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AIRCRAFT CIRCULARS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 198

KAY 33/1 GYROPLANE (BRITISH)*

All-Metal Single-Seat Light Rotor Plane

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KAY 331 GYROPLANE (BRITISH)*

All-Metal Single-Seat Light Rotor Plane

The latest Kay gyroplane - type 331 - is an all-metal single-seater with a Pobjoy "R" engine (75 hp., geared 0.47-1). This gyroplane has a four-blade propeller of wood and a four-blade rotor. The propeller is four-bladed to reduce noise, and the rotor folds with two blades forward and two backward (figs. 1, 2 and 3).

The chief feature of the Kay design is the positive control of lift by variable incidence of the rotor blades while in flight. This is done by a very sound and ingenious rotor hub assembly, which is solely the patented property of the Kay company.

Lateral control is provided by rocking the rotor spindle, but a normal rudder and rudder bar with a toe-action brake pedal and Dunlop Bendix brakes and Dunlop airwheels are provided. The fore and aft control is by a hinged tail plane and normal elevators connected to the spindle which slides to and fro in the dashboard, and is the pivot of the spectacle-type lateral control.

The design of the fuselage is of straight sections of welded steel tube and conforms to modern aircraft practice. It has a normal tail plane of duralumin tube with a pivoted rear spar and a movable front spar and the whole empannage, rudder and fin, may be easily removed from the last fuselage bay by taking off the fairing at the root of the fin to get at the anchorage. The leaf-spring tail skid has a limited swiveling movement.

The tail plane has the rib formers reversed on the port side to change the airfoil section and neutralize the propeller torque reaction at normal speeds like the ordinary autogiro. The oleo leg is another product of the Kay company. It has a travel of six inches and is particularly slim.

When a system of rotors is dragged forward into wind

*From The Aeroplane, December 26, 1934.

with an angle of tilt or incidence, the rotor disk is forced by the aerodynamic lift to "cone" upward slightly, and this "cone" is determined by the centrifugal force of the revolving rotor blades and the "coning" can be kept within safe limits by increasing the rotor revolutions by varying the incidence of the rotor blades. Unhappily, this in the past had to be adjusted on the ground in the same way that the usual variable-pitch propeller of small sizes is altered. This was necessary for different loads.

Then, after the stage to which a gyroplane had to be taxied about the airport to spin the rotor gave place to the time when an extra four inches of travel on the elevators deflected the slipstream upward to spin the rotor, the latest system used direct drive from the engine. This introduced its own problems. First, torque reaction - this mattered not at all while the weight of the stationary gyroplane rested on the ground, but when the rotor reached normal revolutions the partially air-borne gyroplane lost stability and produced other complications. That the rotor spindle should be locked and rigid while starting up or taxying was essential, and the positive incidence of the blades made the avoidance of any appreciable angle of backward tilt important. As a precaution the locking device was on the dashboard and gave a slight forward tilt to the rotor mast when locked, and the gyroplane was faced a little out of wind. The clutch between the engine and the rotor drive was disconnected at all times except when actually starting up.

The Kay gyroplane's main feature, which is the control over eight degrees of the rotor blade incidence while in the air, entirely overcomes all these difficulties.

In the first place, when starting up, a slight negative incidence is put on the rotor blades which prevents the gyroplane from becoming air-borne, and there is an extra negative position for use in high winds which makes the gyroplane cling to the ground like a limpet.

The small incidence, either neutral or two degrees negative, allows the rotor to be motored up to 400 r.p.m., which is the taking-off r.p.m., with an expenditure of only 20 hp. from the Pobjoy engine, which will reach 2,800 r.p.m. at full throttle while turning its own four-blade tractor propeller and the rotor (in the low-drag position) through the 7 to 1 reduction.

At the moment of take-off, which can and should be made with the brakes full on, a lever on the right of the cockpit is pulled back, which does three things. First it trips the clutch gear on both the dog clutch and the cone clutch, and then it puts the rotor, spinning at 400 r.p.m., into its positive incidence position for normal flight. Meanwhile the Pobjoy has transferred its other 20 hp. to the tractor propeller, and by the time the rotor has slowed to 220-250 r.p.m., which is normal speed in flight, and in so doing lifted the gyroplane anywhere from 10 to 20 ft. vertically the tractor propeller will have given the gyroplane full flying speed.

In level flight the positive incidence of the rotor blades can be reduced as the air speed rises to increase the rotor r.p.m. and the consequent centrifugal force, and therefore decrease the "coning" effect on the rotor disk. The fuselage is noticeably nearly horizontal and almost parallel to the ground when at rest. The wide range of blade incidence makes a tail-down position of the fuselage unnecessary. This horizontal position is an advantage when the tractor propeller is pulling the gyroplane away during and after its vertical hop. Fore and after rotor tilt is not used except in a very small degree, and this movement is interconnected with the lateral movement of the control "weapon" (it is not a wheel or a column or a lever) to overcome the gyroscopic and turning radius effects.

Lateral control direct on the swinging stick introduces its own problems, and when the rotor was, say, tilted to the left the nose would be depressed by gyroscopic action, and when to the right the nose would rise strongly. Then the fact that one blade was coming forward and giving considerable lift, and the other was retiring and giving very little, would be altered in ratio on a turn by the less distance travelled by the blade which was inside on the turn. In the construction of the Kay hub has been incorporated a direct method of effecting varying ratios of positive or negative fore and aft bias (or tilt) with different degrees of lateral rotor tilt port or starboard, so that all these effects are compounded and corrected. This is done by the ingenious Z-shape rocker spindle, which is the fore and aft gimbal mounting of the rotor mast bearing.

The fore and aft trim is set in flight by a trimming wheel or by the push-and-pull cockpit "weapon" movement on the elevators. This and the normal rudder do away with the stiffening-up at speed, which is a noticeable feature of the direct control fore and aft tilt arrangement. At any time the gyroplane can be flown, taken off or landed, as a normal fixed-wing airplane. The controls of the Kay gyroplane work in a normal way if used in a normal way, and this is a big point for ordinary pilots, who need have no expensive instructional conversion course.

A reference has been made to "window-sill landings" at sight of any recent rotating wing development, but the success of the slow landing attempts has gone far enough for the present with this type, and the experiments lately have been directed to getting a startling take-off. This is the real step-ahead of the Kay design, although it must not be ignored that the rotor with incidence control, if combined with a variable-pitch propeller and a really streamlined fuselage, should result in speeds as high, if not definitely higher, than that reached by the normal fixed-wing airplane of the same horsepower and all-up weight. Work is being done by the Kay Company on a new V.P. propeller using the same principle as that used at the rotor-blade roots, and the experiment looks very promising.

Several queries arise about the effectiveness and life of detail parts. All these are answered satisfactorily. Experience with reversible propellers in the water shows that the tendency of the blade under load is to climb strongly into the maximum incidence angle. This effect, at the small angles used in the Kay rotor, is almost negligible, and the Z-shape crank in needle bearings which rotates the blade root knuckles provides an irreversible movement. Its acutation is by the latest Bowdenex flexible drive to bobbins under the rotor hub assembly. Lateral control is obtained by spectacles which are linked to the cranked spindle which rocks the hub assembly by direct push-and-pull rod through a 12 to 1 reduction, and is just reversible enough to give "feel". So little power is necessary to operate all the controls that very light gear may be used. An automatic throw-out is arranged inside the internally toothed ring on the hub through which the drive is transmitted.

SPECIFICATION

Type.- Single-seat light gyroplane.

Rotor.- Four parallel-sided blades of swaged steel tube and duralumin former ribs with plywood and fabric covering. Rotor runs at 400 r.p.m. at moment of take-off and 220 to 250 r.p.m. in flight and special stiffened and strengthened construction used. Rib formers are anchored to tubular spar with hollow rivets. Wood tip built up and post fitted in extremity of blade spar to take dynamic balance adjustment. Aluminum fairing fitted to root end of blade and extends to hub knuckle. The rotor rotates anticlockwise direction seen from below. It is driven by an extension of the crankshaft through the rear engine cover, to a dog clutch and by a short shaft to a friction cone clutch with cast elektron external portion and thence by a bevel box to the vertical drive shaft. This drives the rotor through a seven-to-one reduction by an internally toothed annular pinion incorporating a throw-out mechanism which disconnects the rotor if this overruns the engine drive. The two clutches are interconnected and are controlled by one lever in the cockpit. The hub, which is made to the Kay design by Barr and Stroud Ltd., is lubricated by grease gun to the nipples provided. For folding the rotor the two pins through the shock absorbers are removed.

Fuselage.- Of straight lengths of steel tube welded at all joints. Only one bulkhead, which is engine mounting and anchorage for oleo legs and front members of cabane superstructure.

Tail unit.- Normal airplane design. Tail plane with movable front spar and tail trimming gear. Rear spar hinged. Tail plane and elevators of duralumin tube and rudder of duralumin tube and pressed ribs.

Landing gear.- Divided type. Long oleo legs of Kay design with travel in compression of six inches. Dunlop Bendix brakes toe-pedal operated and Dunlop airwheels. Leaf-spring tail skid.

Power plant.- One Pobjoy "R" 7-cylinder radial engine giving 75 b.hp. at 3,000 r.p.m. (geared 0.47 to 1). Fuel and oil tanks in fuselage.

Accommodation.- Single open cockpit.

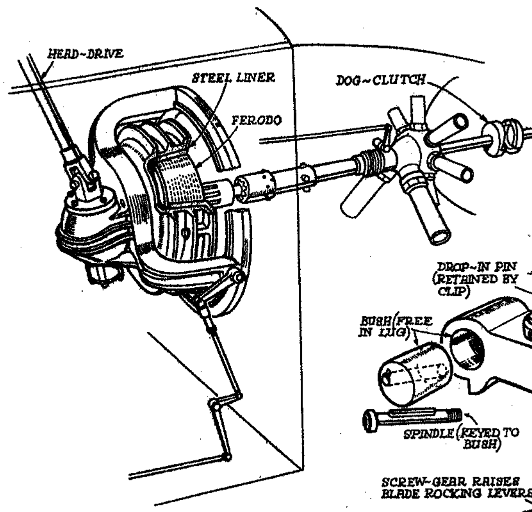
Controls.- See figure 4.

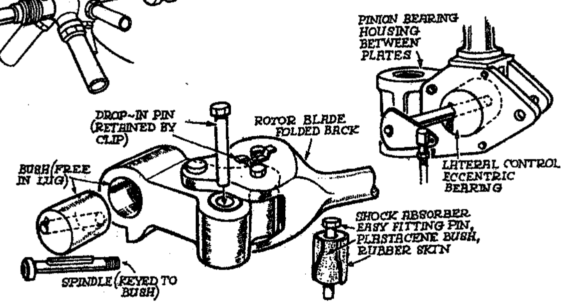
Dimensions.- Diameter of rotor 22 ft. Chord of blades 10 in. Span of tail plane 7 ft. 6 in. Over-all length 17 ft. 11 in. Over-all height 7 ft. 8 in. Chord of tail plane with elevators 3 ft. 2.3 in. Over-all width 15 ft. 9 in.

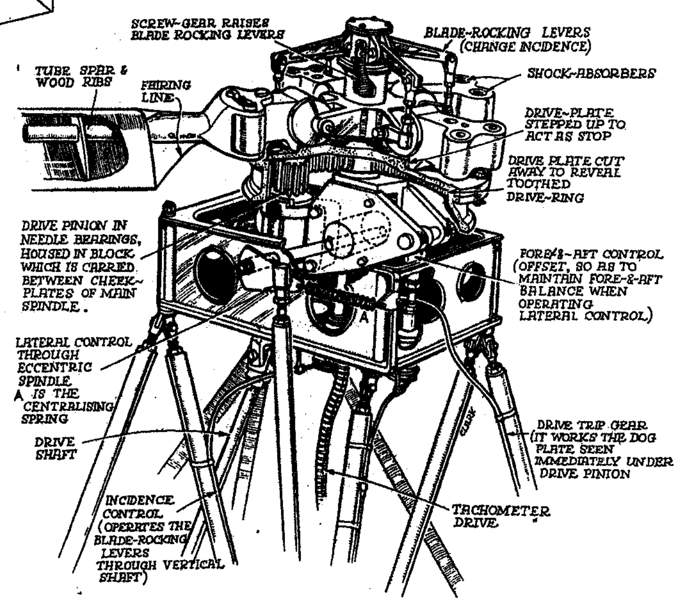
Areas.- Rotor blades (total) 32.4 sq.ft. Tail plane with elevators 15.6 sq.ft. Fins (upper and lower) 4.7 sq. ft. Rudder 4.73 sq.ft.

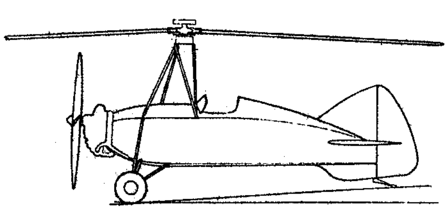
Weights.- Empty 624 lb. Loaded 850 lb.

Figure 4.-
Some Details of The Kay Gyroplane









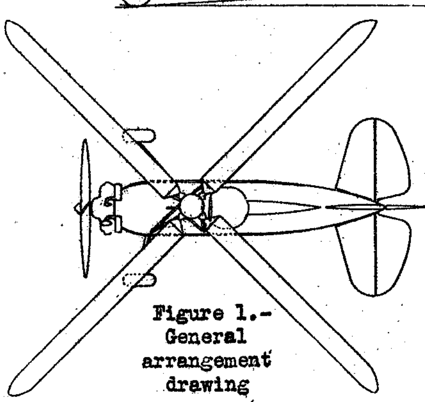
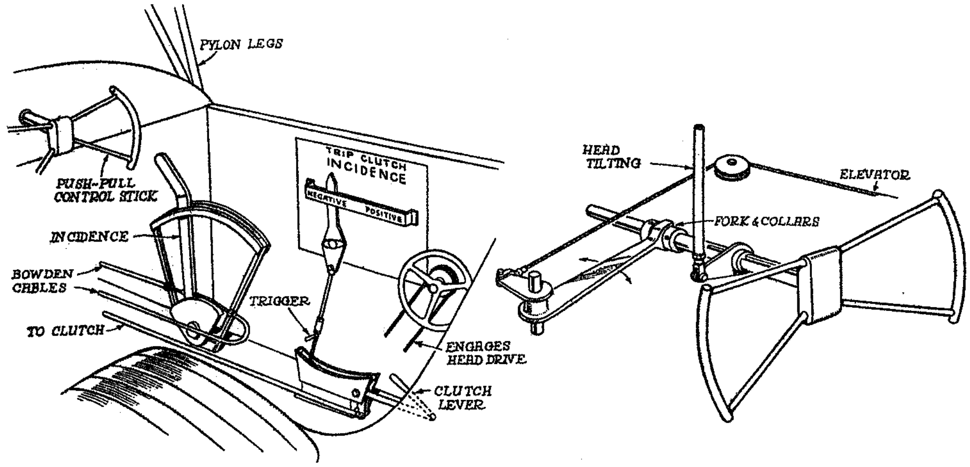


Figure 1.-
General arrangement drawing of the Kay gyroplane, type 331.



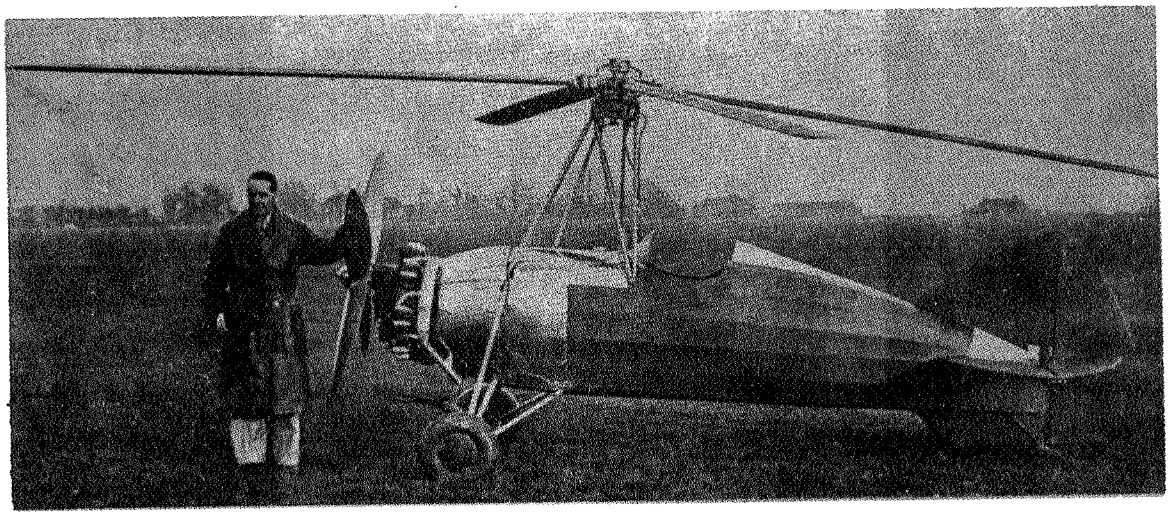


Figure 2.-View of the Kay gyroplane and its inventor.
(75 hp. Pobjoy engine.)

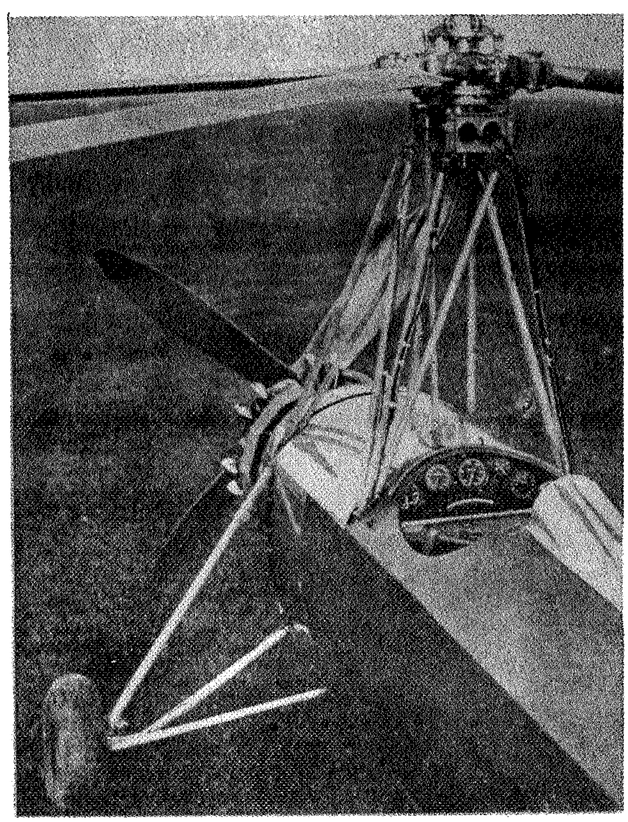


Figure 3.-The rotor-hub and pylon of the Kay gyroplane.