Look what They are doing to our engines

Modification of aircraft, and the engines that power them, is a very popular activity today. Magazine articles frequently tell us of the wonderful changes which occur when a modification has been incorporated; unfortunately, these articles and those who develop and sell modifications often do not touch on the detrimental side effects which may result from the modification. Without question, there are modifications which are well engineered and which provide a positive benefit. The problem is that when we get excited about the prospects of the benefit side, we tend to forget that there is no free lunch - we don't get the benefit for nothing. The purpose of this discussion is to point out some of the hidden problems and costs of engine modification.

Before getting to specifics, it would be well to establish a background for this discussion. Think for a moment about how heavily you rely on that Lycoming engine every time you fly. How can you be so comfortable, and so sure the engine will continue to give you power for flight hour after flight hour? Isn't it the excellent reputation of the company, and the solid engine that you place your confidence in? This does not mean that absolute perfection has been achieved. Any mechanical device may malfunction, wear out, or at some time cause a problem for its owner. All of these things may occasionally apply to a Lycoming reciprocating engine, but we know that any problem we experience with a factory engine will probably not be life threatening.

Did this reputation for reliability just happen? No, it is the result of more than 60 years of experience with aircraft engines. That does not mean that the same individuals who engineered the Lycoming engines of the 1930s and 1940s are still at Lycoming. It does mean that their experience has been passed on. What has been learned from thousands and thousands of hours of test-stand running and engineering flight tests over all of those years provides a solid data base of knowledge which is used to insure that a certified Lycoming engine is a safe and reliable device when operated and maintained as recommended by the manufacturer.

With this background, take a look at some of the modifications being advocated today: for example, "Change pistons and increase the compression ratio of the engine." This does increase the horsepower an engine is capable of producing. It is a tactic Lycoming engineers have used for years. Any Lycoming engine with a compression ratio of 8.00:1 or higher requires 100 octane aviation gasoline and has undergone extensive flight testing to establish an adequate detonation margin.

An individual or company who proposes to make your engine more powerful, by whatever means, will usually concentrate on selling the benefits the modification will bring. You have an airplane powered by a Lycoming 0-235-K, L, or M engine, for example, and are told that by simply changing the pistons it will be possible to get your aircraft off the ground more quickly, to climb faster, and to cruise faster. This sounds wonderful, and it is true. You ask, why didn't Lycoming make the engine like this to start with? Well remember this, it was made that way, but it proved to be less than satisfactory.

By looking at the engine model certification sequence, we find that the O-235-engine started as a low compression engine. The C and E models had a compression ratio (CR) of 6.75:1 and used 80 octane aviation gasoline. Knowing that higher compression ratios (CR) increase engine efficiency and that 100 octane fuel would help to prevent detonation at the higher CR, Lycoming certified the 0-235-F and G models in 1971. The 9.70:1 CR gained 10 horsepower, allowing the new models to be certified at 125 HP. It did not take long to find that although these engines ran well in the test cell, installing them in aircraft and turning them over to pilots in the field produced poor results. Failure to follow critical fuel management procedures resulted, in some cases, in detonation, preignition, and burned pistons. Not many of these engines were installed in airplanes.

The next step for Lycoming was to find a compromise between a 6.75:1 and a 9.70:1 CR which provided acceptable performance and increased detonation margin. The testing which followed led to certification of the 0-235-K, L, and M series engines with a CR of 8.50:1. When the recommended 100 octane aviation gasoline is used in these engine models, burned pistons are rarely ever encountered.

The O-235 is just one example of an engine being modified to something Lycoming engineers already know will demand much closer attention to proper operating technique than the original. An individual called the factory recently and said that he intended to modify a 290 horsepower IO-540 engine by replacing the 8.70:1 CR pistons with 10.00:1 CR pistons. This engine would certainly produce more horsepower, but there are at least three problems. First, the modified engine would not be a certified model and therefore could only be used in an airplane which is operated in the EXPERIMENTAL category. Second, the engine would require a full rich mixture setting over much of its operating envelope in order to avoid detonation. And third, Lycoming models certified for more than 290 horsepower are designed with a heavier crankshaft. Both the higher horsepower with the lighter crankshaft and the increased exposure to detonation make the engine less reliable. This is a modification which is unacceptable in view of Lycoming experience.

The point of this discussion is to show our readers that Lycoming, as a company, has expended a great deal of effort, and has gained a great deal of experience. The result is engine models which generally can be expected to operate reliably as they are certified. When it is suggested that one of these engines should be modified by installing high compression pistons, remember that it was done years ago with poor results. When a modifier with much less experience than Lycoming proposes a change that is almost certain to produce the same poor results, Lycoming is concerned for the engine owner who may believe that this simple change can have no harmful effect.

Another favorite modification is the add-on turbocharger. Are there benefits which become available when this is done? Of course, and anyone who might consider adding a turbocharger will be well aware of those benefits as well as the price of the installation. But will they be aware of hidden costs, such as the possibility that a turbocharger may cause problems which will void the engine warranty, or that modifications to any engine invalidate manufacturer TBO recommendations? At first glance, these policies may seem somewhat unfair to the engine owner who wants to add a turbocharger. But again, the engine manufacturer must rely on the lessons learned from many years of experience.

The first Textron Lycoming model to be turbocharged was FAA certified in 1961. Since that time, about 60 additional turbocharged engine models have been certified. The factory turbocharged engine has a number of design features not usually included on factory-built, normally aspirated engines. These features are incorporated to help the engine withstand the additional heat and pressure generated by the turbocharger and to reduce the possibility of detonation. Low compression pistons help to deal with detonation. Valves and valve guides are made of materials that are more heat resistant. Heat is also carried away from the pistons by oil that is delivered to the back of the piston by oil squirts placed in the engine especially for this purpose. And finally, before an airframe is certified with any factory engine, the fuel flow and detonation characteristics of that engine are carefully checked. This detonation survey insures that power settings specified in the Pilots Operating Handbook provide an adequate margin so that detonation and associated engine damage will not occur under any normal operating circumstances.

When a Supplemental Type Certificate (STC) is issued to allow addition of a turbocharger to a Lycoming engine, the high-compression pistons usually stay in the engine and oil squirts are often not available for cooling. On the surface, it may seem that maintaining a manifold pressure of 30 inches or less should cause the engine to operate about the same as a normally aspirated engine. In fact, the engine runs much hotter because the turbocharger heats the air as it compresses it. Because the turbocharger must work harder and harder as the air becomes less dense with an increase in altitude, the engine may run very hot during climb and during cruise at altitude. The hot running engine with high compression pistons must depend heavily on excess fuel for cooling; this makes correct leaning a critical pilot task. Over the years, Lycoming has received numerous reports of burned pistons in engines that have field installed turbochargers. From this, and for the reasons stated earlier, it has been concluded that in many cases there has been no detonation survey or the survey did not provide enough data to establish reliable power setting and leaning procedures. It can be very expensive to learn about the detrimental effects a turbocharger may have on an engine after the installation is already in your airplane.

If you are considering the addition of a turbocharger to your Lycoming engine, be prepared to ask a lot of hard questions (a list is printed with this article) before putting your money and your engine on the line. You can help yourself by obtaining a copy of FAA Advisory Circular 23.909-1. The subject of this AC is "Installation of Turbochargers in Small Airplanes with Reciprocating Engines." This circular reinforces previous paragraphs of this article when it states that "induction air temperature may become critical at altitude because of the increased compression of air required" and "the addition of the turbocharger to an engine not specifically designed for it may affect carburetor inlet and induction air temperature to APPRECIABLY REDUCE THE DETONATION MARGIN." Several other related items in the AC include such statements as detonation characteristics may be unsatisfactory, a new recommended overhaul period should be established, the standard diaphragm type fuel pump is not adequate to supply a turbocharged engine with fuel under all operating conditions, and the change in the engine power to altitude relationship should be evaluated to determine if propeller certification is valid.

Advisory Circular 23.909-1 also mentions the installation of an intercooler, another popular addition to the turbocharged engine installation. The AC warns of several items that must be considered when an intercooler is installed. It recommends careful evaluation of changes to engine power, cooling characteristics, operating limits, and operating procedures. It also states that addition of an intercooler is likely to significantly affect engine horsepower.

If engineered and controlled properly, an intercooler installation can provide benefits such as a cooler running engine and higher altitude capability. Engine owners should be wary of an add-on intercooler installation from which improved takeoff and climb performance are claimed. Only increased power can improve takeoff and climb performance, and this would indicate that rated engine power is being exceeded as a result of the power generated from cooler induction air. To stay within the FAA certified limits for the engine, manifold pressure and/or RPM settings may need to be reduced when an intercooler is installed. The exact power settings to be used can only be determined by extensive in-flight testing and careful torque meter measurement of the power being produced. If this is not done, the reliability of the engine becomes questionable. This is the reason that Textron Lycoming Service Instruction No. 1009 states, "Reliability and average service life cannot be predicted when an engine has undergone any modification not approved by Textron Lycoming."

Polishing and porting is yet another fad which is receiving a great deal of attention these days. If you are sold on the idea that this type of engine modifying is done in automobile racing circles all the time, consider that the TBO on an automobile racing engine may be less than 100 hours; would you be satisfied if that were all you could expect from your aircraft engine? Magazine advertisements have claimed that cylinder porting will add five horsepower per cylinder. If the added five horsepower per cylinder is a fact, this engine is outside its certified limits and would be illegal except in an experimental category aircraft.

What modifications can be made to a cylinder to achieve the power increases that are claimed? Polishing alone might improve airflow and efficiency slightly, but it is not likely that this improvement would change the power of the engine enough to be noticeable in the aircraft performance. To go a step further, if the cylinder head ports were ground out just a bit, a larger charge of fuel and air would generate additional power. Again, this kind of change would affect the legal certification of the engine. It would also affect reliability because less material in the cylinder head results in reduced strength. A recent report in the aviation press indicates that at least two sets of cylinders subjected to this procedure were found to be unairworthy when inspected by A & P mechanics and FAA inspectors. One of these sets of cylinders had been flown at least through a normal engine break-in period. Cracks were found in the port areas of these cylinders when they were inspected.

To conclude, this article is not intended to discourage innovation. It is meant to educate readers who can easily see and understand the benefits of an engine modification, but who may not be aware of the effect a modification can have on reliability and life expectancy of the engine. Years of experimentation and thousands of engines in the field have given Lycoming engineers and service representatives an excellent knowledge of what will work, and what will not work. This knowledge comes from problems and failures as well as successes. It is from this experience that reliable engine models are developed. The information shared in this article is provided to help engine owners. If you own a Lycoming engine and are contemplating a modification of any kind, use the list of questions provided to help get all the facts. Be sure you are completely satisfied that the modification will leave you with an engine which is legal, safe, and reliable.