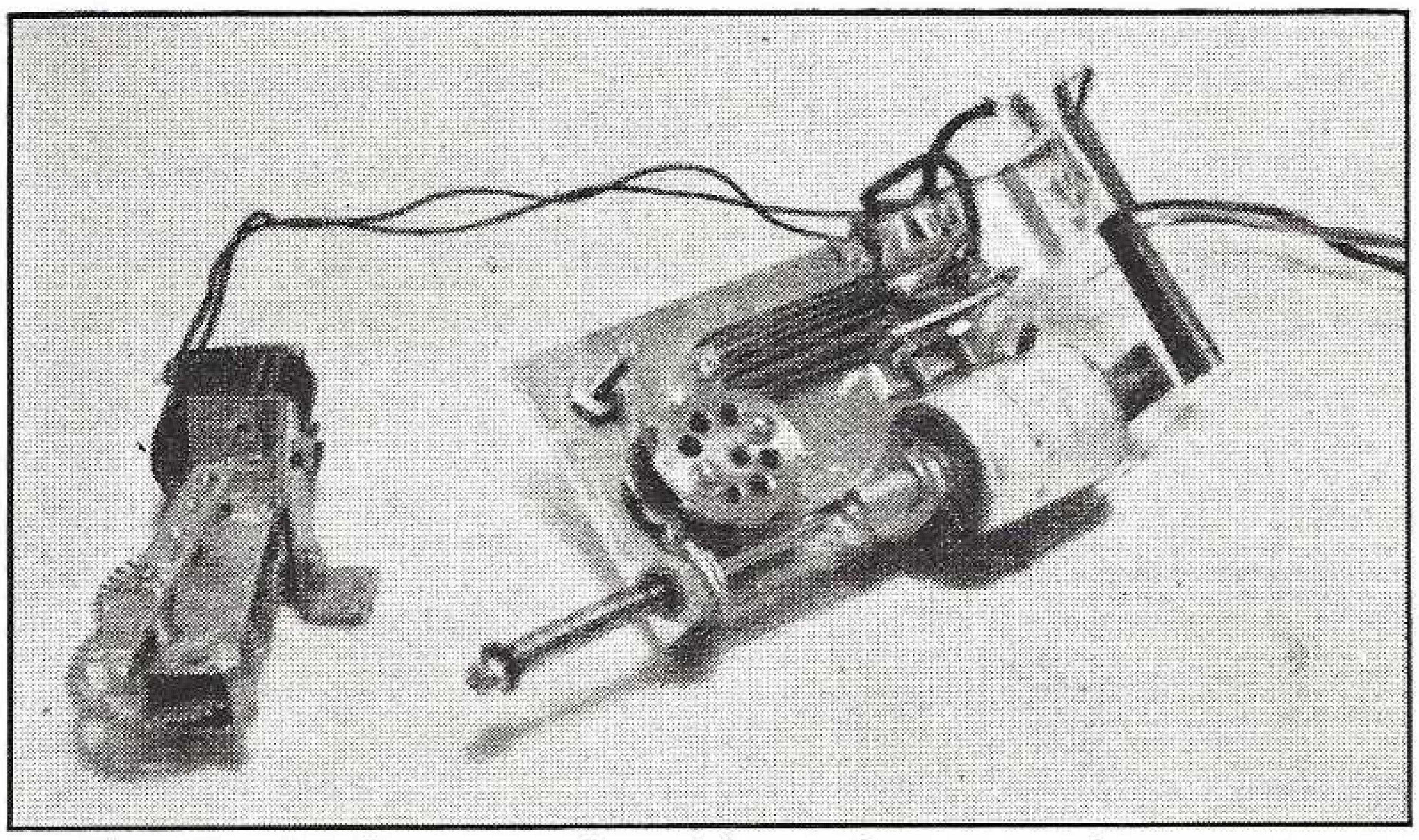


Fig. No. 3. Sequence relay, right, with motor and gear unit

Fig. No. 8. RK34 with oscillator and amplifier coil

ELEMENTS OF MODEL PLANE

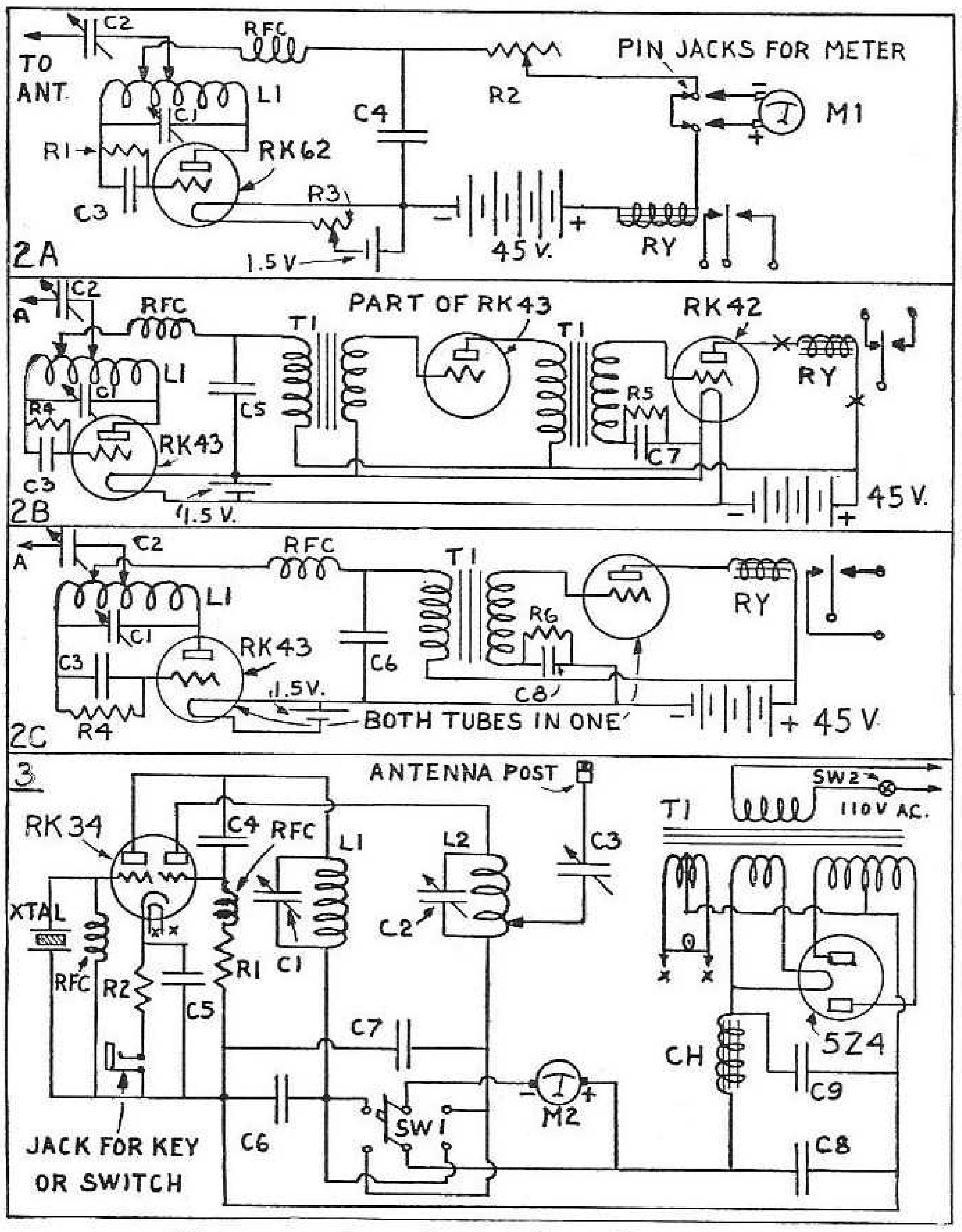
A Complete Outline of Practical Radio Control Systems With Descriptions of the Equipment and How to Apply It

THE subject of radio control of model airplanes has gripped the imagination of practically all builders. The idea of being able to control the movements of a tiny, fast-moving model is certainly one that cannot be dismissed lightly. Unfortunately, as many builders and prospective builders have found to their sorrow, there is much more to radio control than meets the eye. It is *not* simply a job of building a receiver and a transmitter, of putting the former in any model plane you may happen to possess, and presto!—radio control. There are many problems to be met, both large and small, and it is the purpose of this article and those that may follow to give detailed ideas on various angles of radio control and to show tested equipment that the builder may construct with the definite assurance that it will work.

There have been several articles in this and other publications on radio control. For those who have not access to all the radio and aviation periodicals, an outline of the various successful and practical control schemes will be given, together with complete descriptions of the necessary control equipment so that the builder may use whatever scheme his requirements and facilities suggest. In line with this policy it may be noted that there will *not* be any description given of the airplane itself, although such an article may follow in due course. The main idea is to give the dope on practical *equipment* for radio control.

Many constructors have been unable to decide what type of rig to use on the ground end of a radio control system. Complete data will be given for at least two simple transmitters, one of which works from the regular power lines and one that may be hooked to any six volt auto battery.

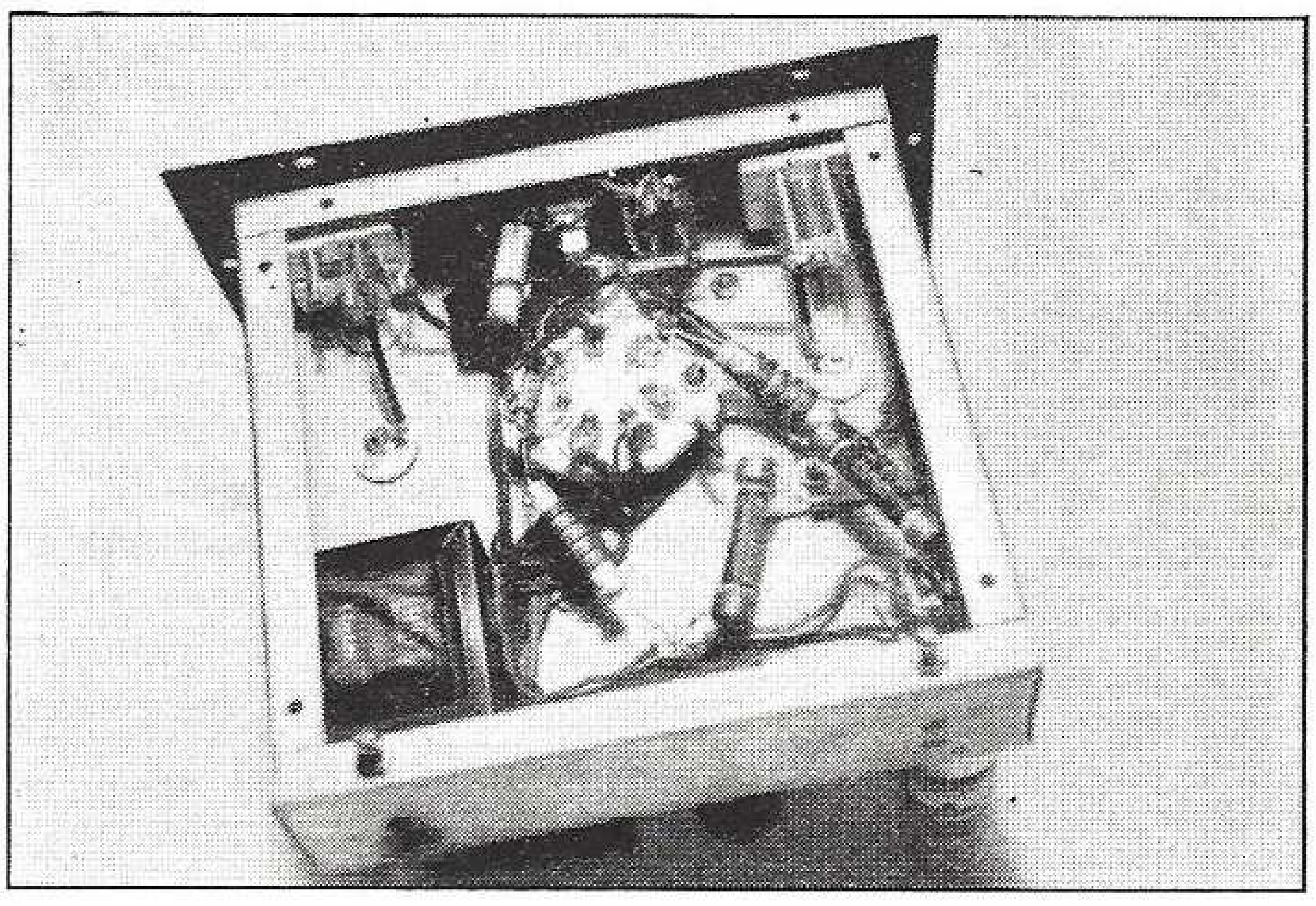
But let's get down to actual practical equipment. It has been emphasized that the simpler the apparatus in the model plane the better. The less complication there is, the better the chance that your



Diagrams of receiver and sending systems

Fig. No. 8. This inside view shows the RK34 in the center with oscillator coil at left and amplifier coil at right. The crystal holder is just to the rear of the oscillator coil

The two main tuning condensers are at the upper part of this view, while the filter choke is at lower left. The tube socket is placed about 3/4" below the chassis top



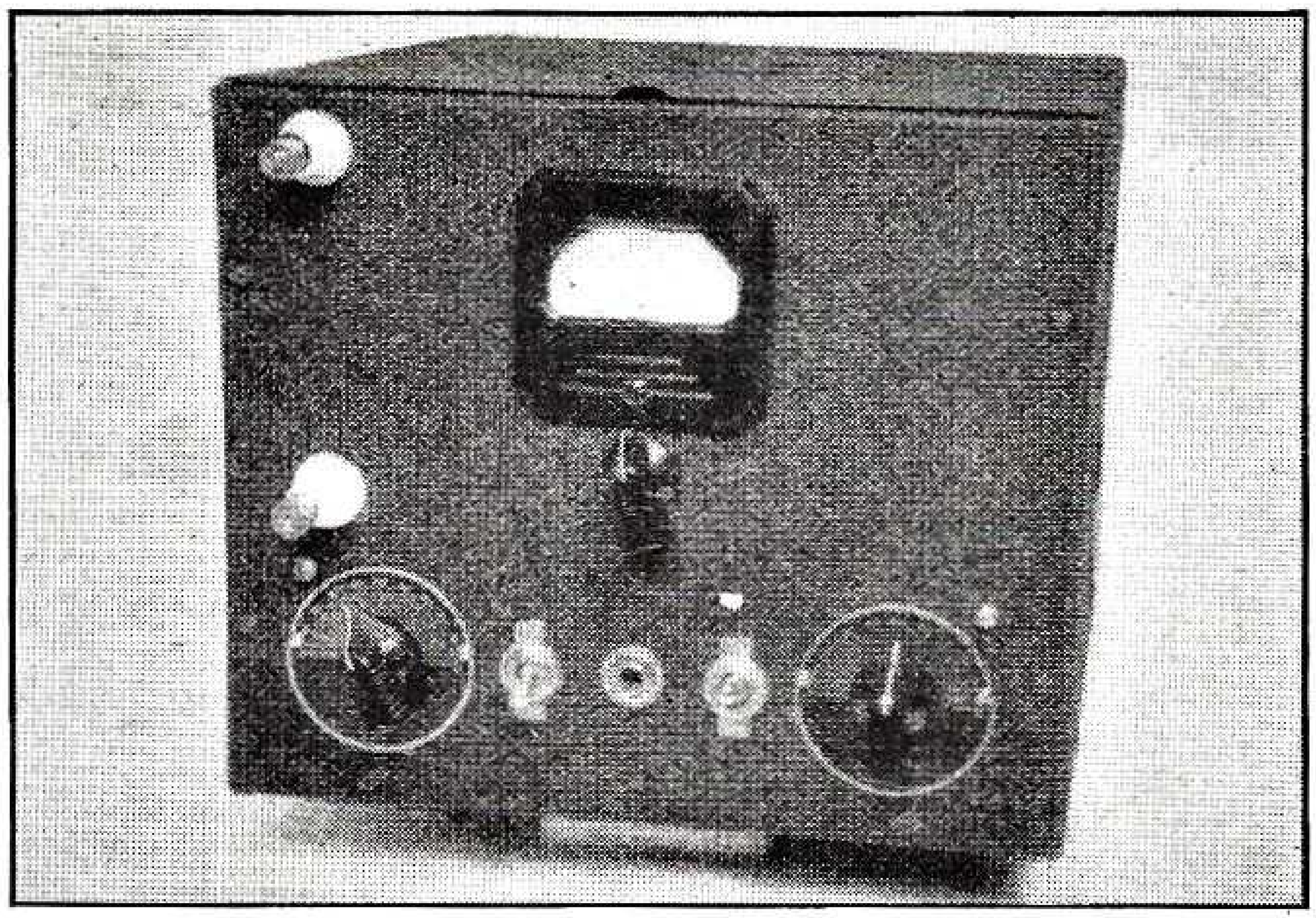


Fig. No. 7. External view of the transmitter

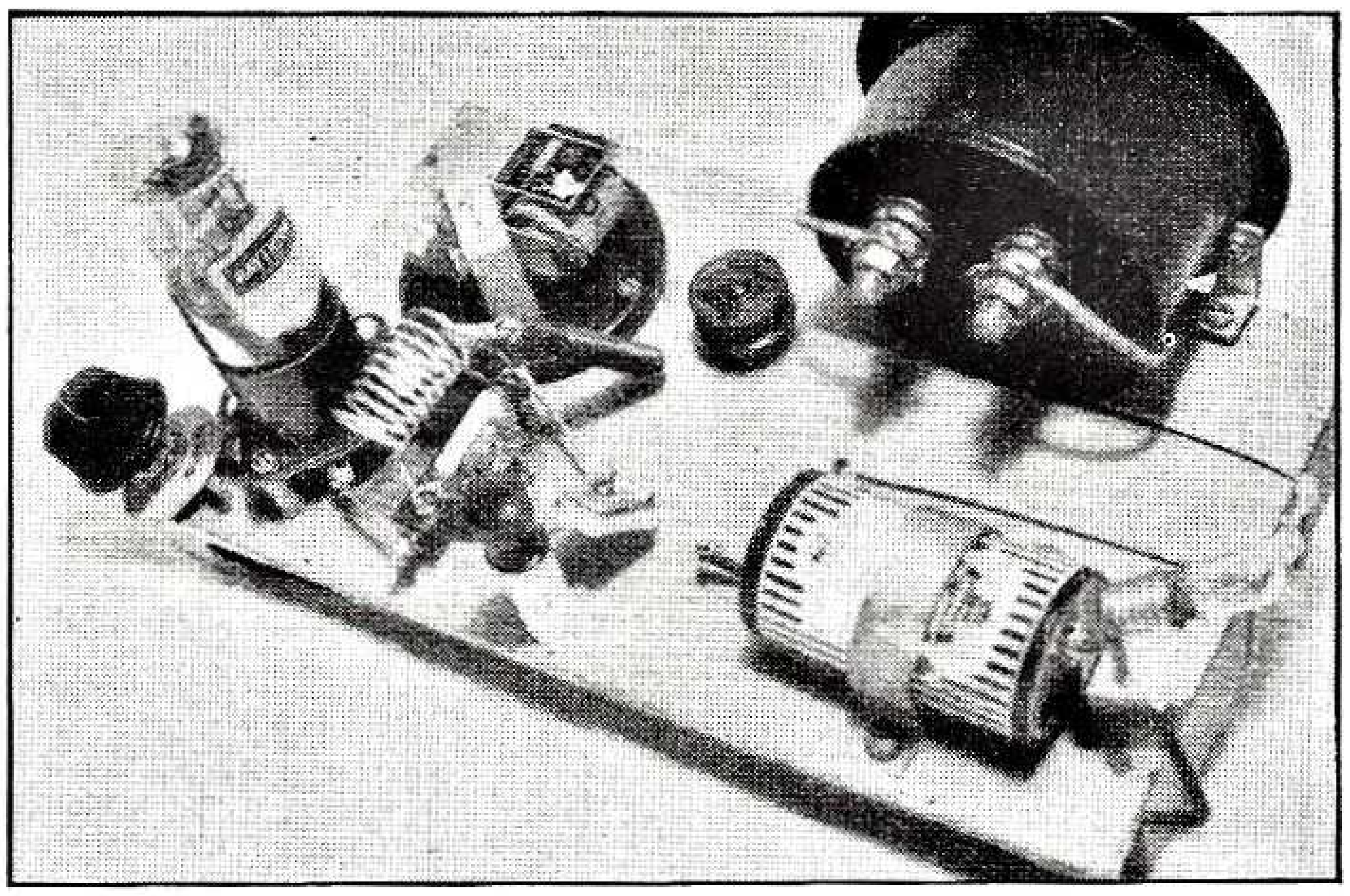


Fig. No. 5. Experimental receiver using RK62 tube

RADIO CONTROL

By

HOWARD G. McENTEE

model will operate properly when way up there in the air with the only connection between you and it an invisible and at times highly perverse thread of radio waves.

Leaving the radio end of the equipment for a moment let us consider what possibilities there are to enable operation of a single moving element, the rudder. The very simplest system is shown in Figure I-A. Here the sensitive relay is connected to an electromagnet and battery. If the rudder is normally in a straight position and the model is adjusted to fly straight, operation of the sensitive relay allows current to flow through the electromagnet pulling down the armature which is linked by cords or by rod to the rudder. This system has the ability to control the model in the maneuvers shown at the right, or of course, in any combination of these. This system is definitely limited since the rudder can only move a certain fixed distance without being able to stop in intermediate positions. Furthermore, if it is desired to cause a series of curves or a spiral, the magnet must stay energized which means a continuous heavy drain on the battery, a highly undesirable condition.

The next step is shown in Fig. 1-B, where the same circuit is used but a tiny motor and suitable gear train is substituted for the magnet. Here our possible maneuvers are greatly increased in numbers, as we may make either direct right or left turns of any desired degree of sharpness. The turns to right are direct, but those to left have a slight hump as shown between X-X which is unavoidable because the motor must pass through the right turn position before going to the left.

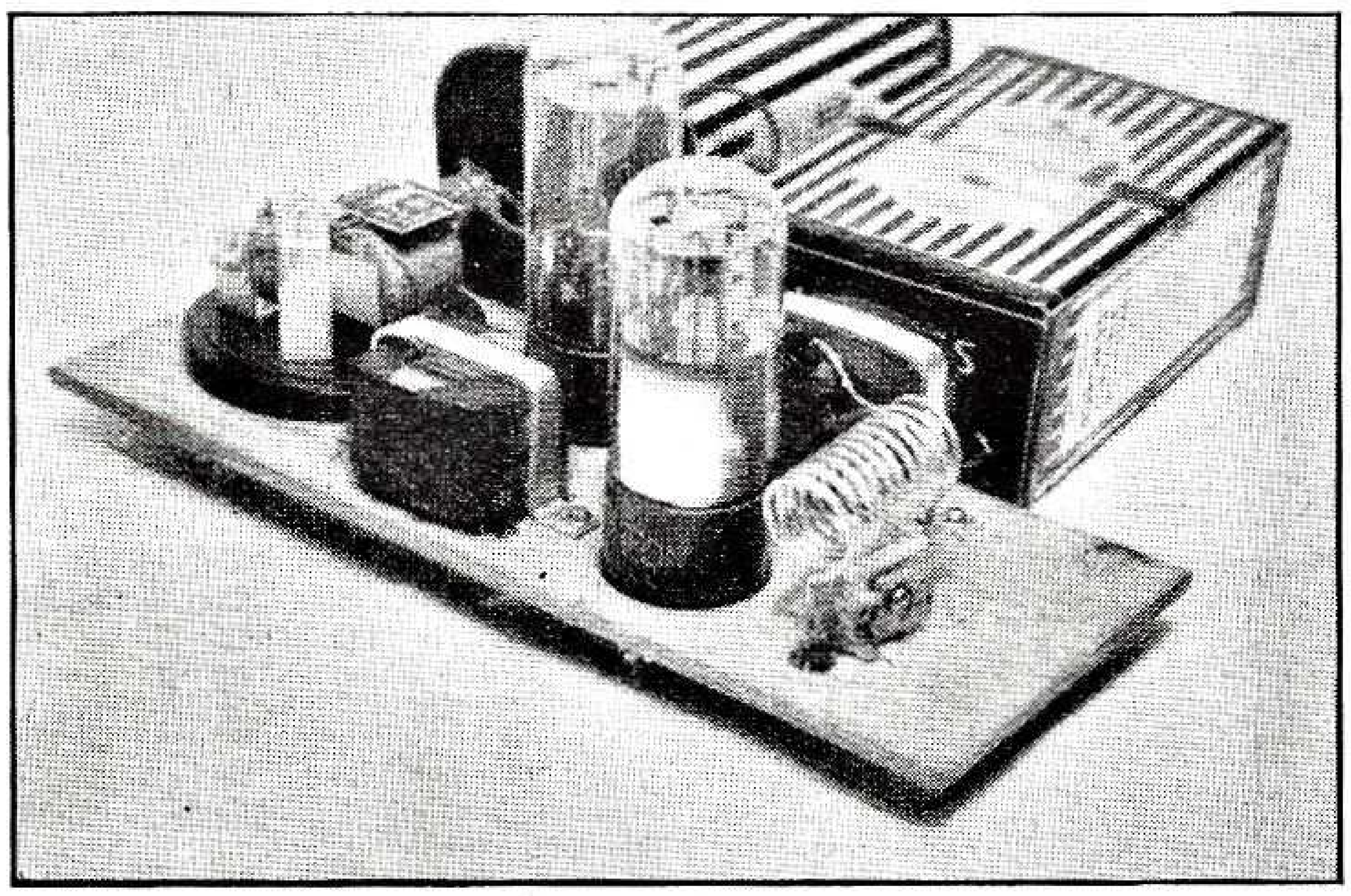
The next step is to expand our control so that we may have selective right *or* left control at will without waiting for the motor to go through the undesired posi-

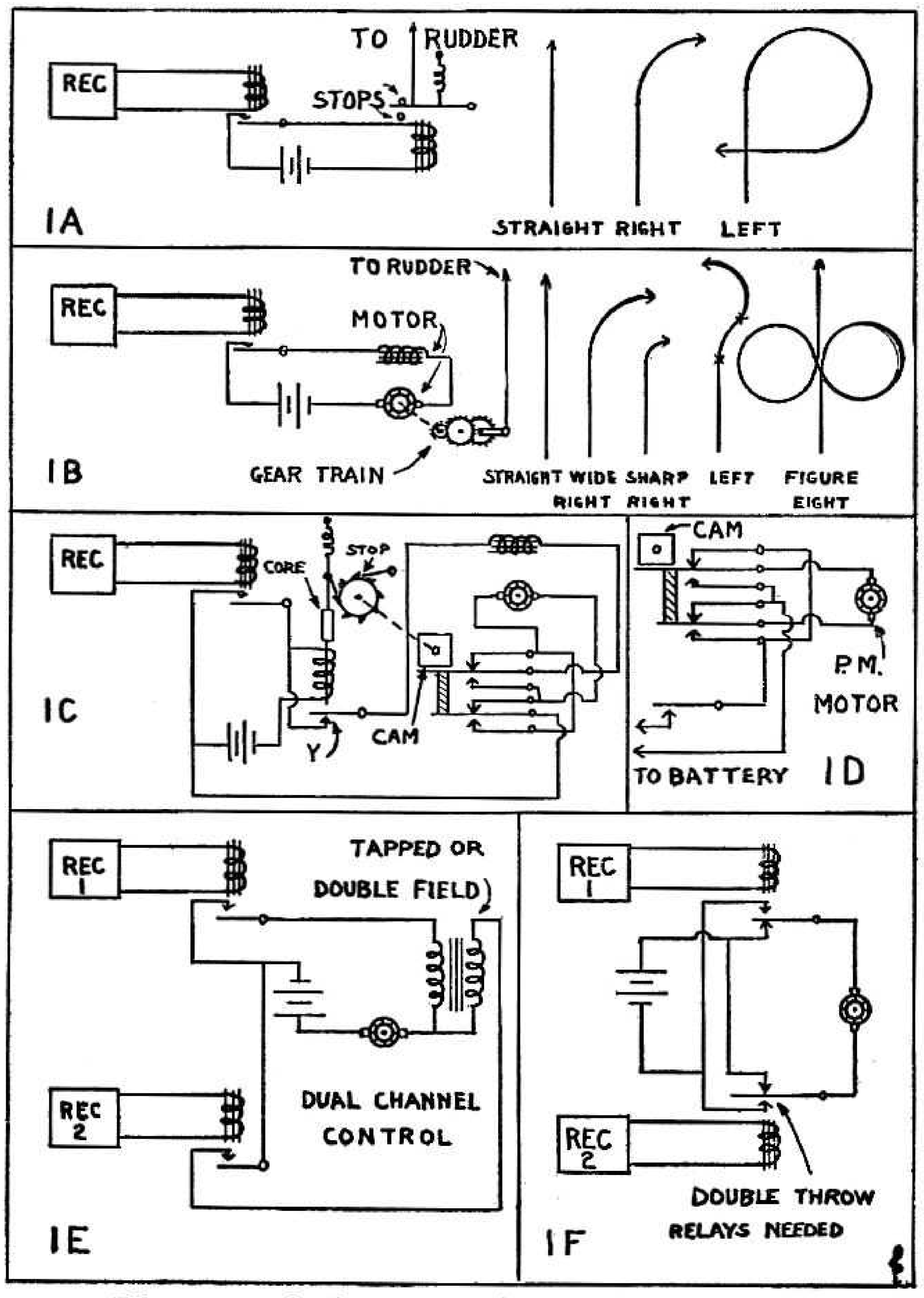
(Continued on page 42)

Fig. No. 7. External view of the transmitter. The collapsible antenna rod is held on the two insulators on the panel. A key or switch may be plugged in the jack in the lower center of the panel

Fig. No. 5. Experimental receiver using RK62 tube. This is a complete unit with the B battery under the wood "chassis." The flashlight bulb at lower right is a very handy indicator. This corresponds to circuit 2-A

Fig. No. 6. This receiver is shown diagrammatically in Fig. 2-B. Larger size batteries are used here and afford considerably longer life, although at some increase in weight





Diagrams of plane control operating systems

Elements of Model Plane Radio Control

(Continued from page 7)

tion. Means to do this are shown in Fig. 1-C. Here the same motor as that shown in Fig. 1-B is used, but means of quickly reversing it is provided by the so-called stepping or sequence relay. A series of dots sent to the receiver will cause the solenoid of this relay to pull in its core at every dot, advancing the toothed wheel one tooth each time. Since there are eight teeth on this wheel and four "highs" on the attached cam, the double pole double throw switch will be in first one position then full over to the opposite. The switch has no intermediate open position, and none is needed. The current to the motor is also controlled by the contacts at the rear of the solenoid. When the latter is fully operated, contacts "Y" close to set the motor in motion. In this system the motor runs right and left in sequence with each dot received. However, if the motor has been turning in one direction and it is desired to continue rotation in the same direction without reverse, two dots are sent close-spaced, thus passing the sequence relay rapidly through the reverse position and bringing it back to position for further rotation in the original desired direction. The change is made so quickly that the motor hardly revolves in the undesired direction.

The latter system may be used with either a so-called universal motor (one with a wire wound field coil) or with a permanent magnet one. Connections for reversing the latter are shown in Fig. 1-D. There seems to be little choice as far as weight goes, but the permanent magnet job offers the advantage of simpler connections. The motors of both types that are made for model railroad use offer the best possibilities as they are very light and small for the power delivered, and may be had in many sizes. Very little power is required; the large gear ratio needed to slow down the high speed motor to a speed suitable for rudder operation also steps up the motor power in the same ratio, so that the smallest available motor is powerful enough for the average sized plane. Among the suitable motors are those made by Knapp and Pittman for HO gauge model railroad use. These weigh about two ounces and a complete gear train with the Knapp motor as shown in Fig. 4 weighs only 2-3/4 oz. This motor operates reliably and with plenty of speed and power on 3 V. with a current drain of .2A. It will work on only 1-1/2 V. but is not considered reliable enough when starting under load.

There are many other sources of motors, some constructors having used those taken from auto horns. Quite a range of miniature motors is also made for use in remote control radio broadcast receivers, some of which are very adaptable to our particular purposes. Everything considered however, the model train motors are probably most satisfactory. While on the subject of trains, it may be said that they also use sequence reverse switches, some of which, especially in the tiny HO gauge size, are highly adaptable to our uses. The solenoid coils will probably have to be rewound for this use, however.

The ultimate in control systems is shown in Fig. 1-E in which instantaneous non-sequence operation of the motor in either direction is possible. This requires (for simplest connections) a motor with a double field coil. Most any motor may have the field rewound for this use. Two field coils, one over the other, but wound in opposite directions are required. The main disadvantage of the system in Fig. 1-E is that two receivers and two transmitters are required, although common power supplies can be used at both ends.

A circuit of similar capabilities to that of Fig. 1-E is shown in Fig. 1-F. Here any motor may be used including the permanent magnet type, but double throw relays are required. Since most available sensitive relays are made this way, the circuit is one of wide application and probably superior to Fig. 1-E, since the motor may be of any construction.

Another popular control system is driven by the power of twisted rubber bands. Only a single magnet or solenoid is needed in addition to the usual sensitive relay. A so-called escapement is used so that each dot received allows the control disc to revolve a quarter turn. A complete description of this equipment appeared in the January 1938 issue of this magazine and the prospective reader is urged to study it carefully. The advantage of this control is that ample power in the form of twisted rubber bands of light weight is available for control surface movement. Also that the electrical equipment is simple and relatively fool-proof. The main disadvantage is that only one degree of movement is possible. The fact that it is a sequence operated system is of no great consequence, as the control may be "snapped" through undesired position by means of a rapid series of dots.

Spring clock motors may also be used for control purposes. A lever is soldered to the second hand for connection to the control surface, and the last wheel in the gear train before the balance wheel is turned down on a lathe or in a drill so that all teeth are removed and a smooth rim left. This wheel is the one which has ratchet teeth on it. A very slight pressure on this wheel will "stop the works" even though the spring be fully wound up. We may utilize this fact by having a small magnet connected in the circuit of 1-A with its armature held by a spring against the wheel. A very small magnet with a single pen cell should suffice; in fact, it would probably be possible to utilize the motion of the sensitive relay armature itself. At any rate, the degree of control possible is that shown under Fig. 1-B, and the extreme simplicity of the system makes it of considerable interest.

The final control system we should mention is that in which an audio modulation is sent over a steady carrier wave, different tones operating different tuned reeds in the receiver, thus allowing many control elements to be worked with a single channel receiver. This requires considerable skill on the part of the builder, and while a properly operating system should approach the ultimate in its degree of control, it is certainly not a project to be tried by the uninitiated or the beginner.

This about covers the practical controls now available, although there are probably many ingenious combinations possible with those shown, and who knows but that some ambitious experimenter will work out something entirely different that will give us selective right or left control of any degree desired and all with extreme electrical and mechanical simplicity? It is with the hope of stimulating some such development that this article is presented, rather than just to provide something that may be copied exactly. Most builders have ideas of their own but are often stuck on some of the details. Well, work them out, gang, and let's see who comes along with the "perfect" control system.

The next topic we must consider is that of receivers which supply the varying current that operates the sensitive relay.

The ultimate in this line has been closely approached by the use of a new tube called the *RK62* and produced by Raytheon. It is similar in size to a type 30 and when operating properly can produce an 8 to 1 (or more) drop in plate current, the change running from a little over 1 milliampere to as low as 0.1 ma. The circuit is shown in Fig. 2-A and the constants shown were found to produce the best all around operation. The most important control aside from the tuning condenser, C-1, is the variable resistor, R-2, which controls the plate current and the general action of the tube. If too little resistance is used here the plate current will not give sufficient dip when a signal is received; while if too much is used, the plate current will not restore to its original value when the signal ceases. The filament rheostat, R-3, also has considerable effect on the action, although the tube may be operated directly from a 1-1/2 V cell, dispensing with R-3 entirely. Condensers C-1 and C-2 are the so-called trimmer variety and have a range of about 3-30 mmf. C-2 should be pretty nearly full open while C-1 must of course be tuned to the desired signal. Enough turns should be used in L-1 so that C-1 is at quite low capacity, as high capacity here makes for inefficient operation or even a total lack of oscillation.

The only sensible way to tune this receiver is to insert a 0-1.5 ma. meter in the circuit in the pin jacks shown. A higher range, up to perhaps 0-5 ma. may be used, but the lower value is best. With a meter it is easy to tune the receiver to exact resonance, something that cannot be done by watching the relay or by the use of headphones. Figure 5 shows an experimental receiver built with the RK62. The filament is heated by a single large flashlight cell, while a ten ounce Burgess type W30BP 45 volt battery supplies the high potential. A flashlight bulb may be seen at the rear of the flashlight cell, and it is connected to the contacts of the relay so that when a signal is received the bulb lights. This is a great aid in working with the receiver at a distance and every constructor who wishes to use this system is urged to familiarize himself with tube and circuit operation by construction of such a unit. The filament rheostat, R-3, is seen fastened to the tube socket while R-2 is controlled by the knob near the relay. The tap on L-1 from the choke RFC should be tried on different turns, but in the case of this receiver it was found to work best near the grid end. The antenna tap should be one or two turns nearer the plate end.

The equipment shown, less the meter, weighs 22 oz. including both A and B batteries. The receiver alone, together with its sensitive relay, weighs about eight ounces.

For those who prefer more conventional tubes, the circuit of Fig. 2-B is recommended. This circuit produces a plate current *increase,* the current running about .4 ma. with no signal and 1 ma. with signal. The circuit is not as tricky to get into satisfactory operation as that of Fig. 2-A and is very reliable in operation. The RK43 dual section tube is used as a combined super-regenerative detector and first audio amplifier. An RK42 serves as the output tube, and has an unusual grid circuit connection. The tube operates much the same as an ordinary grid leak detector, to produce the plate current change. ILLUSTRATED IN FIG. 6.

It is desirable to substitute the sensitive relay with a pair of headphones at X-X to check the operation of the super-regenerative detector. The same comments that were made on circuit 2-A as regards tuning hold here. The input inductance, L-1, should be such that at resonance C-1 is at a low capacity setting. Also C-2 should be at a low setting. This provides loose coupling and produces the maximum amount of "rush" in the headphones with no signal. This rush is what causes the plate current in the RK42 to drop. When a strong signal comes in, the rush stops, and the plate current of the latter rises. After the input circuit is properly adjusted, the relay should be put back in circuit, and a low range milliammeter put in the circuit at X-X so that tuning of C-1 and C-2 can be accomplished most efficiently.

The transformers, T-1 and T-2, are of the midget replacement type, the cores of which are removed, and all but the center tongue sawed off. When reassembled the transformers will weigh less than half what they did and will be more suitable for this particular service. This receiver complete, less batteries, weighs fifteen ounces.

In an effort to cut down weight, circuit 2-C was tried out. Although it is quite a bit more critical than 2-B it offers possibilities for the experimentally inclined. Since only one tube and one transformer are used, the weight is only about half that of circuit 2-B.

With the circuit as shown the plate current of the A.F. section *dropped* from .6 ma. to .1 ma. when a signal was properly tuned in. No rush could be heard on headphones with no signal coming through, and it is not known just what circuit action was taking place. Condenser C-4 seemed to be the deciding value for proper operation and different values should be tried.

Incidentally, it may be mentioned that type 30 tubes may be used in place of the RK42 and 43 where the latter are not available, although this naturally means some complication in the filament circuit to supply the 2 V. that the former require. Also one more tube is required in both the 2-B and 2-C circuits when the 30's are used.

The question of a suitable transmitter has been given much thought by the writer. Of course, a simple self-controlled oscillator will be quite flexible in operation and can cover quite a band of frequencies. This fact is just what makes it doubtful that a self-excited job is best for the purpose. It seems that it would be best to have the transmitter set on a definite fixed frequency, so that careless handling could not cause a loss of control due to change of transmitter frequency. The requirement of fixed frequency should not alarm the prospective builder, however. Now that 10 meter crystals are available a simple crystal controlled M.O.P.A. transmitter may be built with hardly more parts than a single tube self-excited oscillator requires.

An effort to build a practical job for this use is shown in the Figs. 7, 8 and 9 and in Fig. 3. It will be seen that this is a complete M.O.P.A. using only a single RK34 tube. Changes in capacity of C-2 or C-3 such as would be made when setting up a new antenna have only the very slightest effect on the overall frequency of the transmitter. With a job of this kind it is impossible to lose control of your model even if some well-meaning friend tries to "tune up the rig" when your pride and joy is in the air. Resetting of C-1 and C-2 and observation of the meter reading will enable you quickly to get back "on the air."

If built as shown there should be no trouble whatsoever in getting proper operation. With the parts specified the high voltage under load should be between 325 and 350 V. and with 40 ma. plate current on the amplifier section (right hand) of the tube, approximately five watts *output* will be available. This is plenty for very satisfactory control at reasonable distances.

The switch SW-1 enables one to read plate current of either section of the RK34. It is always set for amplifier current except when doing preliminary tuning, and at no time should either section of the tube be allowed to run with a steady plate current of over 40 ma. The amplifier is of course working as a doubler and L-2, C-2 is tuned to five meters; if L-2 is the proper size C-2 will cause resonance at about 1/3 full capacity, while C-1 will be set somewhere near midscale.

The usual antenna is a collapsible rod attached to the insulators on the panel. This rod will extend to around six feet in length for proper operation. When C-3 and the tap on the coil are correct and the rod is of the right length, the tuning of C-2 will not need changing when the rod is attached or removed, although the plate current will naturally change. With proper tuning the plate current will go from 22 ma. with the rod disconnected to 40 ma. when it is in place.

Any sort of control button or key may be plugged in the jack K, but it should be well insulated from the hand.

A short description of the sequence relay and the motor drive shown in Fig. 4 may be in order. The relay is operated by a solenoid which is wound on a brass tube 5/16" inside diameter and with a winding length of one inch. The form ends are 7/8" in diameter and the spool thus formed is wound full of No. 26 DCC wire, which will give a resistance of around 6 ohms and will draw about 750 ma. on 4.5 V. The core is an iron piece 1/4" diameter by 7/8" long, soldered to brass rods which support it in the center of the solenoid. A very light spiral spring keeps the core pulled out when no current is flowing.

The core rod has a thin bronze spring soldered to it, the hook-shaped end of which engages in the teeth of the brass wheel. Another spring pressing on the edge of this wheel prevents it from rotating in the undesired direction. As there are eight teeth, every pulse of current through the solenoid produces an 1/8th of a full turn. A four-lobed bakelite cam is fastened to the underside of the toothed wheel, and when turned, causes the D.P. D.T. switch to be set alternately one way, then the other, with no center position. Thus the motor rotates in a different direction at every pulse through the solenoid. At the rear of the latter are the contacts Y shown in Fig. 1-D.

It is necessary to have a closed magnetic circuit around the solenoid to get proper operation. Therefore the strip that supports it is iron and is soldered to the brass tube before the winding is begun. Also an iron strip runs under the solenoid and up on the cam side, where a hole allows the core to pass through.

Although this unit takes considerable current, it is only on for a fraction of a second at each pulse, so battery life is quite good. Naturally, the pull is quite small so only the thinnest springs should be used for both the D.P.D.T. switch and for contacts "Y;" those shown measuring about .0007 in thickness. Also all parts must move without the slightest unnecessary friction. The sequence switch as shown weighs 4-1/2 ounces complete.

The tiny Knapp motor in Fig. 4 has a worm wheel soldered to its shaft which, with the gear supplied, gives about a twenty to one stepdown. The gear wheels shown, which were taken from an alarm clock, raise the overall ratio to 450 to 1. This gives a complete revolution of the control arm in ten seconds. The gears and motor are mounted on a thin wall brass tube of 7/16" by 9/10" cross section and the whole unit weighs 2-3/4 ounces.

In practice the solenoid is run on three flash cells, while the motor is tapped across only two. The filament of the receiving tube may be heated from the odd cell to equalize the drain. The total weight of a complete control including a Burgess W30BP battery, three flash cells, the RK62 receiver (Fig. 2A) and the sequence control of Fig. 1-D, is about two pounds three ounces.

Parts used are as follows:

Fig. 2: C1, C2,—Hammarlund "Mex", 3-30 mmf.; C3, C6,—Cornell Dubilier 100 mmf.; C4—0.1 mf.; C5, C8,—.005 mf.; C7—.001 mf.; R1, R6,—I.R.C. .5 meg., R5, I.R.C. 2 meg.; R2—Yaxley Midget 10,000 ohms; R3,—Clarostat 5 ohms; R4,—I.R.C. .5 meg.; RY—Sigma model 2A; MI—Triplett 0-1.5 ma. meter; TI,—U.T.C. type R33; LI,—11 turns No. 14, 3/4" O.D., 1-1/2" long.

Fig. 3: Xtal, Bliley 10 meter crystal; RFC—Hammarlund type CHX choke, 2.5 mh.; C1,—Hammarlund HF 100; C2,—HF35; C3,—HF50; C4,—Solar 100 mmf.; C5, C6, C7,—Solar .005 mf.; C8, C9,—Solar 8 mf. electrolytic; T1,—U.T.C. type R2; M2,—Triplett 100 ma., rear illuminated, CH,—U.T.C. type R18; Case,—Par Metal Type HC, 788 with chassis; L1, 6T No. 14, 3/4" O.D., 1" long; L2, 5T No. 14 same size.

Gas Lines

(Continued from page 27)

present prosperity of the sport of gas model flying it is essential that during the year model builders take account of their desires in respect to rules, in order that in coming years they may be able to make wise decisions which will govern their activities, and therefore encourage the normal and healthy growth of this remarkable educational hobby.

In order to separate the ideas born of careful thought and consideration from those which are mere feelings, let us consider this matter and analyze it carefully. Snap judgments are often the product of feeling and not wisdom. Obviously rules which have been carefully thought out and the results of which are thoroughly understood are the ones which in the end will prove most satisfactory.

In order to establish such rules the first step that every model builder should take is to determine his objective; that is, what does he want to accomplish? He should analyze this carefully; set down on paper, if necessary, his thoughts concerning this. Then when he has made his decision he, himself, should endeavor to design a rule which will bring about the circumstances which he desires. In order to test this rule and make sure it actually will do the job he wishes, instead of merely guessing as to its function, he should apply it to a specific case and see exactly what the result will be.

What each model builder will want to accomplish will depend upon whether or not he is thinking of his own individual standpoint, or thinking from a standpoint which will benefit all model builders. We believe that the wisest decisions will be those which will give consideration to the welfare of model builders as a whole, and not merely individual selfish interests.

In other words, if every model builder will sit down and decide what conditions he believes will promote model building nationally instead of sectionally, and then design for himself rules which will promote this condition, we believe that not