TRY AN AUTOGIRO

UNLESS our records are incomplete, the first powered single rotor model Autogiro to be published anywhere in the world, was the Ro-dart by Dennis Neale in the December, 1951, AEROMODELLER. That this design aroused so much interest in Britain is significant that modellers are looking, as they are ever wont to do, for something new and unconventional to occupy their leisure hours. The age of control-line which started in 1947 here, and reached a peak in 1949-50, is now waning and no longer holds the interest normally coupled with something difficult to build and fly.

We suggest, from practical experience, that if you are looking for something different, exciting and eminently satisfying in its performance, then you should certainly put your hand to an Autogiro.

Not wishing directly to copy the Ro-dart, we branched out with the model, subsequently called " Jumping Jiminy " on account of its amazing performance, which is shown accompanying this article and, although we completely lacked even the remotest theoretical knowledge of Autogiro design, our first attempt did, if we may blow our own trumpet, exceed the altitude and rate of climb of the Ro-dart by a creditable margin. Since then, this Allbon Dart powered experiment has maintained regular high performance and this in spite of several facts which have come to light to disclose that many of its design features were far from ideal. In other words, Autogiro design for the .5 c.c. diesel is so flexible that, although the " designer " may tackle the project without previous experience he can, if working within wide limits, be assured of every success.

As far as we were concerned, the performance of our first model was perfectly satisfactory and we were quite prepared to carry on with only structural modifications. However, in the course of correspondence, we located two specialists in the powered model Autogiro and from them and their long experience, we have learned enough to improve flying considerably. These two experts are D. W. Cooper, B.Sc., and R. Coles, M.A., of Newcastle-upon-Tyne and their experiments have centred upon the Frog 150 Diesel. Whereas with our Dart powered model we can, at the most, claim a flight of $\frac{3}{4}$ mile, they have substantiated claims of flights up to 4 miles, reaching an altitude

Alan Baker's 28-inch diameter design for the Dart made many consistent demonstration flights at the 1952 Northern Heights Gala. Total weight is 7 oz. and maximum height would appear to be in the region of 200 feet. A clubmate of Dennis Neale, Baker has pioneered powered Autogiros since the early days of the prototype Ro-Dart.

(Bill Dean Photo)

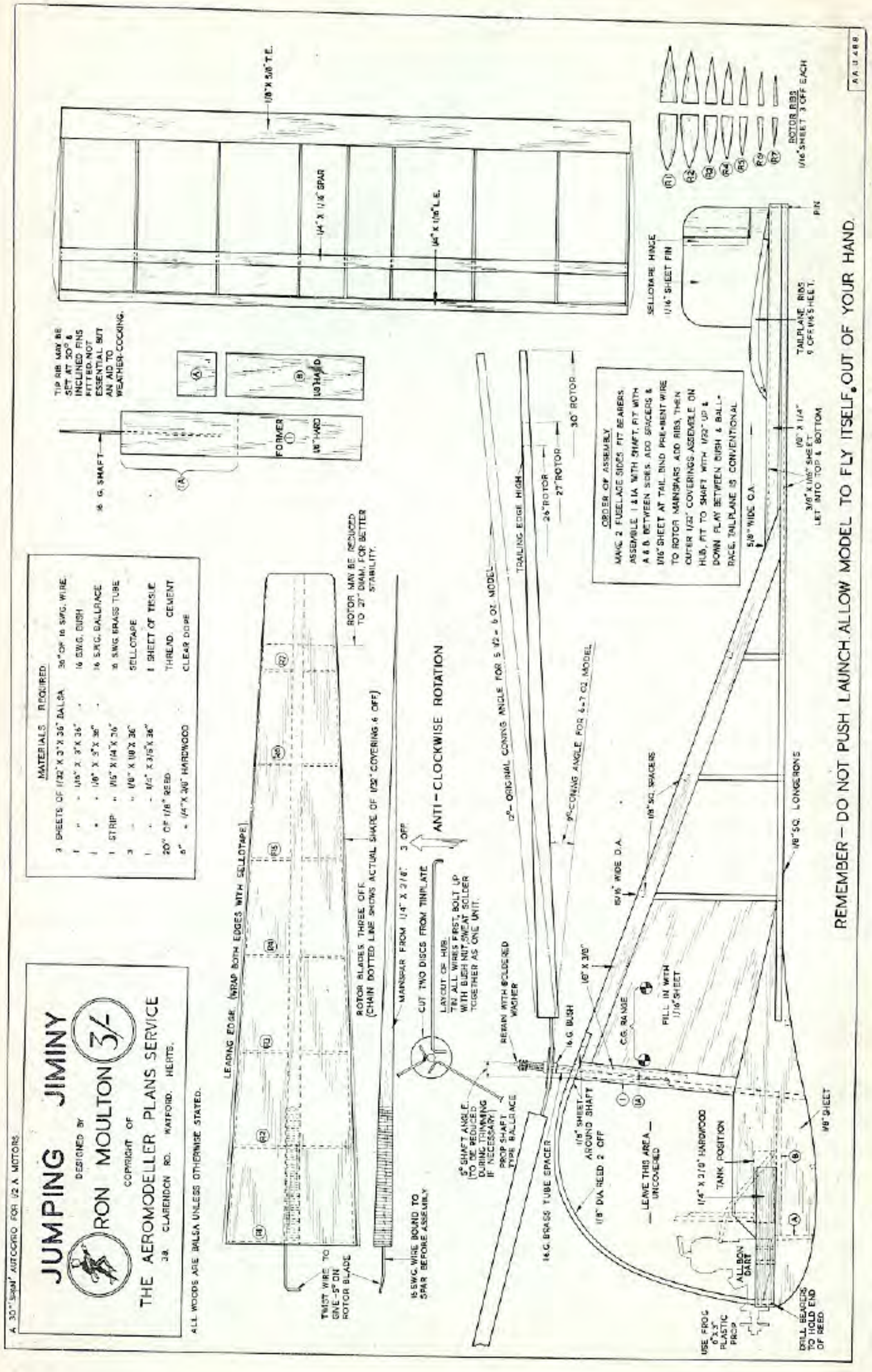
In its original form, with long span rotors, skid type wire undercarriage and inclined tip fins on the tailplane, Jumping Jiminy is seen here. Latest version, produced in plan form overleaf, is slightly different, with modifications born of practical experience. Uncovered cabin portion ensures rearward centre of lateral area

of 500 feet, checked by the local Aero Club's Auster light plane. Impressive though they may be, these flights do indicate the one weak point in known findings and that is the difficulty in obtaining any form of directional control.

If directional control is lacking, other points have come to light to ensure stability and minimise breakage of the vulnerable rotor blades. One great advance in this direction is the hub developed by the Newcastle exponents and which permits each blade to knock off independently, or the actual blade angle to be trimmed for ultimate satisfaction. Spare blades may be carried in the model box for experiment with rotor disc areas or sections and if anything, the whole assembly is no heavier than the all metal soldered fitting described for the Ro-dart and also used on Jiminy.

Tailplane construction can be entirely conventional, as may also the fin, whilst rotor blades open themselves to many varied forms. With a blade area of approximately 80/90 square inches for .5 c.c., a normal built-up structure with tissue covering is practical, although for only a slight concession to weight, it is possible to make the blades from 1/32nd sheet balsa, using a full depth spar and very wide rib spacing. This is particularly useful for blades of streamline section, but in view of the better performance with the Clark Y section blade, it might be more practical to combine normal structure with 1/32nd top sheet covering to maintain an accurate section for the narrow chord. So much for the general construction; now what about the theoretical points which have evolved from practical flying experience ?

A common error in judging an Autogiro's reasons for flying, is that blade area is the criterion and each blade must be regarded as an individual provider of lift. This is erroneous in that lift is provided by the *total* disc area, and if you allow your imagination to run riot, you should consider the disc as a " flying saucer " with the forward part tilted upwards. The airflow against this provides an upward lift, whilst the action of the blade sweeping forwards and into this " tilted" section is assisting matters more than somewhat by virtue of its particular aerofoil section. Obviously, the faster the blades can go round the more " solid " is the disc and the greater the lift generated. Since blade area has a greater effect on rotational speed than on its individual component of lift, the tendency is to high aspect ratio blades for faster rotor speed. Experience now gives us a working figure for this blade area and such a figure is quoted as a



" Solidity Factor," or in other words, the ratio of the actual rotor blade area to the total swept area of the rotor disc. This is the area for all blades and since, for balance and maximum efficiency three blades are used, the actual solidity is divided by three for individual blade area. For example, a suitable rotor diameter for a 1 c.c. engine, would be about 32 inches, which gives a total swept area of 805 square inches and by practical experience, the solidity factor in this case should be about $12\frac{1}{2}$ per cent. Then the total blade area should be about 100 square inches, which means that the individual blades will be 33/35 square inches each. With the blade span fixed by the decided rotor diameter of 32 inches, less allowance for root attachment, the aspect ratio of the blades is thus regulated by the chord necessary to provide this area, which should be approximately $2\frac{3}{8}$ inches giving an aspect ratio of 5.6 for a $14\frac{1}{2}$-inch blade. Using the Newcastle hub, solidity should be less, using approximately same rotor chord.

As the rotor diameter is increased so the solidity factor should decrease proportionately, whilst for smaller diameters the solidity increases.

So much for blade areas; now what about their angles and the means by which they will work. We have already seen that the inclined forward portion of the disc is responsible for some part of the lift and the angle of this forward portion may be considered similar in effect to the incidence used on the wing of a conventional model. Although we managed to convince ourselves that an angle more in keeping with the *dihedral* of a fixed wing is essential here, we reduced the coning angle (or dihedral) from 12 degrees to 9 degrees and also the backward angle of the rotor shaft to 3 degrees. Thus at the most, the upward and forward inclination of the blade pointing forwards will be 12 degrees; and the blade pointing aft will be horizontal. This set-up has been confirmed in practice as the best arrangement for general stability, providing the disc loading is in the region of 2/3 ozs. per square foot—only with a considerably lighter loading was Jiminy successful with the large coning angle of 12 degrees. So now we have another factor for the 1 c.c. Autogiro specification, and that is that it should be approximately $12\frac{1}{2}/15$ ozs. total weight for best performance.

As mentioned earlier, the advancing blade provides lift by virtue of its aerofoil section and it is arranged so that it sweeps spanwise into the forward half of the disc at an angle near enough to neutral. With a backward inclination of the rotor shaft at up to 5 degrees this indicates a fixed negative angle on each blade at minus 5 degrees for first tests. If it is necessary to speed up the rotor then this blade angle may be reduced, as also the rotor shaft angle which should always be kept as small as possible. Best blade section is undoubtedly one of the Clark Y or "arc of circle" variety, although a symmetrical section was used to very good effect and did enable a deeper spar to be used.

With rotors moving in a clockwise direction when viewed from above, there is a tendency to roll to starboard, a very handy fact which helps to counteract torque, whilst an opposite rotor direction means a constant will on the part of the model to roll off to port. One method used by a famous Japanese aircraft designer, Kazuo Kasaki, with his *rubber* driven Autogiro is to make the tailplane with one half upside down to the other and in that way having the tail in constant battle to roll the fuselage in an opposite direction to that desired by the rotors. Whichever way the rotors are fitted, one is assured of success, for our experiments have been anti-clockwise, as with Ro-dart, whilst in Newcastle clockwise rotation is favoured.

Before departing from the rotor we should mention that for motive power a normal tractor airscrew is used on the engine, but there is a distinct advantage to be gained if a larger diameter than normal is used in a combination with low pitch to maintain r.p.m. Use of downthrust has twofold points in favour, for not only does it direct slipstream on to the rear half of the disc, but it also has its more usual helpful effects should the 'giro find itself standing on its tail and grasping for air.

Like their full size counterparts, model Autogiros require a tail unit for general stability, though fin area is by no means critical and is certainly not effective for directional control. Inclined tip fins may be arranged to keep the machine headed into wind for the power run though this is not altogether effective. It does, however, carry on a small air of realism in reproducing the appearance of the Cierva tail-units which were characteristic with their inclined tips. Further realism may be extended to either the open cockpit type of fuselage also common to the Cierva marque or, with a combination of helicopter appearance, one may adopt an open frame cabin around the nose in the manner of the Bell or Hiller helicopters.

Reverting to the tail end, there comes the consideration of tail area, section and tail moment arm. Again practical experience gives us the lead, for, working quite independently, both Mr. Cooper in Newcastle and ourselves in the London area, have found that 7 per cent. of the disc area is ideal. For the 1 c.c. specification this would indicate a 57 square inch tailplane. On section there is a slight difference of opinion in that Clark Y or flat plate tail are used in the north and we are more content, in view of the high angle of attack which the tailplane is often forced to combat, to use a high lift aerofoil of the RAF 19 or Marquardt S-2 variety.

Moment arm should not be short and the leading edge of the tailplane should not be allowed to enter the rotor disc area. In fact, it is better to increase the moment arm to approximately 1.25 times the radius of the rotor disc as a security measure against a peculiar manoeuvre, sometimes described as an Autogiro "stall," but which is more in keeping with a stall turn than the conventional straight forward switchback motion.

One point now remains for us to close this introduction to a non-theoretical approach to Autogiro design and that is the CLA and CG positions. A glance at the Jiminy outline will show you that the CLA is considerably aft of the rotor shaft and we would advise intending designers to make certain of this simple fact. For good stability the centre of gravity should be just behind the rotor shaft, but this will not be found to be altogether critical, though the CG should never be allowed to stray in front of the rotor pivot point.

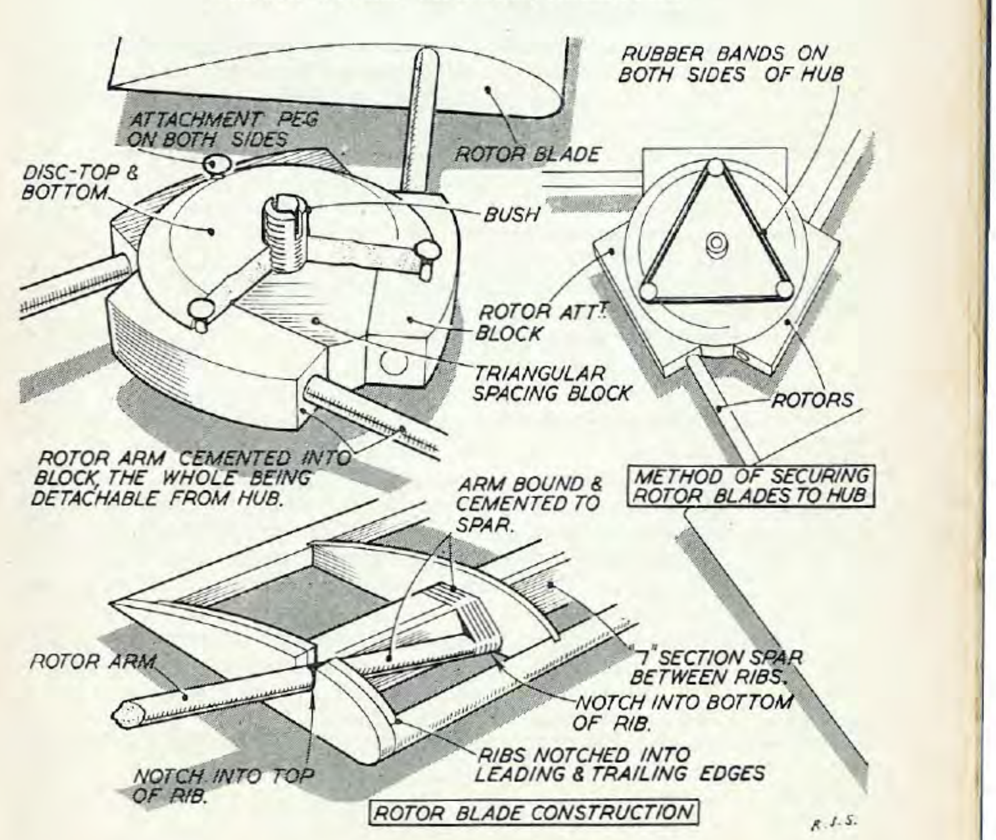
Dennis Neale, who has by no means been standing still after his successful pioneering "Ro-Dart" design, offers his latest findings on these last mentioned points of design.

"An autogyro does not turn in the normal way, by banking, since there are no banking forces (even with dihedral), when the model yaws. If the model banks, it is either due to a very low CG or to the rotors having unbalanced incidences, *i.e.*, one side lifting more than the other. The autogiro turn is merely a pure rotation about the rotor head (or very near it) caused in the first instance by rudder effect and the model follows its thrust line. This combination of rotation and forward movement produces the flat, rather 'skidding' turn of

the autogiro, and dihedral (coning angle), unless excessive, does very little, if anything, to help cure this skid. The only way of stopping this skid is to adjust the rotors to bank the model, which generally screws the job in anyway, so it's safer to skid! Hence, providing the CLA is behind the rotor head, its actual position is immaterial. Dihedral is, however, necessary to correct any serious sideslip that may occur. I have found that if the area of the tailplane is greater than half the blade area of the rotors, and its moment arm is greater than three-quarters the blade length from LE of tailplane to rotor head, the model is perfectly stable."

"Test fly for the first time with the motor at half speed and release only when the rotors develop sufficient lift to raise the model out of the hand. Tendency to roll is due to unbalanced rotor incidence. A spin to the left with anti-clock rotors means too much incidence on the right hand side of the rotor disc. Adjust the incidence until a gentle turn is achieved, then use opposite rudder. Cure stalls with a combination of downthrust and tailplane incidence rather than moving the CG or rotor angle."

Below, the "Newcastle" Hub for quickly detachable blades



With a good diesel, a spot of oil on the ball race *above* the rotor hub, plenty of fuel and enthusiasm, you will find a day's flying with a model Autogiro can be one of if not the most exhilarating branch of our absorbing hobby.

We are indebted to Messrs. D. W. Cooper, B.Sc., and R. Coles, M.A., for their co-operation in assisting us with information on their own experiments and for their goodwill in providing the following fifteen guiding points for the budding Autogiro designer.

1. Lift is dependent on swept area (disc area).
2. Blade area has little effect on lift, but a great effect on rotational speed (Rotor revs.). Small blade area gives high revs.
3. Solidity should be kept as low as possible, but depends on blade chord.
   .125 (.15) up to 24 in. diameter.*
   .100 (.125) up to 24 in. to 30 in. diameter.*
   .080 (.10) up to 30 in. to 36 in.*
4. Backward tilt of rotor shaft is similar to incidence of an ordinary wing. Should be kept as small as possible, 3 degrees to 5 degrees.
5. Blade section can be any good general purpose wing section. Symmetrical sections are not the best : authors find Clark Y good from both theoretical and practical viewpoints.
6. If torque rolls machine to port, rotor should run clockwise when viewed from above.
7. Torque can be controlled to some extent by using a tailplane built in two halves with one half working at a greater incidence than the other. Usually large incidence on port side, small or zero on starboard side.
8. Coning angle (dihedral) of rotor blades should be kept small. Not more than 5 degrees should be necessary. Increase of coning angle produces same effect as increasing backward tilt of rotor shaft (*i.e.*, incidence of disc).
9. Best position of C.G. is *very slightly* behind rotor shaft. Position not critical for power flight, but greatly affects "glide."
10. Authors use downthrust to direct slipstream on *rear* of rotor disc, so that rotor runs at high speed *without assistance from wind*. This is a very necessary factor for ROG flying.
11. Use airscrew about 25 per cent. larger in diameter than that normally recommended for free flight by engine manufacturers. Keep pitch low at 4 in. to 5 in. Use good blade area.
12. Successful flying depends on matching engine torque to *forward speed* of aircraft and rotor characteristics. It is *fatal* to attempt high forward speed unless the rotor runs at extraordinarily high r.p.m. The authors' maximum rotor speed obtained on 32 in. dia. was 350 r.p.m. With Frog 150 maximum forward speed was about 12-15 m.p.h. in still air.
13. Tailplane area similar to ordinary pylon type model. About 1/14th of *disc* area can be used. Aspect ratio 4 to 5. Section Clark Y. Flat plate has been used successfully.
14. Fin area can be small (even non-existent).
15. For successful ROG flight, the ground angle should be such that rotor incidence is at least 10 degrees.

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* In (3) bracketed figures are for short rotor arm attachments