TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 218

THE "AUTOGIRO."

By M. Moreno-Caracciolo.

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For the first time in the world, a flying machine, heavier than the air and distinct from the airplane, has completed a circuit of four kilometers (nearly 2.5 miles) at a height of more than 25 meters (82 feet) above the ground. This event, which marks the beginning of a new era in the history of aviation, took place in Madrid at the airdrome of Cuatro Vientos, in the afternoon of January 31, 1923.

The machine piloted by Lieut. Alejandro Gomez Spencer, which, that afternoon, we saw flying above us, was neither an airplane nor a helicopter. It was the "Autogiro," a flying machine invented and constructed in Spain by a civil engineer, Juan de la Cierva. Between the original conception and this brilliant accomplishment there lay many months of continuous work, a thousand difficulties overcome, experiments begun in many directions only to be abandoned, and yet with a will sustained by an immovable faith in ultimate success.

We are going to give the readers of "Ingeniera y Construccion" the story of the "Autogiro." It is a useful lesson for those who are willing to abandon the well-trodden roads of routine and have sufficient courage to enter the difficult paths of

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research. We will first indicate in a few words, the problems which the "Autogiro" is expected to solve.

A very high percentage of aviation accidents is due to "loss of speed." The lift produced by the pressure of the wind depends on two factors: wing area and speed, as combined in the formula

$$P = Ky\ S\ V^2,$$

in which V is the airspeed or velocity, S the wing area, and Ky a coefficient dependent on the wing section and the angle of attack. Since the velocity is squared, a small diminution of its value may result in a large loss of lift, followed by a catastrophe.

This preponderance of velocity over the other factors by which lift is obtained gives rise moreover to another serious disadvantage. An airplane must fly very swiftly, in order to remain in the air and, when it does come into contact with the ground, the same velocity which prevented its fall carries it violently over the irregularities of the field and any obstacles which happen to be in the way. Airplanes are often upset and aviators killed due to the high landing speed.

A flying machine unaffected by losses of speed in the air and which can alight as slowly as a bird, is the goal long pursued by airplane constructors and only recently attained in the "Autogiro."

In this machine the wings have been eliminated and the lift is produced by revolving wings on a vertical shaft projecting from the fuselage of an ordinary airplane. However, it does not belong

to the family of helicopters since the sustaining propellers of the latter are operated directly by the engine, whereas in the "Autogiro" the wind produced by the motion of the aircraft actuates the blades. Hence, although at first glance it seems to resemble a helicopter, it is really more like an airplane and, had it not been christened the "Autogiro," it would surely have been called an "airplane with rotating wings."

It is easily understood that the blades of the lifting wings will revolve, when the "Autogiro" moves horizontally, pulled by the tractor propeller coupled to its engine. It is also easy to understand that the revolving blades of the "Autogiro" strike the air more violently than the fixed wings of an ordinary airplane, since the rotation speed of the blades must be added to the normal speed, and since one of the blades advances while the opposite one moves back, these component speeds are added on one side of the aircraft and subtracted on the other. Hence the resulting speed will be greater on one side than on the other and the aircraft being unequally sustained, will tip toward the side of the blade which cuts the air with less speed.

The remedy adopted by all helicopter builders (two propellers revolving in opposite directions) was the first one tried by La Cierva and, in October, 1920, "Autogiro" No 1 (Fig. 2) was tested at the airdrome of Getafe, piloted by Don Felipe Gomez Acebo, Captain of Artillery. A single run across the field was enough to demonstrate the necessity of abandoning this method. The upper

revolving wing acted on the lower, the latter rotating much more slowly than the former. The lifts of the two wings were unequal and their effects were not compensated.

Then the construction of "Autogiro" No. 2 (Fig. 3), was begun with only one sustaining wing with five blades. A theoretical study, based on the shape which at that time was thought to be the best for the distribution of pressure, was expected to give a solution of the problem.

Two symmetrical blades, one advancing in the direction of flight and the other going back, cut the air at unequal speeds, but also at different angles of attack, although the geometrical angles formed by their surfaces and the axis of rotation are equal. A careful calculation gave the exact critical angle at which the variation of speed would just be compensated by the angle of attack, but it was necessary to confirm the theory by experiments.

Before the duralumin for the enormous blades of the aircraft arrived in France, a lifting wing with three flexible blades was constructed in a few days. This was attached to the fuselage of an airplane and tests were begun in June, 1921, at the airdrome of Getafe.

The lateral control of "Autogiro" No. 3 (Fig. 4), which was tested at Santa Quiteria field while No. 2 was awaiting the arrival of the duralumin tubes, was obtained by warping the blades, which was easily accomplished by the pilot. The skeptical curiosity with which the tests of No. 1 had been witnessed, had given place to an over-confidence in success.

Before No. 3 left the workshop for the airport, another unnumbered "Autogiro" had made many flights before the eyes of the pedestrians of "la Chopera." In this corner of the park of Madrid and before the Technical Committee of the Aero Club and even a representative of the Academy of Sciences, there had been flown an "Autogiro" with a propelling force of india-rubber, a fuselage of cane, and wings of paper (Fig. 1). It took off after running only a few feet on the ground and remained in the air several seconds, covering distances of more than 100 meters (328 feet).

However, Lieut. Lecca, who piloted "Autogiro" No. 3, always made, at the end of his runs the same discouraging report, that the aircraft always tipped to the right (the blades, seen from above, revolving in a clockwise direction). The pilot said that he could feel the lift and that the aircraft often took the air, but completely out of balance, so that it always fell to the ground, breaking its blades on more than one occasion, when it landed on only one of the wheels of its landing gear.

This was attributed to the fact that the force exerted by the pilot was not the only force which warped the wings. The wind also altered their shape from that in which there was compensation.

At that time (April, 1922), "Autogiro" No. 2 was finished and Lieut. of Cavalry Alejandro Gomez Spencer, who had replaced Lieut. Lecca, prepared to test it. The five blades of the sustaining wing had strong duralumin struts and were rigidly braced. There was no fear that the wind would change their angle of attack.

This did not prove, however, to be the means for obtaining the much-desired compensation. The distribution of pressure had been calculated according to the rectangular law adopted at that time and not according to the elliptical law which experience has since confirmed.

Lateral control was obtained in this machine by warping the tail. This obliged the fuselage to bear considerable torsion which caused some fastenings to give way, resulting in deformation. The damage done by this accident was not repaired, since "Autogiro" No. 4 (Figs. 5 and 6), which took off a few months later, was already being built.

The sustaining wing of this fourth aircraft had four blades, in place of five in the second, and three in the third, but instead of their being rigidly fastened to a common shaft, they were articulated to it and could move freely up or down while revolving around it (Fig. 7). The articulation point of the blades is situated below their center of gravity and the resultant of the lift and centrifugal force acting on each blade, must pass through this point. The blade of greater lift will go up more than the opposite one and the resultant of all the reactions will pass through a fixed point in which the metacentric curve has been concentrated. Therefore, there is no transmission of moments to the axis of rotation, nor are there any gyroscopic effects, since there is no continuity in the rotational plane necessary for producing them.

Would practice confirm the theory? On January 10, last, Lieut. Gomez Spencer gave an affirmative answer. The "Autogiro"

did not balance properly and fell like the former ones, not to the right, however, but to the left, that is to say, in the direction contrary to the one due to the decentralization of pressure. The reason for this lack of balance was immediately found. It was the torque of the tractor propeller which tipped the aircraft to the left. The axis of the sustaining wing was then set a few centimeters off the central line and on January 17, the "Autogiro" left the ground and made several straight flights in the airdrome of Getafe.

During one of these test flights, on January 20, when alighting like an ordinary airplane (the only way tried until then), an accident took place which would have wrecked an ordinary airplane. The engine was accidentally started, when the pilot was nosing up the "Autogiro" in order to rest the tail skid on the ground, and the aircraft went up quickly. The pilot cut off the engine and pulled the control levers and the "Autogiro" descended vertically and alighted slowly, the pilot noticing clearly the lift produced by the rapid revolution of the blades.

The chief of the Getafe airdrome, Capt. Estéfani, who, from the first had enthusiastically assisted the inventor, gives the following report of this incident: "Don José Gonzalez Estéfani y Caballero, Ordnance Captain and Chief of the Getafe airdrome, certifies that, during a test which Lieut. Alejandro Gomez Spencer made on a flying machine designed by Juan de la Cierva y Codorniu, called "Autogiro" by its inventor, because of damage to the hand lever of the engine, the aircraft ascended suddenly to about 8

meters (26 feet), at which height it found itself without any apparent horizontal speed, in a position similar to that of an airplane with complete loss of flying speed. The "Autogiro" landed safely, however, without damage, due to the lift continuously produced by the rapid rotation of the supporting wing.

In witness whereof I sign this report in Getafe, March 10, 1923. (Signed) Jose G. Estefani."

Two days later the official tests took place with a strong wind which the "Autogiro" valiantly combatted. Soon after these tests, the aircraft was sent to the airport of Cuatro Vientos where, on January 31, it made the performance mentioned at the beginning of this article and which is attested by the following official report: "Don Emilio Herrera y Linares, Major of the Engineer Corps and Chief of the Military Aerodynamical Laboratory, hereby certifies that, in the airdrome of Cuatro Vientos, on the afternoon of January 31, last, an aircraft named "Autogiro," designed and constructed by Juan de la Cierva y Codorniu and piloted by Lieut. Alejandro Gomez Spencer, made three flights, the last one covering a distance of 4 kilometers (2.5 miles), in a closed circuit in 3 minutes and 30 seconds, reaching an altitude of more than 25 meters (82 feet) above the ground (Fig. 8). Cuatro Vientos Airdrome, February 1, 1923. (Signed) Emilio Herrera,
Chief of the Laboratory,
Sporting Commissioner of the F.A. I."

The "Autogiro" has ceased to be a scientific curiosity and has become something which can be developed commercially. The tests of last January have proved that it can fly, that it is more stable than an airplane and that it can alight vertically and without speed. We have now to determine its exact efficiency, which should be at least 90% that of an airplane.

In the workshops of the Industrial School, where the most delicate parts of "Autogiros" Nos. 2, 3 and 4 were constructed, "Autogiro" No. 5 is at present being built, under the supervision of La Cierva. This aircraft will have improvements which will increase its efficiency and carrying capacity. It will be able to carry a passenger and to make long flights, which it would not have been prudent to attempt with the previous aircraft, built solely for experimental purposes. "Autogiro" No. 4 was the last of the experimental series, and No. 5 will be the first of the commercial series. Those who have followed its progress will not go to the airport simply to see it fly and descend vertically without any appreciable forward speed, but to see it compete with its elder brother, the airplane.

The "Autogiro" is not a helicopter nor an aeronautic freak pretending to solve a difficult problem of mechanics, but is a perfected airplane, although not designed with the sporting purpose of increasing speed nor with the commercial object of enlarging the the radius of action, but with the humanitarian purpose of reducing to a minimum the number of accidents and the number of human lives sacrificed in the fight for the conquest of the air.

Nearly all aviation accidents are due to loss of speed, which diminishes the lifting force and leaves the airplane subject to the force of gravity. The "Autogiro" is not affected by loss of speed. An engine failure, a sudden "nose up" or a very sharp turn may interrupt its horizontal flight and make it descend toward the ground, but the rotating blades will sustain it in the air and enable it to alight at a very low speed.

Calculations, the details of which need not be given here, lead to the encouraging conclusion that, in the least favorable case, when an accident to the pilot leaves the aircraft without control, the collision with the ground would be similar to that of a fall of a little over two feet, instead of the break-neck horizontal speeds at which airplanes now land. The "Autogiro" will land, in the least favorable case, at a speed of less than 7.5 miles per hour.

The stalling of the engine while in flight over ground which is rough or covered with vegetation, though fatal to an airplane, will only be a mishap of minor importance to an "Autogiro." On the other hand, it will probably be unable to do any looping or other stunts, like fighting airplanes. It will be a commercial aircraft, with which it will not be possible to bring down enemy airplanes, nor give dangerous exhibitions of useless daring.

These constitute two excellent qualities in addition to that of safety in case of loss of speed and its ability to alight slowly and vertically.

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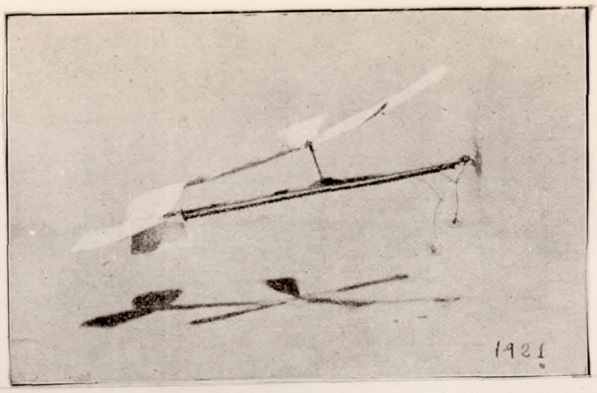

Fig.1. Model of Autogiro, with rubber elastic as propelling force, exhibited before the Technical Committee of the Aero Club in 1921.

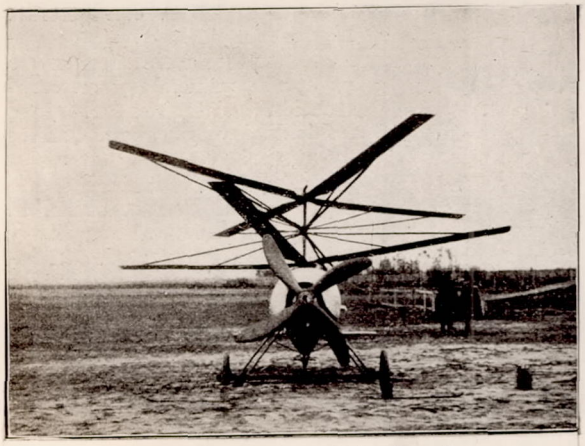

Fig.2. Autogiro No.1.

Fig.3. Autogiro No.2.

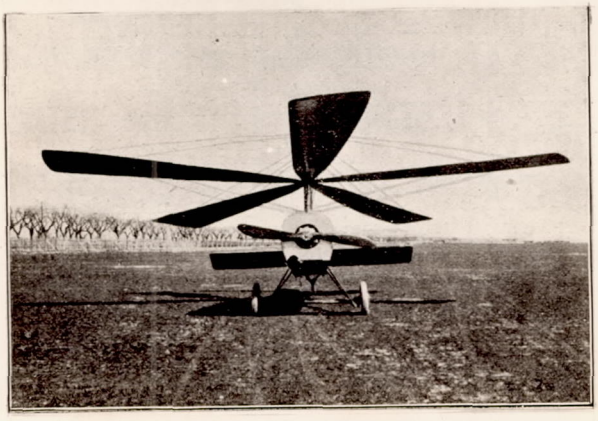

Fig.4. Autogiro No.3.

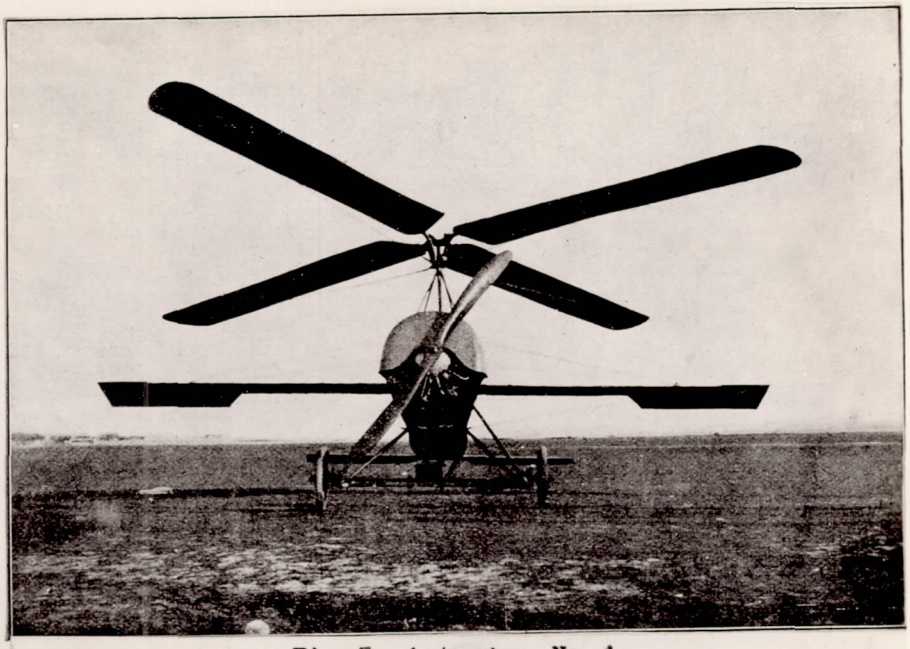

Fig.5. Autogiro No.4.

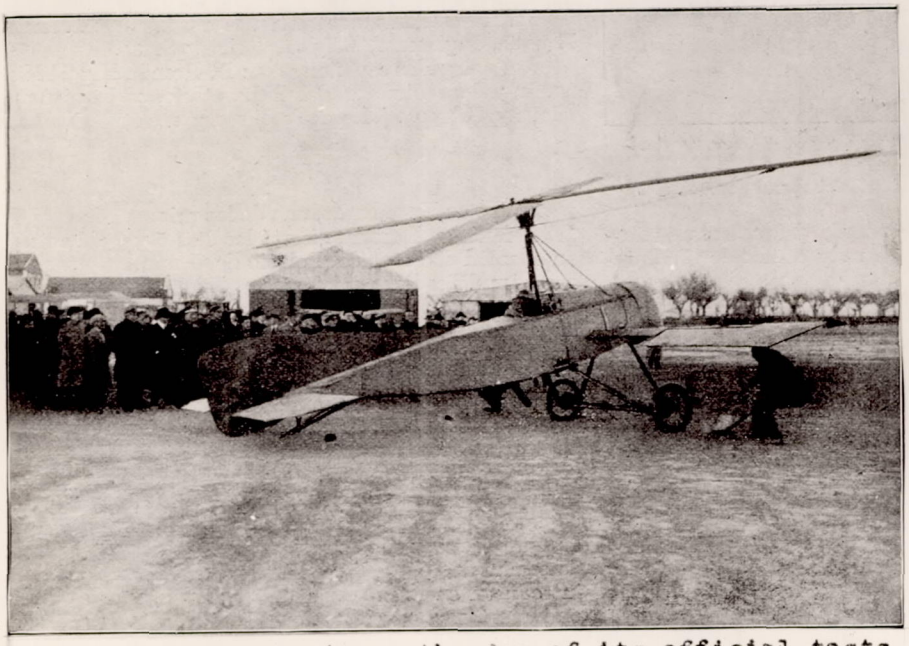

Fig.6. Autogiro No.4. on the day of its official tests, January,23, 1923.

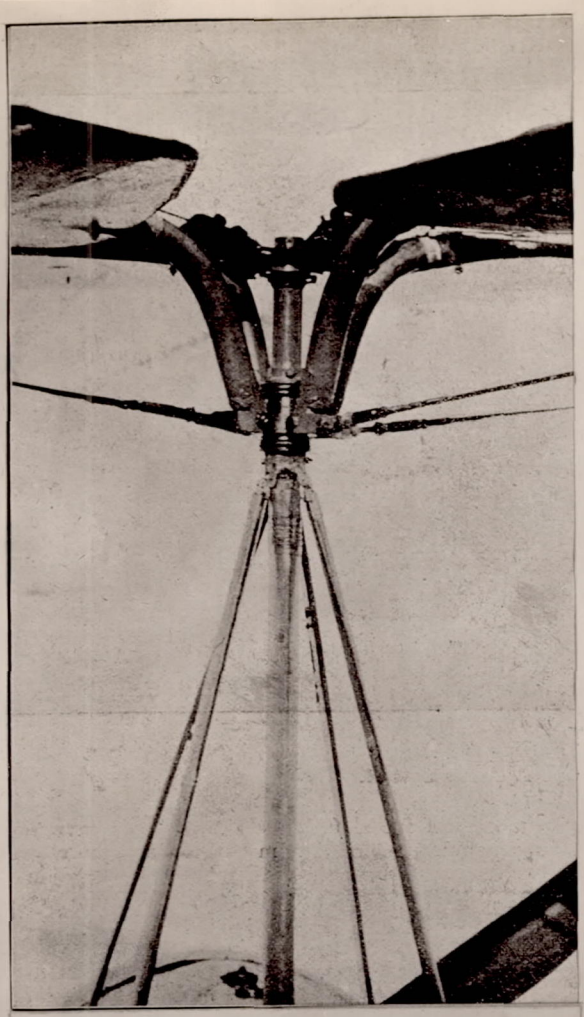

Fig.7. Joints of Autogiro No.4.

Fig.8. Autogiro No.4. flying at Cuatro Vientos Jan.31, 1933.