24 th EUROPEAN ROTORCRAFT FORUM
Marseilles, France – 15th – 17th September 1998

REFERENCE: FM 11

Directional control of a non rudder Autogiro. Landing manoeuvre of the C-30

J. López-Díez, C. Cuerno-Rejado and J.L. López-Ruiz
Departamento de Vehículos Aeroespaciales
Universidad Politécnica de Madrid
Plaza del Cardenal Cisneros 3, E-28040 Madrid, Spain

Seventy-five years ago, on January the 17th, 1923, the first successful flight of a rotary wing aircraft took place. The first gyroplane, Autogiro, was invented by Juan de la Cierva Codorniú. For this reason, in Spain, Juan de la Cierva Foundation has promoted a project to build a replica, authorised to fly, of the Cierva's C-30, the most famous of his Autogiros. The replica is planned to fly only in exhibitions. In this paper an historical review of Juan de la Cierva works is presented, and the C-30 restoration is illustrated and described. C-30 was, is, a "direct control" Autogiro, which makes it peculiar to be piloted, especially on landing. A special attention has been paid to landing manoeuvre. It is shown that a lateral acceleration of 0,66 g or 20° lateral inclination of the tip plane would make the Autogiro to knock over. Based on historical review and analytical studies, a qualitative study is used to establish the best landing procedure. These results are applicable to modern sports Autogiros when landing with engine fail.

1. HISTORICAL REVIEW

Don Juan de la Cierva Codorniú, the inventor of the Autogiro, was born at Murcia, Spain, on September 21, 1895. He became interested in aeronautics when still a boy he heard of Wilbur and Otto Wright's flying in France in 1908. His grandfather, D. Ricardo Codorniú, was a famous civil engineer from the end of 19th century, who stimulated his grandson on the interest of aviation.They travelled together to watch the first flights in Spain, of Julien Mamet on a Blériot in Barcelona on February, 11, 1919, and in Madrid on March 23. He was only a teenager when Juan de la Cierva completed the construction of a powered airplane. This was the BCD-1, known as "El Cangrejo" (crab or cray fish) because of its red colour. It was a two-seat biplane incorporating a 50 hp Gnome Omega rotary engine, which was tested by Jean Mauvois, the owner of the Sommer, in 1912. Surprisingly the BCD-1 flew well and was claimed to be the first Spanish built airplane to fly.

In 1918, after designing several types of gliders and aeroplanes, he designed a tri-motor bomber for the Spanish Air Force. This airplane, in many aspects considerably in advance of its time, flew successfully, but it was crashed later, due to an error in piloting from a stall near the ground. As a result of this mishap, de la Cierva turned his mind to the invention of an aircraft that would be independent of speed for safety in flight. Ironically, Cierva's interest in rotary wings aircraft began and ended with accidents of fixed wing aircraft, because he died in 1936 as a passenger in an airline crash.

Cierva's initial work in Spain on rotary wings, starting with models and then moving on to full size machines, resulted in a series of Spanish patents, the first of which (no.74322) was requested on July 1st, 1920, and granted on August 27. On March 28, 1921, Cierva applied for an extension to his first patent, related to the configuration of his second Autogiro (the C-2). This extension was granted on April 20th, with the number 77569.

The two most fundamental British patents were granted in July 1920 and April 1922. The first (no. 165748 of July 1, 1920) defined "an aircraft having the usual propelling means, and one or more horizontal airscrews supported from the fuselage and mounted to rotate freely in a plane which is slightly inclined upwards to the direction on of motion". In the second British patent (no. 196594 of April 18th, 1922) covering flapping blades, it was defined as "rotary wings are mounted on a base plate, which revolves in bearings around a shaft supported by a tubular pyramidal structure. The wings are stayed by bracing wires and fixed to the base plate by hinges which permit movement of the wings in the direction approximately in a plane passing through the shaft". "Autogiro" was registered first, in Spain, in 1923 and then in other countries as a Cierva's Company trademark. Cierva's most important patent was number 81406 taken out in Spain on November 15th, 1922, covering flapping blades. Cover of this concept was granted in other countries as follows:

France: N° 562756 on September the 14th, 1923.

United Kingdom: N° 196594 on June the30th, 1924.

Germany: N° 416727 on July the 27th, 1925.

United States: N° 1590497 on June the 29th, 1926.

From 1919 to 1925 Juan de la Cierva Codorniú developed six models of Autogiro, known from C-1 to C-6. Autogiro C-1 was the first aircraft to incorporate a freely revolving wing. Two counter rotating rigidly braced four blade rotors, 6 m in diameter, of 30 cm in chord and Eiffel 101 symmetrical profile were superposed on the same axis above the fuselage. A vertical control surface above the rotors provided lateral command, while traditional elevators and rudder were retained for control about the other axes. It was not a success and did not fly because the two rotors turned at different regimes. The unbalanced lift and gyroscopic effect generated rolling the rotorcraft onto its side. The C-1 did, however, confirm the autorrotational properties of a freely turning rotor.

Autogiro C-2 had a single five-blade rotor, 11,5 m in diameter. Each blade was heavily braced above and below by high-tensile steel wire. Tests began in 1922. It achieved more lateral balance than C-1 (and C-3, which flew before the C-2) but still had a tendency to roll over onto its side, a situation in which the control surfaces were insufficiently effective to counteract completely. The machine was damaged and rebuilt three times until April 1922 when trials were abandoned.

C-3 was completed before C-2 and was the second Autogiro trying to fly. C-3 was ready for trial in June 1921. A single rigid rotor of high solidity was used in this model. The aim was to provide lateral control and to compensate the unbalanced lift from the advancing and retreating blades. Juan de la Cierva Codorniú provided the C-3 with a collective pitch to achieve lateral control. However, this control system was not a suitable solution so that the rotorcraft rolled onto its side before, or soon after, taking off. In 1920 Juan de la Cierva Codorniú had undertaken a series of tests with a small model Autogiro C-2 configuration powered, by a twisted rubber. The tests were repeated many times and he concluded that the model, with its rotor with five flexible blades (made of thin palm wood), was perfectly stable. Then, the idea of articulating the blades of a full-size rotor to overcome the unbalance between the advancing and retreating blades, and achieving the same effect as the flexible blades of the model, was got by Juan de la Cierva.

C-4 was provided with a single four articulated blade rotor. On January 17, 1923, the C-4 made the first rotary wing aircraft controlled flight in history. This has been described as the most significant flight since the Wright brothers' flight. It made a steady straight flight of 183 m at a height of about 4 m, at Getafe airfield.

C-5 was completed in April 1923, and flew successfully at Cuatro Vientos during Spring of 1923, but it was destroyed in July in an accident on the ground.

C-6 was one of the most famous Autogiros. Juan de la Cierva Codorniú showed it in multiple international exhibitions. Cierva visited France and England at the end of 1924. On February 7th, 1927, a rotor blade broke off while the C-6C was flying 70 m height. The cause of the accident was found to be the rigidity of the blades in the plane of rotation. So, Juan de la Cierva provided his blades with an additional articulation, incorporating a drag hinge at the blade root. Wires and damping devices were used to restrain excessive movement of the blades in the drag plane.

This assessment of Cierva's work must be finished by summarising his major contributions:

- Discovery and application of the principle of autorrotation of a freely turning rotor.
- A flapping blade with drag hinge solves many aerodynamic and structural problems in a rotor system. These are both features of modern helicopters.
- Although he had not adopted cyclic and collective blade angle variation as control methods (as used on modern helicopters); toward the end of his life he studied in depth this system and registered its main features.
- The direct or jump take-off, developed in 1933, was the first practical demonstration of the helicopter capacity of providing vertical take-off. Although, in this case, the rotor was not engine driven during the jump.
- The three firms which developed the first successful helicopters (Fock-Achgelis, Weir and Breguet-Dorand) and Sikorsky were all Cierva's licensees and use his patents in developing the helicopter.

2. C-30 DESCRIPTION

The Cierva C-30 was the most successful Autogiro. About 180 were manufactured in Great Britain, France and Germany. The C-30 represented a major advance in Autogiro practicability. For this reason, this model has been selected for being reconstructed as the best symbol of Juan de la Cierva Codorniú works.

The C-30 type Autogiro is an open two-seater with a 140 hp Armstrong Siddeley Genet Major 1A engine. The prototype was rolled out later in 1933. The rotor is three bladed of 10,75 m in diameter. The aerodynamic profile is the Gö 606, and the blade chord is 0,275 m. The solidity is 0,0472.

The fin and tail surfaces are fixed; control is achieved by tilting the rotor shaft laterally and longitudinally. An inverted control column pivoted at the rotor head tilting the head through link mechanisms does this. A forward or backward movement of the control tilts the rotor head, and hence the line of action of the resultant force in the opposite direction causing the nose of the Autogiro to fall or rise. A lateral movement of the control tilts the head in the opposite direction laterally, causing sideslip and bank; sideslip in turn generates yaw in the required direction. Figure 1 shows the control column linkages. A swivelling tail wheel coupled to a "rudder" bar provides directional control on the ground.

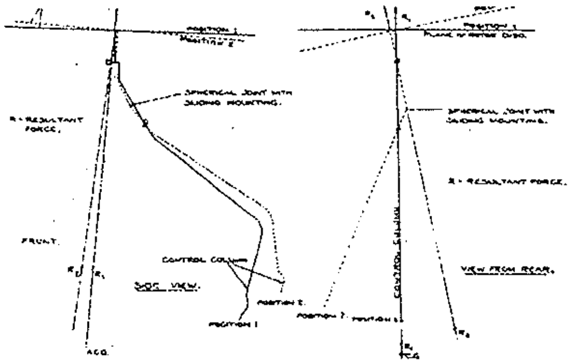


Fig. 1.- Direct control scheme.

Initial rotation of the blades on the ground is obtained by driving them from the engine through a friction clutch, bevel gear and "dog clutch". The normal rate of rotation reached on ground is about 185 rpm, being 200-240 rpm during normal flight (Fig. 2). To take-off, the clutch is slipped and the Autogiro allowed running along the ground, until sufficient air speed for autorrotation of the rotor at flight speed is reached.

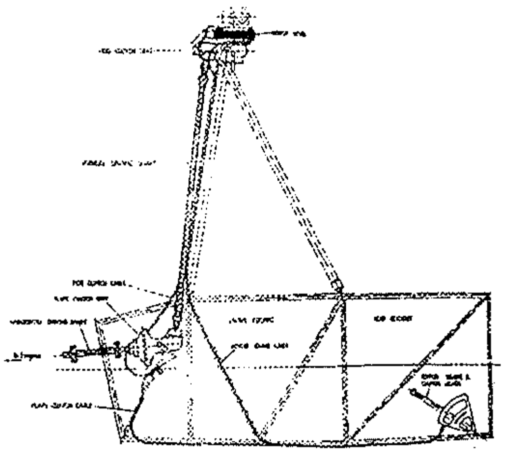


Fig. 2.- General arrangement of mechanical strarter, C-30

The fixed horizontal tail has upturned tips to provide an additional yawing moment for turning. Its starboard half-plane has positive camber and the port negative, to counteract to some extent the engine torque (the engine rotates anticlockwise). Small trimmer tabs, fitted on ground only, are attached to the trailing edges of the tail plane for this purpose, too.

It must be pointed out that the rotors of C-2 to C-5 had all turned in a clockwise direction (seen from above). As a result, each of these Autogiros tended to roll to the right because of the greater lift generated on the left side by the higher relative speed of the advancing blades. The French engines used in the earliest Autogiros all turned anticlockwise (seen from the front). The reaction to a propeller turning in this direction tends to roll an aircraft to the left. Thence, the tilting tendency due to the rotor is reduced.

C-6 was the first Autogiro with anticlockwise rotor and propeller. The flapping hinges on C-4 and later Autogiros were the most important solution to the rolling tendency due to the rotor. Direct Control Autogiros (C-19 and later) also had differential tail planes (that is, with inverted camber on one side) to reduce the propeller rolling moment. So, C-8 and later Autogiros had rotors in which the direction of turning was chosen independently of their engines.

When a prerrotation was achieved by a mechanical transmission, rotor and engine turn directions were linked again. This has been a very important feature during the reconstruction, as it will be presented in next section.

Figure 3 depicts the C-30, and principal dimensions and particulars are shown in Table 1.

Gross weight	862 kg
Diameter of rotor	11,3 m
Number of blades	3
Chord of blades	0,28 m
Solidity	0,0472
Blade section	Gö 606
Blade angle	2° 40'
Inclination of rotor axis to plane perpendicular to fuselage axis	2,5° forward 7,5° backward
Lateral inclination of rotor axis to vertical plane	5° to right and 4° to left
C.G. position	0,15 m after the intersection of front pylon struts and top longerons
Area of tail plane	1,45 m^2
Total fin area	1,51 m^2
Tail incidence	2°
Ground angle	10°
Engine	Genet Major IA
Max. Power	111,7 kW at 2420 rpm
Propeller	Fairey Reed two blader Drg. n° 95193A/X2
Pitch	1,32 m
Diameter	3,18 m

Table 1

3. C-30 RESTORATION

Fundación Juan de la Cierva is a non-profit organisation, which holds the documentation from the personal libraries of D. Juan de la Cierva Peñafiel, a great lawyer and minister of Spanish government, and his son D. Juan de la Cierva Codorniú, the inventor of the Autogiro. This foundation has the objective of putting in flight an Autogiro C-30 in the Spanish Air Force Museum. In this way it is conmemorated the 75th anniversary of the first flight of an Autogiro. This work has been supported by Caja Madrid and Fundación AENA, and has been carried out by the Spanish Air Force.

C-30 was the culmination of the Autogiro as aircraft. It was provided with direct control, with neither lifting surfaces nor tail control (no rudder, no elevator) as the conventional airplanes. More than 180 C-30 Autogiros were manufactured during the thirties, but no more than 10 exists nowadays, localised in Museums all over the world, but especially in Great Britain. Two C-30 are exposed in Argentina and Australia.

In Great Britain four C-30 are exposed at the following museums: London Science Museum, Royal Air Force Museum at Hendon, Imperial War Museum at Duxford and Shuttleword Collection at Old Warden, Bedfordshire. The three first Autogiros are exhibited statically, and the last one, periodically is rolled out in the Old Warden airfield. Also, a lot of original components were localised stored in the Hendon RAF Museum at Cardington. At the very beginning, Juan de la Cierva Foundation tried to obtain the last mentioned Autogiro, restorate it and put it in flight, but Shuttleword Collection authorities rejected.

Then, Spanish Air Force and Fundación Juan de la Cierva decided to manufacture a new C-30. Hendon RAF Museum lent for a year its Autogiro C-30 K-4232 to be used as model and also donated a lot of original components, the main of which are the following: rotor head pylon assembly, rotor blade control arm, rotor head drive shaft, tail plane, tailplane bracing struts, pitot assembly, blade dampers, cockpit canvas covers, shaft anti vibration mount, propeller 80/E/1522, propeller hub, rotor head casting complete with centre hub, rotor blades (3), fuel tank, drive shaft, input and output drive bevel

Figure 4 is a photograph taken during the moving of the K-4232 from Hendon to Spain. This paper describes the work developed to manufacture and putting in flight a new C-30. The main works developed are related to the fuselage (structure, landing gear, flight controls and instruments), rotor, engine and documentation.

3.1 Fuselage

A new fuselage has been completely manufactured. The K-4232 Autogiro has been used as model because almost no documentation was available. The C-30 was provided with a welded steel tube fuselage.

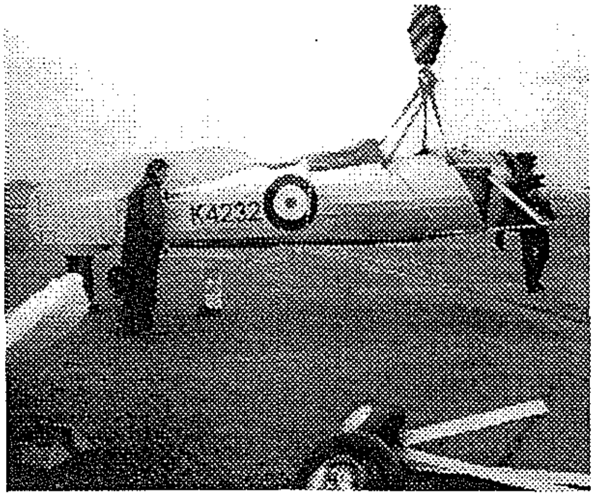


Fig. 4.- Autogiro K-4232 at Hendon airfield being moved to Spain.

The tail plane was manufactured in wood. In Albacete, a town in the middle west of Spain, carpenters who worked in aircraft manufacturing during the thirties and the forties live yet. For this reason, the C-30 has been built by the Spanish Air Force at its workshop in Albacete. The metallic steel tubes have been metric sizes instead of the original British standards. Wooden formers and stringers complete the fuselage, before being cloth web.

Seats, instrument boards, metallic fairings, doors, control rods and gears have been also manufactured. Fig. 5 shows the fuselage during manufacturing process. The new Autogiro is provided with an original landing gear, only new tyres have been installed. A detail of the tailplane can be seen at Fig. 6; inverse camber is observed.

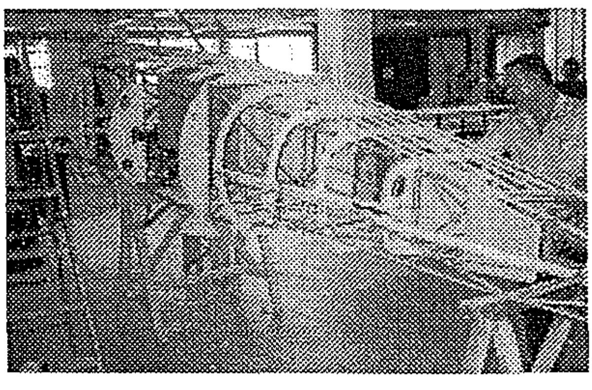


Fig. 5.- Fuselage of the C-30 during manufacturing process.

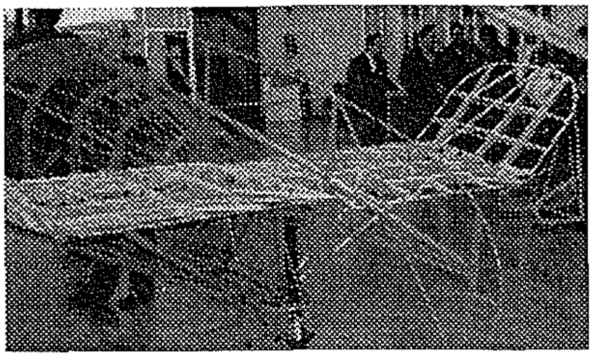


Fig. 6.- Tail plane of the new C.30.

3.2 Rotor

An original rotor has been used. The components obtained at Hendon RAF Museum include three blades, rotor blade control arm, rotor head pylon assembly, rotor head fairings, blade dampers, lateral and longitudinal bias springs, forward pylon tubes, shaft antivibration mount, control rods, spin-up clutch housing and plates, rotor head complete with dog clutch, clucht drive shaft,.... Figure 7 shows a photograph of these components.

Fig. 7.- Original components during their shipping to the Albacete aerodrome.

All these components have been deeply revised with modern quality control techniques, to guarantee the flight safety conditions. Fig. 8 shows the rotor head.

It is important to point out that an anticlockwise rotor has been restorated. The rotor spin-up mechanism depends on the sense of turn and has requested a special attention.

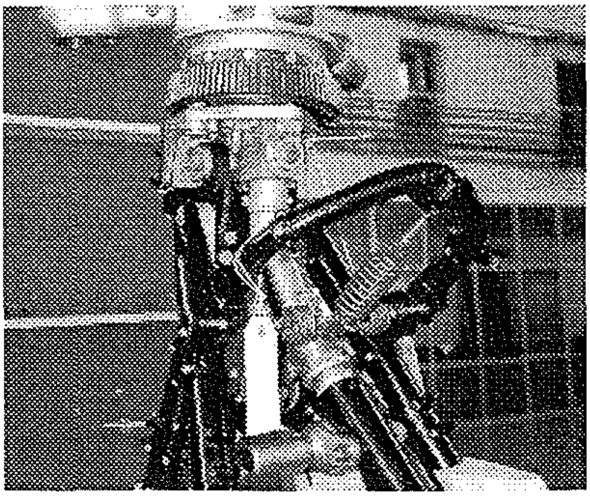


Fig. 8.- Photograph of the C-30 rotor head.

3.3 Engine

C-30 was provided with multiple engines. So, the C-30 prototype was originally engined with a 105 hp Armstrong Siddeley Genet Major I, but a 140 hp Armstrong Siddeley Genet Major IA was early installed in the C-30P. RAF acquired a considerably number of C-30ª with a 140 hp Armstrong Siddeley Civet I, but most of the Autogiros manufactured in the United Kingdom were provided with the Genet Major IA. France and German Autogiros, named Fock-Wulf C30 Heuschrecke, Lioré et Oliver LeO C.30, SNCASE 301 and SNCASE 302 were provided with more powerful engines Salmson 9Nc and Salmson 9Ne. Efforts have been made to obtain an original Genet Major IA fit to fly, but there is none available.

Two Siemens Sh14 were available in the funds of the Spanish Air Force Museum, at Cuatro Vientos. With components from this two engines, the SAF Workshop at Albacete reconstructed one engine perfectly fit to fly. But this engine turns clockwise, opposite to the GM IA used in the British Autogiros. Propeller and spin-up mechanisms are just for an anticlockwise engine.

The engine has been modified as follows to invert its sense of turn. Originally, the cylinders work in the order 1-3-5-7-2-4-6. The magneto and its launching spring have been inversely connected, so now cylinders work as 1-6-4-2-7-5-3. These modifications have allowed to inverse the turn sense, but efficiency decreases because of the difference in the open angle of the inlet and outlet valves. A new camshaft, with mirror image, has been machined, and a Sh 14A turning anticlockwise engine has been obtained, with similar performances as the original one.

Performances of the engine fitted with the propeller have been determined in bench tests.

4. LANDING

4.1 Direct control description

An important feature of the "direct control" Autogiro is that, in addition to the suppression of the fixed wings, ailerons and elevator, there is no rudder. The full control is obtained by tilting the rotor about its axis. The rudder is replaced by a fixed vertical fin, with a hanging stick control column direct from an extension of the rotor hub to the pilot's hand (modern gyrodinos with tilt rotor have a conventional stick instead of the control column but with similar function). This configuration makes impossible to mix controls as with an aeroplane, as there can be only one definite reaction of the rotorcraft for any given movement of the control column during flight. The resultant lift of the rotor disc is located in close proximity to the centre of rotation of the blades, and in a direction that is normal under all conditions to the plane of the disc. In consequence, any tilting of the rotor disc from a normal position by means of the control column results in a displacement of the total rotor lift relative to the centre of gravity, which in turn causes an immediate change in the attitude of the machine. In normal flight, a movement of the control column to the left or right will cause the machine to bank, and at the same time to turn. The latter additional change in direction occurs as a result of the sideslip produced by the tilt of the rotor force. The resultant wind action produced on the large fixed tail surface (fin), acting as a weathercock, makes the Autogiro head to the wind, to make a nonslipping turn. It is impossible, however, to sideslip or bank independently of a turn.

This condition is very important during landing, in the touch down instant. Landing with lateral wind is nearly impossible. On days when there is a light wind varying in direction from point to point on the airfield, or a gusty wind, the inability to correct the drift at the last moment is a serious disadvantage of this type of control. Most of the modern gyrodinos have a rudder flown by the propeller to obtain lateral control. However, in fail engine, present the same problem, moreover, if we take into account that the pilot is not in the habit of flying with only the rotor control.

With any fixed-wing machine, the efficiency of the controls varies according to the speed of flight; whereas with the Autogiro full control is independent of the speed of the machine, and it is constant for all conditions of flight.

It is important to note that Autogiro control is very sluggish compared to fixed wing aircraft. On the other hand, whereas the air controls of an aeroplane are also normal for its control once it ceases to be air borne, such is not the case with the Autogiro. This rotary wing is controlled on ground only by means of the steerable tail wheel, which is foot operated through a conventional rudder bar.

4.2. Landing description

The incapacity to correct the drift during landing makes difficult to land with lateral wind in a runway along its axis. The reconstructed C-30 first flight has taken place on January the 15th, 1998, in Albacete aerodrome. A horizontal steady flight of 1500 m in length and at 8 m in height was carried out. , Figure 8 shows the C-30 during take-off.

Figure 9. First flight. C-30 flying in Albacete on January the 15th, 1998.

The flight was parallel to the runway. To land, the pilot throttled off, and descended to a very smooth touch down on three points. A lateral gust made the Autogiro to yaw. The pilot attempted to apply a correction by a lateral movement of the control column to align the Autogiro in the runway axis. The Autogiro rolled on its side. Rotor blades and propeller were in serious damages. A new set of rotor blades has been donated by the Argentina Airforce, and Hendon RAF Museum has lent another propeller.

A review of existing documents and videos have shown that the landing was a critical manoeuvre, moreover for pilots trained to fly in aeroplanes, because, when troubles, the pilot should act. A very simple study to establish the critical Autogiro landing condition has been performed in order to guaranty the safety in next flights.

4.3. Autogiro model

To study the landing limitations, the Autogiro is modelled as a tetrahedral body (Figure 9). The forces considered are: the rotor lift, the weight, and the ground reactions on the wheels. With this, a simple model from the flight mechanics point of view allows us to analyse the manoeuvre. Figure 10 indicates the main dimensions.

Among the causes of yaw on landing, a contributory factor is the extra-wide-track undercarriage itself. An undulation in the surface of the ground, or even a landing with lateral bank, is sufficient to cause a yawing moment; if the tail wheel has no load, it is not possible to act against the swerve. Thence, the Autogiro describes a non-rectilinear trajectory. The maximum lateral acceleration is analysed.

The Autogiro is assumed to be flying only with one pilot (in the rear seat), and loaded with 40 kg of fuel. A three-point landing is considered, and, when roll starts, the Autogiro turns along an axis BC (it rotates along the line passing through the tail wheel and one of the main landing gear).

Moment induced by the weight:

$$M_W = W_g \times \overrightarrow{MN} \cong 7150 Nm \quad (1)$$

The moment of lateral inertia force:

$$M_I = W \cdot a_y \cdot \cos(17{,}1^\circ) \cdot \overline{GM} = 1109 \cdot a_y \quad (2)$$

The critical lateral acceleration results: a_y=6,45 m/s^2

Another cause to roll when there is yaw on landing is trying to correct the swerve by a lateral movement of the control column.

In order to turn the Autogiro in the air, the control column is moved in the desired direction and from a purely practical point of view, the machine turns and banks simultaneously. In fact, the manoeuvre can be split into three distinct phases: first, the tilt of the rotor, secondly, the bank of the fuselage; and thirdly, the actual turn. The turn is produced without sideslip because of the air forces acting on the fin.

If the same lateral use is made of the control column immediately after landing (the rotor is still lifting), it is impossible for the Autogiro to adopt its normally resultant bank preparatory to the turn, owing the landing gear being in close contact with the ground. The Autogiro is forced to roll in the opposite direction to the yaw, and overturn.

The lateral projection of the rotor lift produces the following moment:

$$M_{Ty} = T_Y \cdot \cos(17{,}1^\circ) \cdot TP \quad (3)$$

If the rotor lift equilibrates the weight, a critical tilt angle, b_1, of the rotor can be estimated as:

$$b_1 = \sin^{-1}(T_Y / T) = 19{,}6^\circ \quad (4)$$

In addition, the answer to an action on the rotor is considered. Figure 11 sketches the problem.

The turn of the machine is governed by the next equation:

$$I_x \ddot{\phi} + W(b\cos\phi - h_G \sin\phi) = T[h_R \sin b_1(t) + b\cos b_1(t)]$$

$$\phi(0) = 0; \quad \dot{\phi}(0) = 0 \quad (5)$$

Considering low angles, and the rotor lift compensating the weight, the bank angle due to a step control $\delta(t)$ in the form:

$$b_1(t) = b_{10} \qquad t>0 \quad (6)$$

the bank angle is:

$$\phi(t) = \frac{b_{10} h_R}{h_G} b_1 \cosh\sqrt{(Wh_G / I_x} t \quad (7)$$

Therefore, if the rotor tilts an angle, b_1, of 7°, the Autogiro rolls 29° in a second. This angle is critical because the blade bits the ground.

5. CONCLUSIONS

- A model C.30 has been recostructed. This model is fit to flight on exhibitions.
- Landing manoeuvre is critical.
- To land, there should be no drift.
- The tail wheel must touch down first.
- Just after touching down, the control column must be pushed forward centrally to the dash and kept it there. Therefore, rotor lift is practically negligible.
- Once the swerve occurs, never the control column must be used to align the Autogiro. Only tail wheel control must be used.

6. REFERENCES

[1] Brie, R. *The Autogiro and how to fly it.* Pitman & Sons Ltd., London, 1934.

[2] Martin Barbadillo, T.,*El autogiro: ayer, hoy y mañana.* Espasa Calpe S.A. Madrid, 1935.

[3] Brooks, P. *Cierva Autogiros.* Smithsonian Institution Press. Washington, 1988.

[4] Woodward, A.E., Bigg, F. J. and Beavan. General investigation into the characteristic of C.30 Autogiro. R&W 1859, 1939.

[5] NTC 005. Control direccional del Autogiro en el aterrizaje. *Autogiro C-30 Reproducción y puesta en vuelo de un modelo histórico.* Fundación General de la Universidad Politécnica de Madrid, Madrid. January 1998.

[6] NTC 001. Datos generales y cálculos preliminares. *Autogiro C-30 Reproducción y puesta en vuelo de un modelo histórico.* Fundación General de la Universidad Politécnica de Madrid, Madrid November, 1997.

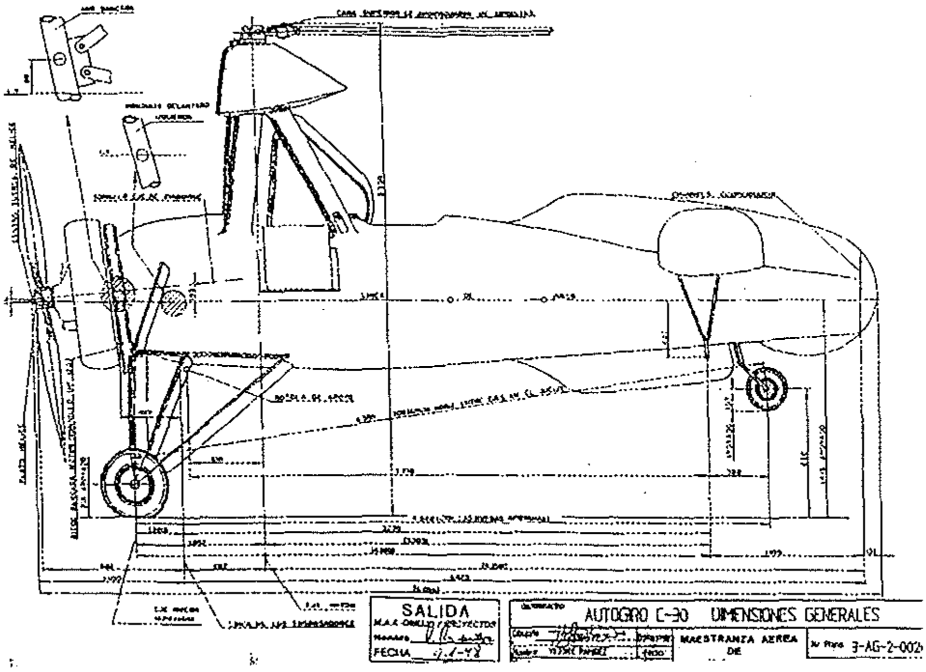
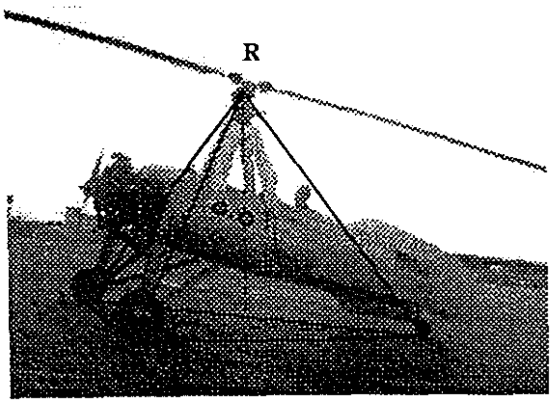
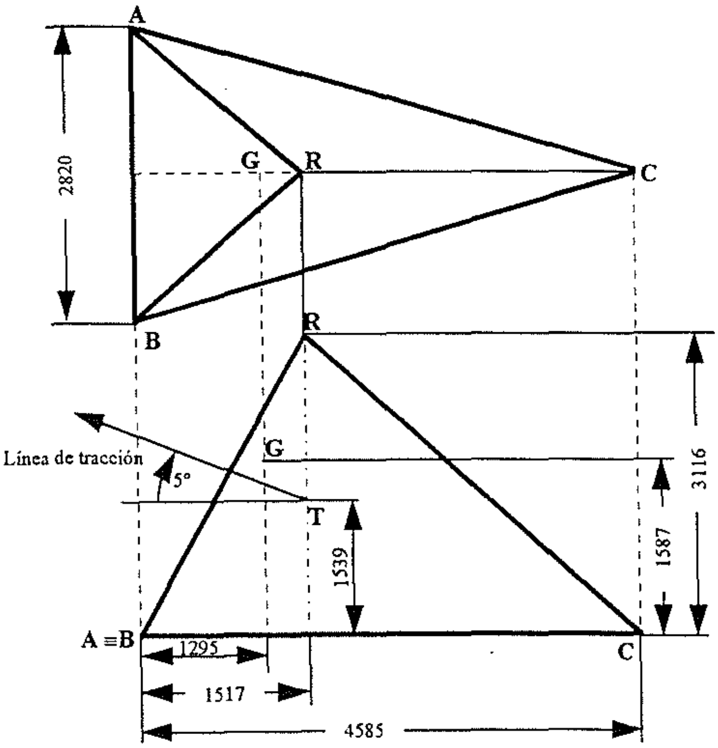


Fig 3. C.30 Drawing.





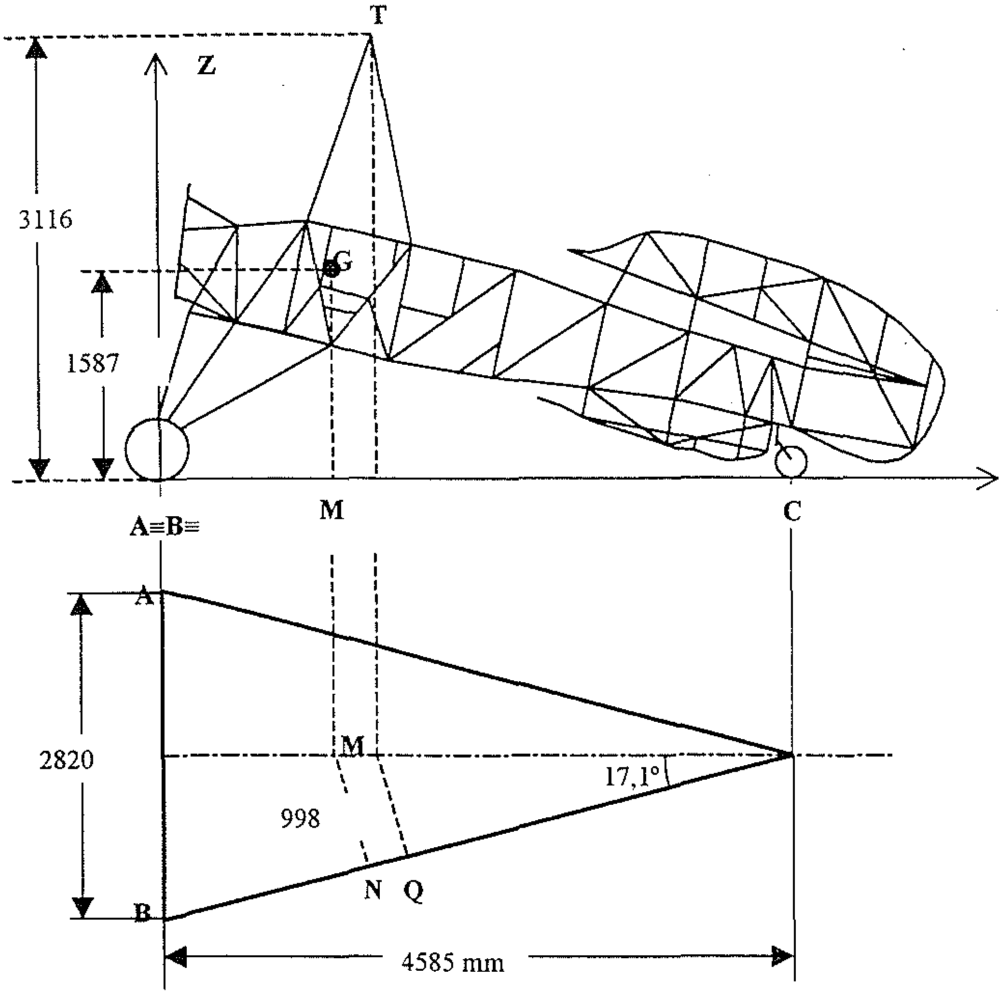


Fig. 11. Auxiliary dimensions required to study the roll.

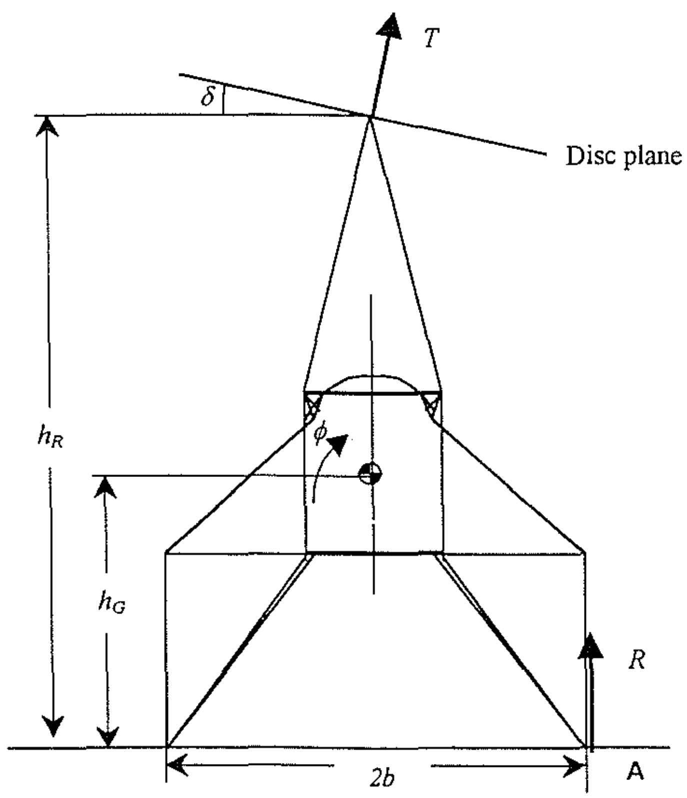


Fig. 12. Rotor effect on bank. Sketch of the Autogiro C-30.