

The Bréguet-Richet Quad-Rotor Helicopter of 1907

by

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At the beginning of the 20th century the French scientist and academician Charles Richet built a small, un-piloted helicopter. Although the machine was unsuccessful, it inspired one Richet's students, Louis Bréguet, who was later to become a famous aviation pioneer. During the latter part of 1906, the brothers Louis and Jacques Bréguet began to conduct helicopter experiments of their own, under the guidance of Professor Richet. The Bréguet Brothers were from the famous Bréguet clock making family, and had a good knowledge of engineering principles and adequate funds to proceed with serious design work. Louis Bréguet made meticulous tests of airfoil shapes, paralleling those of the Wright Brothers—see Anderson's book *History of Aerodynamics*. Without a doubt, the Bréguet's understood the essential aerodynamic theory of lifting wings and had at least a rudimentary understanding of the requirements for vertical flight.

In 1907, the Bréguet Brothers built their first human carrying helicopter—they called it the Bréguet-Richet *Gyroplane No. 1*, which was a quad-rotor. Clearly the Bréguet's approached the problem of the helicopter more scientifically than others at the time, and thought hard about a configuration that was most likely to meet with success. In the words of Louis Bréguet: “....Starting from from my calculations I was lead....to build an aircraft with four propellers [rotors] of 8.10 meter diameter.” The issue of stability was a consideration in the design, but the first requirement for the machine was simply to lift itself and a pilot off the ground under its own power.

The Bréguet-Richet quad-rotor consisted of four long girders made of welded steel tubes and arranged in the form of a horizontal cross, looking somewhat like an assemblage of ladders. Each rotor consisted of four light, fabric covered biplane

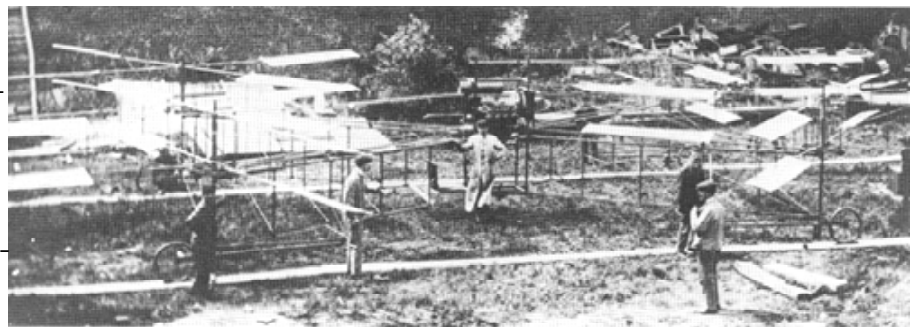


Figure 1: The Bréguet-Richet quadrotor *Gyroplane No. 1*, circa 1907

type blades, giving a total of 32 separate lifting surfaces. The rotors were placed at each of the four corners of the cross. Diagonally opposite pairs of rotors rotated in opposite directions, thereby canceling torque reaction on the airframe. The pilot sat in the center of the structure below an 8-

cylinder Antoinette internal combustion engine, which produced about 40 hp (29.8 kW), although some sources suggest that the engine produced perhaps as much as 50 hp (37.3 kW). The engine drove the rotors through a simple belt and pulley transmission. The bare airframe weighed-in at a substantial 760 lb (345 kg), and the Antoinette engine and fuel weighed about 364 lb (165 kg), giving the machine an empty weight of about 1,124 lb (510 kg). The Bréguet's were able to find a willing helper as a pilot—a Monsieur Volumard—who weighed only 68 kg (150 lb), resulting in a machine with a net gross take-off weight of some 578 kg (1,274 lb).

The first experiments with their *Gyroplane No. 1* were carried out at Douai, France between August and September 1907. The machine is reported to have lifted into flight, and carried the pilot as high a 1.5 m (5 ft), albeit briefly. However, there was no means of control provided to the pilot other than a throttle for the engine to change the rotor speed, and the stability of the machine was found to be very poor. The machine was subsequently tethered so that it could move only vertically upward. Photographs of the numerous attempts at flight show the assistance of several men, one at each corner of the cross-like structure, stabilizing and perhaps even lifting the machine. There is considerable debate as to whether flight was even possible with such a large and relatively heavy machine with an engine of only 40-50 hp (29.8-37.3 kW) installed. Therefore, it is instructive to objectively review the lifting capability of the Bréguet-Richet machine using simple rotor theory.

It is recorded that each rotor of the Bréguet-Richet machine was approximately 8.1 m (26.6 feet) in diameter, and the machine had a gross weight (with pilot) of about 578 kg (1,274 lb). The absolute minimum power required to lift the machine vertically by the rotors can be estimated from the “momentum theory,” which formally embody Newton's laws of motion applied to a fluid moving through the rotors. Assuming each rotor lifted one-quarter of the total aircraft weight, then the momentum theory gives a result for net minimum possible power (or ideal power, P_{ideal}) required to drive all four rotors using the equation

$$P_{\text{ideal}} = 4 \left(\frac{(W/4)^{3/2}}{\sqrt{2\rho A}} \right) \text{ lb ft s}^{-1}$$

where the total take-off weight $W = 1,274$ lb, and where each rotor had a swept disk area, $A = \pi D^2/4 \approx 554.5 \text{ ft}^2$. While the rotors were actually comprised of bi-plane blades, the performance of the rotors is primarily a function of their projected swept area. Working in Imperial units and assuming sea-level air density ($\rho = 0.00238 \text{ slugs/ft}^3$) this gives the ideal shaft power required to

drive all four rotors of the Bréguet machine as

$$P_{\text{ideal}} = \frac{4}{550} \left(\frac{(1,274/4)^{3/2}}{\sqrt{2 \times 0.00238 \times 554.5}} \right) \approx 25.5 \text{ hp (19 kW)}$$

With the relatively primitive types of bi-plane rotors used by the Bréguet Brothers, and with far from optimal blade shape or blade twist distributions and also high profile drag from the bracing between the blades, we could expect the aerodynamic efficiency of their rotors to be quite poor. One can optimistically estimate that the rotor efficiency could be no better than 50% (a figure of merit of 0.5). This suggests a net power for flight of at least 51 hp was required to be delivered at the rotor shafts. The Bréguet's also used an inefficient belt and pulley system to drive the rotors. So taking into account a conservative estimate of transmission losses of some 20%, for their machine to hover free of the ground, the installed power required would have needed to be in excess of 60 hp (47.8 kW). Remember, that the Bréguet-Richet machine used a engine that optimistically produced only as much as 50 hp (37.3 kW).

There are good reports of the experiments conducted with the Bréguet-Richet *Gyroplane No. 1*. We know from photographs and eye-witness accounts that their quad-rotor certainly rose up off the ground into flight, albeit only a few meters. It certainly did not climb high enough from the ground to be free of the benefits of the well-known aerodynamic phenomenon we know as “ground effect.” Therefore, we must correct the power required for flight to account for this favorable effect. We will assume that their machine lifted off the ground by one meter or so, so that the average height of the rotors from the ground would be about one rotor radius. Empirical results quantifying the phenomenon of ground effect, suggest about a 15-20% reduction in the power required to hover at this height off the ground relative to the power required for flight out of ground effect. Therefore, taking ground effect into account, the installed engine power required to lift the Bréguet-Richet machine off the ground needed to be about 50 hp, accounting for the relatively poor aerodynamic efficiency of the rotors and transmission losses as well as the benefits of operating in ground effect.

Clearly, with an engine that produced only as much as 50 hp (37.3 kW), the performance of the Bréguet-Richet *Gyroplane No. 1* must have been very marginal. However, it must have come very close to flying unaided, and was certainly closer to flying successfully than the vastly underpowered tandem rotor machine built by Paul Cornu about the same time. It proved, for the first time, that powered rotors could lift a machine and a pilot vertically into the air. Like all attempts at building vertical flight machines of that era, the Bréguet-Richet machine lacked proper stability and an effective means of flight control for the pilot—these were technical issues

that were only to be properly resolved by the Bréguet's and other some years later. The machine was stabilized in flight by men on the ground, and as Jean Boulet records in his book *History of the Helicopter*, there are eye-witness accounts and other evidence to suggest that that these men may have also helped to lift the machine. However, bearing in mind this was only 1907, when the airplane itself was still in its infancy, the Bréguet Brothers had clearly made a significant accomplishment toward the achievement of successful vertical flight. Perhaps with a slightly more powerful engine and with the use of light-weight aluminum airframe components, their *Gyroplane No. 1* aircraft might have shown the marginally better performance necessary to claim a real success.



Figure 2: The Bréguet-Richet No. 2, which was a hybrid aircraft, circa 1908

While discouraged by the lack of success with their *Gyroplane No. 1*, in 1908 the Bréguet's built another vertical flight machine they called the *Bréguet-Richet No. 2*. This machine used two rotors from the *Gyroplane No. 1*, which were arranged in a lateral side-by-side configuration and were tilted slightly forward

to provide propulsion for the aircraft. The aircraft had a set of fixed tri-plane wings, so this machine was not designed to be a pure helicopter. The photographs we have of this machine suggest a configuration remarkably similar to the modern tilt-rotor. The *Bréguet-Richet No. 2* machine was reported to have made limited flights during the summer of 1908, but it never flew properly and finally crashed in late 1908. To add to their problems, the Bréguet's hangars and construction facilities were wrecked in a storm in May 1909. Because of a shortage of suitable light-weight engines and construction materials, the Bréguet's were soon to abandon their pursuit of vertical flight aircraft, at least temporarily, and turn their attention to the development of fixed-wing aircraft at which they were to become very successful. However, Louis Bréguet never lost interest in the successful achievement of controlled vertical flight, and even by 1908 he had already patented a design of a rotor head with freely flapping articulated blades. In 1932, Louis Bréguet was to return to the development of the helicopter, but that is another story.