

**FUN** WITH



# **RADIO-CONTROLLED MODELS**

BY EDWARD L. SAFFORD, JR.



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# Introduction

**R**ADIO CONTROL is one of the fastest growing hobbies in America. It can furnish pleasure and excitement to the whole family. Picnic gatherings on the flying field or on the shore of the model boat pool, river or lake are sure to introduce you to others interested in R/C.

Entering the competition of a meet is the final step in a radio-control project. While the excitement of trying to make your entry outperform the other entrants may be a never-to-be-forgotten experience, many of the lessons learned during the construction of the model can be equally important for the rest of your life.

Whether you build an accurately detailed scale model or just a rudimentary vehicle to be radio-controlled, there is much to be learned. This book was written in the hope that it would be as understandable to young people as to parents. In fact, it is hoped that everyone, regardless of background or age, will gain a basic understanding of "just how it all works" from these pages. Then, once that understanding has been reached, they too will experience the tremendous fun that can be found in radio control.

While most portions of a radio-control system can be obtained ready-made, there is that great sense of pride that comes from knowing that you have built the model, installed the equipment and made it work. Model control has come a long way in the past years. Once the only remote control over a plane was a switch timer that turned off the motor ignition after a prearranged interval, or a measured quantity of fuel was used to accomplish the same thing. Now it is possible to control speed, steering and the operation of many accessories or devices. It is possible to drop bombs from model planes, fire cannon on boats or blow horns on motor vehicles. Additional controls are possible, limited only by the size of the model and your own ingenuity and craftsmanship with your available tools.

E. L. SAFFORD, JR.



# 1

## first steps in radio control

**R**ADIO signals are not new to us. Every day we turn on the radio and listen to music or turn on our television set and, after setting the channel selector to the station we want, watch the pictures. We know that somewhere a station is sending out those signals we are receiving, and we know that to be able to receive them we must have a radio or a television set. The signals which are sent from the station are called radio signals.

When we radio-control something, we must also be able to send out radio signals. The signals we will send will not be music or pictures when they are received; instead they will be commands which will make a small boat or a model car or airplane go left or right or straight as we want it to.

In the military services, when an officer wants his men to go into battle, he shouts, "Charge" and they all move forward. He can shout the command because he is commanding people who can hear and understand what he is saying. If his men were all robots (machines), he would have to use some other way of commanding them to go forward. He might, in this case, press a button which would cause a radio station to send out a signal which would be received by the robots. When they received the signal, they would "charge".

This is what we have to do when we *radio-control* our models. Since the models are steered by little machines placed inside them, we can send our commands to them from a small radio station by simply pressing a button. If we know just how to send the commands and if we have enough machines in the model, we can

make our little car, boat or airplane do everything a real one does. And we can radio-control it as far as a mile away.

## Main parts of a radio-control system

A radio-control system must have the parts shown in Fig. 101.

Our sending station is called a *transmitter*. It fits into a small, long metal box which we can hold easily in one hand. It has a switch to turn it off and on, and below this switch the all-important *keying button* which is used to send out our commands. Not shown in Fig. 101, but necessary, is an antenna, a thin metal rod which screws into the top of the transmitter case. Inside the case are batteries to make it operate when we push down on the keying button.

We must also have a radio receiver, and it must be small enough to fit easily inside the model, since that is where we put it. It is "tuned to the transmitter" so that each time we push the keying button and a radio signal goes out, the receiver picks up that signal and passes it on to the third main part of our system.

Let us examine this receiver a little more closely before discussing the third part of the system. Notice the wire extending above the little knob on top of the case. This wire is the antenna. It is very short and we have to add a small piece of wire to it. Any kind of wire will do, so long as it is *not* iron. We simply connect one end of our new piece of wire to the metal clip at the end of the length shown.

A plug is fastened to the wires coming out of the end of the case. This plug fits into the socket near it. We have to connect batteries to this socket to make the receiver operate when the plug is in the socket. The other two plugs are connected to the batteries also and provide us with a way to tell when the receiver is operating correctly. The little knob on top of the case tunes the receiver to the transmitter signal.

A radio-control receiver like this one does not have a loud-speaker. It does not even have an earphone, so we aren't going to be able to listen to the signals we send to it. But we must be able to tell when we have it "tuned in." To do this, we must use a small meter (in later pages we will tell you exactly how).

The third and last main part of the system is the device at the top left, called an *escapement*. This could be a small electric motor, and later on we will see how electric motors can be used. Right now, the important idea to remember is that this escapement is the part of the system that actually *moves* the steering wheels of a



model car, or the rudder of a boat or of an airplane. The escapement is generally used in model airplanes because it is small and light and does not need very much power to move an airplane rudder. If we are going to radio-control a model car or boat we would use a little electric motor instead of this escapement, because we do not have to worry about how heavy the motor is and we need quite a bit of power for steering.

Radio-control transmitters, receivers, escapements and electric-motor power units are available, already built, or in kit form, at

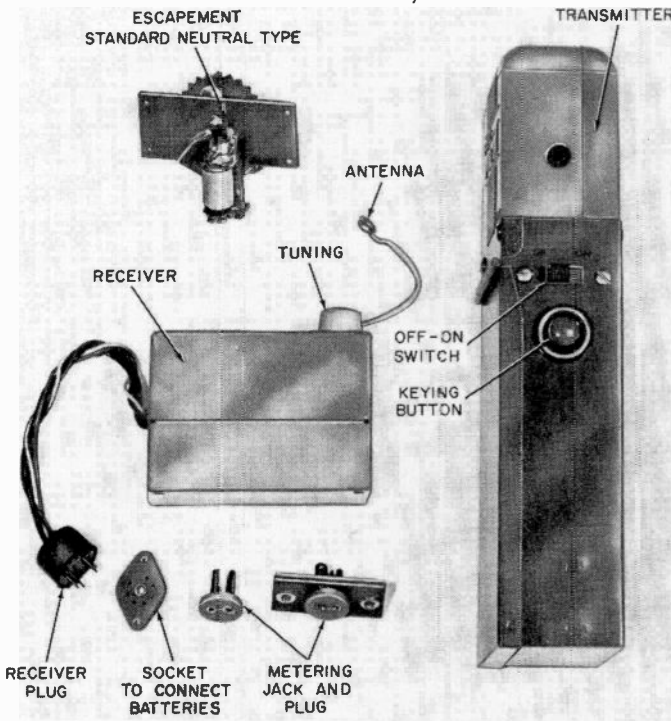


Fig. 101. Some of the major components of the control system. Receiver batteries and transmitter antenna are not shown.

most hobby shops. The particular items shown in Fig. 101 are used in the systems described in this text and are typical of most low-cost radio-control systems.

The only tools needed to connect the parts of such a radio-control system are a pair of pliers, a small soldering iron, some solder, and a small screwdriver or two. You do not have to know anything more about electricity or electronics than you will learn through reading this book. You do have to have a *license* to

operate your transmitter, but you *do not* have to take an *examination*. We will discuss the form you have to get, fill out and mail to the Federal Communications Commission to get your license. These licenses are issued free of charge.

### **Learning the fundamentals**

Radio-control systems vary in cost roughly from \$20 to \$200. The one shown in Fig. 101 is an example of a lower-cost type. The primary difference between the more expensive ones and this one is that, with the expensive kinds, you can do things *more quickly*. Notice that "*more quickly*." We want to make sure that you understand that you *can* do as many things with the less expensive systems, but because of *the way* we have to do them, the more things we have our model do, the more *time* it takes to send the particular commands telling it to do these things. In some cases, this could be a disadvantage; for example, in radio-control of model airplanes, we do not want too long a time between the sending of the command and having the plane do what we tell it to. We *can* use the less expensive systems in model airplanes very successfully, however, so long as we avoid long time delays. We will discuss this in more detail later.

At this time, we are interested in learning all we can about how a radio-control system operates. We can best do this by performing a few simple experiments with parts costing only a few cents. Our tools are a sharp knife, some glue, an old pair of scissors (if you do not have a pair of tin snips handy) and a little balsa wood. We will make a model of a *relay* which represents a radio-control receiver and then some models of the little machines which actually steer the models. The reason we say that a *relay* will *represent the receiver* is that a radio-control receiver operates a relay every time the receiver picks up a signal from a transmitter. You can see the relay in a later figure which shows the case of the receiver removed.

We are not concerned with a model of the transmitter because we know what it does, and we will buy one all assembled anyway. We have talked about pressing the keying button to turn the transmitter on and off, and that's about all there is to its operation. The real trick in radio control is to be able to connect the *receiver* to the little machines and then connect these machines to rudders, steering wheels, throttles or elevators, etc., to steer the model — to make the model go forward or backward, or stop as we command. So let's turn our attention, then, to making an operating model of a radio-control relay (Fig. 102).

## A model relay

Here you see a small flat piece of balsa wood (it can be any other kind, but balsa is easy to work with and makes for strong glue joints) about 3 inches wide, 7 inches long and about  $\frac{1}{8}$  inch thick. At the left of the figure is an ordinary flat head woodscrew,  $1\frac{1}{2}$  inches long. The two uprights are  $\frac{1}{4} \times \frac{1}{2}$ -inch balsa pieces glued to the base about  $\frac{1}{2}$  inch apart.

The first step is to cut the tin strip (actually, tin plated on steel) pivoted between the uprights. This was cut from a coffee can and is 3 inches long by  $\frac{3}{8}$  inch wide. Next, we need a roll of No. 20 *solid* insulated hookup wire (obtainable at any radio parts house). Wind 50 turns of this wire around the screw, starting  $\frac{1}{4}$  inch from the pointed end and leaving a length of wire extending about 3 inches. It will take four layers wound one over the other. When the last layer is wound, bring the free end down and twist it with the starting end. Cut the wire so both ends are about the same length. Now push back the insulation (cloth or plastic covering) as shown in the Fig. 102, so the metal wire is exposed to make good connection to the batteries.

Next, take the tin strip and carefully scrape away all varnish in the center of the brighter side, until the metal is truly shiny.

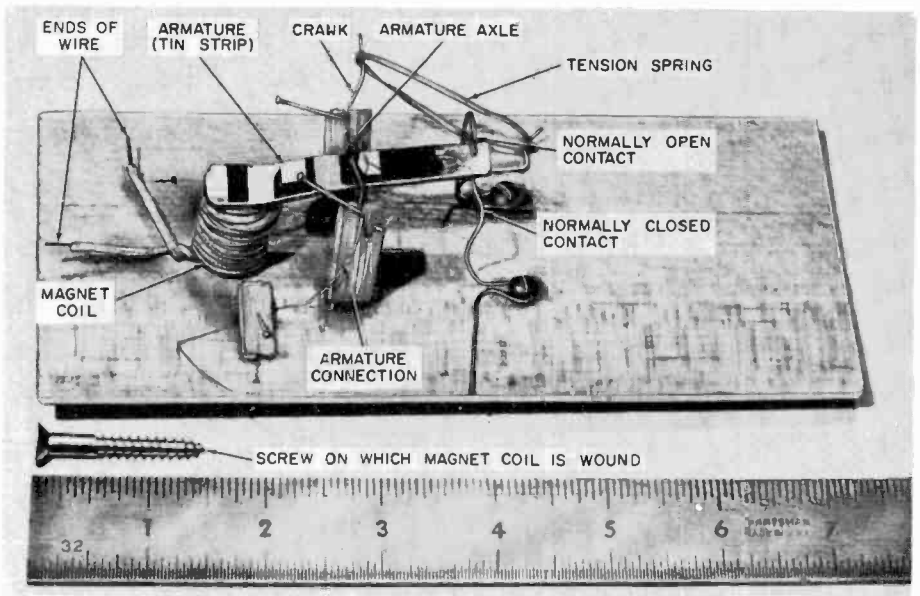


Fig. 102. Easily constructed relay demonstrates magnetic principles. Size and current required make this impractical for use in a model.

Then, taking another piece of the same wire we used for the coil, make the axle shown in Fig. 103-b.

Notice that we bent a small square U in the wire where it rests on the tin strip. This tin strip is the relay *armature* and we will refer to it as such from now on. Wrap the armature and wire U with thread so they are held tightly together, and the wire rests firmly against the bright clean tin. *Do not* use glue to hold them together, and do not use glue on the thread as it prevents electricity from going through this part of our relay. You may solder them together if you want to. Now bend the wire in the form of a small crank as shown in Fig. 103-b.

The coil (which we formed by winding wire around the screw) may now be screwed in place on the base. Add the two uprights, making them just high enough so the armature, when it is level, has about  $\frac{1}{8}$  inch space between this end and the top of the screw. Cut small V-slots in the uprights for the wire to fit in and then hold the armature in place with pins.

Now, scrape the far end, away from the coil, on *both sides* until it is bright and clean. Bend and fasten two more lengths of wire to two small woodscrews (you may add glue here to the screwheads). Bend these wires so the end of one comes up from below the armature (normally closed contact), and the other comes down from the top of the armature (normally open contact). The lower one should be high enough so that, when the tip of the armature rests on it, the other end of the armature is  $\frac{1}{2}$  inch above the screwhead. Adjust the top wire until the armature touches it when it rises  $\frac{1}{16}$  inch from the lower wire.

These two wires represent relay contacts. Notice that the armature always touches one or the other. Finally, add the rubber band from the axle crank to one end of one of the wire contacts. We could have fastened it to another screw. It doesn't make any difference how its other end is fastened, just so long as it pulls the rubber band tight enough so the armature rests on the lower contact wire. This rubber band represents the tension spring of a relay, which all relays have.

Now we can name all the parts of the relay. First, there are the coil, the armature, and the lower contact (this will be called the "Normally Closed contact" from now on). (We can abbreviate this as NC.) The reason for this is that the armature touches this contact when there is *no electricity going through the coil*. When the coil has no electricity going through it, we say that the relay is de-energized. Remember these definitions.

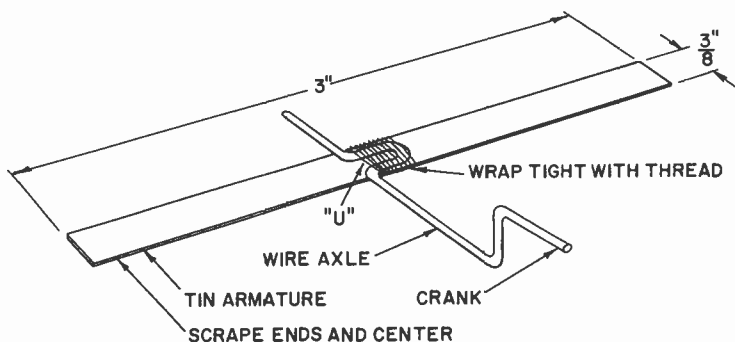
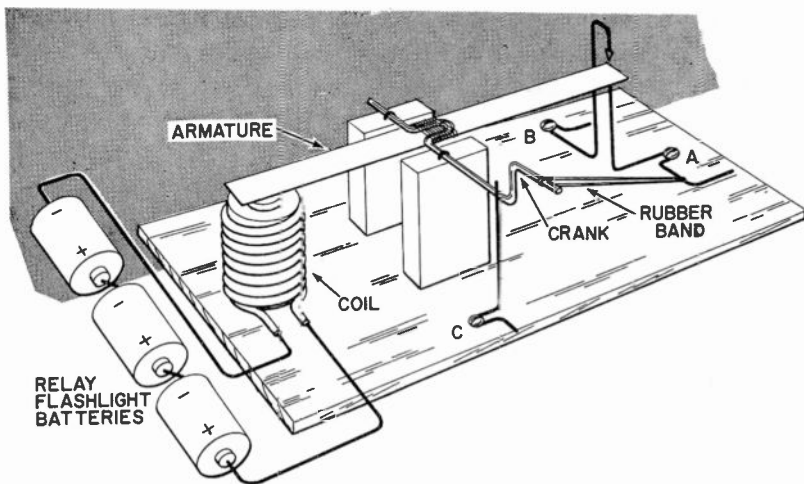


Fig. 103. The completed home-made relay [above]. C is our connection to the armature. B is the connection to the upper contact and A to the lower contact. Armature details are shown in the lower drawing.

The upper contact will be referred to from now on as the *normally open* contact (abbreviated as NO) because it is the one that the armature *does not* touch when the coil has no electricity through it. The armature touches this contact only when the coil is *connected to batteries*. When this happens, the relay is said to be *energized*.

The final part that must be added to make our relay complete is the little wire which comes up from the base and rests firmly against the armature axle. This wire must be bright and clean where it touches the wire axle because we want electricity to go through it, down the axle and out along the armature to one or the other of the two wire contacts.

To test the relay we must have at least two and possibly three

flashlight batteries. Medium-size cells do nicely. Connect the batteries end to end exactly the same way as in a flashlight. The end with the button center will be called the positive end from now on, and the bottom case end will be the negative end. With the two (or three) batteries end to end, touch the positive end of the first battery to one relay coil wire and the case end of the last battery to the other relay wire. If all the batteries are tight together, the armature is pulled down toward the screwhead by the electricity flowing through the coil winding. If the armature does not pull down, the *rubber band* may be *too tight*. Loosen it till the armature does pull down. Make sure that the armature does not touch the screwhead (we will call this screw the pole piece from now on since that is what the metal center of a relay coil is called) but *does touch* the NO (upper) wire contact.

Remove one end of the battery from the coil lead. The armature should be pulled up from the pole piece by the rubber band's tension. If the armature does not pull up, adjust the rubber band till it does.

That is all there is to the fundamentals of relay adjustment: The tension spring (rubber band) must be adjusted so that the armature can be pulled in (pulled down) by the coil when the relay is energized, but it must also be adjusted so that the armature drops out (rises up) from the pole piece when the relay is de-energized.

Sometimes we have to adjust not only the tension spring, but also the NO and NC contacts which set the space between the armature and the pole piece. You will find that, with proper adjustment of the contact spacing and the tension spring, you can make your relay operate with only two flashlight batteries, perhaps even just one.

When the relay takes three batteries to make it operate, we say it is not very *sensitive*. When we carefully adjust everything to make it operate with just one battery, we say it is *very sensitive*. The sensitivity of a relay, then, is determined by how much electricity it takes to make it operate.

A relay operates correctly when the armature pulls down toward the pole piece each time you connect the batteries, and in this condition the armature touches the NO contact. Also, the armature *moves away* from the pole piece when the coil is de-energized and in the second condition makes contact with the NC contact.

## 2

# using the radio control relay

THE next step is to learn how to use a relay. We shall continue our experiments, first learning how a relay can control a small electric motor, and, secondly, how it can control an escapement.

Buy a small electric motor (Fig. 201) which runs when it is connected to one flashlight cell. Note the two wires extending from the motor case to the cell. These let us send an electric current into the motor which makes the motor shaft turn.

Connect one of the motor leads (wires are commonly called leads) to the positive battery terminal. The other one goes to the little wire which rests on the relay armature axle. Connect the negative end (case) of the battery to the upper relay contact (the normally open one). Since the relay is de-energized, the armature touches the lower (NC) contact and is held there by the tension of the rubber-band spring.

We can now test to see if all our connections are right. Push down lightly on the armature, just over the coil, so the opposite end rises and touches the upper contact wire. If all our connections are right, that is, if all metal parts which touch are bright and clean — the motor will immediately run. If the connections are not clean the motor will not run.

Electricity should go from the negative end of the battery, up through the upper contact wire, down through the armature, along the armature axle to the little wire resting on the axle, down this wire to the motor lead and then back into the motor. Since the other motor lead is directly connected to the battery, the *circuit* is complete and the motor runs.

Here is a new term, *circuit*. An electric circuit is the connecting of wires and parts to a battery (our source of voltage) so a current of electricity can go from one end of a battery to the other end of the *same* battery.

If the motor does not run check where the armature axle wire touches the armature connecting wire. This point, often called the

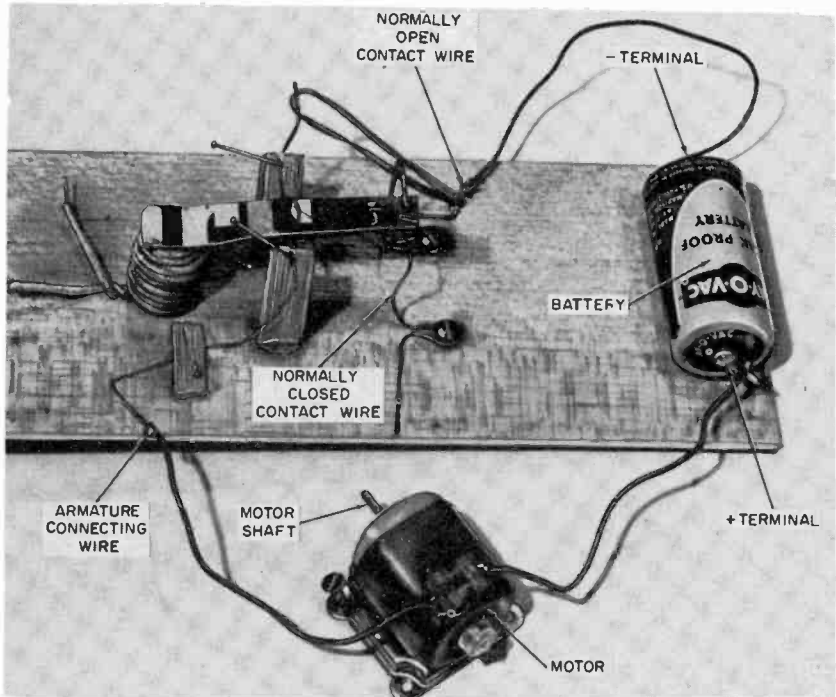


Fig. 201. Finger pressure on relay armature starts and stops motor.

relay *common* connection, is usually the frame of a relay. The next place to inspect is where the armature touches the upper contact wire.

When you have made the motor run by pushing down on the armature with your finger, you can connect the relay coil wires to some additional flashlight batteries as you did earlier, and make the motor run or stop by connecting or disconnecting the *relay-coil batteries*.

When the relay-coil batteries are not connected, the circuit (relay-coil circuit now) is *broken*. When the batteries are connected so the relay is energized, we say that the circuit is *closed* or *complete*.



Often, dirt, dust or corrosion will prevent relay contacts from making good connections to the armature. When a radio-control system suddenly does not operate as it should, and we know the batteries are good, always inspect these contacts and clean and burnish them, using a special burnishing tool, or a sheet of plain white paper. Polish until the contacts, and the points on the armature which touch the contacts, are bright and clean. *Never* use sandpaper or other material which can wear away the contact points.

We have learned that we can make the motor run or stop as we choose by connecting the motor to the relay and energizing or de-energizing the relay. Two *sets* of batteries were required: one for

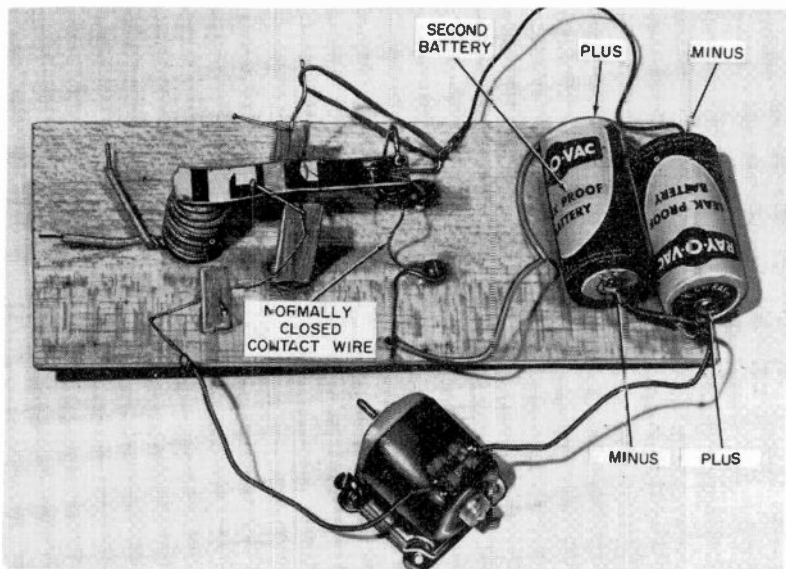


Fig. 202. With two batteries and connections to the *NO* and *NC* terminals the motor runs in either direction.

the relay and one for the motor. Remember this. In radio-control systems, there are receiver batteries and escapement or servo batteries. More about that later.

What we want to do now is to see how an electric motor can be used to steer a model. This brings up that new word *servo*. A servo, in radio-control language, is a device which has electric motors, gears and switches to furnish the power necessary to move the steering wheels, rudders, etc. Some devices which use electric motors are called *actuators* (they may also have other trade

names). An actuator, however, generally has a motor which runs all the time and usually does not have switches built into it.

Let us think, for a moment, about what the motor must be able to do to steer a model. Certainly, it must move the steering wheels to the left and right if we are going to be able to turn the model. It must also hold the steering wheels straight to make the model go straight. Thus, we must be able to stop our motor in any one of three different positions.

There are two general methods of doing all this. First, we can make the motor turn in one direction to go one way and in just the opposite direction to make the model go the other way. Somewhere in between is the straight-ahead position. Second, we can let the electric motor turn in the same direction all the time, but with special attachments (switches) to stop it in any one of four positions. Two are straight-ahead positions, one is left and the last, right. We will perform some experiments to see how each system works.

Let us begin by seeing how we can make the motor go first in one direction and then in the other. (Fig. 202). Here we see that we have added a second flashlight battery. Note how it is connected. Its negative (minus) terminal (bottom of the base) is connected to the positive (plus) terminal of the first battery. The positive terminal of the second battery is connected to the bottom (normally closed) contact wire of the relay.

Immediately, if all connections are made well so electricity can go through them, the motor will start to turn. Depress the relay armature with your finger (or energize it with its own batteries) and the motor will stop and instantly start again, turning in the opposite direction. We reverse the direction of motor-shaft rotation by simply connecting a second battery to the relay. Many *servo* systems used in radio control are based on this idea, and need *two sets* of servo batteries.

The problem with this method is, of course, that the motor always runs. How do you stop that? In systems using this method, this is done by using *two* relays. To have two relays, you would have to have a *two-channel radio* system. The motor shaft, is always connected to a number of gears which slow down the speed at which the last gear shaft (called the output shaft) turns and lets the motor give us more power.

Fig. 203 shows how to connect the motor and the *two* motor batteries to *two* relays. When neither relay is *energized*, the motor does not run. If only relay No. 1 is energized, the motor runs in

one direction. If only relay No. 2 is energized, the motor runs in the opposite direction. A switch completes the circuit to either relay from a single set of relay-coil batteries as shown.

In a two-channel radio-control system using this kind of servo, the transmitter has *two* keying buttons, or perhaps a little lever. Each button makes one relay operate, or, in case of the lever, pushing it in one direction makes one relay close, and pulling it in the opposite direction makes the other relay close.

Fig. 203 is important, not only because it shows us how to connect the relays and batteries, but also because it is one kind of

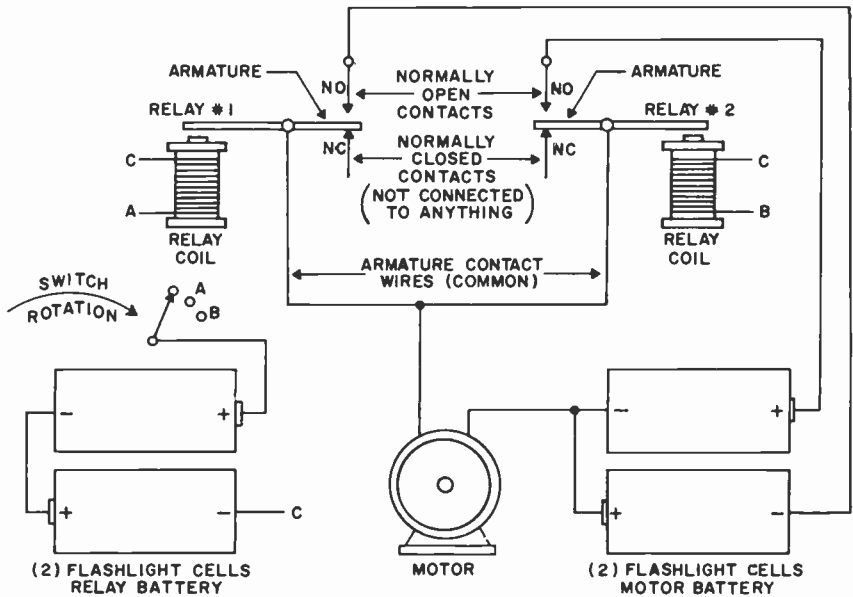


Fig. 203. Two relays and two batteries demonstrate on-off and forward-reverse control of motor in simplified two-channel system. All parts having the same letters are connected by wires. Thus, A on relay No. 1 is connected by a wire to A on the switch, etc.

diagram used to show how electrical connections are made. We will want to be able to understand diagrams of this kind, so let us examine it closely.

First, identify the relay's parts by name — the coil, the armature (represented by a bar) and the contacts, (represented by the arrows). When relay contacts are shown like this, often the abbreviations NO and NC are placed beside the arrow heads. Next, we identify the motor, the flashlight batteries and their *polarity* (which end is plus and which is minus), and the symbol for the switch. From the diagram then we learn the following:

1. We connect a wire from one relay common to the other relay common. The same wire also connects to one motor lead.
2. We do not connect anything to the lower (NC) relay contacts.
3. We connect the upper (NO) relay contact of relay No. 2 to the plus end of one flashlight battery.
4. We connect the upper (NO) relay contact of relay No. 1 to the minus terminal of a second flashlight battery.
5. We connect the other ends of the two 'motor' batteries together and connect the other motor lead to them.
6. We connect one coil lead (C) of relay No. 2 to one coil lead of relay No. 1 (C). Then both leads are connected to the minus terminal of the *relay* battery (C).
7. We connect the plus terminal of the relay battery to the *moving part* (called the rotor) of a three-position rotary switch. This can be a little metal strip, and the two contacts it can touch when moved can be screwheads A and B.
8. The second lead (B) from relay No. 2 is connected to the switch contact B, and the second lead (A) from relay No. 1 is connected to switch contact A.

Where a dot is used when the lines cross, these wires are connected. If we had two lines crossing (but no dot) this would mean *do not* connect these wires.

If we move the arm of our switch away from both switch contacts A and B, neither relay is energized and the motor does not run. If we move the arm to contact A, relay 1 is energized and the motor runs in one direction. If we move the switch arm to contact B, relay 1 is de-energized and relay 2 is energized making the motor run in the opposite direction.

With a number of gears between the motor shaft and the output shaft, the shaft turns slowly enough so that we can put a little pointer on it and position it wherever we desire in its rotation. Later, we will discuss how this output shaft is actually connected to the steering wheels or the rudder of our model.

We said previously that there were *two* ways to use electric motors to steer models; now we are ready to learn the second. This method is the one whereby we do not have to make the motor change its direction of rotation. It is the one most commonly used by manufacturers of model servo's because it needs only one motor battery; that means less weight in the model and less expense in operation, as well as less room taken up in the model by the motor battery supply. Also, we can steer our model with a one-channel radio system such as was shown in Fig. 101.

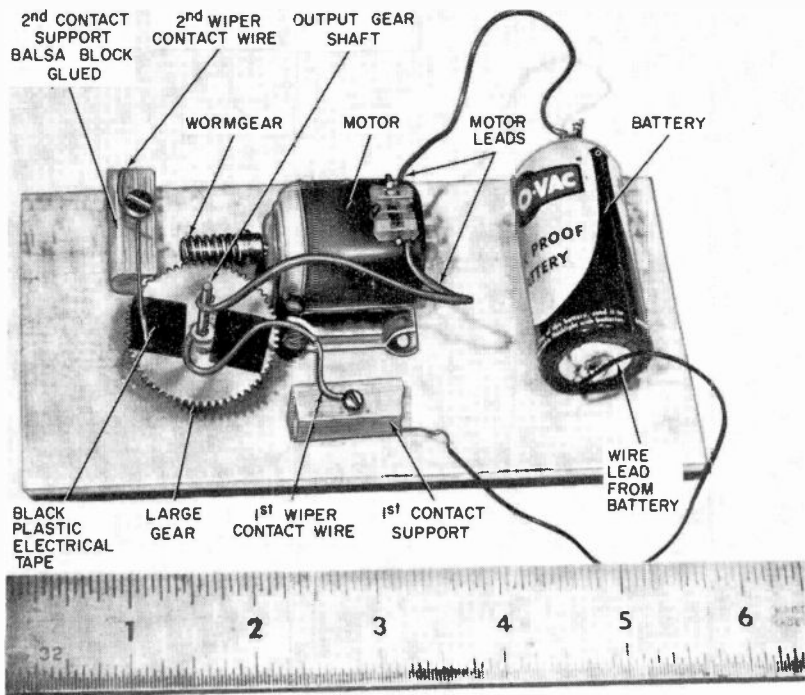


Fig. 204. Gears added to motor demonstrate the action of a simple cyclic servo.

Refer to Fig. 204. We still use the same little electric motor, but now we have added a worm gear to the motor shaft. When it is turned by the motor, this gear makes the larger gear turn. The axle (output gear shaft) of the larger gear also turns since the big gear is fastened tightly to it.

The first step in this experiment, to show how we can obtain left and right movement of a steering wheel or rudder using one direction of motor rotation and one motor battery, is to fasten the worm gear to the motor shaft with the setscrew provided. The next step is to fasten the larger gear to one of the small axles provided in the gear kit, making the fitting tight by means of the setscrew provided for this gear. The axle must protrude through the big gear at least  $\frac{1}{2}$  inch on the lower side.

Now, a small piece of balsa wood  $\frac{1}{2}$  inch wide,  $\frac{1}{2}$  inch long and  $\frac{1}{4}$  inch thick is glued to the base, and a hole just large enough to fit the gear axle is drilled in its center. This hole, if it is just the right size, holds the gear and shaft tightly, but not so tight that the gear can't turn easily. The face of the gear is now  $\frac{1}{2}$  inch above the base board,  $\frac{1}{4}$  inch because of the balsa block and

$\frac{1}{4}$  inch because of the collar fastened to the big gear itself.

Next, place the motor on the base board in the position shown so the teeth of the worm gear mesh with the flat gear. Then, fasten the motor to the base with small woodscrews. Add the two contact support blocks next, one on each side as shown. These are  $\frac{1}{4} \times \frac{1}{4}$ -inch pieces of balsa wood roughly  $\frac{3}{4}$  inch in length. Mount two  $\frac{1}{2}$ -inch woodscrews on the blocks as shown. Make the contact wires from two pieces of the No. 20 solid wire we used to wind the relay coil, and bend these so when they are fastened in place by the two wood screws, they make firm contact to the gear face.

Cut two small squares of plastic electric tape and press into the positions shown on the gear face. Connect one motor lead to the gear shaft by simply making a small loop in the end of the wire and slipping it down on the shaft. The normal bending of the motor lead keeps it tight enough to make a good electrical connection.

Then connect second motor lead to one end of the battery, and this time we do not care which end. The other battery terminal is connected to a short length of wire. This wire is used to connect to the two fixed contacts.

Notice that the nearest fixed-contact wire rests on the bright metal of the gear face while the second rests on the plastic tape patch. This always happens when the motor stops turning the gear. One contact always touches the metal face of the big gear.

Now to see how it operates. If we touch the small wire lead from the battery to the contact which is touching the bright metal part of the disc, the motor runs and keeps running until the tape patch slides under this contact. This breaks the electrical connection from the battery, through the contact wire, through the gear, up the gear shaft to the motor lead and then to the motor. This stops the motor. The big gear will have turned one-quarter turn.

Now move the battery wire to the second fixed contact, which is now resting on the metal part of the gear. Again the motor runs, this time turning the big gear another quarter-turn till the electrical tape slides under this contact and again opens the electrical circuit. Back we go to the first contact, another quarter-turn, and back to the second contact for the final quarter-turn.

Thus, we have been able to stop the rotation of the big gear every quarter-turn. If we fasten a little crank to the shaft of the big gear and connect this crank to steering wheels or rudders, we can move them left, straight, right, then straight, and then repeat these positions over and over again.

We call the two positions which make the model go straight, *neutrals*. In radio control, whenever that term is used, it means that all equipment is operating or positioned in such a manner

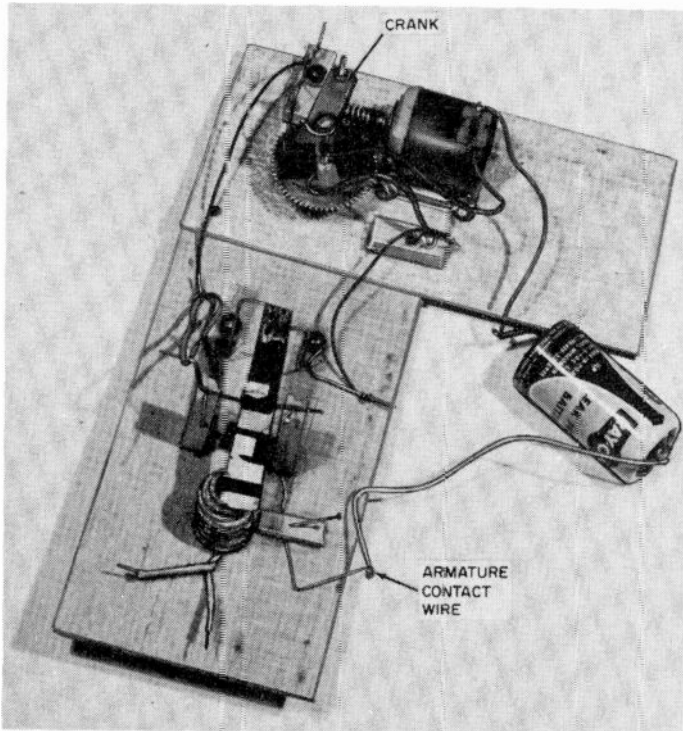


Fig. 205. Contacts opened and closed by the rotating gear stop the motor in a control position or return it to neutral, depending on the position of the relay contacts.

that the model will go straight. It can also mean that any motors or escapements used are in such a position that they do not have any electricity going through them. These are two definitions you should remember. One involves the model itself and the other the position of the cranks of the motors or escapements.

How can we use this arrangement in radio control? Let us find out by connecting our servo model to our model relay. First, however, another definition. A servo of this type, which always turns in the same direction but which can be stopped to give us different positions of steering, is called *cyclic*, a word that means 'to repeat.'

### Connecting the cyclic servo to the relay

In our radio-control system, we want the receiver to operate our

cyclic servo. Our model relay represents the receiver. We can connect the servo to the relay as shown in Fig. 205. Notice the small crank on the servo gear shaft.

To connect this servo to the relay, we simply connect one of the servo contact wires to one (the upper) relay contact wire. Connect the second servo contact to the lower relay contact. The lead from the battery now connects to the relay armature through the armature connecting wire.

When the relay is de-energized, the armature touches the lower (NC) relay contact. This lets electricity go from the battery, through the relay armature, down through the lower contact, over to the gear face, through the gear, up its shaft to the motor lead. The motor runs until the big gear turns enough to slide the plastic patch under the contact wire of the servo. This position is called *neutral* because it is the position the crank takes when the relay is not energized.

Now we connect our relay batteries to the relay coil so the relay is energized. Its armature moves up to connect to the upper relay contact. Electricity can now go out this second contact to the second servo contact wire (we call it a wiper), which would be resting on the metal face of the big gear. Again the servo motor runs till the plastic tape slides under this second contact.

Remember that having the relay *energized* is the same thing as sending a signal over the air by depressing the transmitter keying button. So, if we imagine that we have sent the signal, causing the relay to energize, the crank on the servo has moved to a position which we can call left. As long as we keep sending this signal, the model will continue to turn left.

Now imagine that we have decided that the model has turned far enough. We release the keying button (we disconnect the relay batteries) and the relay armature is de-energized. Again the armature moves up away from the coil and its tip moves down to touch the lower contact. Electricity can now get to the motor lead connected to the big gear shaft, since the servo contact connected to the lower relay contact is now touching the metal part of the gear. *Automatically* then, the servo motor runs, moving the crank around to a position which is directly opposite the starting position. This position is also a neutral. The model goes straight again.

If we send another signal by depressing the transmitter keying button, the crank moves on around to the third position, which makes our model go right. The model keeps going right as long as we keep the relay energized. Releasing the keying button (de-



energizing the relay) again makes the motor run and this time it returns the crank to the original starting position. The model will again go straight.

Now we see how a model can be steered using this type of servo. Whenever we do not send a signal, the model goes straight. If we send a signal, the model turns in one direction and keeps turning as long as we keep sending this signal. To make the model turn in

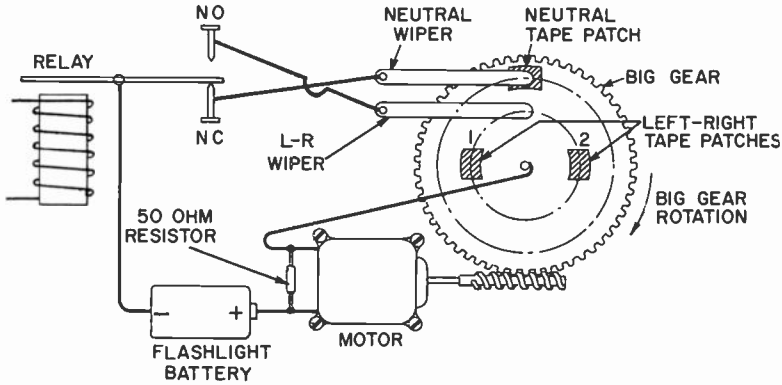


Fig. 206. Basic one-neutral servo. When relay armature is on NC, motor will stop gear in position shown (no signal). With relay held energized the gear will stop when L-R patch 1 is under L-R wiper. If the relay is energized, de-energized and then energized again and held, the gear will stop when patch 2 is under the L-R wiper.

the opposite direction, we must release the keying button for a second and then depress it again.

It would be nice to have a little better method of steering, one with just *one* neutral, so that if we depressed the transmitter keying button and held it down the model would go left and, if we depressed, released, depressed and held the transmitter keying button down, the model would always go right. In other words, two different commands to make the model do two different things.

In most of the servos which you can buy, the servo contacts are put on so you can steer in just this way (Fig. 206). In radio control language, we say *one pulse* is left, *two pulses* is right, and no signal is always neutral, making the model go straight. This is a steering *code*. It isn't difficult at all.

### More about the non-cyclic servo

Now that we understand the use of the plastic tape patches to make our servo motor stop in the different positions, let us go back to our first servo, the non-cyclic type, which needed two bat-

teries and required that the motor turn first in one direction and then in the other to steer our model. We want to learn a little more about how such a servo is used in steering. Three ideas are important to us and, if we learn these, we have mastered the methods of using servos in radio control.

The first idea concerns a *limit switch*. This new term simply means a switch which is so connected to the servo that it prevents the motor from turning the crank too far in either direction. When we discussed this type of servo before, we simply used two relays and two motor batteries and were able, by energizing either relay, to make the motor turn. *But the motor kept turning as either relay was energized.*

Suppose we wanted to send a signal for left. We would send a signal to energize one relay, the servo motor would turn and we would have to watch the model very carefully so we could *stop* sending the signal at just the right instant, otherwise the model would turn too sharply. When we stopped sending the signal, the model would keep turning and we would have to send another signal to make it go straight. With model cars and boats, we can watch the model since they go slowly enough and we would have no problem steering in this way. With model airplanes, however, we might hold the turn signal just a little too long and the model would turn too sharply and crash. We might not be able to send that second signal fast enough.

So what we want is a servo which never moves its crank too far even though we do keep sending a signal for a turn. The limit switch enables us to have this kind of a servo. This kind of a servo is often used on model airplanes to move the elevator because we can then *trim* the elevator and leave it in the trimmed position as long as we desire.

Look at Fig. 207. Suppose we rearrange the contact wires of our cyclic servo so that they are side by side, one on each side of the big gear shaft. Now let us use just one piece of plastic tape on the gear face, exactly in the center between the two servo contact wires. And we connect our servo to the two relays a little differently than we did in Fig. 203.

Now let's see what happens. If we energize one relay, the servo motor turns in one direction and keeps turning in that direction until the tape slides under the contact. We must connect our servo batteries in such a way that the direction of rotation is as shown in Fig. 207 when relay No. 1 is energized. Automatically then, when the tape slides under the contact, the servo motor stops

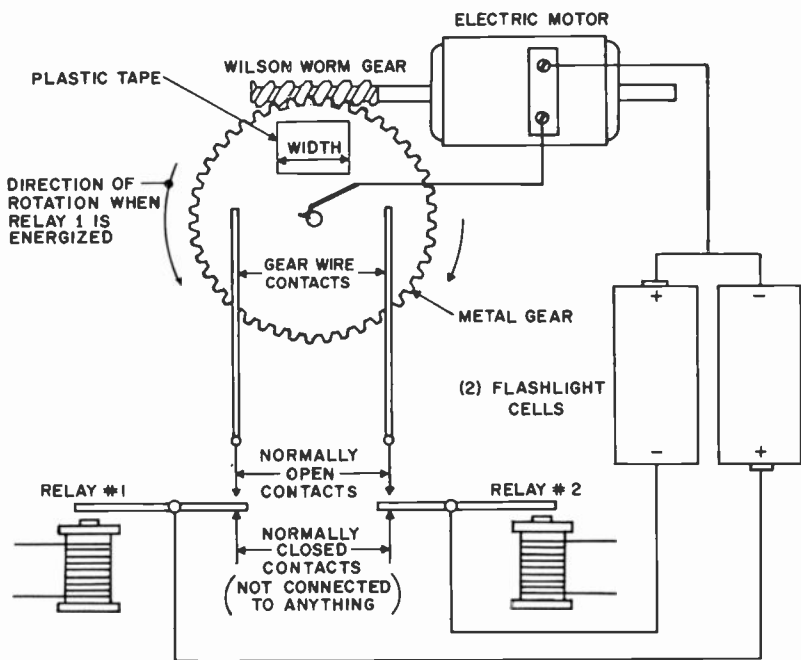


Fig. 207. Motor runs only when relay is energized. Tape insulator acts as limit switch, allowing motor to be operated in opposite direction when limit of rotation has been reached.

even though we keep this relay energized. This is one limit.

To turn the big gear in the opposite direction, we stop sending this particular signal and send a second which energizes the second relay. The motor runs in the opposite direction until the tape slides under this second contact wire. Again the motor automatically stops even though we keep the relay energized. To return the big gear to neutral, we have to "beep" relay No. 1, watching the crank, and, when it is back in the starting position, stop sending signals. This is the way a model is trimmed in flight.

If the model climbs too fast, we "beep" the right channel so that the elevator is depressed a little at a time until the model flies level. If the model dives, we "beep" the other channel to straighten it. Flying with this kind of elevator control requires a fine touch on the control stick and, although the experts use this method, it is not recommended for beginners.

Back to our servo. If we make the tape narrow, the motor can turn the output gear almost a full quarter-turn in either direction before the limit is reached. If we make the tape wide, the motor

turns the output gear only a small amount in either direction. This is called limiting the rotation with limit switches. Almost every type of non-cyclic servo manufactured has this type of switch built into it to prevent moving the steering wheels, rudders or elevators too far.

The next idea to digest is that of *self-neutralizing* action. This is a big phrase but its meaning is not too difficult. What it means is that it is possible to add still more switch contacts to this type of non-cyclic servo so when we do not send a signal, an electrical circuit is completed which *automatically* makes the servo move back to the neutral or starting position. Remember how the cyclic servo did this? The idea here is just about the same except that, in this case, the motor *reverses* its direction of rotation to bring the crank to the neutral position when the relays are de-energized.

There is a reason why this self-neutralizing feature is important. Suppose you are radio-controlling a model airplane, using a servo to move the rudder. Since the model goes fast, we want the rudder to stay in the neutral position all the time unless we send a signal to make the model turn.

If we send a signal operating one relay to turn the model and suddenly see that the model is turning too sharply, we just stop sending the signal and the model quickly and automatically straightens out, as the servo automatically moves the rudder back to neutral. Now we can make sharp or gradual turns easily. If we *hold* either left or right signal, we get a sharp turn. If we beep left or right, we can steer our model in a gradual turn. It makes steering that much easier and foolproof.

In model airplane control, it is common practice to use a self-neutralizing servo to move the rudder. There are two choices for the elevator. A servo with limit switches can be used so the model can be trimmed, or another self-neutralizing servo can be used. With a self-neutralizing servo on the elevator, we can loop and dive and stunt but we always know that in case of panic all we have to do is to stop sending signals and the model will straighten itself out. It is also common practice to use a servo with limit switches to control the motor speed, since here we do not always want the servo to return to a given position. Of course, we can use a two-neutral type of cyclic servo to great advantage, as you will see in subsequent chapters.

Fig. 208 shows how servo contact wires would be connected to two relays and a *special disc* to get both limiting and self-neutralizing action. Let us see how this method operates.

First examine the disc itself and notice the difference from the previous methods. Earlier, we used the larger gear of the servo and thus the disc was metal. For this type of servo, we *must* use a new additional disc of fiberboard, bakelite, plastic or thin plywood — any material which *will not conduct electricity*. This new disc must then be fastened *tightly* to the shaft of the big gear.

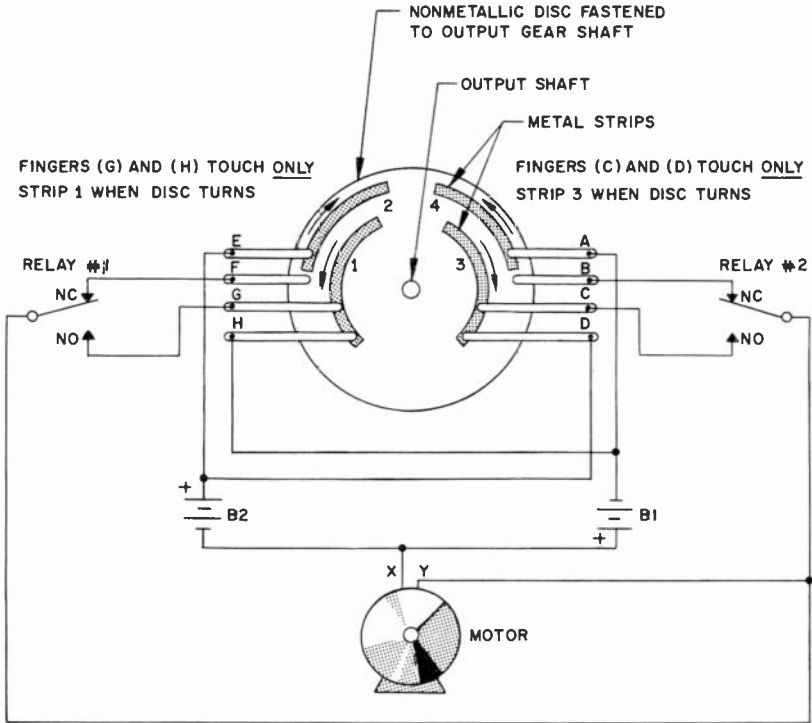


Fig. 208. Insulated disc with strip contacts gives the servo limiting and self-neutralizing action.

On this new disc, we fasten thin, curved, metal strips as shown in Fig. 208. These can be brass, bronze, tin, or even pieces of wire which are at least as large in diameter as the wire used to wind our relay coil. This wire would be stripped bare, of course.

Next we fasten little metallic fingers to another piece of fiberboard or other *insulated* material and position them so they touch the metal strips on the new disc. In the position shown in the drawing, which is neutral, note that fingers F and B *do not* touch a metal strip.

Now suppose we complete the wiring to two relays as shown and then energize relay No. 1. Its armature moves down to touch

the bottom (normally open) contact. This motor lead connects Y through the relay armature, the bottom contact, through finger G to strip 1, through this strip to finger H and from finger H to the minus side of battery B1. This makes the electric motor turn since its other lead (X) is connected to the plus side of this same battery.

The motor turns the big gear and new disc, through gears as before, in the direction of the arrow near strip 1, to the left. The motor keeps turning the disc until finger G slides off the end of strip 1, breaking the electrical connections. Then the motor stops. The output shaft (crank) has turned about one-quarter turn to the left. This makes the model start turning.

Now imagine that the model has turned far enough and we stop sending the signal which energized relay 1. The armature of relay 1 now moves up against the upper (NC) contact. Now the Y side of the motor is connected through the armature, through finger F to strip 2, which now has slid under finger F. From strip 2, the connection is complete to finger E, which also is resting on strip 2. Finger E is connected to the *plus* side of battery B2. Notice that where, before, the Y terminal of the motor was connected to the *minus* end of B1, it is now connected to the *plus* end of B2. The motor now runs again, but this time in the opposite direction. The shaft and disc turn back toward the starting position and do not stop until finger F slides off contact strip 2. This, then, is a self-neutralizing action.

Let's examine the action of relay No. 2. Imagine that you send a second signal which energizes relay No. 2. The armature of this relay moves down to the lower NO contact. The Y side of the motor is connected through the armature of this relay, through the NO contact to finger C, through strip 3 and finger D to the *plus* side of B2. This, as before, makes the motor turn in the direction indicated by the arrow near strip 3 — the same direction which made the servo self-neutralize a moment ago. The motor keeps running till it has moved the output shaft and the big disc around to where finger C slides off the end of strip 3. The motor then stops.

When the model has turned far enough in this direction, we stop sending this signal which is keeping relay No. 2 energized and it de-energizes. When this happens, the Y lead of the motor is connected through the armature, the upper (NC) contact to finger B, which is now resting on strip 4. Electricity goes through strip 4 to finger A and from A to the *minus* side of B1. Once again the motor runs, this time in the direction indicated by the arrow near

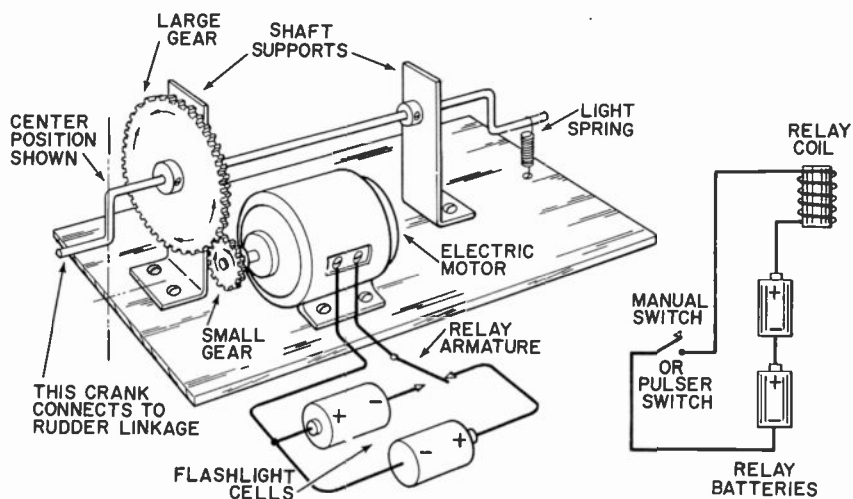


Fig. 209. This electric motor used as an actuator requires pulses of equal duration to keep control surface in one position. If relay on time is longer, motor drives in one direction; if shorter, it goes in the opposite direction.

strip 4, and keeps running till finger B slides off strip 4. The servo and disc have returned to neutral automatically.

If you construct this kind of servo, remember the direction in which the motor must turn the disc to make the servo operate correctly. If energizing relay No. 1 makes the motor turn the output shaft and disc in the opposite direction to the arrow near strip 1, reverse your motor leads. Simply connect the leads so that the one you have going to the common junction X now goes to the common line Y, and the remaining lead to the opposite junction.

### An actuator

The final idea concerning the use of electric motors to steer models takes us back to the experiment we performed using a motor, two batteries and one relay (Fig. 202). We will now discuss a system of steering known as *pulse control*. (Fig. 209).

In Fig. 209, we see the motor is connected to a small gear which, in turn, makes a larger gear rotate. The shaft of the larger gear is fastened firmly to the large gear and mounted as shown with two small cranks formed at the ends of the shaft. One of these cranks has a small spring attached to it and the other end of the spring is anchored to the base board just below. If you turn the front crank by hand about a quarter-turn and then release it, the little spring should be able to pull the crank back to the neutral position when the motor is not connected to the relay or batteries.

Since the no-signal position is a sharp turn, we must send signals to the model constantly to prevent a crackup or sharp circling if it is a boat. Also, it is very difficult to judge the up and down time of the doorbell switch when we operate it by hand. What we need now for this system is a little device called a *pulser* which sends out these signals automatically when we move a little lever to one

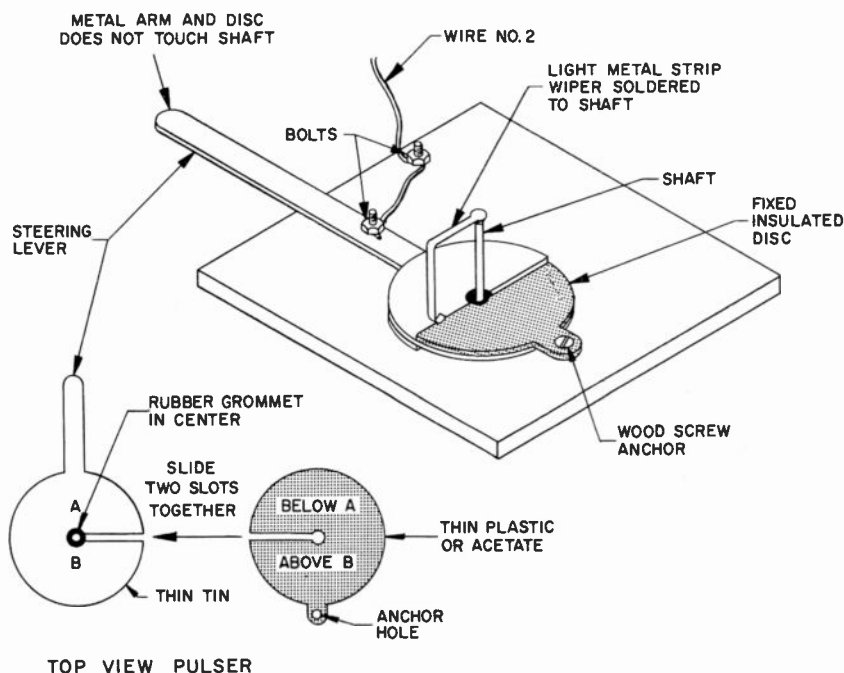


Fig. 212. Pulser contact assembly mounted on back of motor drive board.

side or the other. With the knowledge we have now, we can build such a unit.

We know that if we have a gear face with a little wire contact on it, we can make electrical connections to the disc when the wire touches the metal disc. We also know that, if we mask part of the disc with tape, the electrical circuit is broken when the contact wire rides up on the tape. We will use this basic knowledge to build a pulser.

First, we take a small electric motor and two gears such as we used before, mounting them as shown in Fig. 210. The shaft of the output gear goes down through the base board and extends about 1 inch below. If we connect a battery to the motor as shown in Fig. 210, it runs, turning the output gear round and round in



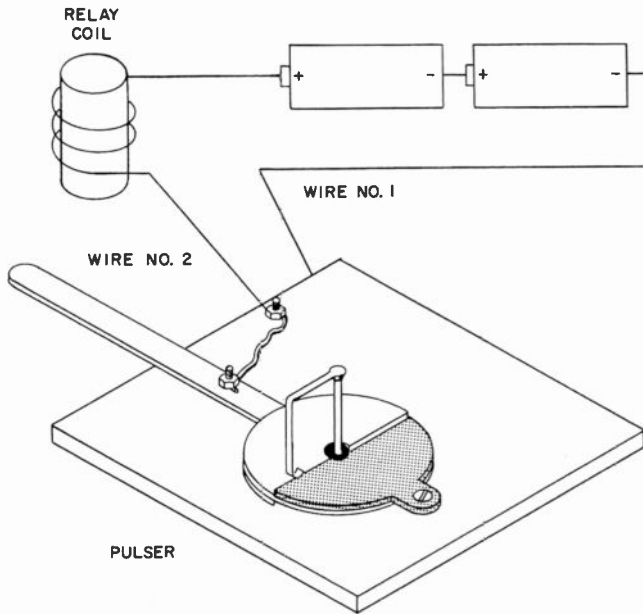


Fig. 213. *Electrical connections for pulser connected to relay coil.*

the same direction, which is what we want it to do.

Turning the base board over, we are now concerned with the shaft coming up from below. Make a *metal* disc about 2 inches in diameter or larger, with a handle as shown in Fig. 211-a. Make a second disc of the same diameter, with a little tab, out of plywood, bakelite or other *insulated* material, also as shown in Fig. 211-a. Cut the slots as indicated and slide these two discs together as in Fig. 211-b. (Make the metal part from a tin can.)

In the neutral position of the lever, exactly half of each disc is exposed. We now buy a small rubber grommet and fit it into the center of the two discs so that, when we position them over the output shaft of our motor pulser, the metallic disc cannot possibly touch the output gear shaft. Note that the base board of the pulser must also be plywood or insulated board.

Fasten the tab of the insulated disc to the base with a little screw and washer so it cannot move. Solder a little brass or bronze finger to the top of the output gear shaft, bending the tip of the finger so that, when the motor turns this shaft, this finger slides around on the two discs, *touching them at all times* (Fig. 212). Drill a small hole in the arm of the lever, insert a bolt through it and fasten a length of insulated wire to the bolt. Connect a second

piece of wire to the metal mounting bracket of the big gear shaft as shown in Fig. 210. Finally, connect these two wires to the relay coil and batteries, as shown in Fig. 213, in place of the doorbell button switch.

Now its operation. We turn the motor switch on so that the motor runs. This causes the little wiper on the output gear shaft to spin round and round over the two discs. Whenever this wiper touches the metal disc, the relay is energized; when it rides up on the insulated disc, the relay is de-energized.

With the lever in the neutral position, the relay is energized exactly the same amount of time it is de-energized, and the crank of the actuator swings back and forth about the center position. The model goes straight. If we move the lever to the left, more of the metal disc is exposed, the relay is energized longer than it is de-energized and the model goes to the left. If we move the lever to the right, less of the metal disc is exposed, the relay is de-energized longer than it is energized and the model goes to the right. When the lever is at neutral, the model goes straight.

In an actual radio-control system, the actuator is connected to the receiver relay and the pulser to the transmitter in place of the keying switch.

When an electric motor is used like this for steering of a model, it is called an *actuator*. The importance of an actuator is that it lets us steer *proportionally*. That is, moving the lever a small distance from center causes the model to make a gradual turn; moving it a long way from center results in a sharper turn (just like steering an automobile). You turn the steering wheel a small amount for a gentle turn and a large amount for a sharp turn.

There is one feature of this type of steering that we must always remember. Transmitter or receiver failure can make the model airplane go into a sharp turn and dive and crack up. Any failure is the same as no signal and, as we have explained, this means a sharp turn to the model. One other disadvantage of this system is that the actuator in the model must run all the time and this runs down batteries faster than other systems. On the good side, however, you can steer your model very accurately. It is excellent for contests and it does give you the feeling of really flying.

# 3

## the basic escapement

**H**AVE you ever had a chance to look inside an alarm clock? It has so many wheels and gears that it seems very complicated, but actually, the basic idea is very simple. We start with a very strong spring which we “wind up”. What we are really doing, though, is storing energy in mechanical form. Naturally, we don’t want the clock to release all that energy in a great big rush. We use the energy just a very little bit at a time by means of a device we call an *escapement*. The idea is a very good and practical one, so we are going to borrow it, change it somewhat, and use it in our radio-control systems.

An escapement is most commonly used in model-airplane radio-control systems because it is small, lightweight, and thoroughly reliable. When we say reliable, we mean that it always works as it should. It does not generate any sparks or cause *arcing*, which sometimes produces interference with the radio receiver. Sparks and arcing are troubles found with servos using electric motors, although there are devices (such as filters) which can be used to eliminate such difficulties.

Escapements can be bought in many different forms, but all work in exactly the same way. We can learn just how they operate by building a small model like the one shown in Fig. 301.

The escapement is exactly like a relay in its operation. Notice the coil of wire, exactly the same as that used in our model relay. Locate the armature, which is exactly the same. Now observe the differences between the escapement and the relay: there are no wire contacts. Instead of the normally closed contact, there is a wooden peg which prevents the armature from falling down to

the baseboard. The end of the armature, made from a tin strip cut from a coffee can, is bent up about 1/16 inch to form what we call armature catch point 1 (Fig. 301-302).

Right at the pivot point of the armature, a second strip of tin is fastened with thread so that it rises up exactly the same distance as the distance from the pivot point to the catch-point end of the armature. The tip of this new strip is bent forward 1/16 inch to form the upright catch point 2 (Fig. 302).

Next, glue a piece of sheet balsa about 1/8 inch thick and about 2 1/2 inches wide by 3 1/2 inches long to the far balsa pivot post, as shown in Fig. 301. A position is marked on this plate exactly above catch point 1 and directly opposite catch point 2. If you have placed the mark correctly, the distance from it down to the armature, over to the armature axle, up to catch point 2 and back to the starting point is exactly the same, forming a perfect square as shown in Fig. 302.

Make a hole, a very small one, in the balsa plate at this point and glue a piece of balsa block 1/2 inch wide, 1/4 inch thick and 3/4 inch in length over this hole to form a bearing. When the glue has dried, drill the small hole through the block, starting the drill in the hole on the plate in the back side. Drill this hole straight, and make it no larger than the diameter of the No. 20 wire used to wind the escapement coil.

A piece of No. 20 piano wire or a paper clip is now bent so that one end forms a small crank. This crank is fastened to a piece of wood (ice cream stick or hard balsa). This is the rotating arm shown in Fig. 302.

The other end of the wire can now be put through the hole in the bearing block and, on the opposite side of the plate, a small hook can be bent into this wire shaft. This wooden part is the rotating finger of our escapement. We can attach another rubber band to the small hook and twist it to make the finger rotate.

Getting back to Fig. 301 notice that the rubber-band tension spring is still required to keep the armature pulled away from the magnet coil when this coil is de-energized. When the escapement is de-energized, there should be about 3/16-inch space between the end of the armature over the coil and the coil itself. You can also see in Fig. 301 that a piece of paper has been glued over the end of the coil. It prevents the armature from sticking when it touches the pole piece of our magnet. The screw used as a pole piece will become magnetized and holds the armature against it,

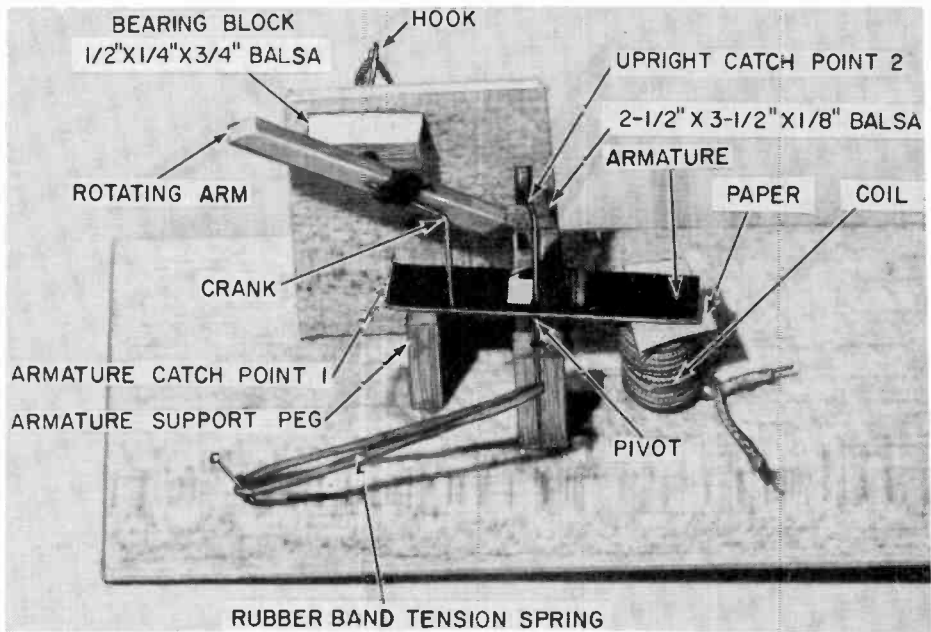
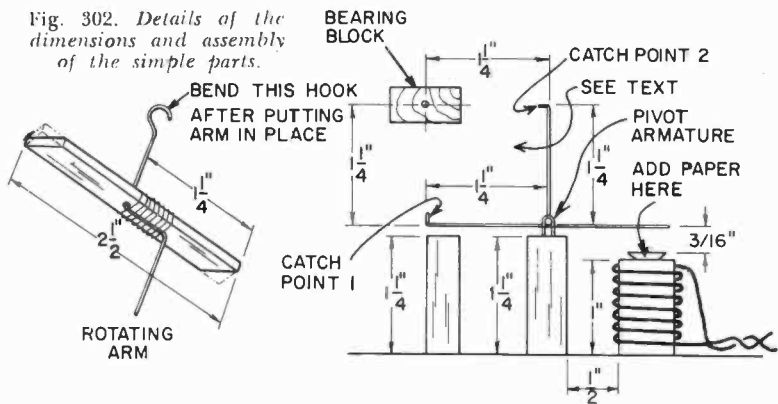


Fig. 301. Basic escapement is easily constructed to demonstrate typical action.

even when we disconnect the battery, unless we add the paper as shown.

We are now ready to see how an escapement operates. Connect a rubber band into the little hook which we bent into the rotating arm shaft. Now *twist* this rubber band in such a direction that the arm itself (Fig. 301) tries to rotate *clockwise*. If you have constructed the escapement model with care, one tip of the rotating



arm will catch on the upright catch point 2 and the arm will be held in this position. Twist the rubber band a little more. Take care not to *pull* on it. Let it get shorter as you twist. We want just the *twist* (sometimes called torque) power, not the *pulling* power. Now, with your finger, depress the end of the armature over the coil and hold this end down. The rotating arm should snap around one-quarter turn and its other tip should now catch on catch point 1. The crank may be above or below the shaft, depending on where it was when you started. Release the armature. If the rubber-band spring tension is correct, the armature pulls up, releasing the arm from catch point 1 and again catching the arm at catch point 2. Depress the armature again. Again, it will be caught by catch point 1. Release it, and it is caught by catch point 2, and the little crank is back in the starting position.

You can operate the escapement magnet coil with two or three flashlight batteries end to end (in series) by simply closing the electrical circuit to its coil. This is what your radio control receiver does when we send it a signal. The relay in the receiver closes the circuit to the escapement and makes it operate.

Let us examine the various positions of the escapement crank and name them. The two positions that the crank has when it is *not* energized are called *neutrals*. In these positions, we want the model to go straight. The first energized position of the crank makes the model turn left (you will see later just how we connect an escapement to a rudder to do this), and the second energized position makes the model turn right. Notice that the power which rotates the arm and makes the rudder move comes from the twisted rubber band. This power *does not* come from the escapement magnet.

You can also obtain a length of model airplane rubber  $\frac{1}{4}$  inch wide and about 10 inches long from your hobby shop and connect it to the rotating arm shaft. Wind it till it has several knots in it. It will get shorter as you wind. Let it! Do not try to keep it out to the same length as you wind.

Fasten the free end of this rubber band 4 or 5 inches from the balsa plate *in a direct line* with the rotating arm shaft. You can connect your model relay to the escapement as shown in Fig. 303 and operate your escapement in exactly the same manner your radio-control receiver does. You may have to use three flashlight cells instead of two to make the escapement operate correctly, and will probably have to adjust the armature-tension rubber band of the escapement. When you have done this and are able to "step"

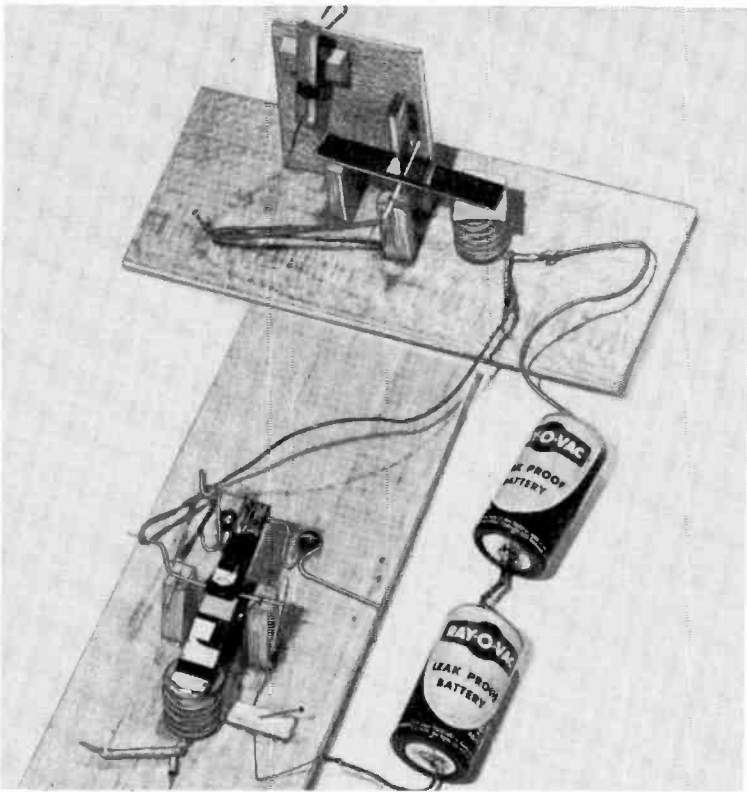


Fig. 303. With this setup you can become familiar with the way in which the relay and the escapement work together

the rotating arm around using your relay, you will have a complete understanding of how escapements are operated by relays in radio-control systems.

There are many additional kinds of escapements. Some have more fingers on the rotating shaft (Fig. 304). Some have a wheel and groove instead of the crank and the fingers are in the inside of the wheel. All the various arrangements are aimed at easier control, particularly those known as the compound types. All escapements, however, operate in just the same general manner.

To see how you would send signals to steer your model using this basic escapement and also a compound type, let us imagine that we have a model airplane in the air and that it has a basic escapement inside for steering. We know that the escapement is in neutral. We depress the transmitter keying button, hoping to turn the model to the left. It may turn left — and it may turn *right*. We won't be certain just which way it will turn because there are *two* neutral positions, and we do not know which one is making the model go straight.

If the model turns the way we want it to, fine. We turn it till we are satisfied with the turn, then we release the keying button to let it go straight again. But suppose the model started to turn right instead of left. What then? Quickly, *we release the keying button and instantly depress it again*. This makes the model go right. Remember this! When using a standard type escapement,

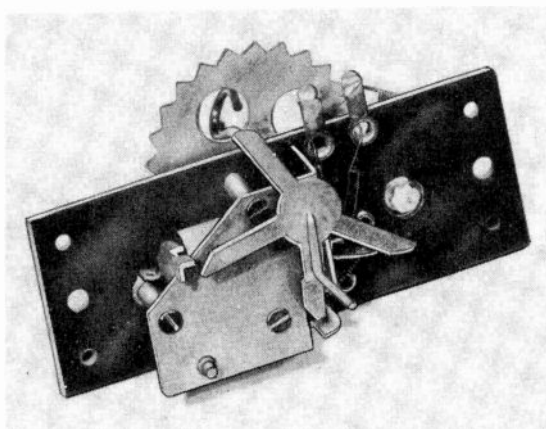


Fig. 304. Known as a *compound, commercial escapement* allows much more flexible control of the model.

depress the keying button for a turn and, if the turn is in the wrong direction, release and depress the keying button as fast as possible. It takes a little practice but, if you let your airplane get a little altitude before you begin trying to steer it, you can "get the hang" of it quickly and have the time of your life flying your radio-controlled model.

### **Flying with the compound escapement**

Compound escapements were developed to take the guesswork out of steering. With this escapement, you have a steering code. *One* pulse is always *right* turn; *two* pulses always means a *left* turn. As a review, remember that one pulse means depress the keying button and hold it down. Two pulses means depress, release, depress and hold the keying button down.

Most compound escapements have a three-pulse position which does not change the model's direction but does make a little switch, built into the escapement, close. This third-position, or three-pulse signal, can be used to make the airplane motor change its speed, or make the model dive or climb more rapidly. It can be used to drop bombs, etc. More about these escapements in later chapters.



# 4

## the transmitter

WE have already had some discussion about the transmitter<sup>1</sup> shown in Fig. 101. Now we are going to examine it in detail to find out what we have to do to make it operate, how we can test it and how to take care of it. Let's take it apart and see just why and how it works.

This particular transmitter is a good example of a small hand-held, carrier-only type of radio-control sending station. A transmitter is called a carrier-only type when it does not send musical tones. Some transmitters do send out "musical" tones and they are called, as you can guess, tone-type transmitters. But ours, like most radio-control transmitters, has no outside tuning adjustments. While it *is* possible to tune it, this is seldom if ever necessary and *you should not attempt it*. Normally, in case of trouble, you send your transmitter back to the factory or to some reliable service organization through your local hobby shop, for repairs or adjustment.

Preparing our transmitter for operation is a simple procedure and is almost the same for any type of radio-control transmitter. You simply open the case (Fig. 401) and put in the kind of batteries called for in the instructions. This transmitter uses three No. 415 Eveready or U-30 Burgess B-batteries and one large flashlight cell. Batteries are referred to as either A or B. The B-types have more voltage than the A's.

Notice the fasteners on the wires inside the case. Each is so arranged that it snaps right onto the battery and can fit only one

<sup>1</sup> While we are discussing a particular transmitter, the suggestions given here are general and can be used for almost any transmitter you plan to buy.

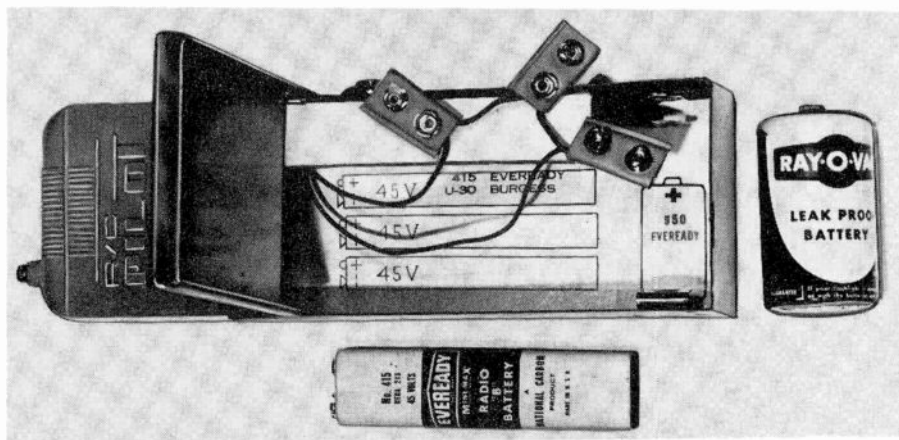


Fig. 401. Battery installation in radio-control transmitter.

way, so you can't make a mistake in connecting them. Attach the three snap fasteners to three B-batteries and put them in place. Now, slip the flashlight cell into place at the bottom of the case, with its positive terminal pointed in the direction indicated, close the lid and that's all there is to installing the batteries.

We must do one more thing before the transmitter is ready to operate a radio control receiver — connect the antenna. A *transmitter antenna* is a very important part of the radio equipment. Furnished with the transmitter, it is a certain exact length. It is very important that you use the antenna furnished and that you do *not* cut or shorten it in any way. If you do, you will not be able to send signals as far as you should.

Simply take the antenna, which is like a fishing pole, and screw the base into the little hole on top of the transmitter case. The transmitter is now ready to operate — turn it on and use the keying button as we discussed previously.

### Testing the transmitter

There are several ways to determine if the transmitter is working properly. We will cover only two. The first is to have a radio control receiver, such as this transmitter's companion unit, connected to its batteries and turned on. If you listen with your ear close to the case of the receiver, you can hear the relay click every time you depress and release the transmitter button. In other words, you send signals to a radio-control receiver which you know works.

The second method is to modify a meter (which we discuss later)

to tune the receiver; you can watch this meter and see the hand move when you depress the transmitter keying button. Now let's build a test meter that can tell us when the transmitter is working correctly without having any receiver around at all. The basic meter, Fig. 402, is a Shurite Model 850. (We will use

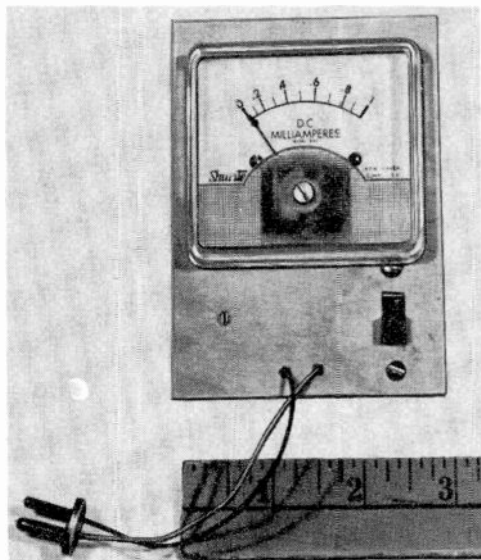


Fig. 402. Front view of the modified Shurite Model 850.

this same meter later on with our receiver). Our first addition to the meter is a switch, a standard single-pole single-throw slide unit. We also need a 1N34 diode and an LS-3, 30-megacycle coil. They are fastened to the back of the meter. The switch is connected to a 110-ohm,  $\frac{1}{2}$ -watt resistor and provides us with two scale readings. With the switch off, the meter scale reads normally. With the switch on, the reading is multiplied by 10. In other words we will have a 1-ma (one milliamper) and a 10-ma scale. Fig. 403 shows how the parts are mounted.

The wiring of the test meter is shown in Fig. 404. Note that a 39- $\mu\text{mf}$  (micromicrofarad) capacitor is soldered to the two coil terminals.

Note also that the plus lead from the meter goes to the large pin of the plug (which is furnished with the receiver). If the meter is going to be used just to test the transmitter, this plug can be omitted.

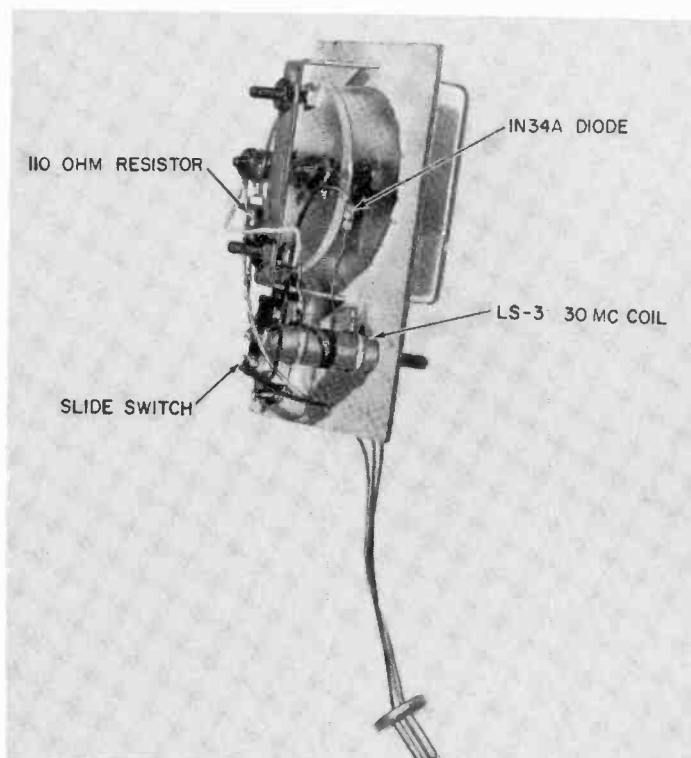
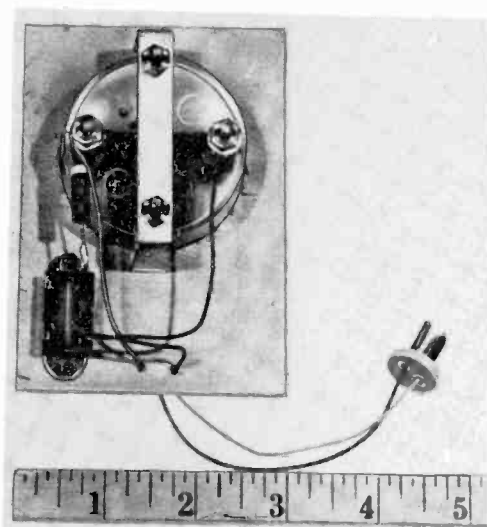


Fig. 403. These views of the inside of the case shows location of parts.

A case is needed for the meter, not only to make a pleasing appearance, but to protect the terminals from accidental contact and the delicate parts from damage. Cases or meter boxes come in many shapes, sizes and materials. Aluminum is quite rugged and is quite easy to work with. Being a metallic conductor it also provides a degree of shielding from unwanted signals which may

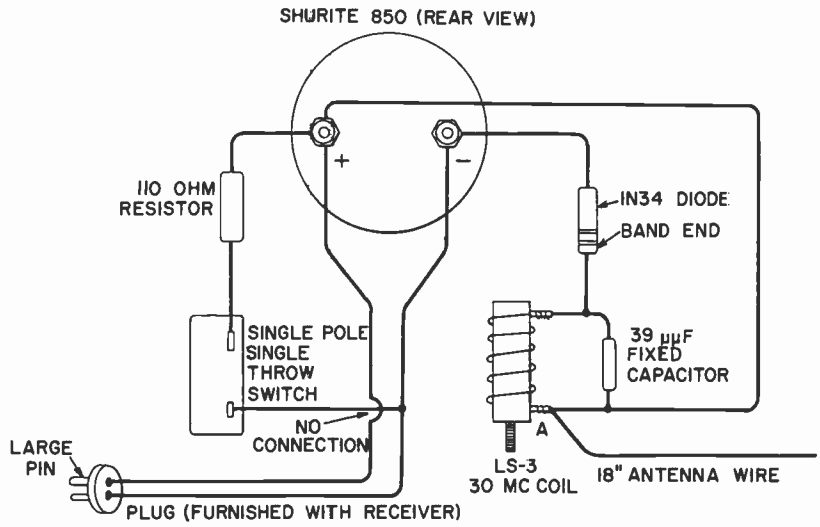


Fig. 404. Pictorial diagram showing connections for all components.

make it give wrong readings. Plastic cases will keep out the dirt but not electrical interference. In any event when you buy the meter, buy a case too. If you don't want a case, mount the meter on a panel. The panel can also be used to support the parts.

Testing the transmitter with this meter is easy. Fasten an 18-inch length of wire to coil lug A. Set the single-pole switch to the off position. Hold the transmitter so that its antenna is about 3 inches from the wire antenna of the meter and exactly in line with it. If the transmitter is working as it should when we depress the transmitter keying button, the meter hand will rise to somewhere between zero and 0.2 on the meter scale. This is all we want to find out — that the transmitter is sending out radio energy and that the meter hand moves up toward the 0.2 number on the meter face. We do not really care how much the meter hand moves, just so long as it does. This is a simple test and not designed to give exact information. You can tune the meter coil by adjusting the slug screw for the highest reading, if you desire.

Radio-control transmitters are very reliable; that is, they work

as they should and give very little trouble. The most common trouble is that the batteries run down, and then of course our transmitter doesn't work right. You can have the batteries checked by a service technician or amateur radio operator. Be sure to ask that the batteries be checked *under load*; that is, with the transmitter switch on, the antenna in place and the keying switch depressed. A good rule of thumb is to replace the flashlight battery (it runs down the fastest of all the batteries) about every 2 to 3 hours of transmitter use.

### **Transmitter maintenance**

Very little has to be done to take care of your radio-control transmitter properly. First, of course, don't drop it or throw it around. It is a delicate instrument and, while it is built to withstand normal handling like a portable radio, do not abuse it.

Second, when you plan to put the transmitter away for longer than, say, overnight, take the batteries out. Be sure to do this if you live *in a hot climate* or store the transmitter in a warm house. Batteries left inside the case may swell and break and make a mess of the inside of your transmitter. Batteries last longer if you wrap them in a cellophane bag and put them in the refrigerator — *not* next to the freezing unit or in the deep freeze, just back in a corner of the refrigerator away from the freezer.

### **Operating the transmitter in the field**

We have said that a signal is sent out whenever we depress the keying button. This is true, but let us consider just a little bit further about getting the signal from the antenna into the air.

Radio signals really don't want to go through the air at all. They do so only when forced to. Actually, they would much rather go into the ground or nearby metal objects such as buildings, automobiles, telephone and electric wires. They would rather go through your body than out into the air. What this means is that we must not provide them with a short-distance path to any of these objects. We must keep our antenna high and well away from people (including ourselves), automobiles, boat hulls, buildings or anything that might have metal, flesh or earth associated with it.

When signals, which leave the antenna, have no easy short-range path to these objects, they reluctantly move out into the air as we want them to and reach the antenna of the receiver in our model. The signals are not absorbed and the success of your radio-control experiment is assured.

It's generally best to hold the transmitter out to almost a full arm's length with its antenna pointing directly up into the sky. When the signals go out from the antenna, they go out sideways and not off the tip. You do not get better reception at the model

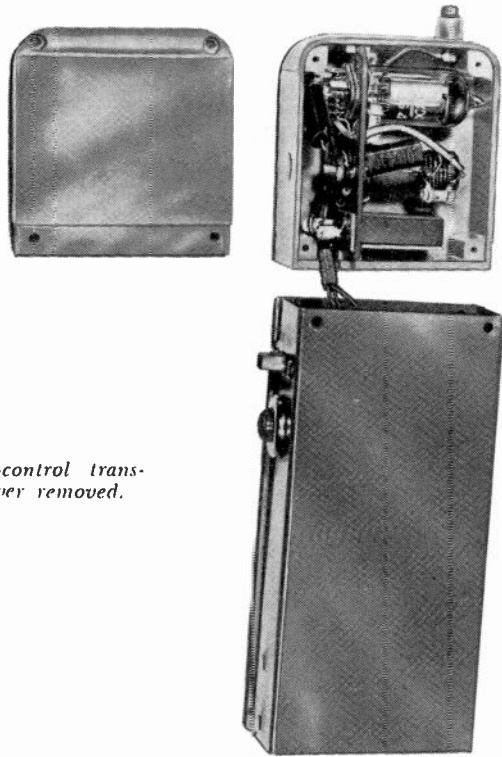


Fig. 405. Radio-control transmitter with cover removed.

by pointing the antenna at it. It is always best to hold the transmitter so that its antenna is *broadside* to the model.

### How does it work?

Do not take the sealed portion of your transmitter apart to see what is inside. It should be opened only in the way the instructions tell you so you can put in the batteries. Transmitters are adjusted at the factory very carefully and one of the wisest rules we can give you is simply this: *as long as the equipment is operating correctly, do not tamper with it.*

To satisfy our curiosity, however, we can examine the transmitter used as an example in this text and see just what parts are inside the case and what they do. All other radio-control transmitters are similar, although they may have two or even three radio tubes, and their cases may look differently.

Referring to Fig. 405, we find three major parts inside the top plastic case — the crystal, a coil and a small radio tube. There are some small parts associated with these major items but we are not too concerned with them.

The first item, and perhaps the most important, is the crystal, which is a piece of quartz in a sealed case. This case has two pins so that it can be inserted into a small socket. This crystal makes the transmitter send out just one frequency, which the receiver can be tuned to. Because only one frequency can be sent out, once we tune the receiver to the transmitter, it always receives the signal if it is operating properly.

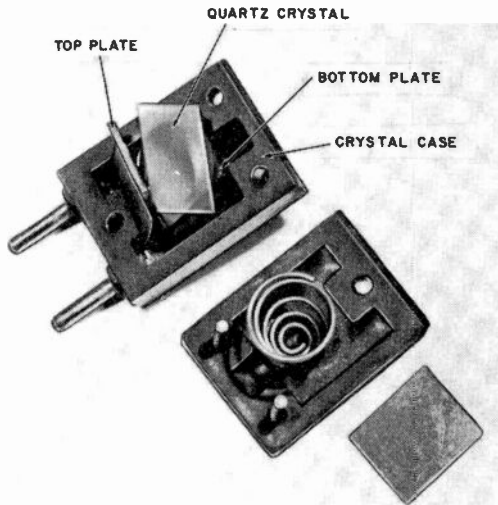


Fig. 406. Here we take a look inside the crystal's holder.

It's like a television set. You tune to a particular channel by simply changing the channel selector. You know exactly where to find this station because the set has been tuned to this particular channel at the factory. The factory knows just what channels the TV stations send out signals on because they know the frequency of the *crystals* used at the stations.

There is another reason for using a crystal. The Federal Communications Commission, which has allocated a number of channels for radio control, wants to make certain that we do not send out signals on other frequencies which might interfere with television, police or other types of radio services. In general, then,



we can say that the crystal keeps us on the right channel for radio control.

Now let us refer to Fig. 406. The crystal holder is open so the piece of quartz (and it is a special kind of quartz), can be seen. Notice that it is between two metal plates, which press against each side of it by the spring which is compressed when the holder is put together.

An almost magical action takes place when the quartz is compressed tightly between these metal plates (and inserted in its circuit): it actually produces a very, very tiny electrical signal. This signal is, of course, on exactly the right channel for radio

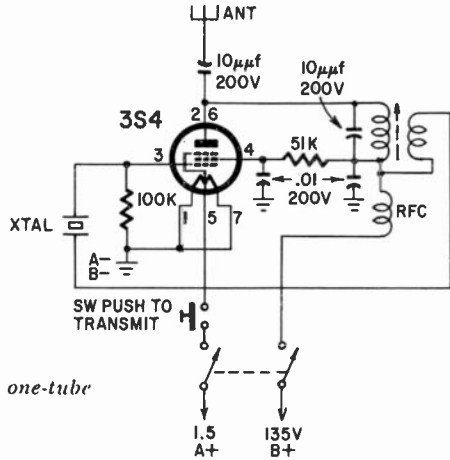


Fig. 407. Schematic of a one-tube transmitter.

control, but it is so weak we could not send it very far. This then is the reason for the radio tube. A radio tube can take such a tiny signal and build it up to be a loud strong signal which can be picked up by the receiver as far as a mile away.

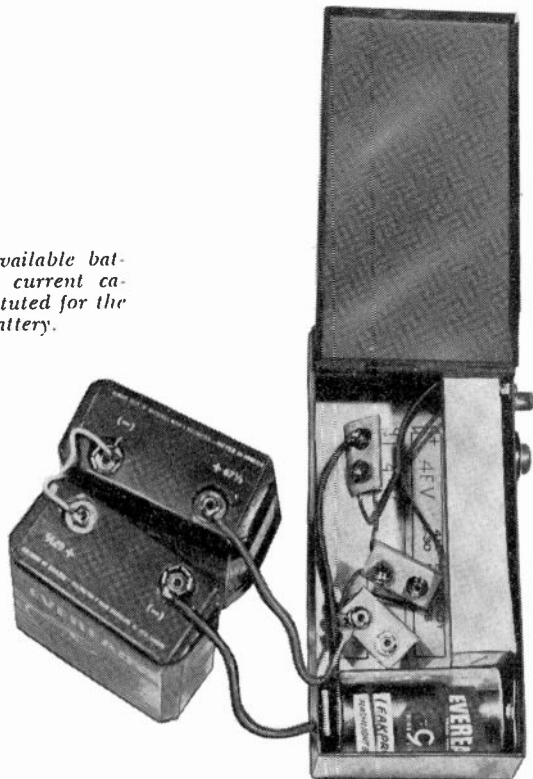
We must have some way to get this powerful signal out of the radio tube, and that is where the coil comes in. When this coil is tuned to the same frequency (channel) as the crystal, the signal leaves the tube and goes into the coil. Since the coil is connected to the antenna, the signal also goes out the antenna and jumps off into space.

Remembering that six channels have been designated for radio control purposes, you may ask how the crystal is selected for a particular channel. The channel that the crystal puts out a signal on is governed by the physical size of the crystal itself. For a lower channel, it is made thicker; for a higher channel, thinner. A manufacturer of radio crystals can cut and grind a piece of this

special kind of quartz to make it produce a signal of a desired frequency.

This discussion has been necessarily somewhat general, and there are other factors and ways of explaining the operation of a transmitter, but it is safe to say that, in general, any transmitter operates in this fashion.

*Fig. 408. Readily available batteries with greater current capacity can be substituted for the original B-battery.*



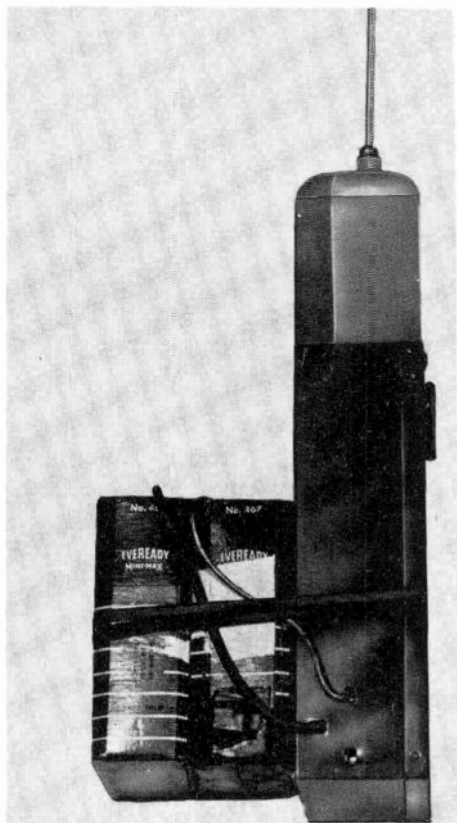
For those who have some familiarity with electronic circuits and would be able to analyze the operation for themselves (and for those who want to learn how) the schematic diagram is given in Fig. 407.

### **Operating the transmitter with larger batteries**

Figs. 408 and 409 show how two standard Eveready No. 467 B-batteries can replace the three B-batteries used previously. Inside the case, a red and a blue lead come from the switch to the three battery fasteners. A wire can be soldered to the terminal connected to the blue lead and this, in turn, soldered to the minus terminal of one No. 467 battery. A second wire can be soldered

to the terminal to which the red lead is soldered, and then this lead, in turn, goes to the positive terminal of the second No. 467 battery. The two batteries are connected as shown. To keep the

Fig. 409. Sturdy rubber bands hold batteries to the case.



unit so it can be hand-held, the two larger batteries can be fastened on the back of the case with rubber bands (Fig. 409).

### **Obtaining a license for radio control**

First, to get a license, *you must be a citizen* of the U.S. and be *at least 12 years old*. Second, the license is issued for a period of *5 years*, but may be renewed 60 days before its expiration date, by simply sending it to the nearest office of the Federal Communications Commission at that time.

It is *not* necessary to take an examination to get a license for radio control. *It is necessary* to get a copy of *Volume VI* of the *Federal Communications Commission rules*. You can get yours by sending \$1.25 and a letter requesting it to the Superintendent

of Documents, Government Printing Office, Washington 25, D.C.

You can also write to the Federal Communications Commission, Washington 25, D.C., and ask for an *application for license for Radio Control, Class C, Form 505*.

Many hobby shops and manufacturers will send you this application form when you purchase a transmitter and, in this case, you will need to write only for Vol. VI of the FCC rules.

Read Part 19 of Vol. VI *carefully* and then fill out Form 505. You will note that there is an instruction sheet which tells you exactly how to fill out your form. At the bottom of *some* forms there is a statement, "I certify I have a current copy of Part 19 of the commission's rules." Cross this out and insert, "I have a current copy of Vol. VI of the FCC rules."

Take your Form 505 to a notary public and have him fill out the affidavit that you have read and understood the provisions of Vol. VI. Send the notarized form to the FCC.

When you have received your license, you *must keep it* and your copy of the rules with your transmitter at all times, or have it where you can get it quickly. That's all there is to getting a license for radio control operations.

But there are rules that must be observed after you get it:

The maximum power that may be transmitted is 5 watts input for five of the channels (26.995, 27.045, 27.095, 27.145 and 27.195 mc). The sixth channel (27.225 mc), 30 watts is the maximum. The frequency tolerance if 5 watts or less is used is 0.005%; if less than 3 watts input is used (which is the case with commercial transmitters), it is 0.01%.

You may not use your radio control transmitter to send *voice* signals, but you can send tones (or have the signal modulated) when adjustments for brief tests or adjustments to the transmitter are being made; and when the station is being used to control models actually in operation, such as a model aircraft in flight.

These are not all the provisions of Vol. VI, but they represent some of the important points. What it all means is that you *must* get your license, you must *not* give this license away or sell it or assign it to anyone; that you *must* use a transmitter which meets the requirements of the Government — we assume that all manufactured transmitters do this — and, finally, when you are out radio-controlling, you should have a portable broadcast radio or car radio which is tuned to a local broadcast station so that, if a Conelrad alarm is sent out, you can immediately stop sending radio-control signals until the all-clear signal is broadcast.

# 5

## the receiver

Now that we have our transmitter ready to operate and understand how to use it and care for it, we are ready to discuss the receiver which picks up the signal out of the air, and in turn, makes things happen inside the model to steer it. We can send signals to make the model run, start and stop or change speed from fast to slow. It is possible to make a model car or boat go forward or back up.

The receiver used in this text as an example is similar to many other types which you might buy. It comes to us as shown in Fig. 101 in Chapter 1. It is in a neat plastic case which has a tuning knob on top, one lead all by itself which we connect to the receiver antenna, and a number of wires coming out the other end and connected to a plug. This cable, as we call it, makes possible the connections to the batteries and also the connections which have to be made to servos or escapements and their batteries.

Notice, back in Fig. 101, that right next to the plug at the end of the cable is a socket. We connect the batteries to this socket, and the receiver is connected to the batteries by putting the receiver plug into the socket. With this arrangement, it is easy to: disconnect the receiver whenever we want to, to use it in another model; take it out for inspection, adjustment or for storage, without having to take out all the batteries and other wires which interconnect the radio-control parts inside the model.

We can use similar sockets in several models so that changing the receiver from one to another becomes quick and easy. We

just unplug it, put it into another model and put the plug into the socket of that model.

We are not furnished an antenna for the receiver as we were with the transmitter. The receiver antenna does not have to be so exact in length. Any piece of flexible insulated hookup wire will do. Piano wire or aluminum tubing can also be used. The length can vary between 12 and 15 inches. The lengths used with other types of commercial receivers may be longer or shorter, but usually the manufacturers state in the instruction sheets furnished with their sets what lengths to use.

The next step in preparing the receiver for operation is to connect the batteries to the socket. Other types of commercial receivers may not have a plug. The wires are there and each one is a different color. The instructions tell you which wire to connect to which terminal of the batteries and which wires go to the steering equipment. In this case, you yourself can connect these wires to a small plug which can be bought at hobby shops or radio parts dealers. You can obtain sockets for these plugs at the same time. Connect the wires to the plug pins by stripping back the plastic (or other insulation) from the ends, running the bare part of the wires down into the plug pins and soldering the ends to the pin where they come through the other end.

Fig. 501 shows the receiver case opened and the parts contained inside. Note the relay, with its coil, normally open and normally closed contacts, and the tension spring. Below the base is the single radio tube which operates the relay when a signal is received. To the left of the relay is the coil which tunes the receiver to the transmitter. This tuning adjustment is made at the factory and we do *not* change it in any way. At the far left is a shaft, connected to a small variable capacitor (this is the shaft that the little knob is connected to). We adjust it to make our receiver operate correctly. The wire lead going up through the case from this capacitor is the antenna lead which we can use, as is, for short-distance operation and to which we add the 12 - 15-inch length of wire when we radio-control a model boat or airplane over long distances.

### **Connecting batteries to the receiver socket**

We connect the batteries to the receiver socket as shown in Fig. 502. Notice that three kinds of batteries are used: three small hearing-aid type B-batteries of 22.5 volts each; one medium-size flashlight cell; and two penlight cells. The B-batteries and flashlight cell operate the receiver, while the penlight cells are required

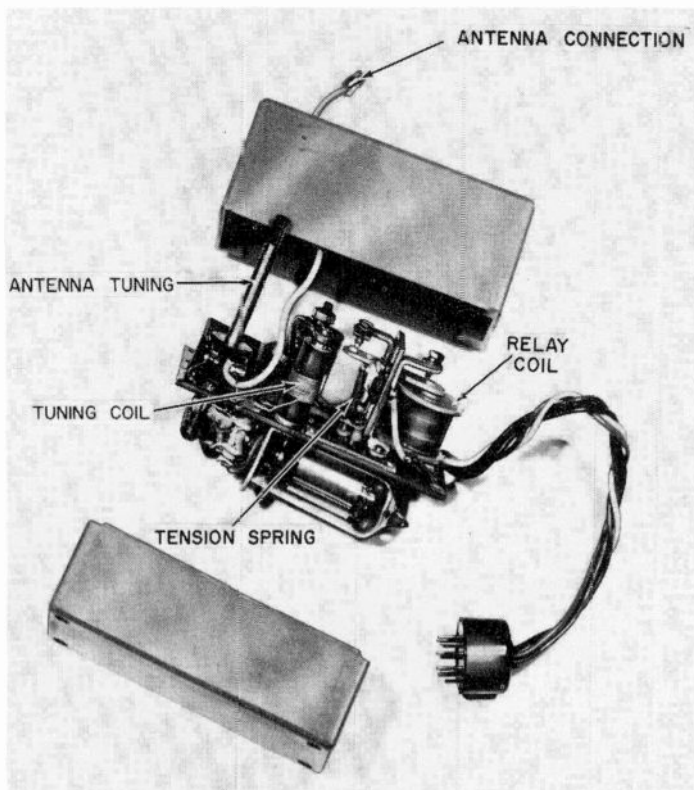


Fig. 501. Radio-control receiver with case removed. A plug is used to disconnect it from the batteries.

to make the pilot light glow when we send a signal to cause the relay to operate. We also insert an off-on switch in the wiring so we can turn the receiver on or off.

In connecting any receiver to its batteries, be very careful to make the connections properly, otherwise you can burn out a tube or ruin a transistor (if transistors are used). Study the instructions furnished with the receiver very carefully until you understand exactly what is to be done. In this case, since we are connecting the batteries to the socket, look at the base of this socket as shown in Fig. 502 and identify the two widely spaced lugs (lower left). Sockets like this are numbered starting from the wide-spaced pin on the left, which is 1, and going around clockwise, 2, 3, 4, 5, 6, and 7. These pins are identified in Fig. 503.

Since the three B-batteries must be wired in series (plus to minus), we do this first, using a small 35-watt soldering iron and then wrapping them with tape to keep them together. The plus

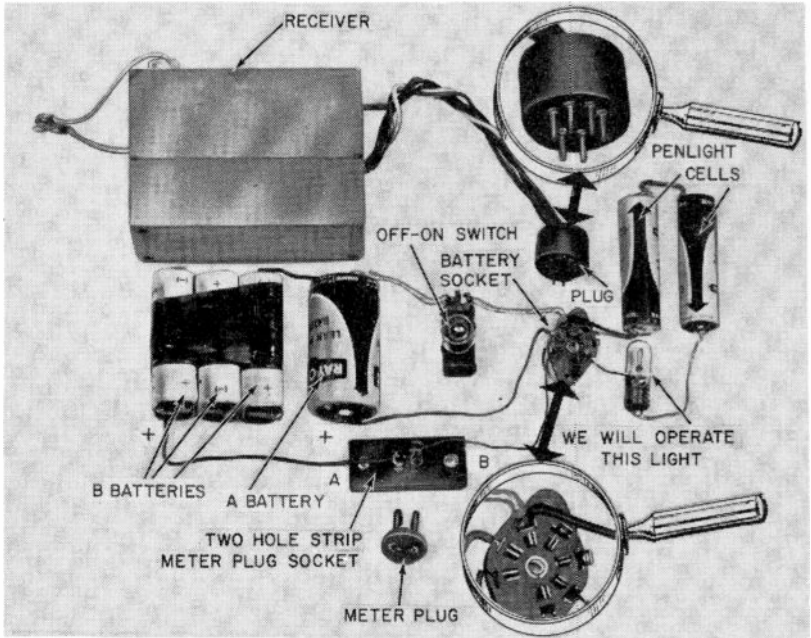


Fig. 502. The A- and B-batteries constitute our receiver power supply. We need the penlight cells to operate the pilot light. We are going to connect a test meter to the receiver by means of a meter plug inserted into a two-hole meter plug socket. The pilot light and the meter are used to give us information on how well the receiver and its relay work.

lead connects to the larger terminal (A) of the two-hole strip, and the smaller pin (B) is connected to pin 1 of the socket.

The minus terminal of the B-battery string is connected to the minus terminal of the flashlight A-battery and the wire goes right on to one terminal of the switch. The other switch terminal is connected to pin 3 of the socket. Note that a second wire is also connected to pin 3 and this goes to the minus terminal of the penlight-cell string.

The plus terminal of the flashlight A-battery goes to pin 2 and the lead from the pilot light to pin 6. The batteries are now all connected, as is the pilot light and its battery, and all we have to do to operate the light (turn it off and on) by radio signals is to fit the receiver plug into its socket, insert the meter plug, adjust the receiver tuning knob and send signals by depressing the transmitter keying button. The circuit diagram of the receiver is shown in Fig. 503 for those who would prefer to examine the connections this way.

A word of caution: when soldering these connections, be sure



to use a *rosin-core* solder. An acid-core solder will ruin your set. Is soldering a new operation for you? In general the tip must be tinned and kept clean. To tin a tip file or sand the flat soldering surfaces until they are smooth and shiny. (Some tips are plated and should not be filed—ever.) When the tip is hot enough, rosin-core solder should melt rapidly and flow smoothly over the cleaned tip. It might be necessary to repeat this for any spots that do not cover with solder.

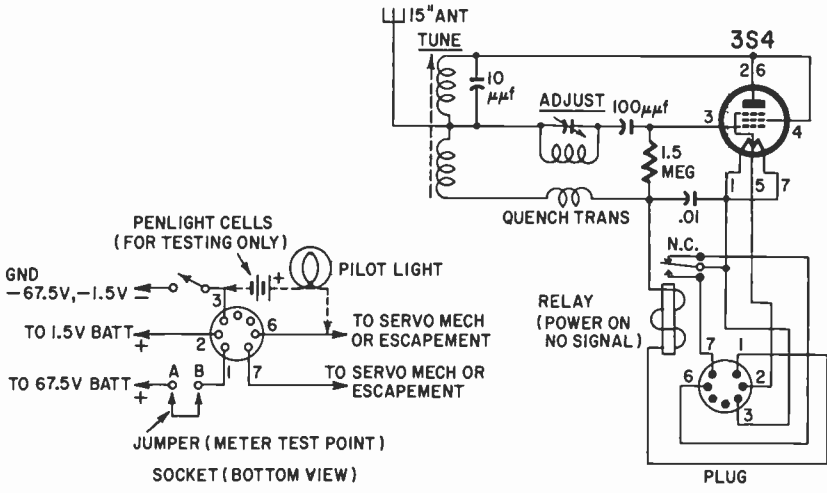


Fig. 503. Schematic of a typical superregenerative receiver used for radio control.

To solder, hold the tip of the iron against the joint or connection to be soldered. The tip must be wet with solder (not just tinned and wiped clean) for best heat conduction to the joint. When solder from the tip starts to flow into the joint apply solder to the top of the joint. Remove the iron and do not disturb the joint till the solder cools and hardens.

A good wire to use in making these connections is the multi-colored, flexible, stranded wire (about 20-gauge) which is sold at most hobby shops. *Do not* use solid wire such as we used in our earlier experiments.

**Adjusting the receiver**

We need our test meter to adjust the receiver (Fig. 504). Set the switch to on (or use a meter with at least a 5-milliampere (ma) scale). Put the plug into the two-terminal socket (A and B in Figs. 502 and 503). Turn the receiver switch to on and the meter

needle will rise. It may read anywhere from 0.2 to 0.4 on the scale.

When you put the receiver plug into the socket, with the receiver switch off, the pilot light suddenly lights up even though the receiver is off. This is as it should be. The light goes out as soon as we adjust the receiver, and then it lights up only when we send signals. The reason for this is that the pilot light is connected to the *normally closed* relay contact (which connects the light to the minus terminal of the penlight cells). The other lead of the pilot light is permanently connected to the plus terminal. When we turn the receiver on the relay is energized. This breaks the circuit, causing the light to go out. When we send a signal to this kind of receiver, the relay *de-energizes* rather than energizes, and, each time it de-energizes, it causes the light to glow.

We now turn the receiver knob clockwise till it's tight—not too tight, but firm. Back it off slowly, turning it counterclockwise. When we turned the knob clockwise, the meter needle dropped to a reading of about 0.2; now as we turn the knob in the opposite direction (counterclockwise), suddenly the meter needle jumps up to about 0.4 on the dial. We remove our hand from the tuning knob and the needle may stay where it is, which is fine, or it may drop back down, or it may jump back and forth between the 0.2 and 0.4 readings. In the last two cases, turn the knob back (counterclockwise) just a little bit more, take your hand away and keep doing this till the needle *stays* at the higher reading (0.4).

The receiver is now ready to be operated by the transmitter. Now, each time you key the transmitter, the meter needle drops to about 0.2 and rises when the keying button is released. This is the correct indication of receiver operation.

If you have made the connections to the pilot light indicated in Fig. 503 — a lead from pin 3 of the socket and pin 6 to the light and batteries — the light glows when the key is depressed and goes out when it is released. When you turn the receiver off the light burns and you *unplug* the receiver to make the light go out.

Pick up the transmitter, put its antenna in place and walk away, around the room or out of doors. Have a friend watch the light to see if it keeps going on and off as you key the sending button. Operate it till you get the feel of sending signals. Try adjusting the receiver again with a 12- to 15-inch antenna till you are sure just what length of antenna works best. In this way, you become thoroughly familiar with your equipment and how to adjust it quickly and surely for the best operation, before trying to radio-control anything.

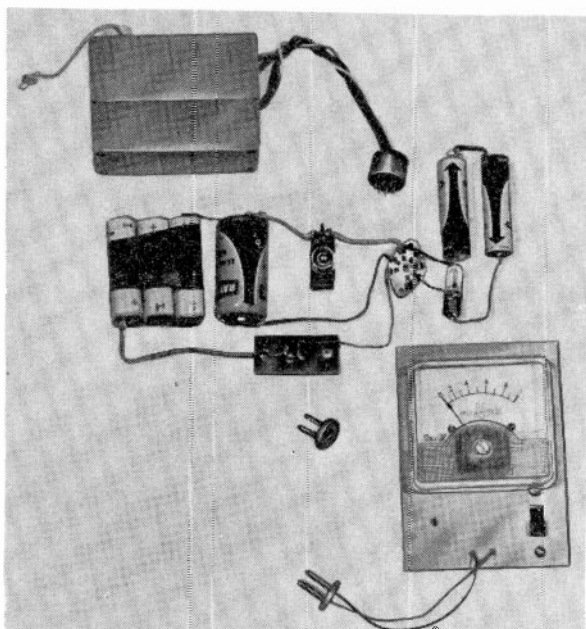


Fig. 504. Test meter plug is to be inserted into meter socket. Be sure to remove the jumper from across points A and B shown in Fig. 503.

## Possible receiver troubles and cure

Usually, with manufactured radio equipment, the troubles encountered by the beginner are those which are of his own making. Or to state it even more bluntly, if your equipment does not operate as it should when you hook it up, do not immediately conclude that it is the fault of the equipment and start to take it apart and make adjustments in it.

Looking for and isolating troubles is a thoroughly methodical procedure. There is always a place to start and certain things to do and check, step by step until we find the cause of the trouble. Let's run through a typical procedure.

The first step, with any radio-control equipment, is to determine what it is or is not doing. You laugh and say, "It isn't operating, any one can see that." True — but *just what is it doing?* If we have our test meter connected into the two-pin socket, we turn to it for our first check. Is it reading at all? Is it possible that its leads are reversed and the meter is reading backward? Carefully we check this item. Now suppose there is no reading at all, so we have nothing to go by.

Our next check is to inspect every bit of our wiring to be positive that each connection is made correctly, that we have not shorted pins on the receiver plug or socket, and that there are no broken wires. Sometimes we find that we do not have connections at points where we have soldered wires to lugs or batteries. The rosin in the solder forms an insulating layer inside the joint but there is no electrical connection. Don't forget to scrape the insulation or covering from the wire and solder over the insulation. The joint can look perfect, it can be stuck together strongly and yet there is *no electrical connection*. Sometimes, when we put the wiring together, everything is fine and then we move it around and break a wire which we do not notice. *Check your wiring carefully, resoldering every joint if necessary! Be positive that electricity can flow through your circuit!*

In most cases, this produces a meter reading. A meter reading is our indication that we *do* have our circuit connected properly.

### **Check the switches!**

Assume you have made this check and there is still no meter reading. Our next step is to check our switches. Sometimes, slide switches move mechanically but do not make an *electrical connection*. Sometimes in using our equipment in the field, dirt gets into these contacts or, in constructing our model, we get dope or glue inside which makes the switch fail. In one case the slide switch would move all right, but it hit the end of a large nut and couldn't go the full distance required to make an electrical connection. The switch was the last part suspected of being bad.

We can check our switches very simply. Get a short length of wire and clean the insulation off the ends. Use it as a jumper; that is, put one end to one lug of the switch, hold it there and then touch the other end of the wire to the other switch terminal. Watch your meter when you do this. If the meter needle moves, you have a bad switch and it should be replaced. Jump every switch with short pieces of wire during this test check if necessary, leaving the jumpers in place until you have definitely run down the source of trouble.

### **Testing batteries**

The third most important check is that of the batteries. Are they connected properly, the plus to minus, the terminals to the wiring? Are the batteries good?

The best test of the batteries you are using is to have someone (if you can't) measure the voltage of each battery while it is in the circuit. If the battery gives no reading, *immediately disconnect it!* Measure the battery out of the circuit and, if it gives a reading, you may have made a mistake in the wiring, the insulation is broken or scraped away and you have a short. If you are using the circuit of Fig. 503 with your jumper wire across the two-pin socket, and the flashlight bulb stops burning, you can suspect trouble with your test meter or a broken test-meter lead.

Not until all these points have been thoroughly checked should you even think of examining the equipment itself—receiver, transmitter or other device which you have purchased. But if all these check out OK, then it is time to look at the receiver proper *with the utmost* caution.

### **Testing tubes and transistors**

Do not attempt to take the *transmitter* apart. Very carefully remove the covers from the receiver. If it has tubes, remove them and have them tested by a competent radio service technician. Some tubes such as the flat hearing-aid types (1AG4, 6007, 5676, etc.), may not fit his tester, but he can tell you whether they are burned out. Once in a while, even though a tube may not be burned out or bad, it just won't work and must be replaced.

Some commercial equipment uses transistors and, in general, these are soldered into the circuit. Unless you have had much experience with electronic equipment, *do not* even attempt to check these. If your equipment uses transistors and you have traced the trouble down to the receiver, send it back to the factory. They will check it out for a small charge and you won't ruin it trying to determine troubles which require expensive test equipment to locate.

Notice we have gone to the tubes or transistors only when our test meter *does not read*. If we have a reading, generally these items are all right and we must look to other possible troubles if the equipment is not working properly. It's a funny thing but, when radio-control equipment doesn't work correctly, a person tends to look for the most difficult troubles first, when usually it is some very simple thing.

### **Manufacturers instructions**

Let us assume you have readings near what the manufacturer indicates you should have, but the receiver does not operate when

initial tuning adjustment close to the transmitter so that we could be sure we were tuned to the transmitter before moving away. Now, we must tune the receiver at a maximum range away from the transmitter.

Have your friend hold down the transmitter keying button as you move the receiver away. Retune again for minimum reading (greatest dip) at, say, 50 feet; then recheck at 100 feet, then at 100 yards, then at 150 and again at 200 yards. Generally, if you tune carefully at this last range, you can keep on walking away from the transmitter out to a quarter of a mile or so, and the adjustment will not change. Doing the tuning this way means that the receiver *will* receive the transmitted signal out at the maximum range and prevent loss of signal and trouble later on.

This same tuning procedure also applies to other types of commercial receivers. They may not have the adjust knob as this receiver does, but they all have a tuning screw or slug adjustment. If they operate with carrier-only, as this receiver does, then they have some provision for a meter in the circuit. One difference may be found in some receivers: you may have to tune for *maximum* current reading instead of minimum. The manufacturers' instructions tell you which. Otherwise, there is no change in the procedure.

Of all the possible methods of tuning receivers to a transmitter, the one we like best is to tune the receiver at maximum distance from the transmitter. In this way, we actually find out two things: first, that the receiver *is* tuned correctly and, second, what the maximum range of the receiver is *on the ground*. Knowing the on-the-ground range gives us a safety margin because a slight additional distance is possible when a radio-control receiver is in an aircraft up in the air. Radio signals in the air are not absorbed by surrounding objects as they are when the receiver is near, or on the ground or water.

### **Other possible troubles**

So far we have discussed three main trouble sources: incorrect or faulty wiring; weak or dead batteries; incorrect tuning. Now we will go on to the fourth major cause of trouble—the relay in the receiver.

Relays are delicate mechanisms in one sense and rugged in another. They are delicate because, when they are used in a radio-control circuit, they are balanced like a stick on the end of your finger. If something happens to upset that balance, the relay does

not work correctly. When using commercial equipment, one general rule is: *Don't adjust the relay unless absolutely necessary!* This means don't adjust it or change its adjustments unless *all* other possible troubles have been ruled out, or unless there has been a very hard aircraft landing or other shock which may have affected the adjustments. How do we know when to suspect the relay and what do we do first?

The best indication that the relay might be at fault is when you do have a current change (indicated by your test meter) of nearly or exactly the value stated by the manufacturer, but the receiver does not operate the other control devices. Of course, you first check the wiring and the batteries and eliminate them as trouble spots.

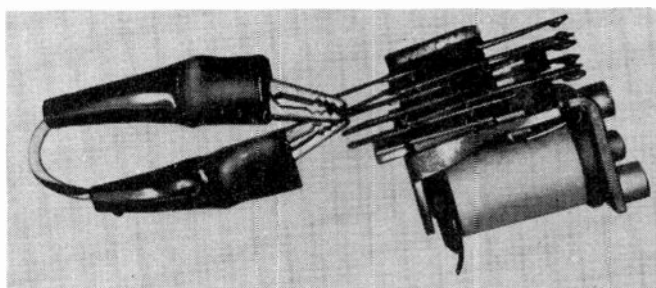


Fig. 506. *Miniature clips on a short length of wire can be useful in checking for defective relay contacts.*

The first point to inspect is the relay contacts themselves. See if dust or dirt is preventing these contacts from closing properly. Using your finger or a small probe of wood, gently push down on the relay armature until it is physically moved enough to touch its normally open contact. You may also test by using a jumper wire across the relay contact lugs (Fig. 506). The equipment should now operate. If it does not, then there is something between the armature and the relay's fixed contacts which is preventing the flow of electricity through them.

### **Cleaning relay contacts**

*Don't grab a file!* Use a thin piece of plain white paper. Slip it between the armature and the contact, press down gently on the armature to exert a slight pressure and then draw the paper through the contacts. This will generally remove any dirt or for-

ign matter from the points. It may be necessary to do this several times and on each side of the armature, between the armature and each contact which it touches. Keep cleaning until you can operate the equipment by depressing the armature with your finger.

There is another possibility. The relay armature may not touch the contact when it is energized. Through vibration or accident, the contact which the armature should touch may have been physically moved so that the armature pulls down against the pole piece but does not touch the *contact!*

### **Do's and don'ts**

How can you tell this? First, a piece of cleaning paper will slide through freely and you will not be able to apply any pressure against it. Second, you may be able to see the space if you look between the armature and the contact in a strong light. In this case, adjust the normally open contact until it touches the armature when the armature is depressed. The armature should *not* touch the pole piece when it touches the normally open contact.

Never adjust a relay tension spring or change the contact spacing *unless you have to*, but if you have to, be certain to mark the original positions so that you can always go back to them if necessary.

### **Spring tension**

The relay in this particular receiver has three adjustments. The spring-tension adjustment governs how much power (current change) the receiver has to have to make the relay close. It also makes the relay armature pull up, drop out or de-energize when no signal is being received. It is possible to have a relay drop out but still have so light a tension that the armature does not press tightly enough against the normally closed contact to make a good electrical circuit. This also must be checked.

The tension adjustment is changed, *very carefully*, if the meter in the receiver circuit drops as it should when a signal is sent but the relay does not operate and you know that there are no broken connections to the relay. If the relay does not drop out when a signal is sent, *increase* this spring tension *slightly*.

If the relay armature does not pull down when the receiver is turned on (or energize in those receivers in which the signal causes the relay to energize), then you must *loosen* the tension a *little*. Notice that we have used the word *little* and *slightly*. These



words mean exactly what we want to say. A half-turn of a relay-tension screw or a very small movement of the lug holding the end of a tension spring can make a big change in the way the relay operates. *Use care when you change the spring tension of a relay!*

### **Contact spacing**

The other two *contact* adjustments control how much spacing is between the armature and the normally open contact and between the armature and the pole piece when the relay is energized. If there is *too little* space between the armature and the normally open contact, the relay can stick to the contacts, or arcing can occur between the armature and the contact, which, in turn, causes trouble. If the armature is too near the pole piece, it can touch it before touching the normally open contact and prevent connection as we have already discussed. Sometimes the armature is so close to the pole piece that, although it does touch the normally open contact, it sticks in the energized position. This happens because the pole piece has become magnetized and holds the armature in the energized position, even though the relay is de-energized.

Once again the spacing of the fixed relay contacts can control how much power (current change) is required to make the relay operate. A small spacing between the armature and the pole piece when the relay is de-energized means a small amount of current can operate it. A large spacing here means a larger current is required. Also, if the spacing is too close to the armature and pole piece, the relay can stick unless the current through the relay is zero or almost zero when we want the relay to de-energize.

Two general types of relays are found in radio-control receivers (Fig. 505). Notice the difference in construction and location of the NO and NC contacts, and the location of the tension springs. The general methods of adjustment and tuning which we have discussed apply to all types of radio control receivers, with the exception of those which have only one main tuning adjustment (no knob) and those which use a transistor instead of a relay. In tuning the one-adjustment type use an alignment tool in the same way we described, and for the second type there are no relay adjustments to make.

### **Tubes or transistors?**

A frequent question when we consider the various sets available is "Which is best, the tube or the transistor type?" *Both types* can give *the finest kind* of performance in radio-control systems.

The major difference is that tube types are generally a little larger and heavier, and require more batteries than transistor types.

There are other considerations, of course. For example, the transistor receiver has the transistors soldered in place because they seldom, if ever, have to be replaced. But *all* transistor receivers are affected by heat. In some cases, when a model was taken out into the field and left in the bright sun so that its internal temperature went up, these receivers stopped operating. One cure for this is to place small pieces of dry ice inside the model cabin near the receiver, to keep it cool.

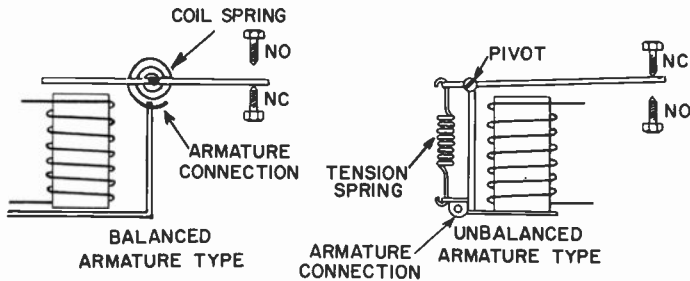


Fig. 507. Relays can have either balanced or unbalanced armatures.

On the other hand, tube-type receivers can have their tubes broken in crackups. When using a tube-type receiver, you must pay constant attention to the A-batteries because, when these get low, the receiver becomes erratic or stops operating. Finally there is the cost. Transistor-type receivers are generally more expensive to buy, but are more economical to operate.

The next question that arises concerns the number of tubes or transistors used. Do more of them make the receiver any better? This is a difficult question to answer. A single-tube receiver, such as we have discussed, can and does give all the performance anyone could desire when it is properly adjusted. However, the single-tube's usually require more attention to adjustments than the others. You might say that with the multi-tube or multi-transistor sets, there is a larger margin for error in adjustments.

### Single- or multi-channel

Another factor is whether the receiver is a single- or multi-channel type. Usually, the multi-channel types have more tubes or transistors and these are necessary to allow for multi-channel operation. A final consideration is the situation regarding patents. If one manufacturer has patented one particular type of circuit,

another manufacturer must use one slightly different. *They all do the job required of them excellently*, and this last consideration is probably why there are so many kinds of radio-control receivers. Regardless of what receiver you buy or build, it has an almost individual personality. You must work with it, adjust it, use it till you know its strong and weak points and, once you know these, you can be sure of success in your radio-control operations.

### **Carrier vs tone**

Another question is, "Which is best, carrier-only or tone-types?" This depends a lot on how you intend to use the receiver; that is, what kind of model you intend to use it in. It also depends on how you use the receiver itself. For example, one problem associated with carrier-only receivers is that they respond to *any* radio signal which is sent out on the same channel your receiver is tuned to. Even lightning can cause them to operate, or sparking from high-tension electric wires or from the motors in the models.

If you change the keying button on the transmitter so that it always *sends* out a signal when it is *not* depressed, and does *not* send a signal when it *is* depressed, you can overcome most of these disadvantages (assuming of course that you have spark filters on the motors in the model). You have to reverse the normal connections to the receiver relay for this kind of operation. The connections that would have gone to the normally open contact now go to the normally closed contact and those which went to the normally closed contact now go to the normally open one. In this case, when a signal is sent all the time, it tells the model that it must go straight, so, if there is interference, the model does not crack up. Since interference normally does not last long, you can depress your keying button and, when the interference dies out, the model turns at your commands.

Tone-type receivers do not, in general, have this kind of problem. Since they need a tone to make the relay operate, static or another carrier cannot operate them. Another tone, however, can cause interference. In some tone receivers, any tone will be satisfactory; in others, a particular tone (or tones) is required. The type requiring very particular tones is the least affected by interference, but we must make sure that *we* are always able to send out just exactly the right tone or we ourselves can't make our receiver operate. Manufacturers of tone-type equipment design their transmitters to match their receivers and to be able to send out the kinds of tones required.

So, in a way, it becomes a matter of personal preference. For model airplane control, when the model is to be flown at great distances, in contests, or at crowded flying fields, we like the tone types. We prefer the carrier types for small aircraft, flying at relatively short distances in uncrowded areas or at flying fields, where all the modelers cooperate with a system whereby no one accidentally tests his transmitter or receiver when someone is flying with a carrier-operated system. The carrier types are also the more economical system.

### **Types of radio-control receivers**

Let us examine, in general terms, the two basic methods of operation currently in use in radio-control receivers—the superregenerative and the superheterodyne—and discuss the electrical circuits used in each.

A superheterodyne receiver is one which is built like your home broadcast radio. It can tune very sharply and separate signals which are very close together. It is a little larger and has many more parts than the superregenerative type. Inside the superhet is an electrical circuit which, like the transmitter, generates a very weak radio signal. This means that, for radio-control types, the superheterodyne must have a crystal such as we found in our transmitter. When we send a signal to this receiver, it picks up our signal and then combines it with the one it produces. The result is a signal which is the difference between the two. In this way, we can build up this *difference* signal more easily than we could the original signal sent from our transmitter.

This difference signal is then made large and powerful by sending it through intermediate-frequency (i.f.) transformers and more tubes or transistors. It is next changed, in a circuit called a second detector, to a signal which we can hear and which can operate our radio-control equipment. The rest of the receiver is the same for either the superregenerative or the superheterodyne type. Superhet receivers normally operate on tones produced in the second detector part of the circuit.

The superregenerative receiver, on the other hand, cannot easily separate signals which are close together. We say it has broad tuning. It does not use a crystal, nor does it require i.f. transformers and extra tubes and transistors to build up the signal. This kind of circuit requires just one tube or transistor to pick up the signal, build it up and convert it (if tones are used) into a signal which we can hear. In a superregenerative receiver, one

tube replaces the many required in the superhet. It has a signal created inside it called a quench signal, but it is not combined with the incoming signal as in the superhet.

Because the superhet tunes so sharply, it is possible for several radio-control fans to operate their models *at the same time*, using different channels. This cannot be done easily with the superregenerative types because, although they are tuned to *one* channel, they *can* receive signals from another. However, the broad tuning of the superregenerative type *can* be an advantage. It allows a larger margin for error in tuning and is less susceptible to impulse-type interference than the superhet.

The chart is an attempt to summarize the major differences between the various kinds of radio-control receivers.

### RECEIVER OPERATION

Receiver	How Operated	Channels
<i>Superregenerative</i>		
(a)*Tube (hard)	Carrier	1
(b) Tube (soft)	Carrier	1
(c) Two tubes or tube plus transistor	Carrier	1
(d) One tube plus many transistors	Carrier or tone	1-8
(e) Multi-tube	Tone	1-8
(f) Many transistors (all-transistor)	Carrier or tone	1-8
<i>Superheterodyne</i>		
(g) Tube	Tone	1-8
(h) Tube plus transistors	Tone	1-8
(i) All-transistor	Tone	1-8

\*The letters identify the same unit through all four charts.

### RECEIVER APPLICATIONS

Physical Characteristics	General Use	Maximum Use
(a) Similar to example	Steering	Unlimited
(b) Smaller tube	Steering	Unlimited
(c) Hearing-aid tube in place of transistor	Steering	Unlimited
(d) Small, flat tube. May have small transformers	Steering; multichannel	Unlimited
(e) Small flat tubes	Multichannel	Unlimited
(f) Very small; no glass tubes	Steering or multichannel	Unlimited
(g) Tubes and small, square i.f. cans	Multichannel	Unlimited
(h) Tube, transistors and i.f. cans	Multichannel	Unlimited
(i) No tubes; small; i.f. cans	Steering or multichannel	Unlimited

## RECEIVER CHARACTERISTICS

Adjustments	Batteries Required (Voltage)	Normal Equipment Used With
(a) Tuning, antenna, quench transformer, relay	(2) 1½, 45-67½	Escapements, cyclic servo
(b) Tuning, antenna, B-voltage, relay	(2) 1½, 45-67½	Escapements, cyclic servo
(c) Tuning, antenna, B-voltage, relay	(2) 1½, 45-67½	Escapements, cyclic servo
(d) Tuning, relay	(2) 1½, 30-45	Escapements, cyclic or non-cyclic servos
(e) Tuning, relays, reed unit	(2) 1½, 30-45	Escapements, cyclic or non-cyclic servos
(f) Tuning (may have relay, may have reed)	3-9	Escapements, cyclic or non-cyclic servos
(h) Tuning, i.f., relays	(2) 1½ and 45-67½	Escapements, cyclic or non-cyclic servos
(g) Tuning, i.f., relays	(2) 1½ and 45-67½	Escapements, cyclic or non-cyclic servos
(i) Tuning, i.f., relays	3-9	Escapements, cyclic or non-cyclic servos

In the superregenerative types, a "hard-tube" receiver is one which uses a standard miniature or subminiature vacuum tube. When we say "standard tube," we mean this tube is not special in any way and may be found in other types of radio and electronic equipment.

## RECEIVER SELECTION

Precautions in Use	Relative Cost	Advantages	Disadvantages
(a) Suppress all arcing. Allow for hand-capacitance. Adjust receiver antenna. May have to adjust quench.	\$5 to \$9	Simple, economical, no special transmitter, long life.	Subject to interference.
(b) See (a)	\$5 to \$9	Same as a, but shorter tube life.	Subject to interference.
(c) See (a). Temperature effect on transistors.	\$5 to \$14	Less critical adjustment, longer "soft" tube life.	Subject to interference.
(d) Same if carrier-operated, except	\$15 to \$25	One tuning adjustment. Can tune	None outstanding.

	no quench. Not so critical of arcing if tones used. No hand-capacitance effect.		with earphones if tone.	
(e)	Same except no temperature effect.	\$15 to \$25	One tuning adjustment. Can tune with earphones if tone.	A-battery drain; size.
(f)	Same plus temperature effect.	\$15 to \$30	Fewer batteries; one tuning adjustment.	Temperature.
(g)	May be sensitive to arcing and must be exactly tuned by using correct crystal.	\$40 up	Sharp tuning sensitivity.	Size; battery drain.
(h)	See (a)	\$40 up	Smaller, less battery drain than (a)	Cost.
(i)	Same; may be sensitive to temperature.	\$40 up	Less battery drain than (a) or (b). Smaller size.	Cost.

A "soft tube," on the other hand, is a tube which has been specifically designed for radio control purposes, such as the RK-61 or the XFG-1. These tubes are made with a small amount of gas in their envelopes which makes them work in a special way to operate a relay. The life of this kind of tube is limited.

The life of a soft tube is directly related to how much current passes through it when it is used. One way to look at this is that if the meter reading is high, say around 0.2 on the meter when the switch is on (2 milliamperes), tube life is around 10 to 15 hours of operation. If, however, the current is low, say a reading near zero on the meter, then its life in hours is greatly extended. In many receivers using this tube, a second tube or transistor is used which allows the "soft tube" to be operated at very small values of current.

The general-use column is intended to show how the receiver is generally used in a model. In most cases, only steering is desired, so it is normal to have a single-channel receiver for this purpose.

The next column, however, shows that steering alone is by no means all that can be done with the single-channel receiver. It is possible to connect it to circuits and decoders so that model boats can be made to steer, go forward and backward, move at high and low speeds and have lights turned on and off as well. In model airplanes, compound escapements or servos are used to control rudder, elevator, motor, aileron and even brakes and

flaps with a single-channel system. In each case, however, the more things we do with a single-channel receiver, the longer it takes to do them. For example, in steering we hold the keying button down to steer left, but to cause the propelling motor of a boat to slow down and reverse may take five or six signals.

### The single-channel challenge

One of the biggest challenges to the radio-control enthusiast is to figure out ways of doing lots of things with only a single-channel receiver and to do them quickly and reliably. Innumerable systems have been worked out, but the challenge is always there. Someday, someone will figure out a simple foolproof method of doing a dozen things, in addition to proportional steering, with only a single channel.

Reading the column on adjustments, do *not* get the idea that all these adjustments have to be made each time you use your equipment. As a matter of fact, using commercial equipment, possibly the only adjustment you ever have to make is the tuning, and sometimes not even that. Just install your factory equipment and radio-control to your heart's content.

In some cases, the number of things you can do is marked unlimited. They are, in fact, limited only by the size of the equipment and the weight that the model can carry. Besides the "standard" methods of connecting control devices to receivers, there are others thought out by hobbyists, so any one channel can do many things. For example, if you were to connect a compound escapement in each channel of a six-channel system, each compound can give three control operations—a total of 18 things you can do. Or, if you were to use one channel to step a stepping relay to any one of, say, 22 positions, a second channel to energize that position and a third to cause the stepper to return to the starting position, and if you had six channels, you could perform 44 operations!

There is a very real advantage to using carrier-operated receivers which are connected so that it is the *absence* of signal which results in steering rather than the sending of signals. If a model gets too far away—beyond the range of your transmitter—the loss of signal causes a turn signal which brings the model either back in range or cause it to spin in. If it does spin in, it may crack up, but you do not lose your motor or radio gear as you would in a flyaway. Besides, the radio gear is put into the model in such a way (see the chapter on airplanes) that it is seldom if ever damaged, even though the model cracks up.



# 6

## a radio-controlled car

ONE of the easiest projects for a beginner is to radio-control a model car. The model itself is easy to build and everyone, everywhere, can operate it. You don't have to go to a flying field nor to find a pool of water; you can operate it in the house, in the yard or on the sidewalk. It won't crack up or sink and is not bothered by vibration or water spray.

We use the equipment already described, and the wiring is exactly the same as was shown in Fig. 503 for the receiver except that we use a commercial servo in place of the pilot light. We can make all the wiring connections on a table or bench (Fig. 601) and test everything before installing it on the car frame. To install the equipment we simply lift it all up and set it down on the flat wooden base.

Before discussing the car itself, let us turn our attention to the new item, the commercial servo, Fig. 602. Notice that it consists of the small electric motor, gears, the contact disc and arm which is moved when the servo operates which in turn can move the steering wheel of a model car or rudder of a boat. To see exactly how it operates, study Fig. 603. Two wiper contacts connect to the relay contacts and rest on the two contact discs fastened to the output shaft of the gear train. Connect the relay's armature to the plus end of the series-controlled flashlight batteries. One lead goes to the metal frame, and thus to the output shaft; the other connects to the minus terminal of the battery.

With the relay armature in the position shown, it touches the normally closed relay contact. This connects the battery to

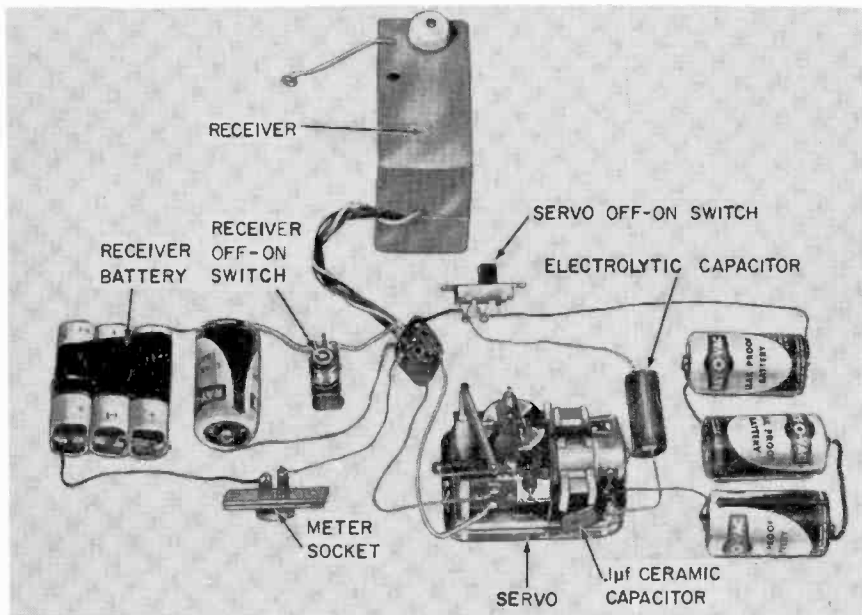


Fig. 601. Bench-check setup allows receiver and servo to be checked conveniently.

wiper 1. Since wiper 1 is resting on the metallic part of the lower disc (B), electrical connection is made through this part of the disc, to the output shaft and through the metal frame to one side of the motor. The other side of the motor is connected directly to the batteries (through a switch which is turned on). So, like the models discussed earlier, the motor turns until wiper 1 slides on the insulated part of the disc (shown in black).

Now upper wiper 2 rests on the metal part of its disc (A); but the relay's armature is not connected to the NO contact, so the motor does not run until we send a signal causing the armature of the receiver relay to move from the NC contact to the NO contact. When we send a signal, the armature changes its position and makes the motor run until the output shaft moves another quarter-turn, which makes wiper 2 slide on the insulated part of disc A. The crank then moves a quarter-turn each time stopping in any one of four positions. Two of them,—the no-signal positions—are the neutrals and the other two are the steering positions, one for left and one for right.

This is the general operation of this and most commercially manufactured servos. Other types may have a different arrange-

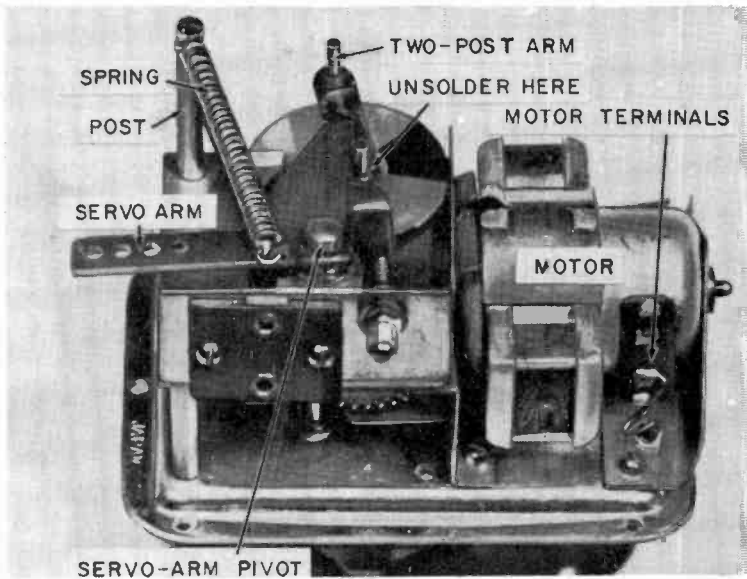


Fig. 602. Commercial servo is sturdy and compact.

ment for the wipers and contacts but, if you examine them closely, you will see the method of operation is *almost* the same. We say almost because there may also be a slightly different arrangement of the gears (or output lever or contact disc).

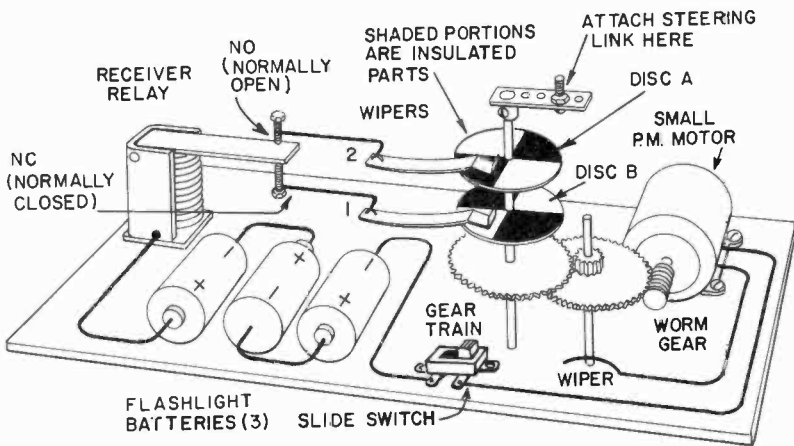


Fig. 603. Pictorial diagram shows the connections between servo and receiver relay.

The servo in (Fig. 602), as you obtain it, however, differs slightly in its operation. When you connect it into the circuit as in

Fig. 603 and depress the keying switch of the transmitter and hold it down, the little arm moves out away from the frame. This would be, say, left. If you release the keying button, the arm returns to the *neutral* position. Now here is the difference in the specific operation of this unit and the general operation we have just discussed. To make the arm move *back* for a *right* steering position, we send the following signal: depress, release, depress and hold the transmitter keying button. We must do this with a kind of rhythm. When we send this signal *with the correct rhythm*, the arm stops in the *back* position, which is the command for the model to turn *right*. It takes a little practice to get the rhythm correct, but it is not difficult and, once you get the hang of it, it's easy.

Now let us go back to Fig. 601 and examine the changes in the original wiring which are necessary to connect the servo to the receiver. Note first that we have added a second switch. This one turns the servo power off so when the receiver is not turned on, the servo does not run down its flashlight batteries (Remember how the pilot light came on when the receiver was turned off earlier?)

The other connections that must be made are not difficult. From pin 3 of the socket, looking at the base and counting in a clockwise direction, a wire goes to one terminal of the servo switch. The other switch terminal is connected by a short length of wire to the minus (base) terminal of a flashlight battery. The plus terminal of this battery is connected to the upper terminal of the servo motor.

Now buy a 0.1 $\mu$ -f paper or ceramic capacitor — 50 to 600 volt sizes are usable; sizes and prices vary — and connect its leads so that one goes to this same upper motor terminal and the other to the lower motor terminal, which is connected to the frame. We also have to buy a 10- $\mu$ f electrolytic capacitor, 6- or 25-volt size. Connect the plus lead of this larger capacitor to the lower motor terminal and the minus lead to the same switch terminal to which our wire from pin 3 of the socket connected (Fig. 601).

Connect a short length of wire to the upper cam contact (A) and the free end of this lead to pin 7 on the socket. Connect the lower cam contact terminal (B) to pin 6 of the socket with an additional short length of wire. That's all there is to it! The rest of the connections are the same as we used when we operated the test pilot light.

To test the servo, put the receiver plug into its socket, insert

the test-meter plug into its socket and set the meter to the on (10-ma) position. Turn the receiver switch on. The meter hand should rise to between 0.3 and 0.4 as before. Turn on the transmitter and depress the keying button—the meter hand should drop to about 0.2 or less. Note that we can use only one section of the transmitter antenna at this time. You should be able to hear the receiver relay click if you listen closely when you key the transmitter. If the receiver test-meter reading drops to the low value but does not rise as you key the transmitter, turn the

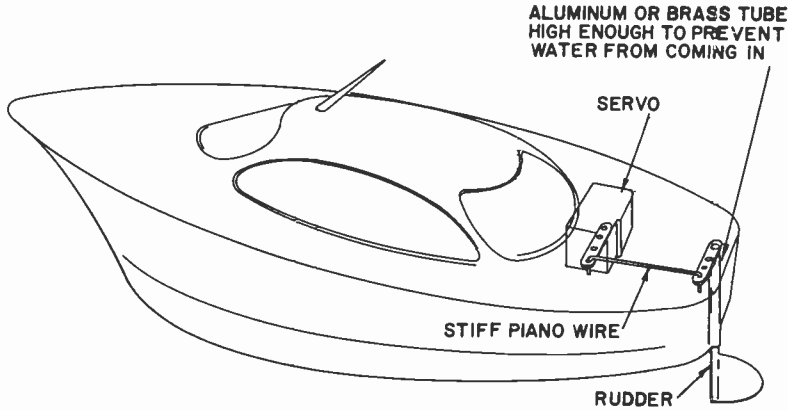


Fig. 604. Servo placement for model boat will vary for each installation. For information on radio-controlled boats, turn to Chapter 10, page 137.

receiver adjust knob a little, till it rises and falls and the relay operates as it should.

With the receiver operating correctly, turn on the servo switch. Normally, the servo arm is in the neutral position and nothing happens. Depress the transmitter keying button and hold it down. Immediately, the electric motor of the servo runs and the arm moves out away from the frame and stops. Release the keying button and the motor runs again, the arm snaps back beyond the neutral position and then moves forward to the neutral position again. Then the motor stops.

Good enough! That is the first command, push down and hold. Let's try the second. Depress the transmitter button, release it and depress it again and hold it down. We want to watch the servo arm as we do this and have our timing so that we depress the keying button the second time just as the arm of the servo snaps back to the second position. Try it. Try it again. It takes a few minutes' practice to get the feel of this operation and to

get the timing correct. If you have difficulty, try counting, "One and . . . two and . . ." If you depress your keying button at the instant you count one, then say the word "and" aloud and release the button after you say this, then depress the keying button on the word "two", your timing will be just about right.

It is very important that you master sending signals with a rhythm. Almost every type of commercial servo (cyclic) and all compound escapements use this kind of command and require this kind of rhythm. Once you have mastered it here, you can operate any other kind easily.

This servo can be used "as is" to steer a model boat (Fig. 604). Just attach a linkage from the arm to the rudder as shown in the sketch. You have to connect the propelling motor of the boat to a separate set of batteries and a switch and start and stop the propelling motor by hand, but you can steer the model by radio control. This is a good way to start in radio control, since you have an uncomplicated system that provides much pleasure.

Right now, however, we are going to build a radio-controlled model car. Also, we are going to make some changes in this servo to get plenty of power to move the steering wheels. We will even be able to start and stop the model by radio commands.

There is a reason for changing the servo. Examine it and you'll see that the little arm is moved in one direction by the force of the pin connected to the silver black disc shaft. In the second position, however, it is spring action that makes the arm snap back. In a boat, where the only force we need to overcome is that of water pressure on the rudder, this is all right. But to move the steering wheels of a model car on a rug, in dirt or on pavement, the spring power is not strong enough. So we make the servo motor furnish the moving power through its gears, and the spring is removed.

We chose this particular model car because you can construct the base frame out of balsa wood, plywood or masonite (as you choose). Being wood, you will not have to worry about short circuits such as you might have with a metal frame. Then, too, the receiver works better inside a wooden model than a metal one with just the antenna wire fastened to the receiver. We do not have to worry about special antenna connections or an additional antenna.

Since we are building the base of wood, there is plenty of room on each side to fasten, with wood screws, any kind of a body you

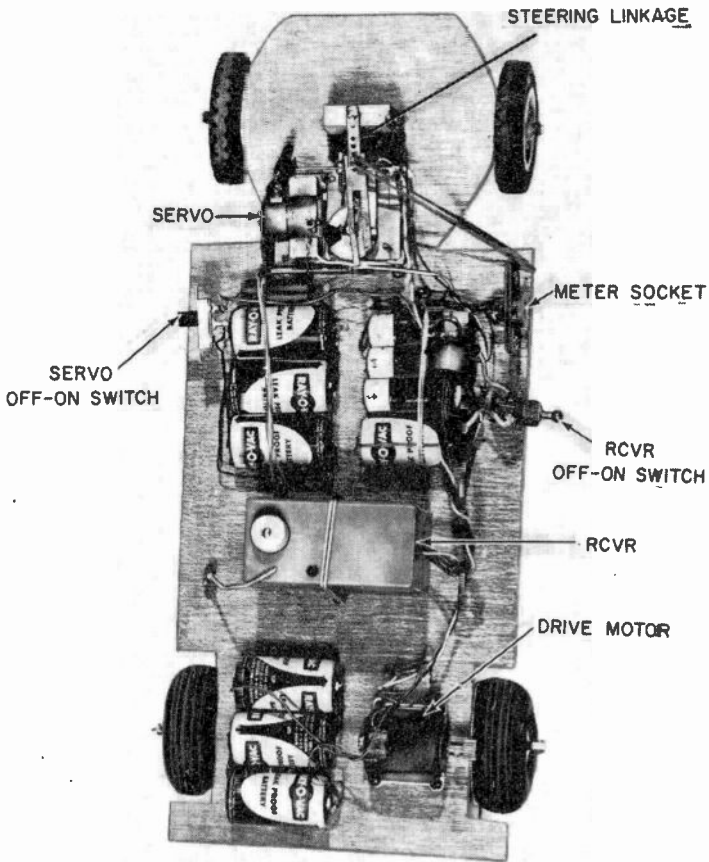


Fig. 605. *Weight of control installation is mostly from the batteries.*

might fancy. You may choose a racing body (and this model really moves along), or you may choose one of the new futuristic body designs and make it exactly to scale—a truck, a bus or even a tank body. The possibilities are unlimited. As a matter of fact, you might have several body frames and change them from time to time for different effects.

Construction is extremely simple yet rugged and reliable, so let's see what we have to do.

We start by referring to Figs. 605 and 606. Fig. 605 shows the completed installation of radio equipment on the frame, and Fig. 606 is a drawing giving the dimensions of the cutouts and major parts locations.

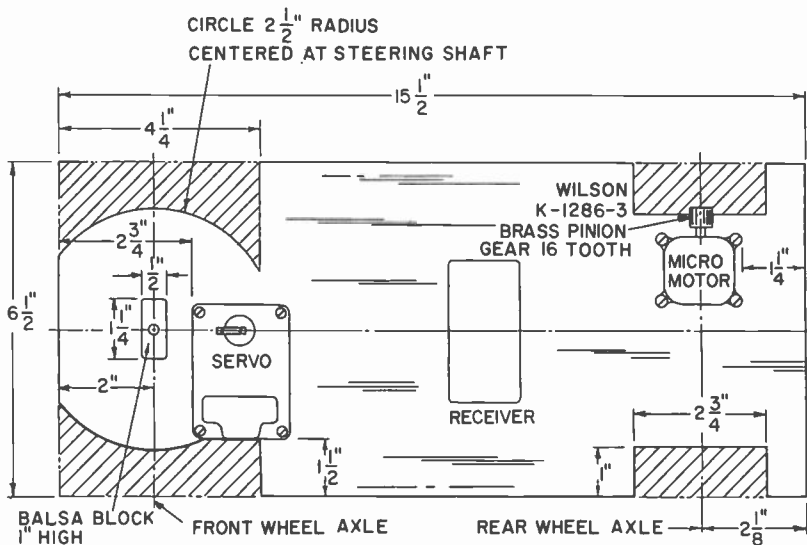


Fig. 606. Simple chassis for car or truck is cut from balsa or  $\frac{1}{8}$ -inch plywood.

You can cut this base out of  $\frac{1}{4}$ -inch hard balsa or  $\frac{1}{8}$ -inch plywood. If you use balsa, you have to glue two 4-inch wide strips together to get the necessary width. Balsa is lighter and the car

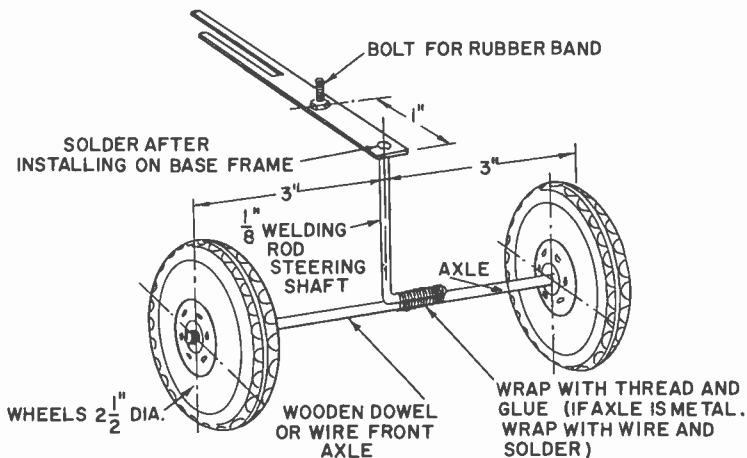


Fig. 607. Front-axle assembly is important. Binding here will make steering difficult.

will perform better than one which uses  $\frac{1}{4}$ -inch plywood for the base.

Locate the steering wheel shaft hole 2 inches back from the



front and exactly centered in the width. With a compass set to a  $2\frac{1}{2}$ -inch spread, use this steering-shaft hole point as the center and draw the two arcs so that they run from the front edge back to a line  $4\frac{1}{4}$  inches from the front edge. Cut out the shaded areas in Fig. 606 for both the front and rear wheels.

Construct the front axle and steering shaft as shown in Fig. 607. Use a wood dowel for an axle. Bind the  $\frac{1}{8}$ -inch welding

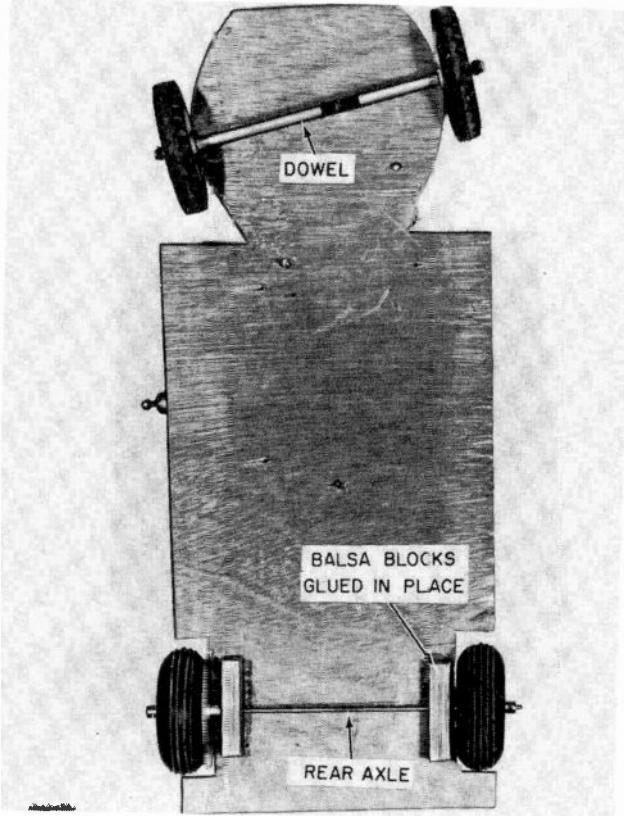


Fig. 608. Underview of chassis shows simple mounting of wheels.

rod to it with thread, then glue the winding tight. Fig. 608 shows the mounting, but first, glue a piece of balsa wood over the steering-shaft hole. This block should be  $1 \times 1\frac{1}{4} \times \frac{1}{2}$ -inch hard balsa. Be sure to locate it as shown in Fig. 606, with one edge directly in line with the end of the servo.

Drill the steering shaft hole through this block, using as a

guide the hole made originally in the base frame. Be sure you get this hole straight and not too large. You can use the steering shaft itself to make the hole by forcing it up with a twisting motion through the base-frame hole into the block. Put the front wheels (which may be any kind so long as they are 2½ inches in diameter and have a rubber tread) on the front axle, then wind thread over the ends of the axle and glue it there to make a wheel retainer.

The rear wheels are type M.S. Airwheels. They can be purchased at most hobby shops and are used because they give us a simpler drive system. These wheels use the same-size shaft that our drive gear requires, which is another advantage.

The rear axle is 1/16-inch piano wire. It is put into place through the two balsa-wood blocks (Fig. 608). The large gear

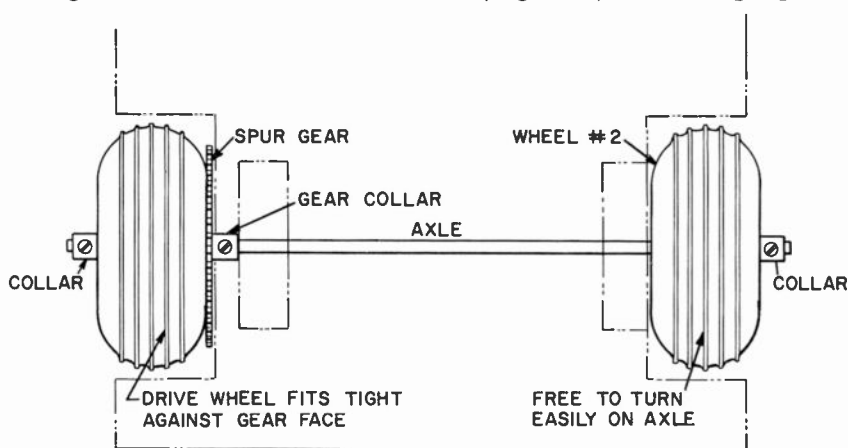


Fig. 609. Drawing shows details of drive system. Spur gear drives rubber wheel by friction between them. Cement is not necessary.

—which comes with the Wilson gear kit K-30700 and which can be obtained through the hobby shops — is part No. K-1288-6, (108-tooth spur gear) and is fastened on one end of the shaft as shown in Fig. 609. Note that the collar of the gear faces the wood block. One of the rear wheels is then slipped on this end of the shaft, pressed tightly against the gear face and fastened there with locking collars provided with the kit.

The second wheel is slipped into place on the opposite end of the shaft and its locking collar is fastened in place about 1/16 inch from the hub so the wheel can turn easily and freely when the shaft is held tight. Fig. 609 shows the details of the rear-wheel mounting.

We can now turn our attention to the servo, the radio and their batteries. The radio receiver is fastened in place in the body center with rubber bands, and its batteries, on-off switch and metering plug are put into position as shown in Fig. 605.

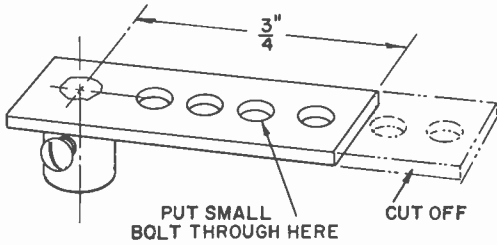


Fig. 610. Servo arm is cut to size before being soldered to output shaft.

They are also held in place with rubber bands. All of the wiring of the batteries to the socket was done earlier and we just lift everything up and put it in place.

Next we must make the necessary changes to the servo itself.

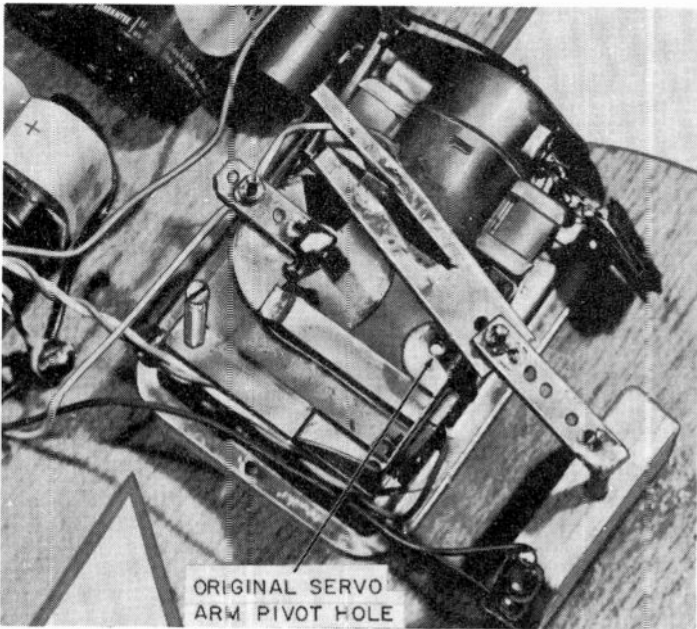


Fig. 611. Servo and linkage to steering shaft installed and connected.

This can be done after it and its batteries are put into position on the car body frame (Fig. 605). The first step is to remove the

spring which is fastened to the post and the servo arm. Second, remove the arm itself from the frame by inserting a screwdriver tip under the arm at the pivot point and twisting until the rivet pulls through the frame mounting lug.

The third step is to remove the two-post arm which is fastened to the silver-black disc shaft (Fig. 602). Heat the soldered joint with a soldering iron and the two-post arm slides right off the shaft easily and quickly.

Now we are ready to make a new arm to fit on this shaft in place of the one we have removed. Take the arm (Fig. 610) furnished with this servo and cut it to the length shown. Insert

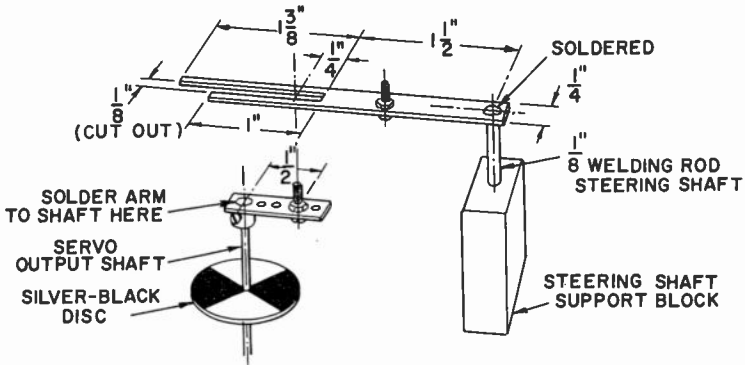


Fig. 612. Details of servo output arm and steering arm.

one of the tiny bolts (also furnished) through the next-to-the-last hole and fasten it tightly in place so the shaft of the bolt extends upward. Fit the arm into place on the end of the shaft, tighten its setscrew and solder it into place. The arm should point directly toward the hole in the frame where the old servo arm pivot was or directly opposite it. Fig. 611 shows the arm in the exact opposite position from the hole. The servo must, of course, have been in its neutral position before we started this operation. We can make sure of this by turning on the receiver switch, with the receiver plugged into the batteries and also turning on the servo switch. Since no transmitter signal is sent, the servo neutralizes if it is not already in the neutral position.

Now the linkage from the top of the steering shaft to the servo can be added. The dimensions are given in Fig. 612. Note how, with the servo at neutral and the steering wheels set to make the model go straight, the steering arm (which may be cut from tin or reasonably heavy brass or copper) is soldered to

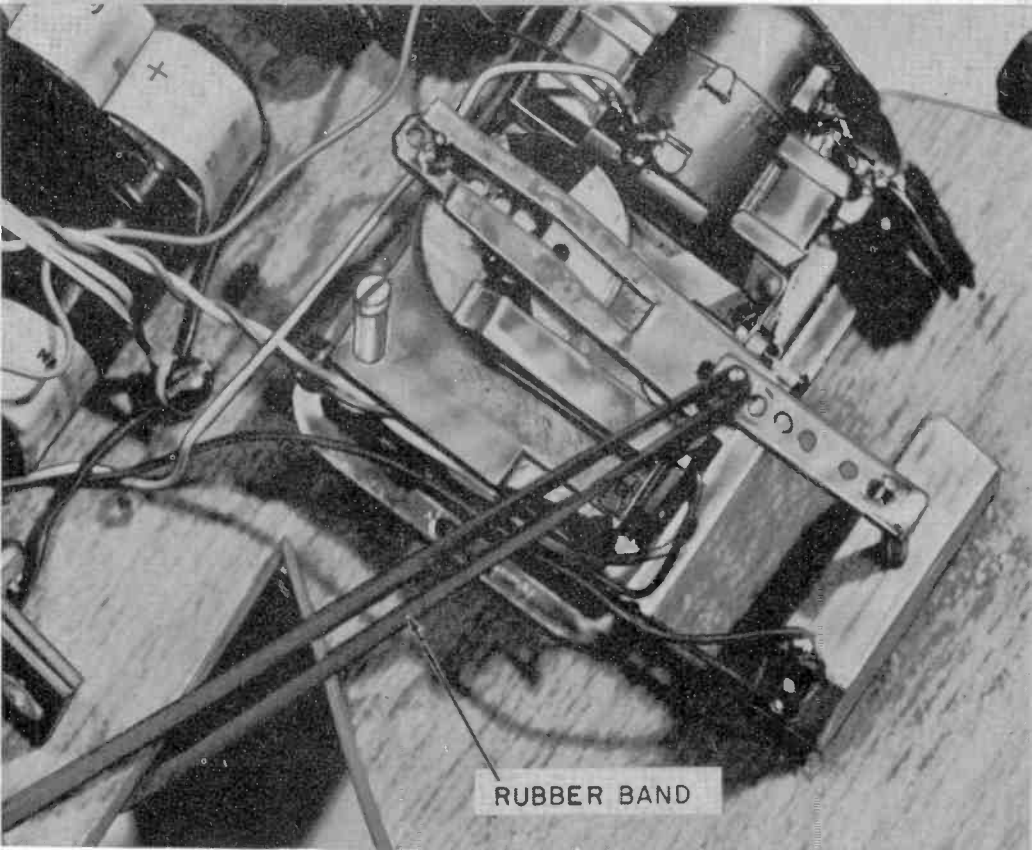


Fig. 613. Rubber band provides tension to return wheels to straight-ahead or centering position.

the top of the steering shaft and so positioned that its slot fits right over the bolt we put in the new servo arm.

Notice that one finger of the fork is shorter than the other. If they were the same length, the shorter one would hit the spring support post which we left on the servo in case we want later to restore the servo to its original operating condition. If you want to, you may cut off the spring support post and make both fingers the same length. Then you would not need the centering rubber band shown in Fig. 613.

Now the operation of the servo is a little different. If we depress the transmitter keying button and hold it down, the steering wheels turn, say, left. When we release the keying button, the wheels straighten out. To turn right, we simply depress the keying button again and hold it down. Releasing the button again causes the wheels to straighten out.

We no longer send one pulse for steering left and two pulses

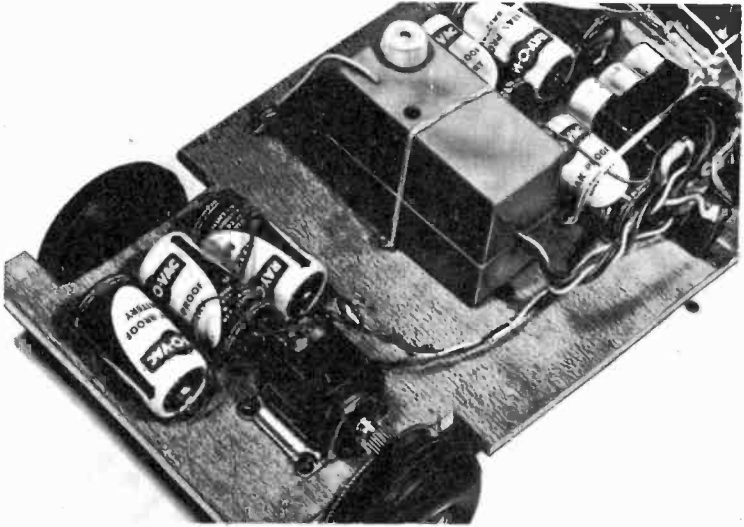
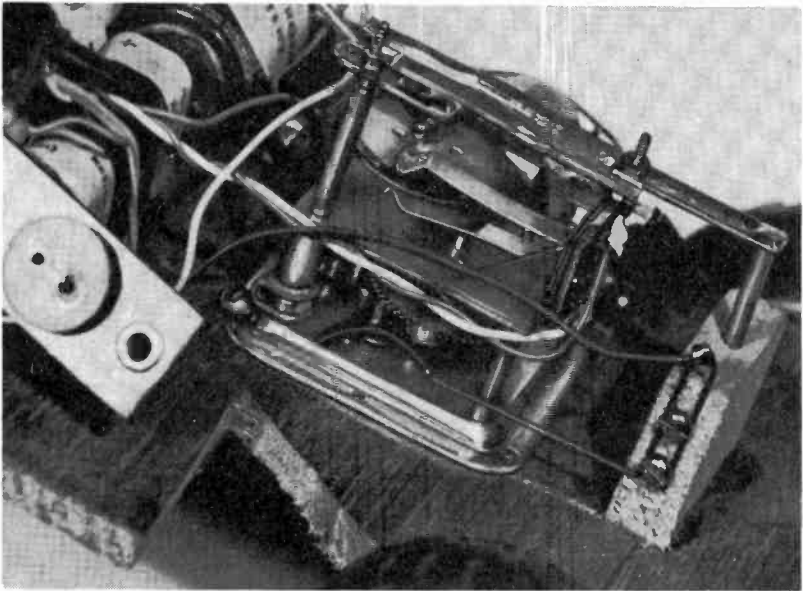


Fig. 614. Three dry cells on the left provide the drive motor with power. Other cells are for servo and receiver.

for right. This servo now acts like a standard, two-neutral escapement. If we had turned left once and wanted to turn left

Fig. 615. Servo steering mechanism mounted in position on the base board of the car.



again, we depress the keying button, release it, depress it and hold it down. The wheels go right and then left and stay in the left position. They move so quickly that the model goes only to the left. This isn't a difficult steering code to master. After a little practice, you will find that you can steer the model easily and surely wherever you want it to go.

Next is the installation of the drive motor itself. Its location and method of mounting is shown in Fig. 605. The motor we used is a powerful, light, reliable type. The motor gear, not furnished with the motor, is a Wilson K-1288-5 pinion gear,

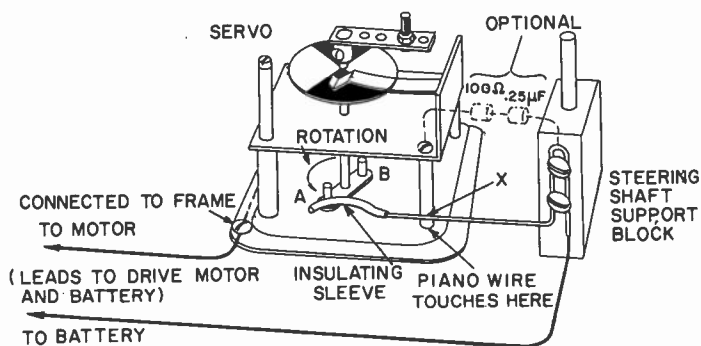


Fig. 616. As servo output arm rotates, pin A or B pushes against insulated part of piano-wire spring, opening contact at X. Optional 100-ohm resistor and series 0.25- $\mu$ f capacitor are used to reduce the spark that occurs when motor circuit is opened.

brass, 16-tooth, 48-pitch, setscrew type. It fits the motor shaft exactly and, when it is in place, is adjusted by positioning the motor so that it meshes well, *but not tightly*, with the big gear on the rear axle. Three medium-size flashlight batteries furnish plenty of power to run the model.

We can now test the drive portion of the model by connecting the batteries directly to the motor and placing the model on the floor. If it runs backward, reverse the motor leads. The weight of the car body and parts on the rear axle make the Airwheel flex a little and, in so doing, it pushes firmly against the big gear for a low slippage drive.

### Starting and stopping by radio command

To add a means to start and stop this drive motor by radio, we now refer to Figs. 614, 615 and 616. On the servo's base plate, attached to the silver-black disc shaft, is another two-pole arm.

When the servo is in the neutral position, this arm is crosswise to the length of the servo. However, we can also position it parallel to the length of the servo when the steering-shaft arm is in its neutral position. These two positions enable us to control the model drive motor.

Make a small spring out of 1/32-inch diameter piano wire, bending the tip of it as shown in Figs. 614 and 616 and covering this curve with an insulating sleeve. The other end of the spring, after bending, is fastened to the steering-shaft block so the spring rests firmly against the servo frame at X, when the two-pole arm is in the normal neutral position discussed previously. Now, if we send a steering signal, the two-pole arm rotates and, as it does, its poles push against the curved part of the spring, forcing it out and away from the servo post at X. We let the servo neutralize normally; that is, we just stop sending signals and then we send a blip or two. Watch the two-pole arm as you blip. It moves just a fraction of a turn each time. You will find that you can stop this arm so that one pole pushes against the spring, forcing it away from the servo frame at X.

One of the drive motor leads is connected to the spring at the steering block, and the battery lead it formerly connected to is connected to the frame of the servo (Figs. 614 and 616). Now let us see how it operates.

If we depress the keying button for a second and release it, the servo moves the steering wheels and then straightens them. The two-pole arm above the servo base plate turns and stops in such a position (crosswise to the length of the servo) that the spring rests against the servo frame. This completes the electrical circuit of the drive motor, and the motor runs. If we blip once or twice, the two-pole arm moves till it pushes against the insulated part of the spring, opening the drive motor circuit, and the drive motor stops. The steering wheels do not move during this blipping signal. To start the drive motor again, we simply depress the keying buttons long enough for the steering wheels to start moving, and then release it. The wheels straighten and the drive motor runs. We can now steer just as we did before, and the drive motor does not stop running till a specific command is sent to it by sending a blip.

It is true that, whenever we send a steering signal, the drive motor circuit is *momentarily* broken, but this happens so fast that we do not see the model hesitate at all. One other fact: you cannot stop the drive motor (unless you put a switch in the





drive-motor circuit or catch the model and disconnect one of the drive-motor leads) *except* by radio command, nor can you start it *except* by radio once you have stopped it. If you turn on your receiver *after* you have turned on the servo switch, the servo operates and the drive motor is energized. Always turn on your receiver *first* when you are going to radio control this model.

Those of you who would like a still faster model can obtain another large drive gear and another motor and small brass gear, and fasten the big gear to the opposite side of the axle and mount the second motor above it. Make sure, however, that you do *not*

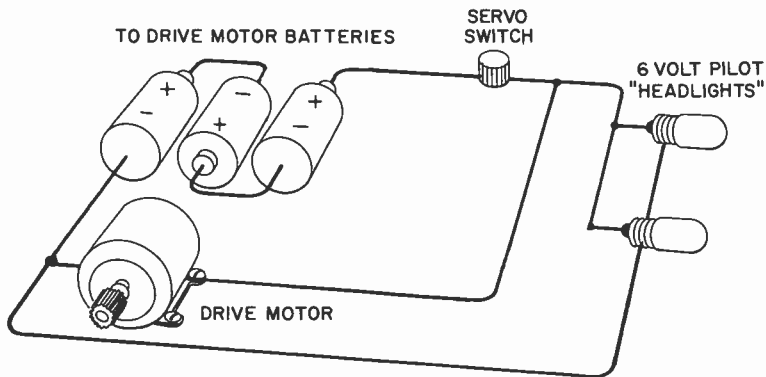


Fig. 617. Pictorial diagram shows addition of headlights to the drive-motor circuit. Lights are on when motor runs.

have the wheel tight against this second gear. You want a tight fit only on one rear wheel. Then connect the wires of the two motors to the battery and switch in exactly the same manner as before.

In operation, we found that the receiver worked nicely without any additional antenna other than the short wire provided with it. Always keep this little antenna away from the other wiring as far as possible.

The car body we used is shown on page 93. It is simply two sides, cut from balsa wood, with end and top pieces glued in place. The lights can be easily added and are wired directly to the motor leads as shown in Fig. 617. The lights glow when the model is running and turn off when it is stopped.

Once, when operating the model, the servo stuck, holding the wheels to one side. We found a little dirt under the relay contacts and, after cleaning them with a piece of paper, had no more trouble.

# 7

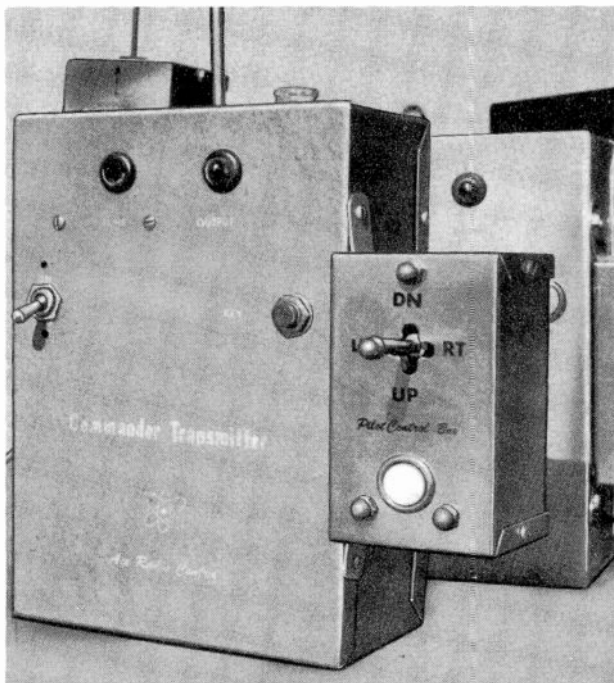
## expanding the basic system

ONE of the fascinating things about radio control is that you are never limited in what you can do. No matter what you want a model to do, there is a way of making it do it. So let us devise a way to make it back up as well as go forward, and also blow a horn.

First, buy two additional parts normally associated with model airplanes; a compound escapement and a standard-neutral escapement. We still use everything that we have in the model thus far.

The compound escapement is the heart of our new control system. It was chosen because it is light, economical and very reliable. We use it as a *decoding* switch, which simply means that it is going to be the part which understands the commands and makes all the other parts in the model operate to make the model obey our commands. The escapements have to be powered with rubber bands, which we must wind up and which run down as we operate. Don't worry about this, though, because one winding gives us a long operating time — so long, in fact, that we probably will stop the model before the rubber band becomes unwound and we can rewind it before starting another radio-controlled run.

Perhaps you are wondering why so much additional equipment is necessary just to be able to do two more things with the model car. The reason is that we have only a single-channel radio system. Generally speaking, the more things that are to be done with a single-channel system, the more the equipment required. With a two- or three-channel receiver, we could use one channel for steering just as we have done, a second channel for nothing but



*Fig. 701. Coder is attached directly to transmitter case. While it restricts the operator's movements it does eliminate cables that may break or fray or interfere with transmitter operation in other ways.*

control of the speed and direction of rotation of the drive motor, and the third channel for operating the lights and horn.

But there is a real challenge in trying to do many things with only one channel. One-channel operation is a real test of imagination and construction ability. The design of coders and decoders can be one of the most fascinating parts of radio control. But let us get back to this system and see how we can add these additional operations. A coder attached to a transmitter is shown in Fig. 701.

First, let us set up some conditions: we want to make the model go forward, and to steer it while it is moving. We want to stop the model. We want to back it up, and steer it while it is backing up. We want to blow the horn, and do not want the model to change direction or speed when we blow the horn. We won't mind, however, if the horn 'bleeps' when we send a steering or motor command.

Now let us examine the compound escapement to the right in

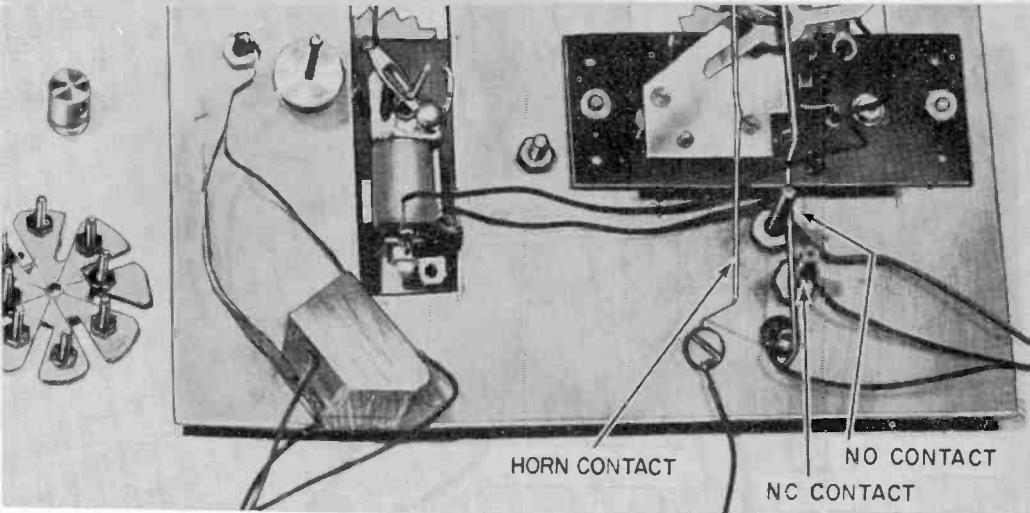


Fig. 702. This compound escapement has four fingers and is capable of being stopped in any of the three energized positions or the one neutral position.

Fig. 702. Notice that there are four fingers, instead of the two in our previous model escapement. Because there are four, the crank can be stopped in any one of four positions. Three of these are "energized" and only one (neutral) is de-energized. The

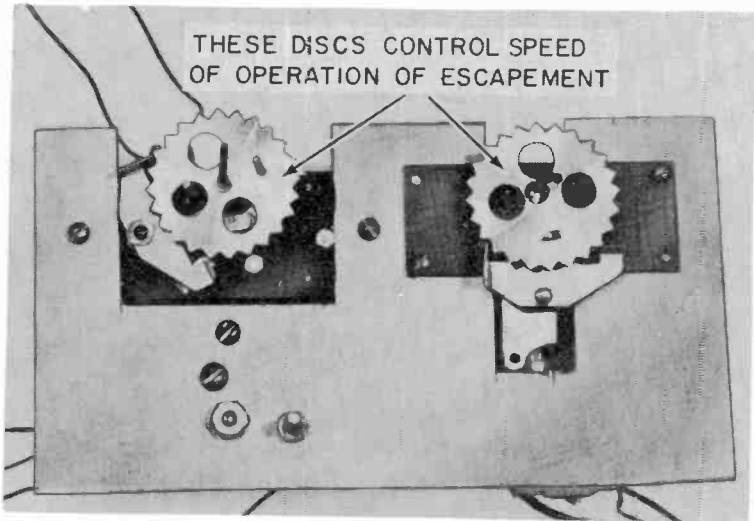


Fig. 703. Toothed wheel and vibrating arm control the speed of the escapement.

three energized positions are left, right and a position so close to neutral that we call it neutral also, but remember that it is an *energized* neutral. In this position, the escapement closes a small

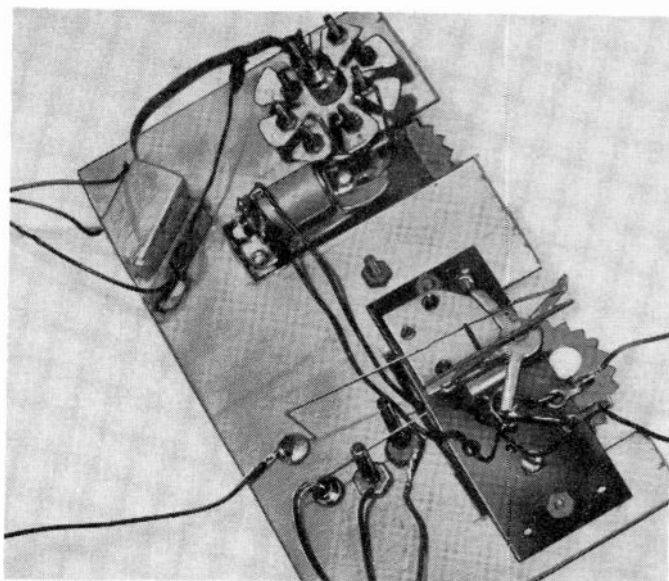


Fig. 704. *Layout of escapement and its connections to servo.*  
*This system allows more control operations.*

built-in switch located under the speed-control gear disc at the left side of Fig. 703.

The method of connecting this escapement to the receiver relay is exactly the same as for the escapement described in an earlier chapter, if we do not care to operate the built-in switch. The signals for operating the escapement are: one pulse, left; two pulses, right; three pulses, closed switch. No signal is *always* neutral. The escapement operates like the servo did before we changed it.

We use the escapement left position to steer our model car. The right position causes the horn to blow, and the energized neutral makes a second escapement (left side of Fig. 703) operate, which in turn, makes the drive motor run forward, reverse or stop.

Because of the changes we made in our steering servo, we can operate it with a switch made from a single piece of piano wire and two bolts. This switch, in turn, is operated by the crank on the compound escapement. Note the wires and bolts below the compound escapement in Fig. 702. Actually, what we do when we add this wire and the two bolts is make the wire act like a relay armature. The top bolt is the same as the normally closed

(NC) relay contact, and the lower one acts like the normally open (NO) relay contact. The wire (in the neutral position of the escapement crank) rests against the top bolt.

With the crank in the neutral position (Fig. 704), the wire touches the upper bolt. We connect our servo to the wires and bolts as shown in Fig. 705. The servo comes to a neutral position

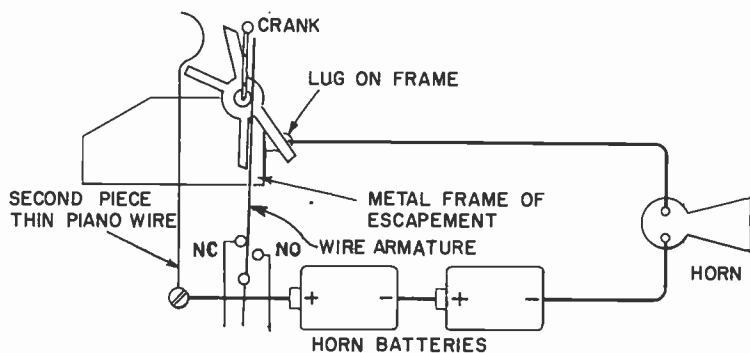


Fig. 705. Basic pictorial circuit for adding electric horn to the control system.

and stops. The model goes straight. (The capacitors must be added to the servo wiring as before (Fig. 601). They are omitted in the diagram for clarity).

If we send a signal by depressing the transmitter button and holding it down, the crank rotates counter-clockwise a quarter-turn and stops. It pushes the wire armature away from the top bolt and over against the lower NO bolt. This makes the servo run, turning the steering wheels to the right. They stay in this position until we release the keying switch.

Releasing the keying switch makes the crank spin around to the neutral (starting) position again, making the servo motor steer the model straight. If we depress the keying button again and hold it down, the crank again moves just as before, moving the wire armature against the NO bolt, but this time the servo turns the steering wheels *to the left*. Releasing the keying button will straighten the wheels. The next time we depress the keying button and hold it down we get right; release and depress, and we get left. We can steer the model just as we choose by watching which way it turns when we depress the button, releasing and depressing it again if the model turns the wrong way. We now have steering, and we have used only *two* of the possible four positions of the compound escapement crank—the neutral and left.

Notice in Fig. 702 that we have covered the top part of the armature wire with a piece of insulation. It can be a piece stripped off hookup wire, model airplane fuel line, or it could be just plain tape. We *must* do this since we do not want the metal of the crank touching the metal of the armature wire.

We can add a second wire, which can be bent slightly so that the metal of the crank touches it *only* when the crank is in the second position. If we do this and connect a small horn (Fig. 705), we can make the horn blow and keep blowing as long as we keep the crank in this second position. We cannot blow the horn while steering left or right, but we can blow it whenever the model is going straight, either forward or backing up. We stop the crank in this second position by sending a depress—release—depress and hold (two-pulse) command. The crank moves so fast that steering is not affected. Of course, the horn beeps each time we send a steering or motor-control signal, but we won't worry about that. If you are running your model before a group of friends, this only adds to their amazement and enjoyment.

So much, then, for the steering and horn-control part of our equipment. Let us now examine the second escapement and see how we can use it to make the model drive-motor run forward, reverse or stop. The wiring of the coil to the compound escapement and of the compound-escapement coil to its batteries and the receiver is shown in Fig. 706.

The way it works is this: When the receiver relay is de-energized by the transmitter signal, the armature rises to touch the NC relay contact. This connects the battery plus terminal through the relay armature, through the normally closed contact, through the off-on switch (this is a second switch, it is *not* the receiver off-on switch) to terminal one of the compound escapement. This terminal is connected to the magnet coils of both escapements.

Since the second terminal of the compound escapement is connected to the battery minus terminal and this terminal is connected *only* to the compound coil and the compound-escapement frame, only the compound coil is energized and its crank moves. This happens in all positions and for all signals except the special one described earlier for stopping the crank in the almost-neutral position. Since the bottom part of the secondary escapement coil has not yet been connected to the battery minus terminal, the secondary escapement has not operated at all.

We are now ready to make the secondary escapement operate.



We depress, release, depress, release, depress and hold down the transmitter keying button. The crank moves to the almost-neutral position. In this position, it closes a switch, the built-in one, which connects the bottom winding of the secondary escapement coil to the frame of the compound escapement. Since the minus terminal of the battery is also connected to this frame, the circuit is complete to the secondary coil and this escapement now operates and remains energized as long as we hold this signal. The crank of the secondary escapement makes a quarter-turn in this energized position. If we release the keying button, the secondary

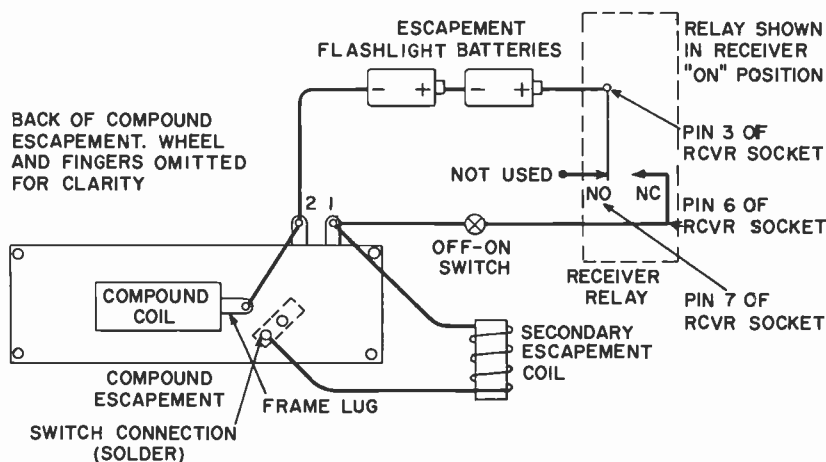


Fig. 706. This diagram shows connections for compound coil, secondary escapement coil, receiver relay and flashlight cells.

and compound escapements de-energize, the secondary-escapement crank moving another quarter-turn and the compound crank just a bit to the starting neutral position.

Now you see how we are going to control the model propelling motor. We will make the motor start and run the car forward with the first half-turn of the secondary escapement, stop on the second half-turn, go backward on the third, stop on the fourth half-turn, the repeat. All we have to do to change the model's direction of movement or to stop or start it is send three pulses for each command to the drive motor.

Examine the slotted wheel with its bolts, the second brass strip switch, and the mounting axle near the left escapement of Fig. 702. These are the parts required. We will have to add a second crank to the finger of the secondary escapement and this can be of No. 20 solid wire. It must be positioned exactly the same

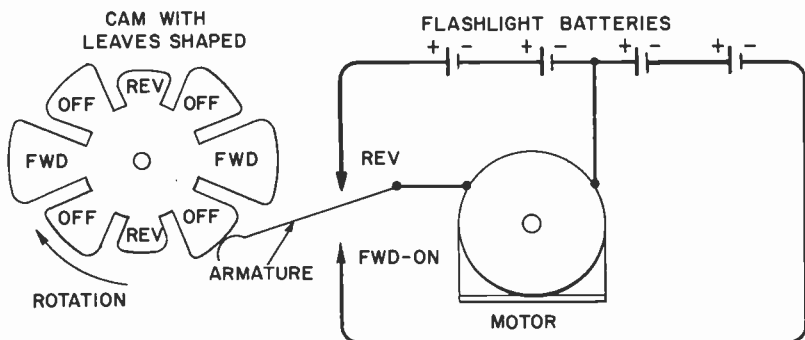


Fig. 707. Cam positions switch for forward, off or reverse motor-drive conditions.

distance from the end that the factory crank is from the other end of the finger (Fig. 704). In this position, when the slotted wheel is placed on its axle, the two cranks just match the slot opening at the edge of the disc.

Here is how the disc works: the top crank (Fig. 704) moves clockwise when this escapement is energized. The crank slides in the slot and pulls the disc counterclockwise a small amount. When the escapement is de-energized, the crank moves to the bottom position, pulling the slotted disc another small amount. The disc then stops, having rotated one-eighth turn, and the position is the same as shown in Fig. 704, ready for another signal. It takes eight on-off signals to this escapement to make the disc move one full turn.

Examine Fig. 707 to see how we use these eight positions. If we make a switch with an armature and two contacts as shown, with the contacts spaced so that the armature can be positioned between them without touching either when the armature is on the off leaf, and, if we arrange the leaves around the disc so that they act like a cam, note what happens: one position of the wheel, as shown in Fig. 707, moves the armature to a position where it does not touch either contact. Since the contacts are connected to the motor batteries and the armature is connected to the motor winding, the circuit is not complete and the drive motor stops. A second signal makes the disc move counterclockwise and causes the raised portion of the cam (FWD) to slide under the armature wiper. This makes the armature move back so it touches the FWD contact, and the model goes forward. The next signal causes the secondary escapement to operate and moves the disc again, bringing the armature to a second off position. The next signal

lets the armature move in closer to the shaft of the disc, this time allowing it, through its own spring tension, to make contact with the REV, or backup contact. The model moves backward. No matter which way it is moving, the next command to the drive motor always stops the model.

Note that we now use two sets of motor batteries and note how they are connected to the motor. Remember the earlier experi-

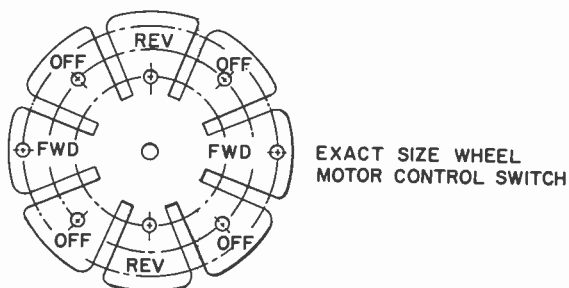


Fig. 708. Easily located holes are used to mount pins, pegs or machine screws which actuate switch arm in either off, forward or reverse.

ment where we were able to make a motor reverse by using two batteries? We use this idea here. The slotted disc of the exact size is shown in Fig. 708 and may be made from aluminum, tin or any other lightweight material. The bolt holes are located on three circles as shown to give the cam effect simply and easily. Fig. 709 shows the completed decoder unit ready for installation

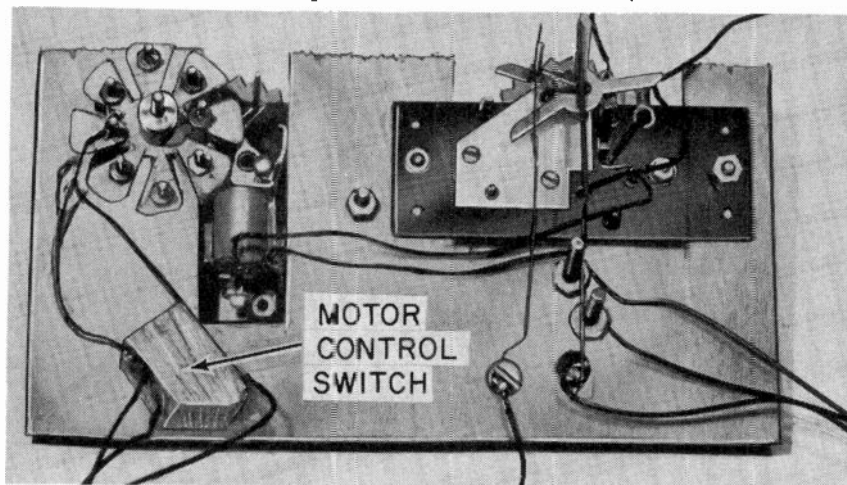


Fig. 709. Completed decoder layout. Escapement is at upper right. Servo with motor-control switch wheel is above motor-control switch.

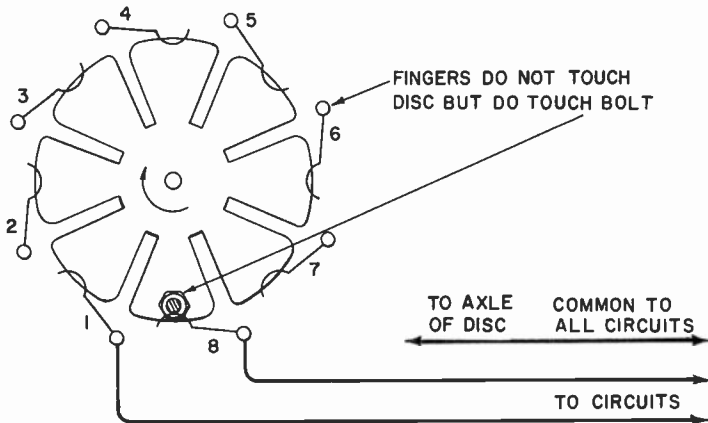


Fig. 710. This disc, driven by a servo, is a practical eight-position stepping switch.

inside the model. Of course, each escapement has to have its own rubber band to furnish turning power for the cranks. The gear-like discs shown in Fig. 703 keep the cranks from turning too fast and make it easier for us to send the right signals to operate the escapements. These are built into the escapements when they are manufactured.

### Another type of motor control switch

The slotted-disc type of escapement switch we have just discussed may also have an application in radio control as an 8-position stepping switch. It might be used with just one bolt and

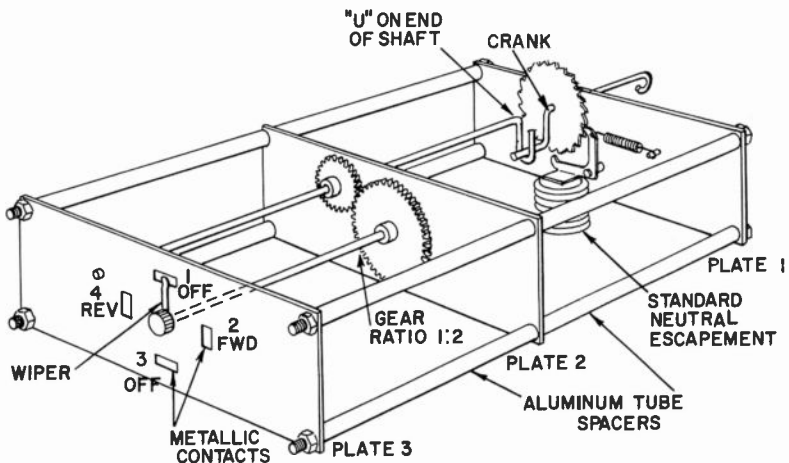


Fig. 711. Escapement-driven switch arm selects one of four positions.

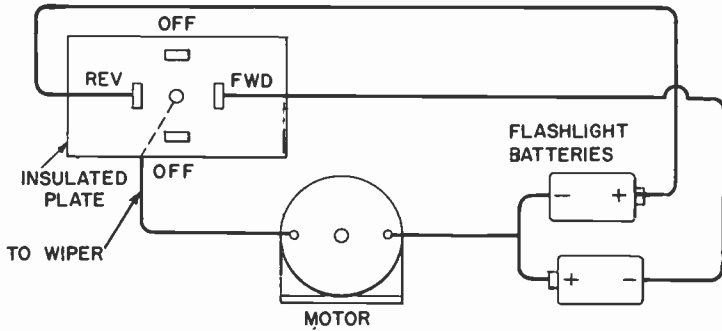


Fig. 712. Connections for escapement-driven switch to control motor by selecting off, forward or reverse positions.

eight metallic fingers, one for each position it stops in, as indicated in Fig. 710. In this case you might want to operate its escapement directly from the receiver instead of from the compound escape-

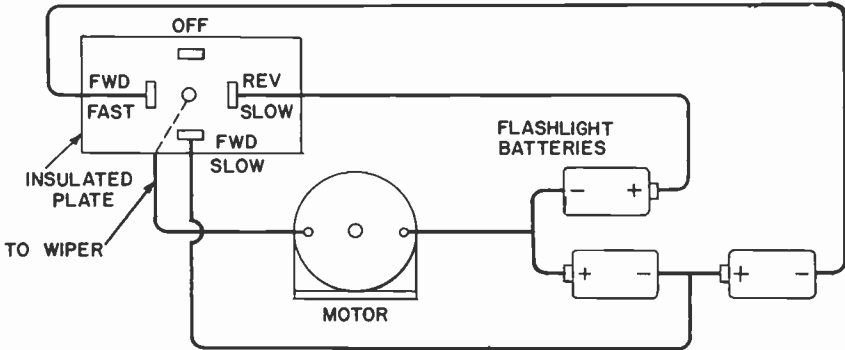


Fig. 713. Additional battery provides a fast forward speed in place of one off position.

ment as we have shown. None of the eight fingers shown in Fig. 710 touch the disc except when the bolt contacts them. In this case, the axle of the slotted disc would be a common connection to eight control circuits.

There is still another way to make a motor control switch so that it does not have the off position after every forward or reverse command. This idea is illustrated in Fig. 711. It uses the same escapement without any changes.

In Fig. 711, a shaft with a small U bent into it is lined up through two plates which have to be bolted to the escapement frame so the shaft is exactly in line with the axle of the escapement crank. The U portion of the shaft slides over the escape-

inent crank so that, as the crank turns, the shaft turns also.

Mounted on this shaft, behind plate 2, is a small gear. The shaft extends on through plate 3, which serves as a bearing only for this shaft. A second gear, just twice the size of the first one, is fastened to a second shaft as shown and so positioned that its teeth engage the smaller gear's teeth. The shaft of the larger gear has plate 2 as a bearing and also plate 3. On the end of this second shaft, where it protrudes through plate 3, a small metallic wiper finger is soldered, and on the face of plate 3 (which should be of plywood or fiberboard or other insulating material) are four metallic contacts.

When the escapement crank makes a half-turn, the big gear makes a quarter-turn and moves the wiper from contact to contact. These contacts may be wired to the motor to produce FWD OFF, REV, OFF, or FWD FAST, FWD SLOW, REV SLOW and OFF (Figs. 712 and 713). Notice that one motor lead must be connected to the wiper shaft. This can be done through another wiping connection which is so positioned that it rests firmly on the shaft of the big gear on the back of plate 3.

### Contests

As you probably know, contests are held all over the United States (and the world, as a matter of fact), in which a persons ability to construct and operate a radio-controlled *airplane* is matched against others. As we consider radio control of our model car, it occurs to us that perhaps contests could be held for radio-controlled model *automobiles*. Contestants could match not only their skill at design of the auto body and type or scale but also the models' speed (racers) or ability to do many things, such as turn headlights off and on, blow horns, open doors, etc. There would be rules regarding driving around a particular course, parking in difficult places, stopping at traffic intersections (models, of course) and so on. It would be quite a challenge to the radio-control enthusiast and model builder and a delight to the throngs of people who could watch the demonstration.

# 8

## the radio-controlled plane

**W**E chose to discuss the radio-controlled car first since, if you construct and operate one, you will learn much about the methods of radio control and methods of sending commands — and any mistake that you might make will not cost you your



*Fig. 801. Loss of control over a radio-controlled plane can result in considerable damage or disappearance of the plane.*

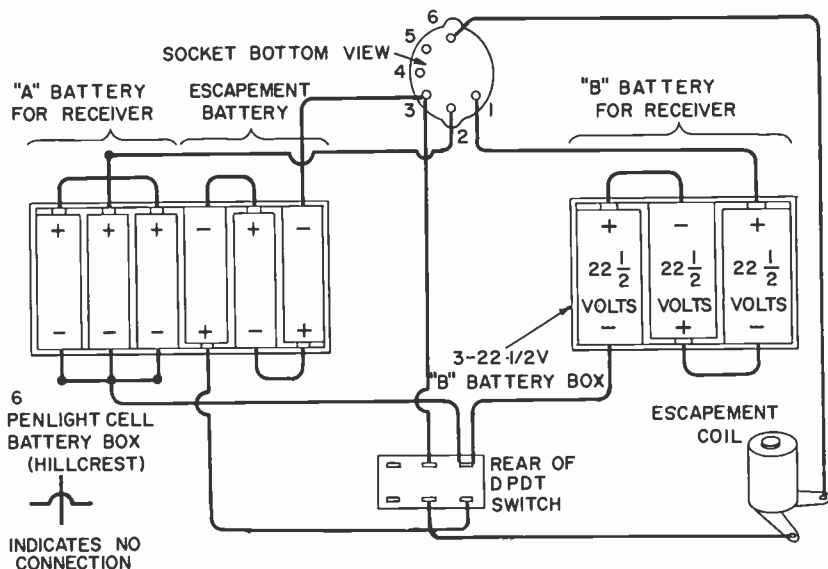


Fig. 802. Circuit for battery box shows connections to receiver socket, switch and escapement coil.

equipment in expensive crackups. Working with a radio-controlled plane (Fig. 801), we have to take many more precautions and exercise much more care in our system to make sure it operates properly.

The first step in radio-controlling a model plane is to select the model. From the types available, we simply choose a style with a big enough wing, so it can carry its own weight and the weight of the radio equipment and batteries we must put in it.

Weigh your radio equipment and batteries on reasonably accurate scales. For example, the receiver may weigh 6 ounces, its batteries another 6, the escapement 2, and the escapement batteries 6, for a total of 20 ounces.

Next select a model and weigh it. This is usually stated on the box or plans. If it is not, then we can make an estimate by taking all the wood, paper, wheels, wires and so forth out of the box, adding the airplane motor to the pile and weighing all these parts. To this total weight, add 10 ounces to account for glue, foam rubber, dope, etc. Add the weight (in ounces) of the model and the radio equipment.

Next, multiply the length of the wing by its width (inches) and divide this number by 144. Take the number resulting from this division and divide it into the total combined weight of the air-



plane and radio equipment. You should come out with a number between 12 and 16, the nearer 12 the better. If the number is much larger, say 18 to 25, the airplane will fly, but would require a large motor, and it would be fast and hard to handle. We want a slow-flying, steady model until we have learned how to steer it and land it.

We start our radio-control installation by first wiring the receiver socket to two battery boxes (Figs. 802 and 803). Battery

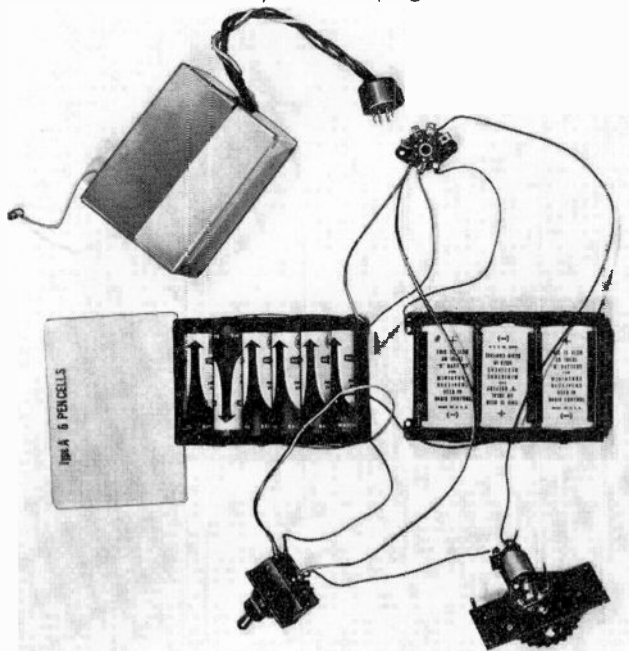


Fig. 803. Photo shows the same battery-box connections as in Fig. 802.

boxes are used because, in an airplane, they make replacement easier and give less vibration trouble. The escapement and switch are also wired at this time. We can test the whole system on the bench by simply inserting the receiver plug in its socket, turning the switch on, and turning and sending signals. The escapement should click each time a signal is sent.

We construct our model leaving the top and the motor section open, as shown in Fig. 804, so that we may install the equipment before finishing the model completely. This way, we can make any changes easily. The installation is simple. All we do is to put the two battery boxes forward and fasten them there with rubber bands or a dowel or two.

The switch can be mounted in the bottom or side of the cabin wall by cutting a small hole to put the switch through and tightening the locking nut in place. The leads to the socket where our receiver connects can be taped together to make a neat instal-

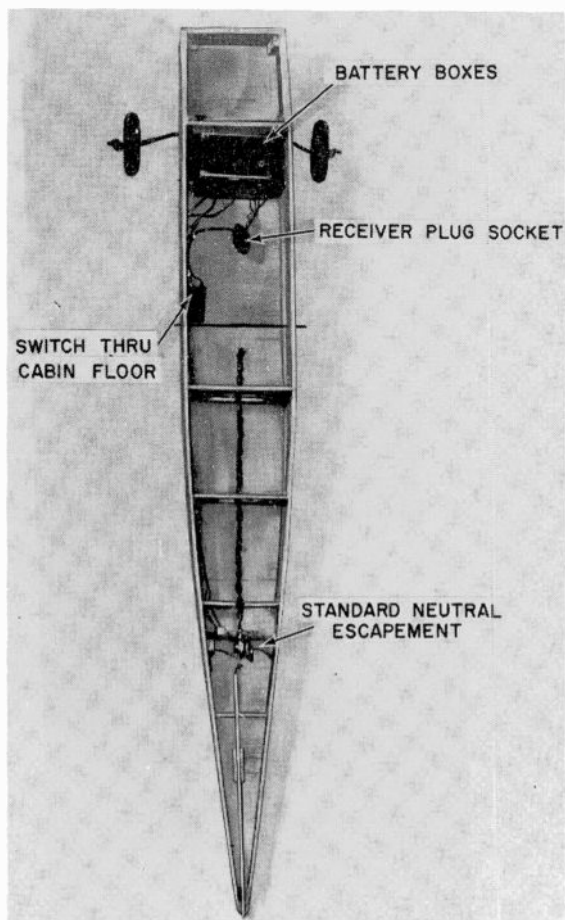


Fig. 804. *With top of plane open, it is easy to install and test the radio control circuits.*

lation. The two leads which go *back* to the escapement run through the partition walls to hold them in place and prevent their jamming the linkages during flights. This makes a quick, simple installation which can be removed easily at any time.

We have chosen the simple standard neutral escapement to

operate our rudder in our first flights. It causes no interference to the receiver, is lightweight and reliable. Figs. 804 and 806 show how the escapement is mounted in the body by mounting it on two 1/2-inch-square uprights glued to the body sides so that its crank points toward the tail. Now we must buy a piece of

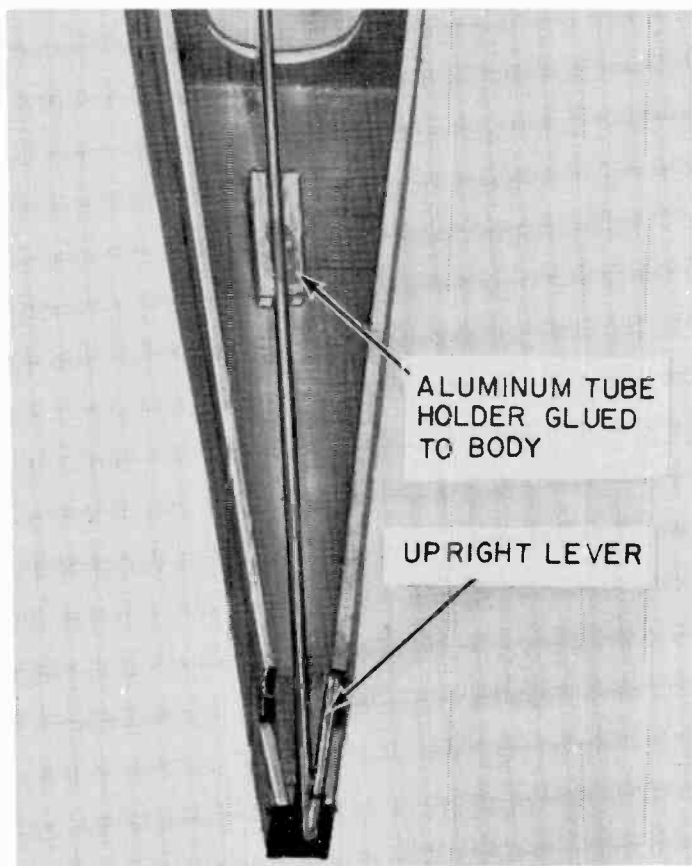


Fig. 805. Details of installed escapement, torque rod and tube.

1/16-inch piano wire and a 6- to 10-inch length of aluminum tubing which will just fit over the wire, both obtainable from hobby shops. We will bend a U in one end of the piano wire. Then we run the wire through the tube, bend the far end upright exactly in line with the U and cut it off about 4 inches above the bend.

The aluminum tubing and wire torque rod are then laid into the body as shown in Fig. 805, so that the crank of the escapement is inside the U. Strips of balsa wood placed along each side of the aluminum tubing can be glued in place and another piece glued over the top to make sure the tubing won't shift around.

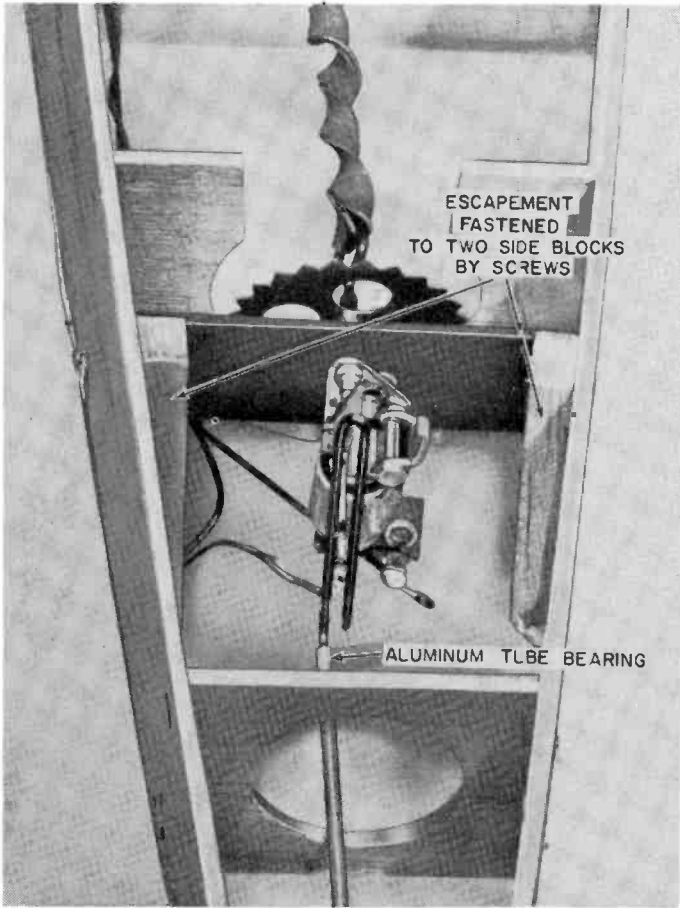


Fig. 806. Added supports for the escapement are used to make mounting easier and more convenient.

As we turn the crank of the escapement around, the wire should move back and forth easily and without binding.

Next, we test this part of the installation by putting our rubber band on the escapement. Use a 3/16- or 1/4-inch flat loop of the rubber normally used to turn the propeller of a rubber-band-

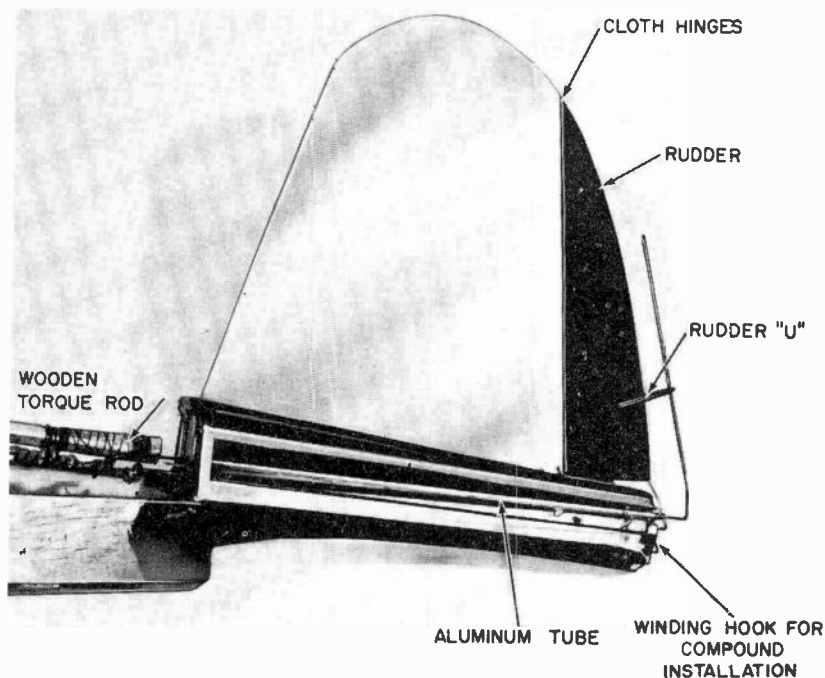


Fig. 807. In this rudder-control installation the rudder escapement can be wound from the rear of the plane.

powered model airplane. We cut it to the right length and then tie a knot in the free ends to make the loop. It should be long enough so that, with no turns in it, it droops about  $11\frac{1}{2}$  inches below a straight line drawn from the place you anchor it in the cabin to the escapement (Fig. 804).

Twist the rubber band until you have a length about half knots, and then put the receiver plug into the socket. Turn the receiver on and send a signal with the transmitter. When you depress the key, the escapement should operate, moving the U-loop left. Release the keying button, and the escapement brings the loop to neutral; key again and the loop moves right; release and it goes to neutral.

### The rudder

Now you can add the tail section of the airplane, fastening the rudder (moving part) in place with cloth hinges. The upright end of the piano wire is fastened to the rudder with another small U-loop as shown in Fig. 807. Now, if you send commands, the rudder moves back and forth as you command.

The position of the rudder U-loop is important. If you get it too close to the body, the rudder can not move enough; if you get it too high, the rudder moves too much. With most aircraft, a movement of about  $\frac{1}{4}$  to  $\frac{3}{8}$  inch each way, measured at the end of the rudder is correct.

If this U-loop is too narrow, then the linkage binds when the rudder is fully deflected, or the rudder may not deflect fully.

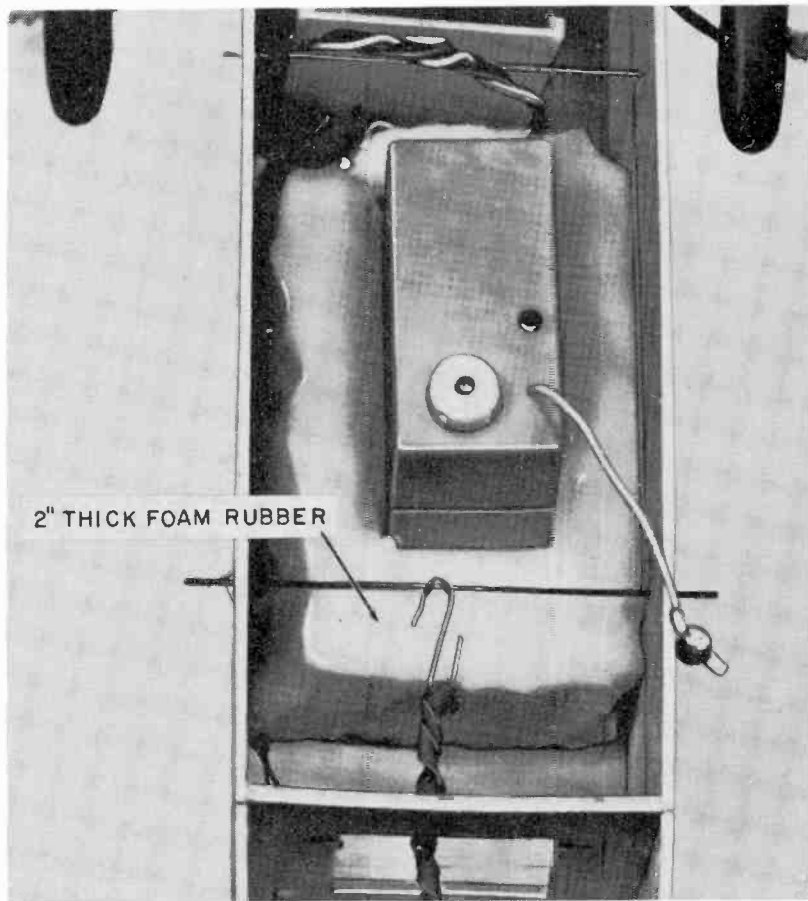


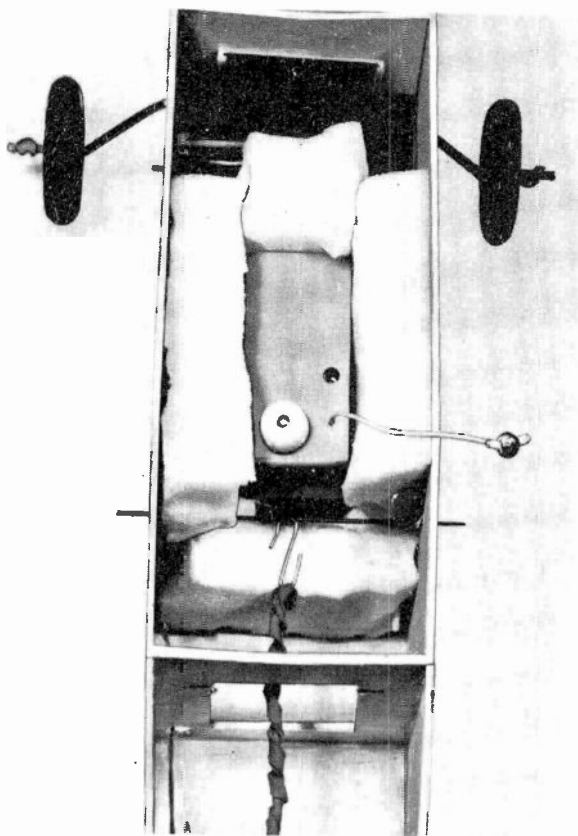
Fig. 808. A cavity is cut into a thick piece of foam rubber to contain the receiver.

Make sure that you have the inside of this loop spaced at least  $\frac{1}{8}$  to  $\frac{3}{16}$  inch for absolutely free movement. Once you have this loop positioned for the correct deflection of the rudder and free movement, glue a small strip of cloth over the ends where

it is fastened to the rudder. This prevents vibration from shaking off the loop.

### Mounting the receiver

The receiver is mounted in the cabin cushioned in at least a 2-inch thick piece of foam rubber (Fig. 808). Use a sharp knife or scissors to make a  $\frac{1}{2}$ -inch-deep cutout in the center to fit the receiver into so it stays in place. Three additional pieces of foam rubber are placed around the receiver (Fig. 809) to keep it in place and absorb vibration from the motor. If you make these



*Fig. 809. Additional pieces of rubber are placed around the receiver to keep it in place and protect it in a crackup.*

pieces fit tightly, the receiver is snugly cushioned and can not be hurt in minor crackups.

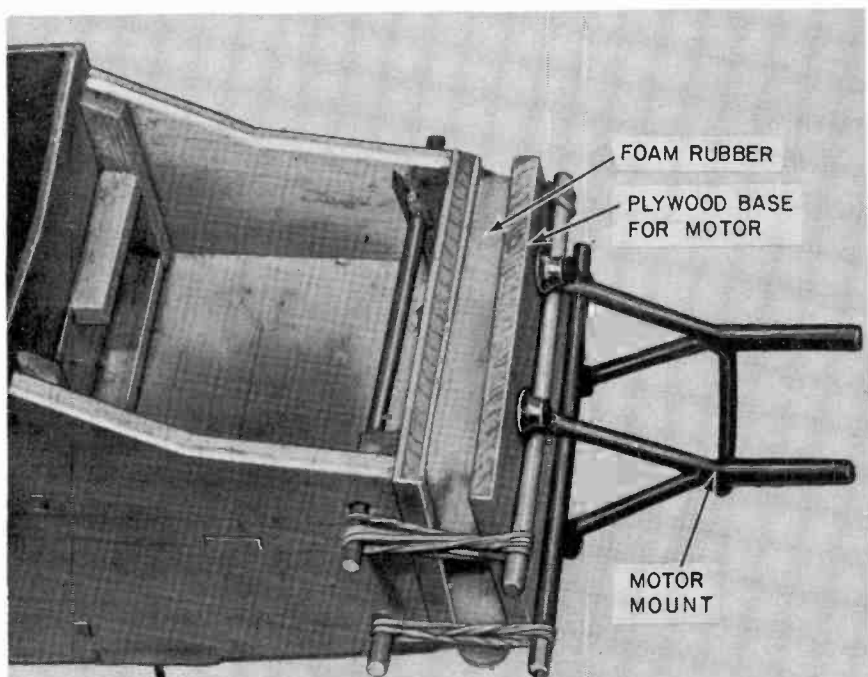


Fig. 810. Motor vibration to the receiver can be reduced by mounting the motor on a soft foam-rubber pad and securing it with rubber bands.

The model motor may now be installed as the plans call for and we are ready for a vibration test. You can't fly an airplane which has a lot of vibration with any hope of really good performance, so *cure this first*.

In spite of every precaution in installing the receiver, sometimes, depending on the motor and propeller used, the running of the motor causes the model to vibrate enough to make the operation of the radio equipment uncertain. Therefore, when you have installed the motor and completed the tail assembly and the covering of the body — in other words, finished the model, except for the wing — a vibration test should be made.

But, before you actually test for vibration, run the model motor long enough to break it in, so that it starts easily and operates smoothly as long as the fuel lasts.

Wind up the escapement rubber band until there is a full row of knots, and start the motor. While a friend holds the plane still — not gripping it tightly, just preventing it from rolling — check to see that the rudder is operating and watch the rubber



band to see if the escapement is turning because of motor vibration. If it does — and remember, the receiver is *not* turned on during this test — then you must either use a different method of fastening the airplane motor to the body (Fig. 810), or change the way you have installed the escapement. The escapement can be mounted in rubber-band supports, cushioned in pieces of foam rubber, or moved to a different location in the airplane body.

Many times a bad case of vibration is due to nothing more than an unbalanced propeller and this should be checked first. Use a good, balanced propeller of either wood or plastic and, in case of trouble, try several types with the same length and pitch. Problems can occur as a result of unevenly enlarging the hole in the

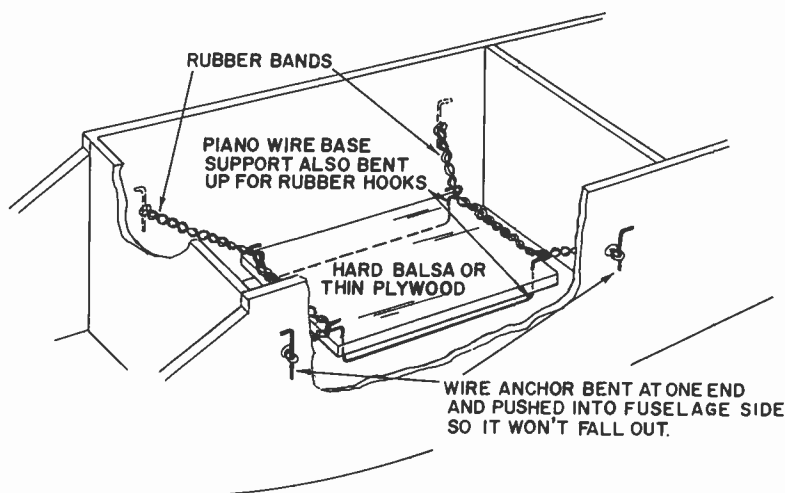


Fig. 811. This shock mount for the receiver does not give the crackup protection that the foam-rubber padding does. Vibration effect on the receiver is greatly reduced.

propeller to make it fit a motor shaft. Or, perhaps a propeller with too large a hole has been fitted on a small shaft "by eye" and is not exactly centered. Make sure the propeller you buy has a factory-drilled hole of the correct size, and don't try to ream it out to make it do. Also, keep in mind when you go flying that, if the propeller is nicked or slightly broken at the tips during flight takeoffs or landings, vibration can suddenly become a problem with an airplane that previously operated perfectly.

If the escapement holds its position and the vibration is not bad — you can tell by holding your hand on the sides of the cabin

and feeling the vibration through your fingertips — then turn on the receiver and send some commands. If the escapement operates as it should — left, neutral, right, neutral — all is well. If it does not, it is possible that the receiver is getting some vibration which is affecting the operation of its relay. This can be checked by removing, temporarily, the three top pieces of foam rubber and letting the receiver float on the deep base cushion. Do not try to fly the model this way. Do this while you keep the model on the ground. If this does cure the problem, then loosen the side pieces so that they do not hold the receiver in so tightly.

There are other methods of installing the receiver in the cabin. One is shown in Figs. 811 and 812. While not as damage-proof as the foam-rubber method, this usually does cure any type of receiver vibration trouble.

Probably the best way to cure vibration is to stop it at its source by using a sponge-rubber pad between the motor mounting plate and the body (Fig. 810).

Now let us consider a procedure for locating troubles when everything works satisfactorily when the airplane motor is not running, but the servos or escapements chatter and you cannot send signals when the motor is running.

The first check is to look for wiring troubles. Check every connecting wire to batteries, switches, servos and escapements to make sure they are not broken or *loose*. The best way to do this is to turn the equipment on, then twist all wires or move them back and forth and pull on them slightly. If a wire is broken or a connection loose, you can immediately see the effect when that particular wire is moved or twisted.

Second, check all plugs and sockets to make sure that a lead has not broken in a plug, or that a fine strand of wire is not loose at one connection and touching another. Make certain that the pins of all plugs fit tightly into *each* socket hole and make a good tight connection to the metal piece in the socket. Sometimes, these sockets holes get spread apart and, while the plug may *seem* to fit tightly, *some* pins do not make good connections.

Next, check the switch and battery case by tapping them smartly with a small rod or your finger, or by moving them back and forth. Some types of slide switches can cause trouble by not making good contact. Rapping them smartly with a small rod usually jars the connection loose and shows that you should replace the switch.

If everything else seems to be all right, check the receiver by tapping it also. If there is a broken wire inside the case, or a bad

tube, this test generally makes the trouble appear by causing the servo or escapement to operate when you tap the receiver with a small rod or your finger. Make a very careful examination of all the receiver connections by eye. In this way, you can sometimes locate connections which are not soldered at all, or are imperfectly soldered or broken.

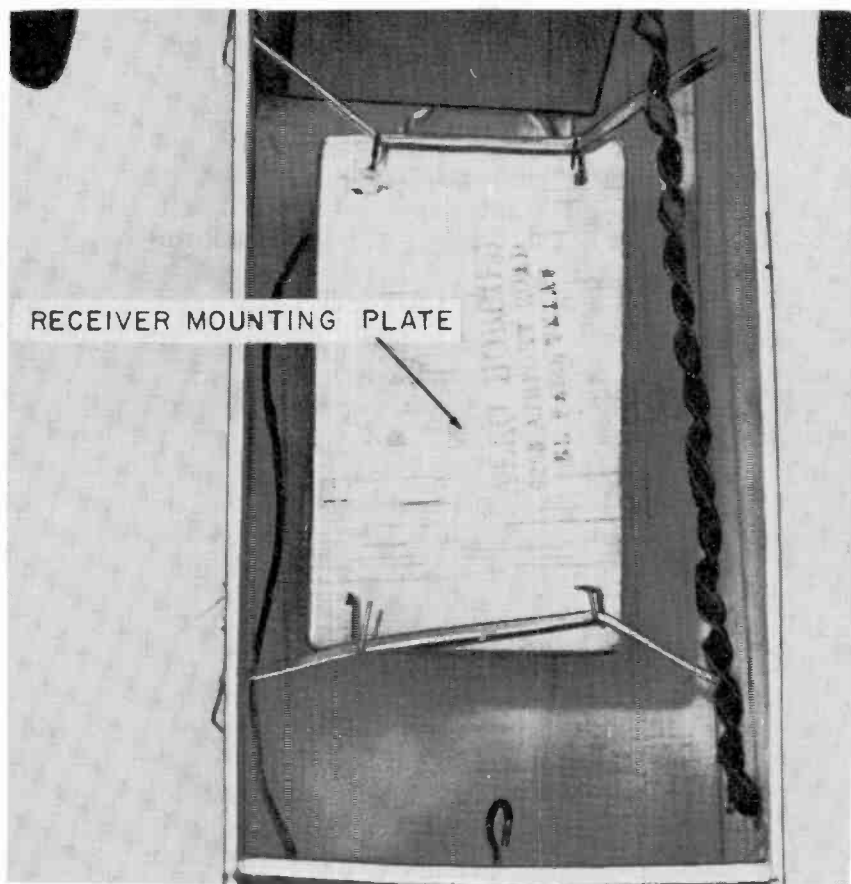


Fig. 812. Rubber-band suspension for receiver. Motor vibration to the receiver circuits is practically eliminated.

You might even use a small wooden probe and push against each receiver connection lightly to make sure it is tight and soldered. If a cold-solder joint or rosin joint is the trouble, this probing breaks the connection loose and shows you the source of trouble.

Going back to the plug and socket, it has been our experience that once in a while a receiver or other equipment uses a plug in which the wires run down into the pins and are soldered on the ends. To all outward appearances, the wires are soldered in place. They are in the pin and the ends of the pin show a good solder cover. But inside, the wires may not be soldered at all. They may touch the pin when the airplane engine is not running, and all the equipment will work. But start the engine and you have vibration troubles. Always pull a little on wires going into plug pins to be sure they are soldered firmly.

### **Troublesome antennas**

The next source of trouble is in the antenna connection to the receiver. Many times this connection is made through a plug or snap and, with wear, this becomes loose. Because this can then be a connection that is not tight, the two wires or plugs or snap fittings bounce when the engine is running and you have troubles. We recommend soldering the antenna connections to prevent trouble from this source.

Then there are the problems which seem to be vibration trouble but are not. If the equipment becomes very sensitive and chatters now and then intermittently, this can be caused by weak batteries. So, when all other checks fail to remedy the trouble, change the batteries or see if you are getting interference from another signal by checking with other people to see if their equipment is acting up.

### **Motor interference**

With some receivers which work well with escapements, using a servo may present a problem and the receiver may not operate correctly. When you send a signal, the servo may start to run and just keep on running. This can be caused by sparking from the servo contacts or motor affecting the receiver. Make sure you use spark filters (a 0.25- $\mu$ f, 100-volt capacitor in series with a 100-ohm resistor — unless the manufacturer recommends another filter) across all connections that the servo breaks and the motor terminals. (On the servo motor we tried, a 0.1- $\mu$ f capacitor is used across the motor terminals and a 10- $\mu$ f capacitors wired into the circuit, so they absorb the sparking that would normally be caused by the contacts rotating on the silver-black disc).

Transistor sockets, flea clips and miniature tube sockets can cause trouble due to vibration, as well as large sockets. Make

certain that transistor or subminiature tube leads fit tightly into the metal parts of such sockets, if they are used.

### **First flight**

Flying a radio-controlled airplane is not difficult. Generally, this is the way it is done: The model is hand-launched. That is, you run into the wind with it until you feel it begin to lift out of your hand; then, you push it forward straight ahead and let it go. Normally, the airplane continues straight ahead for some distance without climbing higher. It may turn gently to one side or the other but continue to fly and gradually get higher. Do not send a signal until the model is about 50 feet off the ground, and always make this first signal very short. Depress the keying button, watching the model. If it was turning before you sent the signal and now goes straight or turns in the opposite direction, everything is fine. Just watch how sharply it turns and, if the turn is sharp, release the button immediately.

If your first command causes the model to *turn sharper* in the same direction it *was* turning, the instant you see this begin to happen, *release the button and depress it again*. This sends the signal for the opposite turn and makes the model go straight.

### **Experimenting with commands**

You have to experiment with these first commands to see how long you have to hold them to make the model turn. Usually, don't try to turn the model completely around with one signal; instead, send several short signals calling for the same direction of turn, letting the model straighten out a little between each one.

Always try to keep the model "up wind" from you so that, in case you cannot send a signal or there is other trouble, it will drift back over you. It's a good idea to try to fly a big circle or square, up wind, the first time, letting the model get plenty of altitude.

The amount of motor fuel should have been measured and timed beforehand so the motor cannot run over about 2 minutes.

When the motor runs out of fuel, the model glides, but you can still steer it. The turns are much less sharp even though you hold the keying button depressed. Try to keep the plane circling the field as it slowly comes down to a landing. Always land *into* the wind.

### **Distance check**

With model airplanes, a *distance* check of the radio equipment

is always important. Do this with the airplane motor *not* running. Just walk away from the field with the model and have a companion send a signal every time you hold up your hand. As you drop your hand to indicate that your companion should release the keying button, watch the rudder to see that it moves each time and returns to neutral. Make sure that the distance over the ground is at least 150 yards or 300 steps. Then, start the motor and repeat the performance with the engine running, just to make sure you still have distance when it runs. Always repeat this distance check after a hard landing or minor crackup before flying again.

Generally, when starting out with radio control of an airplane, there are many other things you have to learn, such as the adjustments to the wing and tail, trim of the motor, and trim of the rudder. We recommend that you build a second model after getting the first to fly correctly to have a nice "pretty" airplane. It's wise to build exactly the same model for the second as you did for the first and to make all the changes in it you found necessary in the first.

You may question whether the use of airplane servos is worth while. The answer is yes, after you have learned to fly and have a good flying airplane. Servos for airplanes are more expensive than escapements and not necessarily more reliable. You *can* do away with having to wind the rubber band, and this is sometimes an advantage. Also, you are not running your servo battery down when you hold a rudder in the left or right position.

# 9

## engine and rudder control

ONCE you have mastered the fundamentals of steering a model plane, the next step is to have some means of changing the speed of its motor or being able to stop it on command. The reasons are simple: You undoubtedly want to fly longer and as you have learned by now, the longer the motor runs, the higher the plane goes.

Up to now, we prevented the plane from getting too high or too far away by either limiting the amount of fuel or by spiral-diving it when it got too high. With the motor control applied to model airplanes, we can let the motor run at full speed to get the plane into the air and high enough to be steered around or stunted, and then we can send a command which makes the motor slow down. The airplane still stays up or may start to come down very sharply, but we can steer and stunt it, and when it gets low, we send a command for high-speed motor and go back up to altitude again. With motor control, we can use larger gas tanks, and flights of 10 to 30 minutes are not uncommon.

Once again a table is used to describe the various methods of motor control now in use and possible with radio-control equipment. All are adaptable to single-channel equipment such as we are using.

Before discussing each individual method, we should learn how the airplane motor changes speed. Normally, fuel is fed into the engine through a needle valve, so-called because it is sharp-pointed and adjusts with a screw. This regulates the amount of fuel that goes into the engine. At the same time the fuel is injected, since

this valve is located in the venturi (air intake of the engine), a certain amount of air also comes in to combine with the fuel and makes a mixture like the gasoline and air combinations used in automobiles.

Method	Device used	Type of control
Sponge in venturi	escapement	High-low
Flapper valve	escapement	High-low
Exhaust baffle	escapement or servo	High-low or variable speed
Two-needle valve	escapement	High-low
Carburetor (venturi valve plus exhaust baffle)	escapement or servo	High-low or variable speed

Once we have started the model engine by connecting a battery to its glow plug (spark plug of a car) and flipping the propeller, the engine heat keeps the glow plug hot enough to keep the engine running. We remove the battery we used to start it. Next, we adjust the needle valve to the point where the engine runs fastest and steadiest. To slow down the engine we can cut down on the amount of air entering the engine, or we can let more fuel come in. When we have this greater fuel-to-air ratio, the engine doesn't fire as regularly as before and thus does not run as fast. This is one method.

Another method is to have a way to regulate the amount of air and fuel that go into the engine. This approach works just like the accelerator on your car. The engine can be made to idle or *gradually* increase speed until it is going as fast as it can. This is the carburetor-type of control.

Finally, if we close the exhaust so the burned gases cannot escape as fast as they do when the exhaust is wide open, pressure builds up inside the engine which makes it run slower. This method can also be used to vary engine speed gradually.

In other words, we can use either a method that gives us high speed on one command and low speed on a second, or one which lets us beep the speed. With the second method, starting from a very low (idling) speed, if we beep for increased speed, the motor speeds up a little at a time, going faster with each beep until it reaches maximum speed. We may reduce speed quickly or slowly by varying the frequency of the beeps. A continuous signal for fast or slow gives us these extremes without any delay.

In radio control of motor speed, then, we must consider the characteristics used to control the speed of the motor. An escapement has just two nonenergized positions (neutrals) — so it would



not be suitable for gradual speed control. An electric motor connected to gears, on the other hand, can move its output shaft a lot or a little, depending on how long we keep the motor energized — we would have gradual control. In the final analysis, for high — low control, we can use escapements and operate these from the compound steering escapement and use a single-channel receiver. For gradual (proportional) speed control, we must use a servo and, normally, two channels in a receiver for motor control alone — one for fast, the other for low or slow speeds.

### Simple method of motor control

One of the simplest methods of controlling the speed of a model-airplane engine is to use a wire linkage from a standard

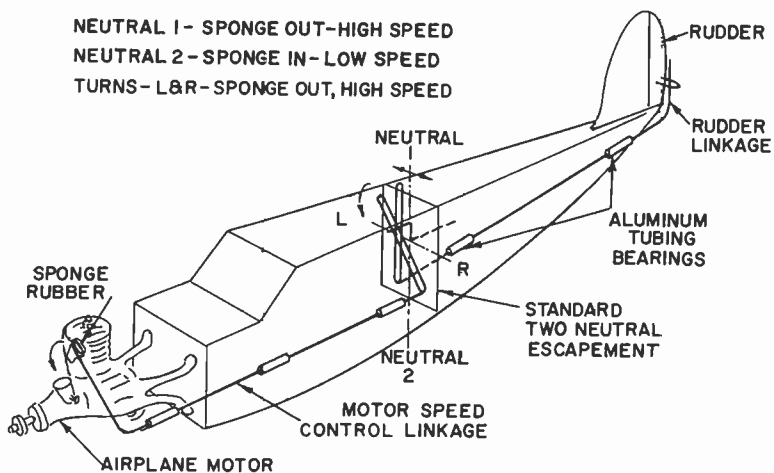


Fig. 901. The neutral positions of the rudder servo can be used to control motor speed.

neutral escapement, so arranged that it inserts a small piece of sponge in the venturi of the motor in one neutral position and removes it in the second neutral position. Fig. 901 shows this method.

The fact that we change our motor speed whenever we send a steering command is really no problem. In normal model-airplane flying, a large amount of time is spent just letting the model fly straight. If the model goes a little too high under high-speed engine, we can signal for low speed and the model will fly steady, either level or losing altitude very slowly.

If we send a turn command, the sponge is automatically re-

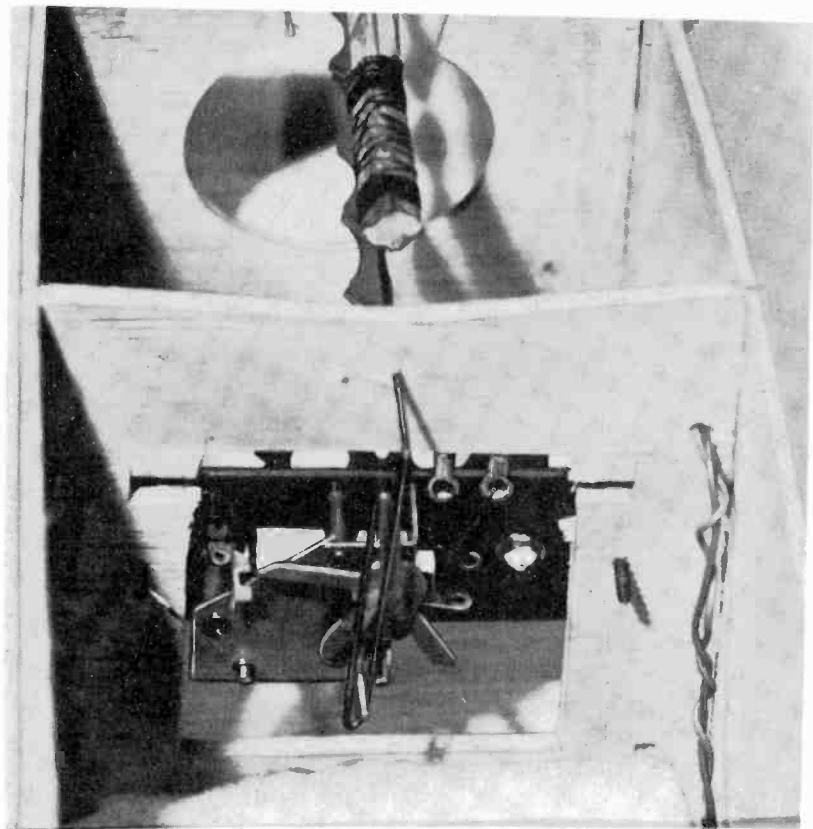
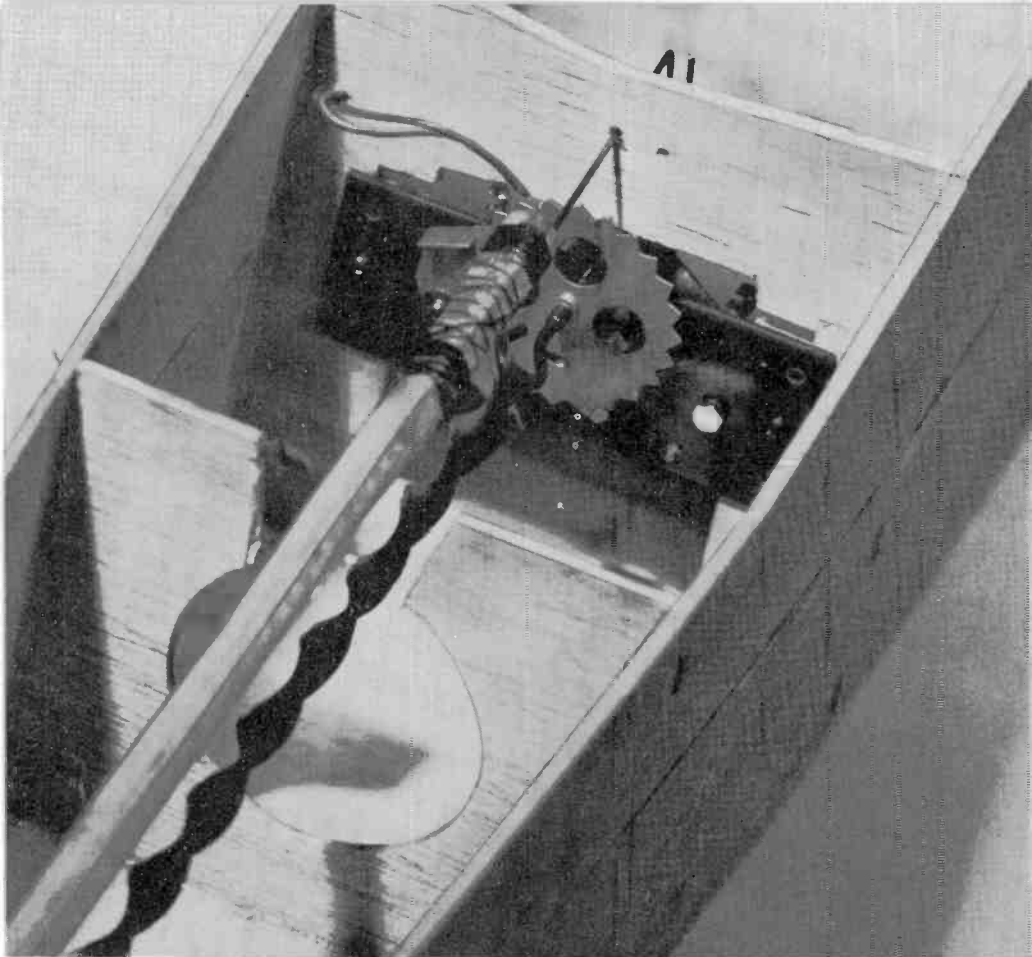


Fig. 902. Escapement mounted on the rear bulkhead of the cabin has many advantages. It is closer to balance point and easy to inspect.

moved from the venturi and the engine picks up speed. This is good since the normal tendency of the model is to lose altitude on turns. When we have it on a straight course again, a blip gives us either high or low speed as we desire.

We do have to replace the sponge frequently, but sponges are cheap. So, for a really easy method of controlling the speed of your airplane, try this.

The next method requires a change in the escapement used for steering. This also is easy. We change from the standard neutral type to a compound type so that we can use that third-command position to give us motor control. A secondary escapement is connected to the compound one as was shown in Fig. 706. This secondary escapement controls a flapper (a hinged piece of tin



*Fig. 903. Balsa rod will not twist or flex. This is something we can expect in a long length of unsupported piano wire.*

which closes over the venturi in one neutral position and lifts up in the second neutral), an exhaust port valve or a carburetor.

Let us spend a moment or two discussing the installation of the compound in the model airplane. Instead of locating it near the tail, now we prefer to locate it on the rear-cabin bulkhead. Normally, we reinforce and strengthen this bulkhead with a thin plywood strip. Fig. 902 shows how the bulkhead is cut to make the installation.

There are several reasons for locating the escapement in this position: it is slightly heavier and should be near the airplane balance point. Secondly, we have two wires going from the escapement into the engine compartment where the secondary escapement is located. Shorter wires are possible from this rear-bulkhead

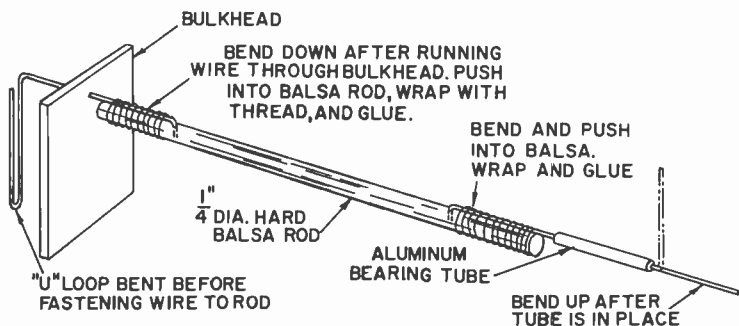


Fig. 904. Detail of splicing balsa rod to piano wire. A little extra care can mean the difference between a smooth, easy-moving linkage and one that sticks and jams.

position. Finally, the escapement is in a position where we can inspect it easily by removing the airplane wing.

With the escapement in the rear bulkhead, the rubber band and torque rod which move the rudder must run back down through

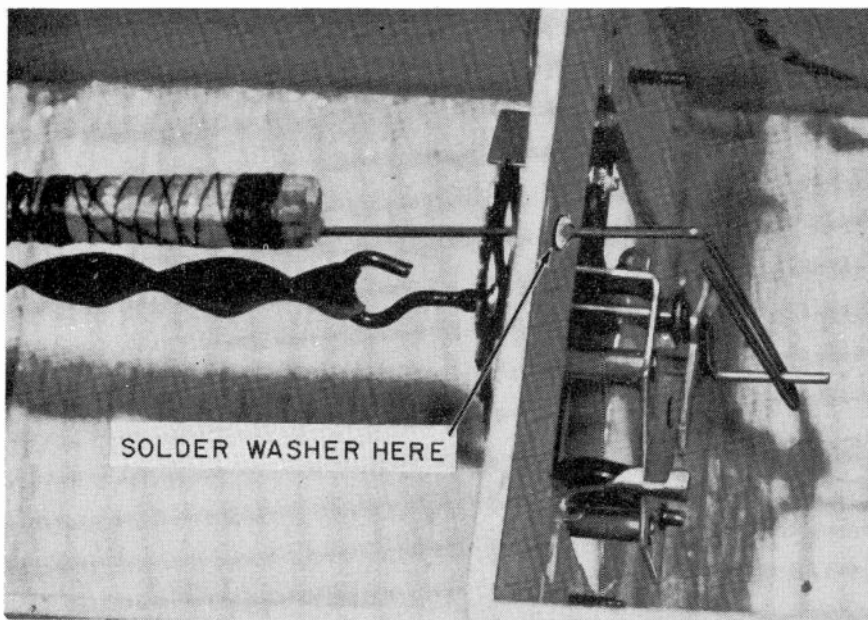


Fig. 905. To prevent rubbing, small washers are often soldered to the wire U-rod.

the fuselage (Fig. 903). Note that a balsa-wood rod with a piano wire loop fastened to one end is used instead of the previous wire. There is a good reason. A long piece of piano wire can twist and

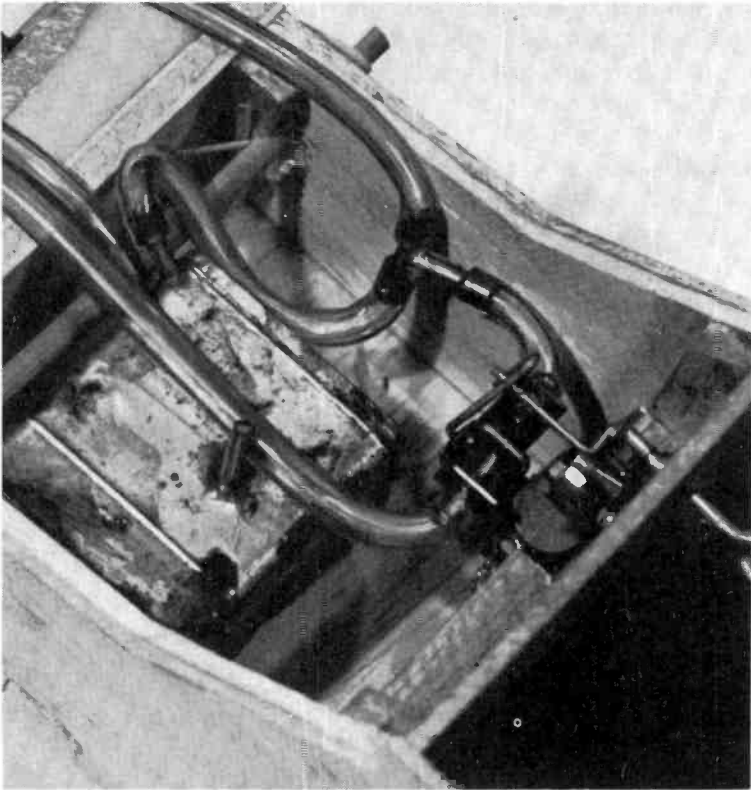


Fig. 906. *A secondary escapement can be used to control engine speed.*

bend or flex, and this we do not want. Fig. 904 shows the complete torque rod.

Note in Fig. 905 how the U loop is brought out through the rear bulkhead far enough so that, while it is engaged by the crank, it is clear of the other parts of the escapement. Small washers are generally soldered to the wire on each side of the bulkhead so it cannot slip back and forth more than  $1/32$  of an inch. This small amount of freedom is allowed to prevent binding.

The rubber band, which also goes back through the fuselage, can connect to a wire hook extending inside the body just forward of the vertical tail. The other end of the wire can come out the back of the body and can be formed into a hook so you can wind the rubber band. Fig. 905 illustrates this first method. Note that there is about an inch length of the wire from the tail bulkhead to the rubber band hook. This allows us to pull the wire out slightly for winding.

Now, with the compound installed and the two wires going to the engine compartment, let us discuss the other methods of motor control which can be accomplished using this secondary escapement. (Fig. 906).

### Two-needle-valve engine control

Fig. 906 shows a two-needle-valve engine, the gas tubing connected to the gas tank, and the secondary motor control escapement which, when the installation is completed, is also connected to the two needle valves of the engine. Note the brass tubing T and refer to Fig. 907 for the tubing connections.

This motor-control system operates by providing an "air bled" in each of the fuel lines going to the two needle valves. When we have a bleed line open to the air, the engine cannot pull fuel through it.

We connect these two bleed lines to the motor-control escapement (Fig. 908), which is designed for this purpose, so one bleed

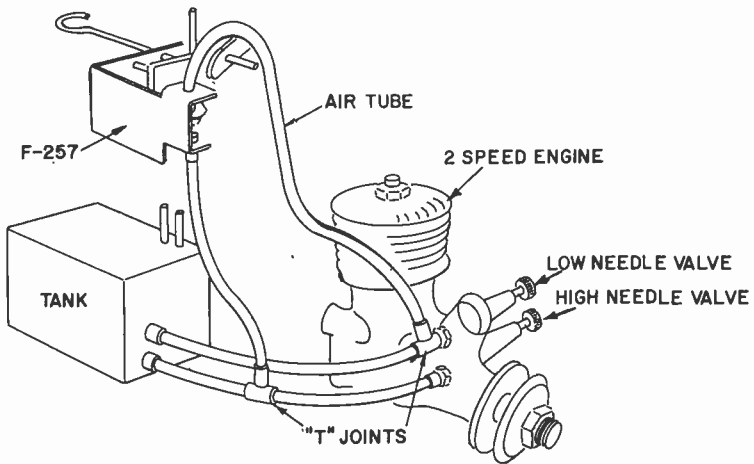


Fig. 907. Two-speed throttle needs extra tubing to control connections on the escapement.

line is open to the air in one neutral position of the escapement and the second is open to the air in the second neutral position. When either one is open, the other is tightly closed by a rubber-band stopper fastened to the U-loop linkage which presses tightly against the brass tubing each line connects to.

To adjust the airplane engine for operation with this system, put the engine-control escapement in one neutral position. Start the engine and adjust the needle valve which has its bleed line

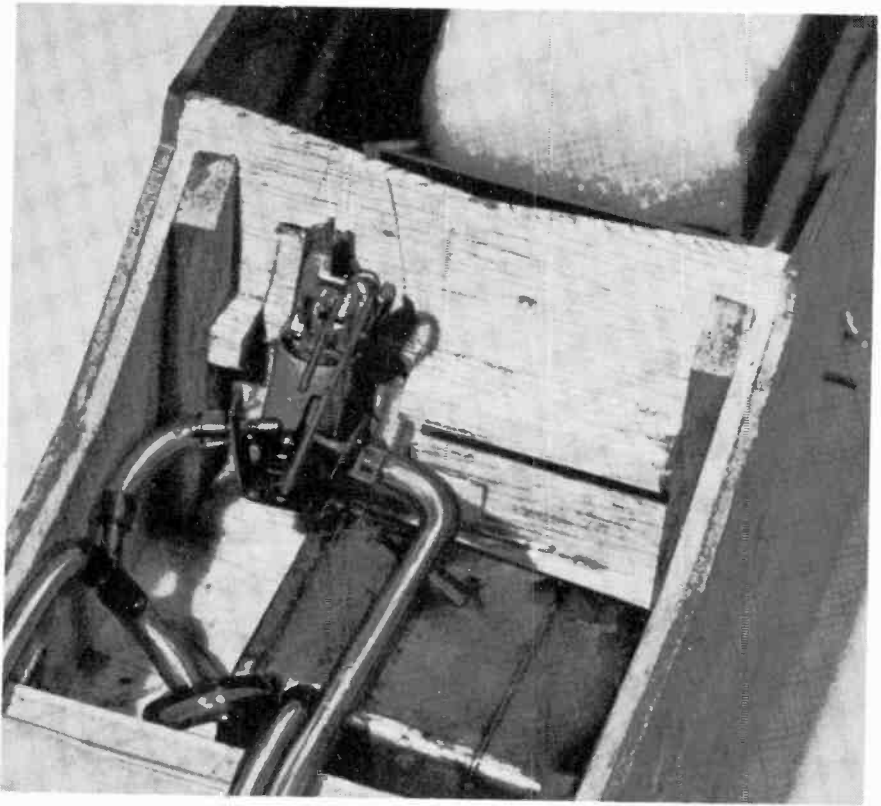


Fig. 908. *Motor-control escapement controls air flow through bleed lines that govern fuel flow.*

closed by the stopper so that the engine runs at its fastest, smoothest speed.

With the engine running, either send a signal to make the motor-control escapement change neutrals, or do it by hand, and immediately adjust the second needle valve for slow engine operation. That finishes the adjustments and, with the exception of minor adjustments to the needle valves when we go out flying, all we have to do to change motor speed is to send a three-pulse command. A vast improvement over the earlier system! In this system, the motor does not change speed under any turning signals. It does this only when we specifically command it to by sending the three-pulse command.

The first T required (shown close to the engine in Fig. 907) is actually a part of the engine. To make the second T required,

cut two small lengths of brass tubing (obtainable from hobby shops), file a V in the end of one, lay the two pieces down on a flat board and solder them together. Place the T in a vise and drill a small hole down through the upright into the bottom sec-

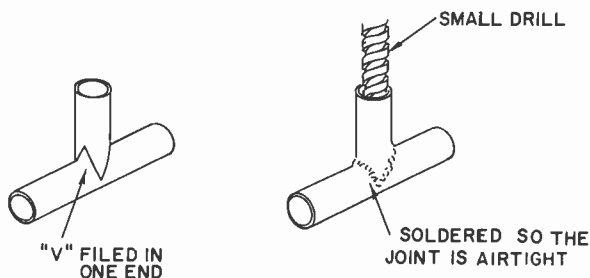


Fig. 909. Detail of bleed-line T construction. Aluminum tubing should not be used as it is more difficult to solder than copper or brass.

tion. Use care not to drill through the bottom end of the cross-piece. (See Fig. 909).

### Adjustable exhaust baffle method

The third method of motor control involves the use of an adjustable exhaust baffle (Fig. 910) which can be bought at a hobby

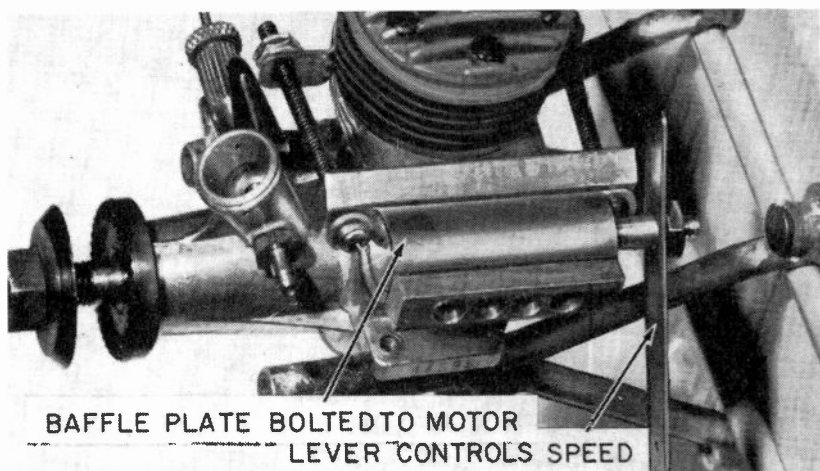


Fig. 910. Adjustable exhaust baffle is another way of controlling engine speed.

shop. It can be bolted firmly to the engine head housing as shown. On the end nearest the front of the fuselage is a little arm which



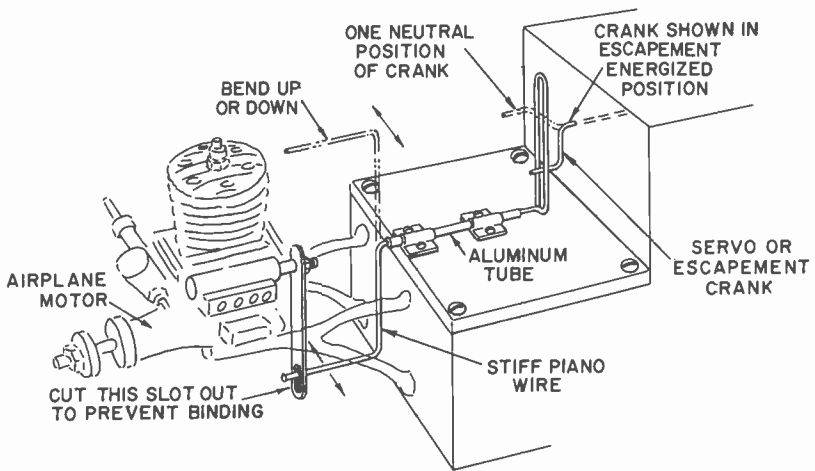


Fig. 911. Exhaust-baffle engine control uses torque rod and U-loops like rudder control.

must be moved back and forth to obtain high and low speeds. Moving this lever a little at a time gives gradual engine-speed changes, but this requires the use of a servo and two channels.

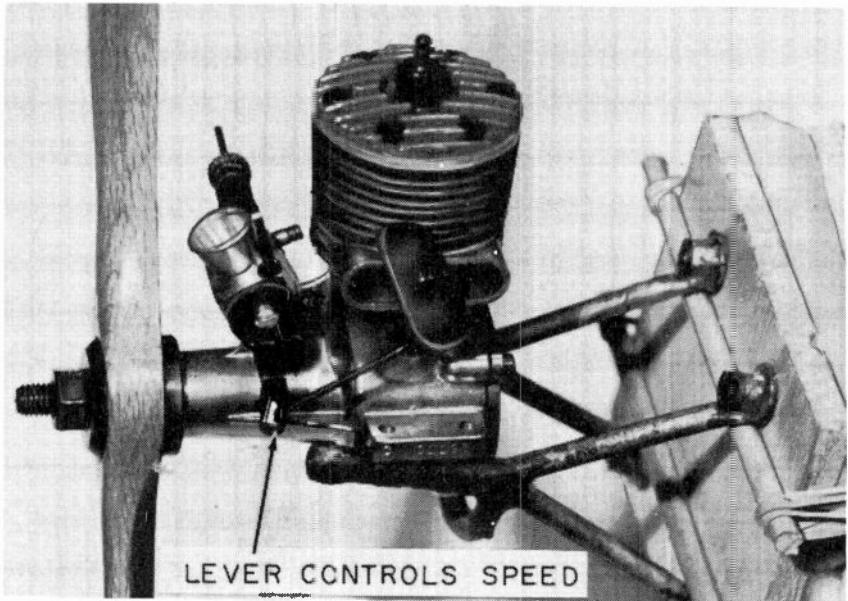


Fig. 912. Combination fuel intake and exhaust baffle provides the smoothest engine-speed control. Needs only connection to a controlling mechanism.

However, we can operate with our standard two-neutral escapement by providing the proper linkage and using high-low engine control. The arrangement is shown in Fig. 911.

The hole in the bottom of the lever arm must be enlarged, otherwise the escapement link crank may bind as it moves the lever back and forth. In the figure, the escapement crank is shown in an *energized* position. The escapement must be positioned in the front bulkhead so that one neutral is in the position shown.

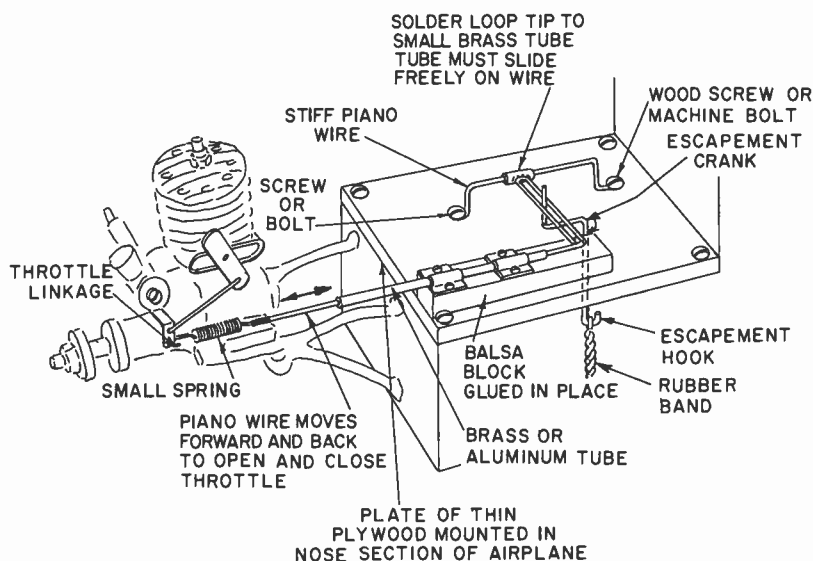


Fig. 913. Push-rod linkage is driven by an escapement. Servo drive (Fig. 915) might be more convenient because of short rubber band used to drive escapement.

The nut on the end of the baffle pivot shaft which holds the lever in place must be loosened to adjust the spindle inside the housing to get the two speeds you want with the movement of the linkage.

### Combination throttling for engine control

The final method of motor control, also adaptable to either servo or escapement operation, uses a motor especially designed for radio-controlled airplanes. It has both a full-intake-type throttle and an exhaust baffle, and these are linked together to provide the smoothest kind of speed control. This engine comes with all parts mounted on it; all that is needed is to provide the right kind of movement from the servo or escapement to move the throttle lever back and forth. (Fig. 912).

The way to get a good back-and-forth movement of a throttle linkage is shown in Fig. 913. Note that this time the escapement is mounted so its rubber band goes directly down through the motor compartment, and that the crank is flat against the top board

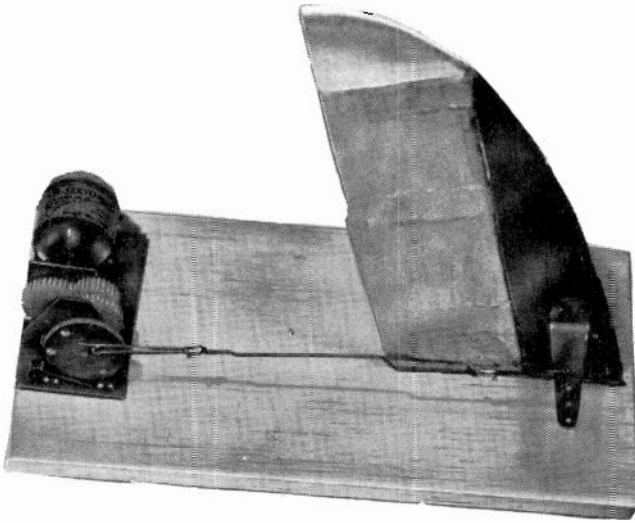


Fig. 914. *This setup allows testing of servo rudder control before installation in the plane.*

over the gas tank. The U-loop which is moved by the escapement crank has a small piece of brass tubing soldered to its tip, while the shaft of the loop goes through a second tube (brass or aluminum) which serves as a good bearing and furnishes support for the shaft. Stiff piano wire bent square is bolted in place after being passed through the U-tip tube. This supports the loop on the other end. When the escapement crank rotates, the loop rides freely back and forth. As it does, its shaft moves back and forth to move the throttle lever and control speed.

The small spring at the end of the loop shaft where it connects to the throttle lever is important. It must take up any play in the lever and yet be strong enough to move it. Using this spring removes the necessity for having exactly the right length of stroke of the loop shaft.

### **Servo control of the rudder**

Many servos are made which operate like escapements and are designed specifically for airplane use with single-channel receivers like the one we have used as our example. The method of sending signals is exactly the same as with a compound escapement: one pulse for left; two pulses, right; etc.

The servo eliminates the need for rubber bands since it can operate on batteries. A servo can provide more power than an escapement and usually, when one is used, the rudder is not adjusted to move quite as far on each side as it is with an escapement. About three-quarters of the movement necessary with an escapement is plenty.

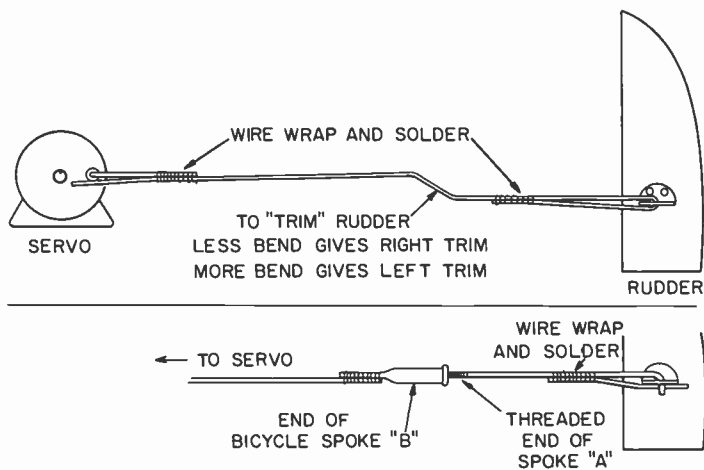


Fig. 915. Methods of connecting linkages to servo and rudder. The bend in the push rod and the bicycle-wheel spoke allows adjustment of length.

The servo is usually mounted in the cabin compartment and the linkage to the rudder can be a stiff piece of piano wire (Fig. 914). As the servo wheel (output shaft) rotates, it moves the rudder back and forth. Note both the method of connecting the wire to the servo wheel and to the rudder, and the small bend in the wire near the front edge of the rudder.

Fig. 915 shows why the bend is used. With an escapement operating the rudder and with the linkage as shown in Fig. 807, we can bend the upright part of the wire which moves the rudder to the left or right to trim the airplane so it flies straight with rudder neutral. With the servo, we can change the amount of this bend, or we can solder part of a bicycle spoke to the wire so we can adjust it in or out to get the same trim. Trim is always necessary and, in some airplanes, part of the rudder itself is used to make this adjustment. If it is, the rudder is cut into two pieces; the top part, usually used for trimming, is not moved by the radio-control equipment.

# 10

## radio-controlled boats

**B**OATS ARE perhaps the easiest radio-controlled models to build. Almost any type of escapement or servo has enough power to move a boat's rudder for steering, and the steering linkages are very simple. Connecting a drive motor to the boat's propeller is also simple — no gears are actually required (although sometimes

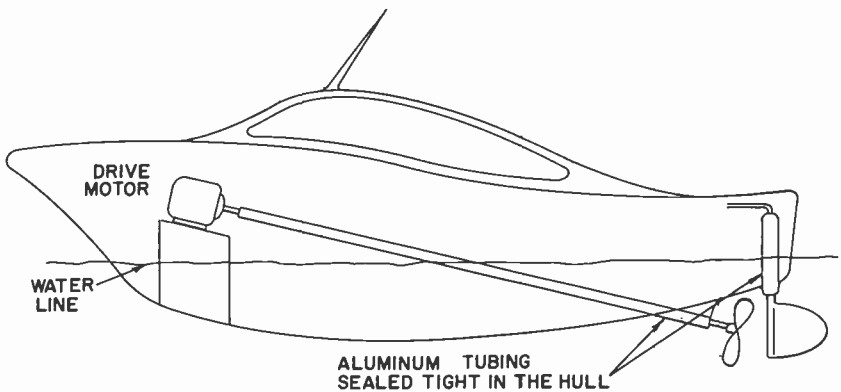


Fig. 1001. Propeller-shaft and rudder-shaft housings must be above water line to prevent water seepage into boat.

they are used) — and almost any kind of little electric motor powers the boat. Of course, the larger the motor, the larger the propeller can be, and the faster the boat moves.

The two primary problems with the model boat are a waterproof propeller-shaft and rudder-shaft housings. An easy solution is to use aluminum tubing or brass tubing long enough so that its

end within the boat is well above the hull water line (Fig. 1001).

Unless the shaft makes a very sharp angle with the boat itself — an undesirable arrangement — the propelling motor has to be well forward in the hull.

When mounting the radio receiver in the model, keep the antenna as far as possible from the rest of the boat wiring. It is usually placed well forward of or high over the other equipment (Fig. 1002). Batteries are located so as to give the model the necessary balance, and the switches should be so placed that they can

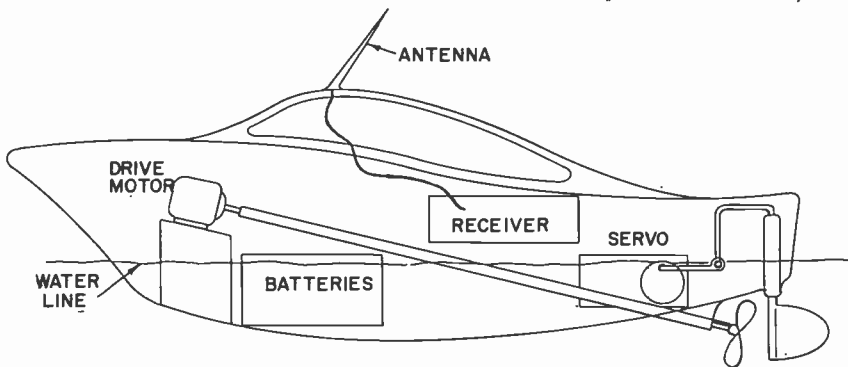


Fig. 1002. Equipment placement must keep the boat in proper balance fore and aft as well as sideways.

be turned on and off *without removing* the deck. Always wrap the receiver in a watertight covering of either rubber or plastic. The wrapping must be nonmetallic.

The method of connecting the receiver to the boat motor and rudder may be exactly like that for a model car. Instead of a steering-wheel shaft, a rudder is turned and, instead of turning the rear wheel of the car, the drive motor is connected to the propeller shaft. If the car had headlights, the boat can have running lights or a searchlight connected in the same manner so they would light when the boat is moving. Actually, the lights would be the same and connected the same but positioned differently on the model.

There is one difference between boats with plastic hulls and those constructed of balsa wood or metal. The plastic hulls can build up a charge of static electricity which sometimes makes the receiver malfunction. The radio-control system in the boat may work as it should when the boat is not in the water, and not work when the boat is in the water, or vice versa. One solution to this problem is to connect a wire from the B-minus lead of the receiver's B-batteries directly to the hull. Scrape the end of the wire

for about 2 inches and tape it firmly against the hull. Boats with metal hulls should also have the B-minus lead connected to the hull. Wooden boats are not subject to this trouble.

The antenna for a model boat can best be made from aluminum tubing or a piece of fairly stiff piano wire so it stands erect from the deck. Plugs and jacks may be used to connect it and also provide a means of removing it when the model is not being used. If a metal hull and deck are used, it is best to cut a small square about 2 inches on a side, bolt in a piece of fiberboard or plastic, and mount the antenna fitting in the center of this insulated plate. *Never* use a phone-type jack and plug directly through the metal

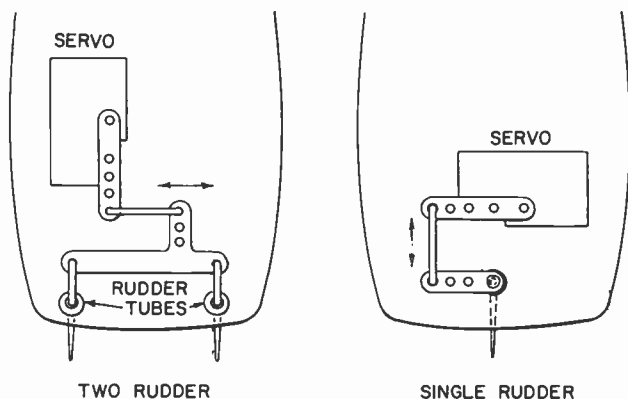


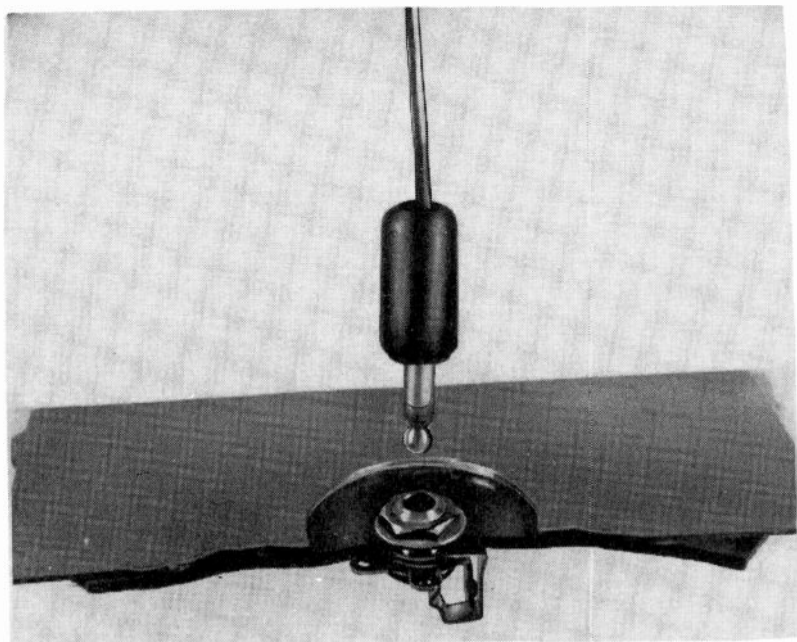
Fig. 1003. Single-rudder and twin-rudder boats require different servo mountings.

hull of a ship. If you do you will have a tremendous loss of signal and greatly reduced range of operation.

Sometimes model-boat motors generate interference which makes the receiver operate incorrectly and cannot be cured by connecting a capacitor across the motor terminals. It will be necessary to replace such a motor. Pittman and Aristo boat motors are generally good and have their brushes positioned to give a minimum of sparking. Controlled speed of a model boat is also possible.

Linkages used with model boats are very straightforward and Fig. 1003 shows how you would connect to a single-rudder and a two-rudder system.

The use of airplane-type engines in a radio-controlled boat is not too common. Although they can be used and greater speed is possible using them, the difficulty is that you cannot start and stop this kind of motor easily by radio. When this type of engine



Cutaway shows metal roof of beat cabin with plastic insert to mount jack for minimum receiver signal loss. All terminals of the jack can be connected together when soldering to receiver antenna wire. Plastic piece may be cemented or attached with machine screws.

is used, generally the model is larger, the motor is started prior to leaving the dock, and then, for the most part, it is steered only until the fuel supply is used up. If you are interested in using this type of motor and want to control its speed, refer to the chapter on model airplanes for methods of motor control.



# 11

## building a receiver

**A**LTHOUGH the November, 1959, ruling by the Federal Communications Commission requires that anyone who builds a radio-control transmitter without using a manufactured and sealed oscillator section must do so under the supervision of a person who has either a First- or Second-Class commercial radio-telephone or telegraph license, there is no restriction on building a radio-control receiver or the other parts of the system.

A simple receiver which you can build quite easily and which is capable of giving reasonably good performance will now be discussed, primarily for the benefit of the experimenter. The cost (\$6 to \$9) for the parts is very close to what you would have to pay for a manufactured unit, so, if you are more interested in radio-controlling than in experimenting, we recommend you buy your receiver instead of building it.

The arrangement of parts and wiring shown in Figs. 1101 and 1102 was chosen to enable you to see exactly what parts are used and just how they are connected. Once you have used this layout and have the circuit working properly, it is quite reasonable to rearrange the parts into a much smaller package. Just make sure that you do not put any wires or other parts near the coil except those shown connected to it.

The following parts are necessary for the first step in the construction:

RK61 or XFG-1 tube

$\frac{3}{8}$ -inch-diameter slug-tuned coil form (Cambridge Thermionic [CTC] LS3)

100- $\mu$ h choke (National R-33)

5 to 25- $\mu$ f trimmer capacitor

5- $\mu$ f fixed, ceramic disc-type capacitor

0-5 ma Meter  
.05- $\mu$ f 200-volt paper capacitor  
10,000-ohm  $\frac{1}{2}$ -watt resistor  
25,000-ohm potentiometer

DPST switch  
100- $\mu$ f fixed, ceramic disc-type capacitor  
2.2-megohm  $\frac{1}{2}$ -watt resistor  
roll No. 22 enameled wire

Wind the coil first—12 turns of the No. 22 enameled wire. Scrape the ends of the wire and solder them to the two lugs provided on the form. Fasten large solder lug under the mounting screw in the base of the form. Solder the trimmer capacitor terminals to two short lengths of solid hookup wire and then solder the free ends of the wires to the two coil lugs (Figs. 1101 and 1102).

Solder one end of the rf choke to the top lug of the trimmer and the 5- $\mu$ f capacitor to the bottom lug. Twist the ends of the wires from the 2.2-megohm resistor and the 100- $\mu$ f capacitor together, clip and solder one twisted end of the pair to the same trimmer terminal as the 5- $\mu$ f capacitor.

Lay the tube in place so that its red dot is nearest the coil. Bend the lead that is nearest the red dot and solder it to the upper trimmer-capacitor terminal. Bend the *third* lead (counting from the red dot) and solder it to the junction of the 2.2-megohm resistor and 100- $\mu$ f capacitor. Put a piece of spaghetti insulation over the second tube wire so that only about  $\frac{1}{4}$  inch of the end of the wire is exposed.

Place the .05- $\mu$ f capacitor alongside the tube. Bend its upper lead over so that you can solder it to the free end of the rf choke. Solder one lead of the 10,000-ohm resistor to this same lead. Solder the lower lead of this capacitor to the tube wire farthest from the red dot on the side of the tube. Solder one end of a 6-inch length of insulated hookup wire to this same junction, and solder the other end of this wire to one end-terminal of a double-pole single-throw switch (Fig. 1101).

Solder the free end of the 10,000-ohm resistor to one end terminal of the 25,000-ohm potentiometer. Solder a 6-inch length of insulated hookup wire to the center terminal of this potentiometer. This wire goes to the minus terminal of our meter. Solder about a 12-inch length of flexible hookup wire to the free end of the 5- $\mu$ f capacitor and stretch this wire out away from the coil. This is the receiver antenna.

Solder one end of an 8-inch length of bare, solid hookup wire to the lug fastened to the mounting screw of the coil form. Solder the other end to the terminal of the switch, directly opposite the end terminal we soldered to previously. Solder a 6-inch length of flexible, insulated hookup wire to this terminal of the switch. This connects to the minus terminal of the B-battery string.



Set the trimmer capacitor's silver dot halfway between the two capacitor lugs, using an insulated (nonmetallic) alignment screwdriver. Next, begin adjusting the slug of the tuning coil. Start with it inserted all the way in the coil, and then turn it so that the slug moves down toward the mounting end inside the coil. Watch the meter. Somewhere in this adjustment, the meter hand will suddenly drop toward zero. This is what you are looking for. The drop indicates that you have tuned to the transmitter signal.

It may be necessary to change the setting of the trimmer capacitor and try adjusting the slug more than once. Juggle and adjust until you find this drop in the meter reading. It may even be necessary to readjust the potentiometer shaft to hold a reading of about 1 ma when *not* tuned to the transmitter as you vary the slug and trimmer.

Once you have found this dip, release the transmitter keying button so that it does *not* send out a signal. The meter hand should rise. Depress the keying button and the meter hand should drop almost, or entirely down to zero.

You now have a one-tube radio-control receiver. You may connect an AR21, Sigma 4-F or other 5,000- to 8,000-ohm relay to the lead from the plus side of the B-battery to the meter and, by adjusting its tension carefully, have it *energize* when no signal is transmitted and *de-energize* when a signal is transmitted.

You may have to shorten or lengthen the antenna wire of the receiver to make it operate correctly. Also, you may find that you need a larger resistance than 2.2 megohms across the 100- $\mu$ f capacitor. Try 3 or 4 megohms, if necessary. Experiment in any way you desire *but* just be sure that you do not let the meter read higher than 1.5 ma. A reading higher than 2 ma at this time can ruin your tube, if it is held for any length of time.

### Adding a transistor

To experiment further and to see how a transistor operates in a radio-control circuit, we now obtain:

.05- $\mu$ f fixed, 200 volt paper capacitor  
.25- $\mu$ f 200-volt capacitor  
1N34-A diode  
CK722 transistor (2N109 can be used)

relay (AR-21, Sigma 4-F, etc.)  
1,000-ohm  $\frac{1}{2}$ -watt resistor  
transistor socket

Connect one lead of this second .05- $\mu$ f capacitor to the rf choke-coil junction of the first .05- $\mu$ f capacitor. Connect the free end of this second capacitor to one end of the 1,000-ohm resistor. One lead (the lead away from the banded end) of the 1N34A diode

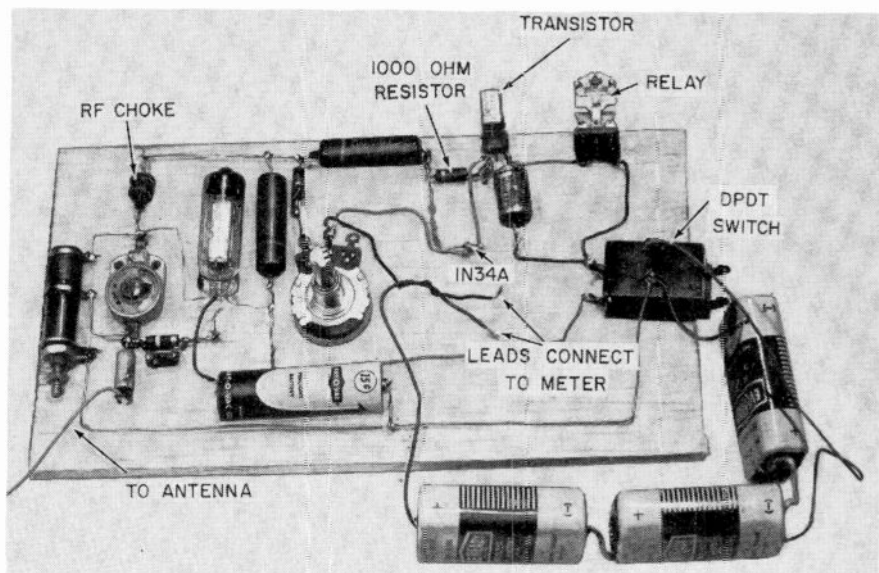


Fig. 1102. Building on a breadboard or a pegboard is a good way to gain experience with parts and layout. Here a DPDT switch is used in place of a DPST — the two terminals on the right are not used.

goes to the junction of the  $.05\text{-}\mu\text{f}$  capacitor and the 1,000-ohm resistor. Solder the free end of the 1,000-resistor to the center pin of the transistor socket. The transistor is not put into the socket until later.

Solder a short length of insulated, flexible hookup wire to the transistor-socket terminal *nearest* the center pin. The other end of this wire is soldered to the lead of the IN34-A diode *nearest* the banded end. Another short length of insulated, flexible hookup wire is soldered to this junction, and its free end is soldered to the center terminal of the potentiometer.

One lead of the  $0.25\text{-}\mu\text{f}$  capacitor goes to the transistor-socket pin which is *farthest* from the center terminal. A short length of flexible hookup wire is also soldered to this pin. The free end of this wire is soldered to one relay coil terminal. The other terminal is soldered to another short length of wire which, in turn, is soldered to the second end terminal of the switch, opposite the terminal used previously. The free lead of the  $0.25\text{-}\mu\text{f}$  capacitor is soldered to this same switch terminal. A 6-inch length of wire is soldered to the opposite switch terminal, just above the terminal we have connected to the coil mounting lug. The other end of this wire connects to the plus terminal of the B-battery whose negative

terminal also connects to the switch. Now we insert the transistor in its socket. If a CK722 is used, the lead nearest the red dot on the case is placed in the end hole of the socket *farthest* from the center hole. The middle lead goes in the middle hole, and the last wire in the opposite end hole. If a 2N109 transistor is used, its pins are spaced to match the socket.

Again the switch is turned on. The meter should now read around 5 ma (indicating the current through both the tube and transistor). Keying the transmitter should drop the meter reading to 1 or perhaps 2 ma (from 0.4 to about 0.2). It may drop more than that, which is fine. Once again we must adjust the relay tension, contacts, etc., until the relay *energizes* when the meter is at 0.4 and *de-energizes* when it reads 0.2. Notice that the relay *de-energizes* when we send a transmitter signal. This is the correct operation.

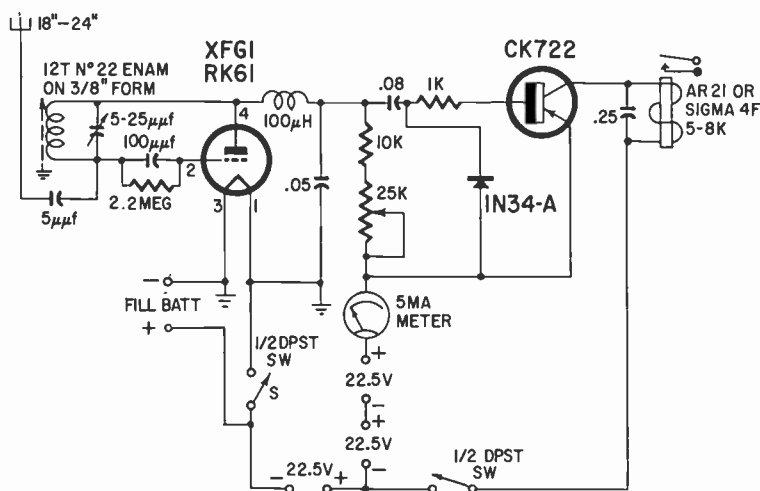


Fig. 1103. Schematic diagram of the tube-transistor radio control receiver.

Again you may have to experiment. You may have to readjust the tuning or the position of the potentiometer shaft to get about the same readings on the meter that we have just mentioned. Just make sure that, when the transistor is *out* of its socket, the meter does not read higher than 1.5 ma. Otherwise tube life will be greatly reduced. Any reading below 1.5 with the transistor out of the socket is excellent. In fact, the lower the reading you can get and still have the relay operate when the transistor is put into the socket, the better. (The circuit is shown in Fig. 1103.)

## Glossary of Terms and Definitions

- A-Battery** Generally, a flashlight battery used to heat the tube filament in receivers or transmitters.
- Ac** Alternating current (or voltage)
- Actuator** Generally, an electric motor used to move steering elements, but which must run all the time. Can mean a magnet which moves when a signal is sent. Any device for steering which is not a servo or escapement.
- Af** Audio frequency
- Aileron** A movable part of a wing tip which, when moved up or down, can cause an airplane to turn or roll around its nose – tail axis.
- Ampere** Basic unit of current
- Antenna (receiving)** A length of wire, usually flexible and often piano wire, which is connected to the radio-control receiver. Lengths from 12 to 36 inches.
- Antenna (transmitting)** A length of tubing or reasonably stiff wire furnished with commercial transmitters. This has a specific length (which must not be changed) of about 9 feet.
- Arc (arcing)** Electricity jumping through the air between two wires or sliding contacts, or the armature of a relay and its fixed contacts. The sparking of an electric motor inside the case.
- Audio (frequency)** Tones or sounds which you can hear. In radio control, audio refers to tones.
- Audio stages** The tubes or transistors after the detector in a receiver (see detector) when the receiver operates with tones.

- B-Battery** The larger battery used with a transmitter or receiver. Generally, hearing-aid type with receivers. Voltages run from 22.5 to 67.5. Usually, several are used connected together.
- Blip** A very short, quick signal. Depressing and releasing the keying switch as fast as possible.
- Bolt** A threaded device usually larger than 3/16 inch. Often prefixed by words such as stove, machine, carriage, etc. (See also Machine screw.)
- Break (broken) circuit** To disconnect the batteries or to have them disconnected accidentally. An incomplete electrical circuit.
- Bugs** Troubles, either electrical or mechanical, in the system.
- Built-in** A circuit or mechanical device which is a part of something. A servo has built-in switches.
- Carrier** The signal sent out from a transmitter but which cannot be heard. A carrier is modulated to cause a tone to be sent.
- Channel** One of a number of keying buttons on a transmitter, or the number of relays in a receiver. Can mean the number of tones where each tone is a command, or the number of transmitters if several are used. The path a signal takes going through the transmitter and receiver into the device furnishing physical motion. A three-channel transmitter has three keying buttons or a three-position switch to send commands. A three-channel receiver has three relays operating three escapements or servos independently of each other.
- Chattering** Relay armature vibrating rudder moving back and forth, etc., in the presence or absence of signal.
- Checkout** Those tests, by eye, hand or by electrical instruments, which tell if everything is connected and working properly. With model aircraft, the term can mean a preliminary flight to check a model's flying ability.
- Choke (audio)** A coil of wire on an iron core which prevents an audio frequency signal from going through it.



<b>Choke (rf)</b>	A small coil of wire which prevents a radio frequency signal from going through it.
<b>Circuit</b>	Wires and metal pieces connected together with batteries, motors, transistors, radio tubes and other components. A path which electricity can follow from one end of a battery to the other.
<b>Coder</b>	A mechanical, electrical or combination mechanical-electrical device which sends out the correct radio signal (when connected to a transmitter) to cause a model to steer, etc., when a lever is moved or a dial turned.
<b>Coil</b>	Turns of wire wound on a form. Tuning coil, relay coil, choke coil are types used in radio control.
<b>Cold-solder joint</b>	A soldered connection in which the solder crystallizes or hardens on each part individually. A soldered joint with no mechanical strength; breaks apart easily.
<b>Compound</b>	A combining of mechanical or electrical motions or operations. A compound escapement or compound servo.
<b>Contacts</b>	Usually, those parts of a relay touched by the armature when it is moved. Can mean the switches built into a servo. Any two metallic parts which come together to complete an electrical circuit.
<b>Control</b>	The process of having a model do what you want it to through sending and receiving of commands.
<b>Cross wind</b>	A wind blowing at right angles to the direction in which a model plane or boat is moving.
<b>Crystal (abbreviated Xtal)</b>	A sealed part of the transmitter which makes it transmit on one channel (frequency) only. A piece of piezo-electric quartz.
<b>Current</b>	The flow of electricity (which in a way is like water). Water flows at so many quarts or gallons per minute. Electricity flows at milliamperes or amperes per second. A milliammeter measures the amount of current flowing. In radio control, we are interested in small amounts of flow and thus, measure in milliamperes.

<b>Current change</b>	A change in the flow of electricity in a radio receiver or transmitter circuit. Most commonly means the difference in electricity flow in a receiver when no signal is sent and when a signal is sent to it. If there is a current of 4 ma with no signal and 2 ma when signal is sent, then there is a <i>current change of 2 ma</i> .
<b>Cw</b>	Continuous wave
<b>Cycle (or cyclic)</b>	Any motion or signal which repeats itself, any series of events which repeat.
<b>Dc</b>	Direct current (or voltage)
<b>Decoder</b>	That part of the receiver which separates the various commands. A reed unit, bandpass filters, escapements with switches or servos with switches.
<b>Delay (time delay)</b>	An electrical circuit which, when energized, remains energized for a period of time after the circuit is broken.
<b>Detector</b>	The first stage in some receivers (superregenerative) which gets the signal from the tuning coil. In a superheterodyne, that tube, transistor or diode which changes the carrier to audio.
<b>Detune</b>	The process of not adjusting a receiver or transmitter exactly to the signal. A change in the sensitivity of a receiver due to the presence of a person or metallic object. With a transmitter, it means adjusting a capacitor or slug of a coil so that a meter does not read the lowest value. With a receiver, it means changing the position of the slug in a tuning coil so that it is not set exactly on channel.
<b>Dip (see detune)</b>	Adjusting the capacitor or slug of a transmitter circuit so that a meter will read the lowest possible value. Since the low value occurs at just one particular spot and high values are on each side of it, this spot is called the dip.
<b>Distance check</b>	The process of adjusting a radio-control receiver when it has been moved 100 yards or farther from the transmitter. Testing at this distance to see if it can be operated by the transmitter.

- Doubler** In a transmitter, a radio tube which passes only the second harmonic of a signal. A signal of 13.6275 million cycles per second would be doubled to 27.255 million cycles per second, a radio-control frequency.
- Drain (current)** The amount of electricity used (drained) out of a battery. A high-drain circuit is one in which the battery is used up fast. In a low-drain circuit, a battery lasts a long time.
- Drive motor** The motor which causes the model to move. Generally used with respect to cars and boats. Drive motor of an airplane is the engine.
- Drop (current)** A smaller reading on a milliammeter. Term is used when comparing a meter reading without signal to one with signal (see Current change).
- Elevator** The horizontal part of an airplane tail which moves up and down to make the airplane go up or down. Elevator control is used primarily with multi-channel receivers.
- Elevator control** The means of sending signals to the model to make the elevator move.
- Erratic operation** Equipment works some of the time and does not work at other times. A radio control system that operates unpredictably with or without signals. Operation that is not dependable. Usually refers to the radio-control receiver. (see Chattering)
- Escapement** A rotating arm, crank or wheel whose motion is stopped at various positions by mechanical stops. The mechanical stops can be made to release the arm when a magnet coil is energized and de-energized. but the rotating part can never run freely.
- Field-strength meter** A meter which can show by a reading that the transmitter is sending out energy. The larger the reading, the greater the power. This meter is not connected in any way to the transmitter and is usually placed at least 6 feet from the transmitter.
- Filter (spark)** A resistor and capacitor put together and soldered to the terminals of a motor or across relay

- contacts to prevent arcing. A spark filter may be a diode.
- Filter (tone)** A coil and capacitor put together so they pass only one tone. A tone filter is also called a band-pass filter.
- Flyaway** A radio-controlled airplane which has gone beyond the range of the transmitter. An airplane in which the equipment has failed but which does not crash. Any airplane over which you have lost control and which keeps flying.
- Frequency** A number of vibrations per second. The channel to which the receiver is tuned. May be referred to as audio frequency or radio frequency. A radio frequency is a carrier. (see Carrier)
- Fundamental frequency** The original or input frequency. A crystal may have a fundamental frequency of 9.085 mc but, due to circuitry, may send out a third harmonic of 27.255 mc, a radio-control frequency.
- Gas tube** A small radio tube which has some vapor in it. An RK61 or XFG-1 tube.
- Grid** The element of a radio tube which controls the current flow through the tube.
- Grid leak** A resistor used in the grid circuit of a tube to provide a discharge path for the grid coupling capacitor.
- Ground** In an electrical circuit, the connection between the circuit and the earth, or some other conducting body or chassis. Generally, this wire also connects to the B-minus terminal. It also means the metal chassis when parts are connected to it.
- Hand capacitance** The effect on the tuning of a receiver from having your hand too close to the receiver or its antenna. Causes the receiver to be detuned so that it does not receive the transmitted signal. A change in the meter reading of a transmitter or receiver due to a person being too close to it.
- Hard tube** A standard radio vacuum tube which may be small or large. Life usually is much longer than that of gas tubes.

<b>Harmonic</b>	A signal which is a multiple of another. A tone of 300 cycles has a harmonic at 600 cycles. This is the <i>second</i> harmonic. The third harmonic would be 900 cycles, etc. In transmitters, a crystal may generate a radio frequency of 13.6275 million cycles per second. This would be called the <i>fundamental</i> . The second harmonic would be used, which would be 27.255 mc, for radio control. When the second harmonic is used, this is called doubling.
<b>Hash</b>	Electrical interference such as that caused by the sparking of an electric motor when it is running.
<b>Hot</b>	That wire, terminal or electrical circuit which is not connected to the metal base of the equipment. The hot terminal of a car battery is the one not connected to the frame of the car.
<b>Ignition system</b>	The electrical circuit consisting of coil, capacitor, breaker-points and battery that feeds high-voltage to spark plug. Modern small model engines now use simpler glow-plug ignition.
<b>Indicate (indication)</b>	An effect shown on a meter, light or other such instrument which shows whether a circuit is operating or not operating.
<b>Insulated (insulate)</b>	To cover a wire or metal part of radio equipment so that it cannot touch another metal part. Covering can be tape, plastic or special tubing called spaghetti. Can mean to use wood, fiberboard or plastic as a mounting base for metallic electrical contacts or parts.
<b>Interference</b>	Any unwanted signal or electrical disturbance which causes the radio-control system to operate incorrectly.
<b>Jack</b>	The receptacle designed to allow a part to be easily connected and disconnected. The wall socket of your house is, in a way, a jack. A jack may have a switch built into it which is operated when the male part, the plug, is inserted.
<b>Juice</b>	Electricity. "There is no juice" means there is no electricity in the battery, or it is not properly connected to the circuit.

- Juggle** To tune and retune, to adjust and readjust (a relay). To change around first one way and then another to get the best operation or position.
- Jumper** A short piece of wire which connects the contact of a relay to an armature, or which connects across the terminals of a switch or makes a temporary electrical connection between any two parts of an electrical circuit. Usually used as a means to determine bad parts in the system, or to test parts of the system in temporary operation.
- Key** The process of pressing and releasing the transmitter button switch. That part of the transmitter which is pressed to cause a signal to be sent.
- Keying switch** Any kind of a switch which must be held down to make it close an electrical circuit. A doorbell-type switch.
- Leading edge** The front edge of the airplane wing or tail. The rounded portion.
- Lean out** Refers to the adjustment of an airplane motor. To adjust the needle valve so that the motor draws less fuel than when it was running rich and the motor speeds up. This happens sometimes when a model is launched; the motor may run a little slow and will speed up as it leans out due to increased airflow.
- Limit switch** A switch which is so arranged and fastened to a motor that makes the motor stop running when it turns a given amount in one or more directions. Any kind of a switch which limits motion.
- Linkage** That wire, rod, metal or wood bar or bars which connects an escapement or servo to the steering wheels, rudders, elevators or motor-control levers in a model.
- Machine screw** A threaded fastener which can be inserted into a tapped (threaded) hole or nut. In numbered diameters with fine threads such as 0-80, 2-56, 4-40, 6-32, 8-32, etc. (See also Bolt.)
- Milliampere** A unit of measure of the amount of electricity flowing in a circuit. 1/1000 ampere. Radio-con-

trol receivers use from 2 to 10 ma to operate relays. Some receivers which use transistors to operate escapements directly use from 50 to 300 ma. Transmitters use from 10 to 100 ma depending on type of power output.

- Mixer** An electrical circuit which combines several signals, such as tones or frequencies.
- Modulation** The process of making the carrier of a transmitter change in such a manner that tones may be sent from the transmitter to the receiver. The part of the transmitter which does this is called a modulator.
- Motor control** The process of being able to change the speed of the model-propelling motor.
- Multichannel** A transmitter-receiver radio control system which has several tone frequencies or uses two or more radio frequencies to send commands. Most common type of multichannel system uses several tones.
- Needle valve** That part of the airplane engine which regulates the amount of fuel flow.
- Neutral** The center position of an escapement, servo, rudder, elevator, aileron or steering wheels. Usually the *non-energized* position of escapements and servos.
- Neutralizing (servos)** Referring to a servo, means the ability to send signals restoring a steering surface to the center position, or having the servo do this itself automatically when no signal is sent. The latter is called "self-neutralizing."
- Neutralizing (transmitter)** Referring to a transmitter, means the process of adjusting the second or output tube so that no signal passes through it unless a battery is connected to this tube and its tuning circuits are correctly adjusted.
- Ohm** A unit of measure of how difficult it is going to be for an electrical current to get through a resistor. Low ohms (1 to 100) mean little difficulty. Large values (1,000 to millions) mean great difficulty.

- Open (connection)** An incomplete electrical circuit due to faulty connection, broken wire, etc. "A coil is open" means a wire is broken somewhere inside.
- Oscillation** With receivers, means a howl, an audible tone generated by the receiver. With transmitters, means the generation of radio energy. In general, a tone or radio signal being produced by radio equipment because the equipment is improperly adjusted or not constructed properly.
- Oscillator (tone)** That part of the transmitter which produces the tone signals which modulate the carrier.
- Oscillator (transmitter)** That part of a transmitter which generates the carrier.
- Pattern** The way you must fly your airplane in a contest. Usually, you must fly straight away 500 feet, make a quarter turn ( $90^\circ$ ) to the left, then a three-quarter turn ( $270^\circ$ ) to the right to bring the airplane back toward you. Overhead you must make figure-eights, circles, rectangles, etc.
- Pile in** To crash the airplane into the ground.
- Pitch (motion)** Motion of plane or boat up and down pivoted at the center of balance.
- Pitch (propeller)** Slant or twist of propeller for airplane or boat.
- Plate pin** That pin or wire of a radio tube on which the signal comes out. This pin is usually connected to the plus terminal of a battery through a resistor or transformer.
- Plug (glow-)** Requires connection to battery only when starting engine. Combustion heat keeps plug hot after engine is started.
- Plug (phone)** A male electrical fitting which makes two or more connections. Normally used on end of earphone cord. (See Jack.)
- Plug (spark-)** Needs battery connected continuously for operation with coil, capacitor and breaker points. Not used for newer, small internal combustion engines.



<b>Prime (motor)</b>	A model airplane engine is primed by squirting a small amount of fuel into its intake before trying to start it.
<b>Printed circuit</b>	An electrical circuit which uses no wires. This type circuit is made from a metal or plastic plate which is cut or etched to form the paths the electricity must follow.
<b>Proportional control</b>	Being able to move the rudder, elevator or steering wheels a small amount at a time so that you can make gradual or sharp turns, etc. Most control systems require that the rudders, etc., be moved all the way to the right or left, and the time you keep them there determines how sharp a turn the model makes.
<b>Pull out</b>	To bring the airplane to level flight or make it climb after it has been in a dive. Most models pull out automatically when no signal is sent.
<b>Pulse</b>	A short radio signal produced by depressing and releasing a keying switch either by hand or by machine. A pulse is a longer signal than a blip.
<b>Pulse rate</b>	The number of times a second that the transmitter is turned off and on.
<b>Pulse spacing</b>	The time the signal is not sent, if you are depressing and releasing a keying switch at regular or irregular intervals.
<b>Pulse width</b>	The length of time a signal is sent. Short time, short pulse; long time, long pulse.
<b>Pulser</b>	A mechanical device usually consisting of a small electric motor moving an electrical contact, so that the transmitter is keyed automatically. Has a lever so that you can set the transmitter's on and off times as you choose (vary the pulse width, spacing and rate).
<b>Push-rod</b>	Similar in purpose to torque-rod but moves forward and back instead of having a rotary or twisting motion.
<b>Quench</b>	A signal generated within a superregenerative radio-control receiver which controls its sensitivity (range of operation) and makes it able to receive radio-control signals.

<b>Ragged</b>	A tone which is not clear, which is fuzzy or erratic.
<b>Range test</b>	See Distance check.
<b>Reed receiver</b>	A receiver which operates with tones and has several thin metal strips which vibrate (reed bank) (usually a multichannel type).
<b>Relay</b>	A switch which can be made to open and close by connecting it to a battery. An electrically-operated switch.
<b>Relay stage</b>	All parts connected to the relay, including the tube or transistor, to make the relay operate.
<b>Rf</b>	Radio frequency.
<b>Rich</b>	In referring to an airplane engine, too much fuel and not enough air. Needle valve open too far, motor runs slow.
<b>R O G</b>	The airplane rises into the air from the ground all by itself although it may be under radio control.
<b>Rudder</b>	The movable part of the upright tail surface of an airplane. The steering surface of a boat.
<b>Rudder control</b>	A radio-control system which lets you move the rudder of an airplane or boat by radio signals.
<b>Servo</b>	That part of radio-control equipment which uses an electric motor and has gears to move the rudders, steering wheels, etc.
<b>Short circuit</b>	The accidental touching of two wires or parts. A path for electricity which we do not want which causes the equipment to operate incorrectly.
<b>Signal</b>	In a receiver, it is the electricity which is present when the transmitter is on and which disappears when the transmitter is off. "Send me a signal" means "turn the transmitter on." Also, a certain way of keying the transmitter; for example, a left signal may mean depressing the transmitter keying button and holding it down.
<b>Signal strength</b>	How powerful the radio signal is. Usually determined by using a field-strength meter. (see Field-strength meter)

<b>Simultaneous control</b>	Two or more commands can be sent at the same time; for example, a command for a turn and a command for up sent at the same time.
<b>Single channel</b>	A radio-control receiver which operates on carrier or uses only one tone. A receiver which has one relay.
<b>Slug</b>	The center portion of a coil which can be screwed in or out to adjust the tuning. It is usually a powdered-iron cylinder with a screw shaft attached.
<b>Spark suppressor</b>	A resistor and capacitor wired in series (or a diode) connected across the terminals of a motor, switch or relay contacts to prevent or reduce arcing.
<b>Spot landing</b>	Landing the airplane on a spot which has been selected earlier. In contests, it is a mark on the flying field on which the contestants attempt to land their airplanes.
<b>Sticking (relay)</b>	When the armature is pulled down by magnetism in the coil and does not release when the coil is demagnetized.
<b>Superhet receiver</b>	A radio-control receiver built like most home broadcast radios. Has very sharp tuning and is very sensitive. In radio control, a superhet receiver has a crystal like a transmitter and does not require tuning.
<b>Super-regenerative (detector)</b>	The first tube or transistor in a superregenerative receiver. The one which connects to the tuning coil.
<b>Super-regenerative receiver</b>	A receiver whose tubes and circuits are designed for tremendous amplification. Characterized by very high sensitivity. Tunes broadly.
<b>Tension spring</b>	The spring on a relay which keeps the armature against one contact when the relay is not energized.
<b>Ticket</b>	The license the Federal Communications Commission issues when you fill out Form 505.
<b>Tolerance (crystal)</b>	The amount or percentage that you can be away from the frequency specified by the Federal Communications Commission. How close the crystal is to the exact frequency in percent.

- Torque rod** A type of linkage which conveys a rotary motion.
- Torque tube** An aluminum tube which serves as a bearing for piano-wire linkages.
- Trailing edge** The sharp edge of a wing, tail or rudder.
- Trim** The adjustment of the airplane wing or tail or engine so that it flies straight and climbs gradually, to fly level. Being able to position an elevator or rudder by radio control to a position to cause the above.
- Tuning** Adjustment of a coil or capacitor to make a receiver pick up a transmitter signal. Adjustment of a transmitter's coil(s) or capacitor to make it produce a radio signal.
- Two-speed control** A means of radio control which allows you to change the motor propelling the model, from fast to slow, and from slow to fast, without any speed in between.
- Vibrator (vibra-pack)** An electrical device which produces the electrical pressure (volts) and current (milliamperes) to operate a transmitter when it is connected to a storage battery.
- Volt** A unit of measure of the amount of electrical *pressure* in a battery. This pressure is what makes an electrical current flow. Flashlight batteries have approximately 1.5 volts (pressure).
- Warp** The twisting of a wing or tail surface due to the drying out of the dope or to incorrect gluing and assembly of the ribs and spars.
- Watt** A unit of measure of electrical *power*. Volts times current is equal to watts. Current must be expressed in amperes or decimal fractions of an ampere.
- Wet cell** A battery which has a liquid in it like a car battery and can be recharged.
- Wing loading** The weight in ounces per square foot of wing area.
- Xtal** See crystal.

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