The Dreaded Engine Overhaul

Part I: Selecting an Engine Shop and Accessories

TEXT AND PHOTOS BY VICKI CRUSE

Performance Aero Engine's clean, organized shop

The assembly room

IF YOU OWN an airplane, there is one maintenance item that will make you cringe more than any other. It's an engine overhaul. The idea of going through this process scares a lot of people for a number of reasons: It's expensive, time-consuming and requires a lot of decisions regarding options. This is why many people opt not to overhaul an engine and sell the airplane before it reaches TBO. Take a look in *Trade-A-Plane*, and you'll see airplanes with high-time engines selling below their expected price because the owner does not want the added expense of overhauling the engine. In most cases, you will not recoup 100 percent of the overhaul cost if you sell your airplane shortly after the overhaul.

To provide a little more knowledge regarding the engine overhaul process, we are going to take you through it from beginning to end with my airplane. As a result, the process should be much easier when it comes time for you to do the same.

Why an Overhaul?

My airplane is a 1981 Christen Eagle with an AEIO-360-A1D engine. In Lycoming nomenclature, "AE" means the engine was designed for aerobatics and has a wet sump, "I" indicates it is fuel-injected and "O" means the cylinders are opposed. This engine is rated at 200 hp.

The engine was new when it was put in the airplane 17 years ago, and I have had no nagging maintenance problems. I have owned the airplane since 1995 and have put 475 of its 1000 hours on it. I am the fifth owner of the airplane, including the builder, so I don't know much of the history prior to my ownership, with the exception of the third owner, who put about 300 hours on the airplane over a two-year period. I do know the airplane sat for several years without being flown.

Your first thought might be, "Why overhaul the engine with only 1000 hours on it?" The airplane is used in aerobatic competition. More than 400 hours of aerobatics in the last two years have resulted in paint cracking and paint loss on the upper wing. Seventeen years is a long time to have a wood-and-fabric aerobatic airplane without recovering the wings; it is impossible to tell what damage may be lurking under the fabric, so I decided it was time for a rebuild.

One of the most complex parts of a Christen Eagle is the paint; mine has a nine-color paint scheme. In addition to recovering the wings, I decided to have the entire airplane rebuilt because it would have been foolish only to recover the wings when there were other improvements that could be made to the airframe. In addition, it would have been hard to match the new paint on the wings to the old paint on the fuselage. In other words, it would have been like restoring a 1955 Cadillac convertible but not replacing the old, faded top.

What does paint have to do with an engine overhaul? Since the airplane was going to be out of commission for the rebuild, I thought it wise to have the engine overhauled at the same time. My fear was having a brand-new airplane to fly, flying it for a few hours and then needing to have the engine overhauled. Having to stop part way into the aerobatic season for major maintenance spells disaster, especially if you're planning to fly a number of contests through the season.

Another reason for the overhaul was to replace the original crank flange with lightening holes for weight reduction with a new solid crank flange. Lycoming determined that lightening holes in the crank flange reduced the weight (something important for aerobatic use) but were also prone to cracking between the holes, especially on aerobatic airplanes. The stresses encountered on some maneuvers resulted in hairline cracks developing in the flange. An advisory was published suggesting replacement crank flanges at a lower-than-new price. The problem is that the engine case must be opened to do this, so it made sense to wait until the engine was being overhauled to tackle this task. Magnaflux tests every 50 hours showed the flange was still in good shape.

Once the decision was made to overhaul my plane's engine, the next thing was to find a shop to do the work.

Engines awaiting disassembly

Selecting an Engine Shop

This is probably one of the hardest parts of the overhaul process and the least pleasant. Selecting the accessories you want is fun, but choosing and dealing with the shop that overhauls your engine can be a nightmare. So, where do you start? The best place is with your friends at the airport. Ask around and seek out information on shops your friends have used or ones they've heard about. Whether you choose John Jerry's Engine Shop or Mattituck, the selection process is the same. If you choose to send out the components and overhaul your engine yourself (under a mechanic's supervision), the same rules for choosing a component shop apply. If you can't get any recommendations from friends, remember that engine shops often advertise, so you can find them that way. Another good source is the publication, *TBO Advisor*, which visits and reviews engine shops. Back issues are available by calling 203/834-0330.

Ask your friends if they were happy with the work. Was it done right the first time? Were they happy with the customer service? If they called with a question, did they get an answer right away, or did they have to keep calling to get one? Was the work done on schedule? Did the shop stick to the quote? Were there any surprises along the way? Did the shop try to sell them accessories they didn't need? And perhaps most importantly, would they go with the same shop if they had to have another overhaul?

Once you have narrowed it down to a few places, give them a call, tell them what engine you have and what you want done. You will be asked a lot of questions that will better enable them to help you get what you want. In some cases, you'll have to make a few decisions up front, such as new or rebuilt cylinders, but you should arrive at a quote that can be compared to others, once you've called all the shops you are considering. Also be sure and ask what the turn-around time is for the overhaul. Will it be six to eight weeks or six months?

A word about references: You can certainly ask for references from a shop, but you are more than likely going to get happy customers. After all, why would a company give you a reference for a customer who wasn't happy? Nevertheless, it's worth a shot, because while the customer may be very happy with the engine, he may not be happy with the service. If customer service is important to you, this is information you'll want to know.

Even better than calling is visiting the shop. Schedule a time to visit and take a tour. This can be important and is worth the investment, if you are new to engine overhauls like I was. Some things to think about when visiting a shop are: Is it busy? Is it clean? How many engines are stacked up waiting to be overhauled? How does the office look? Is it organized? Is the reassembly area clean? Do they have any special equipment? Do they run the engine before shipping it out? Do they have a dynamometer to tell how much horsepower the engine is producing? What's the attitude of the owner? Does he seem interested in your business or just in a hurry to get you out the door?

Another consideration that seems to be debated is service after the sale. One of my concerns was, what if something isn't quite right after the engine is put on the airplane? For this reason, I wanted a shop that was reasonably close to where the airplane would be, once the rebuild was complete—just in case. Most of the time, this is not an option, because there isn't a shop in everyone's backyard. If you have a problem once the engine is back on the airplane, it's likely that your mechanic will be the one that fixes it or gets the solution from the shop. The engine will probably not be sent back to the engine shop, so proximity isn't really important. Nonetheless, I wanted one in my general vicinity.

There are certainly a number of factors that go into choosing a shop to do an engine overhaul, and you have to decide what is most important to you. For instance, you may really want a shop with a dynamometer or one that specializes in experimental engines. Customer service may be very important to you, or you couldn't care less, to the point where you don't want to hear from the shop until the engine is finished. Word-of-mouth is important in the overhaul business, so listen to people around the airport, and get as much input as you can before you make your decision.

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Engine Shop Checklist

Research

- Ask friends and mechanics for recommendations.
- Read shop reviews.
- Ask for references (as a last resort).

Visiting the Shop

- Talk to the owner and/or chief mechanic.
- Is the owner friendly or in a hurry for you to leave?
- Take a tour of the shop.
- Is it clean and efficient?
- Is it organized?
- How many engines are awaiting overhauls?
- Does the shop have any special equipment?
- How long will it take from the time the engine is received?

Engine Shop Questions

- What is included in the overhaul price?
- Does the shop overhaul accessories?
- Will it credit you for things you don't want (mags, starter, etc.)?
- What repairs and replacement parts are included, if any?
- Do you get new or rebuilt cylinders?
- Is the engine balanced?
- Does the shop have a test stand or dynamometer?
- What deposit is required and what are the payment terms?

Cylinders awaiting reassembly

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Decisions, Decisions, Decisions

As you select your shop, questions are going to come up about the work you want done. You may have a lot of choices in some cases, and they will affect the price of the overhaul. Also keep in mind that some shops do not overhaul accessories such as magnetos, but they should be able to send them out for you or let you have your mechanic do it. Things like this will also affect the quote price, so be sure and ask about everything.

After talking with friends, mechanics and three shops, as well as reading reviews and visiting two shops, I made my decision and chose Performance Aero Engines in La Verne, California. I liked what I saw at the shop and what I heard from people who have used the company. In addition, the owner, Ron Monson, flies an aerobatic airplane using an engine he overhauled. The company does a lot of work with experimental aircraft engines. These engines can be "tweaked" to get a little more horsepower and can use the latest technology parts not yet approved for use on certified engines. Certified engines are also overhauled at this facility but cannot enjoy some of the perks available to experimental engines, although the overhaul process is essentially the same.

In the case of my engine, I had to decide whether I wanted new cylinders or wanted my cylinders rebuilt, providing nothing major was wrong with them. My initial feeling was to go with new cylinders because it sounded better. Newer is better, right? With this came a significant price difference. After speaking with Monson, I decided it made no sense to go with new cylinders, since mine only had 1000 hours on them. If these cylinders had been rebuilt a few times, new cylinders would have been the best choice, but this was not the case.

The overhaul also assumes the engine is in such a condition that all major parts are rebuildable. Repairs, replacement parts and complying with missed ADs will be added to the cost of the overhaul. So, if you have a cracked cylinder or case, expect to pay to have those repaired or replaced.

The price of the overhaul included a number of accessories, including magnetos, spark plugs, a harness, fuel pump, lightweight starter and lightweight alternator. This is where I made a few changes. Prior to choosing a shop, I had decided to go with a lightweight starter and alternator, so I had already purchased them. Consequently, the price of those items was deducted from the overhaul price, and I was given my old starter and alternator to do with as I wished. I also chose iridium spark plugs instead of normal plugs because they burn hotter and are less prone to oil-fouling. They also last considerably longer than normal plugs and as a result, are more expensive.

In addition to the normal accessories, I chose a couple of other options to be done to the engine. I wanted a special oil sump that is lighter-weight, provides better oil-cooling and maintains oil pressure for longer periods during certain aerobatic maneuvers. Also with this system is an induction manifold, which does not let the heat of the oil increase the temperature of the inlet air, thus, robbing horsepower. In addition, I decided to go with slightly higher compression pistons. The engine originally came with 8.7:1 compression. However, I chose to go with 10:1, which would give me a little more horsepower, yet not be so detrimental to the engine to cause the TBO to be significantly less (determining TBO on an aerobatic engine is nearly impossible, since the engine is not flown like an engine on a certified airplane). The pistons are not reused, so choosing higher-compression pistons did not add additional cost to the overhaul.

I also decided to use my old Bendix mags, even though the cost of the overhaul included new Slick mags that are lighter. In my case, every chance to drop some weight is a priority on my list. However, just one year ago, I had my Bendix mags overhauled. I shelled out more money for this overhaul than the new Slicks cost. I decided to save myself a little money here and was credited the price of the new Slick mags.

The Next Step

Once you've chosen a shop, the next step is getting your engine to it. If you are close by, you can drive it over, but most shops have some arrangement with a trucking company and will ship you a specially made box in which to put the engine and accessories (if you aren't having them overhauled somewhere else). You can probably expect to pay a 50 percent deposit to begin work on the engine.

If you use a little common sense and listen to those around you who have been through the process, choosing an engine shop to perform your overhaul doesn't need to be a difficult task. If you have some time, make the effort to carefully select a shop and ask a lot of questions. Visiting a shop can make or break your decision.

Above all, make sure you are happy with your choice before you ship your engine. The last thing you want is to deal with a shop that doesn't respond to your needs, doesn't perform the work on time and is a nightmare to deal with.

The Engine Overhaul

Part II: Disassembly and Overhaul

BY VICKI CRUSE

PART I OF this series discussed choosing an engine shop and selecting accessories. This part will take you through the disassembly of an engine and the overhaul of individual components. The next step will be installing the engine on the airplane and break-in.

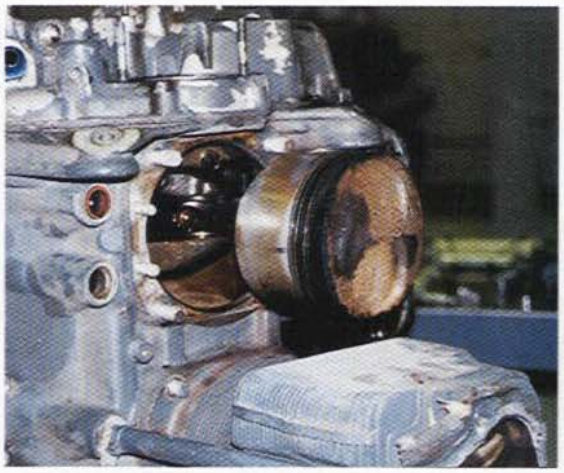
A Little Background

If you missed the first part, we're working on overhauling a 200-hp Lycoming AEIO-360-A1D from a 1981 Christen Eagle. The engine had 1000 hours since new and a little over 450 hours put on it in the past two years. This is not a lot of time on the engine, and there were no nagging engine problems. The Eagle, which is flown in aerobatic competitions, is being rebuilt, providing a perfect opportunity to work on the engine at the same time.

The overhaul process is essentially the same from shop to shop. However, some shops specialize in certain types of engines, and not all work can be done in-house. In addition, shops also vary in their tolerances for components. Some work within the engine manufacturer's parameters, while others work within those parameters, but with tighter tolerances. For instance, engine company X may say opposing pistons must weigh within 20 grams of each other, while the engine shop may insist they weigh within 2 grams of each other.

Both the airplane and the engine are getting some "tweaking" to make them better for competition, but nothing will be done that should detrimentally affect either over time. As a result of the work being performed on the engine, it will be an experimental engine when it leaves the shop. The overhaul described here is typical for most engines, although some work I am having done may not specifically apply to your engine. Because this engine will emerge as an experimental, meaning it is no longer a certified Lycoming engine, the procedures done to it have been described so those with a certified engine will know what work cannot be done. The engine is being overhauled by Performance Aero Engines in LaVerne, California.

VICKI CRUSE



PERFORMANCE AERO

LEFT: The piston from cylinder #4 showing signs of oil bypassing the rings. RIGHT: A cylinder undergoing porting and polishing.

Surprise, Surprise

In part I of this series, we talked about choosing a shop, and one of the criteria I wanted was proximity to it. This is convenient, if you want to see your engine being disassembled or if you want to check up on it during the overhaul process. However, proximity isn't anything an airline ticket won't fix. I was fortunate to be a short flight away from where the engine was being overhauled, and while I was excited about learning more about the process, I was a little apprehensive about what they would find when the engine was torn down.

It's like the saying from the movie, *Forrest Gump*: "Life is like a box of chocolates; you never know what you're going to get." In the case of an engine, this is the last thing you want, so watching the disassembly can cause a little anxiety. After having left the engine and airplane in late September, the engine and I were reunited in the engine shop, where it was given a job number and a multishelved cart for all its parts. It was mounted on a stand and a little more naked without the pipes and hoses. Bird feathers were found under the baffling between cylinders one and three. This was the result of a bird strike by the previous owner about four or five years ago.

During the disassembly, the mechanic does a visual inspection of the engine and notes any failures or other problems the customer will want to know about immediately. The accessories, including the magnetos and fuel pump, were removed first. Next came the spark plugs, valve covers and oil sump. So far, no surprises. The cylinders were removed, one by one. Looking at a Lycoming engine from the front, cylinder number one is the front left cylinder. Cylinder two is the front right, cylinder three is the back left and cylinder four is the back right.

The first cylinder to be removed was number four. This cylinder had experienced oil bypass problems in the past. Fouling of the lower spark plug became a big problem twice in the last year. However, the fix involved installing new plugs in the cylinder, and the problem went away. Upon removing the cylinder, we found evidence that oil had bypassed the rings. We also found some rust in the barrel of the cylinder, probably as a result of the airplane sitting idle over the years. The other cylinders were removed, and the remaining three pistons looked similar to those from cylinder number four, although not as bad. The pistons are discarded, but I requested that one be cleaned as a souvenir. Rust was found in all the cylinder barrels.

Next, the accessory case was removed. All the gears were in great shape and were removed for cleaning. The source of a nagging oil leak from a previously repaired tach cable seal was found.

Finally, the moment of truth arrived,

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of the bearing bores, since half a bearing is in each case half. To remedy this, the case is put back together, and the bearing bores are now align-bored to a standard size. The bearings are then installed.

The case then goes through a corrosion-protection and painting process. The case is alodined to remove and inhibit corrosion and then primed with zinc chromate. It is then painted with a three-part epoxy, baked and cured, resulting in a very tough paint.

Crankshaft

The crankshaft is cleaned, visually inspected and Magnafluxed to check for cracking. It is either micropolished if it is to remain a standard-size, or it is ground to undersize. Most crankshafts are micropolished, unless they have had a failure and metal has been introduced into the engine, resulting in grooves in the crankshaft. In this case, the crankshaft must be ground to the next undersize. With a crankshaft a few thousandths of an inch undersize, new bearings must be used that are the same thousandths of an inch undersized to allow for standard clearances between the parts.

A special machine used by Performance Aero Engines is a Vectorgraphic balancing machine, which dynamically balances the crankshaft in two planes. The crankshaft—with all the parts that are going to be rotating with it, including counterweights, adapters, pins and rollers, and flywheel—is placed in the machine. The crankshaft then begins spinning. A display shows the crankshaft's state of balance in two different planes and indicates where and how much material needs to be removed to achieve perfect balance. With a perfectly balanced crankshaft, the engine will run smoother and longevity will be increased.

Many engine shops don't have a machine like this. As a result, Performance Aero Engines often balances crankshafts for other shops. Prior to choosing a shop to do your overhaul, ask if the shop dynamically balances the crankshaft and what procedure is used.

Camshaft

The camshaft is visually inspected and Magnafluxed to check for cracking. My camshaft had a worn lobe, which is common, and was rendered unusable. Performance Aero Engines offers a choice for the camshaft—regrind it or get a new one. If the camshaft is not considerably worn, it can be reground. If needed,

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certified engines receive a new camshaft.

For experimental engines, the new camshaft receives a high-performance profile. A new camshaft has a stock profile that doesn't necessarily allow for maximum compression of the engine. Performance Aero Engines grinds the camshaft for a high-performance profile that creates a different lift duration and timing of the engine. This changes the compression and allows for more manifold pressure and, consequently, more power from the engine.

Connecting Rods

The connecting rods are rebuilt. The caps are cut, and the larger end is resized. New bolts and nuts are used, and the small ends are rebushed. They are then put in a rod-boring machine that sets the center-to-center dimension identically for each connecting rod. The machine used to do this is accurate to 50 millionths of an inch. The rods are then statically balanced using a digital gram scale. All reciprocating parts, those that are opposed bays to each other (cylinders one and two, for example), such as connecting rods, end caps, pistons and piston pins, are statically balanced. Lycoming allows for a difference of 14 grams or a 1/2 ounce between parts in opposing bays. However, Performance Aero Engines takes this down to 1 gram.

Assembly

When the engines are ready for assembly, the pieces are brought into a pressurized clean room. The air going into this room is filtered and temperature-controlled, with just enough pressure to prevent unfiltered air from entering the room, even through the open door. A gauge outside the room shows the slightly positive pressure maintained in the assembly room.

The parts go through a final wash and are laid out and inspected once again. The engine is actually assembled three times. First, the cases are assembled with no parts in them and the dimensions are checked. The cases are then taken apart and the bearings are put in. The cases are reassembled. The inside diameter of the bearings and the part that will be riding in it are checked together. This gives a bearing clearance. This process is done because, even though the individual parts may be dimensionally correct, when put together, the clearance may not be acceptable.

The case is disassembled again and the engine assembly begins. The assembly procedure begins with the crankshaft on the engine stand. The connecting rods, crankshaft gear, seal and counterweights, as applicable, are attached to the crankshaft. Next, the cases are subassembled. The crankshaft is removed from the stand and placed inside one-half of the case with the camshaft. The case is closed and the halves torqued together. The case then goes back on the engine stand. The cylinders are attached, along with the accessory case, gears, oil pan and finally, the accessories, such as intake tubes, return lines and magnetos.

At this point, the engine may be placed on a test stand or dynamometer—if the shop has this equipment. At the time this engine was overhauled, Performance Aero Engines' dynamometer was being set up. A test stand is just what the name implies: It's a stand to which the engine is mounted and run to check for oil leaks and any other problems. A dynamometer applies load to an engine much as a propeller does. The engine produces power and the dyno tries to stop it by creating a load on the engine. The dyno measures rpm and torque and translates this into horsepower. It can also measure engine parameters, such as oil pressure, temperature and manifold pressure.

After being removed from the test stand or dynamometer, the engine is placed in a shipping container with manuals for new accessories (if any), break-in instructions and any accessories the customer will install, such as an exhaust system. It is then sent out the door.

Keep in mind that engine shops are highly variable businesses, and the overhaul you receive may differ slightly from the one described here. Nevertheless, the basic procedure should be the same. As previously stated, some shops do not do all the work in-house and do not offer some of the procedures described here. It's best to go into the process with as much knowledge as possible and know exactly what you are getting. Hopefully, this article has helped. If you are about to have your engine overhauled, take a look at the first installment of this series (see "Aircraft Tech," "The Dreaded Engine Overhaul—Selecting an Engine Shop and Accessories," April 1999, page 86), if you haven't read it already. It will give you some helpful information about choosing an engine shop.

The last part of this series will cover engine reinstallation and break-in. It begins with the engine arriving in the shipping crate, mounting the engine, replacing baffling and hoses, efficiently running wires in the engine compartment and the all-important break-in of a newly overhauled engine. You'll learn a few secrets along the way, such as why you can never have too many tie-wraps!