The 18 foot plane with graceful gull wings.

A Radio Controlled Powered Soarer

The Story of How an Efficient Radio Controlled Gas Model Has Been Developed by Equipping a High Efficiency Soarer With a Motor and Radio Mechanism

By CLINTON B. DeSOTO

THE original idea which dominated the production of a radio-controlled plane was to build a high-performance soaring plane capable of carrying enough radio gear to accommodate any reasonable system, and soaring with it in light thermals or ridge winds.

The "powered glider" phase is a comparatively recent one. Interminable waiting for favorable weather conditions at the few available sites suitable for hand launching led to consideration of—in desperation—a power winch. Ordinary shock cords and hand tows were out of the question, of course. Then came an article by Peter Reidel in "Soaring," on powered sailplanes, that set us off.

The motor housing was hurriedly assembled, the Forster motor "played with" until fair reliability was achieved, and we started in. So far the synchronization of control gear problems with gusty April winds has not allowed any extended flying; but we do know that "Little Hercules" will keep the ship up and even make it climb a bit, although it must be hand-launched (the run-and-heave system!) still. At least we can now visualize the goal, which will be to have the motor fly the ship into the wind for five minutes or so—long enough to gain the altitude needed for the real sport: soaring the ship into thermals and ridge winds for duration and altitude marks.

The problems of power and radio-control were not the only ones to be solved. Behind them lay the design and construction of the ship itself. Owing to its necessarily increased size and weight, the design of a radio-controlled plane combines the problems of model building and the design of a full sized airplane or sailplane.

In building a ship for the purpose of carrying on further experiments with radio-control methods, the basic requirement was made an ability to carry sufficient weight to permit the use of a wide variety of systems. A consideration of all the systems that might rationally be utilized for model work disclosed that in all probability no single-channel system would weigh over ten pounds, and there was little excuse for a weight exceeding five.

In contrast to full size airplanes, but akin to sailplanes, the abuse received by models in the form of crash landings, etc., necessitates a comparatively low payload /weight ratio. Ross Hull's experiments indicated that the purely structural part of the ship—the strength-giving portions —should have at least twice as much weight as the surplus load. Otherwise, the structure would be too flimsy to withstand landing shocks.

With a control weight of five pounds and a two to one ratio, the basic dimensions could be set up. A wing loading of ten to twelve ounces seemed reasonable,

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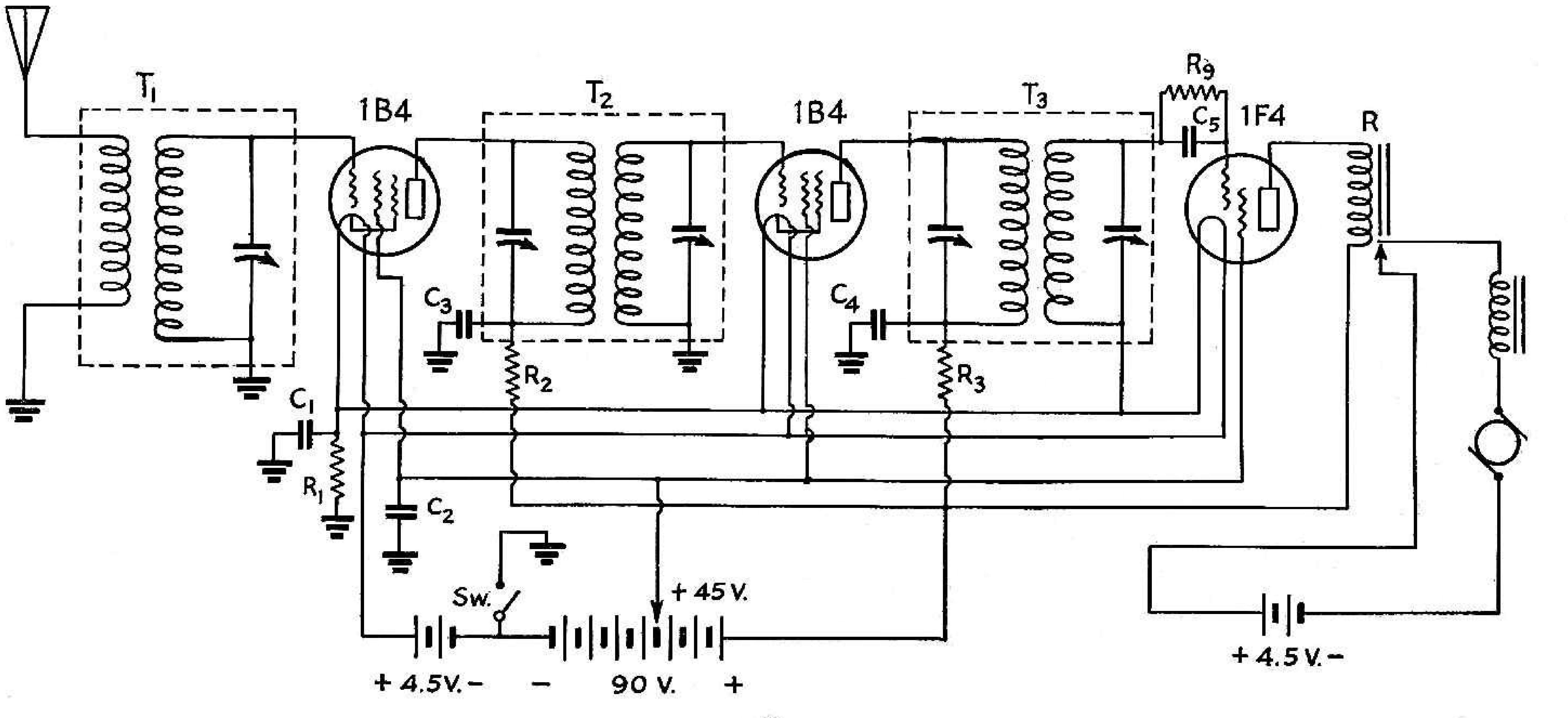
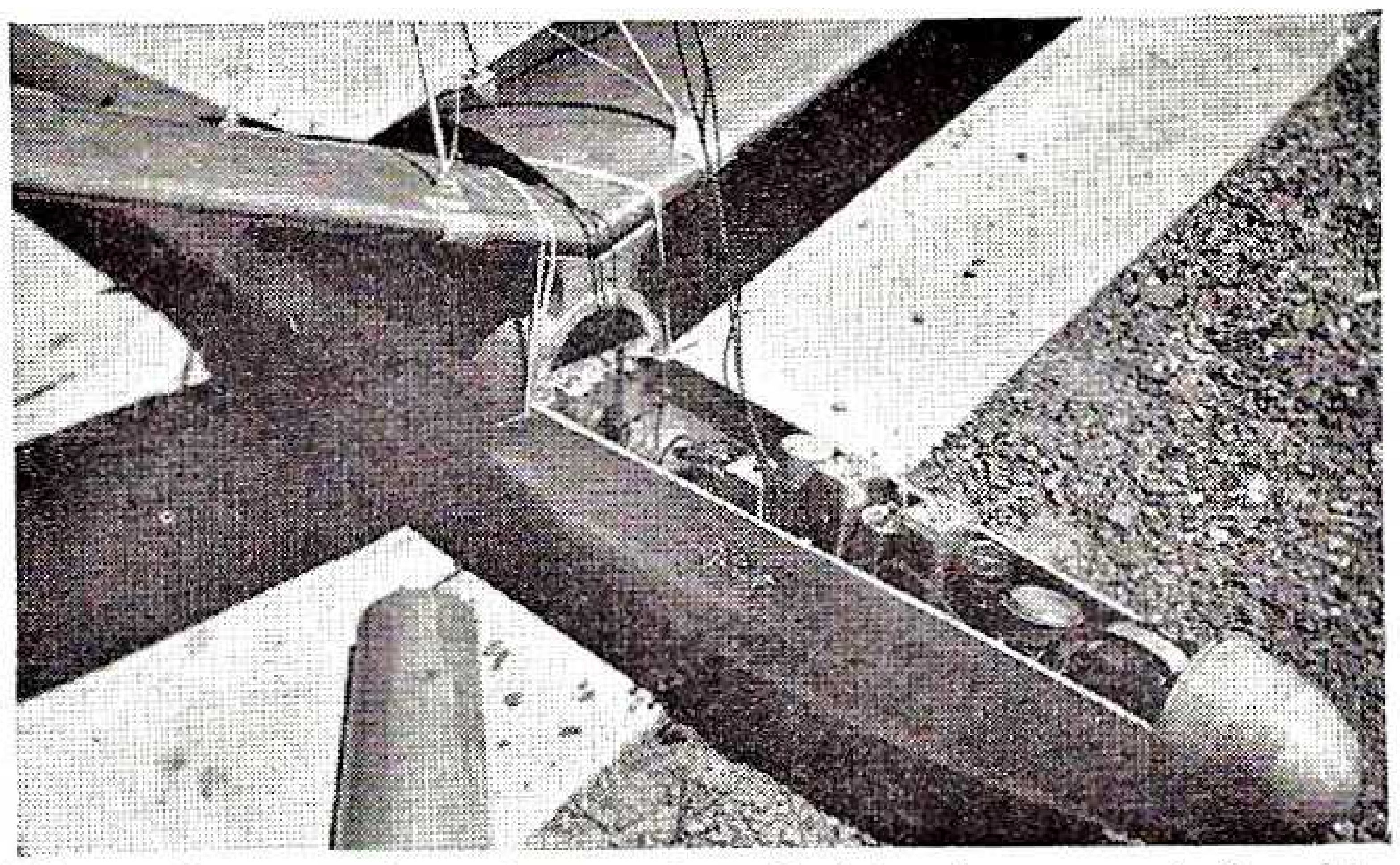
CIRCUIT DIAGRAM OF THE 1750-KC. RECEIVER

T1—Antenna coupling coil (Sickles 4081); T2—1600 kc. i.f. transformer (Sickles 8084); T3—Same as T2; C1, C2, C3, C4—0.01 mfd. 200-volt tubular paper condensers; C5—500 mmfd. midget mica fixed condenser; R1—10-ohm 1/2-watt fixed resistor or 10-ohm rheostat; R2, R3—5000-ohm 1/2-watt fixed carbon resistors; R-4—2-megohm 1/2-watt fixed carbon resistor; R—Eby 5000-ohm relay. Ordinary flashlight cells are used for filament and motor supply; "B" batteries are Burgess X30FL. The antenna is a 5-foot length of wire run the length of the fuselage, inside.

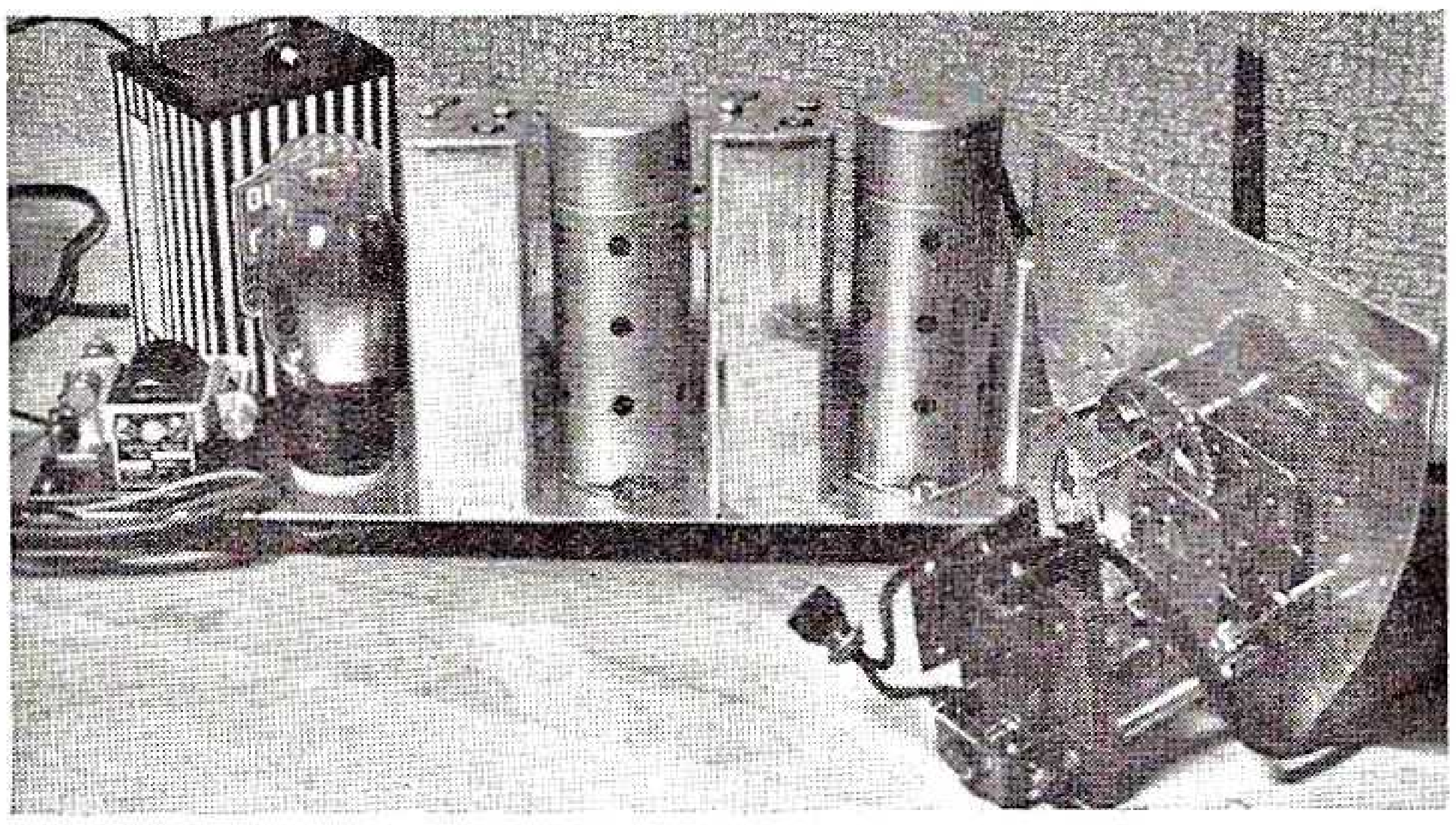


leaving a margin for an even heavier system if that occurred as a necessity (of course, since a heavier system would probably be more reliable the crash danger would be minimized). That meant an area of about twenty square feet, a span of about eighteen feet for an aspect ratio of fifteen with tapered tips, the minimum for a really high-performance soarer.

It should perhaps be emphasized that these dimensions are not the basic minimum required for a successful radio-controlled craft. Even the five pound limit is exceedingly generous for a single-channel control system. The one to be described actually nets about 3-1/2 lbs., and workable systems have been built weighing but two lbs. Indeed, a 1-1/2-lb. figure is in sight. Based on the three lb. figure, the wing area can be reduced to twelve or even ten square feet—twelve to fourteen feet span, with similar A.R. Such a ship is comparable in construction with ordinary gas models, and is by no means beyond the scope of the average model builder.

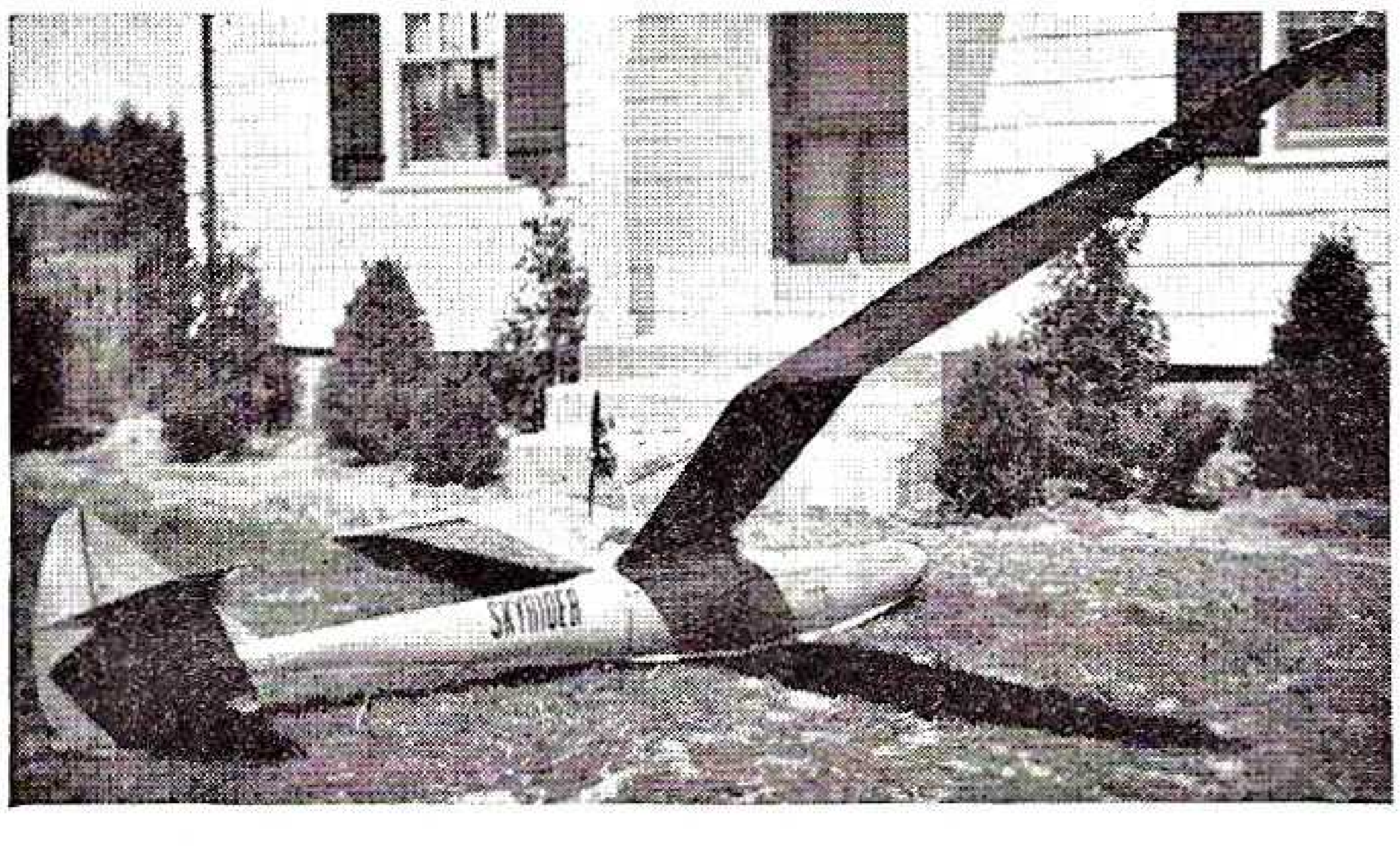

The radio control equipment installed in the nose of the ship. Six flashlight cells occupy the space between the tuning meter (used to facilitate synchronization with the transmitter) and the nose block. A key switch prevents unauthorized tampering; the other two switches control the receiver and ignition.

So the thing took form: A tail arm 2-1/2 times the chord, which is standard practice. A structural weight not to exceed ten pounds. Ruggedness, lightness and high performance. That meant minimum drag at all points through careful streamlining and fairing. A high L/D ratio, to give a large gliding angle. With this must go low sinking speed; or, at least, that was our conviction. Others may disagree. Anyway, a high lift wing section was indicated, one with low drag, too. In actual construction this section was modified to give a reverse curve at the trailing edge, reducing the center of pressure travel, to provide vital stability.


Receiver and control mechanism, showing d.c. motor and gear train. Simple impulses actuate the relay at the left, which turns the motor off and on.

A full cantilever wing of the dimensions shown must combine great strength and lightness. This was achieved by integrating the structure as two complete box spars, comprising the leading and trailing edges. The solid main spar is made up of 36-inch lengths of 1/4" x 2" hard balsa, these lengths fitting conveniently into the general layout. Ribs of 1/8" hard balsa are spaced every four inches, butting into a stepped leading edge and a notched trailing edge. The main box spar is completed by planking the section between the L.E. and the main spar member, using 1/8" x 3/8" medium balsa planking.

The rear box spar is made by adding three widths of the same planking in front of the trailing edge and "boxing" by fitting pieces of balsa between the ribs. Cap strips on the remaining exposed parts of the ribs, small balsa gussets where these cap strips butt onto the spars, and further planking-in around the dihedral joints, center joint and tips, complete the structure. When covered with well-doped 100-weight cambric the wing assembly has great resistance to all distortion except in the vertical plane. Here it is quite flexible, the tips rising perceptibly with rising speed in launching. This doubtless accounts for the fact that it has survived some amazing shocks.



The motor mount and rudder detail are shown here. The fuselage is made of plywood.

The fuselage is made of rolled plywood, glued to 1/4" plywood bulkheads. Ahead of the wing T.E. the thickness of the covering is 3/64ths; toward the rear it is 1/64th. The latter, although light as heavy paper, is surprisingly strong when rolled. With the solid nose block securely attached, the fuselage structure is extremely strong and will absorb all ordinary landing shocks with ease, whether near the nose or along the 1/4" thick spruce keel.

The tail surfaces are built of balsa, in orthodox fashion, with planking similar to that on the wing. The fin and stabilizer are built integrally to facilitate assembly, the latter riding high both to avoid some of the effect of wing wash and to protect it on uneven terrain when the ship rests on a wing tip. A solid rudder post is bolted into the fuselage end, the front of the fin being held by heavy rubber bands over a thin sheet aluminum fuselage reinforcement. The rudder is hinged on small aluminum tabs, allowing free movement.

The motor nacelle is built around 1/4" square spruce stringers, assembled on a pair of plywood bulkheads and a plywood platform which holds the engine. The stringers are covered with 1/8" x 3/8" balsa planking, and the whole finished with aluminum dope. (If the ignition coil touches the aluminum paint it should be well wrapped with tape, by the way, or it may short through the container.) Aluminum flanges bolted to the bulkheads provide mounting connections. The housing is supported by four 1/4" diameter 17S-T aluminum rods, which are in turn bolted to wing clips made of 1/32" sheet aluminum. Four No. 18-gauge steel wires with turnbuckles run to the gull breaks in the wing, serving both to add a little extra strength and to hold the housing down as the motor pushes the ship along in flight.

The pusher type of installation was not originally contemplated, but was necessitated to locate the center of gravity properly with the radio gear stowed as it is. Were it to be made a tractor, some of the batteries would have to be put back of the wing—obviously an awkward proceeding.

Incidentally, this motor and propellor combination is not an entirely desirable one for the job at hand. With comparatively slow flying, under-powered ships, maximum propellor efficiency is attained with large, slow moving props. Our eighteen inch prop turning over at 4000 r.p.m. or more is certainly not that. A twenty-four inch propellor, geared down to 1000 r.p.m. might mean the difference between 50 or 60% and 80% efficiency or more.

Turning now to radio control, the system currently in use differs from that described in the January issue of MODEL AIRPLANE NEWS in both the type of receiver and the control mechanism. Both changes are in the direction of added reliability of operation and ease of adjustment; but they are made, necessarily, at the expense of some lightness and compactness. In other words, this system is for larger and heavier ships. For small, light ships the other is more suitable.

The control mechanism in this case utilizes a small d.c. motor to operate the rudder, rather than the rubber band motor, escapement actuated, of the Hull system. This motor, properly installed, is somewhat more reliable in action than any but a most carefully designed and machined escapement mechanism, and provides appreciably more power, insuring that the rudder will turn even if control wires stick or the air force on the rudder is great. Indeed, when sufficiently geared down the power is so great that the rudder bar can scarcely be stopped with the hand.

But the biggest advantage of the motor is that it provides continuous control, enabling any rudder setting desired. This smooth control obviously permits smoother maneuvers than when only three positions are available. As used, the rudder bar travels quite rapidly through the intermediate stages and pauses appreciably at the extreme of the cycle, owing to the "sine wave" action of the rotary control wheel.

As can be seen in the photographs, the mechanical part of the control system comprises the following elements: (1) An aluminum plate whose outline is the fuselage shape, which serves as a support for the remaining elements; (2) a rudder bar with bearing at the bottom of the plate, slotted to receive a moving pin on the control wheel disc. This bar pulls a length of strong cord over pulleys, the cord being tied into lengths of No. 28 brass wire which connect to the rudder arms; (3) a two inch aluminum control disk mounted on the low speed drive shaft of the gear train, fitted with a pin which operates the rudder bar; (4) a gear train with approximately 1000-to-1 reduction, taken (of course!) from a defunct alarm clock and suitably revised; (5) the motor.

The motor was made for use in an automobile defroster unit, and can probably be secured through automotive wholesalers or dealers. It weighs eight ounces complete with wiring. It will operate on 4.5 volts with a current consumption of about 0.6 ampere. The assembly must be carefully aligned to eliminate undue friction; otherwise the motor may refuse to start on the occasions (about 1 in 10, perhaps) when the armature happens to stop flush with the pole pieces. With six volts at 0.9 ampere it is entirely reliable even with considerable friction.

The exact gearing ratio to be used is a debatable point. Since this installation was in the nature of a preliminary experiment we were perhaps unduly afraid of not being able to realize the exact functioning of the control in operation. In consequence the ratio used is somewhat too high. It takes about ten seconds to complete an entire cycle (one revolution of the control disk). Obviously, this does not permit any rapid maneuvering, but it does provide accurate knowledge of the degree of rudder movement from the ground. We now feel that twice this speed would perhaps be optimum, while a complete cycle occurring in two seconds would be entirely practical for a rather fast ship. Since the motor used operates at something between 4000 and 5500 r.p.m. (depending on loading and voltage), this would mean a gearing ratio of 300 to 500, or even less.

The radio system makes use of a trans-

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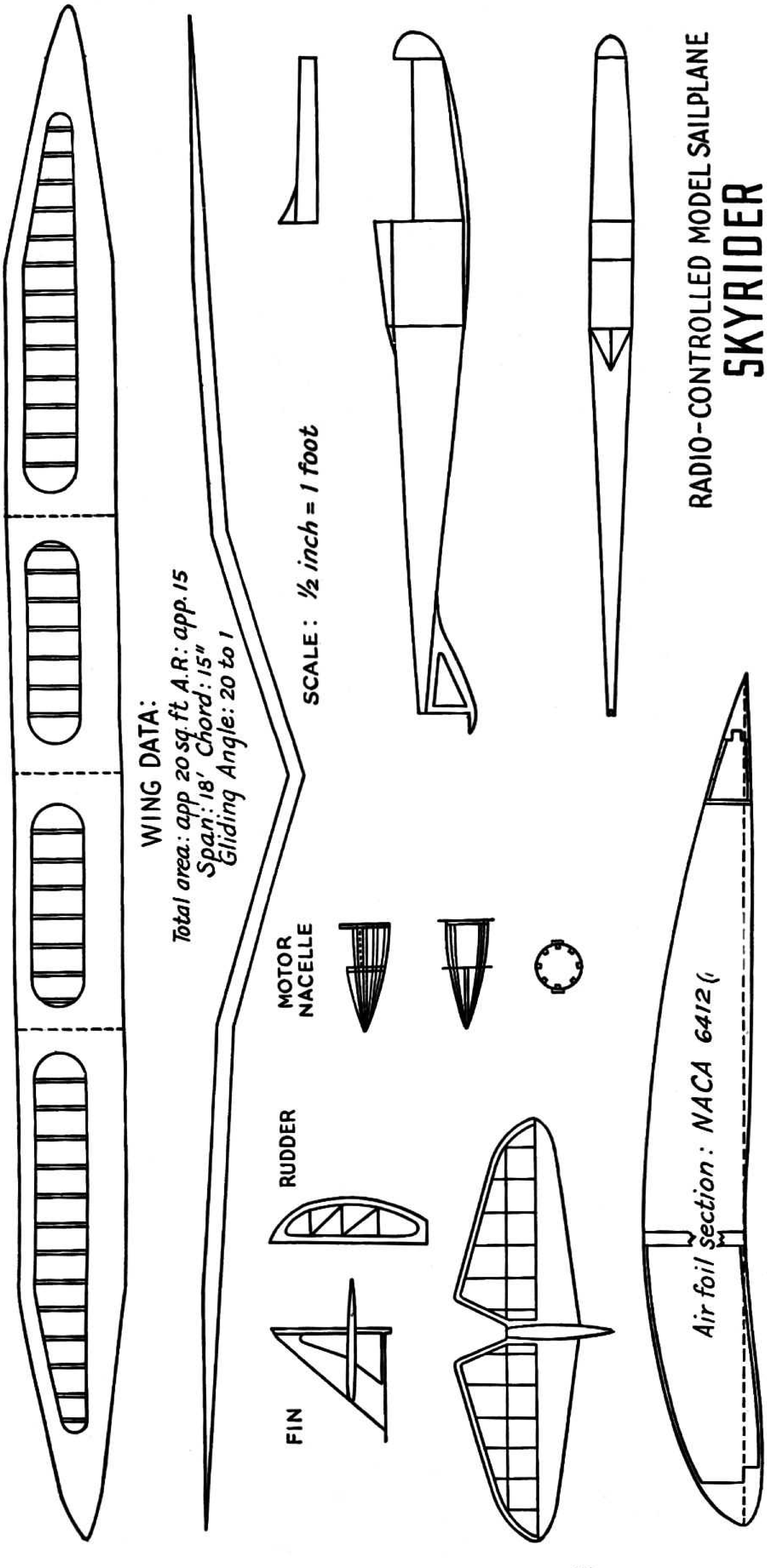

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mitted signal of about 1750 kc., in contrast to the ultra-high frequencies which have been commonly used to date. The occupancy of this radio territory is comparatively sparse, and little interference is received or caused there. Yet radio equipment acts in a reliable, straightforward fashion, and fewer constructional bugs are encountered. Naturally, this frequency has both advantages and disadvantages; but the former do contribute markedly to reliability and simplicity of construction and adjustment.

The receiver consists basically of a two-stage pre-tuned r.f. amplifier and a grid-leak detector. The idling plate current of the grid-leak detector closes the relay, which opens the motor circuit. When a signal of a certain minimum amplitude comes along the detector rectifies and the plate current drops, opening the relay and closing the motor circuit.

The phrase "of a certain minimum amplitude" is quite important. The sensitivity of the receiver cannot be too great or a distant carrier, or worse yet, the local engine ignition noise will actuate it. Yet it must be great enough so that a moderate transmitter power and a modest antenna will provide adequate signal strength. In this case the receiver has a nominal sensitivity of 200 microvolts; that is to say, in the laboratory 200 mv. from the standard-signal generator will provide the one volt of detector input which will just barely ride the plate current down to 1.5 ma., where the relay is set to operate. But complete reliability is not had until the plate current dips to 1 ma. (the spring is set quite heavily so that shocks and jars or the heavy contact current will not affect relay operation), which requires two volts of input signal. This, in turn, requires a minimum field strength of perhaps 500 mv. A 50-watt-input transmitter working into 1/4-wave Marconi antenna-against-ground should give this over a moderate area.

The ignition problem is not altogether easy, but it can be licked without special precautions. The essential thing is limited receiver sensitivity. With the motor and all other metal in the installation bonded to the receiver chassis, it was found that the net effect of the ignition noise did not exceed the 200 mv. minimum provided the coil and condenser were correctly located. These should be moved around in the hand until the sphere of minimum effect is encountered. Had ignition noise been too bad, we were prepared to shield all of the ignition system, including the spark plug; and this may be necessary in more compact installations. In this connection, it may be said parenthetically that a carrier-operated system such as this is less subject to ignition troubles than one utilizing audio modulation, since the ignition pulses must have relatively enormous peak amplitude to produce a net signal level sufficient to simulate a reasonably strong carrier. This effect varies with motor speed, as well.

The receiver circuit is quite straightforward. An ordinary high-impedance antenna coupler is used. a compression trimmer serving as tuning condenser. The interstage couplers are ordinary 1600-kc. i.f. transformers, the diode input type being used because of its closer coupling, giving greater gain and less selectivity. Any coils of this general type, capable of tuning to 1750 kc., may be used.

It is notoriously difficult to build stable high-gain r.f. amplifiers with battery tubes, and it may be that instability may be encountered in duplicating the design, especially if the layout is altered. If oscillation occurs it is almost certain to be in the first stage, and may be eliminated by adding bias or lowering the screen voltage, or both. Reducing the latter to 22-1/2 volts is easiest, and will probably be effective. If this is done, the second 1B4 should be given a screen voltage of 67-1/2 to boost its gain slightly in compensation. If necessary, the grid return of the first tube may be opened and one of the very tiny "C" batteries now available inserted. No more than three volts additional bias should be necessary. The bias battery should be by-passed with 0.01 mfd.

The relay used is a 5000-ohm Eby. It is quite satisfactory, being rugged and dependable and of average sensitivity. A much more sensitive relay, costing considerably more, is the Sigma relay made for laboratory purposes in Boston. On test this relay gave very positive control with but 1/2 ma. variation—something that none of the so-called "half mill" relays we have tried have ever done except when too delicately balanced for flying. The importance of a reliable sensitive relay cannot be over-emphasized; it is the most critical single element in the system.

The battery complement comprises a total of six flashlight cells and two 45-volt "B" batteries. The total weight is about three pounds. One "B" battery could be used on the receiver with satisfactory results; the second is now used primarily to give higher idling plate current in the 1F4 (about 3 ma., in contrast to 1.5 with 45 volts). This adds reliability to the relay operation, but with careful adjustment it is not essential. Elimination of one "B" battery will cut the weight to 2 lbs., 2 oz. Both motor and filaments could be run from the same batteries, but a better plan is to use "penlight" cells for the filaments, with a further reduction to about 1 lb., 10 oz. Since the motor draws rather better than 1/2 ampere the use of smaller cells is impracticable on it.

While we're speaking of weight, if we add eight ounces for the d.c. motor to the minimum battery weight above, and then include about twenty ounces for the receiver (it could be made less by using de-based tubes, a lighter relay, lighter coil assemblies, lighter chassis construction) we get 3-1/2 lbs., the figure mentioned at the outset.

Viewed as a whole, this system has the significant advantage of using standardized principles, parts and methods throughout. Anyone of even limited radio and mechanical experience can be expected to duplicate it with comparative ease. Of course, a licensed operator must man the equipment; it must be used under a regular amateur station license; the carrier must be pure d.c. with no modulation and clean keying; and the call must be signed at least every fifteen minutes. But beyond these formalities no talents or training of a special nature are required.

All in all, this is a good system to use in getting started in the radio-control field. You know, this radio control thing is taking hold all over the country—and the reason is that it offers a thrill that can't be obtained from any other form of model activity; the thrill of actually controlling the movements of your own ship in flight. If you haven't yet gotten in on the fun, start today. Right now the ships are large, the control gear comparatively bulky and quite expensive. But with continued development this is all being changed, and soon your ordinary eight-foot gas jobs will fly under radio control much as the larger ships do now. If you want to know how to do it when the time comes, start learning now.