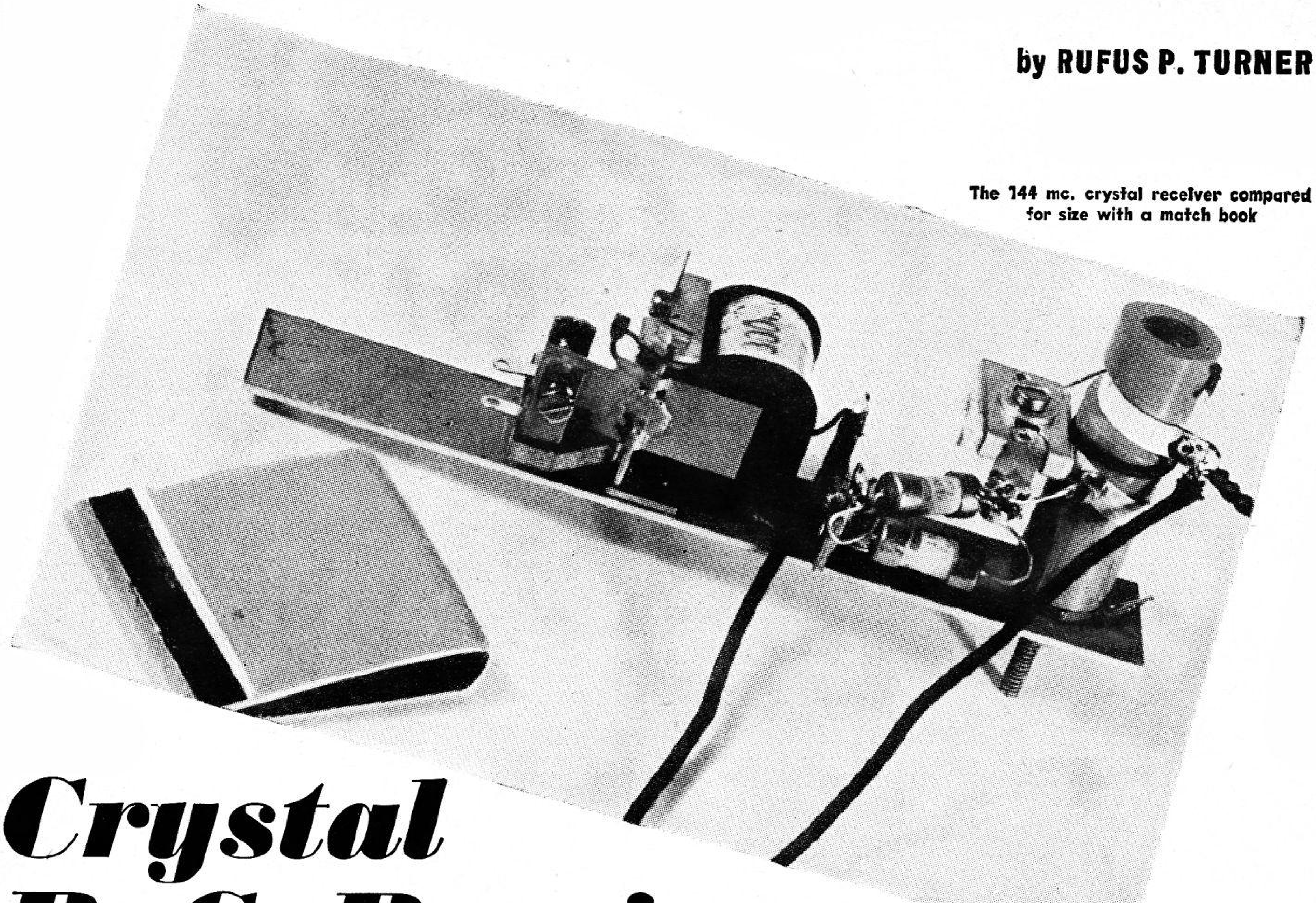
by RUFUS P. TURNER



The 144 mc. crystal receiver compared for size with a match book

Crystal R. C. Receiver

CRYSTAL diodes previously have not been employed to any great extent in radio controlled models. This has been due to the inherent low sensitivity of the crystal detector, a fact which has been regretted by many experimenters because an ultra-high-frequency crystal receiver can be made extremely small, light in weight, and simple.

Recently, Sylvania Electric Products, Inc., introduced a new high-conduction germanium crystal diode, the Type 1N56, which is much more suitable for radio control work than previous types. For a given applied signal voltage, the D.C. current output of the 1N56 is approximately twice that afforded by the more familiar Type 1N34. The new 1N56 has the same physical size as the 1N34.

Still greater output may be obtained by employing two 1N56's in a full-wave detector circuit. And this advantage may be enhanced further by applying to the two diodes a D.C. voltage from a small local battery. The circuit for a radio controlled receiver of this type is described in this article. The accompanying photograph shows the small receiver unit complete with relay, and ready for such control operations as ordinarily are performed in model aircraft.

It is believed that R.C. receivers of this type will meet with favor among model airplane experimenters, since crystal sets require no tubes and are sufficiently compact and lightweight to be installed easily in very small model aircraft. Although the special circuit described in this article requires a small battery, the battery drain is but a tiny fraction of the filament current drawn by one tube; and the same battery may also be used, in a number of cases, for the controlled device in the plane.

PRINCIPLE OF OPERATION. In order best to understand how the author's new circuit operates, it is necessary to review briefly the operation of the older, conventional crystal R.C. circuit shown in Fig. 1. Here, a simple antenna and tuned circuit pick up the radio-frequency control signal and apply this signal voltage to the crystal diode. In turn, the diode rectifies the radio-frequency voltage and delivers a D.C. current to the coil of the sensitive relay. If the control signal voltage is strong enough, a good amount of current will be delivered by the diode and this current will actuate the relay. But a rather large signal must be used (that is, the control transmitter must be relatively high-powered) in order to accomplish this action. This is because the crystal is not so sensitive a radio detector as a tube would be and does not supply amplification as does the tube. Furthermore, the model in which the pickup circuit is installed cannot be flown far from the controlling transmitter without losing radio control, because the strength of the signal decreases rapidly as the gap widens between transmitter and receiver.

Now, suppose we insert a battery and rheostat at the point marked "X" in Fig. 1. The rheostat may be adjusted (in the absence of a received radio signal) to the point where current flowing from the battery, and through the diode and relay coil, is just slightly less than the amount required to actuate the relay. The radio signal then will be called upon to furnish only the small *additional* current necessary to pull-in the relay. In this way, the radio signal is not required to do the

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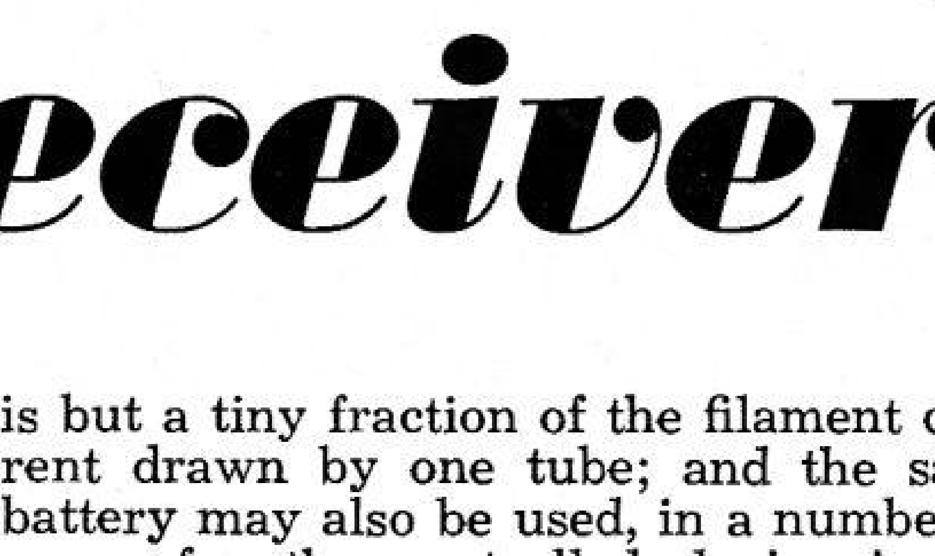

FIG. 1

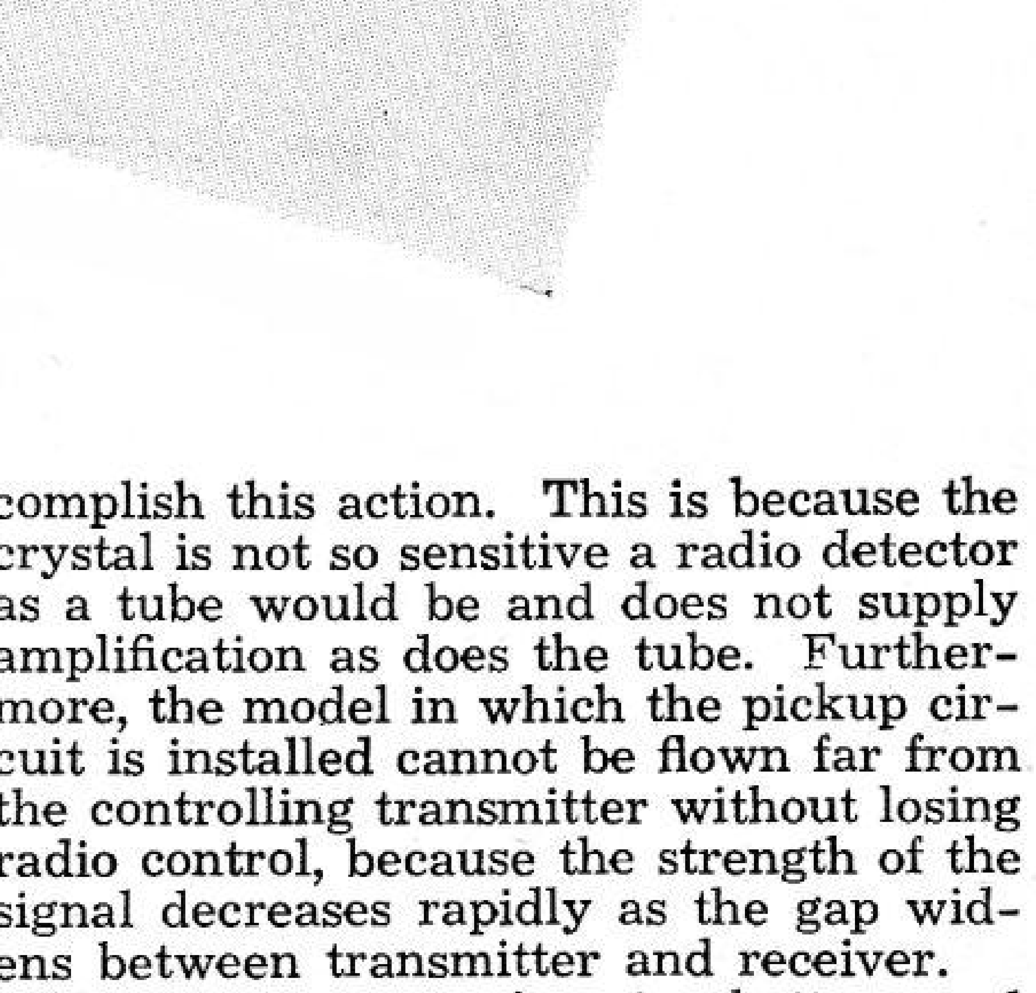

FIG. 2

BE CAREFUL TO OBSERVE PROPER CRYSTAL AND BATTERY POLARITIES.

Crystal R.C. Receiver

(*Continued from page* 33)

whole job, but only a small part of the task of operating the relay—the battery does most of the work. Thus, the receiver will exhibit better sensitivity than will a conventional crystal set. This means that the controlling transmitter need not be so large or powerful, and also that the model may be controlled at a greater distance with a given transmitter.

It is a well-known electrical fact that, for a given applied radio-frequency voltage, a full-wave rectifier (detector) circuit gives more D.C. output current than the simple half-wave (single diode) circuit shown in Fig. 1. In fact, almost twice as much current can be obtained when two diodes and a center-tapped coil are used. All of this adds up to the fact that two crystal diodes in a full-wave circuit *plus* the local bias battery will give a crystal radio control receiver of increased sensitivity, while maintaining the characteristic simplicity of the crystal set. We believe that this arrangement gives the maximum sensitivity possible with crystal reception.

It should be noted again at this point that the crystal circuit (even with the improvements suggested in this article) cannot have anything even approaching the sensitivity of the conventional vacuum tube style of receiver, though it is a great deal more efficient than the single-crystal circuits that have been used previously. To get a usable range, it is probable that a transmitter of 40-50 W input would be required. Also, use of a simple beam-type antenna at the transmitter is another line of approach. Such an antenna would naturally have to be rotated constantly so that the model could be kept in the beam.

A beam-type antenna on 50 mc. would be pretty bulky, and on operation in the 27 mc. band, would probably be out of the question. However, the crystal receiver will work well on 144 mc. and possibly even higher, and in this frequency region, beam antennas become practical.

Thus, this receiver will normally be most useful for models that fly only a few hundred feet from the transmitter; and within this range, it will give almost foolproof operation.

Double-Diode, Battery-Biased Receiver. Fig. 2 is the complete circuit diagram of a crystal radio control receiver applying the principles just discussed. The pickup antenna consists of two short lengths of wire or rod. Each of these should be as long as the model size and permissible air drag will allow, and preferably each 1/4 wavelength long at the operating frequency employed.

The tuning coil, L_2, is a manufactured item, National Type AR-2, which consists of several turns of silver-plated strip wound on a phenolic form. This coil is center-tapped and is made with a metallic slug which may be screwed in and out of the coil (for tuning purposes) by means of preliminary screwdriver adjustment. Coil L_1 is a primary (antenna) coil consisting of 1 turn of insulated hookup wire wound tightly around the center of L_2.

The tuning capacitor, C_1, is a small, screwdriver-adjusted leaf-type trimmer having a capacitance range of 3 to 30 micromicrofarads. Once this component is adjusted for a particular operating frequency, it ordinarily will need no resetting until the frequency subsequently

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is changed. C_2 is a small mica, or ceramic capacitor, used to bypass R.F. energy around the local battery circuit.

The two Sylvania Type 1N56 high-conduction germanium diodes are connected with their anode terminals to the ends of coil L_2 and their cathode terminals (labelled "CATH" on the crystal cartridge) together and to one end of the relay coil. It is imperative to observe the correct polarity of the crystal diodes *and* of the battery, as shown in Fig. 2, when wiring-up this circuit.

B is the local bias battery which, for size and weight considerations, may consist of several 1-1/2-volt pen-size flashlight cells connected in series. R is a 3,000-ohm midget rheostat used to set the value of current through the relay coil. The size of the battery, in conjunction with this rheostat, will be determined by the sensitivity of the relay (that is, the number of milliamperes or microamperes required to actuate the relay).

The sensitive relay used for these experiments was an 8,000-ohm *Sigma;* this relay is obtainable in war surplus for a dollar or so, and is ideal for our use, since it is very easy to adjust. It is possible that a lower resistance relay would work even better than the 8,000-ohm unit shown here, but this was not tried. A lower resistance coil in the relay would mean that the bias battery could be of lower voltage (although the current drain would, of course, be higher) and it would be possible to use fewer pen-cells in series for this purpose.

By adjusting the spring tension of the relay, reliable operation was had at 1-1/2 milliamperes. This required 6 volts of battery which was obtained from four 1-1/2-volt pen-size flashlight cells in series.

The same battery may be employed to actuate the controlled device in the model plane (if the battery voltage is sufficient for this purpose) by making the dotted-line connections shown in Fig. 2.

When rheostat R is set so that battery current flowing through the relay coil is very close to the threshold of operation of the relay, the crystal diodes then need to supply only a few hundred microamperes of additional current from rectification of the radio signal.

The battery must not be left connected in the circuit when the apparatus is idle, since the continuous current drain through the diodes and relay coil, while small, eventually will devitalize the battery.

Adjustment and Operation. The receiver first must be tuned-up to the frequency of the control transmitter. To do this:

(1) Switch on the transmitter, using an unmodulated signal.

(2) Attach to the receiver pickup antenna the two leads from coil L_1.

(3) Place the receiver reasonably close to the transmitter, but not closer than about 10′.

(4) Temporarily remove the battery and connect a 0-1 D.C. milliammeter (or a D.C. microammeter, if available) in its place. The negative terminal of the meter must be connected to the lead from the center tap of coil L_2.

(5) Screw the metal slug halfway into coil L_2.

(6) With a sharpened bakelite rod, radio neutralizing tool, or other non-metallic screwdriver, turn the adjustment screw of tuning capacitor C_1 until a sharp maximum upswing of the meter pointer is obtained. At the exact point of maximum deflection of the meter, the receiver is tuned to the transmitter frequency.

(7) Switch off the transmitter, disconnect the meter from the receiver circuit, and re-install the battery. The tuning range of the receiver will be approximately 130 to 210 megacycles with the components specified in Fig. 2.

After the receiver has been tuned-up according to the preceding instructions, adjust the battery voltage in the following manner: (1) Keep the transmitter switched off for the present. (2) Vary rheostat R until the relay just pulls in. (3) Back off the rheostat setting until the relay just drops out. (4) Observe how small a rotation is made between these two settings of the rheostat, and carefully re-set the rheostat to a point just a little below the point at which the relay operates. (5) Switch on the transmitter and the relay should pull in quickly. (6) Switch off the transmitter. The relay should drop out.

Pointers on Construction and Installation. *Vibration Proofing.* The author's tests do not indicate that the receiver is unusually susceptible to shock. However, the spring tension of sensitive relays ordinarily is slight, so that chattering of the contacts might possibly result from vibration of the motor. With this in mind, we recommend that the entire control receiver be mounted on sponge rubber or some similar shock absorbing material.

Handling the Crystals. The crystal diodes are of rugged mechanical construction and have been given standard drop tests by the manufacturer. However, they should not be handled carelessly. These diodes are provided with pigtails of good length and as much of this lead length as practicable should be used when soldered in place in the circuit. This will prevent the conduction of excessive heat from the soldering iron along the pigtail and into the crystal unit. A good scheme is to hold the pigtail with a pair of long-nose pliers close to the cartridge end of the pigtail lead while soldering. The larger metal mass of the pliers aids in conducting soldering iron heat away from the crystal unit.

Battery Circuit. The batteries and rheostat may be included on the mounting base with the other components, or (as in the author's unit—see photograph) the batteries and rheostat may be enclosed in a small lightweight plastic or thin aluminum box, and located elsewhere in the model, as required for proper weight distribution. Since the rheostat ordinarily will not need frequent readjustment, it will not be necessary to attach a knob to this component. Cut the rheostat shaft down to about 1/2″ length and saw a slot in its end for adjustment with a screwdriver.

Circuit Components

B—Miniature battery (see text).
C_1—3-30-mmfd. leaf-type trimmer capacitor.
C_2—0.002-mfd. midget mica or ceramic capacitor.
L_1—1 turn of insulated hookup wire wound tightly around L_2.
L_2—Manufactured, slug-tuned high-frequency coil—National Type AR-2.
R—3,000-ohm midget rheostat.
Relay—8,000-ohm Sigma or equivalent.

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