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AIRCRAFT CIRCULARS  
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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No. 205  
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THE HAFNER A.R.III GYROPLANE (BRITISH)

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THE HAFNER A.R.III GYROPLANE (BRITISH)\*

The Hafner gyroplane is a single-seater driven by a 90-horsepower Pobjoy Niagara III engine. Before describing the mechanical details of the Hafner gyroplane (fig. 1), it may be of assistance if the fundamental principles are explained briefly.

The rotor blades are attached to the head in the orthodox manner, with horizontal hinges which permit the blades to "flap," and vertical hinges with friction dampers for permitting the blades that slight freedom to alter their spacing to which one has become accustomed. The actual attachment of the blades to their hinged forks is, however, by way of a wire, so that in addition to the freedom provided by the two sets of hinges the blades have a third degree of freedom, i.e., to alter their pitch angle. The last-mentioned freedom is, however, restricted or damped, as will be explained later.

The inner end of each blade carries a crank arm on a vertical hinge, the hinge being incorporated in order to leave the blades free to "catch up" or lag behind one another. A so-called "spider" is mounted centrally above the rotor head, and also carries three arms mounted on vertical hinges (figs. 2, 3, 4, 5, and 6). The free ends of the blade cranks are connected (by a cup and ball joint) to the free ends of the spider cranks. When the spider is raised, by means of a separate control in the cockpit (fig. 7) its three crank arms rise with it and carry with them the free ends of the blade cranks, thereby increasing the pitch angles of all three blades (the spider rotates with the rotor head, of course), and when the spider is lowered the pitch angles are reduced. This control might be termed the lift control, as it varies the amount of lift given by the blades, and is used for steep take-off and for checking sinking when landing.

The flying control has the effect of shifting the center of lift of the whole rotor system by causing the blades to assume an increased pitch angle at one point of their travel around the circle and a decreased pitch angle at

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\* From Flight, February 18, 1937.

other points. This is effected quite simply by tilting the "spider." Obviously, if the spider is tilted back the blades will assume a low-pitch angle when passing through their rearmost position and a larger pitch angle when passing through the foremost position, thus shifting the center of lift ahead of the rotor pivot and thereby causing the craft to climb. If the spider is tilted to the left the pitch angle will be large on the right-hand side and small on the left-hand side, and the craft will bank and turn to the left.

Flying controls on the A.R.III gyroplane also include a trimming tail plane and a pedal-operated rudder of orthodox type.

The rotor blades have single steel-tube spars of small diameter but heavy gage. No attempt has been made at saving weight on the rotor blades; in fact, weight has deliberately been kept fairly high in order to obtain a good flywheel effect to assist take-off and to ease the craft down gently through the last couple of feet of the landing. In this connection it may be pointed out that the mass of the blade per unit of frontal area is important. In the A.R.III, Mark II, this value reaches a high figure and has much to do with the good energy-assisted take-off and the shockless landing without preliminary glide which are features of this craft.

At its outer end the blade spar has screwed into it a steel plug used for balancing purposes. The rotor blades are of airfoil section over the outer two-thirds only, the inner third of their length being of plain streamline section. The main blade spar terminates at its inner end approximately at the point where the streamline and airfoil sections merge into one another. From this point to the vertical rocking hinge fitting on the rotor head the centrifugal pull of the blade is normally taken not by a continuation of the tubular spar but by a steel tie rod of relatively small diameter. This is, in fact, the "wire" of our theoretical blade suspension. At its outer end this tie rod is screwed left-hand into the outer spar tube, and at its inner end it is screwed right-hand into the knuckle root fitting.

## PRECAUTIONARY MEASURES

The main blade spar does have a tubular inward extension, but normally this does not carry the centrifugal loads. The tube has a shoulder at its inner end, and the length of the tie rod is so adjusted that normally the shoulder is just clear of a collar attached to the knuckle fitting. Should, however, the tie rod stretch (through, for instance, over-revolving of the rotor), or should it break, the shoulder of the tubular spar root will bear on the collar, and the blade will be secured against centrifugal pull. The friction will, however, be so great that the blade incidence will be locked and the pilot will at once know that something has happened, as the rotor will become "rough" and his incidence control will be inoperative. That does not mean that he has lost all control, but merely that the craft will have to be controlled by the normal flying controls, viz, rudder and elevator; lateral control will, of course, be lacking, but it should be possible to land the craft without doing very serious damage. In any case, there is little likelihood of a tie rod breaking, as its load factor both in tension and torsion is high. Fatigue might be feared, but experiments have shown that in view of the length of the rod and the small amount of twist to which it is subjected, there is little reason to fear trouble from this source. The spar-root tube, it will be realized, serves to carry the blade in bending when the rotor is stationary, its inner end making a bearing but not a tension anchorage.

The rest of the Hafner rotor head mechanism is fairly straightforward. The hub is a partly conical bowl with an internal cylinder which carries the taper roller bearings by which it is attached to the rotor spindle. A fork or yoke forms the attachment of the blade root to the rotor hub. The three yokes are identical but unsymmetrical, the longer arm of each taking its bearing on the outer wall of the cone and its inner on the internal cylinder. The hinge pins are so arranged that their axes intersect the rotor axis and so avoid any couples about the center of the hub, such as might arise due to unequal lifts of the blades in flight.

## PITCH ADJUSTMENT

The spider which carries the three crank arms used for varying the incidence simultaneously on all three blades, is carried on a spindle mounted in a piston which can slide up and down inside the rotor axle. The spider, of course, turns with the rotor head, but the piston is prevented from rotating, as is also the extension of the spider spindle which terminates in the joy stick. A double-jointed arrangement is incorporated in order to provide the usual aircraft type of control, i.e., pull-for-climb, push-for-dive. The piston is moved up and down by means of a Simmonds-Corsey control, the operating lever of which is placed on the left-hand inside of the cockpit, its neutral and forward positions being locked by a pawl and teeth on a quadrant. The rearmost part of the quadrant is without teeth in order to compel the pilot to hold the lever back. This is done because this setting, which corresponds to maximum pitch angle, is used for landing only and for the initial part of energy-assisted take-offs. As soon as the pilot releases this lever it moves forward automatically until the pawl engages with the quadrant tooth which corresponds to normal pitch angle.

The drive for starting the rotor includes a clutch and gear-box unit, and there is, of course, a freewheel arrangement. The drive is interesting and has had a good deal of development work done on it but, unfortunately, space does not permit of describing it in detail. It incorporates such refinements as a synchromesh device, and great trouble has been taken to protect the rotor head and blades against shock loads during the revolving-up process. That this is necessary will be realized when it is pointed out that each of the three rotor blades weighs about 35 pounds, and that the rotor is speeded up to some 240 r.p.m. for energy-assisted take-offs.

## STEEP ANGLE OF CLIMB

A recent demonstration at Hanworth showed the Hafner gyroplane to leave the ground with a run of about 2 yards, the subsequent climb being very steep. Actual measurements are not available but it is estimated that the A.R. III, Mark II, should be able to clear the standard 66-foot "screen" after a run from a standing start of about

60 yards. Actual official performance figures have not yet been established, but it is expected that the top speed should be about 125 to 128 miles per hour, and the cruising speed approximately 115 miles per hour. Owing to the amount of energy which can be stored in the rotor, landings can be made straight off the "sink approach" with preliminary glide.

At an all-up weight of 890 pounds, the craft carries 70 pounds of gasoline and oil and 180 pounds of pilot and luggage. The duration is  $1\frac{1}{2}$  hours, or 170 miles in still air. The diameter of the rotor is 32 feet 10 inches, and the rotor-disk area is 846 square feet. As each blade has an area of 6.68 square feet, the "solidity" is 2.37 percent. The loading per square foot of rotor blade area is 43.6 pounds.

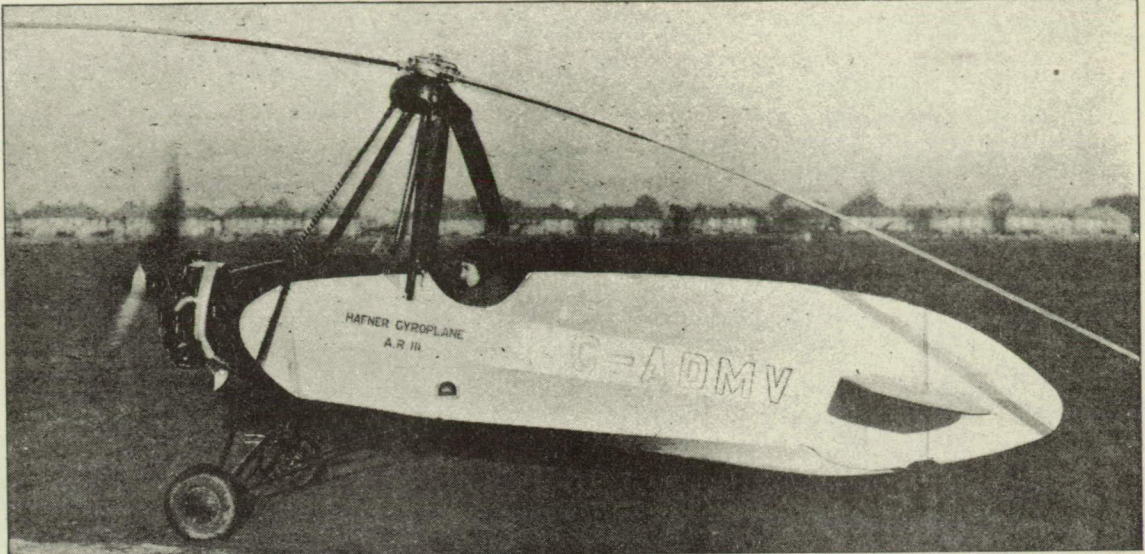


Figure 1.- The Hafner A.R. III, Mark II, has a very short take-off run (about two yards) and climbs remarkably steeply. The engine is a 90 hp. Pobjoy Niagara III. *Flight*

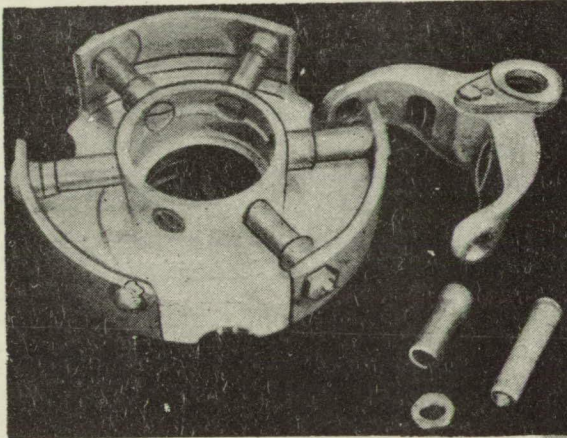


Figure 2.- The rotor hub with one of the three yokes and the hinge bolts which take their bearings on the inner and outer flanges of the hub. *Flight*

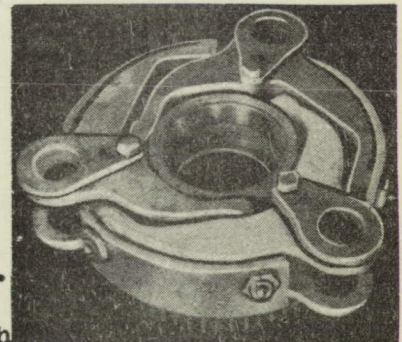
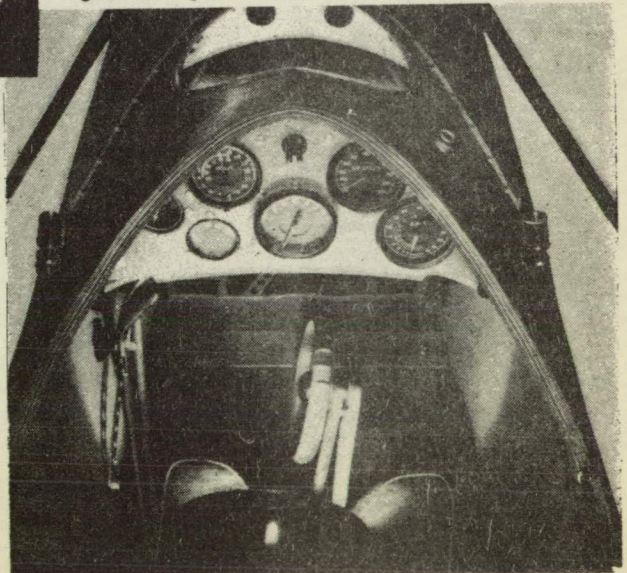


Figure 3.- The three interlapping yokes in place on the hub. The larger arm of each yoke is slotted to accommodate the hinge pin of the shorter arm of the adjacent yoke and vice versa. *Flight*

Figure 7.- Looking down into the cockpit of the Hafner A.R. III. On the left is the lever which operates the spider. In the center the trimming wheel for the pivoted tail-plane. The end of the joystick is out of sight below the instrument board. *Flight*



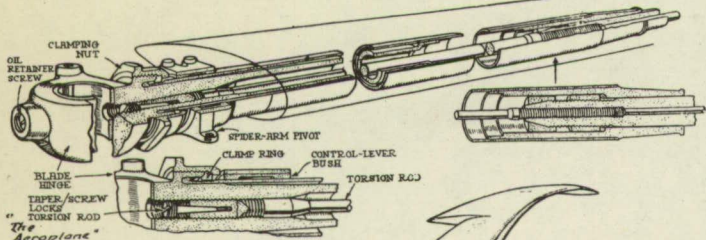


Figure 4

The three ways in which the pitch of the blades is altered.

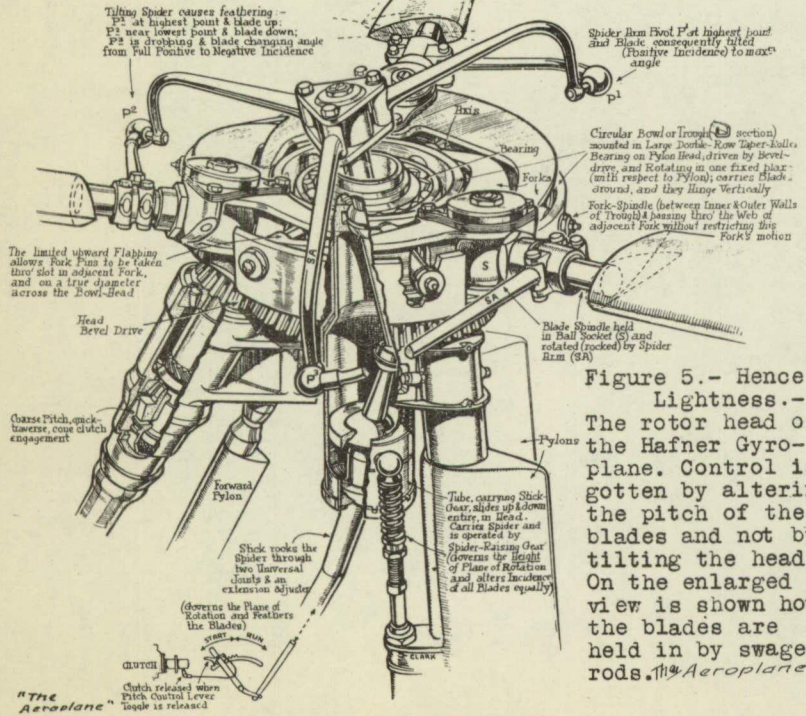


Figure 5.- Hence Lightness.- The rotor head of the Hafner Gyroplane. Control is gotten by altering the pitch of the blades and not by tilting the head. On the enlarged view is shown how the blades are held in by swaged rods. *The Aeroplane*

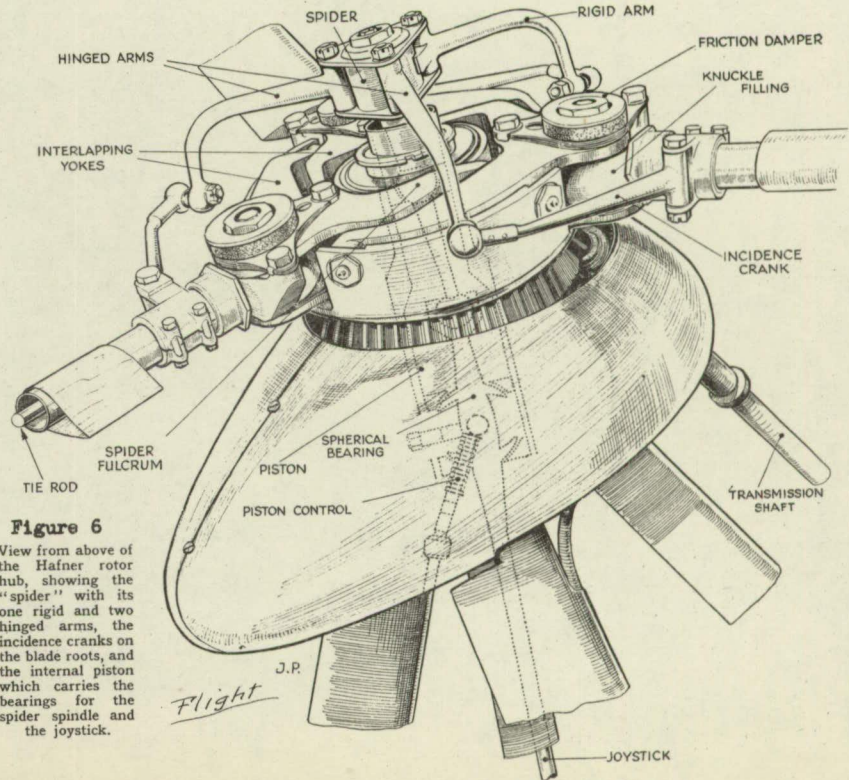


Figure 6  
View from above of the Hafner rotor hub, showing the "spider" with its one rigid and two hinged arms, the incidence cranks on the blade roots, and the internal piston which carries the bearings for the spider spindle and the joystick.