Gnome Monosoupape Type N Rotary

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History

The rotary engine is unique in that, unlike fixed radial engines, it has a stationary crankshaft bolted to the firewall, with everything else (cylinders, crankcase, propeller) all rotating. The rotary in its original form is extinct, with the term now being used to describe "Wankel" rotary combustion engines such as those built by Mazda. Though automotive and motorcycle rotaries were built in the United States and Australia in the 1890s, the design was developed for aircraft in Europe. Laurent Seguin and his brother Louis, of the Societe des Moteurs Gnome did this in France. Their engine took the aviation world by storm when displayed at the Paris Air Show of 1908. By 1917, rotaries composed 80% of the engines used in World War I (WWI). Originally introduced as a 50-hp 7-cylinder engine, the Gnome developed rapidly into 80 and 100 hp 9-cylinder engines. A 160 hp 14-cylinder held the world speed record before WWI. The Gnome was widely licensed, and copied in many forms by those clever enough to get around Gnome patents.

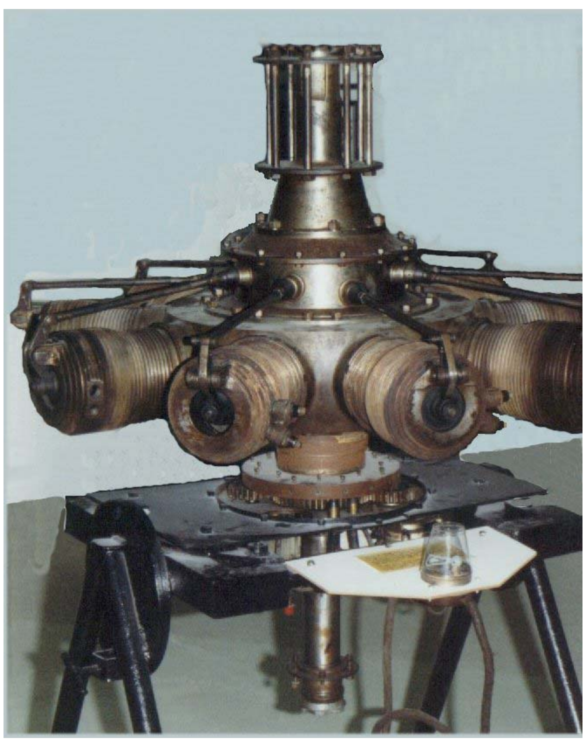

Figure 1. Gnome Monosoupape Rotary

Design and Development

One might ask how such an evolutionary dead end as the rotary became such a popular engine. Simply put, it was the right engine for the time. Its primary advantages, low weight, relatively low vibration, and reliability (when properly maintained) allowed the creation of many new aircraft designs. Early engines, running on extremely poor gasoline, had low compression ratios and turned very slowly. Propellers were not advanced enough to allow more than about 1,500 RPM. At these slow speeds, most early engines vibrated quite a lot. This was partially because of unbalanced moving parts and partially because of so few power pulses per revolution. A flywheel could have been used to damp out the power impulses, but would have added weight. Also, engine cooling was poorly understood in liquid-cooled engines and understood even worse in air-cooled engines. So the genius of the rotary was to reduce weight, provide a flywheel, make the reciprocating parts move in circles instead of straight lines (further reducing vibration), and cool the engine, all with the same construction.

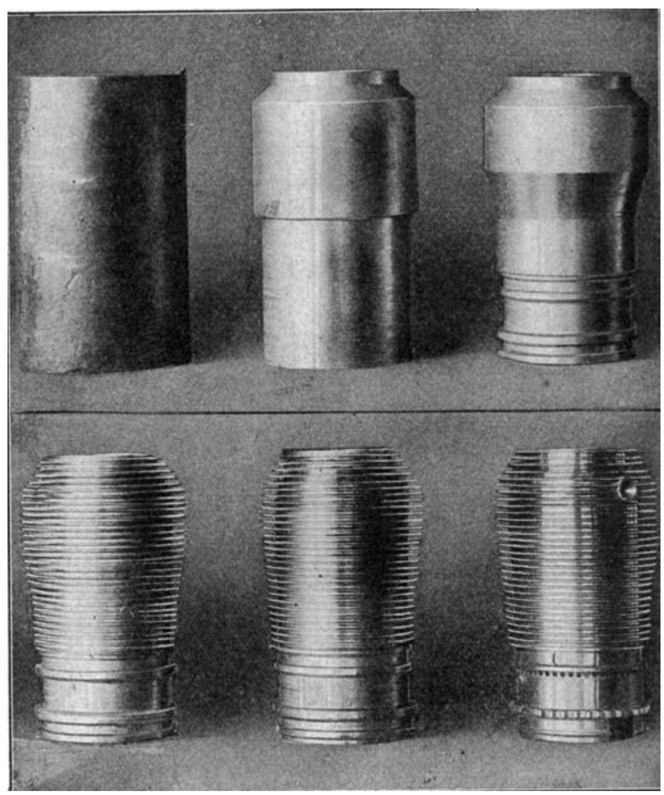

Figure 2. Cylinder Fabrication Sequence

Gnome engines were beautifully constructed of polished steel, with many finely machined cooling fins and tiny fasteners. They were mostly built of forged steel machined to very thin sections for lightness. Each cylinder, for example, began life as a 97 lb nickel-steel bar. When it was completed, it was only 1.5 mm thick and weighed 5.5 lb. Similarly, the crankcase started as a 106 lb forging and was reduced to a final weight of 13.5 lb. Although this fabrication technique is common in today's aerospace industry, it was quite unusual at the time.

Induction

Induction and exhaust in the early Gnomes was interesting. There was no carburetor or intake manifold. Air entered the engine through the hollow crankshaft. A simple needle valve, in combination with an air valve, facilitated the pilot's selection of the correct fuel/air mixture. This along with lubricating oil entered the crankcase, was thoroughly mixed by the thrashing of internal parts, and distributed by centrifugal force. On each intake stroke, automatic intake valves in the crown of each piston opened, admitting the mixture to the combustion chamber. These valves were counterbalanced to account for centrifugal force and piston acceleration, with just the right balance to allow the suction of the intake stroke to open them. Once in the combustion chamber, the mixture was compressed, ignited via a spark plug, burned to produce a standard power stroke, and finally exhausted directly to the atmosphere past exhaust valves in the top of each cylinder. The exhaust valves were operated by push rods and controlled by a central cam ring.

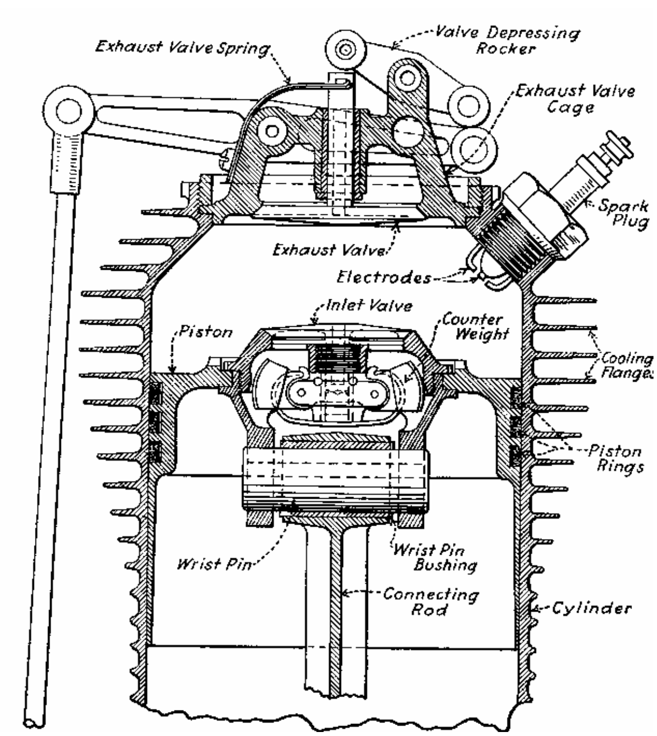

Figure 3. Early Cylinder and Valve Details

Since the crude fuel delivery system had no provisions for throttling, most rotaries ran at wide-open throttle all the time. Slight variations in power were possible by careful adjustment of the fuel/air mixture, and this allowed formation flight. The aircraft control stick was fitted with a "blip switch" which served to momentarily shut off engine ignition, making powered landings (and go-arounds) possible.

The automatic intake valves of the early Gnomes turned out to be quite a headache for maintenance personnel. In addition to presenting a fundamental limit on engine speed and volumetric efficiency, they got out of balance easily, gummed up and got sticky, and worked poorly at higher altitudes. Thus, they presented constant maintenance problems, accounting in large part for the extremely short time between overhauls (TBO).

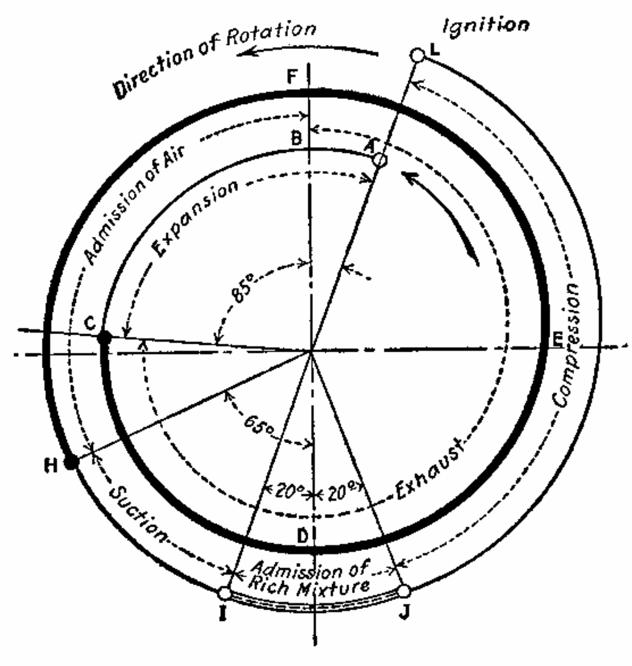

Figure 4. Monosoupape Induction Timing

The Seguin brothers, realizing these problems, introduced the Gnome Monosoupape (meaning single-valve) in late 1912. The automatic intake valve was eliminated and a standard piston substituted. This piston uncovered a ring of intake ports at the bottom of its stroke. On the exhaust stroke, the exhaust valve was opened early to release pressure and reduce temperature in the cylinder during the power stroke. When the piston passed Bottom Dead Center (BDC), the pressure in the cylinder and crankcase were hopefully equal and the rich mixture in the crankcase hopefully did not ignite. The exhaust port remained open for the entire exhaust stroke and was left open past Top Dead Center (TDC) of the exhaust stroke until about 90° after TDC on the intake stroke admitting fresh air to the cylinder. The exhaust valve then closed, allowing the piston to create suction in the cylinder and ultimately uncover the intake ports at the bottom of the cylinder. The very rich mixture in the crankcase was then transferred into the cylinder via the uncovered ports where it mixed with the fresh air and was compressed. Although this technique eliminated the troublesome automatic intake valves (and may have contributed to perhaps doubling the TBO of the engine), it further damaged the Gnome's already poor fuel consumption.

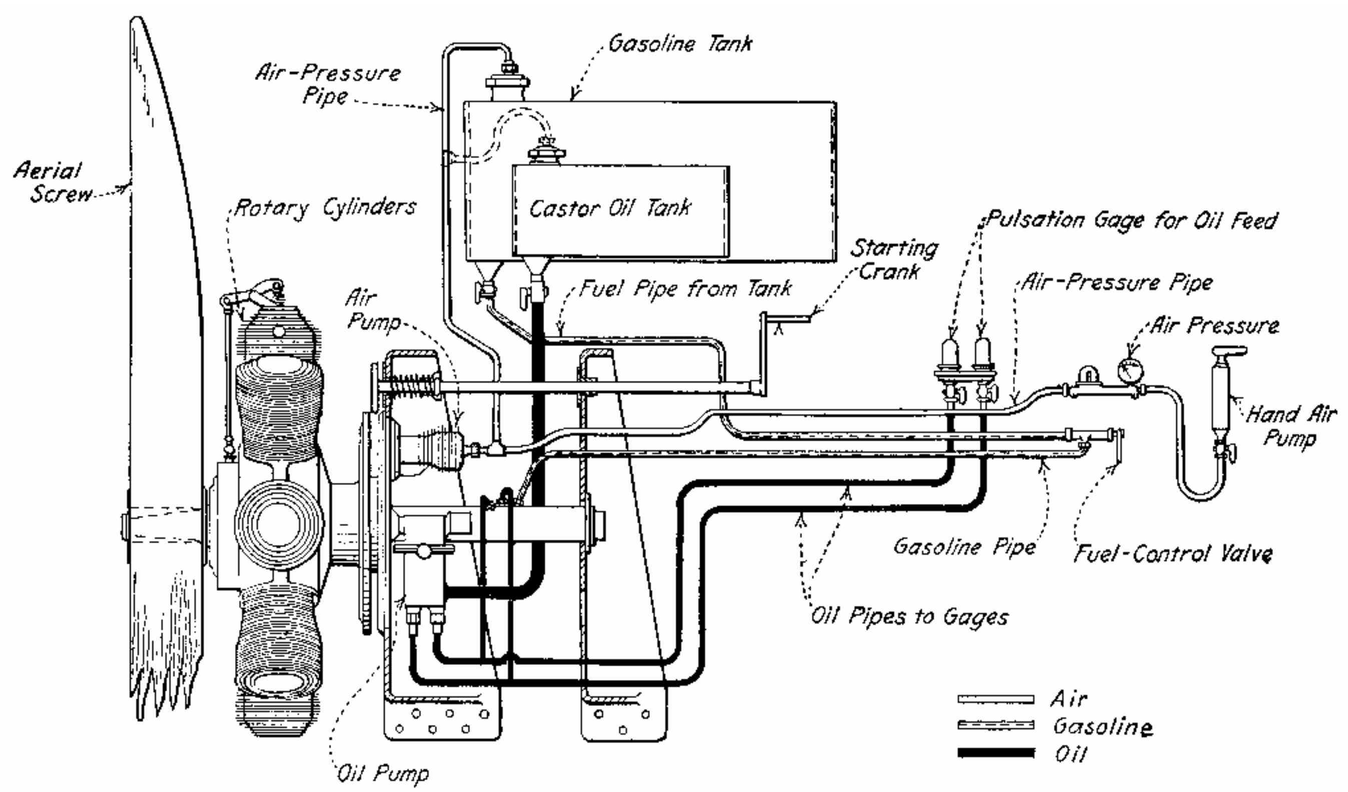

Figure 5. Rotary Installation and Plumbing

Lubrication

Lubrication of the Gnome was accomplished by injecting castor oil into the fuel/air mix with a small pump. Castor oil was used because it could not be easily dissolved into the gasoline fuel, and because it possessed lubrication qualities superior to mineral oils of the day. The lubrication system was a total-loss type, with over two gallons of castor oil being sprayed into the air during each hour of engine operation. This explains why most rotaries were fitted with a three-quarters cowl ring, open at the bottom. The cowl directed the spray of castor oil, along with sparks from the exhaust, away from the flammable airplane structure. In spite of these attempts to deal with the excess lubricating oil, pilots were still subject to, and in many cases the victim of, the well-known laxative qualities of castor oil. Many unscheduled stops and off-airfield landings were credited to the call of nature. Some pilots reportedly kept a flask of blackberry brandy as an antidote to the effects of the oil.

Service

The Gnome was, for its time, light and reliable. Compared to liquid-cooled engines of the day, it started easily, warmed up rapidly, and allowed its pilot to become quickly airborne to do his days bidding (We must not forget the Gnome was in large part the prime-mover of a weapons system). Due to the gyroscopic forces of this rapidly rotating mass, aircraft handling characteristics in a dogfight were strange. The craft turned left instantly, but right very reluctantly. In the hands of a skilled pilot, this could be quite an advantage in combat.

Starting the engine was an adventure. It was turned over by hand in a nearly flooded condition, and would often catch fire due to the excess gasoline. The fire would typically be confined to the cowl ring and grass under the engine. The pilot would shut off the gas and allow the engine to continue to run on the excess as ground handlers hauled the aircraft backward out of the fire. All would wait for the fire to burn itself out. At just the right moment, the pilot would re-open the fuel valve and a successful start would have been achieved. When the engine warmed up, the air valve was opened wide and fuel re-adjusted to produce a correct mixture. The engine was then run at full throttle for the take-off, climb, and cruise, and landed through the use of the "Blip switch", which was used to temporarily ground out the ignition.

Though the Gnome was widely used and had a number of advantages in its particular niche, it also had a number of problems. It had a very high fuel consumption so that the total weight of engine plus fuel and oil placed it at a distinct disadvantage for long flights. Its performance fell off rapidly with altitude. Though reliable if properly maintained, it was extremely temperamental, requiring skilled mechanics to overhaul it at typical intervals of 15-20 hours. It was expensive, with a 70 hp motor costing $4,000 in 1912! Finally, its rotating mass limited its size and consequently, its ultimate power. By the end of the war, when tactics favored a single high-speed pass instead of the dogfight, larger liquid-cooled engines prevailed and the rotary was rapidly becoming an anachronism.

Specifics (Monosoupape Type N, 1916)

Configuration:	9-cylinder air-cooled rotary radial
Output:	160 hp @1,300 RPM
Weight:	330 lb
Displacement:	970 in³
Bore x Stroke:	4.53" x 6.69"
Compression Ratio:	5.45:1
Mean Effective Pressure:	100.5 psi
Specific Weight:	2.06 lb/hp
Specific Output:	0.165 hp/in
Fuel Consumption:	29.1 gal/hr @ full power
Specific Fuel Consumption:	1.09 lb/hp/hr @ full power
Oil Consumption:	2.56 gal/hr @ full power
Specific Oil Consumption:	0.12 lb/hp/hr @ full power
6 hr mission specific weight:	1.55 lb/hp/hr (engine + fuel + oil)

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