TBO, TOH, MOH

Clarifying some terms that are often confusing to the airplane owner

by KEN GARDNER / AOPA 132319

■■ Aircraft maintenance is an expensive situation and becoming more so each year. However, there are some redeeming features designed into the airplane that are seldom, if ever, found in other types of private transportation vehicles. The general aviation airplane is designed to last indefinitely if reasonably cared for.

The basic all-metal airframe is subject to little, if any, deterioration when well maintained. Of course some components are subject to wear and eventually need to be replaced or repaired. Fortunately not many of the components subject to wear are designed to be "throwaway" replacements. The reciprocating aircraft engine, for example, is designed for the most part to be completely rebuilt when necessary. The question becomes how long the engine can be expected to operate without extensive repair.

Aircraft engine manufacturers are required to provide some figure that can serve as an expectant safe engine life prior to a major overhaul (MOH). Consequently most aircraft sales brochures and sales people reflect the expected time to overhaul in terms of engine hours.

This yardstick is defined as time between overhaul (TBO). In itself this abstract is somewhat misleading between what it is intended to imply and what is often mistakenly assumed. Let's say your particular engine has a TBO figure of 1,500 hours. Most owners realize that this does not mean 1,500 hours of operation without maintenance. What many do not realize is that it *does not* mean the engine absolutely will make it through 1,500 hours of operation without an overhaul.

The TBO figure is a *recommended* figure and not a guarantee and furthermore the TBO is predicated on engine operation and required maintenance within the confines of its manufacturer's recommendations. Abuse such as overlean mixtures, extended times between oil changes, inadequate maintenance, etc., will most certainly reduce the possibility of achieving a recommended TBO. It is also possible that an engine will have to be top overhauled (TOH) for various reasons such as insufficient activity prior to its actual attainment of its recommended TBO. (A TOH is limited to work on components on "top," or above the crankcase of the engine—valves, piston rings, of one or more cylinders—and is much less extensive and expensive, than an MOH.)

For example, let's say a 2,000-hour-TBO engine required a *top* overhaul at 1,000 hours but actually reached 2,000 before needing a major overhaul. Under these circumstances the owner might have been disappointed because the top overhaul was needed and assumed that his engine should have gone all the way to 2,000 hours prior to *any* overhaul.

The term TBO implies time between *major* overhaul and does not apply to such maintenance as a top overhaul. This misinterpretation is quite common and, I must admit, a rather logical assumption. The engine manufacturers would do well to change the abbreviation to TBMO and thereby eliminate the confusion between major and top overhauls.

Another misconception about TBO is

TBO, TOH, MOH continued

that a major overhaul is mandatory upon reaching the recommended TBO limit. It is not mandatory for private owners; only commercial applications such as airlines, and some air taxis, etc. are so affected. When the engine does reach its recommended TBO the private owner may elect to overhaul or to continue operating.

For continued operation beyond the recommended TBO, it would be to the owner's advantage to have the engine checked by a licensed A & P mechanic and certified in the engine log book as airworthy for a 100-hour period beyond the TBO. Operation would be continued beyond the TBO in 100-hour increments with the aforementioned checks at the end of each 100-hour period. This proc-

ess could be continued for as long as the A & P mechanic determines the engine to be airworthy for another 100-hour period.

The owner pursuing operation beyond TBO should also be aware of the chance involved. I knew of a situation where an owner reached the recommended TBO for his engine and it was operating so well he elected to continue on with the 100-hour increments. The recommended TBO of 1,600 hours was surpassed by an additional 700 hours. Needless to say he was quite pleased with all this bonus time until a magneto coupling failed on takeoff. Pieces of the failed coupling became entangled with the accessory gear train, causing its subsequent failure followed by complete engine failure.

The resulting engine and aircraft damage caused by the off-airport forced landing more than negated the bonus of those 700 hours. That magneto coupling would likely have been replaced had the engine been overhauled at the recommended 1,600 hours. Such possibilities are part of the chance that you take with extended operation beyond the recommended TBO.

In a similar situation another owner reached the recommended TBO of 1,500 hours and continued operation to 2,200 hours. At this point the engine was removed for overhaul. The crankshaft, camshaft and cylinders were all worn beyond service limits, necessitating expensive work usually not needed on first overhauls. Wear of engine parts is greatly influenced by the amount of clearance between moving parts. Wear causes these clearances to increase and as clearance increases wear is accelerated, causing even greater clearances.

Under normal operating conditions an engine wears more rapidly during the latter part of its life and principally because of increasing clearances. Had this owner chosen to overhaul at 1,500 hours he might have saved considerable money, in fact, from $600 to 800. This is another of the chances involved with extended operation beyond recommended TBOs.

Many owners wonder how the TBO is arrived at and who actually decides what it shall be. Some believe that the FAA arbitrarily determines TBOs. In the beginning the FAA did ask the engine manufacturers to come forth with some numbers as to just how long any given engine model could be expected to provide safe and reliable service prior to a major overhaul.

I don't believe any engine builder relished the idea of such an "over the barrel" commitment; however, without some set of guidelines it would be anyone's guess and that could be anything anyone wanted it to be. Needless to say, the present TBO recommendations are better than the alternative. So the engine manufacturers set about determining a reasonable amount of hours between an MOH for each model engine. Establishment of TBOs is predicated on actual field experience and not on theoretical or test cell possibilities.

If field experience indicates that a particular engine model will usually operate quite satisfactorily for 1,000 hours between major overhauls, that is a logical place to start. Both Avco Lycoming and Teledyne Continental Motors receive many "run out" engines (those that have reached or extended beyond their recommended TBOs) in exchange for factory remanufactured engines.

In the course of rebuilding these run-outs much is learned about how the engines were operated, maintained and,

subsequently, how they fared under those conditions. Similar information is received from the worldwide field organizations of the firms.

When all of this information is compiled it is possible to determine if existing TBOs are on target, too low or perhaps too high.

Barring unforeseen difficulties, operated with the recommended procedures and properly maintained, an aircraft engine should easily reach its TBO. During a Cessna Aircraft Co. service test of its model 336 Skymaster a total of 1,200 hours was accumulated on its two Continental IO-360 series engines. A service test is actually an accelerated wear test conducted by the company's engineering department. Each test flight lasts about 2.5 hours and is repeated from dawn to dusk and sometimes at night.

The Skymaster was at full gross load for the first 600 hours. Every piece of radio and electrical gear was on at all times or as necessary for each test flight. Much of this testing was conducted in the months of July, August and September when conditions are hot and dusty. Imagine eight takeoffs and landings an hour for the first hour of each flight, and on a rough dirt field to boot. I know exactly what it is like because I was one of the pilots in that service test.

At 1,200 hours both engines were removed and sent to Continental Motors for examination. The examination of both disassembled engines revealed excellent results with virtually no appreciable wear. From those glowing reports one could conclude that the IO-360 engine could easily top 2,000 or maybe 2,500 hours in average service where conditions would never be that severe, but is that really true? In this test the engines operated seven days a week, all day every day and cooled down only at night when maintenance was performed. That alone makes a difference in engine wear.

Then, too, this machine was maintained by factory mechanics and was at all times flown in strict accordance to factory recommendations. The test accomplished exactly what it was supposed to do, an accelerated wear under tough but not abusive conditions. The ultimate purpose was to assure that the machine would do what its manufacturer claimed and nothing less. Thus the TBO numbers were based on average conditions, not the best, nor the worst.

Mentioned earlier is the top overhaul (TOH), which consists of piston ring and valve service. Engines, especially those operated quite infrequently, will sometimes lose compression and/or commence burning oil prior to reaching the TBO. Under such circumstances the A & P mechanic removes the cylinders and performs the necessary repairs. Often the cylinders will be sent off to an engine rebuilding facility where their walls will be rehoned or even reground if necessary.

The valves are removed, inspected and reground or replaced. Valve seats are also reground and the valve guides replaced if necessary. New piston rings are installed and the cylinders reassembled. Thus a complete top overhaul includes servicing and/or replacement of valves, seats, guides and piston rings.

Sometimes only a few or even one of an engine's cylinders may require overhaul. A top overhaul by no means constitutes a major overhaul and is nowhere as involved. Most engines usually make it to their TBOs and the necessity for a TOH along the way does not constitute failure to make its TBO. Having to top overhaul an engine before it reaches its TBO may not be as gloomy as you might think.

Let's consider a present-day, high-performance, single-engine airplane. The engine has a TBO of, say, 1,500 hours and it needed a top overhaul at 900 hours. At first it may seem that the owner lost out because there were still 600 hours to go to the TBO but, remember, that 1,500-hour TBO was a time to a *major* overhaul, not a *top* overhaul. Consider that this owner got a conservative 170 mph for 900 hours; that's 153,000 miles on those piston rings and valves. How many stock automobiles

will do that on 65% to 75% power for 153,000 miles? When this engine did reach its recommended TBO it gave the owner 255,000 miles on all of the internal parts and, what's more, those parts did not end up shot, only some were worn to replacement.

When an engine eventually does reach it's recommended TBO the owner has several choices. He can replace it with a brand-new engine on an exchange basis. This would be the most expensive route. A brand-new Continental IO-520-L for a Cessna 210 would cost approximately $10,800 providing the run-out engine is acceptable upon its return to the factory. Or he could replace it with a remanufactured or rebuilt engine. A factory rebuilt engine of the same type would cost about $7,900 with acceptable exchange of the owner's run-out engine. This is quite similar to a new engine because it is completely restored to the same clearances and tolerances as a new engine.

If ordered from the original engine manufacturer such an engine will have the same warranty as the new engine. Rebuilt engines are also available from individual rebuilders in the field and in some cases with even better warranties than the original engine manufacturer might offer. For example, the IO-520-L engine mentioned earlier could be rebuilt for about $5,800 if an owner chose an independent rebuilder.

Or an owner could choose to have his engine major overhauled. Such an MOH constitutes a complete disassembly of the engine with all parts being checked and inspected for airworthy condition. The engine is reassembled to service limits and any parts not within service limits must be replaced with parts that are, or with new parts.

At this point the owner should be well advised as to the difference between an MOH and a rebuilt or remanufactured (both of the latter terms describe the same situation) engine. The engine manufacturer establishes two distinct sets of limits for engine clearance tolerances. Closer tolerances are required for rebuilt and remanufactured engines than for major-overhauled (service limit clearance tolerances) engines.

Earlier I mentioned that wear accelerates with increasing clearance. Since an MOH is permitted greater tolerances, the clearances will be greater than those allowed for new or remanufactured-rebuilt engines. Consequently one cannot honestly expect an engine that has gotten an MOH to give the same length of service as an engine built or rebuilt to the closer clearances of new engine tolerances. While an MOH initially is less expensive than a remanufactured or rebuilt engine, it very well may not be as economical in the long run, especially if the owner plans to keep his airplane for a long time. (An MOH for the IO-520-L engine would cost in the $4,200 to $4,600 range.)

Quite frequently I am asked why aircraft parts are so expensive, especially when many of them are made by the same companies that make automotive parts. One reason is that they are made for long service. For example, I recently had the opportunity to examine a Continental Motors TSIO-520 crankshaft that had just been replaced after 9,000 hours of service to its owner. The replacement cost of this particular crankshaft was approximately $2,900. While that seems like a lot of money for one part, that crankshaft delivered a conservative 1,530,000 miles at 170 mph for most of its life.

That crankshaft went through five rebuilds as well as its first 1,500 hours. Based on its replacement cost it operated for $.32 per hour or $.0019 per mile. That kind of service certainly puts a different light on the replacement cost. I realize that the average owner probably won't put 9,000 hours on his airplane, but it does happen and perhaps more often than some may realize.

I have seen light, twin-engine aircraft built as late as 1963 with over 14,000 hours on their airframes. One major oil company operated a fleet of small, single-engine aircraft for pipe-line patrol and all had over 10,000 hours on the airframes. At a conservative cruise that still comes close to one million miles.

Without a doubt the general aviation aircraft is designed and built to fully utilize the service that is built into the engine. □