SIKORSKY XR-5

By Prof. T. N. DeBobrovsky

SCALE 1" = 22" **ROTOR SPAN 26 ¼"**

PLEASE READ THESE INSTRUCTIONS BEFORE YOU START TO BUILD.

GENERAL: We are sure, that the first thing you will want to know is - HOW DOES IT WORK? So, we shall satisfy you with a short description of the mechanism. Probably you have built flying models of all descriptions, such as rubber or gas powered monoplanes and biplanes, tractors and pushers. Regardless which you built, they all had wings and tail-surfaces. They also had single or twin propellers. Now, here you opened a plan of a model, which is wing -less. No wings, no stabilizer or fin. IT IS A HELICOPTER of the type, which does not use any wing surface! How can this thing fly? It is easy. The same propeller, which you use to stick to the nose of your model, is now mounted with shaft placed vertically and instead of pulling forward, now it pulls upward. If a propeller mounted horizontally pulls the model forward and when mounted vertically it pulls upward, so if the shaft is inclined from the vertical position, it will pull in the direction of the inclination. So, the helicopter is able to fly in any direction, forward, backward, sideway, according to this inclination. It is simple. To turn? Well, you may have heard or you know, that there is an effect called TORQUE. This tries to turn the model in opposite direction than the propeller turns. If you wind up the rubber motor in one of your models and lift it by the propeller and hold it by it, the whole model will start to turn around and around. So does the helicopter. To overcome this, there is a propeller mounted to the end of the model, with shaft placed at right angle of the fuselage. It's blades are set so, that when revolving it creates a push which will overcome the torque effect. If this push is equal to the torque, the model will be balanced; if the push is greater than the torque, the model will turn in the same direction as the main propeller and if smaller, it will turn opposite. So this is the rudder, while the main propeller is the combined "lifting and propelling wing", with the effect of the ailerons and elevators.

THE PLAN: The layout of this drawing is unusual. It Is not the usual three view drawing of a model. The main drawing is divided in three sections: #1 shows the mechanism (the fuselage is only outlined): #2 includes all the parts of the mechanism, each one in several views; finally #3 the fuselage with the landing gear. This arrangement is made, so, that the drawing may be cut up along the borderlines for easier handling. The plan also shows, that you must build ONLY two rotors (In case of helicopters, the propellers are called rotors) and they mechanism, to which are added the fuselage and the landing gears. Your working sheets will be # 2 and #3, while #1 is used only to follow the assembly. In the drawing every construction part is numbered, which permits easy location of the parts both on the drawing; instructions; assembly & on printed wood. Every part is drawn to full size, except the birds-eye-views. Use a good divider for checking the dimensions and locations. The key letters used:

T means TOP VIEW	RL means REFERENCE LINE	CR means CROSS SECTION
S means SIDE VIEW	CL means CENTER LINE	W means WASHER
F means FRONT VIEW	B means BIRDS EYE VIEW	

HOW THE MECHANISM WORKS: This is another question for which you want an answer.

Well, look over drawing #1 and the birds-eye-view on drawing #2. It consists of a regular motor-stick. Instead of propeller a pulley (A) is mounted on the shaft. The end of a string is fixed to this (A), which through guides is led to another pulley (C), which is mounted on the main rotor shaft. The string is wound on this pulley (C). When the wound rubber motor is released, pulley (A) will pull the string from pulley (C) and by doing so the shaft and rotor will turn. Below (C) is another pulley (D) and at the end of the fuselage still another (E). String is wound on (E and when the rotor shaft turns, it will roll up on (D) through wire guides - and so the torque propeller connected to (E) will revolve. That's all...

<u>CONSTRUCTION:</u> The above description seems very simple, but the parts shown on drawing #2 look complicated. Truly it is simple, only it is unusual, because you have never made such parts before. Start with the motor-stick. To the front end, cement 11 and to the rear 12. No. 11 is fitted with a bearing 15 for the shaft 19, to which pulley (A) is mounted. This and the rest of the pulleys are made of three parts, two plywood sides and balsa center. For instance (A) consist of plywood front 14 and rear 15 and balsa center 16. The center is rounded from balsa, the sides are cemented to it and when dry, the pulley is drilled for 19. Nos. 17 & 18 are washers, those facing the pulley should be soldered to 19. A pin, which is goes through the pulley and soldered to the face of the washers, is recommended. Hole G in 14 is for the end of 19. Ready made guide pulley 20, is mounted between wire fork 21, using a piece of wire for shaft No.21 is cemented to the motor-stick and bind this and 11 with thread. No. 12 is fitted with end of metal tube, to which solder washer 23. Mount the crank, for which the motor-stick is cut, as shown. Guide is cemented to the motor-stick. Drill the motor-stick for bushing 26, which will house the rotor-shaft. Cement and bind 26 to the motor-stick. The upper bearer of the shaft is wood (27), drilled for bushing 26 and fitted with a double hook 29. This 27 is cemented to the four balsa struts 30 & 31, which are cemented and bind to the motor-stick. Cement 32 in place. NOW, the rotor mechanism. The rotor blade plate; the control plate and the driving pulley must be mounted to the rotor-shaft. First prepare all the parts and then assemble. Your attention is called that all the revolving parts must be absolutely balanced, both individually and as a unit, to avoid vibration and failure! Photos shows, that the SIKORSKY helicopter has three rotor blades. Drawing #1 shows only one, to lessen assembly complications. Drill 33 as shown. Blade shafts 34 are 1/8" diameter dowels. To them cement and bind the L - shaped wires 35. The free ends of 35 are placed into celluloid bushings 36, which are cemented and bind to 33, as shown. Each of the blade shafts 34, now rest on 33, but each has free up movement and very small for & aft movement. These movements are very important! Cement balsa 37 to 35. Solder 38 to the rotor shaft, push the plate on and solder 39 to the shaft. This plate system must be firm with the shaft. NEXT, the pitch guide. This will not be mounted to the shaft firmly! It consists of a pulley # 4O, 41 and 42, pushed on the shaft. Next, prepare the pulleys C & D. Between disks 43 & 44 cement the balsa disk 47; between 44 & 45, the balsa disk 46. # 46 is 3/8" and 47 is ½" high. When dry, drill them for the shaft. Give to all the pulleys several coats of dope and cement. Now, push the rotor-shaft through 28, the blade plate & pitch control guide should be above 32! Next, push three washers on the shaft, then the pulleys, and another three washers. Now, push the shaft into 26 and mark the shaft for exact position of C & D. Lift the shaft out of 26 and solder the washer facing 45 to the shaft. Replace the shaft in 26. Solder, washer facing 43 to the shaft and also the one above it. See drawing #1. Oil the bushings and washers lightly and spin the shaft. It should revolve easy and without any oscillation! Pulleys C & D must revolve with the shaft. WELL, it looked complicated, but the main parts of the mechanism are now ready.

The rotor blades and pitch control are the next work. Shape the blades with utmost care. Use the templates N & 0. Each blade must be true in construction, in weight and shape. Sand them smooth and give several coats of clear dope, sanding in-between and checking for weight and against any distortion. When ready out them for 34. On the end of 34, cement rings 48, which act as retainer. Bend three of 49. These are cemented into the rotor blades as shown. The free ends should fit between the pitch guides, (40-42). Place the blades on 34 and tape firmly the blades and 49. Use cellulose or linen tape. The blades should be free to rotate around 34. By moving the pitch guide up and down on shaft, the angle of the blades will change. Now, cut out the half-rings 51. Hang rubber bands 52 on each aide of 29 and pass them through the pitch guide. Small dowels 53 holds 52. The rubber bands should pull the guide in 32. This position of the guide will now hold the blades at a high angle of incidence. Slip 52 (by pairs) between the guide and 32. The angle of incidence of the rotor blades now will decrease, so, by placing more or less 51, the pitch for the three rotor blades will decrease or increase collectively. THIS IS THE COLLECTIVE PITCH CONTROL.

Cut out 54 and sand to a wedge shape as shown, then fit it with a pin-handle. Now, set the pitch guide as shown in FIG. 5, to assure uniform and positive angle of incidence to all the three blades. Push 54 in place, as in FIG. 6 - and see what happens. The rotor blade parallel with the motor-stick remains at the same angle as before but the one on the right side will have an increase and that on left a decrease angle incidence. Start to rotate slowly the rotor-shaft and you will observe, that the blades on the right side will have increased angle; will have normal angle at front; decreased on the left side and have normal on rear position. It is easy to understand, that the blades passing the right side will give increased lift and passing the left aide will give decreased lift; thus the craft in the air will tilt to left or fly to left. THIS IS THE CYCLIC CONTROL. Easy, isn't it.

Look at Fig. 7, it shows four top views of mechanism with shaft in the center and 54 placed in four different position. In the first, you will be in the same position as described above. You already know, that the craft will tilt or fly left. In the second, the position of 54 is changed; the result will be a forward tilt or flight. Third position gives a backward tilt or flight and the fourth a right side tilt or flight. Try and study it! Now you should be able to change the angles of the rotor blade collectives from negative to a positive incidence and with 54 assure a cyclic control!

The torque rotor and its mechanism are mounted to the end of the fuselage, so start building with the fuselage. This is of the conventional type having a center frame, to which the bulkheads are cemented. The rear part of the fuselage is hinged, so, that the rubber motor can be reached and serviced for winding by the crank or winder that's inside the formers and the bulkheads. Cover #3 with wax paper and pin formers 56 to 58 in place, the rest of the center frame made of 1/16" sq. strips. Cement the bulkheads in place, Line up carefully and add the 1/6" sq. stringers. Do not cement 66 & 67 to each other! While this framework is drying, fix one end of 15 ft. of string to 43 as shown and wind the rest around 47. Take another 15 ft. of string, fix one end in hole J of 14 and wind the rest around pulley A. Now, lift the fuselage frame from the drawing and cement it to the motor-stick and pylon. The joining point will be at 62b and 62e; 32 to 63 and 66 to the motor stick. Next, cement the other side of the bulkheads to the center frame and add the stringers. Cement 71 to the end of the stringers and then cement and bind wire fork 75. Assemble the torque pulley (E), with shaft 79. Solder washers W to 79 shaft, facing the pulley sides and another washers outside of 75; (E) should run freely with the shaft. Torque propeller hub 80 is mounted on 79, solder washers to each side. Do not cement the blades into 80 before the model is put on wheels! The string from pulley (D) now can be pushed through guides 20 and 81. The end should be fixed to pulley E. The motor-stick is fitted with an eyelet or tube, into which place the starter 82. The end of 82 should pass through hole in 15. This arrests (A) when the rubber motor is wound and by pulling it out, releases it to revolve.

Next, the landing gear. Cut out formers (83 - 85 and 86) and assemble them with 1/16" sq. balsa spars. Cement these struts to the fuselage. This part of the fuselage may be covered with balsa sheet pieces to reinforce it. To 83, cement round balsa struts 87, which are drilled for the wheel shafts 88. Solder washers to 88, above and below 87. # 89 are cemented to both 83 & 87. The rear wheel mounting is shown clearly, rear wheel should be free to swivel.

Cement wire hooks to the fuselage for rubber band 97. Prepare the hinge and cement to the upper part of the fuselage. Bind with thread to stringer. Cut stringers between 66 & 67. Now you will be able to lift the rear part of the fuselage. Cement two pieces of short dowels into 67, which should fit into 66, when the fuselage is closed. The rubber band 97 should hold it closed. Cut, shape end cement the torque propeller blades into 80. Give several coats of clear dope and sand them. This propeller must be well balanced.

Cover the fuselage with tissue paper. The grain of the paper should run parallel with the stringers. The front part, ahead of 65 can be covered with bond paper or 1/32" balsa sheet. Use celluloid for the cockpit panels. The cockpit allows for inspection of the mechanism, also the cutout in bottom of the fuselage above 97. We suggest to hinge a door in one side of the fuselage near 19. The front enclosure of the cockpit can be made with five or more celluloid pieces. Cut out the four pieces of formers, marked "front", cement them to 62a as dotted lines show. Cover the space between them with one piece celluloid. Above and below this window you may use two-two pieces of celluloid or several sectors. When ready and trimmed, remove the "front" formers. For a perfect job, we suggest to shape the front out from scrap balsa, coat this six times with clear dope, next with wax* give an even coat over the surface (about 1/16" thick) and start covering it with very thick clear dope. Coat after coat will give a clear and even surface. When it reaches about 1/32" thickness, remove it and cement it to the model.

Spray the paper covering with water and apply clear dope. Cement the Speed Indicator to the pylon; 98 and the exhaust 99 to the fuselage as indicated. The color scheme is silver with red and black trim. Consult the photos.

<u>TESTING & FLYING THE MODEL:</u> Your helicopter model is now ready for pre-tests. Instead of the usual gliding, you now have some new tricks to learn. First, set the rotor blades at zero degree (Fig. 4). Open up the fuselage and the suggested front door and hang six starnds rubber band between 19 and the S-hook. Pull out the crank so that #100 can be pushed on the crankshaft. When this is properly placed, the crank is free to turn. Close the fuselage, put 97 in place and by turning the torque propeller anticlockwise, the string from (D) will wind on (E) and from (A; to (C). While you do this, the crank will free wheel. This done, open the rear of the fuselage. Push the starter 82 through H to lock it. Now, start winding the rubber motor by the crank, turning it in clockwise direction. Give the motor 50 turns. Pull out #100 and push the crank in place. Close the fuselage. The helicopter now is ready for the first run, but naturally not for the first flight, because the rotors are set at zero degree of angle; they are not yet balanced; and the torque effect is also unbalanced. If you lift the model by the rotor shaft, the Center of Gravity must be either coincident with the shaft or maximum 1/8" aft. If not, correct it with weight, adding it to the bottom of the model. Place the model on your worktable, be certain that the rotors will be free to revolve and pull out 82. Both rotors will start to turn and the model having a swiveling wheel, will start circling on the table on a crazy pattern. If the parts of the mechanism and especially the main rotor was properly balanced, this only will happen, but with unbalanced rotor it will try to "capsize*. Observe the behavior of the model. Repeat this test several times. It will be necessary that each time you rewind the strings. At your next test hold the rear wheel so that the model cannot roll and watch the main rotor. Even at zero degree of angle, the tips of all or some blades may rise too much. This may mean, that 49 is not bent properly or the blade is too light. Set the blades to a small positive angle for the next test and still hold the model by the rear wheel. Increase the blade angles and also the winding turns of the rubber motor in each following test. The number of strands can also be increased. Drawing #1 shows the coning angle of the blades, at which angle the centrifugal force and the lifting force should be balanced. This angle is somewhat similar to the dihedral angle of a wing. It may be less or more in different helicopter models, depending on weight, r.p.m., power output, section, tip speed, etc. If the blades or some of them rise too much, put paper clip near the tip to overcome the exaggerated coning angle. As soon as the proper blade balance and angle is attained, the model will show a tendency to rise or make a "jump take off". Now, you ready to give your attention to the rear torque propeller. You have already noticed, that the

torque propeller revolve with a much greater speed than the main rotor, also that the torque effect is lessened and it was easier for you to hold the wheel. Next, let the model climb without holding it. The result will be a slow climb of a few inches, with a quick side turn of the tail and a hovering flight with the tail standing steadily or turning. If it is steady, the torque is balanced. If not, the blade angle of the torque propeller must be increased or decreased. To do this use cellulose tape. If the fuselage turns clockwise the blade angle must be increased, if it turns anti-clockwise it must be decreased.

From now on your helicopter model is airborne and you can start your experiments. Do them indoor. Here is a general description of what you may do: Small amount of small rubber motor with low blade angle will give a smooth low climb and hovering. If the blade angle is increased the climb will be higher. There will be a limit to the angle increasing and the model will not rise off the ground. With an increased number of rubber strands and turns, at low blade angle the performance will be short duration, at right angle the climb and ceiling will be rapid and high and at too high angle the take off will be unstable. Still greater power can be used for Jump-take-off at high angle or high altitude at medium angle. In these tests try to let the model 12" to 24" off the table, so that you may observe and correct the settings. After these tests try a high altitude flight with increased rubber motor and winder winding. Starting from the floor.

There is a limit to the vertical ceiling. Even full size helicopters are unable to rise vertically to high altitude. In fact, the test helicopters used now, have ceiling of 100 ft. or less. So don't be discouraged if your model does not hit the "ceiling" of the room. Altitude with helicopters are reached with climbs at forward speed. In this indoor vertical altitude flights you will observe that the blade angle effects the vertical landing behavior. While full size helicopters use the De La Cierva autorotation patents and systems to land in case of motor trouble, or just decreasing the blade angles for vertical descent, this model is not fitted with free-wheel (some of .you will use it) or automatic blade angle control. Neither one was necessary, although they were tested. The reason is, that the blade angle set for climb is not too high and certain numbers of motor turns - at the end of the flights - are sufficient to keep the rotors turning for a good or fair landing. At altitude tests you will observe that the model tends to nose down slightly, hence float forward at the end of the hovering and landing. The reason for this is, that the Center of Gravity of the model will change it's position slightly, due to the winding of the strings from E to D and from C to A.

Now, flights with cyclic control. If you set 54 as shown in second sketch (Fig.7) and use small rubber power, the model will roll forward. By changing the position of 54, the helicopter will roll backward, sideway or any other direction. Set 54 for forward rolling with low blade angle and half wound motor. Let the model roll and watch the blades of the main rotor, as they pass right side of the fuselage. You will notice, that when the blades pass forward on the right side of the fuselage, the coning angle will increase and show a tendency to slow down. Passing the opposite side, they coning angle is decrease and the blade speeds up. This was not possible if the blades were not hinged to 33 so, that they are free for up and down (flapping), also for for and aft (drag) movements. Without this or similar system, a single rotor helicopter would not be able to hover in wind or fly in any direction with stability. This is the reason why wingless autogiro models, without using it, were unable to perform. Let see what happens. When the blades rotate for instance with 50 mph tip speed, in undisturbed air, it is natural that they can revolve around, at a set angle, without encountering any offsetting effect, but now the model is rolling ahead with a certain speed, say the speed is 10 mph. This will mean much to the rotating bades. The blades advancing against the direction of the roll will advance with 40 mph speed (30 plus 10), while on the opposite side only with 20 mph (30 minus 10). It is easy to understand that the blade a t 40 mph will create more lift and drag, than at 20 mph. So, at one side of the model the lift will be much more than needed, while on the other side much less. This certainly would upset the balance and crash the model if in the air or let the model fall on it's side when rolling. With hinged blades the problem is solved. The blade facing the direction of the movement or wind will be able to rise and retard, to lessen the lift and drag while passing the opposite side will be able to decrease the coning angle and increase the tip speed, to increase the lift. All this is done automatically.

If now you increase the blade angles collectively, leaving 54 in the same place and increase the motor turns, the model will climb, nose down slightly and fly forward. Changing the position of 54 will make it fly in any other selected direction. If the power is increased, the model will climb continuously with forward speed. If in addition, the torque rotor pitch is changed slightly, the model will circle during the level or climbing flight. When you have mastered the model, move outdoor. More rubber power will increase the performance. For indoor use only, the main rotor blades can be changed for lighter and thinner blades, with increased chord.

THE SIKORSKY XR-5 HELICOPTER: It is built by SIKORSKY AIRCRAFT; Bridgeport, Conn. Mr. Sikorsky designed two unsuccessful helicopters in his native Russia in 1909 & 1910. In 1939 he was once more at work and his third helicopter, the VS-500, flew. It had one three bladed main rotor, two smaller tail rotors and a torque propeller. In further tests this system was simplified to one main, one tail rotors and one torque propeller; finally to one main propeller (rotor) and one torque propeller. This was accepted and used in R-4, XR-5 and Xr-6 helicopters. The first set up was more original than the last one. In the first, the main rotor had collective pitch control only and the tail-rotors had pitch and reverse controls. The present control system is a combination of various systems used previously by different experimenters.
The main rotor blades are hinged, according to the DE LA CIERVA Autogiro patents (1925)
The torque rotor (or propeller) was suggested by many, but it was used successfully by OEMICHEN (1923) and BAUMHAUER (1925).
Collective control was used by de BOTHEZAT (1922).
Cyclic control by PESCARA (1922) and BREGUET (1931).

It should be stated, that SIKORSKY was the first, who successfully combined these systems. The XR-5 was planned In 1942, after the success attained with R-4. It was ready in 1943 and flew first time in August 1943. Accepted by the U.S. ARMY in February 1944. The XR-5 is the largest single rotor helicopter, also has the largest engine used in such craft. The rotor span is 48 ft. The engine is 450 HP P&W WASP, mounted with shaft vertically. The fuselage is built in three section, similarly as R-4 and R-6. Steel tubing, plastic plywood, aluminum are used in construction. The cockpit is covered with Plexiglass. Seats are in tandem, with dual controls.

STORY BEHIND THIS MODEL: It was at the end of 19O9, when the designer of this model, first built a helicopter model - an order for an inventor. A spring motor from a talking machine was used for power. It rose a few inches, but was unstable. Since that model - up to now, he has designed and built more helicopter models, than anybody on record. In 1924, a two bladed single rotor helicopter model (without torque rotor) of his design established world's duration and distance records, which are still standing. He built and tested almost every well known and many little known full size helicopters and patent ideas - in model forms, for the purpose of finding the reasons of the failures or instability of early crafts. In many cases, he succeeded In making scale models flyable or stable, while the full size craft was ground-bound or unstable. For instance; his CURTISS-BLEECKER helicopter model (published in Model Airplane News, some 15 years ago), at first was unstable, same as the original, later, after modifications and by using cyclic control, the model performed well, while the original was abandoned. One of his BANTAM engine powered gas helicopter models made several hundreds of free flights, in the period of 1939-1943 hovering uncannily for 6 to 12 minutes almost motionless or maneuvering by a pre-set device. As Soon as the present engine situation is changed for the better and metal fittings can be made, this company intends to release a helicopter kit for gas engines. The mechanism used in this model was used successfully in several of his models; some of it was published in U.S.A. (1930) and abroad (1924).

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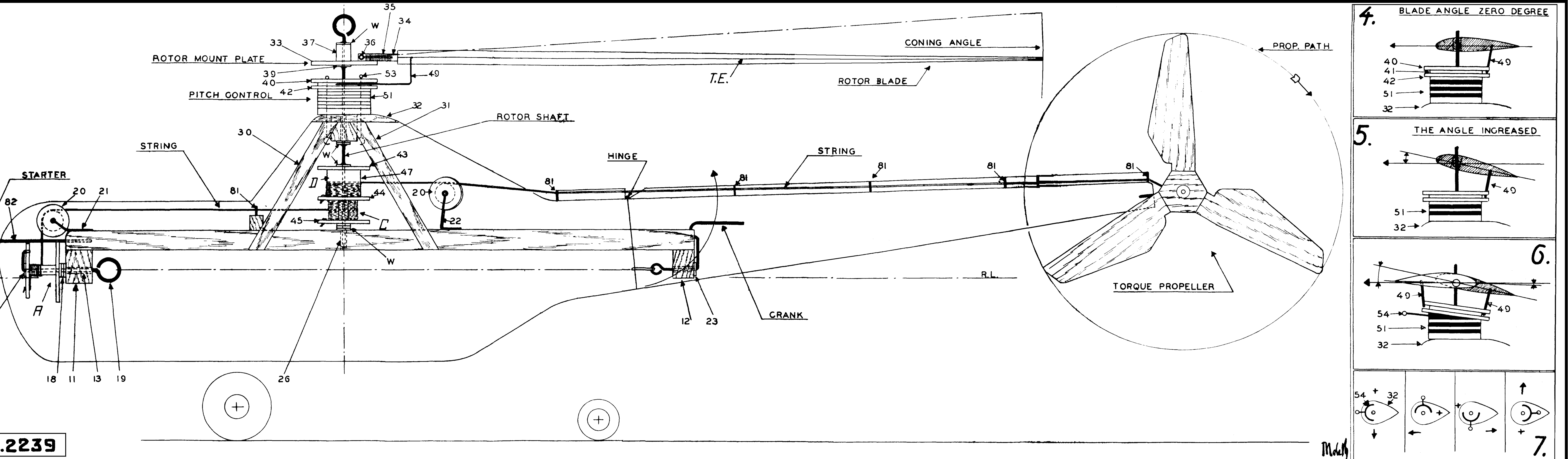
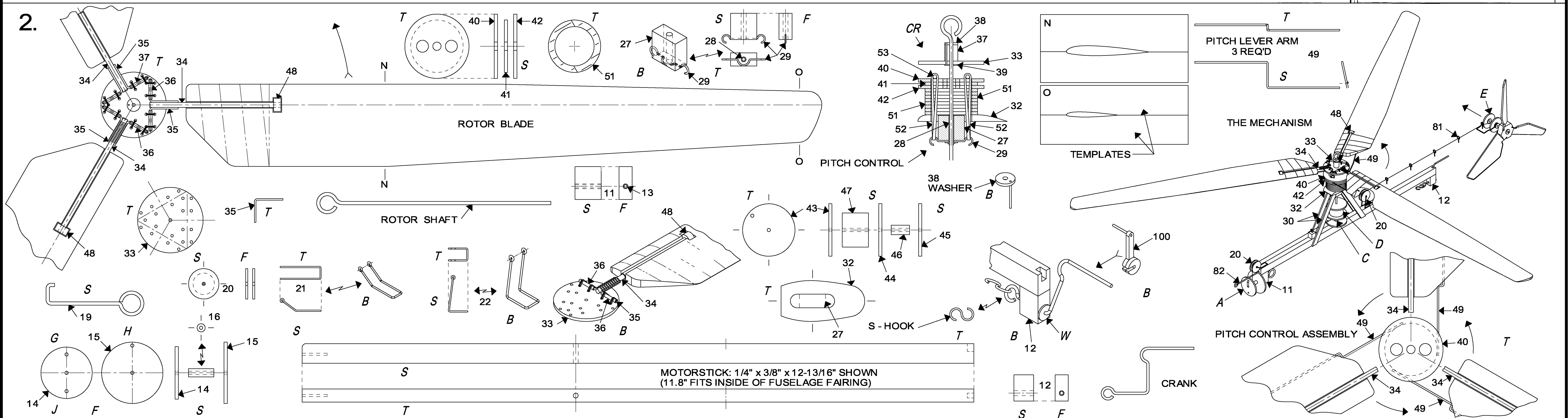
1.



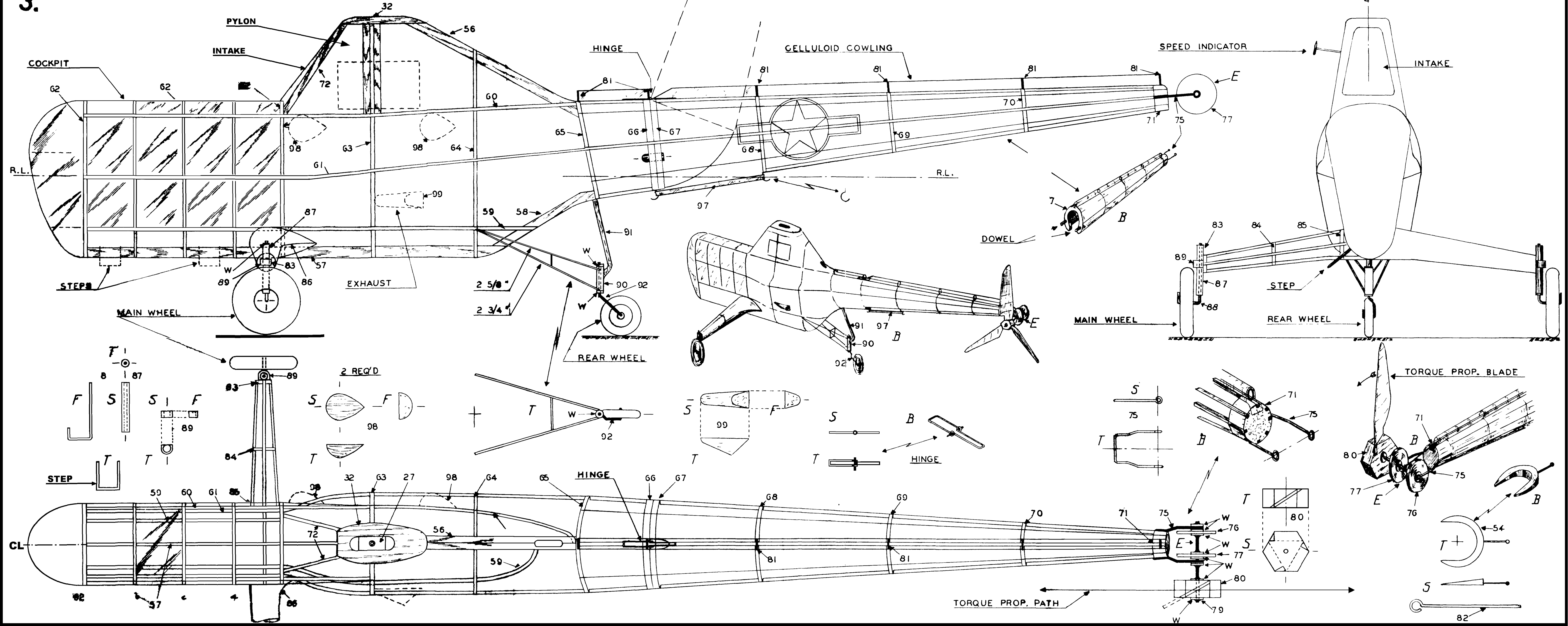
ROTOR MOUNT PLATE
PITCH CONTROL
CONING ANGLE
T.E.
ROTOR BLADE
ROTOR SHAFT
PROP. PATH
STRING
STARTER
HINGE
R.L.
CRANK
TORQUE PROPELLER
R.2239
4. BLADE ANGLE ZERO DEGREE
5. THE ANGLE INCREASED
6.
7.

2.



ROTOR BLADE
ROTOR SHAFT
PITCH CONTROL
38 WASHER
TEMPLATES
PITCH LEVER ARM 3 REQ'D
THE MECHANISM
S - HOOK
PITCH CONTROL ASSEMBLY
MOTORSTICK: 1/4" x 3/8" x 12-13/16" SHOWN
(11.8" FITS INSIDE OF FUSELAGE FAIRING)
CRANK

3.



PYLON
INTAKE
COCKPIT
HINGE
CELLULOID COWLING
SPEED INDICATOR
R.L.
STEPS
EXHAUST
2 5/8"
2 3/4"
REAR WHEEL
DOWEL
MAIN WHEEL
STEP
2 REQ'D
TORQUE PROP. BLADE
CL
TORQUE PROP. PATH