Sky Ranch Engine Manual

by John Schwaner

2nd Edition

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Introduction

How Your Engine Works

Piston engines are classified as heat engines. The production of power in a heat engine is attributable to the expansion of gases due to the release of heat. The kinetic theory of gases states that gas volume increases with temperature through energy of movement imparted on the gas particles. In a heat engine there must be a hot source and a cold sink. Heat flows from the hotter source to the colder. Therefore the heat source must be hotter than the exhaust heat. The difference between the two defines the thermodynamic efficiency of the heat engine.

Internal combustion piston engines, such as your car or airplane, operate as a constant volume engine. The release of heat is enclosed in the combustion chamber and creates pressure that drives a piston. Constant volume engines include internal combustion engines and external combustion engines. External combustion engines use an external boiler and heat exchangers. The most common example is the steam engine. External combustion engines, because of the large amount of discarded heat in the form of steam, are not as efficient as internal combustion engines. However, they can burn a lower grade of fuel and thus use a less costly, and more efficient fuel.

There are two types of internal combustion engines: spark ignition and compression ignition. These terms describe how the release of heat is initiated. Spark ignition engines use a spark plug to ignite fuel. Compression ignition engines, better known as diesels, auto-ignite fuel from the temperature increase of compression. The efficiency of spark ignition engines is less than optimum since the maximum compression ratio of the engine is predicated on the control of detonation. Diesel engines are not efficiency limited by compression because the fuel is timed to inject directly into the combustion chamber at the optimum point of heat release. Diesel engines cannot preignite and can take advantage of the increased fuel efficiency resulting from higher compression ratios.

Spark ignition engines can be either two-stroke or four-stroke. We will only discuss the four stroke-engine. The intake stroke sucks the fuel and air mixture into the cylinder. The compression stroke compresses the mixture. The ignition stroke (I prefer the less common term, but more descriptive, “expansion” stroke) burns the fuel, releasing heat which adiabatically expands the gases.

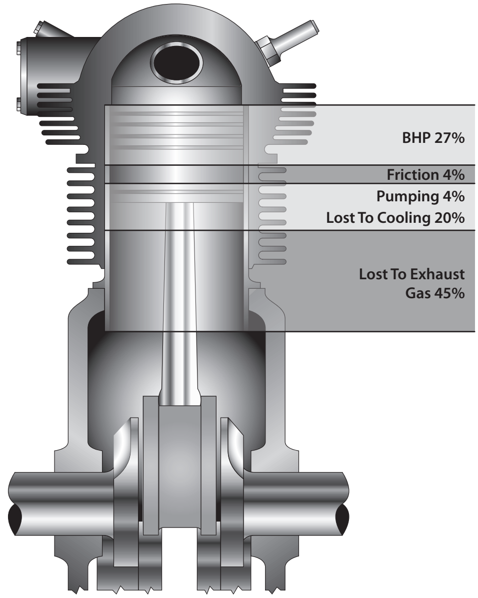


Figure-1. Approximately 27% of the heat energy is converted into useful work. By comparison, the human body converts approximately 25% of the heat energy of food into muscular energy.

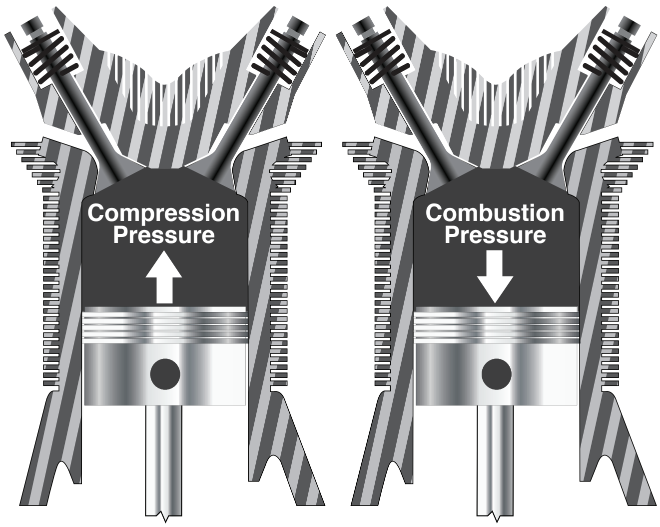


Figure 0-2. Compression pressure builds up as fuel/air mixture is squeezed by the rising piston. Combustion pressure; which forces the piston downward on the power stroke; is much higher. To compute approximate compression pressure; multiply the engine's compression ratio by the atmospheric pressure; then add the atmospheric pressure; and add the number 5 to the total. On a standard day at sea level an engine with a 7.00:1 compression ratio will have a compression pressure of 124.7 lbs. per square inch.

The expanding gas in the combustion chamber performs the following work: work in moving the piston, work done in overcoming friction, and work done in pushing back the atmosphere. The exhaust stroke pushes the remainder of the burned gases out the exhaust pipe.

Spark Ignition Engines

With carbureted engines, the fuel and air enters the engine through the carburetor which has the function of: (1) providing the quantities of air and fuel that are required by the engine at each instant; (2) atomizing and vaporizing the fuel and (3) mixing the air and fuel so the mixture is homogeneous when it leaves the carburetor. A throttle is the part of the carburetor used to control the inducted air. The downward movement of the piston in the intake stroke creates a partial vacuum in the cylinder. This pumping action draws air through the carburetor. Since fuel flow is metered in proportion to the air flow, the throttle controls power.

Carburetors restrict the air flow by the use of a venturi, whose function is to increase the velocity of the incoming air. This increase in air velocity lowers the pressure within the venturi and that, in turn, draws the fuel through the jets from the float chamber. The shape of the venturi forms a restriction within the throat of the carburetor. This limits the amount of mixture passing into the cylinders and thereby limits engine power. Larger venturis allow more mixture to flow into the cylinders at full power settings but then the low power end suffers because of insufficient pressure drop at the venturi. Multiple venturis ("barrels") attempt to compensate by having several venturi sizes; small venturis for idle and low end performance and large venturis for full throttle and high end performance. Fuel injected engines offer the advantages of not requiring a venturi which restricts air flow at high power settings. This makes fuel injected engines less dependent upon the design of the intake manifold for even mixture distribution. After the mixture leaves the carburetor, it travels to the cylinder through the intake manifolds. The shape of the intake manifolds is determined primarily by the space available for them and not to facilitate even mixture distribution from the carburetor.

When the intake manifold (inlet) pressure between the throttle plate and intake valve is less than atmospheric pressure, the engine is throttled. When the inlet pressure is equal to atmospheric pressure, the engine is at full throttle . When the inlet pressure is higher than that of the atmosphere, the engine is supercharged. Turbocharging is a method of supercharging the engine with a turbocharger installed in the exhaust manifold. Supercharging increases the volumetric efficiency of an engine. Manifold pressure between the turbocharger and the throttle butterfly is referred to as "upper deck pressure".

The fuel injector on fuel injected engines provides a continuous flow into the intake port. The primary advantage of fuel injection over carburization is the improved fuel distribution to each cylinder. Fuel injection reduces the tendency of one cylinder operating with a lean fuel/air mixture while another operates with a rich fuel/air mixture. Improved fuel

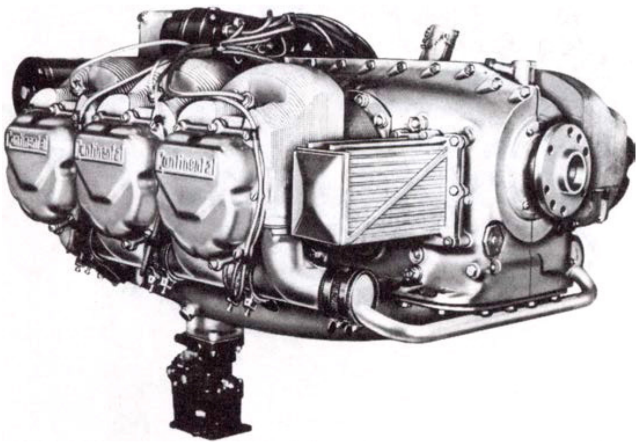


Figure 0-3. Continental 230 horsepower 0-470R.

GASOLINE CHARACTERISTICS

Weight per Cubic Foot	45lb.
British Thermal Unit (BTU) Content	19,000 BTU per lb.
Chemically Correct Fuel/Air Ratio	0.0667 (Air to Fuel Ratio of 15 to 1)

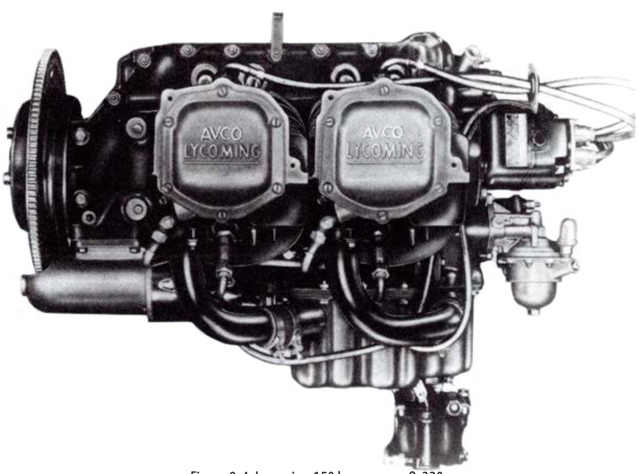


Figure 0-4. Lycoming 150 horsepower 0-320.

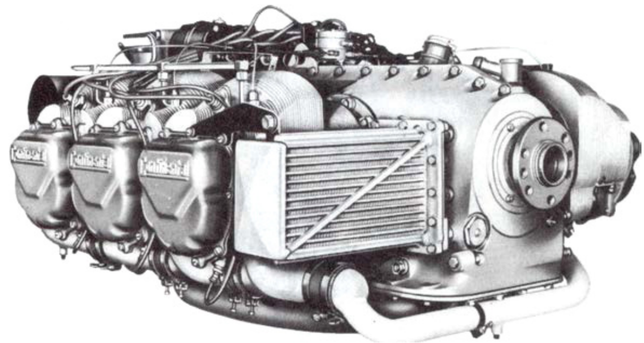


Figure 0-5. Continental 285 horsepower TSIO-520-C.

distribution allows leaning to slightly lower fuel consumption. Poor fuel distribution in carbureted engines' results in cyclic combustion variations. This causes engine roughness and therefore necessitates a mixture setting that is richer than the best power setting.

The fuel/air mixture that supports combustion ranges from 20:1 (20 parts air to one part fuel) on the lean end to 8:1 on the rich end. For practical purposes, Lycoming engines range from 16:1 at lean to 10:1 when operating full rich. At the theoretical ideal fuel to air ratio of 15:1 by weight, the engine draws in 9000 gallons of air for every gallon of gas. In smaller terms that is half a teaspoon of gas for each cubic foot of air. A 15:1 fuel/air ratio is the theoretical point where all of the hydrogen atoms in the fuel are converted to molecules of H_2O and all of the carbon atoms in the fuel are converted to molecules of CO_2 This is called a stoichiometric reaction.

Mixture is admitted and expelled from the cylinders by "poppet" valves that open and close at the proper times. Most engines incorporate "rotators" on the exhaust valves. Rotators allow the valve to rotate as the valve closes on the seat. Rotation prevents the formation of combustion deposits on the valve and seat face and equalizes the temperature of the valve face. Valve spring retainers, also called locks or keepers, fasten the valves to the valve springs. Valve springs force the valve closed. Valve spring tension must be great enough to prevent the exhaust valve from sucking open during the intake stroke. On supercharged engines, where intake manifold pressure is greater than atmospheric, spring tension must be strong enough to prevent the intake valve from being pushed open when it is meant to be closed. Valve springs must also be strong enough to close the valve before the next valve event and they must have a natural frequency range different from the frequency of valve opening and closing. Otherwise, the valve will not fully close before the next valve opening and the valves "float". Maximum speed, in revolutions per minute of the engine, rpm without a propeller load, is limited by valve float. On six cylinder Continental engines there is a valve seal on the intake guide stem. Since the intake port is normally below atmospheric pressure, the seal prevents oil from sucking into the intake port.

The camshaft rotates at half engine speed and imparts a cyclic motion to the camshaft follower (tappet) in a direction perpendicular to the axis of camshaft rotation. Valve motion is controlled by lobes on the camshaft. The shape of the lobes determines when the valves open or close and what their rates of opening and closing will be. Camshaft followers (also called tappets) ride on the cam lobes and transfer rotary motion of the camshaft into reciprocating motion of the tappets.

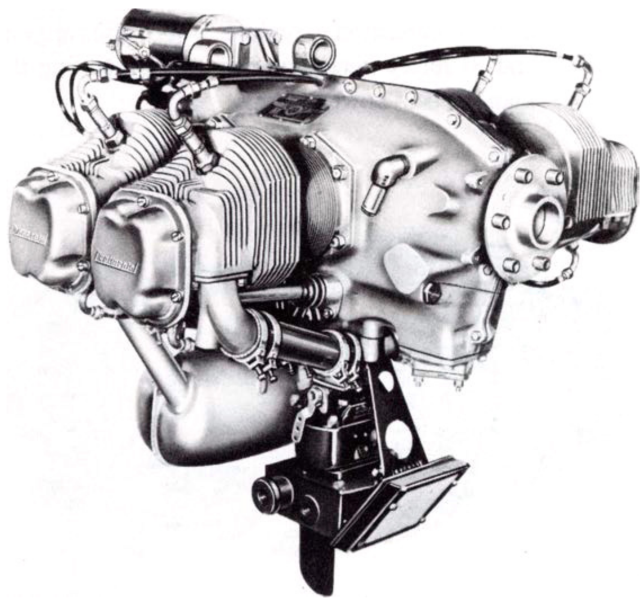


Figure 0-6. Continental 100 horsepower 0-200.

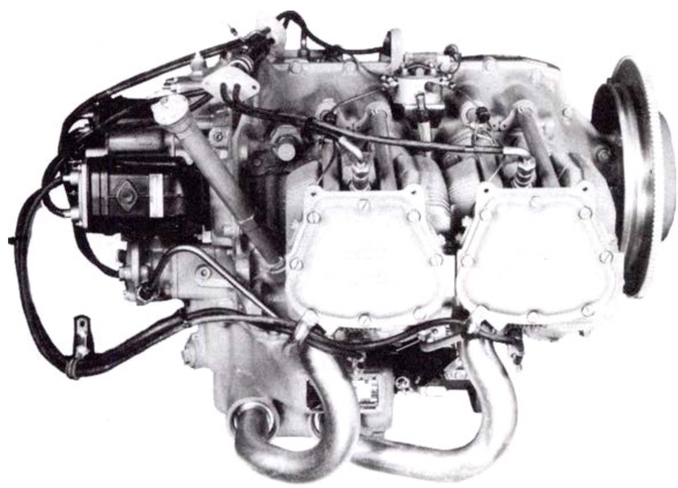


Figure 0-7. Lycoming 180 horsepower IO-360-A1A.

Lycoming tappets are called “mushroom” tappets because of their shape. Mushroom tappets cannot be removed from the engine without splitting the crankcase. Lycoming ‘76’ series engines are an exception, they do not use mushroom tappets. Continental engines except for the “E” series engines do not use mushroom tappets. The hydraulic lifter incorporates an oil-filled cylinder with a piston plunger. The lifter takes up any slack in the valve train as the engine expands and contracts because of thermal changes.

The pushrod is a piece of tubular steel placed between the lifter and the rocker arm. The pushrod has a swedged ball on each end, one end riding on the hydraulic plunger socket and the other end into the socket of the rocker arm. Most push rods are hollow allowing oil to flow up the pushrod and into the rocker arm where it lubricates the valves and rockers.

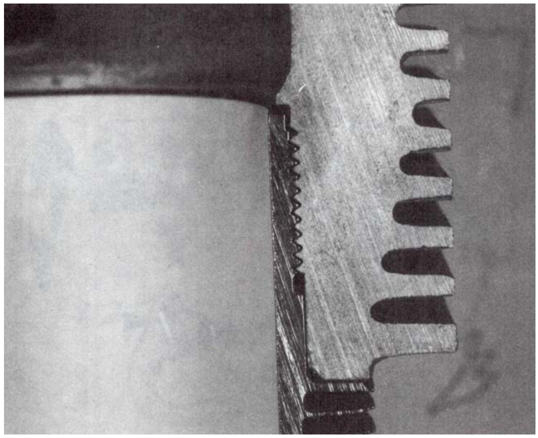


Figure 0-8. Continental 0-200 cylinder. Steel barrel is screwed into aluminum head. This design is used on all Continental and Lycoming cylinders.

There are two rocker arms for each cylinder, exhaust and intake. The rocker arms oscillate up and down on a shaft held in place by the cylinder rocker bosses. The cylinder consists of an aluminum head that is permanently screwed and shrunk onto a steel barrel. Cooling fins throughout the cylinder head and barrel dissipate heat to the atmosphere.

Two major components control the containment of the ignited fuel/air mixture in the cylinder: the piston/ring combination and the valves. The valves must form a gas-tight seal against the valve seats to prevent leakage. The piston normally incorporates two top rings that seals against combustion gases. These are compression rings. A third ring, usually a two-rail center vent design, is an oil control ring. The function of the oil control ring is to meter oil to the top compression rings. Occasionally, there is a lower ring on the piston skirt, called a scraper ring, that scrapes oil up into the cylinder. The connecting rod, fastened to the piston by a piston pin, transfers the reciprocating motion of the piston into the rotating motion of the crankshaft. The rod cap and two bolts fasten the connecting rod to the crankshaft rod journal. Piston pin plugs on the end of the pin are of the full floating kind and bear against the cylinder wall. Split style (two piece) bearings incorporate a steel shell with a layer of soft metal called Babbitt which provides the bearing surface for

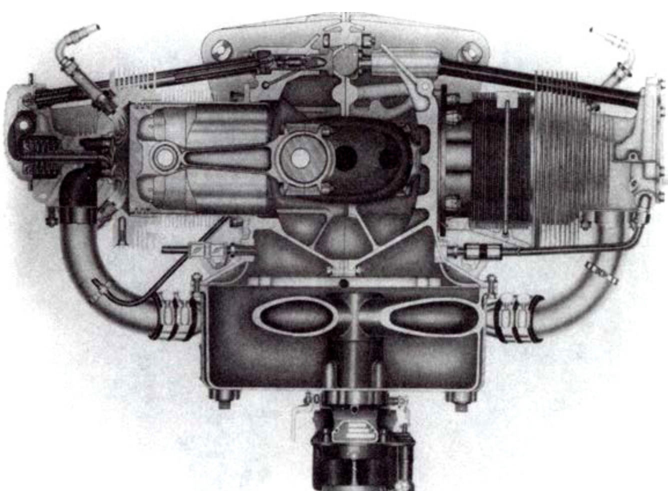


Figure 0-9. Lycoming four cylinder engine cutaway front view.

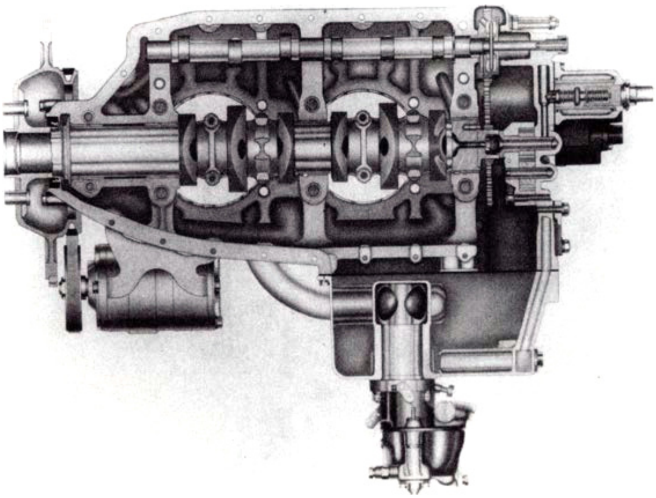


Figure 0-10. Lycoming four cylinder engine side view.

the crankshaft journal. Some bearings are called thrust, or flanged bearings. As the name implies, these bearings have side flanges to control any horizontal fore-and-aft movement of the crankshaft. Split bearings are designed with a crush factor. Each half of the bearing is slightly larger than an exact semicircle. When installed, the face extends slightly beyond the parting surfaces. This slight protrusion is the crush. When both halves of the bearings are in place and the cases are tightened, crush forces the bearings halves tightly into the crankcase bore. A tight fit prevents bearing movement and provides optimum thermal conductivity.

Bearings have oil holes or oil grooves to provide a flow of oil to the bearing surface. Bearing grooves provide a greater flow of oil than a hole. The oil leaving the rod and main bearings is thrown off the crankshaft in a spray. This spray provides oil to lubricate the cylinder, piston, and piston pin. Solid pushrod engines such as the Lycoming 0-235 depend upon splash lubrication to get oil to the valve train. In cold weather the oil must not be too thick or splash lubrication will not occur.

The torque output of the engine is determined by the gas pressure on the piston and the length of the crankshaft throw. The power output of an engine is in units of horsepower (you could also use watts). Power is governed by two variables, torque and rpm. Torque is the result of pressure applied to the pistons. Rpm determines how fast these power impulses occur. To increase horsepower, just increase the rpm's. Instead of installing expensive modifications to increase the horsepower, just adjust the propeller governor higher or flatten the pitch on the propeller.

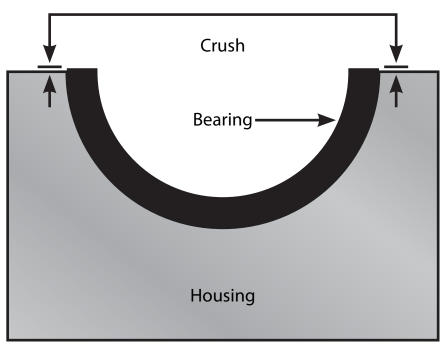


Figure 0-10. Bearing crush keeps the bearings tight in the receiving hole.

As rpm's increase, there is less time for the fuel/air mixture to enter the cylinder. This results in decreased volumetric efficiency. Cylinder pressure produces engine torque and therefore as volumetric efficiency falls, so does the torque curve. As rpm's increase, mechanical efficiency drops off because of increased frictional losses. As a result, more and more of the indicated horsepower is used to overcome frictional and volumetric efficiency losses. There is a limit to the amount of additional horsepower that can be achieved through rpm's. Not all of the power produced by the engine shows up at the propeller shaft. There are two losses: frictional losses and accessory losses. Most practical limitations on rpm's are structural limitations attributable to the inertia loading of parts.

A pilot should know more about his aircraft engine than the typical car driver knows about his engine--the penalty for not knowing is greater in aviation.

—Joe Diblin "Engine Joe"

LYCOMING MODEL CODES

10-540-13B6D

Prefix
L - Left Hand Rotation Crankshaft
T - Turbocharged (Exhaust Gas Driven)
I - Fuel Injected
G - Geared (reduction gear)
S - Supercharged (mechanical)
V - Vertical Helicopter
H - Horizontal Helicopter
A - Aerobatic
AE - Aerobatic Engine
0- Opposed

Displacement
Cubic Inches
A displacement ending in "1" indicates a specific engine model which incorporates integral accessory drive. (541)

Suffix
A or AA Power Section & Rating
3 - Nose Section
B - Accessory Section
6 - Counterweight Application
D - Dual Magneto

An "A" on the end of the engine serial number designates a "wide-deck" engine.

CHAMPION SPARK PLUG DESIGNATION SYSTEM

R H B 37 E

Resistor
None - No Resistor
R - Resistor for Erosion Protection

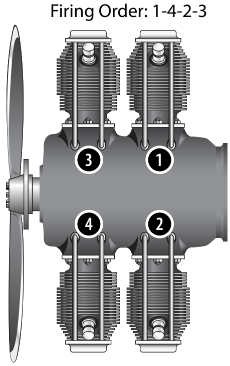
Barrel Style
None - Unshielded
E - Shielded 5/8” - 24 thread
H - Shielded 3/4” - 20 thread (All Weather Plug)

Heat Rating
Low Number - Cold
High Number - Hot

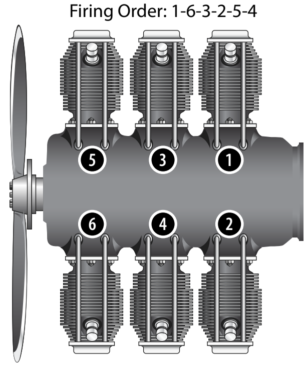
Electrode Design
None - Conventional Style
E - Two Electrode Massive
N - Four Electrode Massive (Obsolete)
S - Single Electrode (Iridium)
B - Twin Electrode
R - Push Wire
Y - Projected Core Nose

Mounting Thread	Reach	Hex Size
B - 18mm	13/16”	7/8
M - 18mm	1/2”	7/8
J - 14mm	3/8”	13/16
L - 14mm	1/2”	13/16
U - 18mm	1 1/8”	7/8

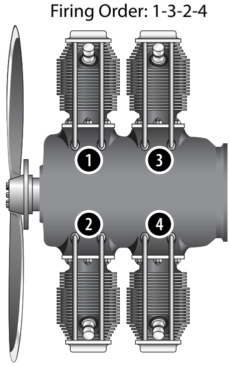
Continental Four Cylinder Engine
Firing Order: 1-4-2-3



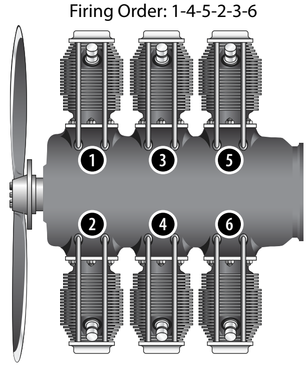
Continental Six Cylinder Engine
Firing Order: 1-6-3-2-5-4



Lycoming Four Cylinder Engine
Firing Order: 1-3-2-4



Lycoming Six Cylinder Engine
Firing Order: 1-4-5-2-3-6



Continental Engine Specifications

MODEL	C.R.	HP	RPM	WEIGHT	HEIGHT	WIDTH	LENGTH
0-200	7.0:1	100	2750	188	23.18	31.56	28.50
0-300-A,C	7.0:1	145	2700	270	23.25	31.50	39.75
0-300-D	7.0:1	145	2700	272	27.00	31.50	36.00
IO-360-A,C,D,G	8.5:1	210	2800	294	24.33	31.40	34.60
IO-360-J, JB	8.5:1	195	2600	294	24.33	31.40	34.60
IO-360,K,KB	8.5:1	195	2600	294	24.33	31.40	34.60
TSIO-360-A	7.5:1	210	2800	300	23.75	33.03	35.84
TSIO-360-C,CB	7.5:1	225	2800	300	23.75	33.03	35.84
TSIO-360-G,GB	7.5:1	210	2700	354	31.90	33.88	33.57
TSIO-360-H,HB	7.5:1	210	2800	313	22.43	31.38	35.34
TSIO-360-K,KB	7.5:1	220	2800	359	26.44	31.30	56.58
O-470-G	8.0:1	240	2600	431	26.69	33.58	37.56
O-470-J	7.0:1	225	2550	380	27.75	33.32	36.03
O-470-K,L	7.0:1	230	2600	404	27.75	33.56	36.03
O-470-M	8.0:1	240	2600	409	19.62	33.56	43.31
O-470-R	7.0:1	230	2600	401	28.42	33.56	36.03
O-470-S	7.0:1	230	2600	412	28.42	33.56	36.03
O-470-U	8.6:1	230	2400	412	28.42	33.56	36.03
IO-470-C	8.0:1	250	2600	431	26.81	33.58	37.93
IO-470-D,E	8.6:1	260	2625	426	19.75	33.56	43.31
IO-470-F	8.6:1	260	2625	426	23.79	33.56	37.22
IO-470-H	8.6:1	260	2625	431	26.81	33.58	38.14
IO-470-J,K	7.0:1	225	2600	401	26.81	33.39	38.14
IO-470-L	8.6:1	260	2625	430	19.75	33.56	43.17
IO-470-M	8.6:1	260	2625	430	19.75	33.56	47.16
IO-470-N	8.6:1	260	2625	433	26.81	33.58	38.14
IO-470-S	8.6:1	260	2625	426	19.75	33.56	41.41
IO-470-U	8.6:1	260	2625	423	19.75	33.86	44.14
IO-470-V,VO	8.6:1	260	2625	423	19.75	33.56	43.69
TSIO-470,B,C,D	7.5:1	260	2600	423	20.25	33.56	39.52
IO-520-A,J	8.5:1	285	2700	431	19.75	33.56	41.41
IO-520-B,BA,BB	8.5:1	285	2700	422	26.71	33.58	39.71
IO-520-C,CB	8.5:1	285	2700	415	19.75	33.56	42.88
IO-520-D	8.5:1	285	2700	430	23.79	35.46	37.36
IO-520-E	8.5:1	285	2700	427	19.75	33.56	47.66
IO-520-F	8.5:1	285	2700	430	19.75	35.91	41.41
IO-520-K	8.5:1	285	2700	428	19.75	33.56	40.91
IO-520-L	8.5:1	285	2700	431	23.25	33.56	40.91
IO-520,M,MB	8.5:1	285	2700	413	20.41	33.56	46.80
IO-520-B	8.5:1	300	2700	422	27.32	37.97	37.97
IO-520-C	8.5:1	300	2700	433	19.78	33.56	43.31
TSIO-520-B,BB	7.5:1	285	2700	423	20.32	33.56	39.75
TSIO-520-C,H	7.5:1	285	2700	433	20.04	33.56	40.91
TSIO-520-D,DB	7.5:1	285	2700	423	22.34	33.58	43.25
TSIO-520-E,EB	7.5:1	300	2700	421	20.32	33.56	39.75
TSIO-520-G	7.5:1	300	2700	433	20.04	33.56	40.91
TSIO-520-J,NB	7.5:1	310	2700	412	22.50	33.56	54.36
TSIO-520-K,KB	7.5:1	285	2700	412	20.32	33.56	54.36
TSIO-520-L,LB	7.5:1	310	2700	514	20.02	33.56	50.62
TSIO-520-M,P	7.5:1	285	2700	436	20.04	33.56	40.91
TSIO-520-R	7.5:1	285	2700	436	23.54	33.56	40.91
TSIO-520-T	7.5:1	310	2700	426	32.26	33.56	38.20
TSIO-520-U,UB	7.5:1	300	2700	536	28.86	33.56	44.73
TSIO-520-V,VB	7.5:1	325	2700	456	20.41	33.56	39.25
TSIO-520-W,WB	7.5:1	325	2700	539	20.02	33.56	50.62
L/TSIO-520-AE	8.5:1	250	2400	365	21.38	33.29	38.07
TSIO-520-AF	7.5:1	285	2600	418	23.54	33.56	40.31
TSIO-520-BE	7.5:1	310	2600	566	33.50	42.50	42.64
TSIO-520-CE	7.5:1	325	2700	527	25.00	34.00	41.00
GTSIO-520-C	7.5:1	340	3200	481	23.10	34.04	42.56
GTSIO-520-D	7.5:1	375	3400	508	26.78	34.04	42.56

Continental Engine Specifications (continued)

MODEL	C.R.	HP	RPM	WEIGHT	HEIGHT	WIDTH	LENGTH
O-235-C	6.75:1	108/115	2600/2800	213	22.40	32.00	29.56
O-235-L,M	8.50:1	105/112/118	2400/2800	218	22.40	32.00	29.05
O-235-N,P	8.10:1	103/110/116	2400/2800	218	22.40	32.00	29.05
O-320-A,E	7.00:1	140/150	2450/2700	244	22.99	32.24	29.56
AEIO-320-E	7.00:1	150	2700	258	23.18	32.24	29.05
AEIO-320-D	8.50:1	160	2700	271	23.18	32.24	30.70
O-320-B,D	8.50:1	160	2700	255	22.99	32.24	29.56
IO-320-B,C	8.50:1	160	2700	259	19.22	32.24	33.59
LIO-320-B,C	8.50:1	160	2700	259	19.22	32.24	33.59
O-360-A	8.50:1	180	2700	265	24.59	33.37	29.56
O-360-F	8.50:1	180	2700	270	19.96	33.37	31.83
IO-360-B	8.50:1	180	2700	270	24.88	33.37	29.81
AEIO-360-A	8.70:1	200	2700	299	19.35	34.25	29.81
AEIO-360-B	8.50:1	180	2700	275	24.64	33.37	29.81
IO-360-A,C	8.70:1	200	2700	293	19.35	34.25	29.81
LIO-360-C	8.70:1	200	2700	306	19.48	34.25	33.65
TO-360-C	7.30:1	210	2575	343	21.02	36.25	34.50
TO-360-F	7.30:1	210	2575	343	21.02	36.25	34.50
TIO-360-C	7.30:1	210	2575	348	21.65	33.37	35.82
O-540-B	7.20:1	235	2575	372	24.56	33.37	37.22
O-540-J	8.50:1	235	2400	356	24.56	33.37	38.93
O-540-L	8.50:1	235	2400	369	20.43	33.37	38.93
O-540-A	8.50:1	250	2575	356	24.56	33.37	38.42
O-540-E	8.50:1	260	2700	375	24.56	33.37	37.22
IO-540-C	8.50:1	250	2575	375	24.46	33.37	38.42
IO-540-D	8.50:1	260	2700	381	24.46	33.37	39.34
AEIO-540-D	8.70:1	260	2700	384	24.46	33.37	39.34
IO-540-K	8.70:1	300	2700	438	19.60	34.25	38.93
IO-540-S	8.70:1	300	2700	444	19.60	34.25	39.24
AEIO-540-L	8.70:1	300	2700	445	24.46	34.25	38.93
TIO-540-C	7.20:1	250	2575	456	30.33	33.37	40.38
TIO-540-S	7.30:1	300	2700	502	26.28	36.02	39.56
TIO-540-A	7.30:1	310	2575	511	22.71	34.25	51.34
TIO-540-F	7.30:1	325	2575	514	22.42	34.25	51.34
TIO-540-R	7.30:1	340	2575	521	22.60	34.25	51.52
(L)TIO-540-J	7.30:1	350	2575	518	22.56	34.25	51.50
(L)TIO-540-U	7.30:1	350	2500	547	22.59	34.25	47.40
(L)TIO-540-V	7.30:1	360	2600	547	24.44	34.88	53.21
(L)TIO-540-W	7.30:1	360	2600	536	23.55	34.88	54.19
TIGO-541-D,E	7.30:1	450/425	3200	706	22.65	34.86	57.57
IO-720-A,B,D	8.70:1	400	2650	568	22.53	34.25	46.08
O-320-B2C	8.50:1	160	2700	255	22.99	32.24	29.56
HIO-360-B1A	8.50:1	180	2900	290	19.38	33.37	32.09
HIO-360-D1A	10.00:1	190	3200	321	19.48	35.25	35.62
(L)HIO-360-F1AD	8.00:1	190	3050	293	19.97	34.25	31.36
VO-435-A1F	7.30:1	260	3400	399	24.13	33.58	34.73
V0-435-B1A	8.70:1	265	3200	430	24.02	34.11	39.46
TVO-435-D1A	7.30:1	270	3200	465	35.67	33.58	34.73
O-540-F1B5	8.50:1	260	2800	369	24.56	33.37	37.22
HIO-540-A1A	8.70:1	290	2575	474	19.60	34.25	39.34
VO-540-C2A	8.70:1	305	3200	441	25.57	34.70	34.73