	a.	Pressure in the induction system.
_______2.	Fuel Control Unit	b.	Controls the flow of air to the engine.
_______3.	Fuel Pump Adjustable Orifice	c.	Pressure of the fuel in pounds per square inch at the manifold valve.
_______4.	Manifold Pressure	d.	Mixture control setting that provides the maximum ratio of parts fuel to parts air.
_______5.	FULL RICH	e.	Regulates fuel pump pressure at FULL POWER.
_______6.	Fuel Pump Low Pressure Relief Valve	f.	Pressure of the fuel in pounds per square inch at the outlet of the engine driven fuel pump or inlet of the fuel control unit.
_______7.	Throttle	g.	Regulates fuel pump pressure at IDLE SPEED.
_______8.	Metered Pressure	h.	A mechanically controlled valve that meters the amount of fuel based on throttle position.
_______9.	Mixture Control	i.	Control that allows the fuel/air ratio to be changed.
_______10.	Unmetered Pressure	j.	Permits fuel from the aircraft boost pump to flow through the fuel to the fuel control unit for engine starting.

1. Which Service Bulletin addresses Fuel Injection Set-Up and Adjustment?
   a. SB92-21
   b. SIL95-14
   c. SID97-3
   d. SID97-4
2. Which Service Bulletin addresses lubrication of Fuel Injection Set-Up system components and control rod ends?
   a. SB92-21
   b. SB95-2
   c. SID97-2
   d. SID97-4

Refer to SID97-3 for the following questions.

3. What test equipment is recommended by TCM for measuring metered and unmetered pressure during set-up and adjustment of the fuel injection system?______________________________

____

4. What is the FULL POWER Unmetered Fuel Pressure for a TSIO-520-UB? ______________

____

5. When torquing a #5 hose (.500-20) end fitting to a steel fitting what torque value would you use?

____

6. What factors reference the X & Y values on the Altitude Leaning Chart for the IO-550-A?

____

7. Referring to Table 10, Chart 7 of SID97-3B, what is the permissible fuel flow range for an IO-550-B at 9000 feet?

____

Refer to Table 2 of SID97-3B for questions 8 & 9.

8. When adjusting the IO-360-ES, the *best* FULL POWER metered fuel pressure reading attained was 14.9 PSI with the FULL POWER RPM at 2720. Is this aircraft ready for the customer to fly?

____

____

9. What is the FULL POWER Metered Fuel Pressure range of the IO-550-N when the ground run will only achieve 2620 RPM? ______________________________

   What Correction factor is used to derive this range? ______________________

10. What is the manifold pressure at full power setting for the TSIO-360-RB? ______________

11. List the weight of gasoline at 70°F. ______________________________

12. What is the full power RPM for an IO-240-B? ______________________

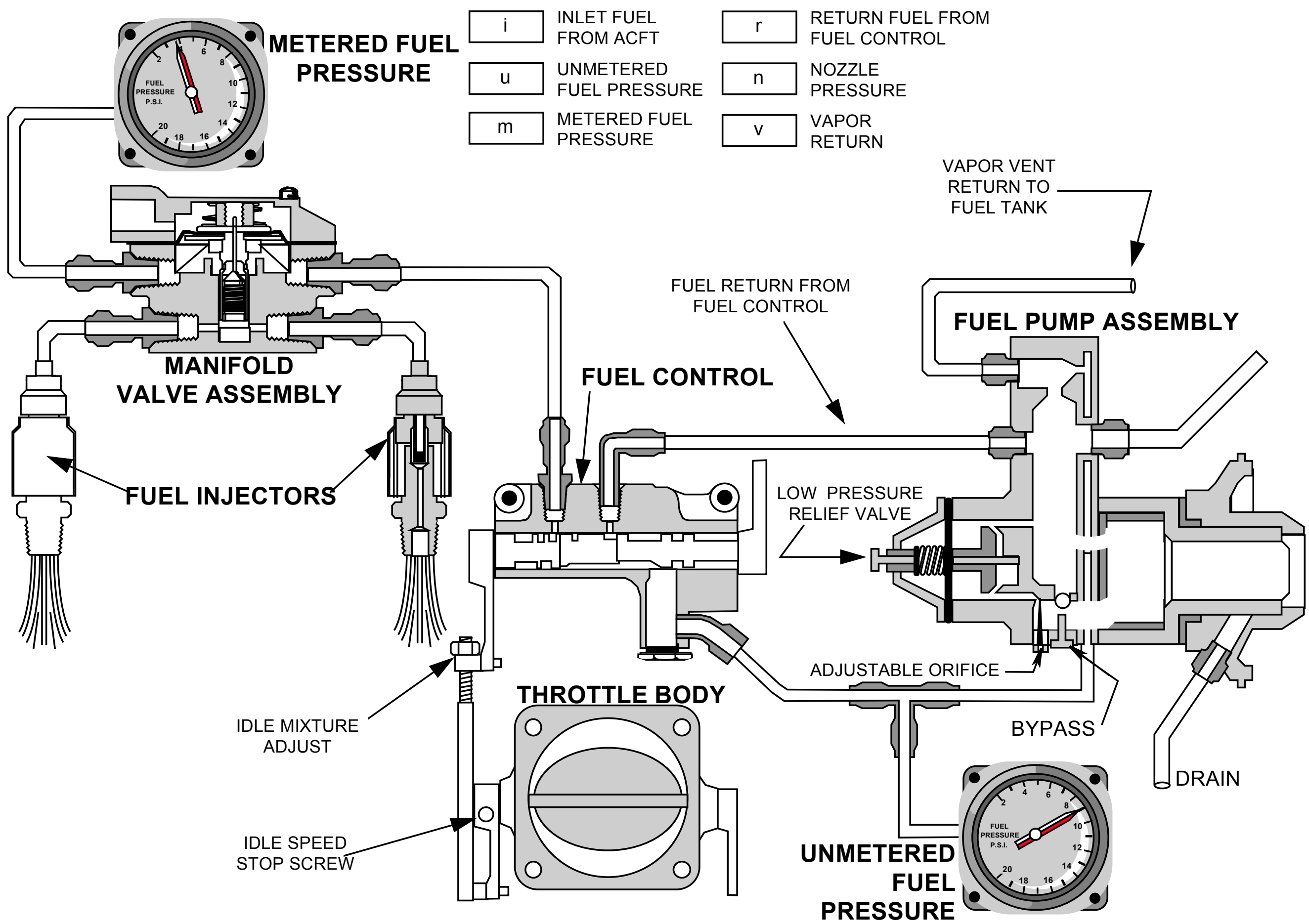
13. During a Full Power static ground check of the fuel system, the engine runs at 60 RPM less than its rated Static Engine RPM. What Correction Factor would be used in Table 2?

____

14. During set-up of the fuel injection system, what adjustments (if any) are made to the IDLE speed stop screw? ______________________________

____

15. Draw the fuel flows through the fuel system schematic shown below.



16. What is the purpose of the relief valve installed on the rear of all fuel pumps? ______

____

____

17. What element in the schematic shown above is adjusted to set the fuel pressure at Full Power?

____

18. Which component system in the fuel pump permits the aircraft fuel boost pump to supply fuel through the engine driven fuel pump for priming and engine starting?

____

19. Which unit in the fuel injection system is responsible for providing positive fuel cut-off?

____

INTENTIONALLY

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Chapter Seven

Induction & Turbo-Induction Systems

CHAPTER 7 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Identify the components that comprise an Updraft style Induction System

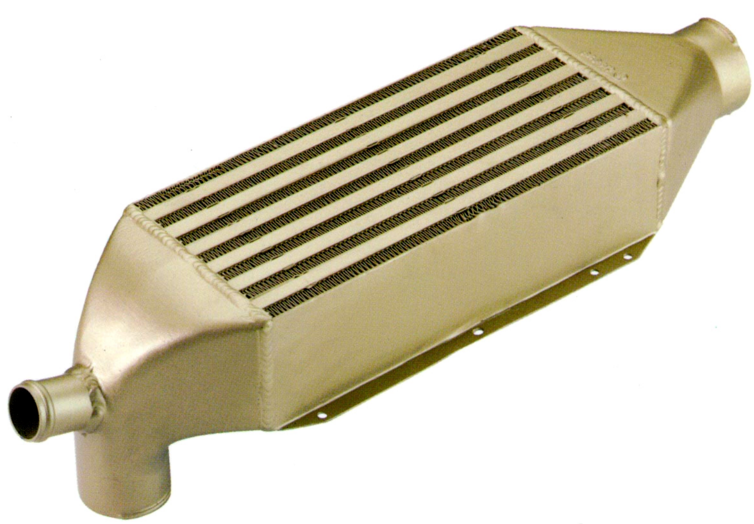
② Identify the components that comprise a Downdraft style Induction System

③ Describe the airflow paths through the Updraft & Downdraft systems

④ Identify the components that comprise a Turbo-Induction system

⑤ Describe the airflow paths through the Turbo-Induction system

⑥ Describe the process for removing and replacing Induction system components



Aftercooler for Turbo-Induction System

INDUCTION SYSTEM DESCRIPTION INTRODUCTION

The engine's induction system serves to distribute the air to the cylinder combustion chambers needed for the combustion process. The engine is basically an air pump and when a given cylinder is on the intake stroke, the cylinder intake valve is opened and the piston draws in fresh air as it travels toward bottom dead center. The efficiency to which the air is drawn into the cylinder is largely determined upon the induction system design.

Earlier engine models incorporated an updraft induction system design allowing the induction system and carburetor to be mounted below the engine. This was primarily done to facilitate engine mounting in a relatively small area in the aircraft cowling and to mount the fuel under the hot engine on carbureted models.

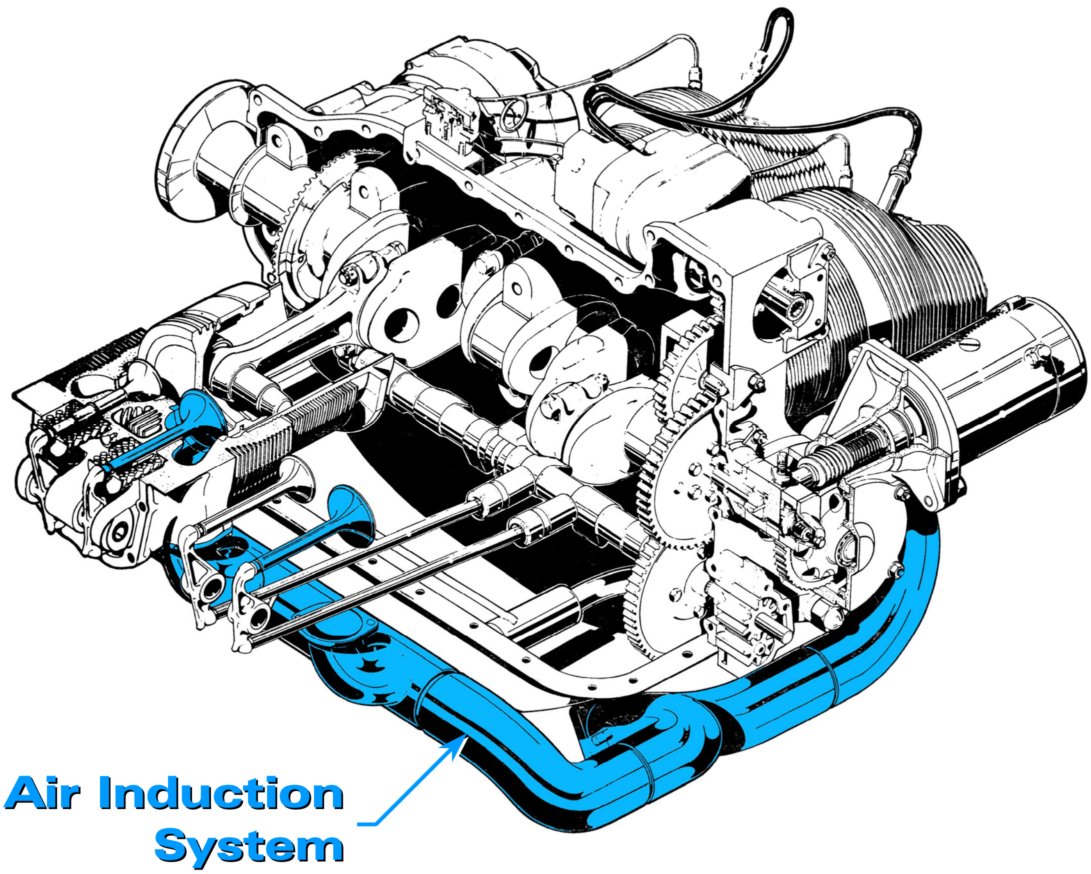


Figure 7-1. Updraft Runner Induction System.

Engine components through which intake air flows following the aircraft air inlet filter/alternate air door are the throttle assembly and manifold, through the induction tubes and into the cylinder intake ports. Air flows through these components in the order listed.

The updraft induction system utilizes an intake manifold with an air distribution system mounted below the engine cylinders. It consists of two runners and a balance crossover tube. It serves to carry induction air to the individual cylinder intake ports.

The cylinder intake ports are cast into the cylinder head assembly. Air from the manifold is carried into the intake ports, mixed with fuel from the injector nozzles where it enters the cylinder as a combustible mixture when the intake valve opens.

UPDRAFT INDUCTION SYSTEM COMPONENT DESCRIPTION

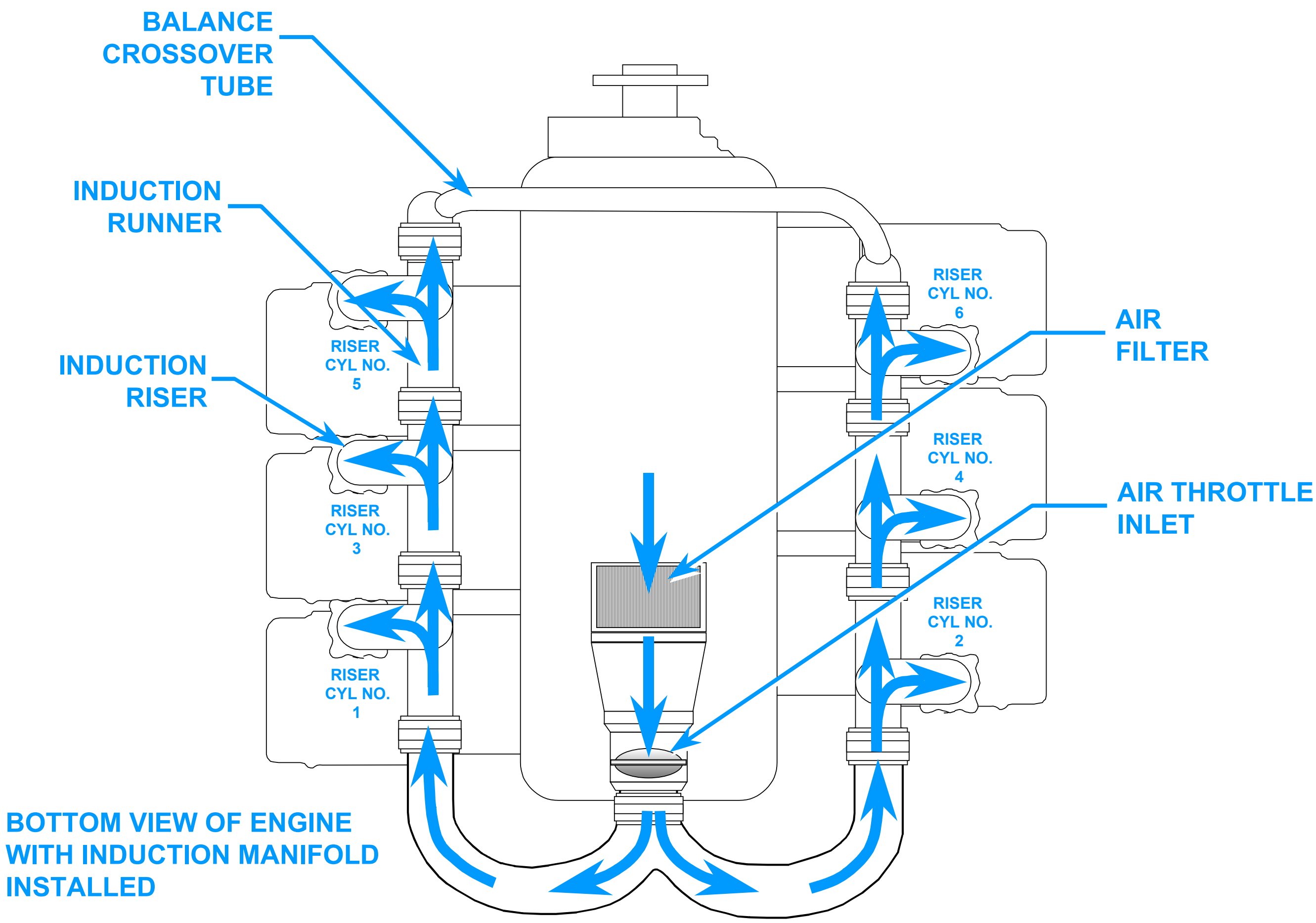


Figure 7-2. Bottom View of IO-550-B Updraft Runner Induction System.

Engine components through which intake air flows following the aircraft air inlet filter/alternate air door are the throttle assembly and manifold, through the induction tubes and into the cylinder intake ports. Air flows through these components in the order listed.

The intake manifold is an air distribution system mounted below the engine cylinders. It consists of two runners and a balance tube. It serves to carry induction air to the individual cylinder intake ports.

The balance crossover tube is designed to reduce pressure imbalances between the left and right side induction runners. These potential imbalances can occur due to the air waves accelerating and reflecting in the runners as the individual cylinders run through their respective intake sequences.

The cylinder intake ports are cast into the cylinder head assembly. Air from the manifold is carried into the intake ports, mixed with fuel from the injector nozzles where it enters the cylinder as a combustible mixture when the intake valve opens.

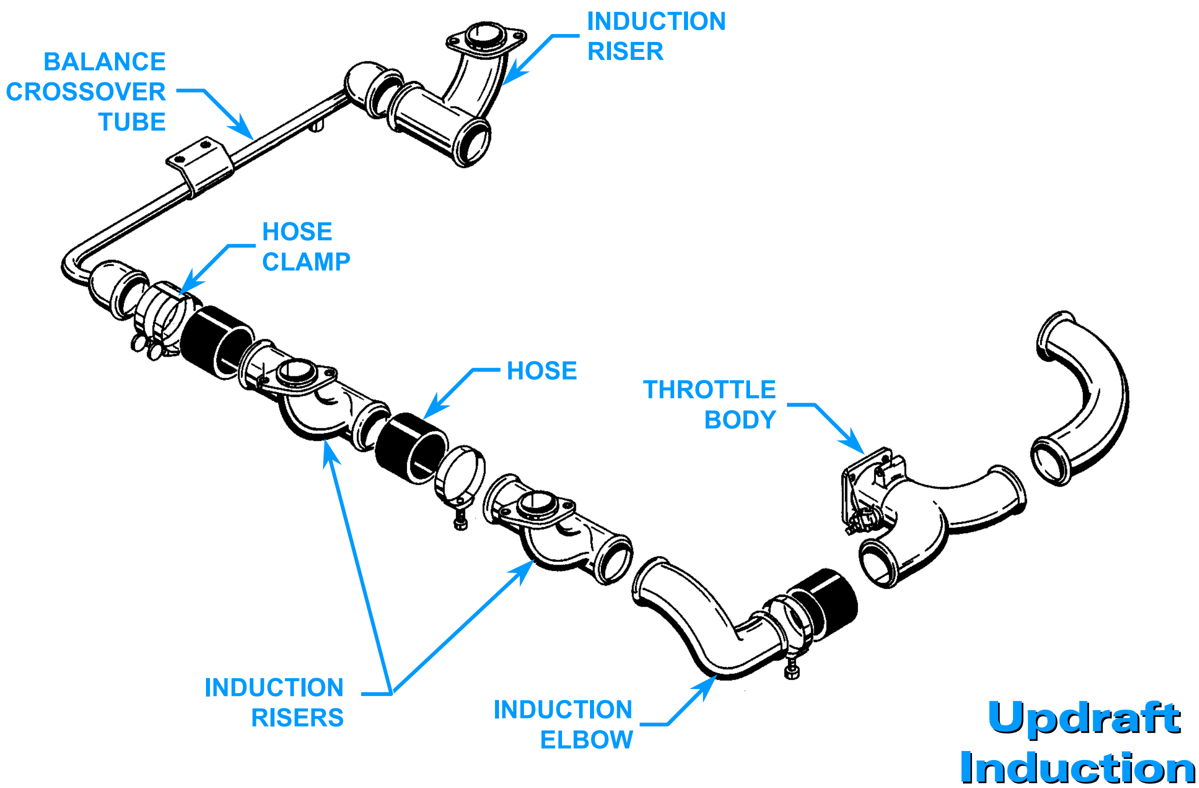


Figure 7-3. Exploded View of Updraft Runner Induction System.

The diagram shown above illustrates the parts that make up the updraft runner induction system. The throttle body permits the pilot to control the amount of air that is introduced into the engine as a function of measured manifold pressure. Also attached to the throttle body is the fuel control unit, which was discussed previously in the fuel injection chapter. The fuel control unit meters fuel as a function of throttle angle to more closely match the fuel to air ratio.

The throttle body is attached to the air induction elbows which directs airflow to both the left and right side induction runner/riser assemblies. The induction elbows serve to act as an interface between the throttle body and the individual cylinder induction risers. These tubes are attached to the together via a rubber hose and hose clamps.

When removing or replacing induction components, it is important to ensure that the individual cylinder risers are torqued first to the cylinder head before the hose and hose clamps are tightened to the induction manifold assembly.

DOWN DRAFT INDUCTION SYSTEM COMPONENT DESCRIPTION

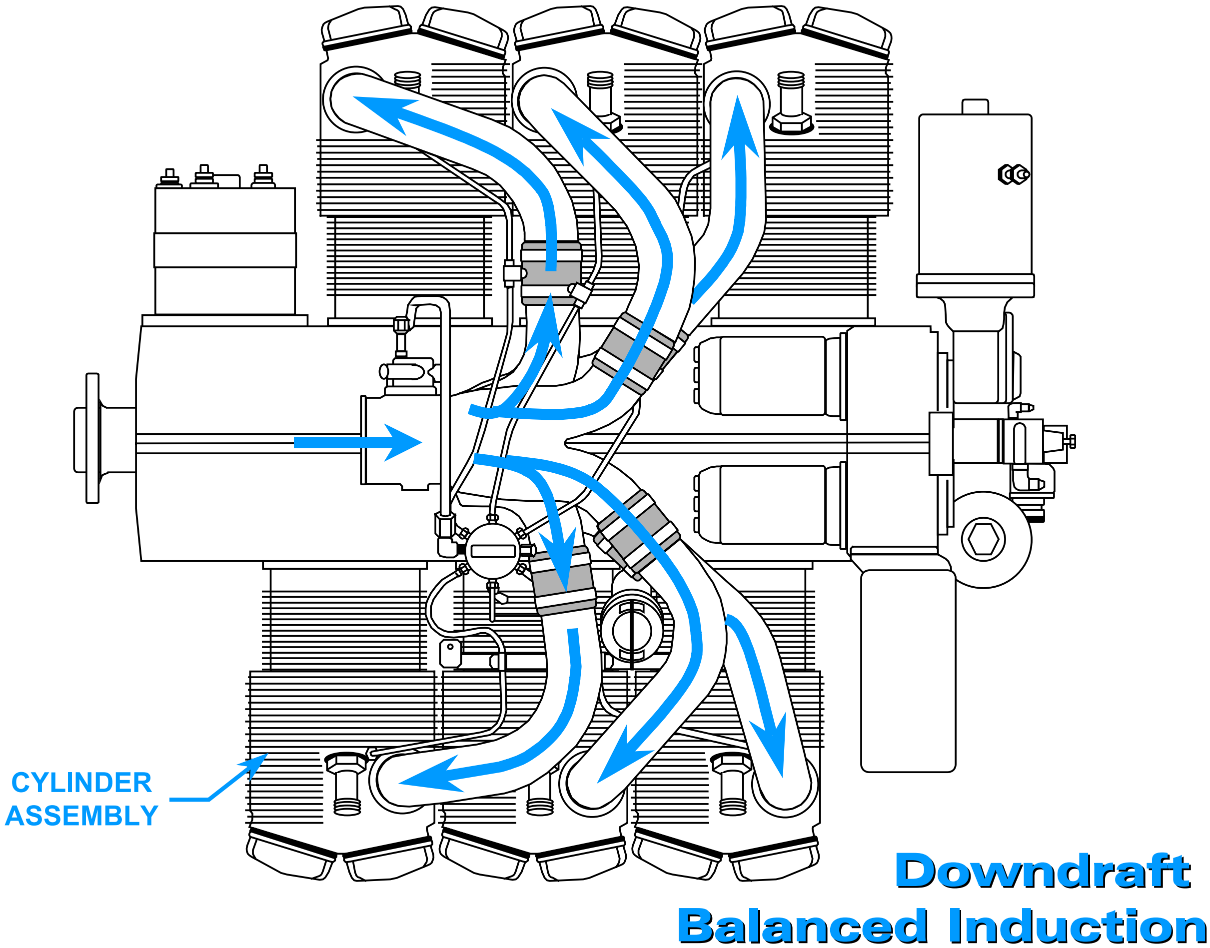


Figure 7-4. IO-550-N Downdraft Induction System.

The balanced induction system shown in the above figure provides optimum airflow to each of the individual cylinders across a broad operation rpm range. With balanced airflow and precisely metered fuel injected into the cylinders, a much smoother and efficient running engine can be achieved. This is due primarily to better matched fuel to air ratios in all of the cylinders.

The cylinder intake ports are cast into the cylinder head assembly. Air from the manifold is carried into the intake ports, mixed with fuel from the injector nozzles where it enters the cylinder as a combustible mixture when the intake valve opens.

The IO-550-G, N, P, & R series engines use a cross flow cylinder head design. The intake ports are located on top of the cylinder head while the exhaust ports are located below. This cylinder design is used in conjunction with a Balanced Induction System mounted above the engine. This design permits the top mounted downdraft induction of the type shown in the figure above.

The separate induction risers for each individual cylinder permits not only a balance of airflow to optimize the breathing in each of the cylinders, but also serves to isolate any shock waves of air that would tend to migrate between cylinders in the earlier runner induction design.

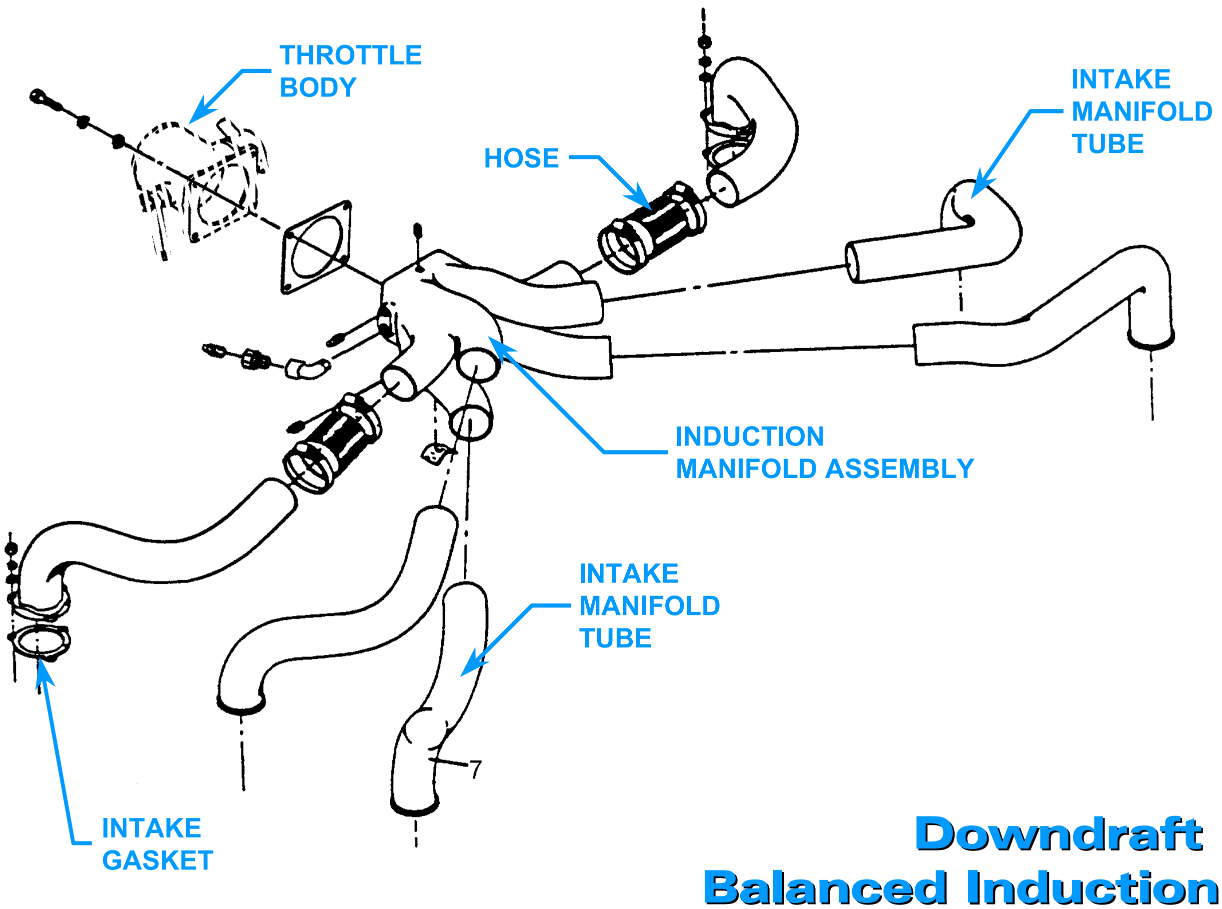


Figure 7-5. Exploded View of Top Mounted Downdraft Induction System.

The diagram shown above illustrates the parts that make up the downdraft balanced induction system. The throttle body permits the pilot to control the amount of air that is introduced into the engine as a function of measured manifold pressure. Also attached to the throttle body is the fuel control unit, which was discussed previously in the fuel injection chapter. The fuel control unit meters fuel as a function of throttle angle to more closely match the fuel to air ratio.

The throttle body is attached to the air induction manifold assembly. This device serves to act as an interface between the throttle body and the individual cylinder intake manifold tubes. These tubes are attached to the manifold assembly via a rubber hose and hose clamps.

When removing or replacing induction components, it is important to ensure that the individual cylinder intake manifold tube is torqued first to the cylinder head before the hose and hose clamps are tightened to the induction manifold assembly.

TURBO-INDUCTION SYSTEM COMPONENT DETAILED DESCRIPTION

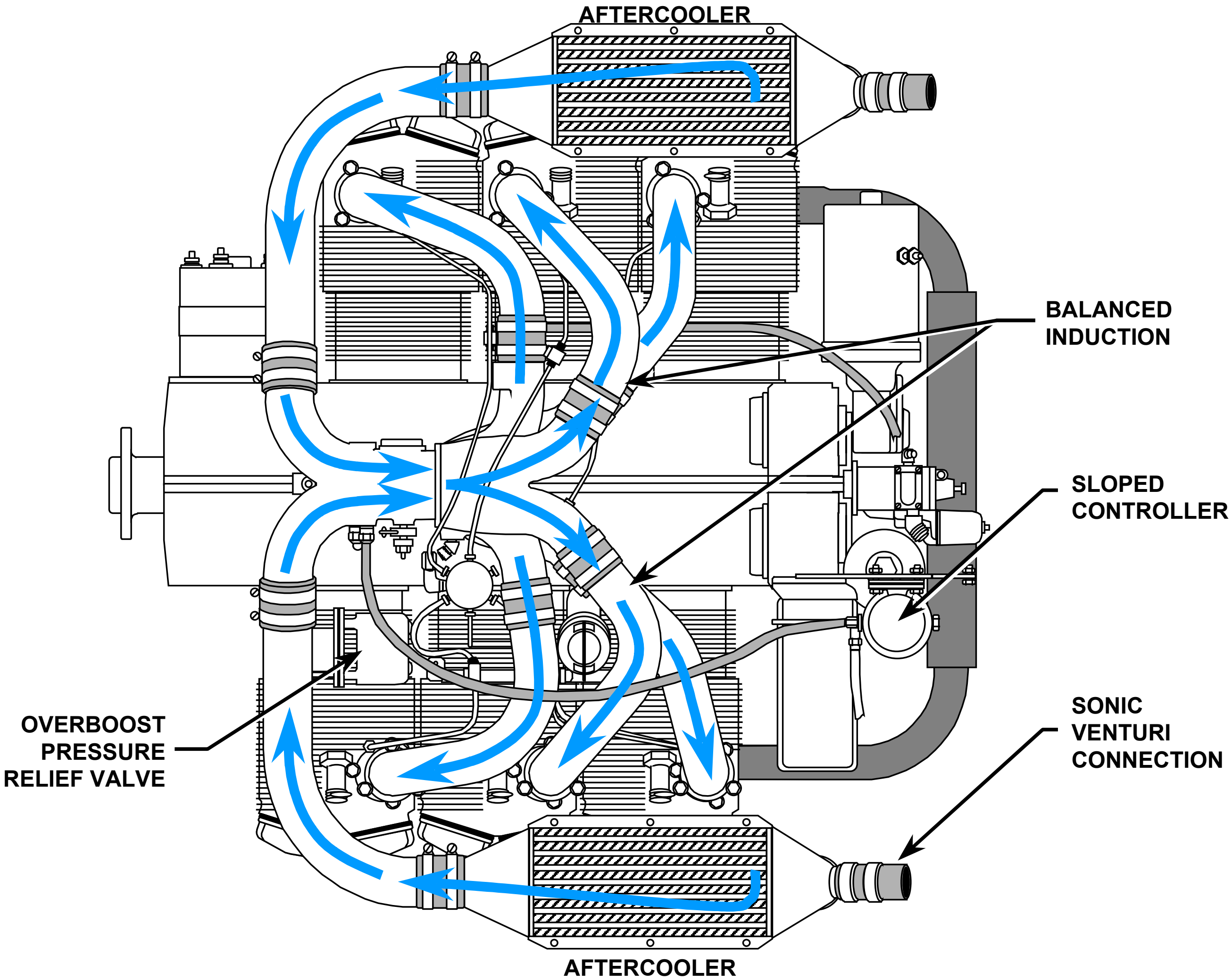


Figure 7-6. Top View of TSIO-550-E Induction System

Engine components through which air flows following the aircraft air inlet filter/alternate air door are: turbocharger compressor, aftercooler, overboost pressure relief valve adapter, fuel metering unit throttle area, balanced manifold, induction tubes and cylinder intake ports. Air flows through these components in the order they are listed.

As the compressor wheel rotates, high volume compressed intake air is discharged from the compressor housing outlet. The turbo-compressor can cause the compressed air to heat up to a point that far exceeds the maximum air throttle inlet temperature allowed for a given engine design. If the charge air temperature exceeds the maximum allowable inlet temperature, the engine will run closer to detonation. Therefore, certain high power turbocharged engine models will incorporate after coolers to cool down the charge air before entering the engine cylinders. This cooled air permits the engine to perform far outside the margin of detonation. The added benefit comes from cooling down the charge air thus increasing charge air density and improving overall engine performance.

This compressed air flows through induction tubing to the aftercooler. The cooled compressed air flows from the aftercooler through induction tubes to the throttle assembly.

Installed on the controller, overboost valve adapter assembly is an overboost valve that will relieve excessive deck pressure in the event of wastegate/controller malfunction. Air exits the fuel servo/throttle assembly and flows into the balanced induction manifold where it is distributed to the individual cylinder intake ports through induction tubes. Induction air flows into the intake ports and mixes with fuel from the injector nozzles. This air and fuel enters the cylinder as a combustible mixture when the intake valve opens.

The overboost valve consists of a housing, spring, valve head and aneroid bellows assembly. The valve head is held in the closed position by the spring and aneroid bellows. The overboost valve is set to open slightly above maximum deck pressure to prevent damage in the event of a system malfunction.

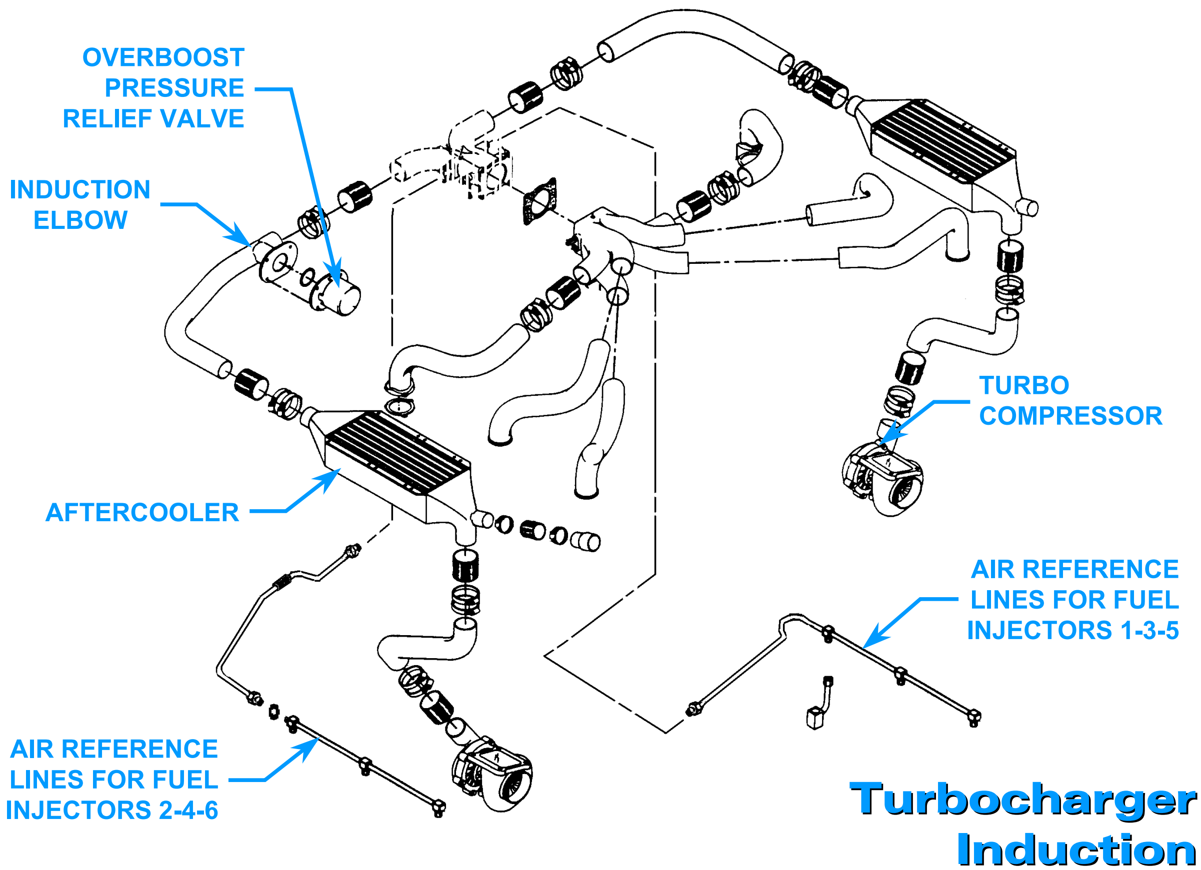


Figure 7-7. Exploded View of TSIO-550-E Induction System Components

The diagram shown above illustrates the parts that make up the downdraft balanced induction system for the turbocharged TSIO-550-B, C & E engine models. The throttle body permits the pilot to control the amount of air that is introduced into the engine as a function of measured manifold pressure. Also attached to the throttle body is the fuel control unit, which was discussed previously in the fuel injection chapter. The fuel control unit meters fuel as a function of throttle angle to more closely match the fuel to air ratio.

The turbo-compressor section of the turbocharger blows the charge air up to the aftercooler. The individual intake tubes which make up the induction transfer system for the engine are attached together by rubber hoses and hose clamps.

An overboost pressure relief valve is incorporated on turbocharged engine models to prevent the engine from receiving an excess amount of air to which the engine fuel injection system cannot match fuel. The hazard of running in an overboost situation is the same as leaning aggressively while at high power. This can cause cylinder degradation or in worse cases can cause detonation. The overboost pressure relieve valve is set to open at roughly 2” to 4” of mercury above the rated maximum manifold pressure of the engine. This acts as a “fail safe” device to prevent the engine from reaching an overboost situation.

The throttle body is attached to the air induction manifold assembly. This device serves to act as an interface between the throttle body and the individual cylinder intake manifold tubes. These tubes are attached to the manifold assembly via a rubber hose and hose clamps.

The airflow that runs from the turbo-compressor outlet to the inlet of the throttle plate is referred to in short terminology as “Upper Deck Pressure.” All airflow after the throttle plate is referred to as manifold pressure. Upper deck pressure is used as an air reference to the fuel injector nozzles as was previously mentioned in the fuel injection chapter. The upper deck pressure is referenced to a wastegate controller. The newest controller, the Slope Controller will be discussed in the next chapter dealing with principles of turbocharged engine models. Upper deck pressure is also used as a reference to the fuel pump, to provide pressurization for magnetos, and for cabin pressure on selected pressurized aircraft.

It is good practice to wash an engine during 100 Hour or annual inspection intervals. During the time the engine is being cleaned and is soaked in soapy water, it is recommended that the engine be pressurized to check for air leaks. While the engine is wet, any signs of air bubbles escaping around air fittings, hoses, etc., can be easily detected and corrected.

When removing or replacing induction components, it is important to ensure that the individual cylinder intake manifold tube is torqued first to the cylinder head before the hose and hose clamps are tightened to the induction manifold assembly.

KEY TERMS

ADMP	Absolute dry manifold pressure, is used in establishing a baseline standard of engine performance. Manifold pressure is the absolute pressure in the intake manifold; measured in inches of mercury.
Ambient	A term used to denote a condition of surrounding atmosphere at a particular time. For example; Ambient Temperature or Ambient Pressure.
Critical Altitude	The maximum altitude at which a component can operate at 100% capacity. For example, an engine with a critical altitude of 16,000 feet cannot produce 100% of its rated manifold pressure above 16,000 feet. "Critical Altitude" means the maximum altitude at which, in standard atmosphere, it is possible to maintain, at a specified rotational speed, a specified power or a specified manifold pressure. Unless otherwise stated.
Density Altitude	Altitude as determined by pressure altitude and existing ambient temperature. In Standard Atmosphere (IAS) density and pressure altitudes are equal. For a given pressure altitude, the higher the temperature, the higher the density altitude.
Hg"	Inches of Mercury. A standard for measuring pressure, especially atmospheric pressure or manifold pressure.
Humidity	Moisture in the atmosphere. Relative humidity, expressed in percent, is the amount of moisture (water vapor) in the air compared with the maximum amount of moisture the air could contain at a given temperature.
Manifold Pressure	Pressure as measured in the intake manifold down-stream of the air throttle. Usually measured in inches of mercury. Standard Day at sea level = 29.92 in hg
Naturally Aspirated	A term used to describe an engine which obtains induction (Engine) air by drawing it directly from the atmosphere into the cylinder. A non-supercharged engine.
O.A.T.	Outside Air Temperature.
Pressure Altitude	Altitude, usually expressed in feet, (using absolute static pressure as a reference) equivalent to altitude above the standard sea level reference plane (29.92" Hg).
Standard Day	By general acceptance, temperature -59°F/15°C, pressure -29.92 In. Hg.
Volumetric Efficiency	The ability of an engine to fill its cylinders with air compared to their capacity for air under static conditions. A "normally aspirated" engine will always have a volumetric efficiency of slightly less than 100%, whereas superchargers permit volumetric efficiencies in excess of 100%.

Chapter Eight

Turbocharging Systems

CHAPTER 8 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Describe the functional purposes of the components which comprise the turbocharging system.

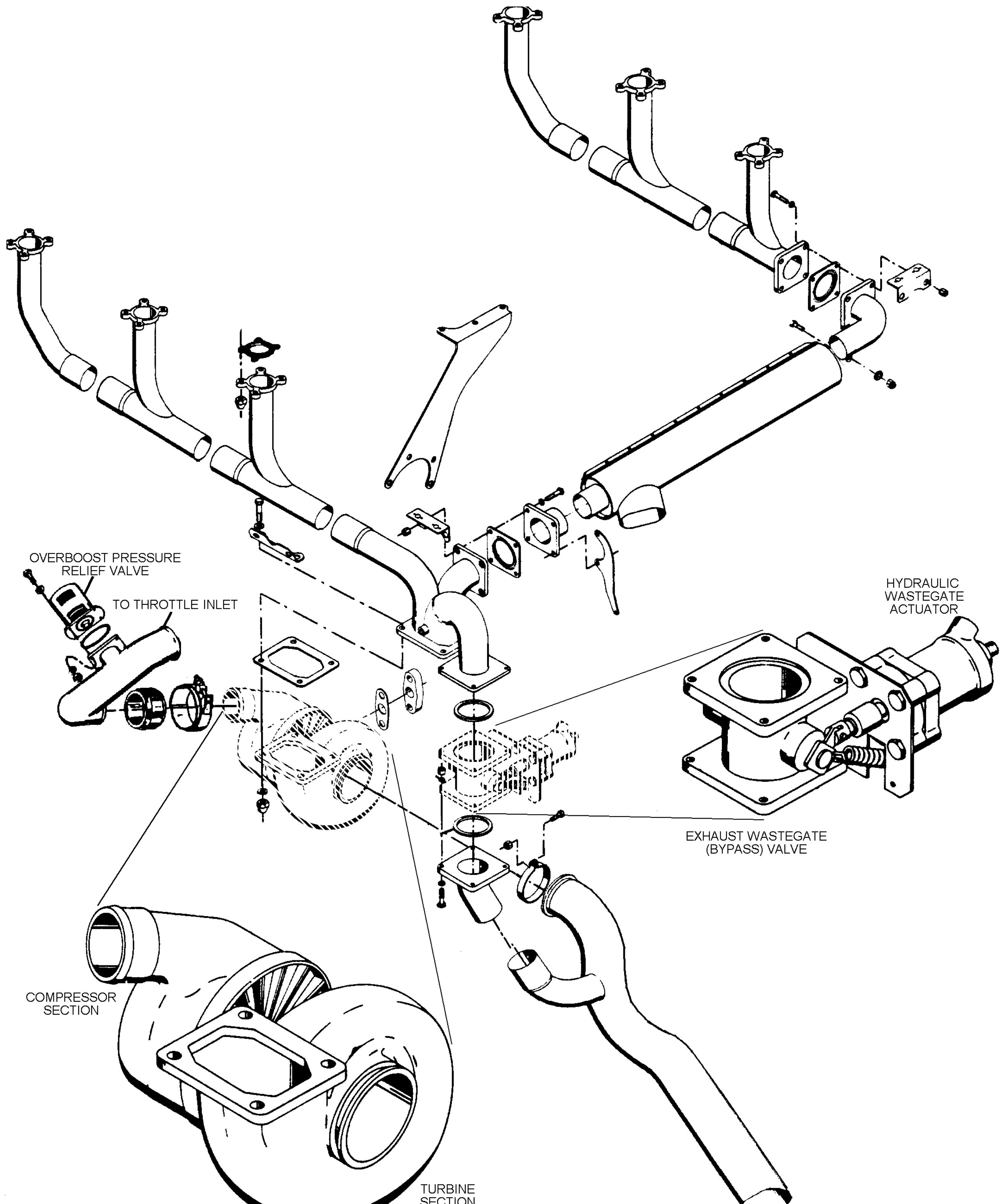
② Describe the functional operation of the turbo-compressor section

③ Describe the functional operation of the turbo-exhaust section

④ Describe the functional operation of the various wastegate controllers

⑤ Identify those components which interact with the Fuel Injection System.

Variable Absolute Pressure Controller Installed on Throttle Body



TSIO-520-UB Turbocharger System Components Exploded View

INTRODUCTION

The information in this chapter is intended to provide you with an understanding of the exhaust and turbocharger systems used on some of the Teledyne Continental Motors engines. The theory will also explain the functions of the various components in the turbocharger system.

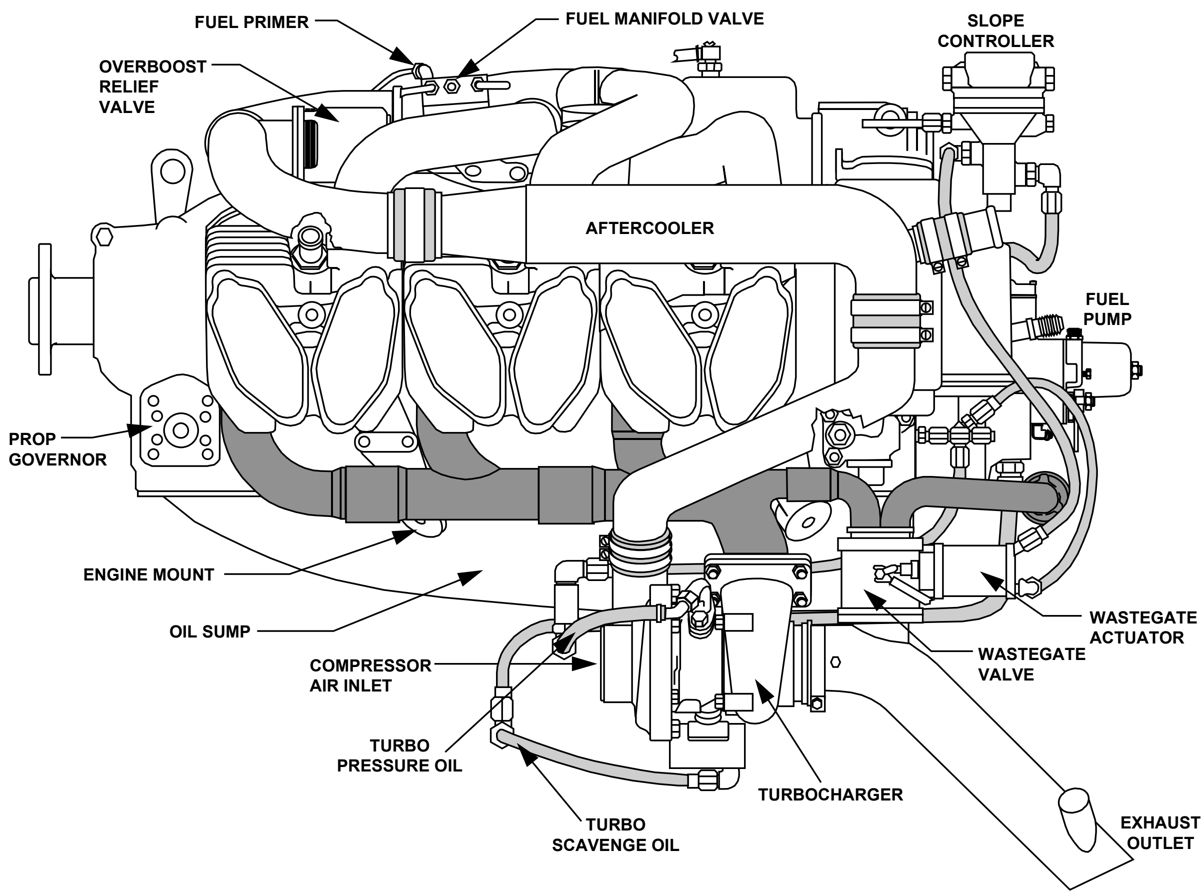


Figure 8-1. Turbocharger Components - TSIO-550-E

TURBOCHARGER SYSTEM DESCRIPTION

The turbocharger system contains the following engine components: turbocharger, aftercooler, hydraulic controlled exhaust by-pass (wastegate), wastegate controller, lubrication plumbing, exhaust collector assembly, and turbocharger tailpipe assembly. Special lines and fittings are also attached to the upper-deck pressure for air reference to the fuel injection system and in some cases for pressurizing the magnetos.

During normal engine operation, exhaust gases exit the cylinder combustion chambers and flow through the exhaust collector to the turbocharger turbine housing inlet. The exhaust gas flow provides turbine wheel rotation and exits through the turbine housing discharge port and tailpipe assembly. The turbine wheel drives the compressor wheel which is connected by a common shaft.

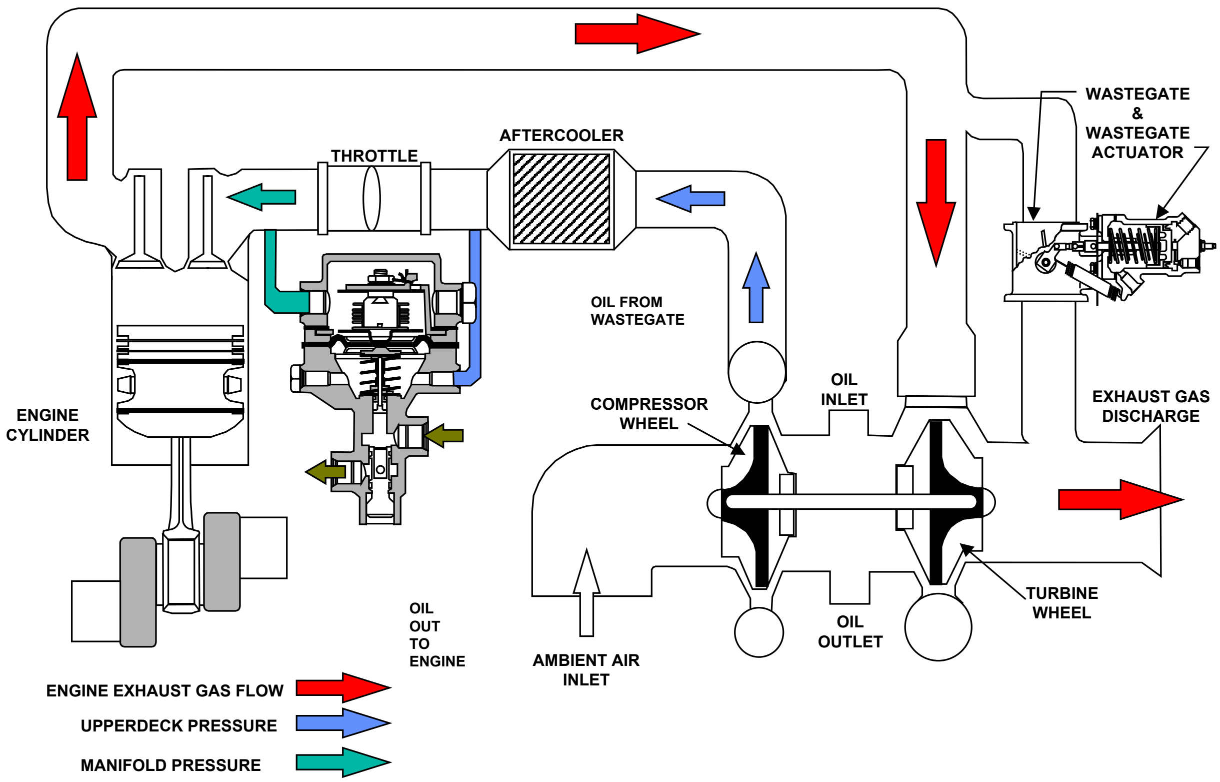


Figure 8-2. Turbocharger Simplified Diagram

Engine manifold pressure is maintained within the specified limits by controlling the turbocharger compressor discharge pressure.

Compressor discharge pressure (deck pressure) is regulated by controlling the flow of exhaust gas through the turbocharger turbine. This is accomplished with a hydraulically controlled exhaust by-pass valve (wastegate) in the exhaust system prior to the inlet of the turbine housing. The wastegate valve is spring loaded to the open position and closed by pressurized oil from the engine.

The controller monitors deck pressure by sensing the output of the compressor. The controller controls the oil flow through the wastegate actuator which opens or closes the exhaust by-pass. When deck pressure is insufficient, the controller will restrict oil flow thereby increasing oil pressure at the wastegate actuator. This pressure acts on the piston to close off the wastegate valve, forcing more exhaust gas pulses to turn the turbine faster and cause an increase in compressor output. When deck pressure is too great the opposite will occur. The result is the exhaust wastegate will fully open and bypass some of the exhaust gases to decrease exhaust flow across the turbine.

An aftercooler is installed in the induction air path between the compressor stage and the air throttle inlet. Most turbochargers are capable of compressing the induction air to the point where it can raise the air temperature by a factor of five. This means that full power takeoff on a 100°F day could produce induction air temperatures exiting the compressor at up to 500°F. This would exceed the allowable throttle air inlet temperature on all Continental Engine Models. Typically the maximum air throttle inlet temperature ranges from a low 230°F to a high of 300°F. Exceeding these maximums can place the combustion chambers closer to detonation. The function of the aftercooler is to cool down the compressed air, decreasing the likelihood of detonation and increasing the charge air density and improving the turbocharger performance for that engine design.

On engine start, the controller senses insufficient compressor discharge pressure (deck pressure) and restricts the flow of oil from the wastegate actuator to the engine. This causes the wastegate butterfly valve to close. As the throttle is advanced, exhaust gas flow across the turbine increases, thereby increasing turbine/compressor shaft speed and compressor discharge pressure. The controller senses the difference between upper deck and manifold pressure, if either deck pressure or throttle differential pressure rises, the controller poppet valve opens, relieving oil pressure to the wastegate actuator. This decreases turbocharger compressor discharge pressure (deck pressure).

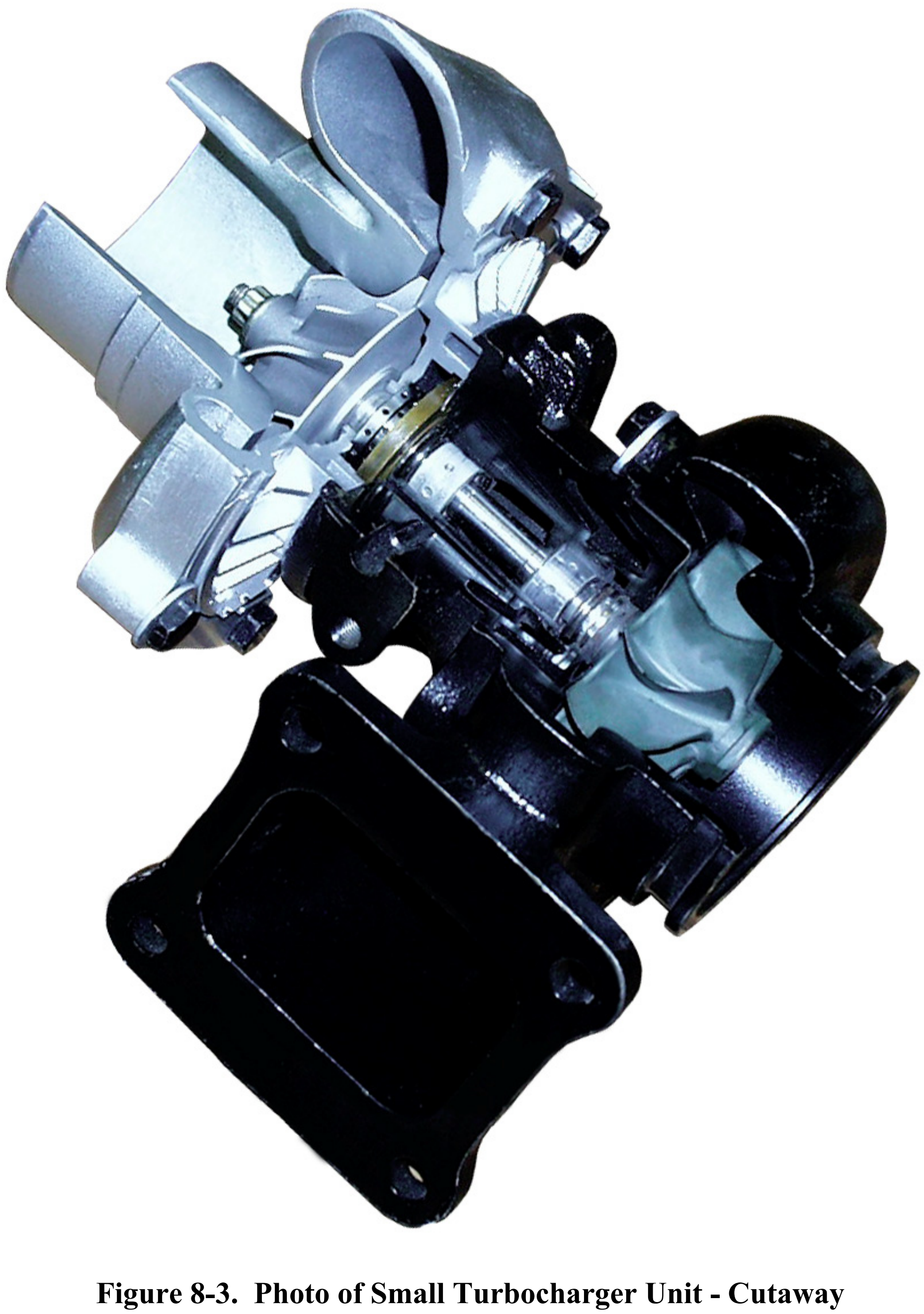


Figure 8-3. Photo of Small Turbocharger Unit - Cutaway

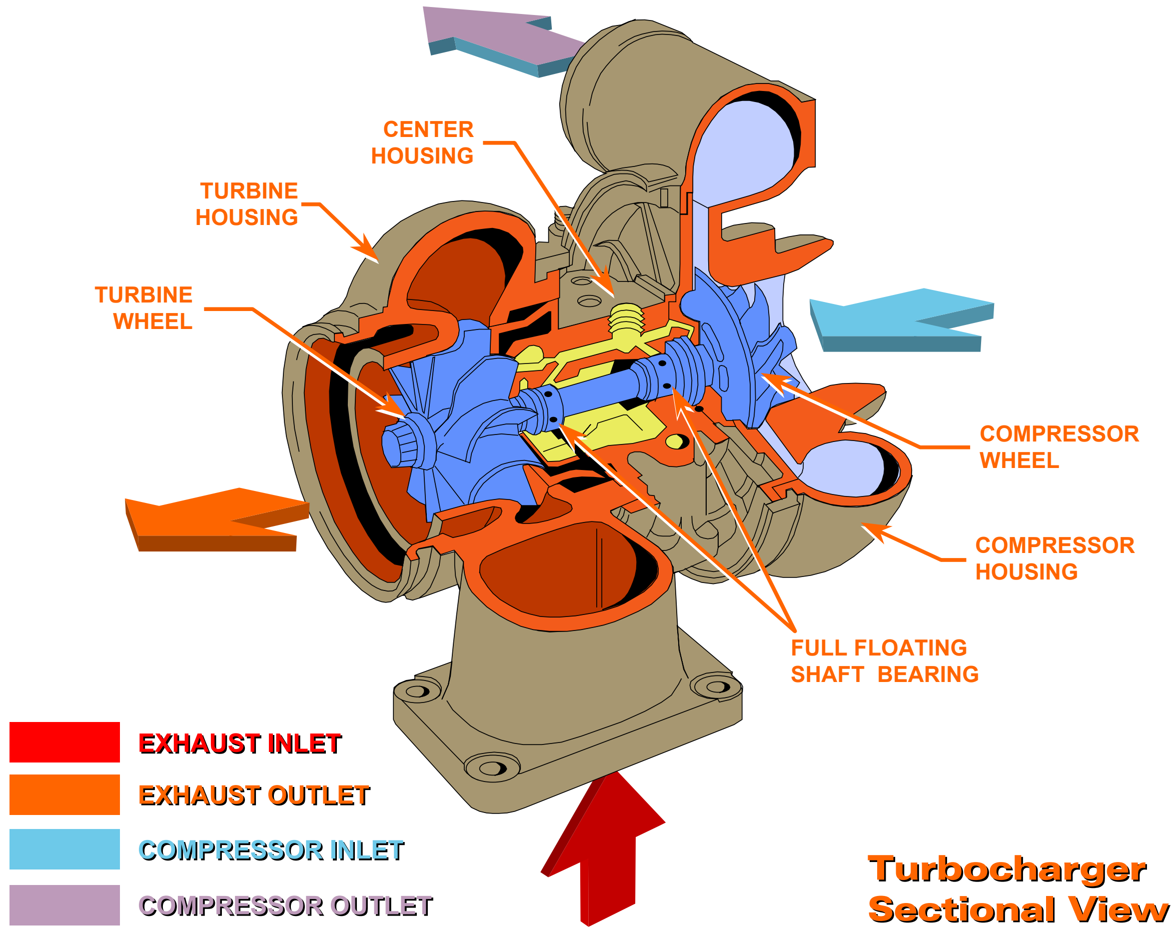


Figure 8-4. Turbine and Compressor

TURBOCHARGER DETAILED DESCRIPTION.

The turbocharger consists of a radial inward flow turbine and turbine housing, a centrifugal flow impeller (compressor) and compressor housing, each bolted to a center housing.

The center housing incorporates bearings that support the turbine/compressor shaft. The shaft and bearings are lubricated with pressurized engine oil that enters the center housing through an oil inlet check valve and fitting. Drilled passages direct the pressurized oil to the bearings. After passing through the bearings the oil is evacuated from the center housing oil outlet and check valve by an engine driven scavenge pump. Oil seals installed outboard of the turbine/compressor shaft bearings retain the oil in the center housing. In some installations inlet and outlet check valves are installed to prevent oil from flooding the center housing when the engine is not operating.

During engine operation, exhaust gases from the engine pass through the turbine housing and cause the turbine wheel to rotate. Since the turbine wheel and compressor are attached to a common shaft, the compressor rotates within the compressor housing. The compressor impeller draws in ambient air, through the aircraft induction system, compresses the air and delivers it to the engine intake manifold.

As engine power is increased the flow of exhaust gases increase which increases the speed of the turbine/compressor assembly and the output of the turbocharger. The flow of exhaust gases through the turbocharger are controlled by the Exhaust By-pass Valve or wastegate.

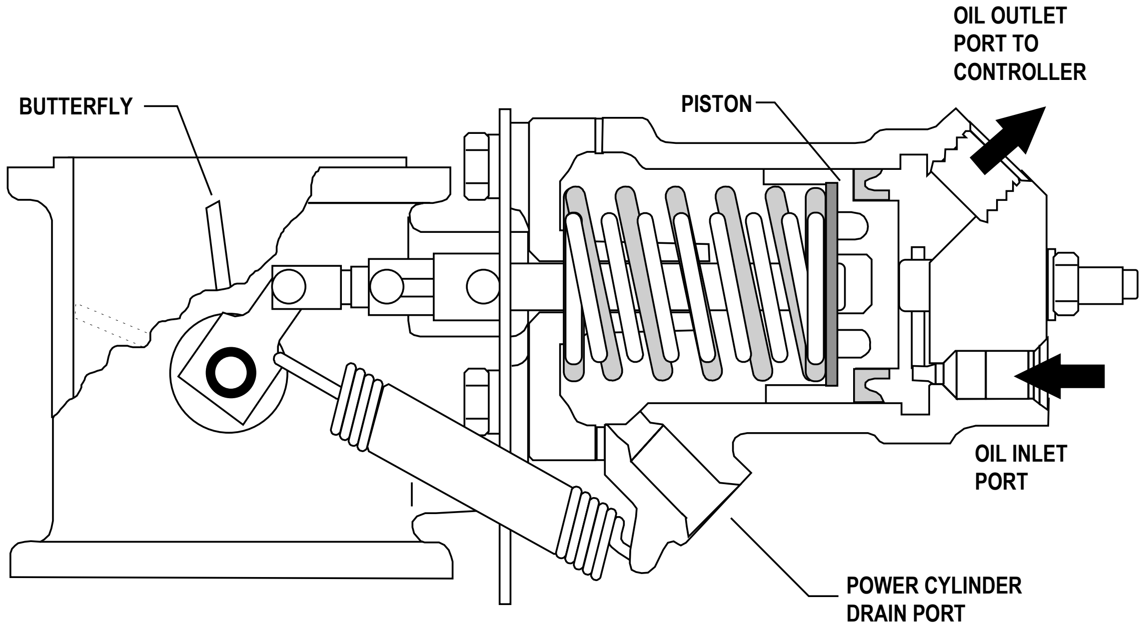


Figure 8-5. Wastegate & Wastegate Actuator

Exhaust By-pass Valve (Wastegate) Description - The wastegate is an oil actuated valve. The wastegate valve is connected to the actuator by mechanical linkage. The wastegate is installed in the engines exhaust system, near the turbocharger, in an exhaust by-pass pipe that allows some of the exhaust gases to by-pass the turbocharger turbine.

The wastegate valve is spring loaded to the open position. Pressurized oil from the engine is directed to the inlet of the wastegate actuator. The pressurized oil acting on the actuator plunger and against spring pressure, drives the wastegate valve to the closed position.

A controller is connected in the oil return line from the wastegate actuator to the engine. The controller controls the oil pressure acting on the wastegate actuator by increasing or decreasing the return oil flow restriction. We will now discuss the various types of wastegate controllers.

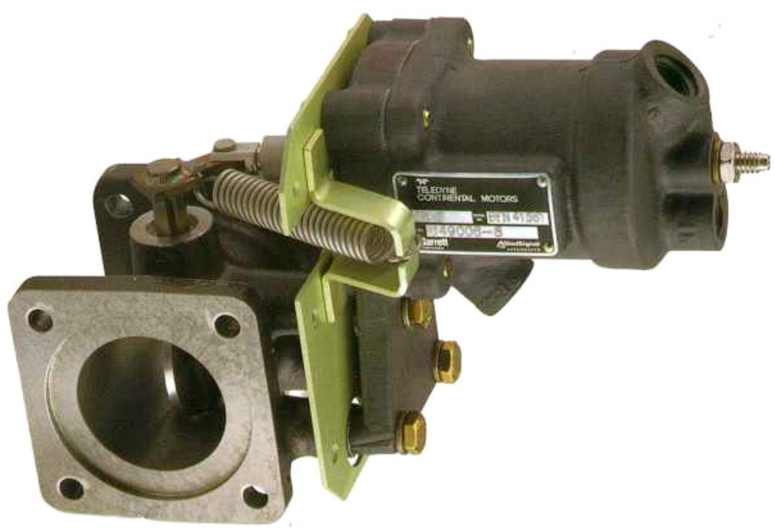


Figure 8-6. Photo of Wastegate and Actuator Assembly

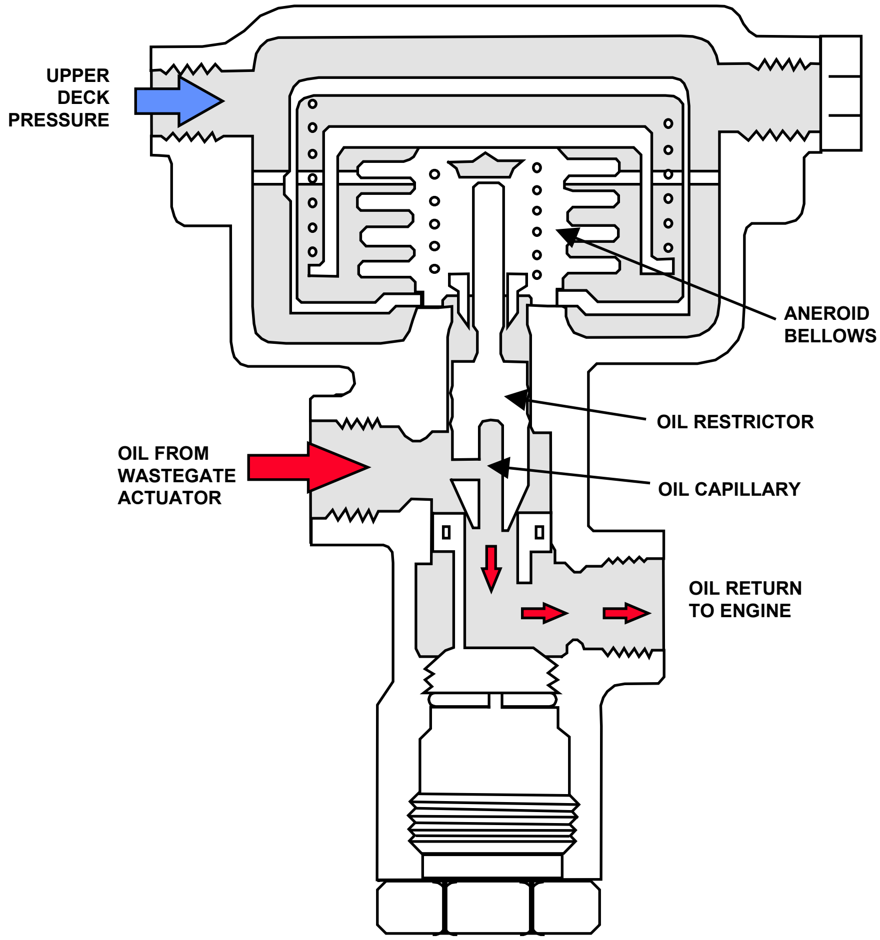


Figure 8-7 Absolute Pressure Controller

Absolute Pressure Controller - The absolute pressure controller regulates the wastegate actuator to prevent upper deck pressure from exceeding the prescribed pressure as determined by the manufacturer for each particular application.

Engine oil flows under pressure from the engine to the wastegate actuator and then to the absolute pressure controller and back to the engine. The oil pressure exerted on the actuator piston is controlled by restricting the oil's return to the engine.

The absolute pressure controller contains an aneroid bellows that is referenced to upper deck pressure. When the upper deck pressure drops below a specific level, the aneroid bellows expands and closes the oil restrictor valve, thereby restricting the flow of oil returning to the engine. This causes the oil pressure to increase at the wastegate actuator. The increased oil pressure on the wastegate actuator piston will force the piston to begin to close off the butterfly valve in the wastegate. As the pressure increases the wastegate will close off more of the exhaust bypass. The more the bypass closes, more exhaust gas pulses flow across the turbine. More exhaust gas pulses are now driving the turbine and the compressor increases the upper deck pressure output.

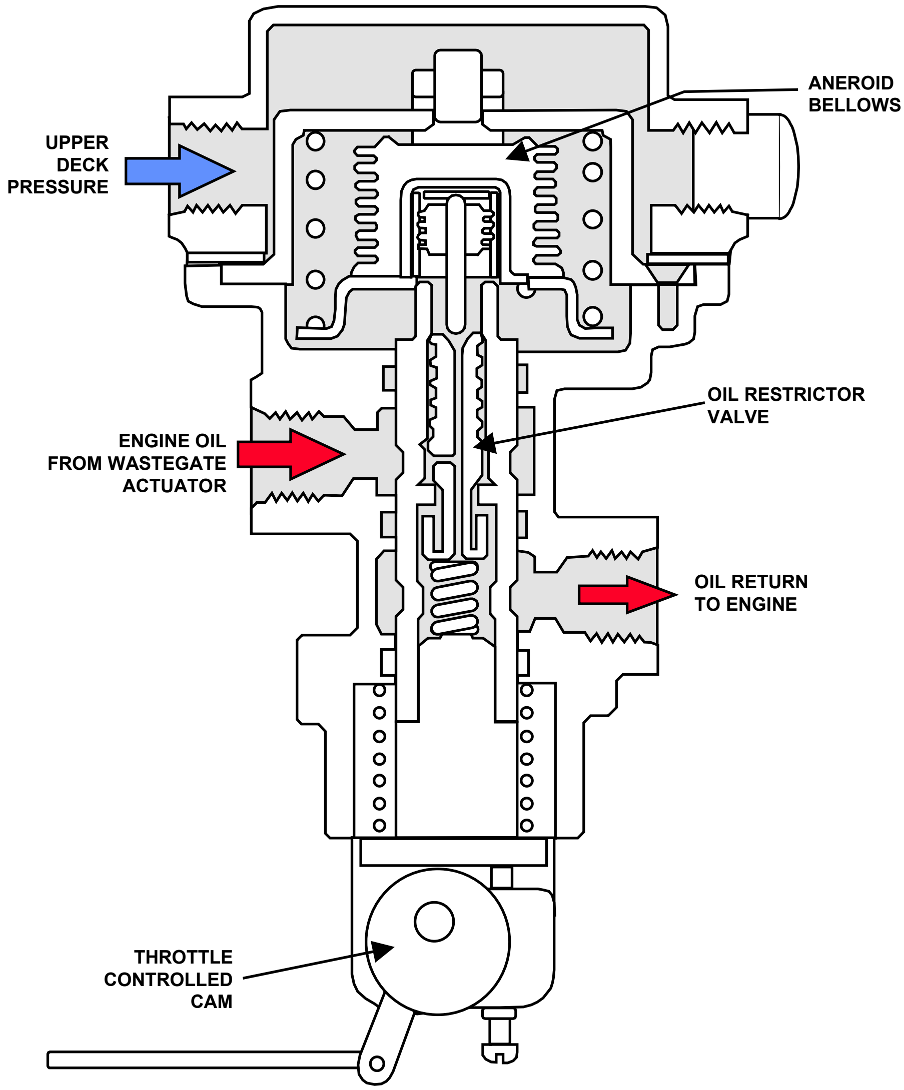


Figure 8-8. Variable Absolute Pressure Controller

Variable Absolute Pressure Controller (VAPC) - The VAPC contains an oil control valve similar to the other controllers that we have discussed. The oil restrictor is actuated by an aneroid bellows that is referenced to upper deck pressure.

A cam connected to the throttle mechanism applies pressure to the restrictor valve and aneroid. As the throttle is opened to greater values, the cam applies a greater pressure to the aneroid. This increases the amount of upper deck pressure necessary to compress the aneroid and thereby open the oil restrictor valve.

What this means is the scheduled absolute value of upper deck pressure that is required to overcome the aneroid is variable by throttle position.

As the throttle is opened wide, obviously the manifold pressure and upper deck pressure requirements greatly increase.

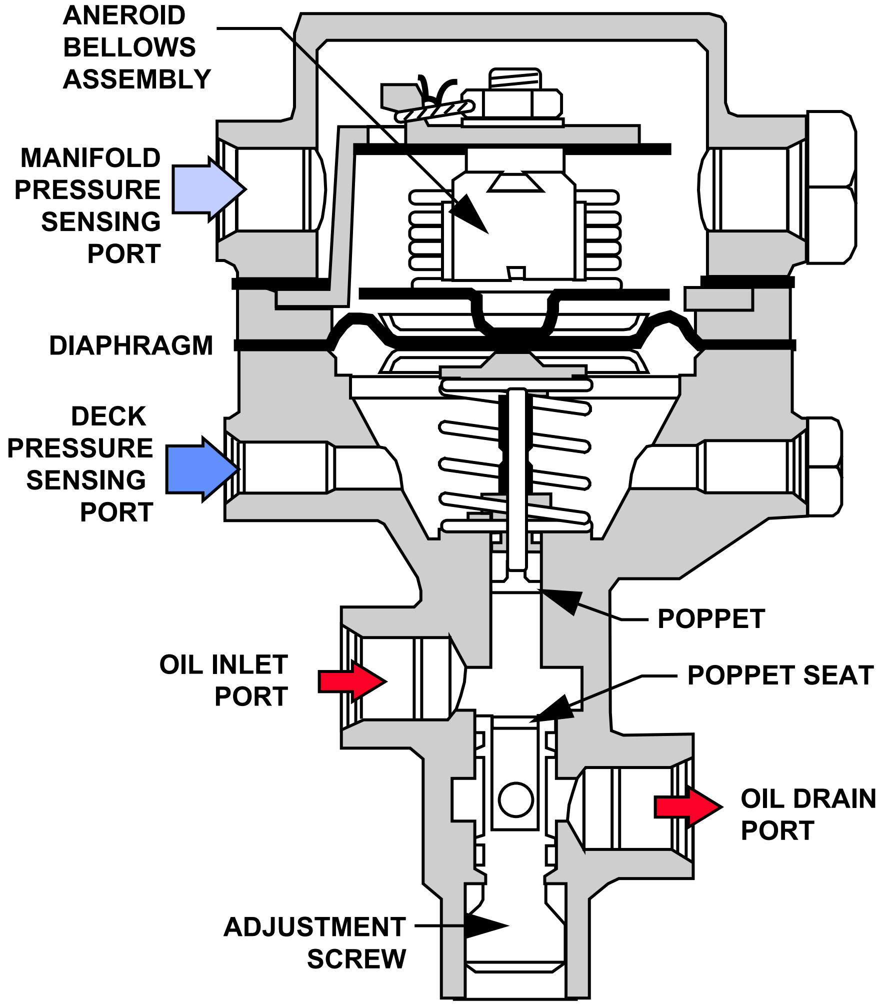


Figure 8-9. Sloped Controller

Sloped Controller - The sloped controller is designed to maintain the rated compressor discharge pressure at wide-open throttle, and to reduce this pressure at part throttle settings. A diaphragm, coupled with a spring-supported bellows for absolute pressure reference, is exposed to deck pressure and intake manifold pressure through ports located before and after the throttle, respectively. This arrangement constantly monitors deck pressure, and the pressure differential between the deck and manifold pressure due to a partially closed throttle. If either the deck pressure or throttle differential pressure rises, the controller poppet opens and decreases turbocharger discharge (deck) pressure. The sloped controller is more sensitive to the throttle differential pressure than to deck pressure, thereby accomplishing deck pressure reduction as the throttle is closed.

Turbocharger Lubrication System - This discussion will use the TSIO-550-E as a model. Turbocharger lubricating oil is engine supplied. An oil supply hose from the rear of the oil cooler directs oil through a tee and two hoses to the turbocharger center housings and bearings. Two oil hoses teed into one hose return oil from the turbochargers to the oil scavenge pump located on the rear of the starter adapter assembly. Oil to the wastegate assembly and controller is tapped from the rear of the oil cooler. Oil returning from the controller enters through the crankcase rear or accessory drive section.

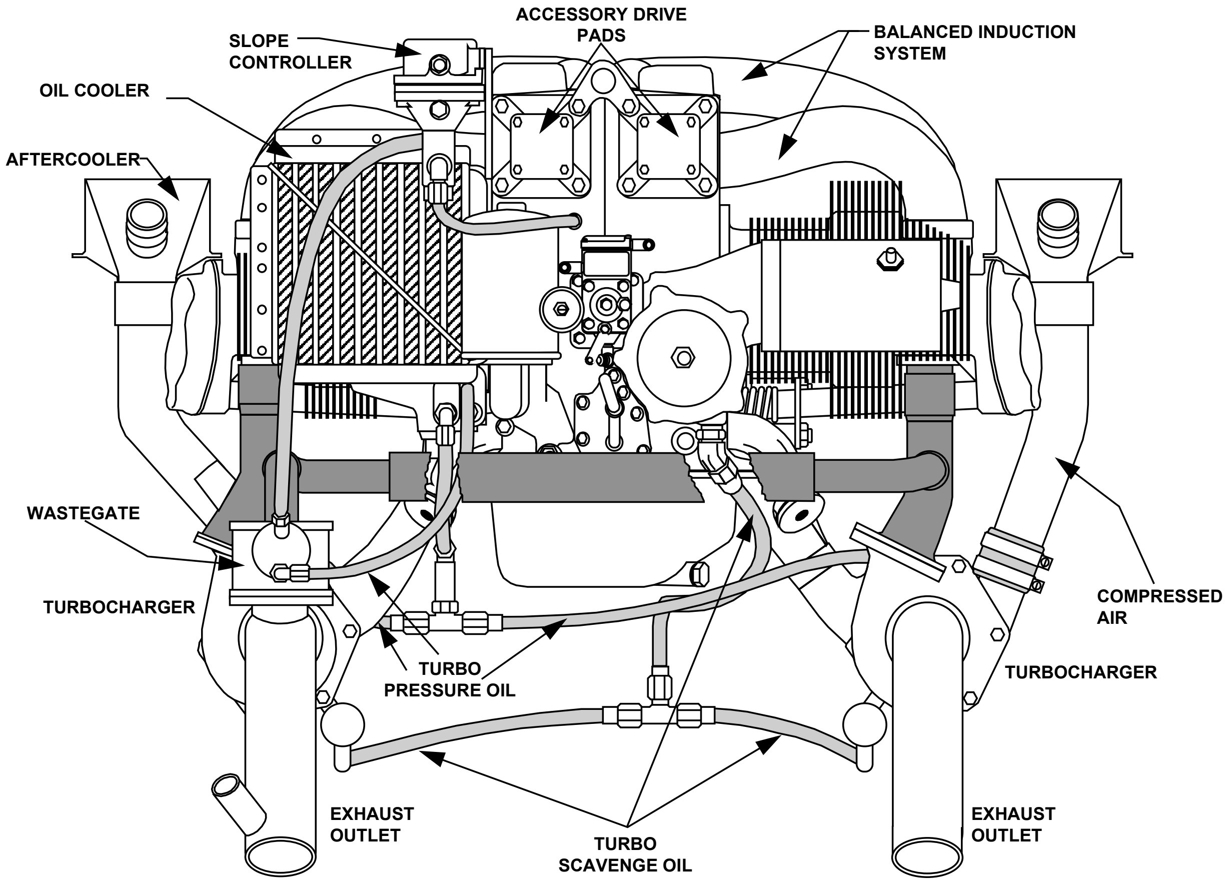


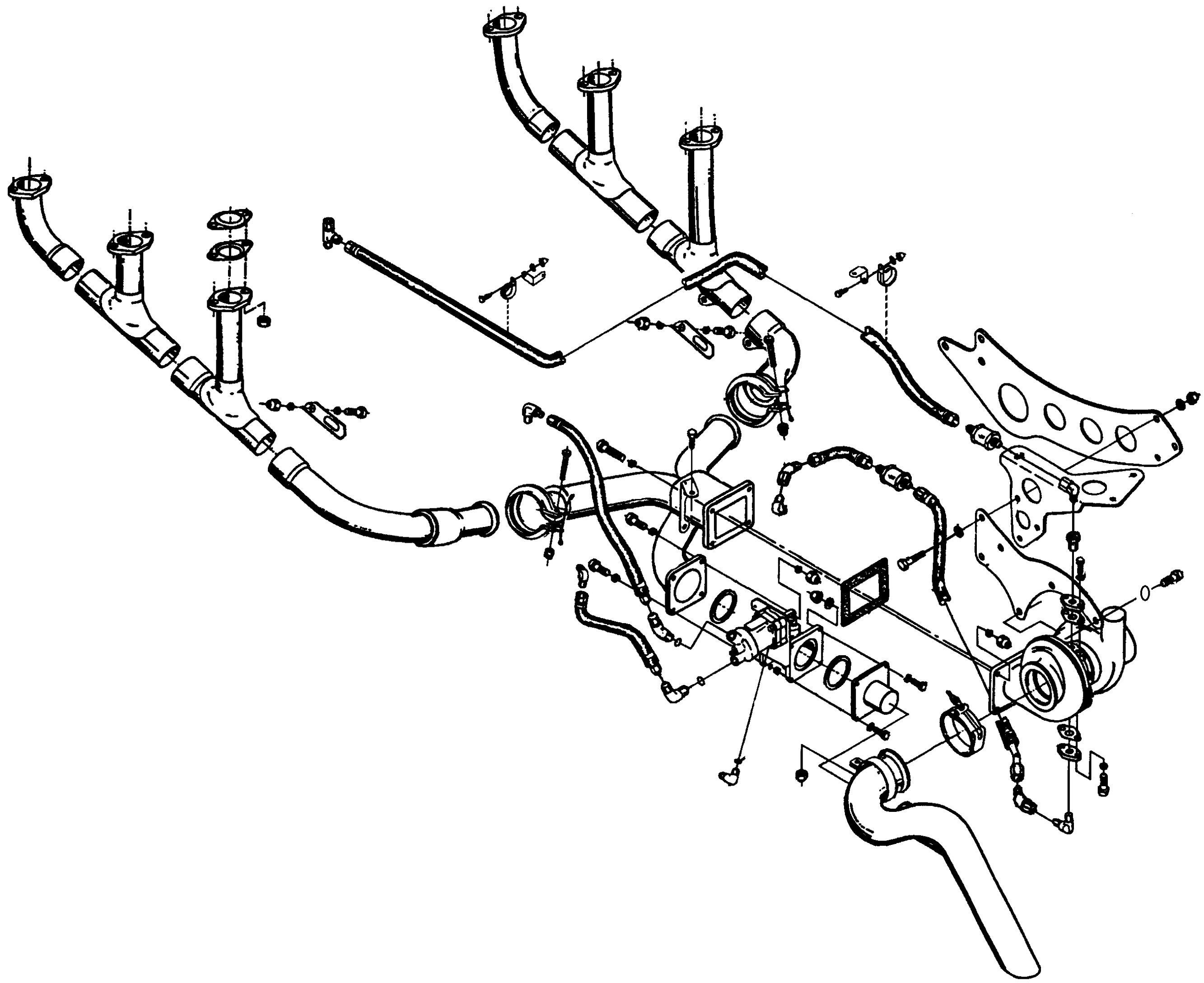
Figure 8-10. Turbocharger Lubrication System - TSIO-550-E Rear View

The one way check valve in the oil supply line prevents oil loading of the turbochargers during static engine conditions.

Piston-ring like oil seals are used on the compressor wheel shaft to prevent the lubricating oil from entering the turbine and compressor housings from the center housing.

SUMMARY

This chapter covered the functions of the components of the turbocharger system and how it uses the exhaust system. We saw how exhaust gases turn the turbine which is connected to a compressor. We discussed the deck pressure output to the engine. The use of a wastegate and some sort of hydraulic controller was used to prevent overboosting the engine whenever the deck pressure was too great. The whole purpose of the turbocharger system is to provide sea level performance at higher altitudes for aircraft.



TSIO-360-RB Turbo & Exhaust System

KEY TERMS

ADMP	Absolute dry manifold pressure, is used in establishing a baseline standard of engine performance. Manifold pressure is the absolute pressure in the intake manifold; measured in inches of mercury.
Ambient	A term used to denote a condition of surrounding atmosphere at a particular time. For example; Ambient Temperature or Ambient Pressure.
BHP	Brake Horsepower. The power actually delivered to the engine propeller shaft. It is so called because it was formerly measured by applying a brake to the power shaft of an engine. The required effort to brake the engine could be converted to horsepower - hence: "brake horsepower".
Critical Altitude	The maximum altitude at which a component can operate at 100% capacity. For example, an engine with a critical altitude of 16,000 feet cannot produce 100% of its rated manifold pressure above 16,000 feet. "Critical Altitude" means the maximum altitude at which, in standard atmosphere, it is possible to maintain, at a specified rotational speed, a specified power or a specified manifold pressure. Unless otherwise stated.
Density Altitude	Altitude as determined by pressure altitude and existing ambient temperature. In Standard Atmosphere (IAS) density and pressure altitudes are equal. For a given pressure altitude, the higher the temperature, the higher the density altitude.
E.G.T.	Exhaust Gas Temperature. Measurement of this gas temperature is sometimes used as an aid to fuel management.
Exhaust Back Pressure	Opposition to the flow of exhaust gas, primarily caused by the size and shape of the exhaust system. Atmospheric pressure also affects back pressure.
Hg"	Inches of Mercury. A standard for measuring pressure, especially atmospheric pressure or manifold pressure.
Manifold Pressure	Pressure as measured in the intake manifold down-stream of the air throttle. Usually measured in inches of mercury.
O.A.T.	Outside Air Temperature.
Overboost Valve	A pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

Pressure Altitude Altitude, usually expressed in feet, (using absolute static pressure as a reference) equivalent to altitude above the standard sea level reference plane (29.92" Hg).

Scavenge Pump A pump (especially an oil pump) to prevent accumulation of liquid in some particular area.

Sonic Venturi A restriction, especially in cabin pressurization systems, to limit the flow of air through a duct.

Standard Day By general acceptance, temperature -59°F/15°C, pressure -29.92 In. Hg.

T.I.T. Turbine Inlet Temperature. The measurement of E.G.T. at the turbocharger turbine inlet.

Turbocharger A device used to supply increased amounts of air to engine induction system. In operation, a turbine is driven by engine exhaust gas. In turn, the turbine directly drives a compressor which pumps air into the engine intake.

Variable Absolute Pressure Controller A device used to control the speed, and thus the output of the turbocharger. It does so by operating the wastegate which diverts, more or less, exhaust gas over the turbine.

Wastegate Valve A unit, used on turbocharged engines, to divert exhaust gas through or around the turbine, as necessary to maintain turbine speed. As more air is demanded by the engine, due to throttle operation, the compressor must work harder. In order to maintain compressor and turbine speeds, more exhaust must be flowed through the turbine. The wastegate valve closes and causes gas, which would go directly overboard, to pass through the turbine. The wastegate is usually operated by an actuator which gets signals from the turbocharger controller.

Wastegate Valve (Fixed Orifice) A ground adjustable by pass located in the turbine exhaust bypass duct. The position of the fixed orifice wastegate valve remains constant throughout all modes of engine operation.

EXERCISES

1. What is the maximum continuous turbine inlet temperature rating for the TSIO-520-AE?

   ____

   How about for the TSIO-550-E? ______________________________

2. Explain the difference between upper deck pressure and manifold pressure. ______________

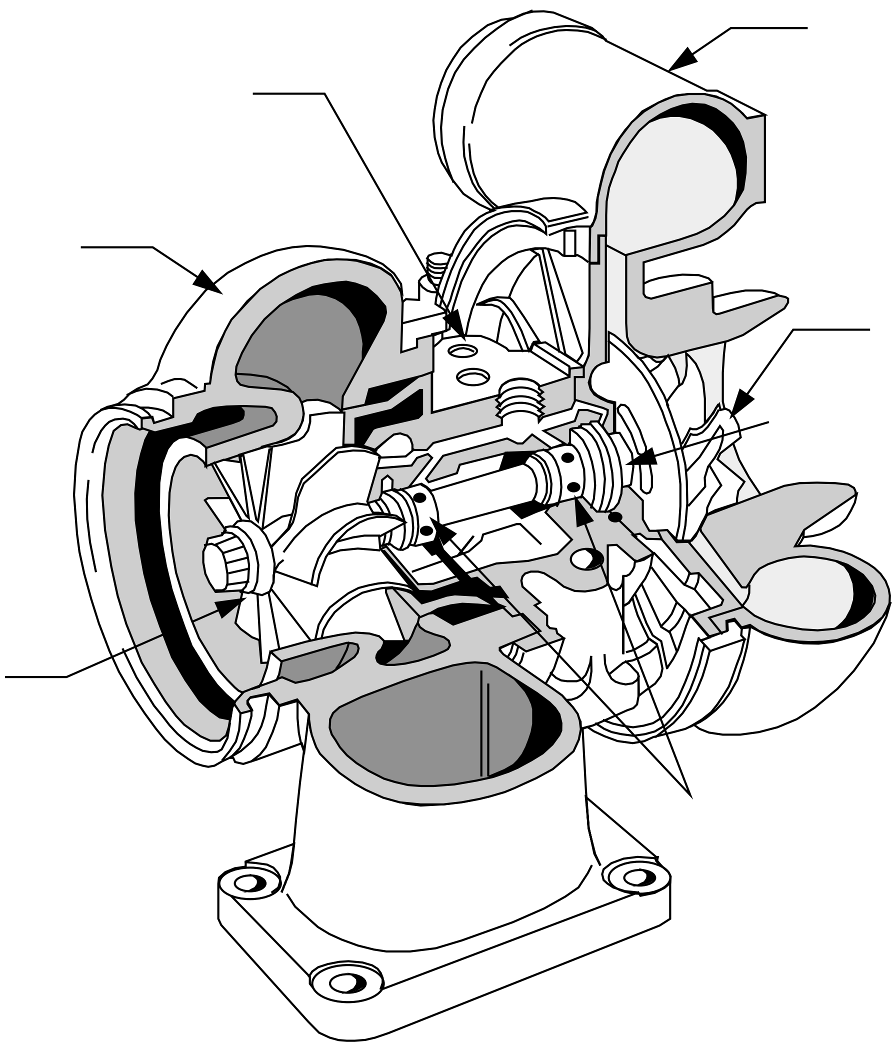
   ____

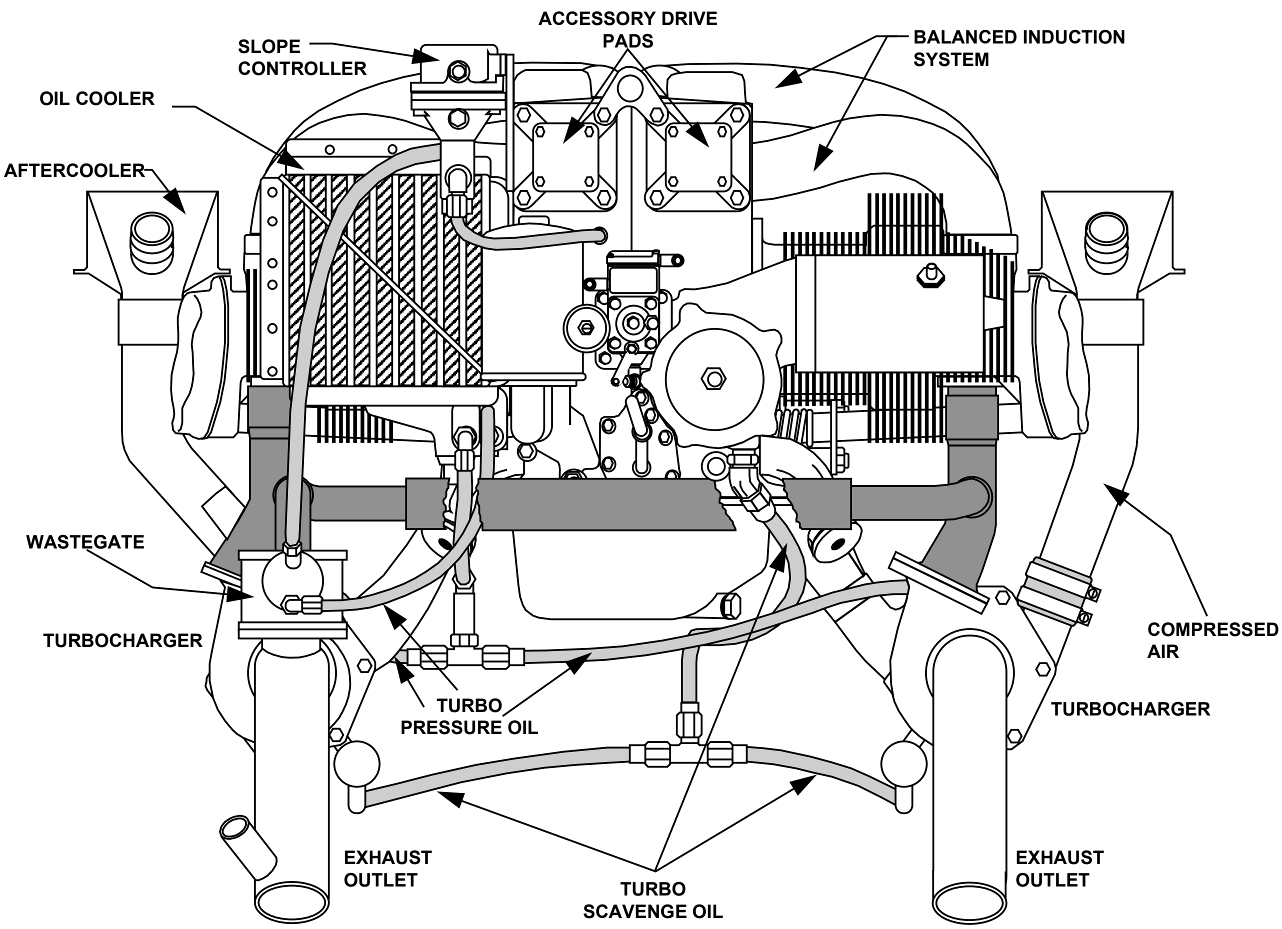
3. Why are check valves used on some turbocharger installations. ______________________

   ____

   ____

4. Fill in the labels for the callouts in the diagram below.





Refer to the above diagram to answer questions 5 & 6.

5. Describe the oil path from engine to wastegate and back to engine. ____________________

____

____

6. How does the turbocharger return oil to the engine? ______________________________

____

7. What component is used in most wastegate controllers to sense and respond to changes in upper deck pressure? ____

8. Explain how the Variable absolute pressure controller differs from the absolute pressure controller. ____

____

Chapter Nine

Ignition Systems Principles

CHAPTER 9 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

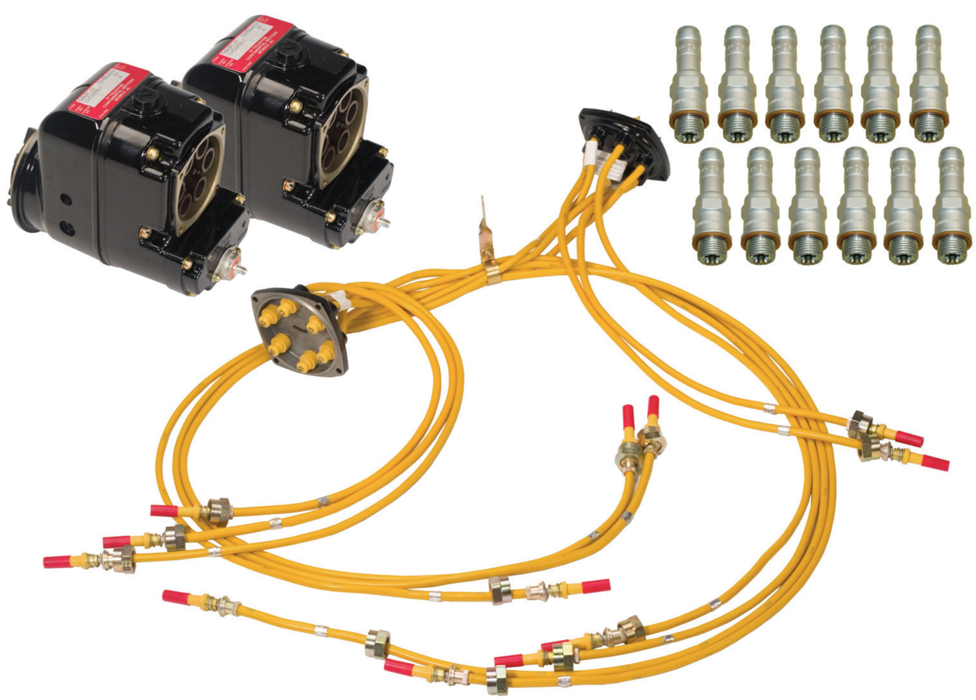
① Describe the functional purposes of the components within a Magneto

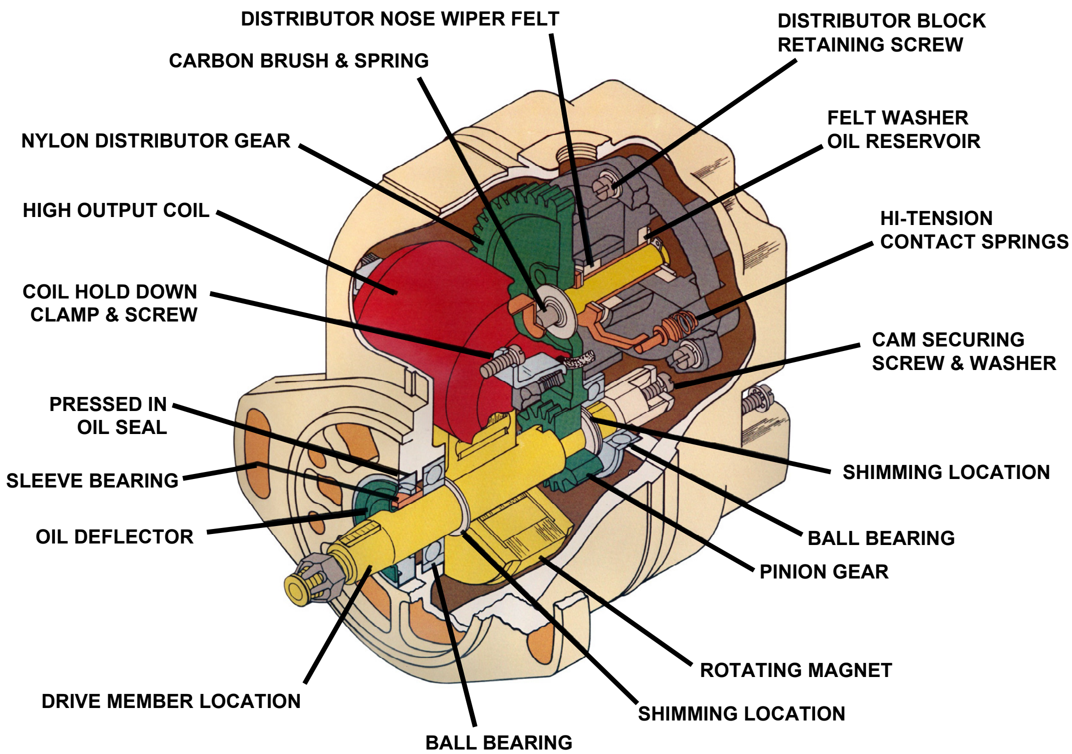
② Describe the fundamental purposes of the Impulse Coupling

③ Describe the differences between the Impulse Coupled & Shower of Sparks Ignition System

④ Using the TCM LINK Information Services CD ROM, identify the Service Bulletins relating to magnetos.

⑤ Using the TCM LINK Information Services CD ROM describe the magneto to engine timing procedure.





20 Series Bendix Magneto Cutaway Diagram

Dual ignition is provided by two magnetos. On six cylinder engines, the left magneto fires 1-3-5 lower and 2-4-6 upper spark plugs, while the right magneto fires the 1-3-5 upper and 2-4-6 lower spark plugs.

The TCM S6RN-20, 25, 201, -205, 1201, 1205 series magnetos are designed to provide ignition for six cylinder aircraft engines. The magnetos generate and distribute high tension current through high tension leads to the spark plugs. Because of the one piece housing design, these high tension magnetos are comparatively easy to maintain between overhauls. The magnetos must be overhauled at engine overhaul or four calendar year interval in accordance with the applicable Magneto Service Manual.

To obtain the retard spark necessary for starting, the S-20 series magnetos and some S-1200 series magnetos employ an impulse coupling. The purpose of the impulse coupling is to: (1) rotate the magneto between impulse trips faster than the engine cranking speed thus generating a better spark for starting the engine, (2) automatically retard the spark during engine cranking, and (3) act as a drive coupling for the magneto. S-200 series magnetos and some S-1200 series magnetos employ the "shower of sparks" ignition system, including a starter vibrator. The purpose of the "shower of sparks" is to: (1) boost ignition energy by feeding pulsating battery voltage to the magneto primary circuit during starting and (2) automatically retard the spark during engine cranking.

The following pages will cover in detail how the magneto is self exciting and generates the necessary spark to satisfy the ignition/combustion requirements for the Continental aircraft engine.

MAGNETS AND FLUX LINES

The operation of TCM Aircraft Magnetos is based on the properties of the permanent magnet. A permanent magnet has a magnetic field consisting of many individual paths of invisible magnetic flux commonly known as "lines" of flux. Each "line" of flux extends from the north pole through the intervening air space to the south pole, thereby forming a closed loop as indicated in Figure 9-1.

The presence of the lines of flux can be shown by placing a magnet under a piece of paper on which iron filings are sprinkled. The iron filings will arrange themselves in definite positions along the lines of flux indicated in Figure 9-1, which comprise the magnetic field.

The lines of flux have the characteristic of repelling one another. Consequently, they will spread over a considerable portion of the air space between the poles as represented graphically in Figure 9-1.

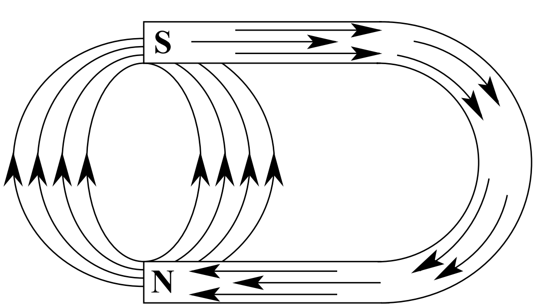


Figure 9-1

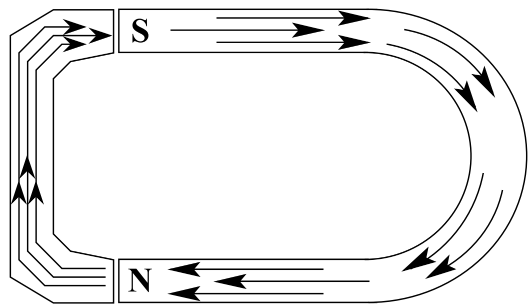


Figure 9-2.

The lines of flux also have a natural tendency to seek the path of least resistance between the magnet poles. A laminated soft iron bar provides a much easier path for the flux than does the air, and for this reason the lines will crowd together and pass through such a bar if it is placed near the magnet.

This can be seen in Figure 9-2 where the "lines" of flux comprising the magnetic field are shown concentrated in a defined path within the bar instead of occupying a large portion of the air space. Therefore, the density of "lines" of flux within the bar is very high. The application of the laminated soft iron bar to magnetos will be explained later in this text.

The direction of the flux in the laminated soft iron bar when placed in a magnetic field is determined by the polarity of the permanent magnet. The permanent magnet is made of special alloy steel which has the characteristic of being able to retain a large portion of the magnetism induced in it when it is "charged" by passing through it lines of flux from a strong electromagnet. The laminated bar is of magnetically "soft" iron, which does not retain an appreciable amount of magnetism when magnetic lines of flux are passed through it.

Therefore, should the magnet in Figure 9-2 be turned over so that the north pole was at the top of the picture, the direction of the lines of flux would be reversed in the iron bar.

GENERATING AN INDUCED VOLTAGE

Experiments can be made with a magnet to show how a voltage is generated or induced in a coil of wire. The coil should be made with a few turns of heavy copper wire and connected, as shown in Figure 9-3, to a meter which indicates any voltage by deflection of its needle.

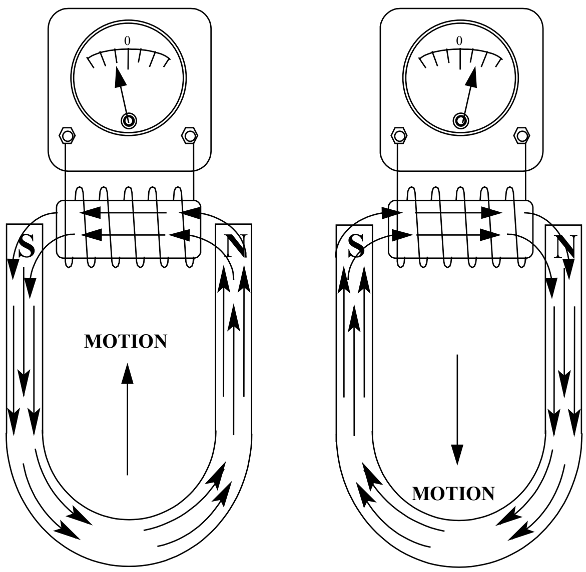


Figure 9-3. Current Direction

The lines of flux of the magnet, when in the position illustrated in Figure 9-3, pass through or "link" the turns of wire in the coil. When one line of flux passes through one turn of a coil, it is known as one "flux linkage." If one line of flux passes through six turns of a coil, six "flux linkages" are produced. Accordingly, if six lines of flux pass through six turns of a coil, there are thirty-six flux linkages, and so on.

If the magnet is brought up from a remote position to the position shown in Figure 9-3a, the number of lines of flux which are linking the coil would be constantly increasing during this motion. In other words, there would be a change in flux linkages as the magnet is moved.

This change in flux linkages, produced by moving the magnet, induces a voltage in the coil of wire. This voltage (or force) will be indicated by the deflection of the meter needle. Should the magnet be removed back away from the coil as shown in Figure 9-3b, the flux linkages would be constantly decreasing during this motion, inducing voltage in the coil in the opposite direction as indicated by the meter needle.

The voltage induced in the coil is proportional to the rate of change of flux linkages. The flux linkages can be increased by adding more turns in the coil of wire or by using a stronger magnet having more lines of flux. The rate can also be increased by moving the magnet faster thus increasing the speed of the flux change. The deflection of the meter needle will indicate the magnitude of the voltage when any of the foregoing experiments of increasing the rate of change of flux linkages are tried.

No voltage will be induced in the coil of wire if the magnet is held stationary even though the lines of flux link the coil turns because the rate of change in flux linkages is zero. This experiment shows that there must be a change in flux linkages to induce voltage.

This is an important principle when applied to a magneto because it points out that the lines of flux must be given a magnetic path through the coil and, also, that there must be a movement of either the coil or the magnet to produce a change in flux linkages.

It is interesting to note that voltage in the same proportions would be induced in the coil of wire by holding the magnet stationary and moving the coil to provide the necessary relative movement to produce the change in flux linkages. This principle of a moving coil and a stationary magnet has been used in some early makes of magnetos. TCM Aircraft Magnetos, however, still employ their original design of having the magnet rotate to produce the change in flux linkages.

EFFECT OF CURRENT IN THE COIL OF A GENERATOR

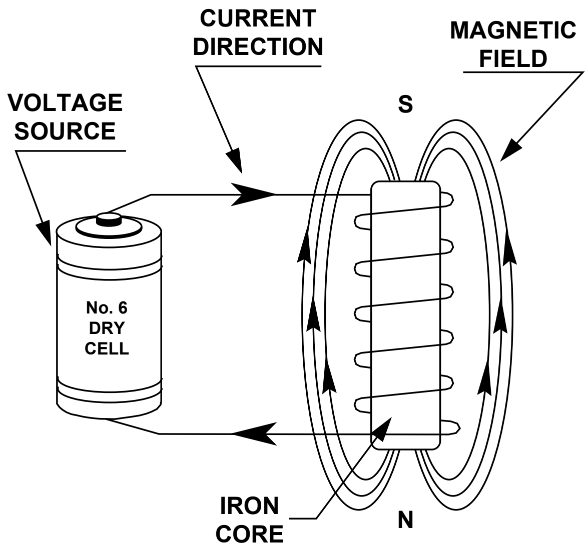


Figure 9-4. Current Direction

Nearly everyone is familiar with the common electromagnet in which a temporary magnetic field is produced by sending a current through a coil of wire. Figure 9-4 is a sketch of a simple electromagnet in which the energizing voltage is obtained from a dry cell.

The magnetic field of the electromagnet consists of flux lines and has the same properties as the field of the permanent magnet previously discussed, the only difference being that if the battery is disconnected from the electromagnet, the field will disappear. We might say that the iron core becomes a temporary magnet during the time the current is "on" and is just an ordinary iron bar when the current is "off".

This principle of an electromagnet can be used to further investigate the properties of the coil and magnet pictured in Figure 9-3, with interesting results. For example, if we short-circuit the terminals of the meter in Figure 9-3, the voltage induced in the coil of wire will cause a current to flow through the circuit. Note that we now have a coil of wire wound on an iron core with a current passing through the wire.

This is essentially the same condition that we had with the battery in Figure 9-4, except that the voltage is now provided by the motion of the magnet instead of the battery.

When a change in flux linkages sets up a current in a coil, the direction of the current is always such that its magnetic field opposes the motion or change in flux linkages which produced the current. This phenomenon is known as Lenz's Law and is of the greatest importance to the operation of the magneto, as explained later in this text.

This will be clearer if we refer to Figure 9-3. Here it was demonstrated that when the magnetic lines through the coil were increasing (magnet moving toward the coil), the voltage induced was of the opposite direction to that induced when the lines of flux were decreasing (magnet moving away from the coil).

If we performed the experiment shown in Figure 9-3, using an ammeter instead of a voltmeter, and observing to make sure that the direction in which the coil was wound and the polarity of the magnet were as shown in the picture, we would find that when the magnet was moved up to the coil, the current would flow up the right hand wire through the ammeter and down the left hand wire.

If we applied the "right hand rule"* to this current, we would find that the field which it sets up opposes the field which repels the field of the magnet and tries to push the latter away.

> ***NOTE:** The *"Right Hand Rule"* is a convenient means of determining the polarity of a magnetic field when the direction of the current and the direction of the winding of a coil are known. If the fingers of the right hand extend around the coil in the direction of the current, the thumb will always point in the direction of the flux, or the North end of the field.

While the magnet is being moved up toward the coil as shown in Figure 9-3a, the normal tendency is to increase the flux through the coil core in the direction from right to left of the picture, as shown by the arrows. However, as soon as the flux starts to increase, current begins to flow in the coil and it sets up a field of a direction from left to right. This field opposes the increase of magnetic flux and actually exerts a small mechanical force which tends to push the magnet away from the coil.

When the magnet is moving away as shown in Figure 9-3b, the current in the coil will flow up the left hand wire, through the meter, and down the right hand wire. By the "right hand rule," the field of the coil is now aiding the field of the magnet. As the magnet is moved away from the coil, the flux linkages decrease. Here again, however, just as soon as the flux linkages start to decrease, current begins to flow in the coil and this current sets up a magnetic field which, in accordance with Lenz's Law, opposes the change. Since the change is now a decrease, the coil field will not in this case oppose the magnetic field, but will rather aid it, trying to keep it from dying out or decreasing. Actually, a small mechanical pull is exerted on the magnet by the coil, tending to resist the motion of the magnet away from the coil.

To sum up our understanding of what is happening in these experiments we can consider the magnet and coil as a simple type of generator. If the generator is operated (magnet moved) without a load connected (such as would be the ease if a voltmeter were connected across the coil terminals) no current will flow and only voltage will appear across the terminals. If the generator is operated in a short-circuited condition (such as with an ammeter connected across the coil terminals) a current will flow but the voltage will be low. This effect of decreasing output voltage when an increased output current is taken, can be observed on any simple unregulated generator.

EFFECT OF INTERRUPTING THE CURRENT

Suppose we set up the apparatus as shown in Figure 9-5 with a contact switch connected across the coil, and the spring of the contact switch connected to the magnet with a piece of string such that as soon as the magnet has moved a slight distance from the coil, the string will pull the switch open.

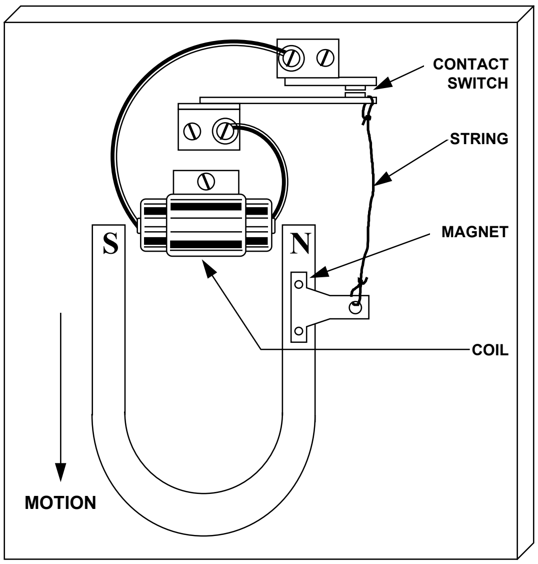


Figure 9-5

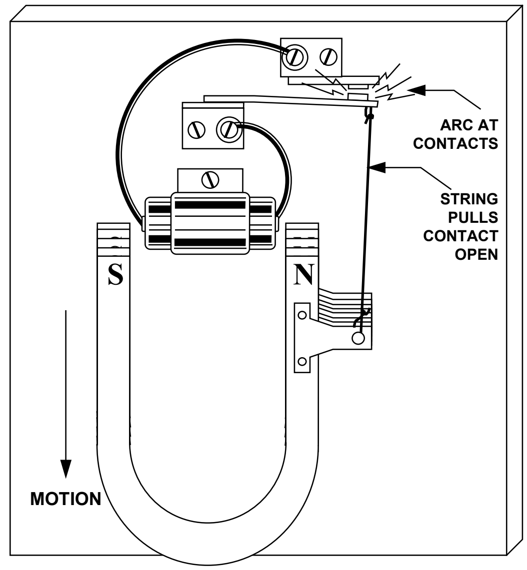


Figure 9-6

Now, as the magnet is moved away from the coil, the flux through the coil core will decrease, Figure 9-6. This decrease in flux will induce a voltage in the coil and since the coil ends are connected together through the contact switch, a current will flow in the coil. This current will cause the coil to act as an electromagnet and try to prevent the flux in the coil core from decreasing. In other words, the coil will, by its electromagnetic action, keep most of the original amount of flux in the coil core even though the magnet has moved away from the core.

By the time that the magnet has been moved far enough to pull on the string, it will be so far away from the coil that it actually contributes very little to the amount of flux in the coil core, most of the core flux being produced by the electromagnetic action of the current in the coil itself.

When the magnet pulls the string, the contacts open. As soon as this happens, the current in the coil must stop flowing, since the circuit is open. When the current stops, the coil ceases to be an electromagnet and thus the field of flux which was being held in the coil core by this electromagnetic action very quickly disappears. This action produces a very rapid change of flux in the coil core during the time that the contacts are separating, inducing a voltage which causes an arc at the switch contacts, Figure 9-6.

Just before the switch opens, the electromagnetic action of the coil is retaining most of the original field in the coil. But as soon as the switch contacts start to separate, the current in the coil decreases, thereby allowing the flux to "escape" from the core. The effect of the contact switch and coil is to hold back, or delay the flux change until there is a stress or "stretch" in the flux lines, at which time the opening of the switch releases the flux and lets the change occur very rapidly.

REQUIREMENTS FOR AIRCRAFT IGNITION

Actually the device pictured in Figure 9-5 is a form of magneto. Some old fashioned stationary gasoline engines employed an ignition system very similar in principle to this simple demonstration apparatus. Such engines had the breaker contacts inside the engine cylinder instead of a spark plug, one contact being pivoted so that it can be moved away from the other at the instant ignition is desired to occur in the cylinder. The arc which occurs at the breaker points then ignites the gas in the cylinder. Obviously such an arrangement is not suitable for aircraft ignition for a variety of reasons, but the principle involved forms the basis of design for all types of magnetos, as will be pointed out later in this text. It is not too difficult to "draw" an arc between two contacts while they are in the process of separating. This is because the voltage required is quite low.

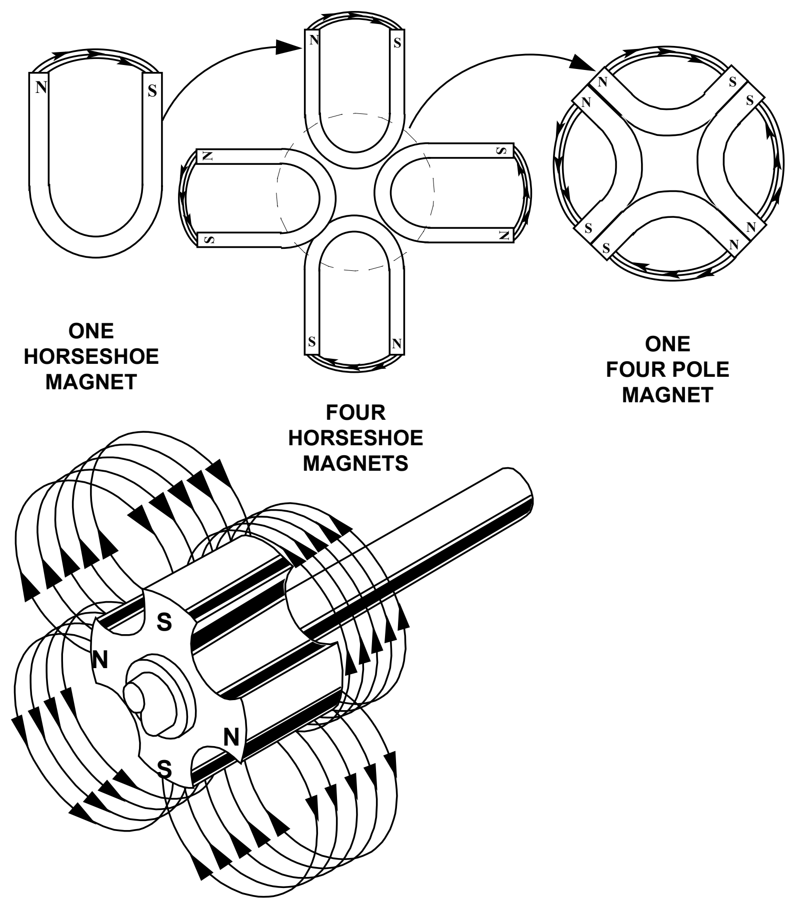


Figure 9-7. Four Pole Rotating Magnet

It is quite a different matter to produce the voltage required to break down a spark plug gap in an engine, since this latter process is not one of "drawing" an arc but is rather one of puncturing or breaking down the layer of gas between the spark plug electrodes. The voltage required to do this may be as high as 12,000 to 15,000 volts under some conditions of engine and spark plug operation.

To obtain this high voltage with a single coil as shown in Figure 9-5, would necessitate such a large coil and magnet that it would not be practical and would require a good deal of power to move the magnet rapidly enough to produce the required rate of change of flux linkages.

Therefore, we must modify this arrangement somewhat to provide a compact and efficient source of high voltage, which is necessary for aircraft ignition. There are two avenues of approach to this problem, both of which will be discussed, in the following pages of this text.

APPLICATION OF FUNDAMENTAL PRINCIPLES

Magnets used in the Aircraft Magneto - The properties of the common horseshoe magnet are present in the rotating magnet of TCM Aircraft Magnetos. An illustration of a four-pole rotating magnet is shown in Figure 9-7. The lines of flux of the rotating magnet, when not installed in the magneto, pass from a north pole through the air space to a south pole as indicated. This closely resembles the magnetic field of the horseshoe magnet shown in Figure 9-1.

The pole shoes and their extensions are made of soft iron laminations cast in the magneto housing. The coil core, also made of soft iron laminations, is mounted on top of the pole shoe extensions

The pole shoes (D) and their extensions (E), together with the coil core (C) as shown in Figure 9-8, form a magnetic path similar to that made by the coil core illustrated with the common horseshoe magnet in Figure 9-5. This magnetic path produces a concentration of flux in the core of the coil when the magnet is in the positions shown in Figure 9-8. This is known as the "full register" position of the rotating magnet.

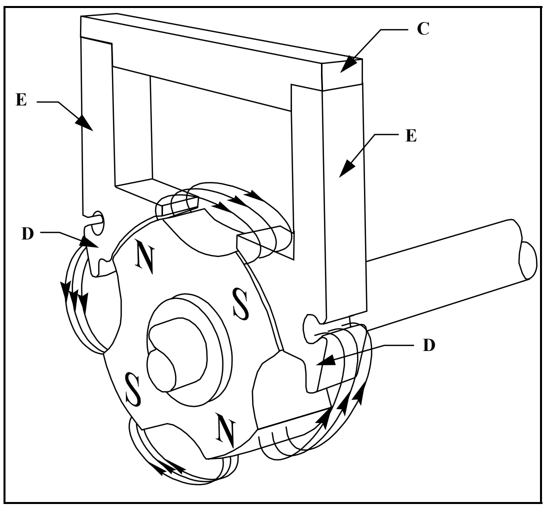


Figure 9-8. *"Full Register"* Position

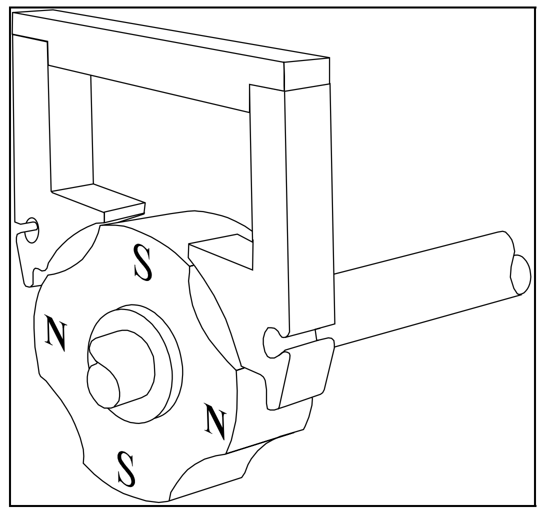


Figure 9-9. *"Neutral"* Position

When the magnet is rotated to the position where one of the pole pieces is centered between the pole shoes in the magneto housing (Figure 9-9), lines of flux do not pass through the coil core because they are "short-circuited" by the pole shoes. This is known as the "neutral" position of the rotating magnet.

The reader should note that no primary or secondary windings are shown on the coil core in Figures 9-8 & 9. These have been omitted to permit a clearer description of the magnetic action. By first observing the action without the windings, we can later obtain a better understanding of their function in the magneto.

If the magnet shown in Figures 9-8 and 9 is rotated, it will pass through four full register positions and four neutral positions during one complete revolution. Each time the magnet is in a full register position, a maximum number of lines of flux pass through the coil core. And each time the magnet is in a neutral position, the magnetic flux through the coil core is zero.

Although the pictures presented up to this point show only a few lines, actually the field of the magnet consists of many thousands of lines of flux. For this reason it will be simpler to portray the action of the magnetic circuit by means of a graph from this point forward in our discussion. Such a graph, showing number of lines of flux plotted against magnet position in degrees, is shown in Figure 9-10. For convenience in visualizing the relation of the magnet to the pole shoes at various angular positions, a series of small sketches of the magnet and pole shoes is shown underneath the graph curve.

The curve in Figure 9-10 shows how the flux in the coil core changes when the magnet is turned with no windings present. This is called the static flux curve, because it represents the normal magnetic condition of the circuit. If the magnet is turned with no windings on the coil core, the flux will build up through the coil core in first one direction and then in the other as shown by this curve.

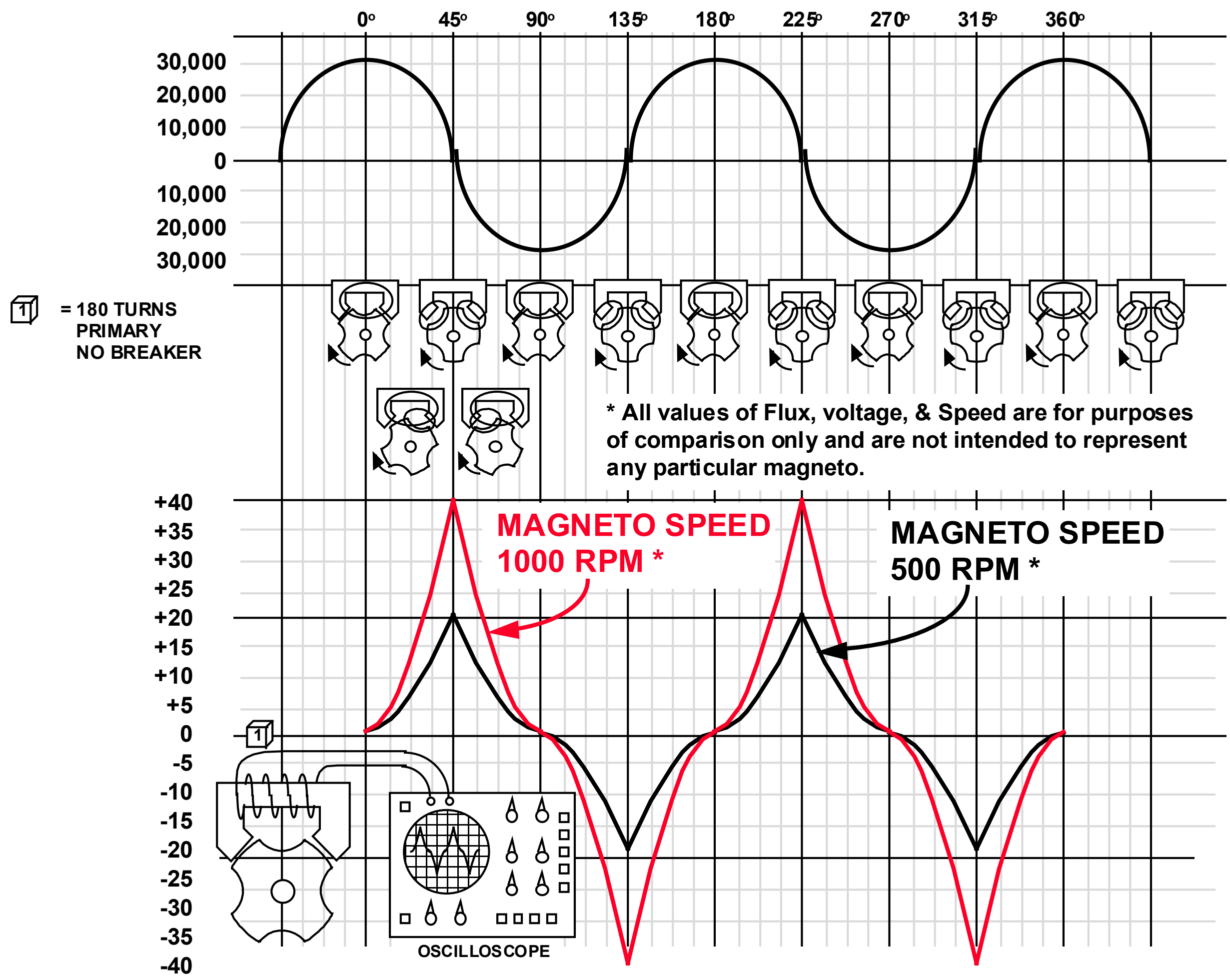


Figure 9-10. Static Flux Curve and Voltages Generated by Rotating Four Pole Magneto

It is important to realize that this curve represents both the direction and the concentration of the flux. When the curve is above the line the Flux is passing through the coil core in one direction. The higher the curve above the line, the greater the number of lines of flux in the core. The lower the curve goes below the line the greater the number of lines through the core in the other direction (Note arrows on flux lines in sketches). Each time the magnet passes through a neutral position the flux in the coil core falls to zero and then builds up again in the opposite direction.

Therefore the greatest change in *flux* occurs during the time the magnet is passing through the neutral position, as shown by the steep slope of the curve at the points corresponding to the neutral positions of the magnet.

For example, suppose there are 32,000 lines of *flux* passing through the coil core in a direction from left to right (see Figure 9-10) when the magnet is in the full register position indicated by "zero degrees" of the graph.

If we turn the magnet clockwise, the *flux* value will decrease along the curve indicated by the graph, until at the 45° position we have zero *flux* in the coil core. Thus in 45° of rotation of the magnet we have produces a *flux* change of 32,000 lines in the coil core.

If we continue to turn the magnet, the *flux* through the coil core will increase again, but this time it is passing through the core in the opposite direction, that is - from right to left (see sketch with arrow under 90° position of graph). When we have reached the 90° position of the magnet we find (see graph) that we have 32,000 lines of flux in the coil core again, but this time of the opposite direction,

As far as the coil core itself is concerned, the total change in *flux* produced by this 90° turn of the magnet is 64,000 lines, since the *flux* changed from a positive value of 32,000 lines, to zero, and then changed further to a negative value of 32,000 lines.

If we continue to turn the magnet in a clockwise direction, the *flux* value will again reach zero at the 135° position of the magneto. It will then start to increase in a positive direction until a value of 32,000 lines is reached at the 180° position of the magnet.

In turning the magnet from its 90° position to its 180° position we have again produced a change of 64,000 lines, since we started with a value of 32,000 below the zero axis of the graph, and ended with a value of 32,000 above.

In the same way we have just described, a flux change of 64,000 lines is produced for the 180° - to - 270° interval and the 270° - to - 360° interval of rotation of the magnet.

From the above description it should be clear that the four pole magnet provides four flux changes for each complete revolution thru which it is turned, and that further, each of these flux changes has a value of approximately twice the number of flux lines which the magnet is capable of forcing through the coil core.

Having now obtained an elementary understanding of how the static flux curve (Figure 9-10) is produced, let us see what the effect is when a primary winding is installed on the coil core. We will not connect the breaker points into the circuit just yet, since we wish first to observe the open-circuit voltage of the primary without the breaker installed.

The primary winding is made up of, let us say, 180 turns of heavy, insulated copper wire, and is wound directly around the coil core. See sketch, Figure 9-10. Now, any change in flux in the coil core will cause a change in flux linkages in this winding and induce a voltage in it.

The voltage induced in this coil will depend on how fast the magnet is being turned when the voltage is being measured. This is because the amount of voltage produced is proportional to the rate of change of flux linkages, as explained in connection with Figure 9-3.

We can prove this by connecting an oscilloscope across the primary winding and measuring its open circuit voltage while the magnet is being rotated. If we turn the magnet at 500 RPM we will obtain a voltage curve something like that shown in the solid line in the lower part of Figure 9-10. If we drive the magnet at 1000 RPM, we will obtain a curve like the gray line shown in Figure 9-10, which, since the rate of change of flux linkages has been doubled (speed of magnet doubled) gives us, for all practical purposes, twice as much voltage as we got at 500 RPM.

As was expected, the open circuit voltage curve reaches its maximum value peaks at the neutral positions of the rotating magnet, which represent the positions where the rate of change of flux is greatest.

While the voltage values shown in Figure 9-10 are not presented as being actual values for the open circuit primary voltage of any particular magneto, they are never-the-less approximately correct in a general way for most magnetos, and can serve to show on a comparison basis, that something less than 20 volts is available from the primary at low speed. A little simple figuring will show that it would require a coil of over 100,000 turns to get 12,000 volts from a coil-and-magnet generator of this type, and even to do that would require that the magnet turn at 500 RPM or over. Such a coil would be nearly as big as an entire modern magneto!

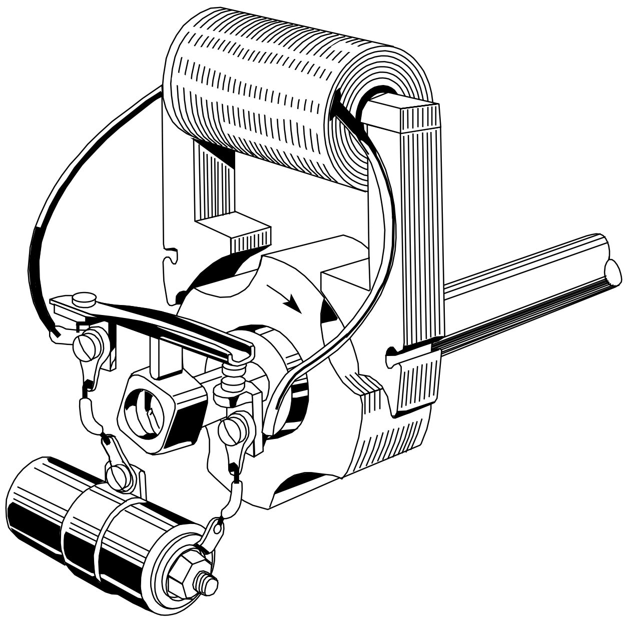


Figure 9-11. Breaker Points and Condenser to Interrupt Primary Current

Further, even if we could work out the difficulties of getting proper voltage, it would be impossible to time such a unit to an engine. This is because the slope of the voltage curve shown in Figure 9-10 is quite gradual, and depends on engine speed. As an example, suppose the voltage values shown in Figure 9-10 could be stepped up one thousand times by increasing the number of coil turns. Then 12,000 volts would be obtained at the point on the graph indicated by 12 volts on the voltage scale of Figure 9-10. But 12 volts is not reached at the same position of the magnet on the 1000 RPM curve as it is on the 500 RPM curve.

Since the magnet is driven mechanically from the engine crankshaft, the engine spark timing or firing position would be different for every different speed of the engine. Further, since no two spark plugs fire at exactly the same voltage, the engine spark timing would also vary for every spark plug.

By using a current interrupter of the type described in connection with Figure 9-5, we can meet the requirements for precisely timed sparks with a mechanism of minimum size and weight. Further, we can increase the speed of the flux change greatly, so that high voltage can be obtained with a relatively small coil.

However, you will recall in connection with Figure 9-5, the opening of the contacts caused a considerable arc at the contact surfaces, this arc having been used for ignition purposes in some of the early gasoline engines.

While this arrangement might pass on a stationary engine, the arc is destructive, and it will very quickly burn away the surfaces of the contact points, causing their life to be short. In order to use the interrupter or breaker in an aircraft magneto where long periods of dependable service are required, the arc must be attenuated.

This can be done by connecting a condenser across the contact points of the breaker as shown in Figure 9-11. The condenser prevents arcing of the contacts of the breaker as they arc being opened, by allowing a "by-pass route" for the current during the time the contacts are being separated.

The action which takes place in the condenser and breaker circuit is as follows: Before the breaker opens, the condenser is in a completely discharged condition, since the breaker itself forms a connection across the condenser terminals. During the time the breaker points are separating the current will be by-passed around them in the form of a charging current in the condenser. During the time the condenser is charging, the breaker contacts move further apart, so that by the time the condenser is fully charged and brings the current to a stop, the contacts are so far apart that an arc cannot "jump across" between them.

The breaker contact points are electrically connected across the primary coil, and the magneto breaker mechanism is timed to the magnet so that the contact points close at the position where there is a maximum of flux in the coil core. The condenser is connected across the contact points of the breaker as shown in Figure 9-11.

With the breaker points, cam and condenser added to the circuit as in Figure 9-11, the action which takes place when the magnet is turned will be somewhat different from that portrayed by Figure 9-10 for a magnet and coil with no breaker points.

The action of the device shown in Figure 9-11 is depicted by the graph curves shown in Figure 9-12.

At the top of the Figure 9-12 the original static flux curve of the magneto is shown for reference purposes, together with degrees of magnet rotation.

Underneath the static flux curve is shown the sequence of opening and closing of the magneto breaker. Note that the breaker is timed by means of the breaker cam to close at a position where a maximum amount of flux is passing through the coil core (34° before neutral), and to open at a position 11° after neutral. Note also that there are four lobes on the cam, so that the breaker will close and open in this same relation to each of the four neutral position of the magnet. Note also that the point opening and point closing intervals are approximately equal.

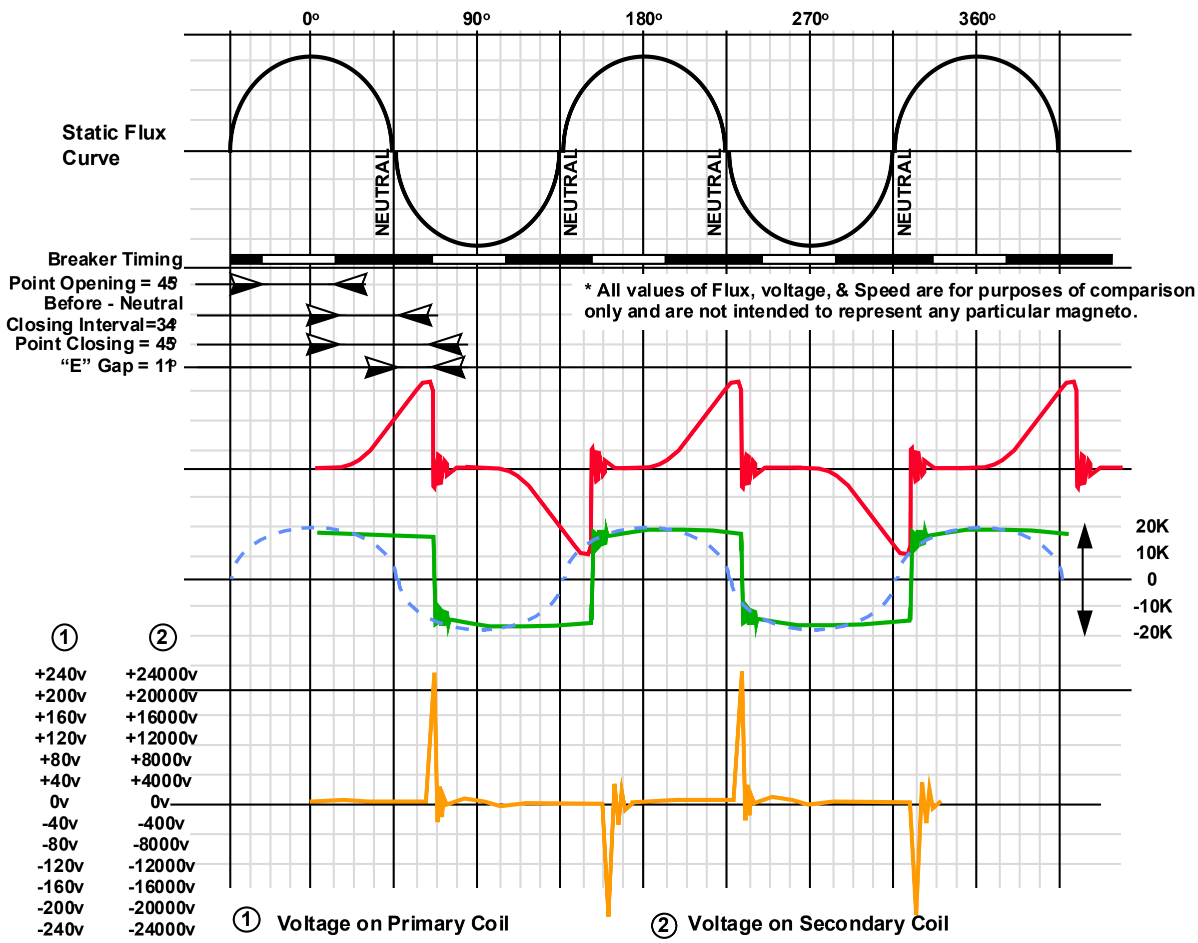


Figure 9-12. Operating Circuit Waveforms of a Magneto

Now, starting at the maximum flux position (marked "0°" at the top of the Figure 9-12), the following sequence of events will take place.

As the magnet is turned toward the neutral position, the amount of flux through the coil core starts to decrease. (See Resultant Flux Curve Figure 9-12). This decrease or change in flux linkages induces a current in the primary winding, as depicted by the curve marked "Primary Current" in Figure 9-12.

As previously stated, a current-carrying coil produces a magnetic field of its own. Accordingly, the current induced in the primary winding will set up a magnetic field of its own.

In accordance with Lenz's Law, the magnetic field set up by this current will oppose the change of flux linkages, inducing the current. This is shown graphically by the curve marked "Resultant Flux" in Figure 9-12. Without current flowing in the primary winding, the flux in the coil core would decrease to zero as the magnet was turned to neutral, and then start to increase in the opposite direction as represented by the dotted "static flux" curve. However, the electromagnetic action of the primary current prevents the flux from changing as explained above, and temporarily holds the field in the coil core instead of allowing it to change. This is represented by the solid curve line which is known as the "resultant flux" curve.

As a result of this process, there is great stress in the magnetic circuit by the time the magnet has reached the position where the contact points are about to open, a few degrees past the neutral position.

At this time, the primary current is maintaining the original field in the coil core where the magnet has already turned past neutral and is now attempting to establish a field through the coil core in the other direction.

The contact points, when opened, function with the condenser as described in connection with Figure 9-11, to interrupt the flow of primary current in the coil, causing an extremely rapid change in *flux* linkages. In less than a thousandth of a second, the *flux* linking the coil changes from a positive value of nearly 30,000 lines (See Resultant Flux Curve, Figure 9-12) to a negative value of nearly 30,000 lines. This change of nearly 60,000 lines, occurring in less than a thousandth of a second, gives a tremendous rate of change of flux linkages, inducing several hundred volts in the coil. The voltage is shown in graphic form directly underneath the resultant *flux* curve in Figure 9-12. The values of voltage indicated for this curve are not intended to represent those for any particular type of magneto, but are for comparison purposes, to show that with a breaker and condenser installed, the same magnet and coil which formerly produced about 20 volts at 500 RPM (Figures 6- 11 and 12), now can produce 12 times this much voltage.

The very rapid *flux* change produced by the use of breaker points and a condenser makes it possible to obtain the high voltage required for ignition without the need for an extremely large coil. Further, the timing of the rapid *flux* change is accurately controlled, by the breaker, and this together with the very steep nature of the rise of the voltage wave (Figure 9-12) complies with the requirement for precise timing of the spark in an engine cylinder.

THE HIGH TENSION IGNITION SYSTEM

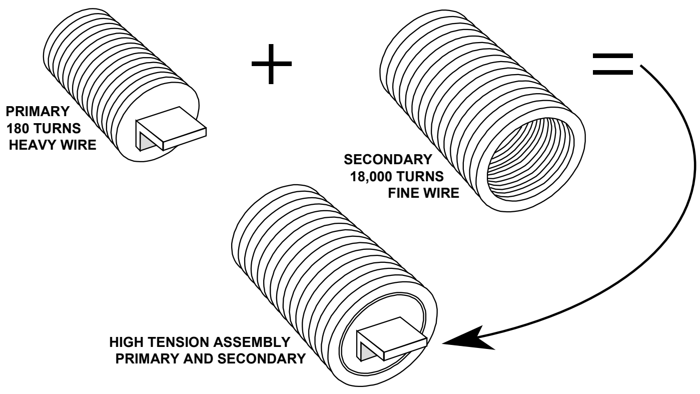


Figure 6-13. Evolution of Coil for High Tension Magneto

The most common way in which the rapid flux change discussed in connection with Figure 9-12 can be made to produce the necessary high voltage for firing a spark plug is to remove the coil from the assembly shown in Figure 9-11 and to wind a secondary winding of about 18,000 turns of fine wire directly over the 180 turn primary already on the coil core.

Upon reassembling the unit (see Figure 9-13) we would find that since the secondary contains 100 times as many turns as the primary, and, since the primary was capable of producing 240 volts (Figure 9-12) the secondary is capable of producing 24,000 volts. This type of coil is used with minor variations in all conventional high tension magnetos.

This secondary winding, containing 100 times as many turns of wire as the primary, gives a voltage equal to 100 times that of the primary. Therefore the open-circuit secondary voltage graph will look exactly like that shown for the open circuit primary voltage in Figure 9-12, except that the voltage values would be multiplied by 100. (See ② Figure 9-12.)

However, the magneto does not develop its full open-circuit voltage when operating in a normal manner on the engine. In fact the voltage required for a well maintained spark plug is usually less than 5000 volts during cruise power operation of the engine.

This means that as soon as the magneto secondary voltage has risen to the firing or sparking voltage of the plug, the plug gap becomes conductive and a current starts to flow in the secondary winding of the magneto.

The flow of secondary current to the spark plug alters considerably the shape of the voltage and resultant flux curves. This is due to the electromagnetic effect of this current flowing in the secondary coil. As has already been pointed out in connection with Figures 6-5, and 6-6 any current carrying coil acts in accordance with Lenz's Law to oppose the flux change which is producing the current. Therefore, as soon as secondary current starts to flow, the rapid flux change will be retarded or slowed.

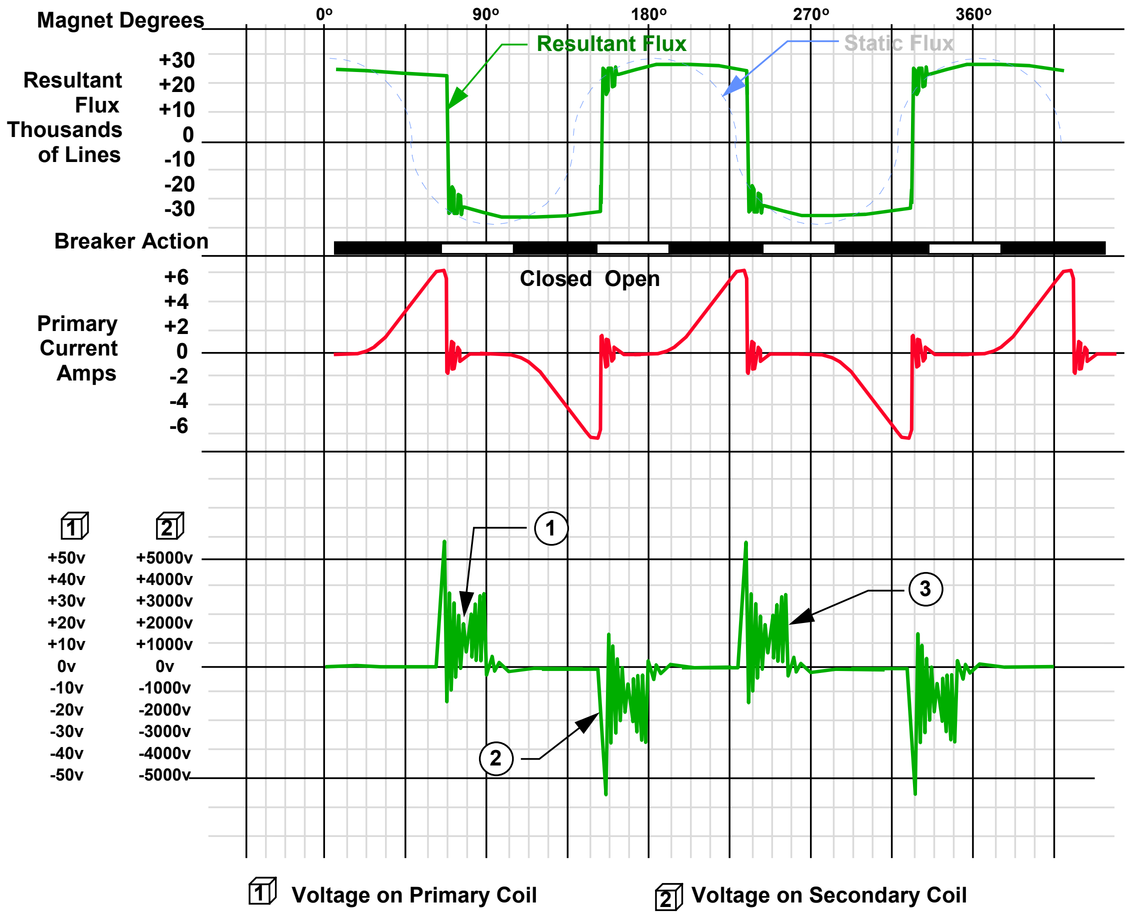


Figure 9-14. Waveform Representation when Firing a Spark Plug in Engine Cylinder

Figure 9-14 shows graphically the sequence of events which occurs in the magneto when the latter is running in a normal manner on an engine.

Up until the time the breaker opens, the action of building up a primary current, and of holding back or delaying the flux change are the same as for the open-circuit condition described in connection with Figure 9-12. Also the rise of primary and secondary voltage takes place when the breaker opens in the same manner as previously outlined.

* All values of flux, current and voltage are for purposes of comparison only, and are not intended to apply to any particular magneto.

NOTE 1. Transition point caused by very low resistance of plug gap when burning gas is present in gap.

NOTE 2. Initial oscillations due to sudden current load placed on coil when secondary starts to conduct current.

NOTE 3. "Quench" oscillations caused by the effect of turbulence and pressure on the current flowing across the spark plug gap.

However if the magneto is connected to a spark plug which "fires" at 5000 volts, the plug will "break down" and become conductive when this voltage is reached, and current will start to flow. This is shown graphically in Figure 9-14, in which the factors of Resultant Flux, Static Flux, Breaker Timing, Primary Current, Primary and Secondary Voltage are shown plotted against magnet degrees for a magneto in actual operation on an engine.

When the high voltage in the secondary winding discharges, a spark jumps across the spark plug gap which ignites the fuel in the cylinder. Each spark actually consists of one peak discharge, after which a series of small oscillations occur as indicated by the secondary voltage curve carrying brief explanatory notes in Figure 9-14. During the time it takes for the spark to completely discharge, current is flowing in the secondary winding.

However, just as soon as current flows in the secondary winding, a magnetic field is set up which will oppose the change in flux which produced it. Therefore, the flux change is slowed up, as indicated by the tapering portion of the resultant flux curve.

In spite of the "slowing up" effect of the secondary current the spark normally becomes completely discharged before the next "closing" of the contact points. That is, the energy or stress in the magnetic circuit is completely dissipated by the time the contacts close for the production of the next spark. This is shown in Figure 9-14 where it will be seen that the resultant flux curve has tapered off so it exactly coincides with the static flux curve at the time the contact points close.

In other words, all the electromagnetic action of the coil has dissipated, and the magnetic circuit has returned to its normal or static condition and is ready to begin the build-up of primary current for the next spark, which is produced in the same manner as the first.

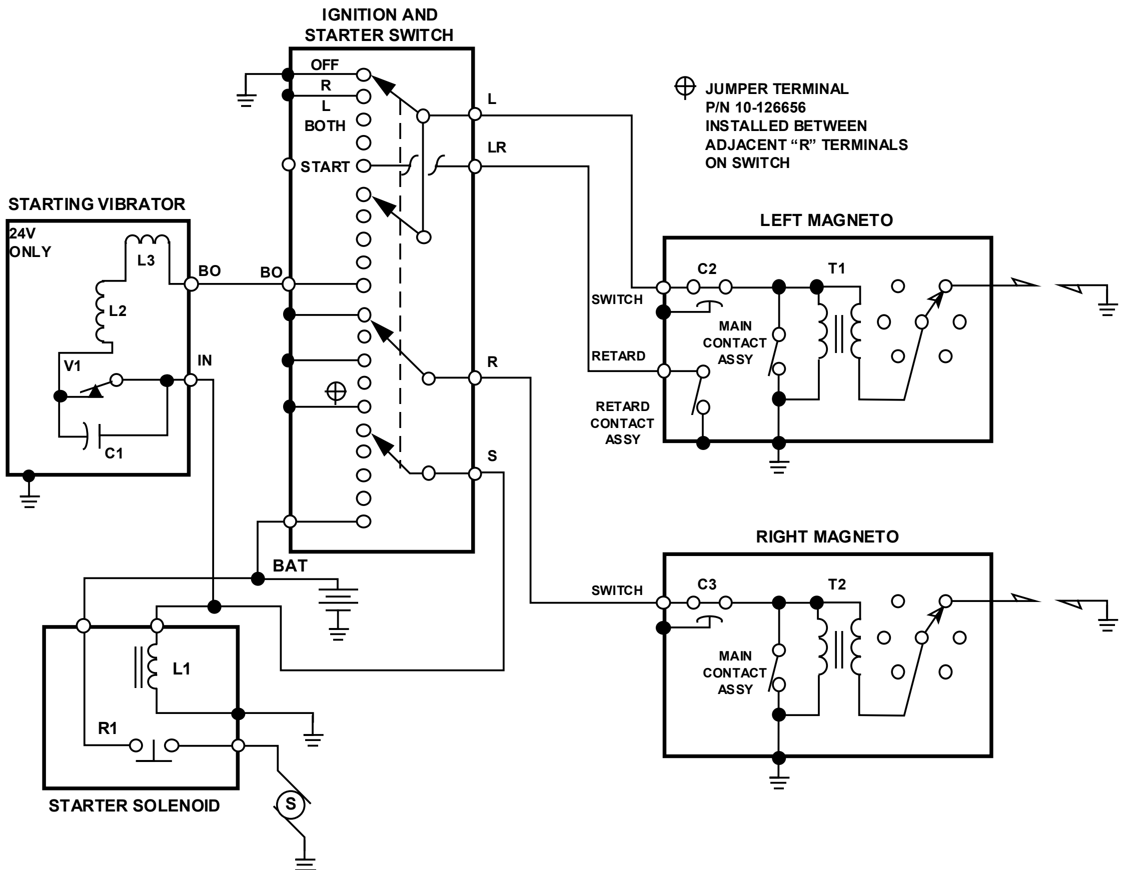


Figure 9-15. Schematic Diagram of Magneto Circuit and Starting Vibrator

Figure 9-15 illustrates a complete high tension ignition system consisting of two magnetos, radio shield harness, spark plugs, switch and a starting vibrator.

One end of the primary winding is grounded to the magneto. The other end is connected to the insulated contact point of the breaker. The other breaker point is grounded. The condenser is connected across the breaker.

The ignition switch terminal on the magneto is electrically connected to the insulated contact point. A wire connects the switch terminal on each magneto with the ignition switch. When the switch is in the "OFF" position, this wire provides a direct path to ground for the primary current. Therefore, when the contact points open, the primary current is not interrupted. This prevents the production of high voltage in the secondary winding.

One end of the secondary winding is grounded to the magneto. The other end terminates at the high tension insert on the coil. The high tension current produced in the secondary winding is then conducted to the central insert of the distributor finger by means of a carbon brush. From here, it is conducted to the high tension segment of the distributor finger and across a small air gap to the electrodes of the distributor block. High tension cables in the distributor block then carry it to the spark plugs where the discharge occurs.

The distributor finger is secured to the large distributor gear which is driven by a smaller gear located on the drive shaft of the rotating magnet. The ratio between these two gears is always such that the distributor finger is driven at one-half engine crankshaft speed. This ratio of the gears insures proper distribution of the high tension current to the spark plugs in accordance with the firing order of the particular engine.

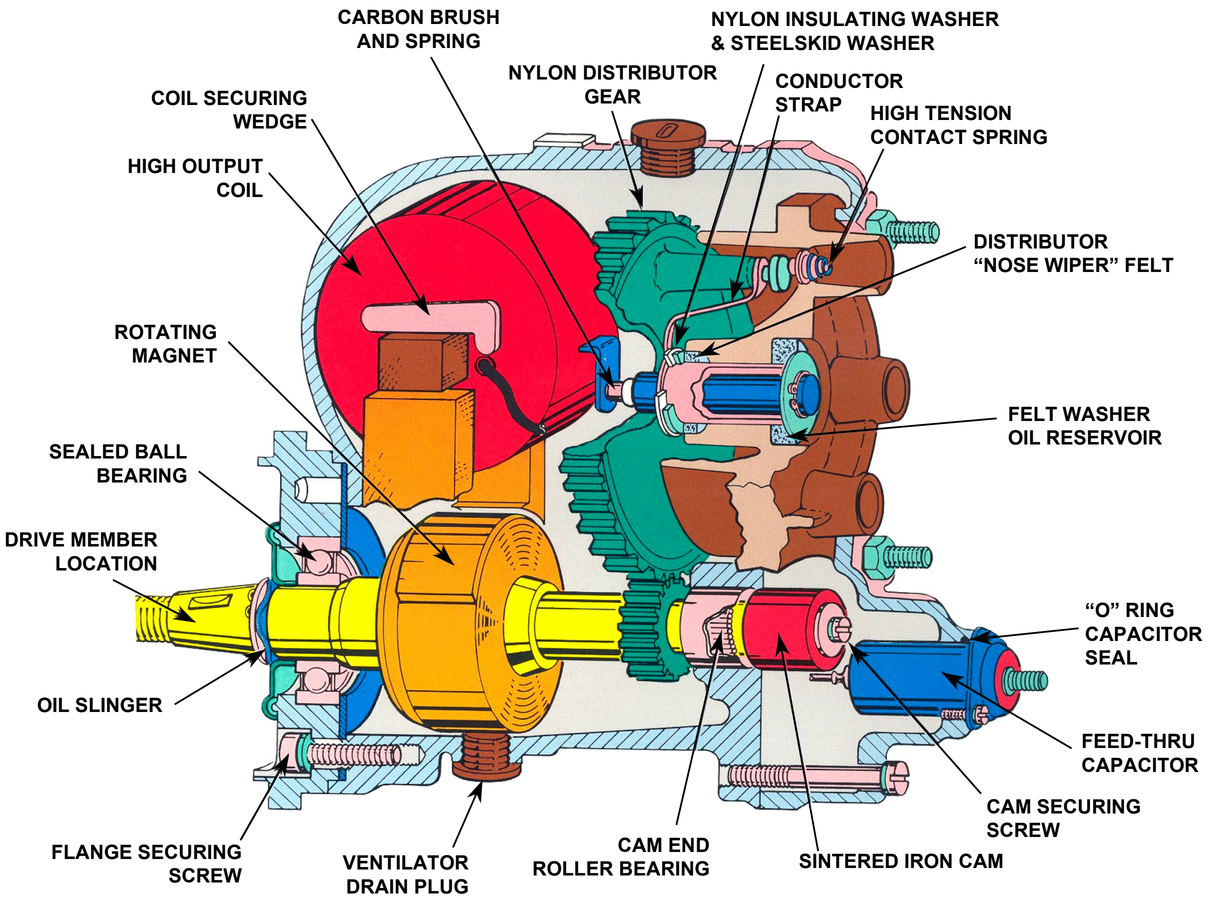


Figure 9-16. The TCM S-1200 Series Magneto Cutaway Diagram

Practically all aircraft engines operate on the four stroke cycle principle. Consequently, the number of sparks required for each complete revolution of the engine is equal to one-half the number of cylinders on the engine. The number of sparks produced by each revolution of the rotating magnet is equal to the number of its poles. Therefore, the ratio of the speed at which the rotating magnet is driven to that of the engine crankshaft is usually half the number of cylinders on the engine divided by the number of poles on the rotating magnet.

The numbers on the distributor block denote the magneto sparking order and do not represent engine cylinder numbers. Therefore, the distributor block position marked "1" must be connected to No. 1 cylinder, distributor block position marked "2" to the second cylinder to fire, and the distributor block position marked "3" to the third cylinder to fire, and so on.

Sparks are not produced until the rotating magnet is turned at or above a specified number of revolutions per minute at which speed the rate of change in flux linkages is sufficiently high to induce the required primary current and the resultant high tension output.

This speed varies for different types of magnetos but the average is 150 RPM. This is known as the "coming-in" speed of the magneto.

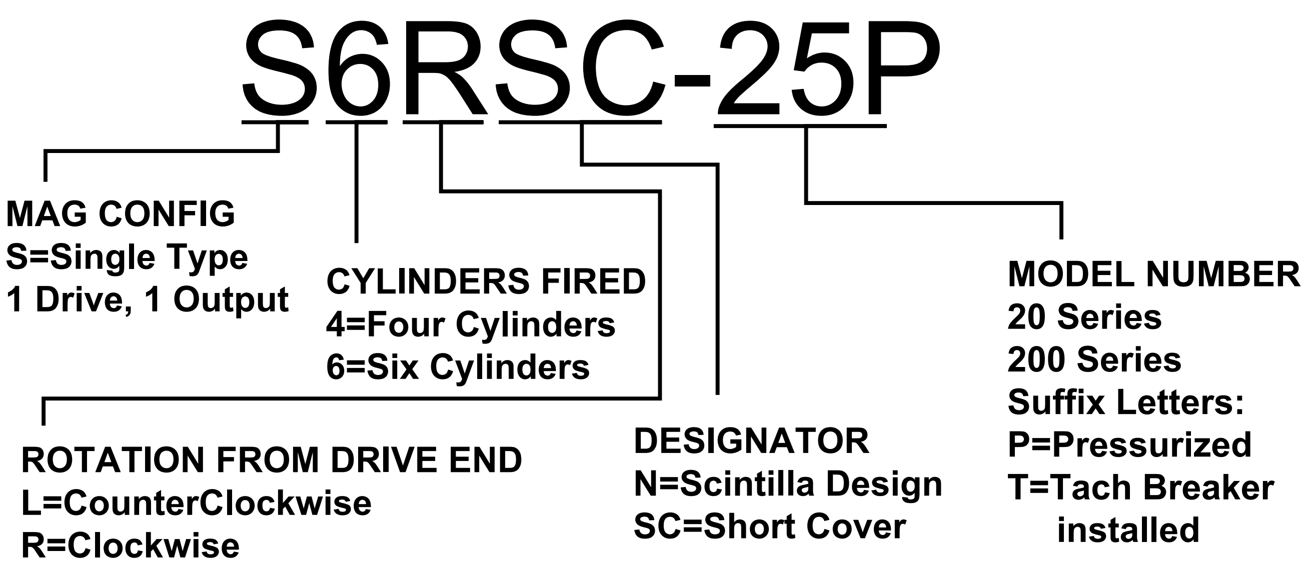
When conditions make it impossible to rotate the engine crankshaft fast enough to produce the "coming-in" speed of the magneto, magneto timing must be altered and input energy boosted for starting purposes. This may be accomplished in the form of an integral impulse coupling or an external battery-powered starting vibrator. In the former, flyweight pawls on a spring-loaded cam catch stop pins until tripped by rotation of the body-thus storing and rapidly releasing mechanical energy and retarding timing. In the latter case, the vibrator points in the starting vibrator serve to supply an interrupted or pulsating current to the primary of the ignition system. Grounded until the retard contacts open, this pulsating current is stepped up by transformer action in the magneto coil to provide the required voltage for firing the spark plug.

In as much as a magneto is a form of high frequency generator, radiation emanating from it during operation will cause interference with radio reception in the airplane if the ignition system is not shielded. The radio transmitting station radiates waves of a controlled frequency, while the oscillations produced in the magneto during operation are uncontrolled in that they cover a wide range of frequencies.

If the high tension cables and switch wire of the magneto are unshielded, they can serve as antenna from which these uncontrolled frequencies are radiated. Since the receiving aerial on the airplane is relatively close to the ignition wiring, the uncontrolled frequencies will be picked up by the aerial along with the controlled frequencies from the radio station, thus causing interference to be heard in the radio receiver in the plane.

To prevent this interference, the entire ignition system is enclosed in a special metallic covering known as "radio shielding". The various parts of the shielding are bonded together and grounded to the engine, to prevent the undesirable radiation of noise from reaching the receiving aerial.

KEY TERMS



Breaker Points — A set of contact points, which when opened, causes current in the primary winding of the coil to cease. The magnetic field around the primary winding of the coil collapses, causing a high voltage to be induced into the secondary winding of the coil.

Capacitor — The capacitor provides a brief charge/discharge path during the moment the breaker points open, preventing them from arcing and ultimately destroying them selves. The capacitor in circuit with the coil also acts as a low pass filter and provides radio shielding.

Coil — A series of windings of wire which consists of two circuits; the primary winding and the secondary winding.

Distributor Block — Made of a polyester insulating material and houses electrical contact terminals to conduct the high voltage current to the spark plug terminal harness connection.

Impulse Coupling — A mechanical device used in some magnetos to retard the ignition timing and provide higher voltage at cranking speeds for staring.

Retard Breaker — A device used in magnetos to delay ignition during cranking. It is used to facilitate starting.

Shower of Sparks — A system attached to the magnetos where a starting vibrator is used on the left magneto for starting while the right magneto is grounded. The shower of sparks system uses a retard breaker in addition to the normal breaker points in the left magneto to prevent the engine cylinders from combusting the fuel air mixture in full advance.

EXERCISES

1. Referring to the S-20/S-200 Series High Tension series magnetos the S6 refers to ________

   ____

   ____

2. Locate the "E" Gap adjustment procedure and describe the settings for the S-20 Series Magneto.

   ____

   ____

   ____

3. Explain the purpose of the condenser in parallel with the breaker points.

   ____

   ____

   ____

4. What is the turn ratio of the Magneto to engine for a six cylinder engine?________________

   ________________ For a four cylinder engine? ________________________

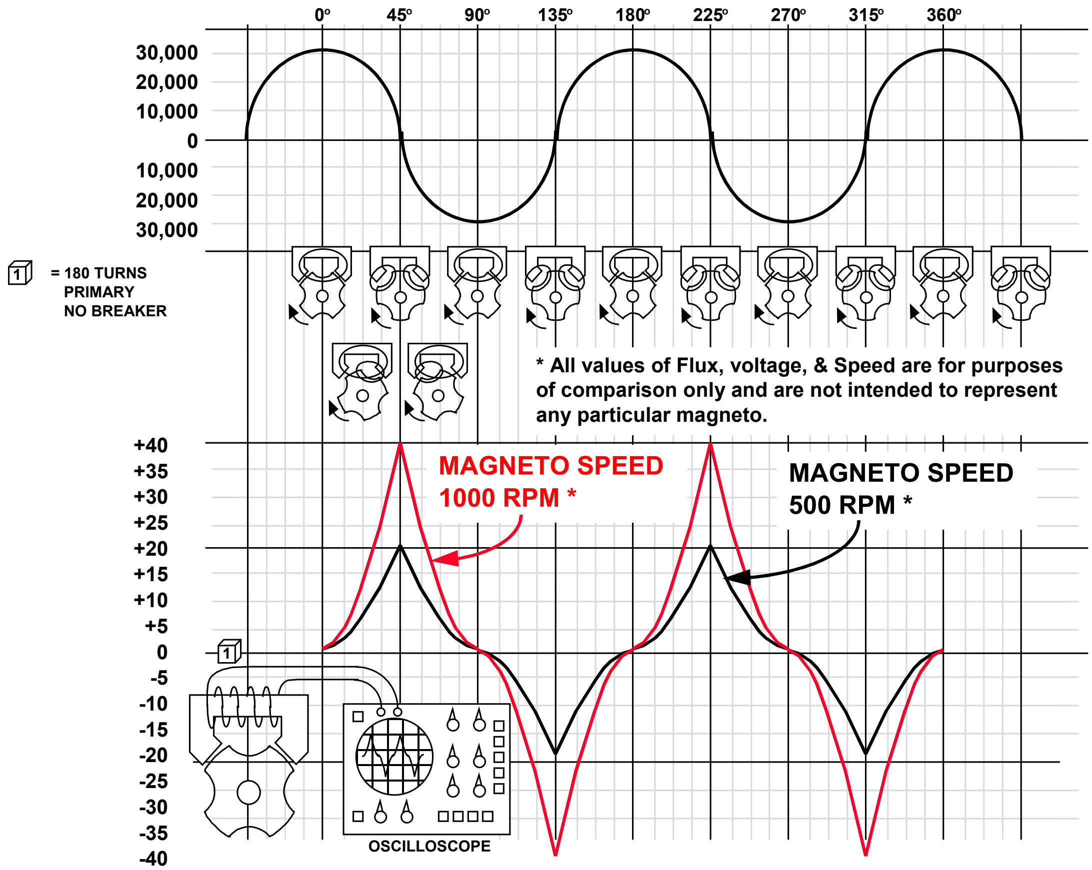
5. Which series magneto employs the retard contact assembly? ________________________

   ____

6. What feature is also employed with this series magneto that would dictate the need for the retard contact assembly? ________________________________

   ____

Refer to the following figure to answer questions 7, 8 & 9.

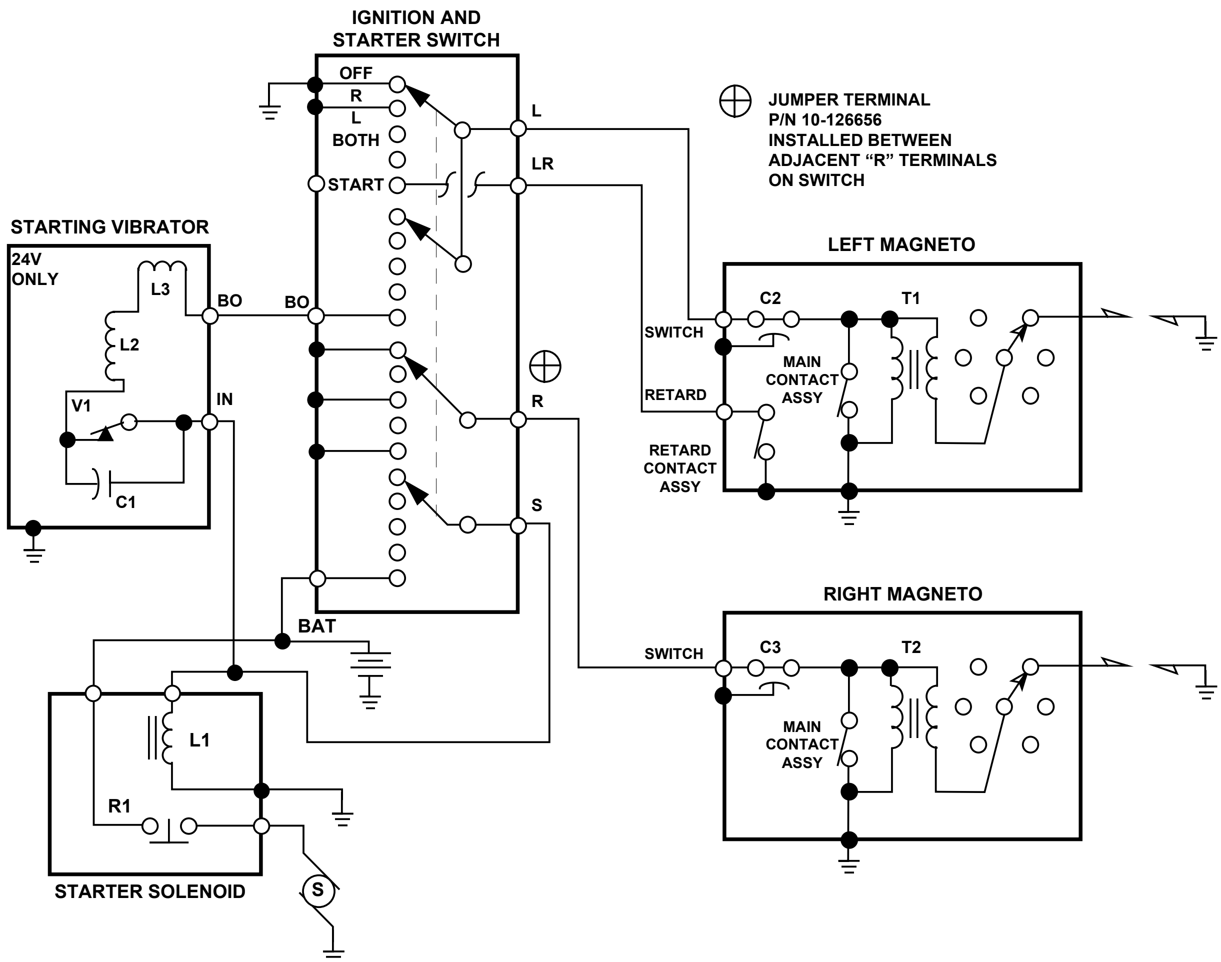


Four Pole Magneto Waveforms

7. Referring to the above magneto waveforms, which angle produces the greatest rate of change in flux?
   a. 0°
   b. 45°
   c. 90°
   d. 180°
8. At which angle does the magneto produce the highest voltage spike?
   a. 90°
   b. 180°
   c. 270°
   d. 315°
9. Explain why the voltage is highest when the flux is lowest. ______________________________

   ____

Refer to the following Magneto Schematic Diagram to answer questions 10 - 14.



10. Identify which circuit has the retard breaker. ______________________________

11. Which position of the IGNITION STARTER SWITCH will disable the Left Magneto?

____

12. How does the IGNITION STARTER SWITCH enable a magneto? ______________________________

____

13. What does C3 in the RIGHT MAGNETO represent? ______________________________

14. Which magneto is typically used in the START position for the Shower of Sparks Ignition?

____

Why? ______________________________

INTENTIONALLY

LEFT

BLANK

Chapter Ten

PowerLink™ FADEC System Description

CHAPTER 10 OUTLINE

What You'll Learn

Once you complete the lessons in this chapter you will be able to:

① Identify the components which comprise the FADEC System

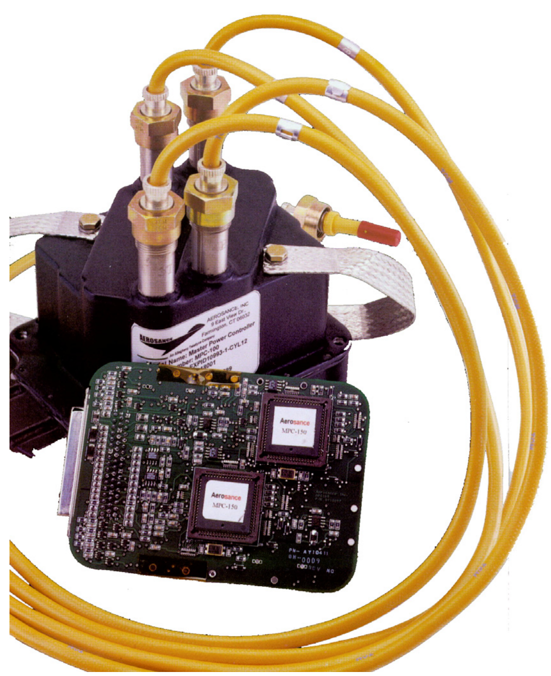
② Describe the functional operation of the components which control ignition

③ Describe the functional operation of the components which control fuel injection

④ Identify the sensors inputs to the ECU

⑤ Identify the operations of the ECU to control the engine

⑥ Describe the levels of redundancy for the critical sensors and the back-up power system



The FADEC Engine Control Unit

FADEC SYSTEM DESCRIPTION

PowerLink™ FADEC is a solid-state digital electronic ignition and electronic sequential port fuel injection system with only one moving part that consists of the opening and closing of the fuel injector. PowerLink continuously monitors and controls ignition, timing, and fuel mixture/delivery/injection and spark ignition as an integrated control system. PowerLink monitors engine operating conditions (crankshaft speed, top dead center position, the induction manifold pressure, and the induction air temperature) and then automatically adjusts the fuel-to-air ratio mixture and ignition timing accordingly for any given power setting to attain optimum engine performance. As a result, engines equipped with PowerLink neither require magnetos nor manual mixture control.

This microprocessor-based system controls ignition timing for engine starting and varies timing with respect to engine speed and manifold pressure.

PowerLink provides control in both specified operating conditions and fault conditions. The system is designed to prevent adverse changes in power or thrust. In the event of loss of primary aircraft-supplied power, the engine controls continue to operate using a Secondary Power Source (SPS). As a control device, the system performs self-diagnostics to determine overall system status and conveys this information to the pilot by various indicators on the Health Status Annunciator (HSA) panel.

PowerLink is able to withstand storage temperature extremes and operate at the same capacity as a non-FADEC-equipped engine in extreme heat, cold, and high humidity environments.

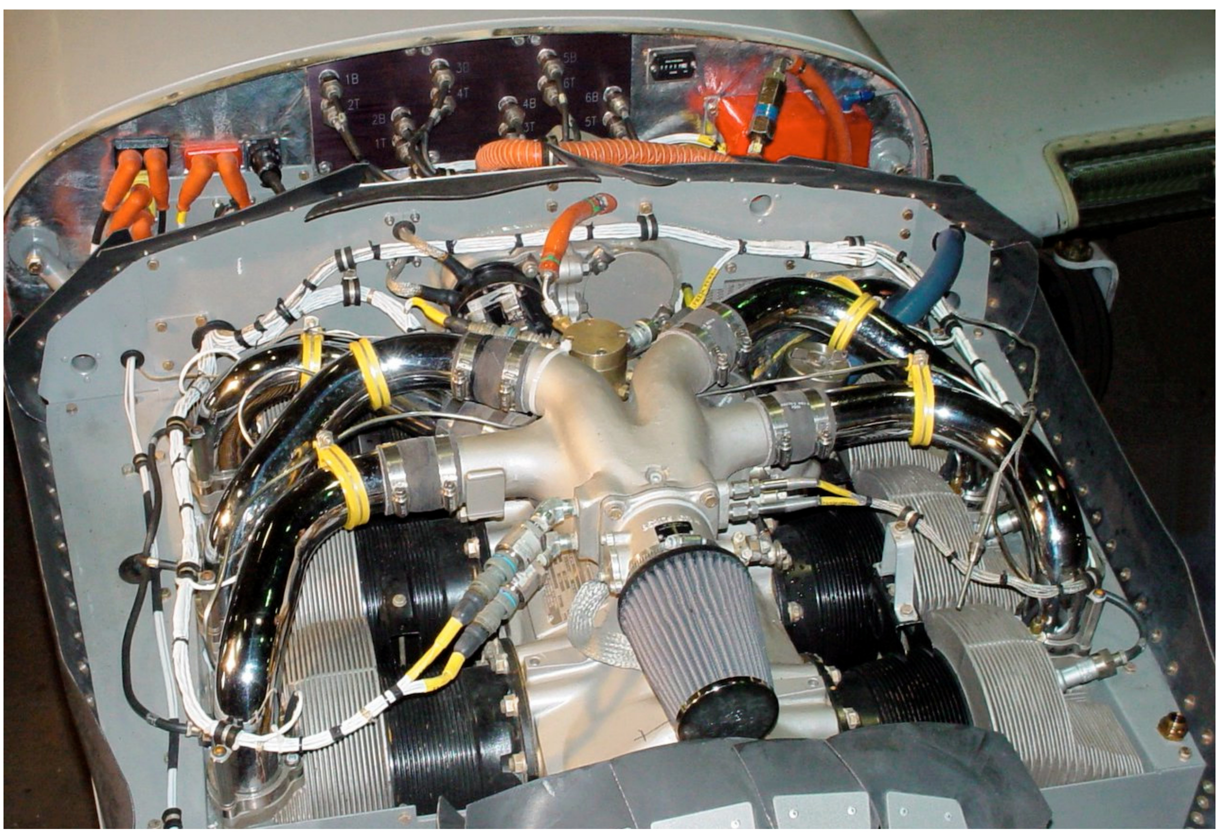


Figure 10-1. IOF-550-N PowerLink™ FADEC system installed in aircraft.

FADEC SYSTEM OVERVIEW

PowerLink includes the following components:

- Low Voltage Harness
- Cabin Harness
- Best Power/Best Economy Switch
- Electronic Control Units (ECUs)
- Health Status Annunciator (HSA) (panel installed in the cockpit)
- Electronic Ignition System (High Voltage Harness)
- Electronic Sequential Port Fuel Injection System
- Fuel Flow Transducer
- PowerLink Engine Sensor Array
- Speed Sensor Assembly (SSA)
- Cylinder Head Temperature (CHT) Sensor
- Exhaust Gas Temperature (EGT) Sensors
- Manifold Air Pressure (MAP) Sensor
- Manifold Air Temperature (MAT) Sensor
- Fuel Pressure Sensors

LOW VOLTAGE HARNESS

The low voltage harness shown in Figure 10-2, connects all essential components of the FADEC System. This harness acts as a signal transfer buss interconnecting the Electronic Control Units (ECUs) with aircraft power sources, the Ignition Switch, Speed Sensor Assembly (SSA), Health Status Annunciator (HSA), temperature and pressure sensors. The fuel injector coils and all sensors, except the SSA and Fuel Pressure and Manifold Pressure Sensors, are hardwired to the low voltage harness.

This harness transmits sensor inputs to the ECUs through a 50-pin connector. The harness connects to the engine mounted pressure sensors via cannon plug connectors. The 25-pin connectors connect the harness to the speed sensor signal conditioning unit.

The low voltage harness attaches to the cabin harness by firewall-mounted bulkhead fittings or connectors. Information from the ECUs is conveyed to the HSA and the cockpit-mounted data port through the same cabin harness/bulkhead connector assembly. The bulkhead connectors also supply the aircraft electrical power required to run the system.

Figure 10-1 shows the low voltage harness installed on an engine. Figure 10-2 is a photo of the components that comprise the electrical control and low voltage harness for a four cylinder engine. Figure 10-3 is a schematic that shows the electrical control and low voltage harness for six cylinder engines.

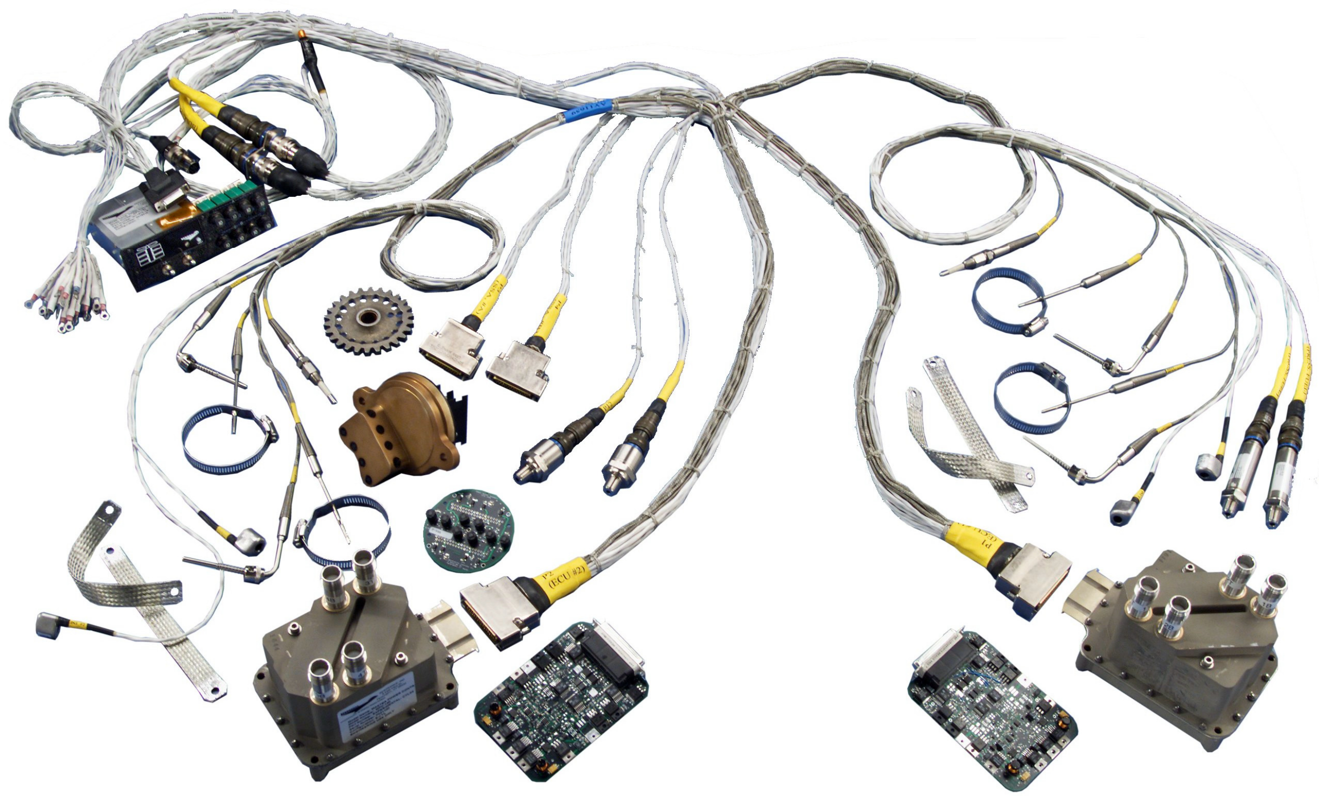


Figure 10-2. PowerLink System Components

The ECU is at the heart of the system in providing both ignition and fuel injection control to operate the engine with the maximum efficiency realizable. Each ECU contains two microprocessors (which we will refer to as a computer) that control two cylinders. Each computer controls it's own assigned cylinder and is capable of providing redundant control for the other computer's cylinder.

The computer constantly monitors the engine speed and timing pulses developed from the camshaft gear as they are detected by the Speed Sensor Assembly (SSA). Knowing the exact engine speed and the timing sequence of the engine, the computers monitor the manifold air pressure and manifold air temperature to calculate air density and determine the mass air flow into the cylinder during the intake stroke. The computers calculate the percent of engine power based on engine rpm and manifold air pressure. From this information, the computer can then determine the fuel required for the combustion cycle for either best power or best economy mode of operation. The computer will then precisely time the injection event and the duration of the injector "on" time for the correct fuel to air ratio. The computer then sets the spark ignition event and ignition timing again based on percent of power calculation. Exhaust gas temperature is measured after the burn to verify the fuel to air ratio calculations were correct for that combustion event. This process is repeated by each computer for it's own assigned cylinder on every combustion/power cycle.

The computers can also vary the amount of fuel to control fuel-to-air ratio for each individual cylinder to control both Cylinder Head Temperature (CHT) and Exhaust Gas Temperature (EGT).

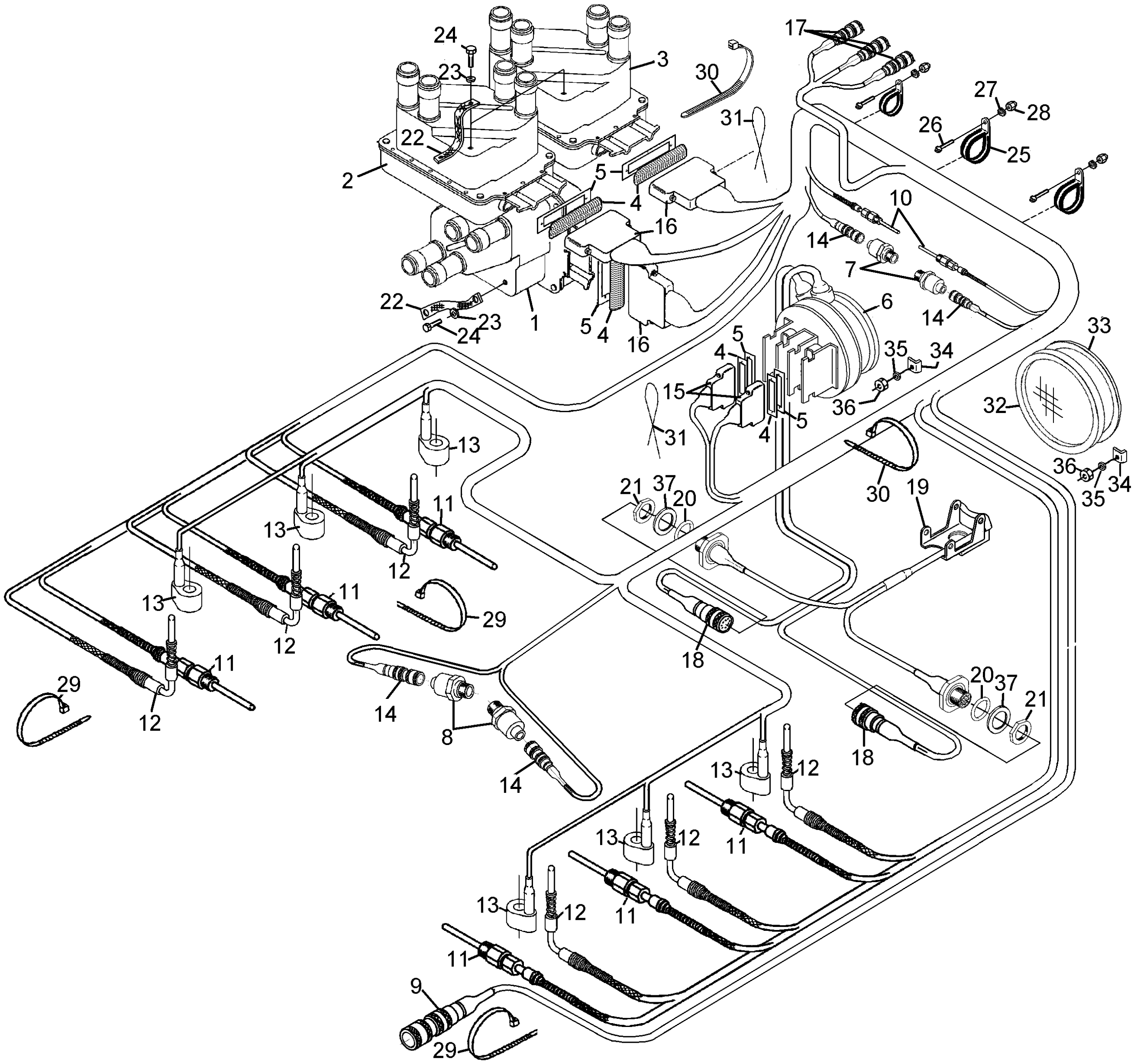


Figure 10-3. Typical 6-Cylinder Engine Electrical Control and Low Voltage Harness

1. Elec. Control Unit 1 (Cylinders 1 & 2)
2. Elec. Control Unit 2 (Cylinders 3 & 4)
3. Elec. Control Unit 3 (Cylinders 5 & 6)
4. Sealant Strip
5. EMI Gasket
6. Speed Sensor Signal Conditioner
7. Intake Manifold Air Pressure Sensor
8. Fuel Pressure Sensor
9. Propeller Governor Connector (Optional)
10. Intake Manifold Air Temperature Sensor
11. Exhaust Gas Temperature Sensor
12. Cylinder Head Temperature Sensor
13. Fuel Injector Solenoid Coil
14. Six-Pin Connector
15. 25-Pin Connector
16. 50-Pin Connector
17. 19-Pin Connector
18. 13-Pin Connector
19. Speed Sensor Assembly (SSA)
20 O-Ring
21. Nut
22. Ground Strap (six each)
23. Washer
24. Bolt
25. Clamp
26. Screw
27. Washer
28. Nut
29. Tie Wrap
30. Safety Tie
31. Lockwire
32. Cover
33. Gasket
34. Hold Down Washer
35. Lock Washer
36. Nut
37. Washer (Steel Sump)

ELECTRONIC CONTROL UNITS (ECUs)

An Electronic Control Unit (ECU) (Figure 10-4) is assigned to a pair of engine cylinders. On six-cylinder engines, there are three ECUs required, one unit for every pair of cylinders.

The ECUs control the fuel mixture and spark timing for respective engine cylinders; Electronic Control Unit 1 controls opposing Cylinders 1 and 2; Electronic Control Unit 2 controls Cylinders 3 and 4, and Electronic Control Unit 3 (if equipped) controls Cylinders 5 and 6.

Each ECU is divided into upper and lower portions. The lower portion contains an electronic circuit board; the upper portion houses the ignition coils. The electronic circuit board contains two, independent microprocessor controllers which serve as control channels. During engine operation, one control channel is assigned to operate a single engine cylinder. Therefore, one ECU can control two engine cylinders, one control channel per cylinder.

The control channels are independent and there are no shared electronic components between the control channel pair within one ECU. They also operate on independent and separate power supplies. However, if one control channel fails, the other control channel in the pair within the same ECU is capable of operating both its assigned cylinder and the other opposing engine cylinder as backup control for fuel injection and ignition timing.

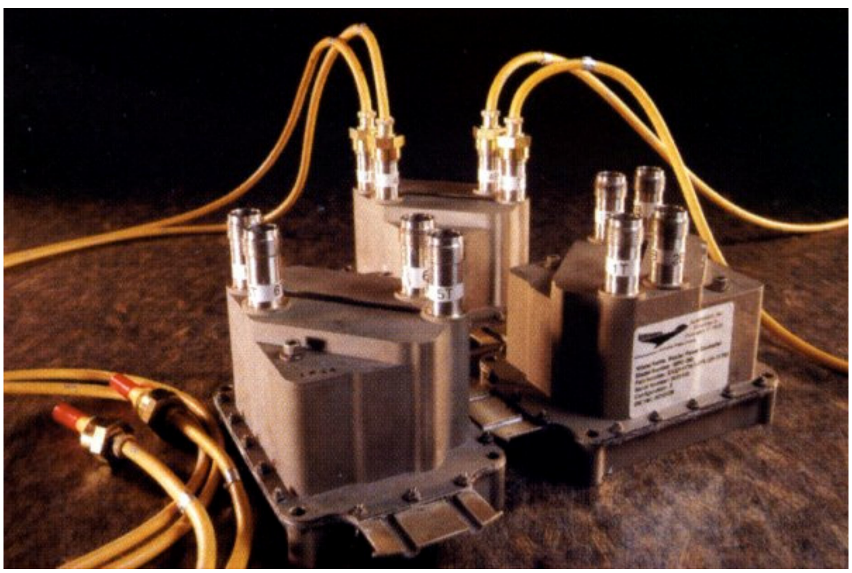


Figure 10-4. Electronic Control Unit (ECU)

Each control channel on the ECU monitors the current operating conditions and operates its cylinder to attain engine operation within specified parameters. The following sensors transmit inputs to the control channels across the low voltage harness:

- Speed Sensor which monitors engine speed and crank position
- Fuel Pressure Sensors
- Manifold Pressure Sensors
- Manifold Air Temperature (MAT) Sensors
- Cylinder Head Temperature (CHT) Sensors
- Exhaust Gas Temperature Sensors

All critical sensors are dually redundant with one sensor from each type pair connected to control channels in different ECUs. Synthetic software default values are also used in the unlikely event that both sensors of a redundant pair fail.

The control channel continuously monitors changes in engine speed, manifold pressure, manifold temperature, fuel pressure based on sensor input relative to operating conditions to determine how much fuel to inject into the intake port of the cylinder. Fuel injection timing is based on engine speed and crankshaft position.

The control channel uses this input to precisely trim the fuel-to-air ratios independently for its cylinder's next combustion event. A solenoid-type electronic fuel injector (one per cylinder) injects the required fuel quantity into each cylinder intake port upstream of the intake valve at the appropriate time.

The fuel injector solenoid on the fuel injector is driven directly by the associated control channel. The control channel actuates the fuel injector by commanding the solenoid-controlled fuel injector valve **ON** or **OFF**.

The control channel calculates duration of actual fuel injection based upon a volumetric map of the engine's breathing characteristics. The map is the baseline mixture for the cylinder at any normal engine condition.

The control channel compensates this mixture in response to variations in the following:

- Intake manifold pressure
- Intake air temperature
- Fuel pressure
- Cylinder head temperature
- Exhaust gas temperature
- System voltage
- Engine speed (revolutions per minute (RPM)
- Throttle setting

The control channel calculates the air density within the intake chamber of its cylinder. PowerLink contains a volumetric map of the engine's breathing characteristics as it applies to engine speed and air density to allow PowerLink to precisely match fuel delivery on demand. PowerLink also compensates for changes in altitude by monitoring the intake manifold pressure.

Based on these calculations and other relevant input, the control channel adjusts the fuel mixture and ignition timing as needed for its assigned cylinder as required. PowerLink monitors combustion efficiency and the Exhaust Gas Temperature (EGT) using EGT Sensors. PowerLink uses this input to precisely trim the fuel-to-air ratios independently for each cylinder.

For example, if EGT Sensor input to the ECU indicates that a fuel mixture needs to be either leaned or enriched, the control channel operates its assigned cylinder to adjust the fuel mixture for the cylinder. The required fuel quantity is injected into each cylinder intake port at the appropriate time, with respect to crank position, by the cylinder's solenoid-controlled fuel injector. The injector's control coil is driven directly by the associated control channel.

The CHT and EGT Sensor input helps the control channels determine combustion efficiency.

Each channel controls its assigned cylinder in a manner that will yield optimum performance for the current operating conditions to prevent exceeding normal operating parameters. The fuel mixture may be enriched or leaned and ignition timing may be retarded to minimize the extent of limit excursion for the given parameter.

In this respect, a FADEC-controlled engine is different from a non-FADEC engine in that an individual cylinder can be leaned or enriched by its control channel without affecting the other cylinders.

PowerLink Ignition System

The Ignition System consists of the high voltage coils atop the ECU, the high voltage harness and spark plugs. Since there are two spark plugs per cylinder on all engines, a six-cylinder engine has 12 leads and 12 spark plugs.

One end of each lead on the high voltage harness attaches to a spark plug and the other end of the lead wire attaches to the spark towers on each Electronic Control Unit. The spark tower pair is connected to opposite ends of one of the ECU's coil packs. Two coil packs are located in the upper portion of the ECU. Each coil pack generates a high voltage pulse for two spark plug towers. One tower fires a positive polarity pulse and the other of the same coil fires a negative polarity pulse.

Each ECU controls the ignition spark for two engine cylinders. The control channel within each ECU commands one of the two coil packs to control the ignition spark for the engine cylinders. Figure 10-5 illustrates this scenario.

The high voltage harness carries energy from the ECU spark towers to the spark plugs on the engine.

PowerLink^{TM} employs a waste spark ignition system. In this type of ignition, each cylinder's spark plugs are fired twice per engine cycle - once on the compression stroke and again on the exhaust stroke. The control channel in an ECU emits a high voltage pulse through the high voltage harness to fire its top spark plug on the compression stroke and the bottom spark plug on the exhaust stroke for the opposite cylinder.

Electronic Control Unit 1 fires the top and bottom spark plugs for Cylinders 1 & 2; Electronic Control Unit 2 fires the top & bottom spark plugs for Cylinders 3 & 4, and Electronic Control Unit 3 fires the top and bottom spark plugs for Cylinders 5 & 6.

For both spark plugs in a given cylinder to fire on the compression stroke, both control channels must fire their coil pack. Each coil pack has a spark plug from each of the two cylinders controlled by that coil pack's ECU Unit.

The ignition spark is timed to the engine's crank position. The timing is variable throughout the engine's operating range and is dependent upon the engine load conditions. The spark energy is also varied with respect to engine load.

NOTE: Engine ignition timing is established by the Electronic Control Units and cannot be manually adjusted.

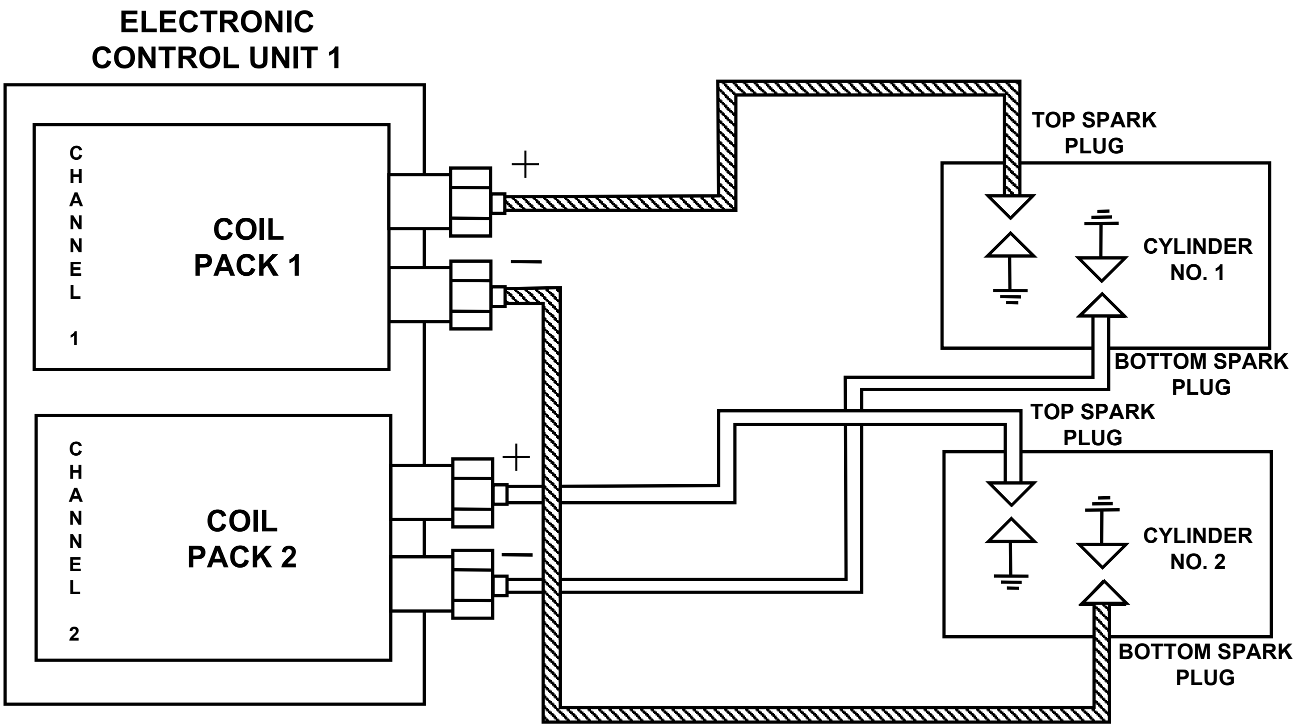


Figure 10-5. Ignition Control Conceptual Diagram

FADEC FUEL INJECTION SYSTEM

The FADEC Fuel Injection System (Figure 10-6) is composed of:

- An engine-driven Fuel Pump
- Fuel Distribution Block
- Solenoid-controlled Fuel Injectors
- 20-Micron & 10-Mircon Filters
- Engine-mounted Fuel Filter
- Fuel Bypass Solenoid
- Fuel Flow Transducer

The positive displacement style fuel pump is directly driven at the same speed as the crankshaft. Therefore, fuel pressure varies directly with engine speed. Fuel pressure is constantly monitored by the ECUs using dual redundant Fuel Pressure Sensors mounted on the fuel distribution block.

Fuel is metered to the cylinders under control of the respective Electronic Control Unit (ECU). The ECU monitors changes in air density and engine speed to determine how much fuel will be injected into the intake port of the cylinder.

The fuel distribution block distributes fuel to each of the fuel injector nozzles.

PowerLink controls the fuel supplied to each cylinder using solenoid-actuated sequential port fuel injectors. A fuel injector assembly is located in each cylinder head, one fuel injector per cylinder. The fuel injector is threaded on both ends (Figure 10-7) and the outlet screws into the tapped fuel injector boss in the cylinder head.

The fuel injector assembly is made up of two parts: the control coil and the injector as shown in Figure 10-8. The internal components of the fuel injector consist of a pintle valve and a spring. The solenoid creates an electromagnetic field to lift the pintle valve and open the path for fuel to flow. The solenoid coil fits over the pintle valve body and is held in place with two jam nuts that thread onto the valve body. When electrical current ceases to flow through the solenoid, the spring force closes the pintle valve and shuts off the flow of fuel from the fuel injector. The valve design and injector end form a self-atomizing feed for the fuel.

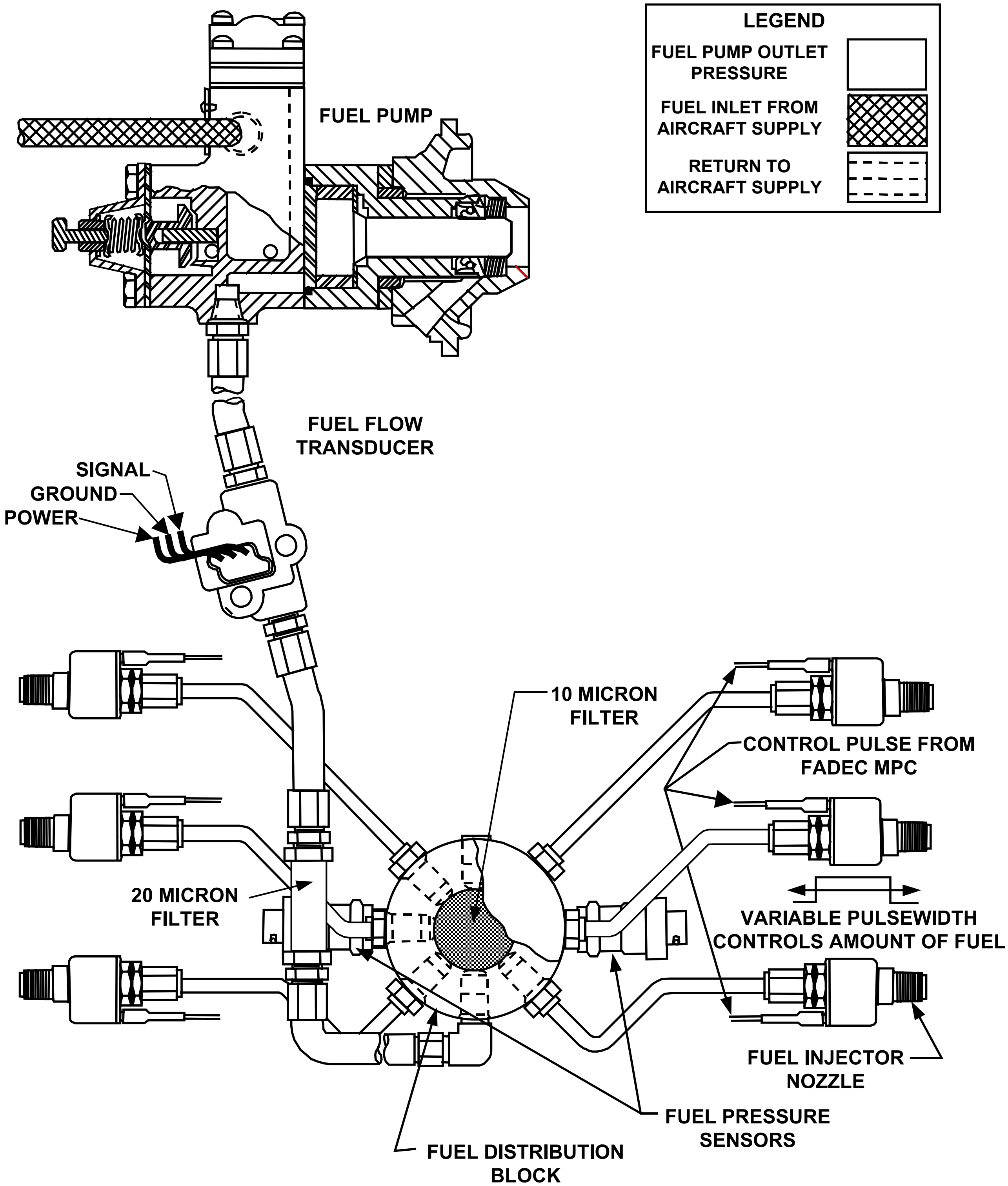


Figure 10-6. Fuel Injection System

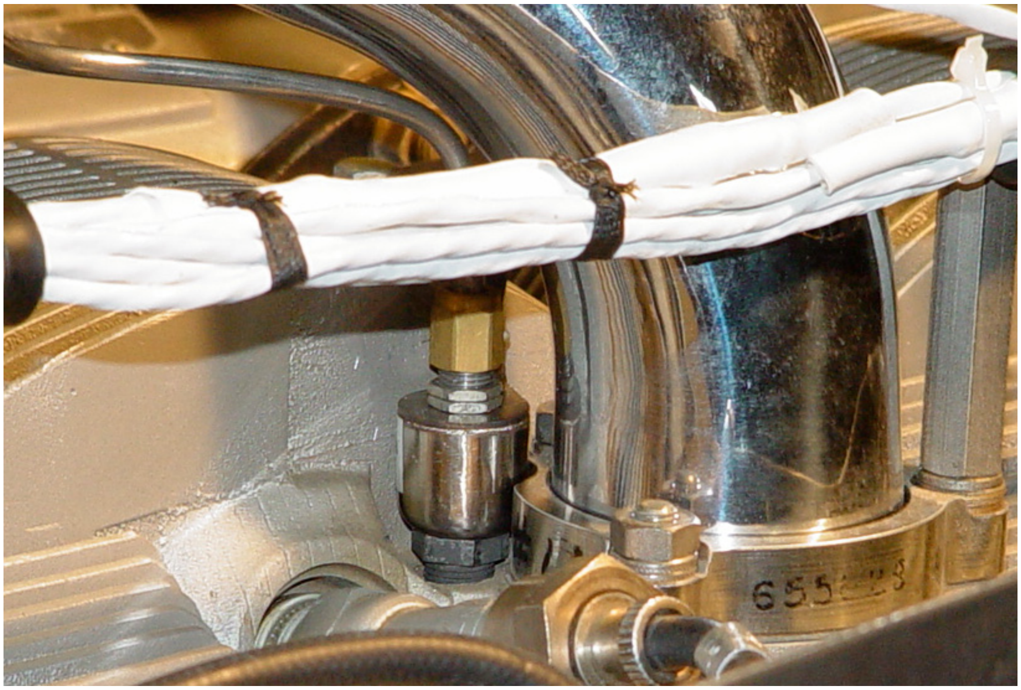


Figure 10-7. Fuel Injector

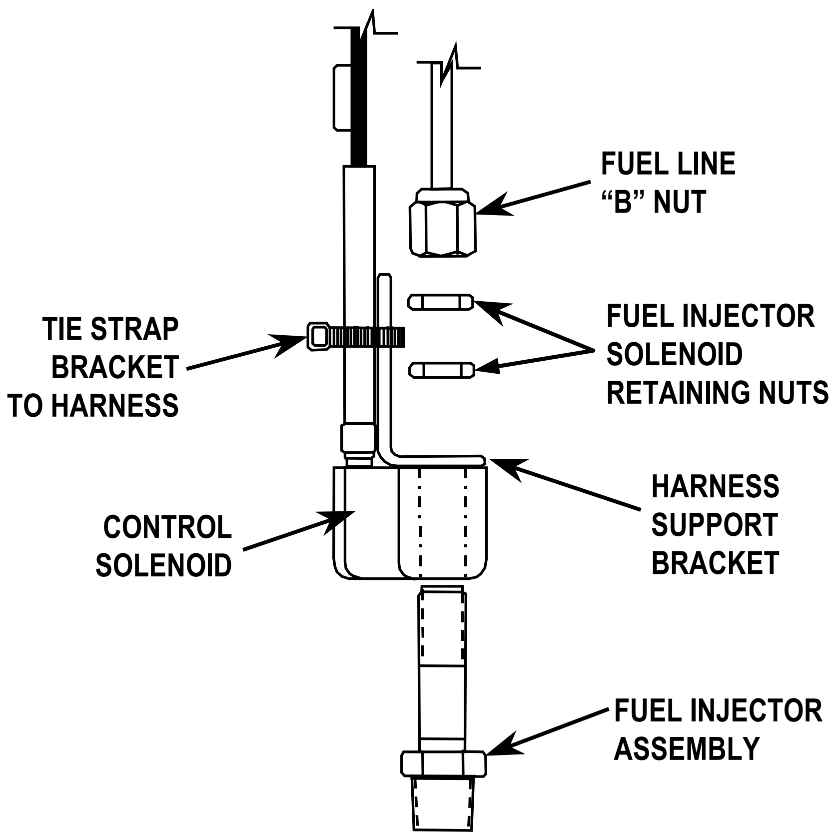


Figure 10-8. Fuel Injector Parts

PowerLink constantly measures the fuel pressure at the fuel injector inlets under all engine operating conditions using dual Fuel Pressure Sensors mounted on the fuel distribution block. With this input, the ECUs control the amount of fuel flow to each cylinder by controlling the duration of time that the solenoid control valve on the fuel injector remains open, allowing fuel to flow through the fuel injector into the intake port. The two control channels within a given ECU directly regulate the amount of fuel delivered to each channel's assigned cylinder via the fuel injector assemblies. The ECU monitors changes in air density and engine speed to determine how much fuel to inject into the intake port of the cylinder.

The control channel in the ECUs of PowerLink controls fuel flow through the fuel injector by switching electrical current **ON** and **OFF** to the control coil of the fuel injector assembly. When the current is **ON**, fuel flows through the injector. The amount of time the injector is held in the **ON** state determines how much fuel is delivered to the cylinder. In the **ON** state, the solenoid coil creates an electromagnetic field that lifts the pintle valve opening the path for fuel to flow. The **ON** time for a given injection event is referred to as the "injection duration." The control channel receives information from PowerLink sensors and uses this information to determine the appropriate injection duration for the next air intake cycle.

In the **OFF** state, electrical current ceases to flow through the solenoid and the spring force closes the pintle valve which shuts off flow from the fuel injector.

Each control channel will independently vary its cylinder's injection duration depending on current engine operating conditions. At the appropriate crank rotation angle, the control channel will fire its injector for the required injection duration to deliver the appropriate amount of fuel for the combustion event.

When PowerLink detects the need for more fuel to be injected to a given cylinder, the solenoids are held **ON (OPEN)** for a longer duration permitting more fuel to flow into that given cylinder. The amount of time the injector is held in the **ON** state determines how much fuel is delivered to the cylinder.

Note that fuel is injected through each fuel injector for a cylinder as needed as determined by the control channel assigned to that cylinder.

FADEC SENSOR SET

The FADEC sensor set includes all sensors used by PowerLink to monitor engine performance. The FADEC Sensor Set Table below lists the sensors and corresponding control channels (abbreviated CC) for six-cylinder engines.

FADEC Sensor Set for Six-Cylinder Engines		
Speed Sensor Assembly:		
P1	P2	P3
CC 1 & 4	CC 2 & 5	CC 3 & 6
Six Cylinder Head Temperature (CHT) Sensors:		
One per engine cylinder		
Six Exhaust Gas Temperature (EGT) Sensors:		
One per engine cylinder		
Manifold Air Pressure (MAP) Sensors:		
J1	J2	
CC 1, 3 & 5	CC 2, 4 & 6	
Manifold Air Temperature (MAT) Sensors:		
CC 1, 3 & 5	CC 2, 4 & 6	
Fuel Pressure Sensors:		
J3	J4	
CC 1, 3 & 5	CC 2, 4 & 6	

Each control channel performs diagnostic checks on itself and the sensors it utilizes. If a fault with one of the sensors is detected, an HSA lamp will be illuminated.

A laptop computer with the TCM FADEC Diagnostics Software Tool installed can be used to communicate with each control channel to determine specific information regarding detected sensor faults to be obtained. Refer to Chapter 4, Troubleshooting for details on using this diagnostic software tool.

For PowerLink to operate at optimum performance, all sensors must be operational.

SPEED SENSOR ASSEMBLY (SSA)

The Speed Sensor Assembly (SSA) provides PowerLink with information about the engine's crank position and engine speed. Different SSAs are provided for Permold and Sandcast engine configurations. Refer to the applicable subsection for a description of the respective SSA on your engine.

SSA on Permold Series Engines

The SSA consists of two separate parts: a signal conditioner (Figure 10-9) and a (Hall effect) speed sensor array (Figure 10-10). Looking from the rear of the engine, the signal conditioner is mounted on the right-hand side (1-3-5 side) magneto drive pad and the speed sensor array (Figure 10-11) is mounted on the interior bottom of the oil sump.

Two sealed electrical circular connectors, installed in the oil sump walls, one on each side, conduct signals from the speed sensor array to the signal conditioner (Figure 10-12). A pair of cables extending from the signal conditioner mate with the sump-mounted connectors.

The speed sensor detects the camshaft position. The speed sensor array consists of six sensors that detect the speed and position of the camshaft gear. The six sensors are paired into three sets, each having a speed target sensor (for reading the outer track of 12 drilled holes on the camshaft gear (Figure 10-13) and a cam target sensor (for reading the inner track of the camshaft gear).

The SSA sensor pairs detect the outer track of targets in the camshaft gear as it rotates past the sensor array generating a signal pulse train that is proportional to engine speed. The sensor sets also detect the top-dead-center target on the inner track of the camshaft gear generating the cam pulse. This pulse is timed with the piston in Cylinder 1 reaching top dead center (TDC) on the compression stroke.

When the SSA detects an "open" hole on the outer track of drilled holes, the SSA creates and sends a corresponding electrical pulse to the Electronic Control Units (ECUs) to determine engine speed and crank/cam position.

The signal conditioner filters both the electrical power supplied to and the signals generated by the speed sensor array. The conditioned signals are passed on to the ECUs where they are used to coordinate ignition and fuel injection timing.

Figure 10-9. Speed Sensor Signal Conditioner Assembly on Permold and Sandcast Engines

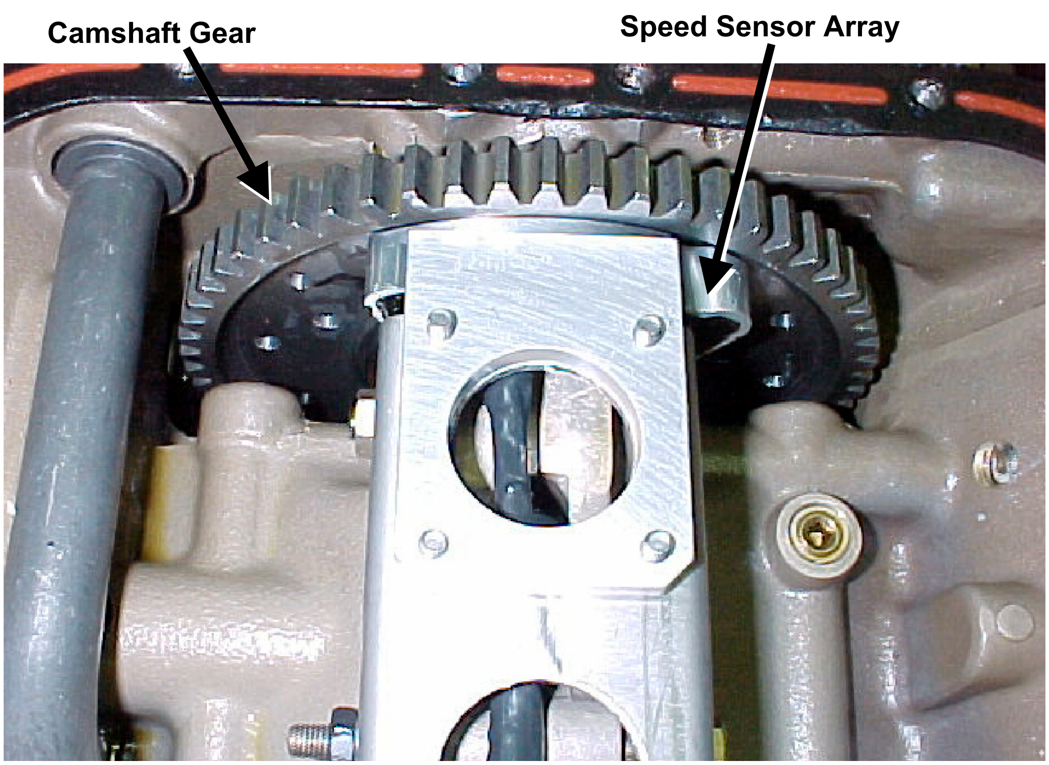


Figure 10-10. Speed Sensor Array on Permold Engines

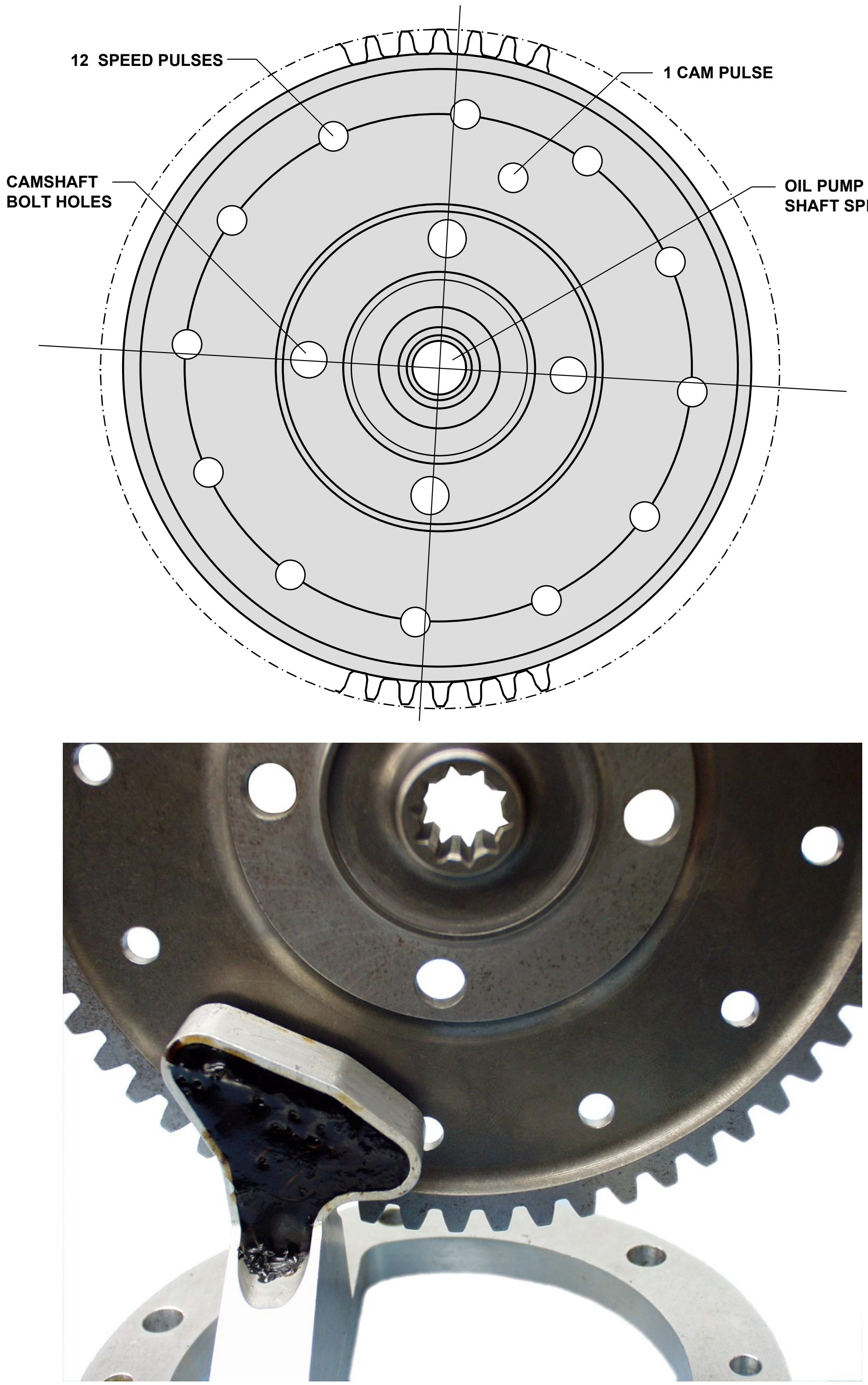


Figure 10-11. Camshaft Gear

CYLINDER HEAD TEMPERATURE (CHT) SENSORS

Each cylinder is equipped with a Cylinder Head Temperature (CHT) Sensor to monitor and help maintain the temperature of the cylinder within specified operating parameters.

The CHT Sensor (Figure 10-12) is mounted on each engine cylinder via a bayonet style adapter which threads into the cylinder head. A spring-loaded locking ring on the sensor reinforces this attachment. The CHT Sensor is hardwired to the low voltage harness.

The CHT Sensor emits a temperature signal to the corresponding control channel (in the assigned Electronic Control Unit (ECU) which monitors and controls the engine cylinder. The ECU will use this signal to control the cylinder head temperature. The signal is conveyed to the control channel via the low voltage harness.

Each CHT Sensor is independent and operates for a respective engine cylinder.

The sensing element in the CHT Sensor is a thermistor. This type of device changes resistance with temperature in a linear and repeatable manner. Measuring the resistance of the sensor alloys enables an accurate determination to be made of the temperature at the sensor tip.

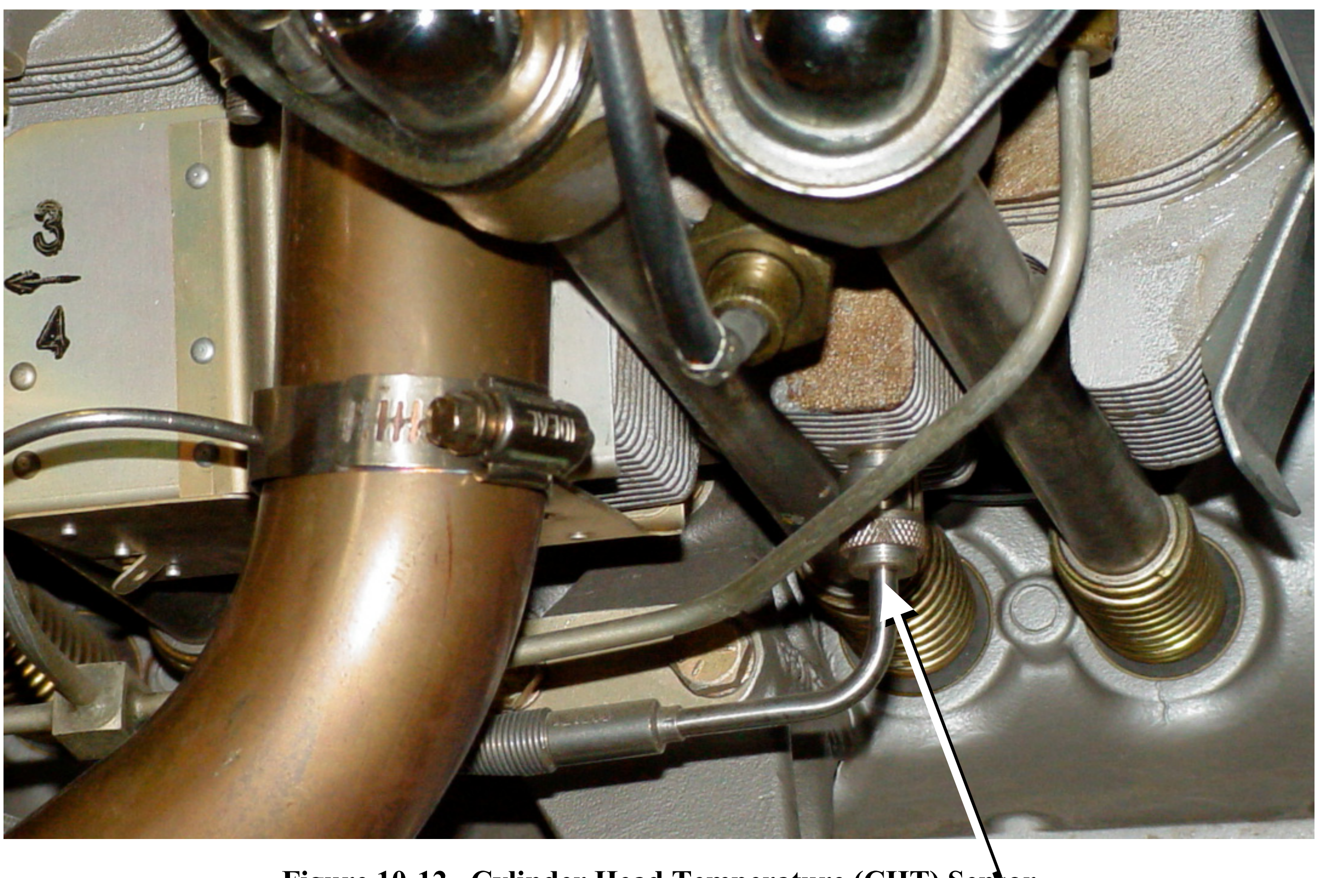


Figure 10-12. Cylinder Head Temperature (CHT) Sensor

EXHAUST GAS TEMPERATURE (EGT) SENSORS

Each cylinder's exhaust port is outfitted with an EGT Sensor.

The EGT Sensor emits a temperature signal to the corresponding control channel (in the assigned Electronic Control Unit (ECU)) which monitors and controls that engine cylinder. The ECU will use this signal to control the fuel-to-air ratio. The signal is conveyed to the control channel via the low voltage harness. The EGT Sensors are hardwired to the low voltage harness.

Each EGT Sensor is independent and operates for a respective engine cylinder.

The sensing element in the EGT Sensor is a K-type thermocouple. Two conductors made of dissimilar metals are fused to form the sensing element. The sensing element generates a small voltage in proportion to the temperature it is exposed to. By measuring the voltage produced by the sensing element, an accurate determination can be made of temperature at the EGT Sensor tip.

The EGT Sensors are attached to the exhaust system by means of a worm screw clamp (Figure 10-13).

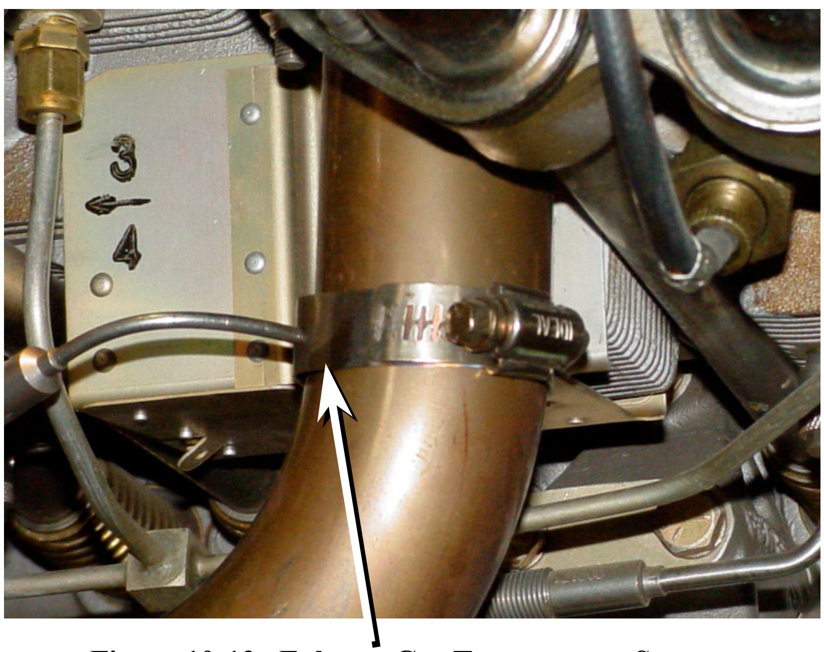


Figure 10-13. Exhaust Gas Temperature Sensors

MANIFOLD AIR PRESSURE (MAP) SENSORS

PowerLink utilizes two MAP Sensors (Figure 10-14) for measuring the engine's induction air pressure (manifold air pressure). These sensors are self-contained, non-serviceable units that are thread-mounted into tapped bosses on the intake plenum on top of the engine.

The low voltage harness uses removable, circular connectors to interface with the MAP Sensors.

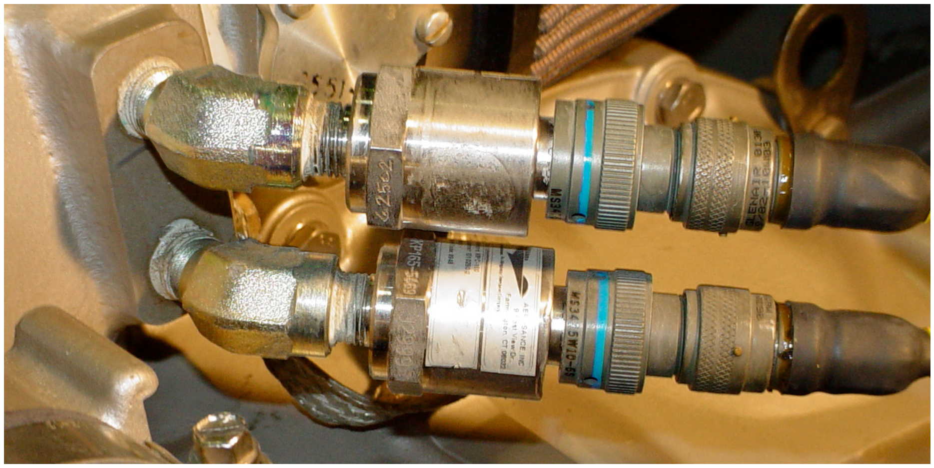


Figure 10-14. Manifold Air Pressure (MAP) Sensor Installed

MANIFOLD AIR TEMPERATURE (MAT) SENSORS

PowerLink utilizes two MAT Sensors (Figure 10-15) for measuring the intake manifold air temperature. These sensors are mounted in the intake plenum using compression fittings. The fitting body threads into bosses on the intake plenum manifold. The sensors are hardwired to the low voltage harness.

The sensing element in the MAT Sensor is a thermistor, similar to the CHT Sensor.

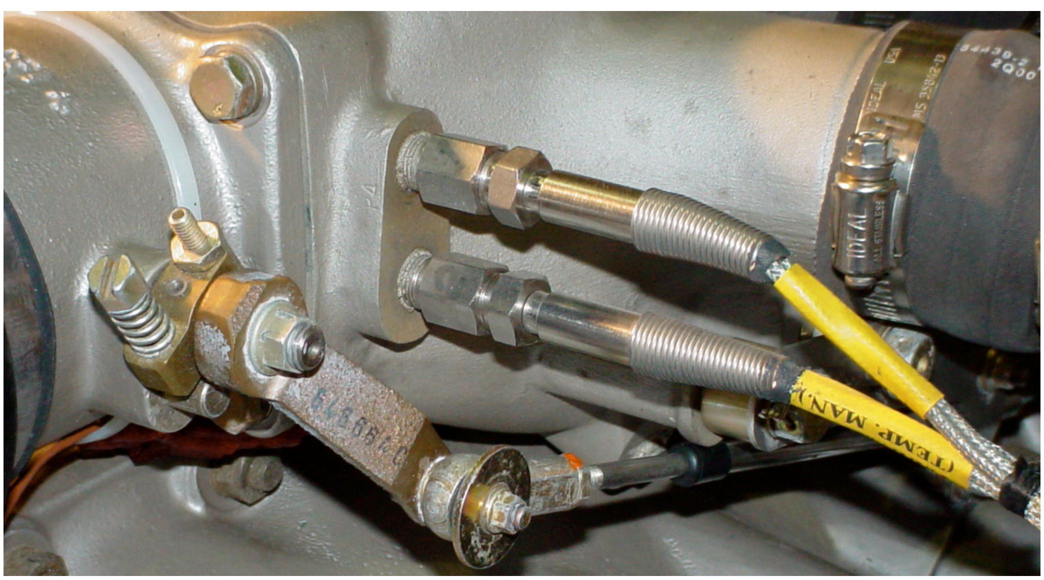


Figure 10-15. Manifold Air Temperature (MAT) Sensor Installed

FUEL PRESSURE SENSORS

PowerLink utilizes two sensors for measuring the engine's fuel pressure. The Fuel Pressure Sensors (Figure 10-16) are self-contained, non-serviceable units that are thread mounted into the fuel distribution block on top of the engine aft of the intake plenum.

The low voltage harness uses removable, circular connectors to interface with the Fuel Pressure Sensors.

Refer to the schematics (Appendix C in this manual) for your engine model for "P connections for these sensors.

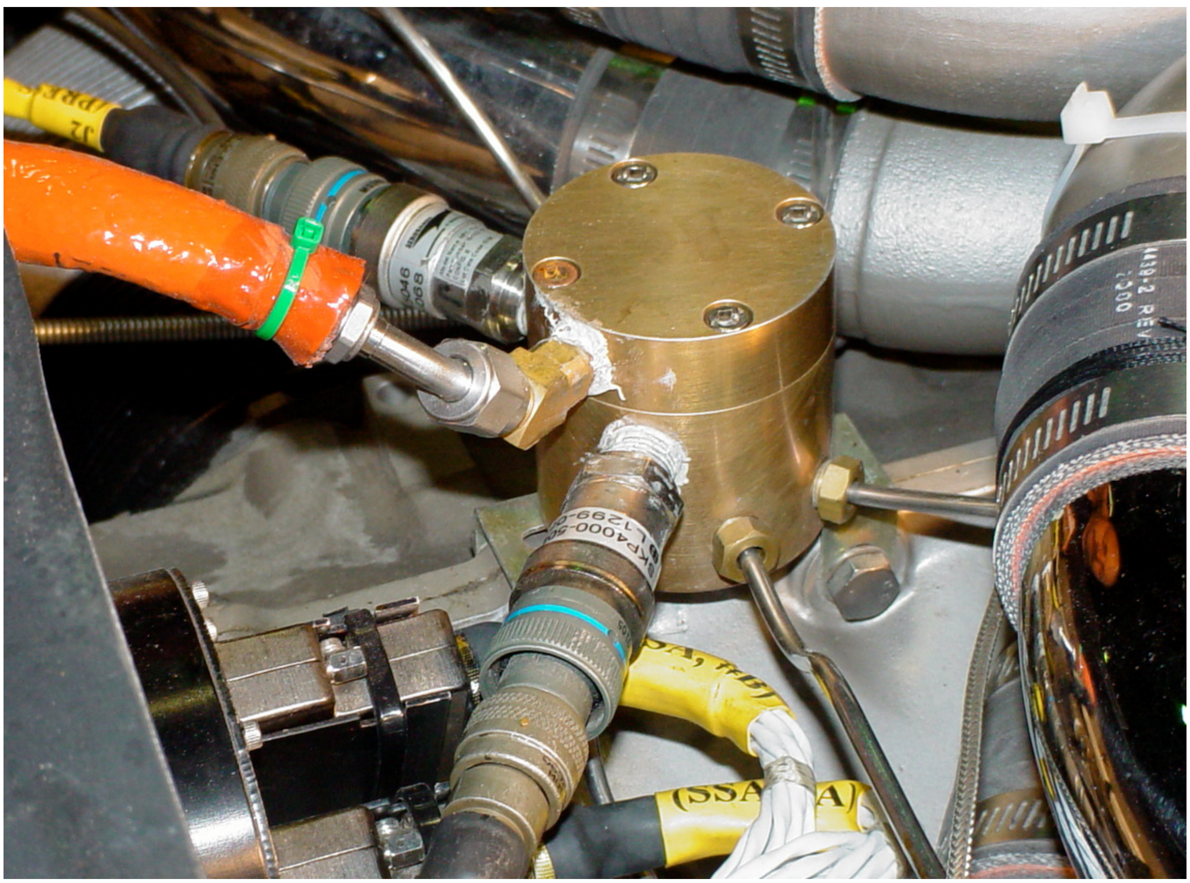


Figure 10-16. Fuel Pressure Sensor Installed

POWER SUPPLIES

PowerLink is electrically powered and is supplied current by the aircraft's primary electrical buss and a secondary power source (SPS). The SPS may be:

- a dedicated backup battery
- a second alternator-battery (either installed on the single engine or the alternator installed on the other engine in a twin engine installation)
- a dedicated, self-exciting backup generator

The Electrical Power Supply Summary Table below describes the various electrical system configurations that can be used with PowerLink to comply with the redundant power requirement.

Electrical Power Supply Summary Table	
Configuration	**Description**
Dual Alternators & Dual Batteries*	PowerLink can operate indefinitely on the primary power source alternator and also can operator indefinitely on the SPS because it too has an alternator
Single Alternator & Battery Plus a Dedicated Backup Battery	PowerLink can operate indefinitely on the power source having the alternator; PowerLink must be capable of operating on the backup battery for at least 1 hour. The backup battery is solely dedicated for this purpose and is not used to supply any other loads or for cranking. **NOTE:** This configuration requires use with a battery condition monitor. The HSA prevents the main aircraft bus from drawing on the backup battery. The HSA provides indication when the backup battery is low (EBAT FL). If the backup battery voltage is low or if the ECU(s) is/are operating on the backup battery, the PPWR FL annunciator will illuminate on the HSA.
Single Alternator & Single Battery Plus a Dedicated Backup Generator	The self-excited dedicated generator allows continued operation of PowerLink while the primary power is interrupted for diagnostics.
*An electrical power system having two electrical busses each supplied by a separate and independent alternator and battery complies with the requirement for two separate power sources	

The SPS is used to supply power to PowerLink independently from the aircraft's primary buss.

If the SPS is a battery, it will be constantly charged by the aircraft's primary power buss. The charging current supplied to the SPS battery is monitored by the HSA and the charging circuit is protected by a breaker labeled "SPSC" which means "secondary power source charge."

Electrical power to PowerLink is controlled from the cockpit by two separate, independent switches used to interrupt the primary power and secondary power. The cabin harness through the bulkhead connectors to the low voltage harness conducts primary/secondary power. Information from the Electronic Control Units (ECUs) is conveyed to the HSA and the cockpit mounted data port through the same cabin harness/bulkhead connector assembly.

The two power supply circuits are isolated from each other and each has a separate set of breakers and power switch. The Primary Power Switch and breaker set control the primary power supply to the FADEC System; the Secondary Power Switch and the breaker set control the secondary power supply to the FADEC System.

Two breakers protect the SSA and HSA power supply circuits, one breaker being assigned to each of the two power supplies.

The pilot starts, enables, and stops PowerLink using a conventional aircraft-style Ignition Switch.

Power switchover is instantaneous and automatic. There is now switchover relay or mechanical breaker. There is no interrupted power period to the FADEC system when transitioning from one source to another as long as both sources are above the minimum voltage level and have sufficient current capacity to run the FADEC system. The FADEC will draw 5.2 amperes total at 2700 RPM and will decrease it's current draw to approximately 1.9 amperes at idle speed. These current values do not include the operation of the electric fuel pump.

FAILSAFE OPERATING CONTINGENCIES

PowerLink is functionally redundant:

- If a control channel incurs a fault, the other control channel within the same ECU is capable of operating its assigned cylinder as well as the cylinder experiencing the fault condition.

- All critical sensors are redundant with one sensor from each pair connected to channels in different ECUs. Synthetic software default values are also used. This arrangement supports the functional redundancy of the FADEC System.

FAULT DETECTION

The fault detection function is a total self-checking system intended to inform the pilot when the conditions of the various components of the system require diagnostic attention.

Each of the sensors and other analog input signals is tested and annunciated for low range values, high range values and noisy signal operation. The Low Range CHT sensor check (misfiring cylinder check) is not performed below 2000 RPM in order for the cylinders to be allowed to warm up properly prior to take-off and to prevent false alarms.

The FADEC System detects and annunciates the following:

1. The occurrence of excessive CHT and EGT values. Both conditions may indicate an engine condition requiring maintenance.
2. A fuel pump transistor-driver faulted condition. This fault precludes automatic operation of the electric boost pump, and should be investigated.
3. An in-range fuel pressure fault. If the fuel pressure sensor has failed within the upper and lower electrical limits a fault will be annunciated. This fault may also be annunciated due to a reduction in the fuel pressure from the nominal-operating curve of pressure versus the engine curve. The fuel system should be investigated for clogged filters, degraded or maladjusted fuel pump, and leaks.
4. Improper speed signal faults. This fault is indicative of a speed sensor or low voltage harness failure.
5. A misfiring cylinder. A misfiring cylinder fault is annunciated when CHT falls below 800^{o} F, and should be investigated.
6. Processor faults. A processor fault should be remedied by replacing the applicable ECU.

SUMMARY

In this chapter we discussed the functional operation of the components which comprise the PowerLink™ FADEC system. We covered the Engine Control Unit and Low Voltage harness and saw how the microprocessor-based System monitors engine operating conditions through sensory input and then automatically sets the fuel mixture and ignition timing accordingly for any given power setting. We also recognize that engines equipped with the FADEC System do not require magnetos and eliminate the need for manual fuel/air mixture control.

KEY TERMS

Best Power/Best Economy Switch	Cabin mounted switch that allows for certain levels of pilot control of the calibration function.
Boost Pump Mode Switch (BPMS)	Used to select the operating mode for the aircraft's electric fuel pump. There are two possible operating modes (**OFF** or **AUTOMATIC**).
Channel lamp	Six HSA panel lamps that indicate some level of fault or system operating condition with the associated control channel. Each channel is assigned to a specific cylinder.
CHT Sensor	FADEC Sensors connected in hardwired fashion to the Low Voltage Harness for the purpose of sending the Cylinder Head Temperature values in degrees Fahrenheit to the FADEC Computer.
ECU	Engine Control Unit. An electronic computer control box providing both ignition and fuel injection control to operate two cylinders of the engine with the maximum efficiency realizable. It houses two separate computers (one for each cylinder), and two separate high voltage coils for ignition. One ECU is required for each pair of cylinders on an engine.
EGT Sensor	FADEC Sensors connected in hardwired fashion to the Low Voltage Harness for the purpose of sending the Exhaust Gas Temperature values in degrees Fahrenheit to the FADEC Computer.
FADEC	Full Authority Digital Engine Controls.
FADEC lamp	An HSA lamp indicating a fault condition which may require an immediate emergency response by the pilot.
Fuel Pressure Sensor	FADEC Sensors connected by quick disconnect plug to the Low Voltage Harness for the purpose of sending data to the FADEC Computer pertaining to the available fuel pressure required for the fuel injection event.
Health Status Annunciator (HSA)	A cockpit-mounted indicator panel used by the FADEC System to convey system health information to the pilot.
MAP Sensor	FADEC Sensors connected by quick disconnect plug to the Low Voltage Harness for the purpose of sending data to the FADEC Computer pertaining to the available Manifold Air Pressure for the cylinder combustion event.
MAT Sensor	FADEC Sensors connected in hardwired fashion to the Low Voltage Harness for the purpose of sending the Manifold Air Temperature values in degrees Fahrenheit to the FADEC Computer.
Primary power	This is the primary electrical power supply to the FADEC System. It is supplied by the aircraft's primary electrical buss.
Primary Power Switch	Switch used for interrupting the primary electrical power supply to the FADEC System.

Primary power breakers	Breakers used to protect the FADEC System's primary power supply circuit.
Push to Test (PTT) button	Button on the HSA panel for conducting a lamp test. Depressing this button illuminates all HSA lamps.
Secondary power	This is the secondary electrical power supply to the FADEC System. It is supplied by the SPS.
Secondary Power Switch	Switch used for interrupting the secondary electrical supply to the FADEC System.
Secondary power breakers	Breakers used to protect the FADEC System's secondary power supply circuit.
Secondary Power Source (SPS)	A redundant electrical power source for the FADEC System. May be an engine driven device, such as an alternator, or it may be a battery.
Secondary Power Source Charge (SPSC) breaker	Breaker which protects the SPS battery charging circuit.
Speed Sensor Assembly	FADEC Sensors connect to the Low Voltage Harness via two 25 pin connectors which sends data to the FADEC computer indicating crankshaft speed and piston position for ignition timing and fuel injection events.

EXERCISES

1. Engine Control Unit #2 on a six cylinder engine would control ignition and fuel injection events for cylinders ________.

    a. 1 & 2

    b. 3 & 4

    c. 5 & 6

    d. Any ECU can control any cylinder

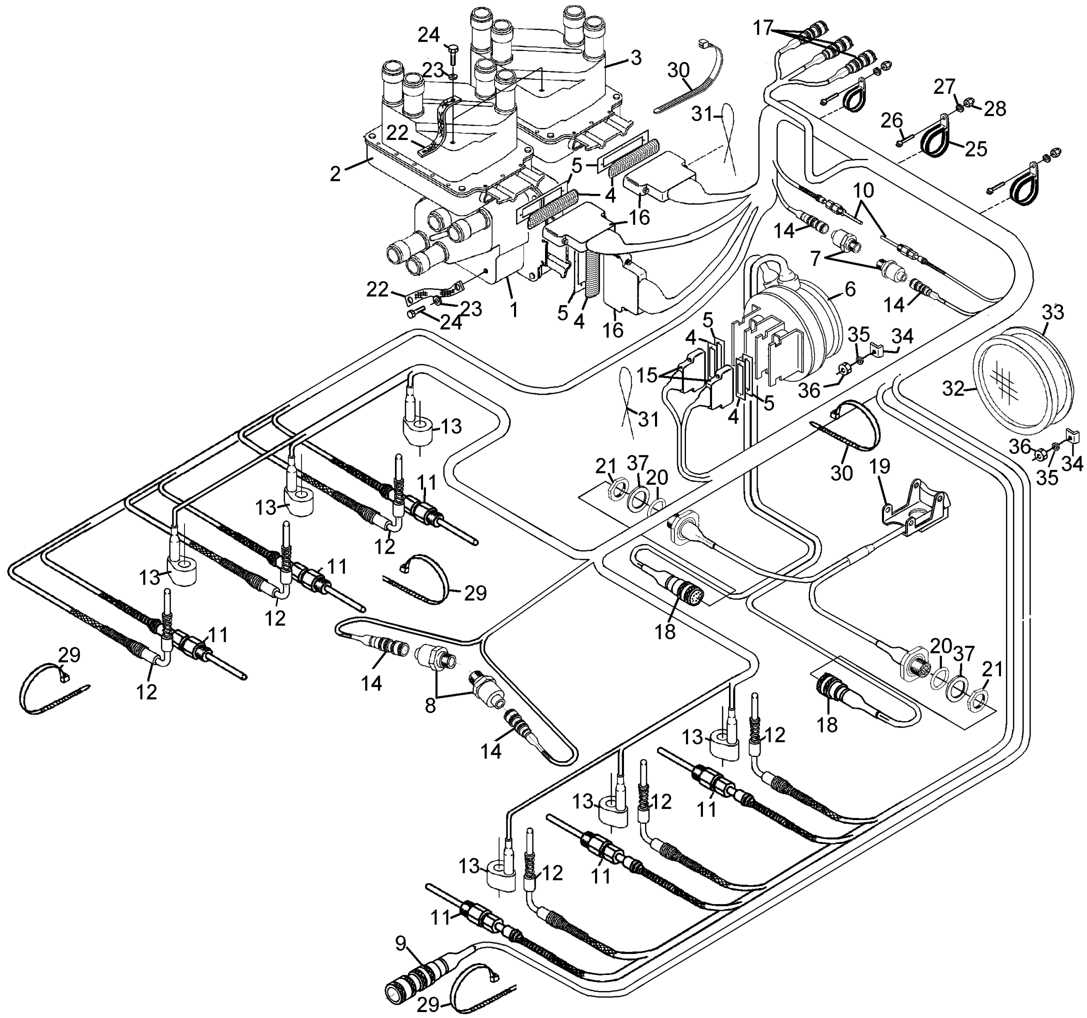
2. Which sensors are connected to the Low Voltage harness by way of quick disconnect type cannon plugs?

    a. Manifold Air Temperature MAT Sensor

    b. Cylinder Head Temperature CHT Sensor

    c. Exhaust Gas Temperature EGT Sensor

    d. Fuel Pressure Sensor



Lable the components shown in the figure above.

1.	13.	25.
2.	14.	26.
3.	15.	27.
4.	16.	28.
5.	17.	29.
6.	18.	30.
7.	19.	31.
8.	20	32.
9.	21.	33.
10.	22.	34.
11.	23.	35.
12.	24.	36.
		37.

NOTES