FUEL INJECTING THE JACOBS ENGINE

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In the past few years there has been much discussion about the viability of fuel injecting the Jacobs and other small radial engines. In this article I would like to present an overview of what has been done and recount our experiences in certifying such a system.

The Jacobs R755 series engine is a seven-cylinder air-cooled radial engine supplied with fuel by a one barrel Bendix Stromberg updraft carburetor. The fuel/air mixture is delivered from the carburetor to the cylinders through an induction chamber cast integral with the engine power case, and then through steel intake pipes to the cylinder heads. This induction system can be compared to an octopus with seven tentacles, each of varying length. As with other radial engines of similar design, the R755 engines suffer from widely varying cylinder head temperatures (CHT) and exhaust gas temperatures (EGT) from cylinder to cylinder due to the inefficiencies of this poor fuel/air delivery system. Below are EGT readings taken from a Jacobs R755B2 (275hp) engine that displays the characteristic disparity in EGT from cylinder to cylinder due to uneven fuel mixture distribution.

JACOBS R755B2 at cruise power (21 inches and 2000 rpm) 2000 ft altitude Full rich

cylinder #	EGT (F)	cylinder #	EGT (F)	cylinder #	EGT (F)
1	1230	2	1310	3	1190
4	1240	5	1345	6	1360
7	1385				

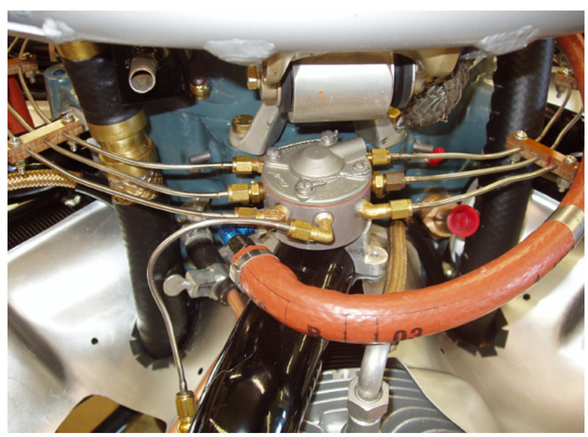
Cylinder #7 (the leanest cylinder) and cylinder #3 (the richest cylinder) display a 195 degree difference in EGT. When the engine is leaned, it is being leaned to #7 alone, leaving six other cylinders with varying degrees of an overly rich mixture. This rich condition in most of the cylinders contributes to several problems:

1. Excessive fuel consumption. The rich condition in all but one cylinder causes a higher than necessary fuel consumption.
2. Uneven power production, cylinder to cylinder. If only cylinder #7 is receiving an optimum fuel mixture, then it will be the only cylinder producing its potential power. Cylinder #7 may be producing 42 hp, whereas cylinder #3 with its overly rich mixture may only be producing 33 hp. In addition to the lack of overall power, another result of this condition is:
3. Engine roughness. It was only after we began to run the Jacobs engine with fuel injection and experienced the turbine-like smoothness that accompanied it, that we realized just how rough the carbureted engines are.

4. Exhaust valve deposits. This is probably the most serious result of running with an overly rich mixture in some cylinders. In the twenty two years that we have overhauled and maintained Jacobs engines we have observed many instances of excessive carbon and lead deposits building up on the valve and valve seat, causing a loss of compression. In nearly all these cases, the problem valves were running in the overly rich cylinders. The exhaust gas temperatures were just not high enough to burn the deposits. All the above factors led us to consider fuel injection as a possible correction to the weaknesses in the Jacobs (and most other small radial engine's) fuel delivery system.

Through the years, several Jacobs fuel injected engines have been tested. In the mid 1970s Page Industries designed and test ran a fuel injected R755 engine that showed great promise. However, the project was terminated due to a lack of funding. In 1986 a Canadian STA (equivalent to our STC) was issued for the installation of a Jacobs R755-9 on the Cessna 195. The one aircraft that was converted has been flying successfully since that time. In 1999 and again in 2001, Radial Engines, Ltd. overhauled Jacobs R755B2 engines that were subsequently fitted with fuel injection systems. Both of the aircraft were licensed in the Experimental Category and demonstrated the viability of fuel injection on the Jacobs engine.

In 2001, Radial Engines, Ltd. began designing a Jacobs fuel injection system for certification on standard category aircraft. The decision was made to use the tried and tested Bendix RSA10 series fuel injection servo with its matching flow divider (all from the IO-720) along with adapter plates top and bottom to match perfectly the height of the carburetor which it is replacing (minimal air box modifications necessary). Photo here shows the flow divider. GAMI injector nozzles were chosen to optimize fuel flow to match cylinder airflow. The nozzles inject fuel directly into the intake port of each cylinder through specially modified intake pipes. An engine driven fuel pump and electric boot pump are utilized to provide the required 26 psi. fuel pressure. The entire system requires very little modification to the engine or airframe for installation, and is for the most part a bolt together installation.



Detonation testing

In the summer of 2004 we ran extensive FAA supervised tests with fuel injected Jacobs 275 and 300 hp engines on our dynamometer. Horsepower calibrations with and without fuel injection, detonation tests, and vibration surveys were done. The engine experienced very even EGTs cylinder to cylinder, about two gallons per hour less fuel consumption than with a carburetor, and the smoothest Jacobs engine that we had ever run. The 300 hp engine was then installed on a Cessna 195 and a fuel flow test, unusable fuel test, hot fuel test, and engine-cooling test were accomplished. Around Christmas of 2004 the 275 hp Jacobs engine was installed on a WACO Classic YMF-5 and this aircraft went through the same ground and flight-testing as was done with the Cessna 195. All testing was successful and shortly thereafter we were granted three fuel injection STCs. We now have numerous systems installed both on Cessna 195s and WACOs, and the performance of these fuel-injected engines has met and exceeded our expectations. Plans are underway to fuel inject other radial engines as well as to install those engines on other models of aircraft.

Unusable Fuel Test – left slip

Unusable Fuel Test – right slip

Hot Fuel Test

Engine Cooling Flight Test