GAS TURBINE ENGINES INSTRUCTIONS FOR CONTINUED AIRWORTHINESS **WHY?**

by Ralph **Hawkins** | *Contributing Author*

This is the second in a two part series. In the series first part that was published in our June/July issue, Ralph Hawkins discussed the why of using engine start carts, ground idle compressor speeds and in-flight cruise engine temperatures. In this article Hawkins discusses the why concerning compressors, silicon dioxide, fuel nozzles and sulfidation.

To re-cap the introduction from part one of this article, gas turbine engine manufacturers make aircraft engines (i.e., turbojet, turbofan, turboprop and turboshaft.) These manufacturers provide Instructions for Continued Airworthiness (ICA), usually in the form of an overhaul manual, maintenance manual, a service bulletin specifying the life limits for life limited parts (e.g., compressor and turbine disks and sometimes turbine blades.) Service bulletins also specify recommended engine overhaul intervals and recommended hot section inspection/repair intervals, and possibly additional documents. These ICAs are then approved by the airworthiness regulatory authority of the country of engine manufacture (e.g., Federal Aviation Administration, Transport Canada, et al.) The only alternative to this is to prepare your own Instructions for Continued Airworthiness or have someone else do it for you. Then you provide a suitable (that is detailed) substantiation for your "instructions" and submit your Instructions for Continued Airworthiness to your country's airworthiness regulatory authority for approval. As someone who has prepared alternative Instructions for Continued Airworthiness, I can tell you that the preparation is difficult and the substantiation is worse. The final result is the ONLY Instructions for Continued Airworthiness that are allowed to be used are the ones that have been approved by the appropriate airworthiness regulatory authority.

These Instructions for Continued Airworthiness tell you what to do, but often lack an adequate explanation of WHY. The purpose of this article is to explain why. Since I have spent the past 28 years working on Pratt & Whitney Canada PT6A turboprop and PT6T turboshaft engines, I will use those engines as examples, but these general principals apply to all gas turbine aircraft engines.

Compressor

In 1983 when I began working in a PT6A & PT6T engine overhaul facility, the conventional wisdom was that there were two ways to make a PT6 engine run well – spend $10,000 on the compressor or spend $30,000 on the hot section. Twenty-eight years of inflation has increased these dollar amounts, but the three to one ratio has NOT changed. This illustrates the importance of compressor maintenance. Every mechanic knows that only a small amount of ice or snow accumulation on a fixed wing aircraft's wing will significantly degrade the lift that the wing can produce. The rotating blades and the stationary vanes in a compressor are also adversely affected by anything that degrades blade and vane surface finish and airflow. Regular motoring washes with clean water only helps remove loose "dirt" and contaminants that cause airfoil corrosion. Periodic but less frequent performance recovery washes with a cleaning compound and water help remove stuck on "dirt" and contaminants. Both the compressors and turbines MUST be rinsed with clean water after any wash procedure. Then run the engine to dry it out. Obviously you must follow the engine manufacturer's specific wash instructions. A clean compressor is a more efficient compressor. A more efficient compressor requires less fuel to produce the same power. A lower fuel flow rate at the same power level reduces hot section temperature, prolongs hot section life and provides a modest fuel savings. At today's high jet fuel prices, modest fuel savings can pay for the time and cost of the wash procedures. Many engine manufacturers recommend the use of de-ionized water. A machine to produce de-ionized water is expensive! As an alternative, many mechanics go to Wal-Mart and purchase DISTILLED water in one gallon plastic bottles. Distilled water at Wal-Mart is less than $2.00 per gallon and it only takes 4 gallons of distilled water to wash a PT6 engine. It is also necessary to periodically examine the compressor looking for dirt, corrosion, etc. If dirt etc. is observed, changes to the wash procedure or wash schedule are necessary.

Silicon Dioxide

The chemical name for ordinary beach sand is Silicon Dioxide. Plain old fashioned dirt contains a large percentage of Silicon Dioxide. Turbo prop aircraft can stir up sand and dirt during takeoff and landing, especially when propeller reversing is utilized. Helicopters can stir up even larger quantities of dirt during takeoff and landing. This stirred up sand and dirt can be ingested into the engine. When the sand and dirt particles are struck by the compressor blades, they are shattered into a very fine dust. Air from the compressor that is contaminated with this fine dust is then extracted to pressurize the engine labyrinth seals that help keep the oil in the bearing compartments. This process allows the dirt/dust to enter and contaminate the engine oil system. Grit mixed with moving air is called sand blast. Grit mixed with a moving liquid is called slurry blast. Once a mechanic realizes an engine oil system that is contaminated with dirt/dust is a flying slurry blast machine, and that engine oil is slurry blasting the ball and roller bearings, gears, etc., in the oil system, the mechanic understands the need for careful monitoring. Periodic Spectrometric Oil Analysis is a very effective means to monitor the quantity of silicon in the engine oil. Obviously when elevated silicon levels are detected, oil filter cleaning along with an engine oil change is necessary. Companies such as Aviation Laboratories and Jet-Care International can perform spectrometric oil analysis on an oil sample to measure the amount of silicon, as well as other metals in an engine oil sample. At the same time, Aviation Laboratories can analyze the debris from your oil filter to determine which metallic alloys, etc., are present in your oil filter debris. The cost of this analysis is reasonable and provides a major benefit. Additionally the regular utilization of inlet covers and exhaust covers helps minimize the entry of dirt and sand into the engine(s) while the aircraft is parked.

Fuel Nozzels

The purpose of the fuel nozzles is to atomize the fuel into very tiny droplets (e.g., a fine mist.) It is important to keep the fuel nozzles in proper working condition to continually properly atomize the fuel. As the fuel nozzles condition deteriorates, the size of the fuel droplets begin to increase. The fuel droplets are only able to burn on the surface. As a result slightly larger fuel droplets will not burn completely and very find carbon particles can be produced. The air flowing through the turbine vane ring (i.e., turbine airflow nozzle) approaches the speed of sound. These very fine carbon particles can then erode the coating off turbine nozzles and turbine blades. Leading edge tip erosion on the first stage turbine blades is frequently caused by faulty fuel nozzles. As the condition of the fuel nozzles continues to deteriorate, the size of the fuel droplets continues to increase. When the fuel droplets are sufficiently large they will not burn completely, and unburned fuel droplets will impact the turbine nozzle airfoils (vanes) where they will splatter. If you have seen napalm attacks in movies or on television, you can easily visualize the damage that fuel droplet splatter can do to turbine vane rings. The Pratt & Whitney Canada PT6A maintenance manual recommends an initial fuel nozzle inspection and cleaning interval of 400 hours, and allows this to increase to 600 hours provided that the fuel nozzle condition is satisfactory.

On the other hand the MORE Company's PT6A Instructions for Continued Airworthiness only allows a maximum fuel nozzle inspection and cleaning interval of 300 hours, and requires this to decrease if fuel nozzle condition is NOT satisfactory. Engines using the MORE Company inspection interval almost never have fuel nozzles that are not flowing properly at the end of the MORE Company's inspection interval. Repair stations that inspect and clean PT6A fuel nozzles usually only charge a few hundred dollars to clean and inspect an engine set of fuel nozzles. In the long run, shorter fuel nozzle inspection intervals can save money.

Sulfidation

Pratt & Whitney Canada has written two Service Information Letters (SILs) that are helpful in understanding sulfidation. They are SIL No. 1023 "Sulfidation Attack" (May 20, 1985) (i.e., ref 1), and SIL No. GEN PT6-016 "Sulfidation Attack" (Mar 9, 1998) (i.e., ref 2). When iron or steel is attacked by oxygen, they corrode. We call this corrosion rust. When high nickel alloys or high cobalt alloys are attacked by sulfur, they also corrode. We call this corrosion sulfidation. Sulfidation "is caused by the condensation of an alkali metal salt, usually sodium sulfate, on the surface of the part." (Ref 1). "Most aviation turbine fuels contain traces of sulfur in sufficient amounts for sulfidation to occur if a source of sodium is present." (Ref 1). Sodium (e.g., sodium chloride (i.e., salt) is found in the air above salt water up to an altitude of one mile, along with air pollution, volcanic dust, gasses and agricultural chemicals. Ref 1 contains a map of the United States showing where sulfidation occurs. The Atlantic, Pacific and Gulf coasts have sulfidation problems caused by salt water. The North East (i.e., the portion of the United States that is both north and east of Saint Louis, Missouri,) has sulfidation problems caused by air pollution. The South East (i.e., the portion of the United States that includes Louisiana through South Carolina,) has sulfidation problems caused by air pollution. Last year a volcano in Iceland erupted throwing enormous amounts of volcanic dust and gasses into the atmosphere. My local television weatherman said that both the Icelandic volcano and the La Nina weather pattern were the cause of our severe winter weather.

In summary, it is impossible to fly anywhere in the Northern Hemisphere without encountering sodium to a greater or lesser degree from one or more of these sources. "A proven method of minimizing sulfidation is the turbine desalination wash using plain water". (Ref 2). More frequent wash intervals are appropriate for heavier contamination. Ref 2 says that chromium aluminide, platinum aluminide and Sermaloy J (i.e., silicon aluminide) have improved sulfidation resistance. Based on my experience with Parts Manufacturer Approval (PMA) replacement parts, Sermaloy J seems to be the better coating choice in small and medium PT6A turboprop engines. The washes that I mentioned previously while discussing compressors have a two-fold benefit in that these washes benefit BOTH the compressor and the hot section.

"It has been suggested that the power level at which an engine is operated may have an effect on the rate of sulfidation." (Ref 2). "PWC does not recommend attempting to resolve a sulfidation problem through changes in operating regime." (Ref 2). Two real world examples will help illustrate this point. The maximum turbine inlet temperature (i.e., CT vane inlet temperature) on a PT6A-20 engine is 1821°F (994°C). The maximum inter- turbine temperature (i.e., CT blade outlet temperature) on a PT6A-20 engine is 1382°F (750°C). The power turbine blade exhaust temperature is approximately 1000°F (538°C). "Researchers have found that sulfidation attack takes place when condensate coated surfaces operate at temperatures in the range of 1250° to 1800°F." (Ref 2). Hence most of the hot section parts will be exposed to some degree of sulfidation. The PT6A-21, PT6A-28, PT6A-34 and the PT6A-

114A have the same compressor, combustion chamber liner, CT blades, PT vane ring and PT blades. PT6A-21 and PT6A-28 have the non-air cooled CT vane ring, while the PT6A-34 and PT6A-114A have the air cooled CT vane ring. The maximum allowable operating temperatures for these four engines are significantly different, and this significantly affects where sulfidation usually occurs. PT6A-21 maximum temperature is 1283°F (695°C), and the most frequent sulfidation location is the CT vane ring. PT6A-28 maximum temperature is 1382°F (750°C), and the most frequent sulfidation location is the CT blade airfoil. PT6A-34 maximum temperature is 1455°F (790°C), and the most frequent sulfidation location is the CT shroud segments. PT6A-114A maximum temperature is 1481°F (805°C), and the most frequent sulfidation location is the underside of the CT blade platform. These examples show that sulfidation will continue to occur, and significant changes to the engine operating temperature will only change the location where the sulfidation will occur.

Summary & Conclusion

The older and more experienced engine mechanics are already familiar with the topics in this article. Hopefully these more experienced mechanics will consider this article a helpful refresher course. As for the younger and less experienced engine mechanics, it is hoped that the lessons provided in this article will be used to prevent the kinds of problems that cause prematurely gray hair. This can be said another way. There is a very old cliché "Pay me now or pay me later." The choice is yours!

ABOUT THE AUTHOR

Ralph Hawkins is the Chief Engineer for MORE Company, Minden NV. MORE Company holds eight Federal Aviation Administration Supplemental Type Certificates (STCs) providing alternative Instructions for Continued Airworthiness for PT6A engines. These STC(s) prescribe an enhanced inspection methodology that allows the operator and their mechanics to recognize engine problems in their early stages and to correct them promptly. In turn, the prompt correction of engine problems allows the engine overhaul interval to be safely extended to 8,000 flight hours. These eight MORE STCs include several of the techniques mentioned above as well as several additional techniques that are especially well suited to the PT6A turbo prop engines. The MORE Company STCs apply to PT6A-11 through PT6A-45R and PT6A-110 through PT6A-135A engines. MORE Company began providing the use of their alternative Instructions for Continued Airworthiness to operators in the autumn of 1993. As of January 20, 2011, there were 1782 PT6A engines operating in thirty nine countries that are now or had been using MORE Company's STCs. MORE's web site is www.morecompany.net ◄