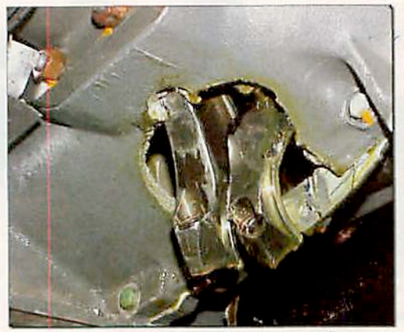


Colloquially known as "ventilating a crankcase," (left) crankshaft failures are most often catastrophic in nature.



Dave Leonard's turbocharged Mazda 13B-powered Van's RV-6 (right).

Bear with me as I steadily get to the point. It takes the crank 1 second divided by 40 (or 0.024 seconds) to rotate once. To rotate from noon to 3 o'clock it took one quarter of that or 0.006 seconds. Therefore, the piston accelerated from a dead stop to 55 fps (or 37 mph) in only 0.006 seconds! The average acceleration is then 9200 feet per second in one second. Well now, let's see. One G is only 32 feet per second, so 9200/32 is about 290 G! And that is just the average. Peak acceleration means probably twice that.

Let's assume for the moment that the connecting rod, the piston pin and the piston with the rings weigh 7 pounds. They all move the same way the piston does. Mr. Newton said, and he seems to be right, that force equals weight times G. The 3-pound piston alone looks like 870 pounds to the rod in the form of inertial load. Mr. Connecting Rod has to push or pull that 870-pound piston back and fourth once every 0.006 seconds. As far as Mr. Crankpin is concerned, that 7-pound collection of parts looks like it weighs about 2000 pounds.

This is a simplification of course. The compression and combustion pressure loads sometimes add to and sometimes subtract from these inertial loads. I cannot imagine a piston engine made without lightweight pistons. The piston engine, as we know it today, would not be possible without aluminum pistons.

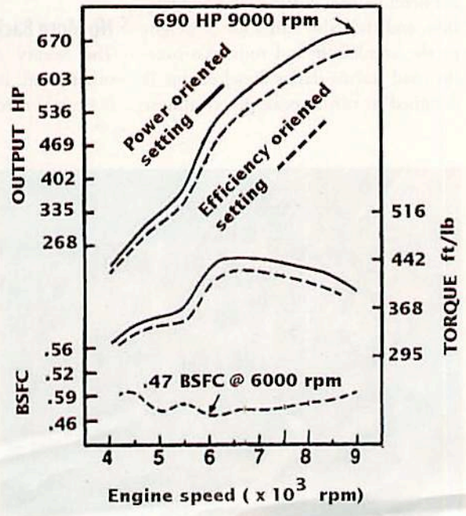
## Oh, So Tired...

Metal fatigue happens when the force and, therefore, the stress repeatedly reverse on a part. The cylinder spacing, rod length, rod journal diameter, main journal diameter and cylinder bore all have a large effect on the fatigue life of a piston-engine crankshaft.

According to Charles Fayette Taylor, in the seminal *The Internal Combustion Engine in Theory and Practice, Volume 2*, the major problem with piston-engine crankshafts is the fillet radius between the rod and main journals and the crank cheeks. The fatigue limit stress can be as little as 5% of the breaking stress of the crankshaft if these fillet radii are too small. The fatigue limit is defined as that stress level where the part will live indefinitely. Usually if the crank does not crack in 2 million revolutions (or 13 hours at 2500 rpm and max power), it will live forever. Nobody does that test, however. The FAA engine certification test requires full power at sea level for only 5 minutes at a time. If you run an aircraft engine mostly at 75% power, it will probably last about 2000 hours.

Unlike a traditional aircraft engine, the automotive engine cylinder spacing is too close to allow adequate fillet radius in the crank cheeks. Engine size and length are everything to an automotive design engineer. The engines are absolutely no larger than they need to be, and they're not that large to begin with thanks to liquid cooling. Cylinder spacing was a major factor that held back the Orenda V-8 aircraft engine, which was based on a Chevrolet big-block V-8.

If you run an automotive piston engine at 6000 rpm and full power, you will exceed 2 million cycles in about 6 hours. Automobile engines only reach full power for a fraction of a second in a flat-out acceleration run, but there is some modest manifold pressure and horsepower level where the auto engine will live indefinitely. That level tends to remain unknown because most auto engines are designed to run indefinitely




1991 Le Mans winning four rotor engine.

Power from small packages is the Wankel hallmark, but look at the torque curve starting at 6000 rpm. You don't have to spin this engine to the stars to have good torque production.

*Photos: Courtesy Paul Lamar*





while generating only about 50 horsepower or less. What you wind up with is an engine that has a poor power-to-weight ratio or a limited life when used in an aircraft, where the expectation is for use of a high percentage of maximum power over the life of the engine.

These limitations can be circumvented to a certain extent, and the life of the engine increased, by substituting better materials such as forged and heat-treated 4340 for the cast iron typically found in automotive crankshafts and rods. But this increases the cost of the engine almost to the point of a traditional aircraft engine, while the TBO is unlikely to exceed 1200 hours.

What if we increase the diameter of the rod and main journals to provide more overlap? This will work—up to a point. Plain journal bearings have a limited range of ratios of diameter to width in which they will work. If the diameter is too large relative to the width (read cylinder spacing), dynamic oil pressure in the space between journal and rod or between journal and main saddle will be lost and the bearing will fail. Large-diameter journal bearings also add friction, and they also add a lot of weight to the crankshaft and rods. An over-the-road tractor-trailer diesel engine is designed to run at peak power almost




Crankshaft failures usually start at the highly stressed web-to-journal fillet.

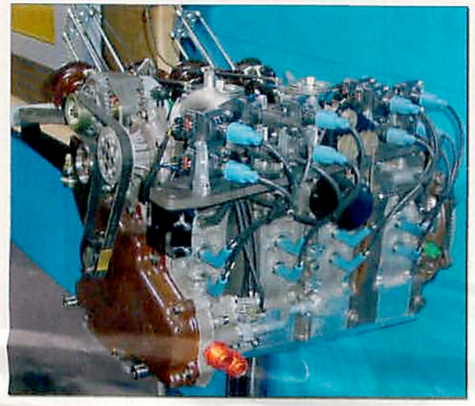
indefinitely. Such a 300-hp piston engine would weigh in the neighborhood of 2000 pounds.

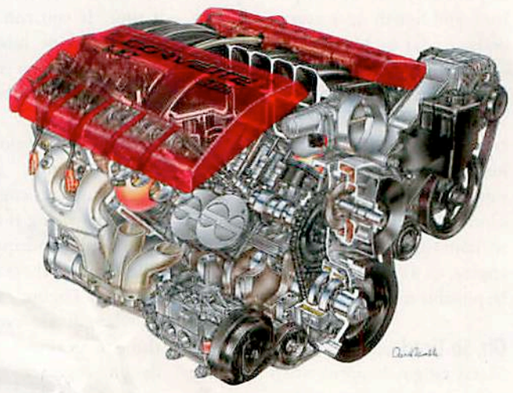
If you are going to design a V-8 or V-12 aircraft piston engine, you need to start with a clean sheet of paper. The V engines (and all other in-line piston engines) are trying to shove their crankshafts through the bottom of the blocks. The extra main bearing structure required to support this is heavy. A horizontally opposed engine will weigh less due to the more efficient structural layout. The load from one side is partially balanced by the load from the opposite side.

## No More Back and Forth

The beauty of the Wankel, on the other hand, is that the eccentric shaft is straight through, yielding no concentrated stress problems up through four rotors and maybe more. The loads on the eccentric shaft are always in one direction; they do not reverse. Load reversing is what causes metal to fatigue. Consequently, the life of an eccentric shaft is unlimited, and the same thing can be said of the rotor. If the wear of the seals and the sliding surfaces can be reduced to low levels, the life of the rotary could be 10,000 hours or more. There is some evidence that silicon-nitride ceramic apex seals moving on the chrome-plated rotor housings may have a life of 30,000 hours.

All things being equal, like intake breathing, the horsepower of an internal-combustion engine is directly proportional to the rpm at which it can be run. The Wankel engine breathes extremely well at high rpm due to the





Compare the configurations. The Wankel rotary (left) can be expanded along the eccentric-shaft axis to include multiple rotors. The four-rotor racing engine is potent. The highly developed Chevrolet small-block V-8 (right) is a complicated beast.