WHAT'S THE SCORE ON

helicopters?

By ROY L. CLOUGH, JR.

• Easily the most fascinating thing that flies, the helicopter is making a name for itself in peace and war as the marvelous machine that can land or take off anywhere, hover over one spot or tuck its nose down and scoot away in any direction the pilot chooses.

It is only natural then that model builders have been attracted to the type, for here is a flying machine which does its stuff close in where it may be observed and enjoyed, does not require huge tracts over which to fly, and which should give more solid hours of model fun than anything ever invented.

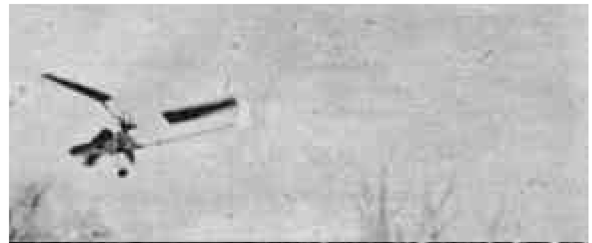
Or so it would seem at first glance. However, as many a model builder who has tried it will testify, it isn't quite that simple.

To some who have tried it, at first it appears a rather straightforward proposition—merely arrange a prop to pull upward, provide some method of torque nullification, presto, there is a helicopter. And several bitter disappointments later, the model builder sweeps up the shattered balsa wood, lays aside his tools and tries to dig up some information on the type.

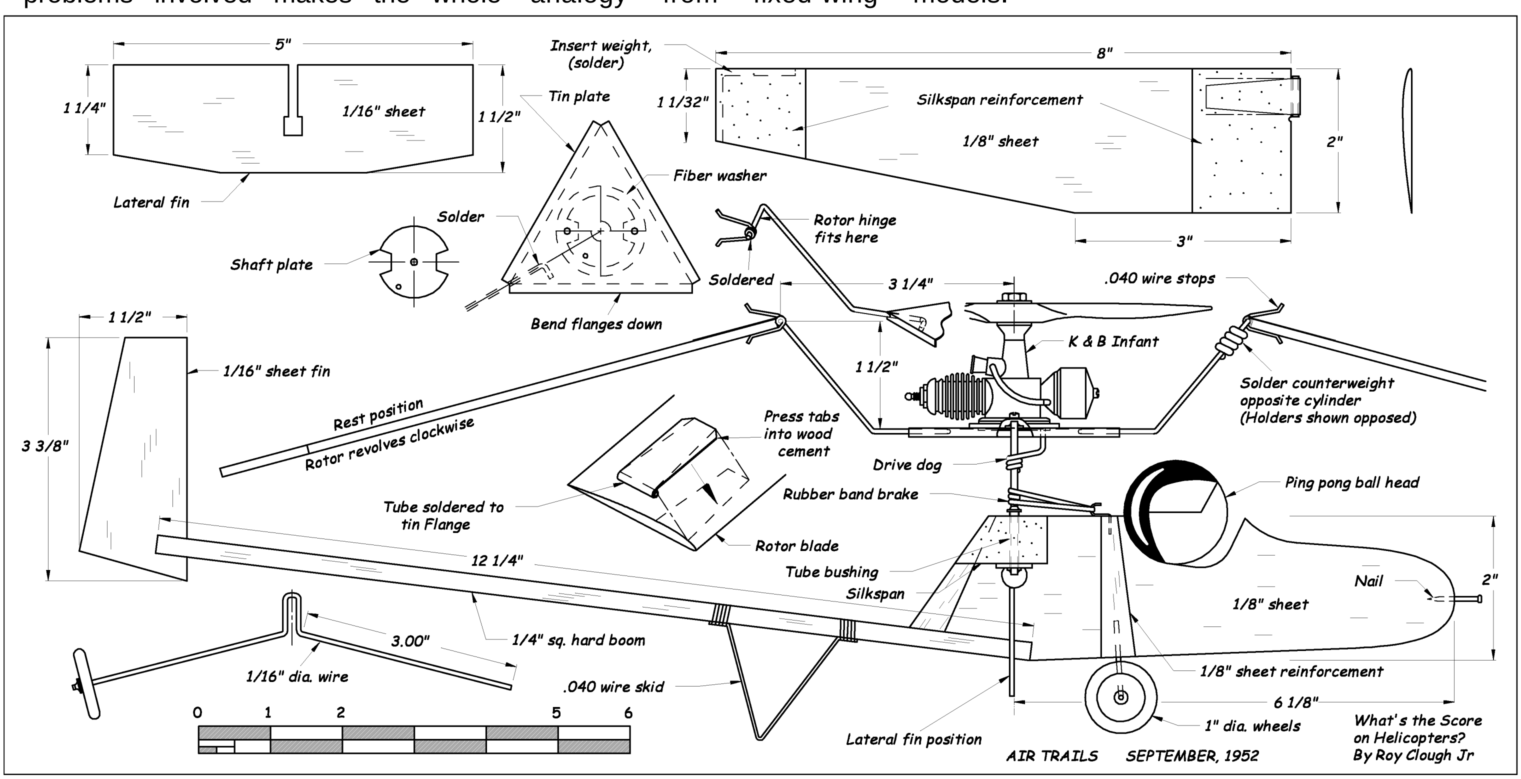
In many cases a study of the problems involved makes the whole thing look so impossibly complex that there seems to be little point in trying it at all. The envisioning of complicated controls, pushrods, flap hinges, dampers, complicated power transmissions, hairline adjustments and impossibly complex and delicate structures places the designing and building of a successful free flying model helicopter on the level of a major engineering feat—so the modeler puts the whole thing aside and starts sketching a new pylon job.

The truth of the matter, as in most cases, lies somewhere between the two extremes of utter simplicity and impossible complexity. A fair statement of the case is that a good model helicopter is no more difficult to build and fly than any other type of fairly advanced model aircraft.

What may appear to be *difficult* at first becomes at second glance merely *different.* This is because there is very little in the way of carry-over analogy from fixed-wing models. Roughly speaking, the differences are of the same order as those between building a hot engine into a speed job



Power output controlled by mixing No. 2 fuel in various combos with Plus 30. 50-50 mix produces gentle climbing or "hovering" as in Infant-powered helicopter here. Author in foreground.

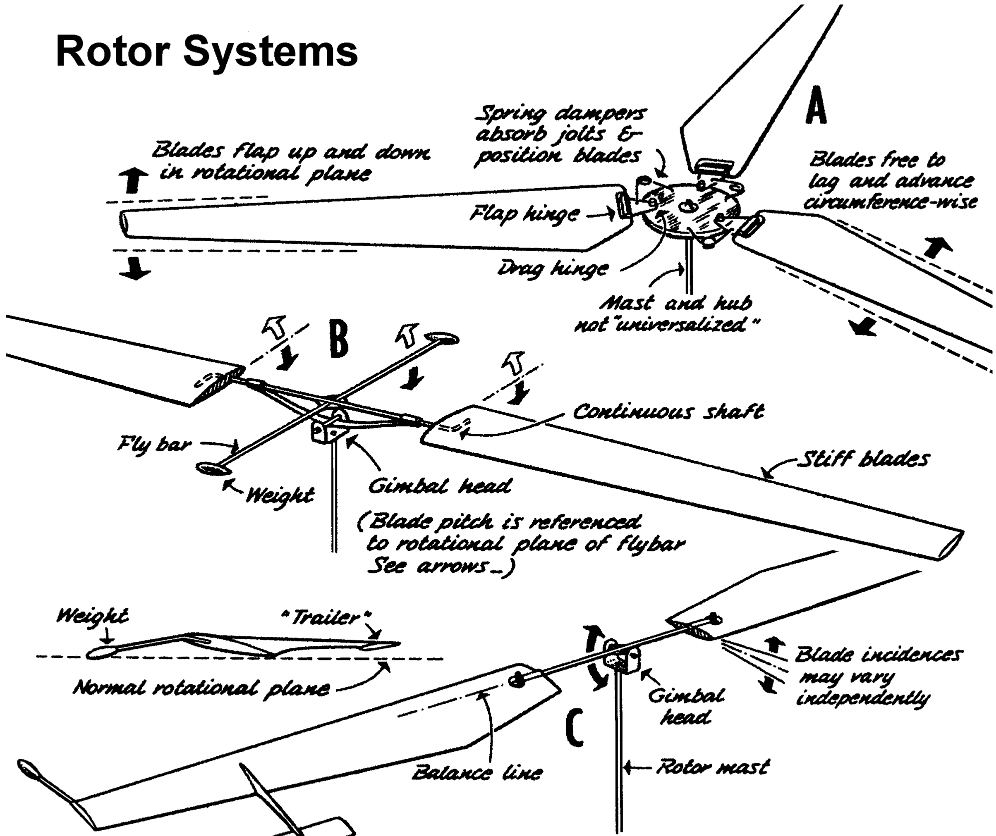


and building the same engine into a boat. The principles are approximately the same, but the factors are different.

Helicopter information, in the empirical form in which it is most useful to model builders, has unfortunately been neither complete nor widely available. Therefore the design picture has been a bit clouded. Any up-to-date aviation fan, if he scratches his memory a bit, will recall having read that "articulation" is a good thing, that helicopters are inherently "unstable," that there are a great number of things like "cyclic" pitch and gyroscopic precessive forces to be dealt with. All of which contains elements of truth, yet just how these things apply to sitting down and actually building a flying model helicopter has been obscure.

The writer scored considerable success in rubber-powered helicopter models with his development of the cage drive co-axial system, which allowed two rotors to revolve in opposite directions about a common center, thus canceling out both torque and gyroscopic effects. With this system, which first appeared in Air Trails some time ago, incorporated into the model, stable power-on free flight was possible for the first time without the use of complex control arrangements. Extremely steady in flight, the machine and a later variation of it were capable of rather surprising duration when winder-wound.

Rotor Systems

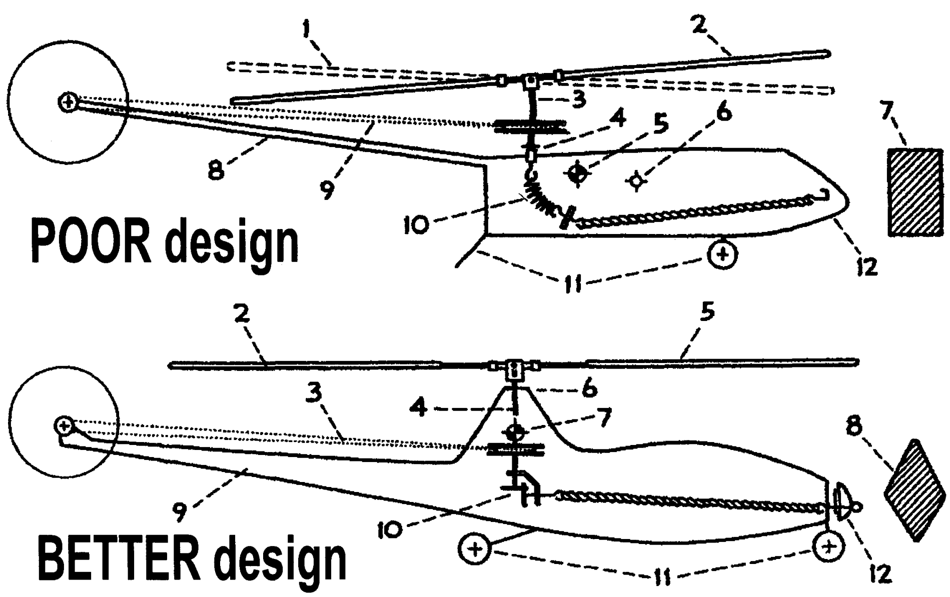


A. ***Fully Articulated*** **rotors. Not advisable for model use, being gyro-dynamically unstable. Centrifugal force holds blades in nominal rotational plane.**
B. ***Feathering Rotor*** **(simplified). Rotor free to rotate on span-wise axis as unit. Forward flight possible under C. G. shift when plane-seeking "fly-bar" produces cycling effect. Best bet for 'copter beginners.**
C. ***Feathering Trailer*** **using elements of Kaman and Young systems. Most stable of all types for vertical and hovering flight. Angle of attack controlled by trailer flaps; freewheeling here is automatic.**

However, these flights were very largely vertical; it was not possible to secure any marked forward flight with the machine, barring the use of extreme nose-heavy trim.

POOR DESIGN. I: Rotor blades out of track. 2: Blades out of balance. 3: Rotor mast misaligned. 4: Mast not well supported. 5: Center of gravity misplaced. 6: Keel center too far forward (poor horizontal flight). 7. Rectangular section bad for vertical wash. 8: Flimsy boom. 9: Torque drive subject to fouling by rotor. 10: Inefficient "trick drive." 11: Skid and front wheels makes poor ground bearing. 12: Winding must be done by turning rotor blades themselves.

BETTER DESIGN. I: Cant torque rotor to eliminate sidewise "creep." 2: Very little rotor blade zone. 3: Torque drive clear of rotor. 4: Perfectly aligned, firm shaft. 5: Heavy, thin blades, welt balanced. 6: Support close to rotor. 7: Center of gravity properly located. 8: Diamond section reduces rotor interference and aids torque correction. 9: Rigid boom. 10: Smooth-running bevel gears at ratio: unity. 11: Tricycle gear, good ground stability. 12: Nose plug for winding.



Later a further development, a kit design manufactured in limited numbers, featured a stabilizing or "damper" fin which permitted a fair degree of forward flight, with great steadiness and every indication of stability. So consistent was this type that by counting the number of turns stored in the motor the model could be flown from one table-top to another, time after time alighting within an inch or two of the desired spot. Several further variations of this machine were built, performing well.

Now, note that no blade articulation of any sort was used in these models. There was no provision for cyclic, pitch changes and gyroscopic action did not enter the picture. Yet they flew very well under rubber power. Keeping that empirical fact in mind, let us further examine the co-axial system.

This system—meaning two rotors revolving in opposite directions, about a common center—is one of the oldest designers' answers to the question of what to do about torque reaction. Further, it appears to be ideal in many respects because it would seem that any disturbances, either aerodynamic or gyroscopic, which occur in one rotor would be balanced immediately by the reverse of that reaction in the other. Now then, why, if this system is so theoretically ideal, with equalized thrust, cycling and gyroscopic moments, has it not appeared in any machine which has *demonstrated* itself to be of practical commercial importance?

String-and-pulley system for power to rotor.

The answer lies in the fact that co-axial systems have two major requirements, and, from a practical standpoint, these requirements tend to be mutually exclusive.

First, it is desirable that the two rotors be mounted close together. The reason for this is that widely spaced rotors introduce great stresses in the mast and rotor system when the blades are cycled for forward flight, that is, when the blade angle is increased at the rear and reduced at the front each revolution of the rotor. The uppermost blade will require a greater pitch change than the lower blade in order to equalize the couple between the points of applied force and the center of gravity. Thus, if we wish to avoid excessive stressing of the rotor and mast system, the rotors must be quite close together.

Second, the rotor blades of a co-axial machine must be spaced with a large gap from one set to the other because otherwise they may clash together due to the flexibility of the rotors. Blade deflection due to gusts or even normal cycling pitch changes is great enough, ordinarily speaking, to make any spacing of the rotors less than one third rotor diameter apart definitely hazardous. Thus, the rotors must be far apart.

From these two requirements it can be seen that the only way out of the problem is not actually an "out" at all, for it will mean building the rotor systems impossibly heavy and rugged and thus losing many, if not all, of the advantages of the co-axial system. In the practical sense, then, this means that co-axial systems are limited in use to such cases as where it may be possible to stress the system all out of proportion to its size—models and tiny man-carrying jobs.

Now, what is this business about cyclic pitch? Did we not just describe rubber models, which flew well without it? Why not merely eliminate cycling pitch from the co-axial system and fly forward by shifting the C.G. ahead?

The rubber models did fly forward by means of the stabilizing fin and C.G. shift. But don't overlook the fact that a rubber model flies with continuously diminishing power after the rotors come up to speed. This is very important because it meant the writer could eliminate cycling controls because of a characteristic of the power plant. Just why this was so may be explained as follows:

Picture a purely hypothetical co-axial model helicopter in which the thrust *does not* vary, which has stiff, fixed-pitch rotors, and which is trimmed nose heavy to make it fly forward. All set?

The machine, because of the unequal loading of the disk (area covered by the rotors) begins to slide forward. It will not tip to either side since the advancing blade of one rotor, creating more lift as it encounters a relative wind due to forward motion has a balancing counterpart in the blade, which is rotating forward on the opposite side. This, incidentally, is a major advantage of the co-axial configuration.

Now, as the machine gains speed we find that the front edge of the rotor disk is entering the wind while the rear edge is leaving it. This means that the rotor is lifting more at the front than at the back, and it will tilt upward, moving the machine into what is actually a stall—one of the few analogies which occur between fixed and rotating wing craft. Now this will happen no matter how much weight is placed in the nose, consistent of course with the ability of the machine to lift it.

Now, when this stall occurs, the helicopter will slide backward increasing the lift at the rear of the rotor disk until the model stalls tail up, whereupon it repeats the trick, oscillating back and forth with increasing amplitude and violence until it finally crashes.

The reason the rubber-powered models flew steadily ahead under C.G. shift is that the power gradually decreased as the machine flew forward and the damping fin provided a stabilizing surface, which served to maintain the proper angle. Thus it might be said with considerable accuracy that the rubber models actually made use of the oscillating tendency of stiff rotors to secure forward flight and that they were successful in doing this because the oscillation was damped at proper time by the motor running out.

Or, to put it a bit differently, the co-axial rubber model helicopters with damper fins as developed by the writer were simply highly modified co-axially driven planes flown vertically. Have you ever seen Jim Walker do the Saber dance? The principle is the same.

Thus, to fly forward in a co-axial machine, as in any other, requires that the pitch of the blades decrease in front and increase at the rear of the rotor disk. And, since we must be able to control the pitch of the rotor blade around the circumference of its sweep, we may as well abandon the co-axial configuration and its power transmission problems and go over to something simpler, the single rotor and torque prop. Either that, or power the rotor itself by means of tip jets or motors which eliminate torque effects entirely.

For most model work, and at this stage of the game, we will find the torque prop type more practical, since this gives us a heading and trim control and the boom helps to round out the design by balancing the weight of the power plant, which will be forward in most cases.

Which means we promptly dive head first into the rotor head business—but don't let it scare you.

The earliest successful helicopters used a refinement of what is known as the flapping, drag link rotor originated by Juan de Cierva, the autogiro inventor. To Cierva's basic invention were added mechanisms to secure collective and cyclic pitch control and with such an arrangement the first man-carrying machines flew.

This system (Fig. 2) makes use of a hinge between the blade root and rotor mast. This allows the blade to flap up and down relative to the plane of rotation and was originally introduced in the autogiro to permit the machine to fly forward without tipping over due to relative wind differentials.

Soon after this was invented it was found necessary to add another hinge which would allow the blade to swing fore and aft, since, as the blade coned upward on the advancing side it would tend to lag behind the retreating blade, thus setting up terrific stresses in the flap hinge. This drag hinge then had to be fitted with a dynamic damper—a gadget similar to the device which closes doors without slamming —to absorb the jolts and shocks that such a system was heir to and to assure a correct nominal circumferential position of the blade.

This system is in wide use among full-scale helicopter makers but it has some limitations in that it is not truly stable, although quite flyable with a competent pilot.

As far as model helicoptering is concerned the system is of interest chiefly as background material. In practice it proves tricky to build, fragile and easily misaligned, and it falls down on a most important model requirement in that it will not fly "hands off."

As a matter of fact, it is not even a satisfactory free flight autogiro arrangement as the writer discovered some years ago, and this lack of satisfactory flight characteristics started a series of experiments, which led into contact with a type of rotor arrangement that would perform satisfactorily on an autogiro.

Initial experiments with articulated rotors on rubber model autogiros resulted consistently in dismal crack-ups at the end of erratic flights of a few feet. Apparently the fault was somehow connected with the articulation that was supposed to promote flight stability. So we committed heresy. We stopped articulating the rotor blades.* This was better, but still not good, and then came the inspiration—why not articulate the blades in some other fashion, so that the effect would be the same, but the big bounce would be taken out?

Why not, instead of allowing the blade to flap upward, allow it to rotate span wise— that is, instead of letting the tip fly up, let the trailing edge flap upward?

A new rotor was built with the blades spring-loaded against their span wise axis at zero pitch, and since the rotor was stiff, tip-to-tip, the mast, which held the rotor, was jointed, or articulated to the fuselage to prevent the transmission of disturbances back and forth. Aerodynamic pressures would result in the slight negative pitch angle necessary for autorotation, and a sort of automatic cycling pitch would be obtained as the advancing blade flattened to the relative wind, which would flip the trailing edge down as the blade passed in front and started back dh the downwind side.

It worked.

*Louis Garami built a successful non-articulated, non-feathering giro at about the same time which flew by using torque of the motor to counteract the progressive tipping of his stiff four-bladed rotor. This appeared in Air Trails.—RLC.

(To *be continued in subsequent issue.)*

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(Continued from previous issue)

This initial model was soon followed by others, simplified greatly by eliminating the springs and mast rubbers, and using thin wood blades attached to a stiff spar and a flexible wire mast. Models built here and in England proved the soundness of the system. Fig. A.

The articulated rotor mast was fine for autogiros, with due restrictions on the articulation to prevent clipping the prop or the tail, because it permitted the initial tilting, which starts the gyroscopic wobble, to* damp out without running through a cycle of self-excitation back and forth through the mast. But, for model helicopter work a flexible mast seems impractical.

If rotation is supplied by the rotor, as in the case of the autogiro, it will run concentric and true if in balance. But, if one tries to feed power into the rotor through a flexible mast the whole thing will jump out of line and wobble violently with the whole system acting as an eccentric.

In the practical sense, then, this means that a flexible mast cannot be used on model helicopters except, possibly, where the propulsive force originates in the rotor, as for example, tip-jet propulsion.

At this point the writer became acquainted with the work done by Arthur Young, who designed the Bell helicopters, and this takes us into a discussion of the so-called "feathering rotor" system in which the blades neither cone upward nor drag back, and in which, for the first time, we begin to see inherent stability introduced into rotary wing flight.

In order to understand the differences between the fully articulated and feathering systems it is necessary to look a bit more closely at gyroscopics, the seemingly puzzling, but actually rather simple set of shenanigans which take place when a rotating system is disturbed.

Any rotating system, and this applies with particular emphasis to helicopter rotors, is a gyroscope, and jointing, hinging or springing it will not make it anything else; it will still observe the natural laws which govern gyroscopic action. This is probably the most puzzling and least understood factor in rotary wing flight, and the reader will find it of value if at this, point he takes the trouble to make up a small "understanding tool" and follow along with the text.

Cut out a six-inch circle of heavy cardboard and mount it with a pin through the center in the end of a short length of 1/4" stock which has its sides numbered consecutively: 1, 2, 3, 4. This represents a rotor—and a gyroscope. If you wish, mark the disk with an arrow showing left hand rotation (most model helicopter rotors will be left hand in rotation because of mechanical considerations which will develop later on).

First, flick the disk with the fingers to make it spin rapidly, then poke gently under the rim of the spinning disk on the side of the stick marked 1. . What happens? The edge of the disk rises, not where you poked at it, but at 90 degrees, the side, marked 4. Repeat the experiment, only this time - poke it at 3. It rises at 2. What is happening? Simply this: the deflecting force is modified by a factor of 90 degrees.

This is the first rule: that a gyroscope, if deflected, reacts with a displacement proportional to the deflection at 90 degrees in the direction of rotation from the impingement of the deflecting force. (Of course it also deflects an equal amount in an opposite direction 90 degrees back from point of impingement, but we're trying to keep this thing simple.)

With the understanding tool at hand this becomes quite easy to understand, or think of it this way: if a rotor blade is deflected at one point in its circumferential travel, it will tend to pop up 90 degrees further along in the direction of rotation.

Now, spin the disk again and gently tilt the stick. Note that while the gyroscope initially tends to remain in its original plane, it will now gradually readjust itself until it is spinning with its plane perpendicular to its axis (the stick). If the disk were mounted on a universal joint and driven by rotation of the stick this effect would be even more pronounced.

This occurs because it is a function of centrifugal force to' cause the rim of the disk to recede as far as possible from the axis, and this condition is satisfied at. 90 degrees.

These two related phenomena are of extreme importance to helicopter designers: first, a deflection reacts at 90 degrees; second, a gyro seeks rotation perpendicular to its axis.

Now remove the stick and take the disk outside and scale it through the air with a quick spinning motion. Note how it tips over toward the advancing side. Two factors are responsible for this behavior. The first is related to the Magnus effect and is due to differing pressure gradients on the surface of the spinning disk, and the second, which is our primary interest helicopter-wise, is that the air pressure at the entering edge of the disk is producing a gyroscopic resultant at 90 degrees, thus turning the disk over.

Bear in mind these vital functions as we consider the requirements of a stable helicopter rotor. One thing should be evident, that forward flight produces a problem in tip speed differentials, the advancing blade in meeting a faster relative wind than the receding blade tends to tip the machine toward the retreating blade side due to, aerodynamic forces, but these aerodynamic forces are balanced to a large extent by gyroscopic forces, provided the blades do no flap upward or drag back circumference-wise and are free to rotate, within limits, about their span-wise axis.

And, if the rotor head is mounted in a gimbal, rotor deflections will not be transmitted back and forth between rotor and fuselage through the mast, which means that the helicopter will be stable. By the addition of a stabilizing fly-bar between mast and fuselage connected by linkages, which can alter its plane of rotation, the rotor can be made to take up any position desired by the pilot.

In other words, then, if we use a flapping blade with drag links we must also include a device to alter the pitch of the blades cyclically, mechanically; but, if we eliminate the flap hinges and drag links and allow the blades to "feather" as it rotates, cyclic pitch is automatic in accordance with the gyro-dynamics of the system.

This basic discovery about the helicopter rotor was made by Arthur D. Young of Bell helicopter fame. In this writer's opinion, based on literally scores of experiments with flying models, this discovery is one of the great aerodynamic advances of the century. Not only for the mechanism which Young worked out, which is remarkably effective, but for the principles his work outlines, which it is not extravagant to state mark the greatest single contribution to rotary wing flight.

From these principles we can arrive at a stable rotor for model helicopter work. Fig. B illustrates such a rotor. The simplicity of the thing is its beauty. With a little study of the sketch no reader will have trouble duplicating it. Note that the fly-bar is moved up level with the blades. This is simply a length of wire with a few turns of solder on the ends to provide operating momentum—not much weight is needed.

Note that the function of the fly-bar is to steer the rotor blades back into the proper position with respect to the mast through a damping interval, hence cyclic control may be had by arranging the fly-bar in such fashion that it can be deflected into a new plane of rotation—but, very important, the fly-bar must not be rigidly attached to the mast because this will cause rapid following; that is, the mast will tend to swing immediately the rotor is displaced, because the independent nature of the system will have been destroyed.

In Fig. C we see a system developed by the writer, which uses the independent rotor principle together with control "trailers" similar to the Kaman system. The advantages of this system for model work is that it provides automatic-rotation in addition to the stability of the Young system, plus the fact that cyclic control by trailer deflection (only one trailer need be connected) is very easy to arrange with a line up through a hollow mast and out to a "loaded" trailer.

The other end of the line being attached to a cam ring which may be set to produce the cyclic deflection at any desired point. The drag of this system is higher than others and it must be designed carefully if maximum lift is to be obtained, yet its many advantages make it attractive and it is certainly capable of much greater development, particularly since it is possible, with trailers, to make use of high lift sections with less regard for pitching moments.

This system is particularly attractive for jet work, and it should be noted that by placing the line of thrust of the jet motor a bit below the center of the span-wise hinge the blade pitch will be controlled by the thrust output of the engine. However, this factor must be used judiciously because too great a moment here will result in the blade mushing around slowly at a very high pitch, which will produce no lift at all.

Remember too that trailers, in operation, should drop down into the rotor plane— don't seek to drive them either above or below the plane, since this puts them at a great, mechanical disadvantage and may result in their control over blade pitch becoming ineffectual and the drag of the system very high.

Note, of course, that it is possible to use H series stable airfoils and eliminate the trailers entirely; however, if this is done the rotor system may show a tendency to tip back in forward flight, and cyclic control installation may be more difficult. But for straight hovering or vertical flight this system is unmatched for stability.

I have been asked, "How does the Jetex kit helicopter work?" This model is a good performer with a very fair duration for this type of craft and in flight exhibits stability. If we examine the machine we can find the answer. Two blades are used which are articulated to a supporting beam. These depend, as does the Cierva system, upon centrifugal force to keep them at the proper angle in flight, without a rigid connector.

Underneath the rotor is a thrust beam to which are mounted two Jetex engines and the machine is driven by the reaction of these units.

Now, please note that the mass of the jet motors is quite high in-regard to the total mass of the ship; that is, it has a sort of high-momentum flywheel beneath an articulated rotor with the mass of the pod, or fuselage being quite negligible.

Thus we see here a combination of the articulated blade system with the fly-bar stabilizer, which operates well if we confine activity to vertical flight. In essence this machine is dynamically similar to the writer's little Infant job of a couple years back, but being jet powered it requires no damping fins or fuselage-rotor-mast brake to retain proper heading.

However, in its present form forward, flight by changing the C.G. trim will be found unreliable; the machine isn't designed for that sort of thing. It should prove a very interesting experiment to move the power beam up level with the rotor blades, and rebuild the rotor along the lines shown in Fig. B. This should produce a model capable of forward flight, as well as vertical, but the problem of auto-rotational letdown will have to be solved with some new mechanism to alter blade pitch. Also it may prove necessary to introduce a small amount of friction between the motor-fly-bar and its gimbal connection to the mast in order that adding weight to the nose will make it go forward and not just alter the angle of dangle of the fuselage from the rotor.

On the basis of experiment the writer suggests that configurations for first experiments be kept as simple as possible. The first helicopter should be rubber powered, something along the lines of a simple stick model, probably direct drive. It won't fly for very long with this limited power, but it can be fooled with indoors at great length and the rotor set-up ironed out. After you get the "feel" of the rotor set-up and a bit of experience in handling rotary wings, try something in gas or jet power.

The best bet for gas engines is the single rotor, or tandem rotor type—like the Piasecki jobs with a rotor at each end of a long fuselage. Coaxials, or rather composite rotor jobs, such as the writer's little Infant machine, are very simple and okay for direct vertical flight, but they won't do well in forward flight and will return to earth with quite a thump unless some free-wheeling arrangement, other than spin-in-reverse is used.

Better than freewheeling, which will mean pitch change too, is engine two-speed control. Have a timer rigged to drop a partial obstruction into the venturi after a certain interval. This will bring the model down under power, quite gently. The really ambitious may use spark ignition in conjunction with timer control—but watch the weight. It takes power to fly helicopters.

It is impossible of course, in a 2-part article to cover all phases of helicopter design. However, it is quite possible and the writer hopes he has been successful in this respect, to outline some primary essentials. In answer to the question, then: "What's the score on the helicopters?" the reply is this: you can build them and fly them successfully if you understand the basic dynamics.

In this report are shown two stable rotor designs. They work, they have been flown, they do not hop and jump madly about and there is no element of luck about it; they can be duplicated by any average modeler who will take the time to understand just what forces are involved and how they react. If, in times past, the reader has tried unsuccessfully to design his own, or has purchased kits which did not perform as well as expected, he should re-examine his experience in the light of the material he has just read, make a couple more experiments and decide for himself that practical model helicopters are not only possible but downright fascinating.

In general, then, we may sum it up as follows: It is better to use a shallow pitch and run the rotor at a good clip; make the blades of high aspect ratio—and thin section. Be sure the pitch is equal on both blades; mount the torque prop as far aft as practical—it will absorb less power, and keep the design of the model as simple as possible and the bearings as near perfect as you can get them.

There are several things to watch out for. For one thing, the rotor blades should be quite stiff. Balsa wood if hard is pretty fair, but pine or even birch is better. Because of the thin sections, which must be used, and the high rotor speeds, an overly flexible rotor blade may develop "whip" due to resonance. This will make the blades run out of track, absorb a terrific amount of power and may result in tearing the model apart, particularly if a whipping blade connects with the drive string to the torque rotor.

Some of the writer's early models used exceptionally flexible blades without articulation or feathering features, yet flew. How? By adding quite a bit of weight to the tips. Thus as the rotor was spinning up for take-off as the model sat on its wheels a gyroscopic plane or reference was established which held the model fairly steady for the brief duration of the rubber power.

This won't work well if power is continuous, as for a gas motor; the model will gradually tip over a bit to one side and then jump violently at 90 degrees. The reason for this behavior is that a sort of cycling occurs due to blade flexibility, at the first small tilt, and this condition is rapidly excited back and forth until something disastrous happens.

With single rotor and torque prop models a change of heading may be noticeable immediately after jump-off. This may be only a few degrees or a quarter circle, even if the balance of thrust is correct. The way to minimize this is to hold the model for a second or two to allow the rotors to come up to speed. For gas jobs use old friend "stooge" to hold the model down until ready.

Theoretically the axis of the torque prop should lie in the plane of rotation of the rotor. Practically it must be somewhat below this plane. This is due to fuselage effects, aerodynamically speaking, and to the mechanical consideration that we must keep the prop drive string (or shaft) well clear of the rotor tips. Empirically it works out rather well, because design considerations necessary for power location, landing gear, lateral areas, etc., work out so as to make it possible to locate the torque prop axis well down out of the way.

Assuming a left hand rotor, it will be noted that if the axis of the torque prop is too high the machine will fly sidewise to the left, and if the axis is too low it will fly to the right. Properly located, the model shows no tendency to slide off in either direction.

This is a very happy circumstance because it means that by combining a few factors, such as level of the torque prop-axis with C.G. we may make a model of very simple design fly in any desired direction without a separate cyclic control mechanism.

This statement reads rather simply, but go back and look it over again, for it contains the essential elements 'of practical model helicopter flying in that we see how that adjustment of the model helicopter, and the mechanism to make that adjustment possible, are not a complicated mess of pushrods, cams and levers, but are in fact no more complicated than the adjustment of an ordinary free flight model of the conventional type, and in many ways simpler.

And, incidentally this is no condemnation of cyclic controls, as such, for they have much to offer the purist and the researcher. However, and analogically, the writer must point out that we do not find it necessary to build operating ailerons, rudder, elevator and flaps into a conventional free flight model in order to enjoy it tremendously.

Power transmission may scare the uninitiated at first, particularly the bevel gear drive shown in one of the pictures. It shouldn't. It does present a new problem, true, yet a simple drive of this nature is but the work of a few minutes to produce, requiring far less effort than the control system of, say, a team racer.

The gears are readily obtainable in any toy store; for 20 cents two toy eggbeaters yield six gears, four small and two large ones. You can't even buy a good bell-crank for that. There are dozens of ready sources of small gears, toys, old alarm clocks, etc. Fuel line (brass) and landing gear wire takes care of the shaft and bearing problems nicely and adequately.

To drive the torque prop use balsa wood pulleys faced with #1 sandpaper and a string belt. About 2½-to 3-1 is a practical ratio and slippage with this system is nil.

Gas power requires heavy reductions in speed and some sort of shock clutch or take-up may be necessary if any considerable weight or power is to be used. We hope to cover this phase more fully at a later date and show some simple gas motor hook-ups, which require no machining or difficult work.

One pitfall to avoid is the idea that a large, high pitch, slow moving rotor will produce longer and better flights. It won't. Power requirements will be tremendous, which means a thicker motor will be required, meaning more weight, meaning it can't be wound as many turns, meaning a great deal more power will be needed for torque correction—a vicious circle that adds up fast.

Rotor blades should be of fairly high density, thin in section and operated fairly fast at low angles of attack. For the present, helical pitch should be shelved in the interests of simplicity; use flat blades of uniform pitch until you build up a little experience at helicopter flying.

The sketches show general proportions and sound design practice. Stick pretty closely to these layouts, at least for your first machine, then strike out on your own.

ROY L. CLOUGH, JR.

AIR TRAILS SEPTEMBER and NOVEMBER, 1952