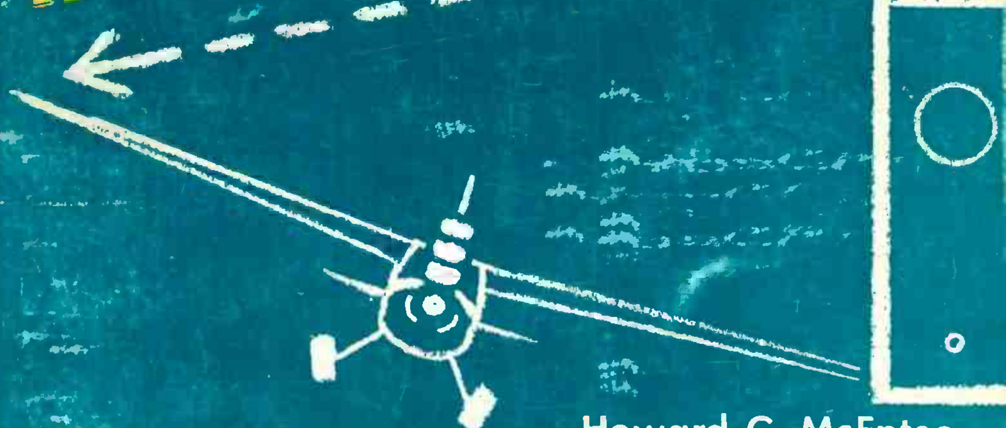
radio-control handbook



Howard G. McEntee

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RADIO-CONTROL HANDBOOK

by

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Gernsback Library No. 53

PUBLISHED BY

Gernsback Publications, Inc.

Publishers of RADIO ELECTRONICS

25 West Broadway,

New York 7, N. Y.

Library of Congress Card No. 54-10600

Radio-Control Handbook

Introduction

EVEN though the interest in radio control of models continues to increase by leaps and bounds, the reader may wonder "why another book on the subject," when the publisher already has the very popular "Model Control by Radio." This new volume is intended as a complementary work to the Safford book; while the former describes R-C systems and ideas by the dozens, many experimenters have expressed a wish for more detailed information on the actual construction of a limited number of practical units. Also, there seems to be a dearth of data on trouble shooting, installation of equipment, and even on what sort of equipment is suitable for various needs.

It will be noted that there is very little straight theory in this book. Guided by the requests of many readers, the publishers feel that the present need is for a book directed to those who may have a fair knowledge of electronics, and possibly model design and construction as well, but just do not know the practical methods for tying these two fields of knowledge together.

This book describes relatively simple control systems. Those who have need for more complex layouts can obtain all the data they need from "Model Control by Radio." We feel that the two books will constitute a fairly complete library of radio control, as it is practised today.

It will be noted that model airplane terms—such as fuselage, elevators, spiral dive, etc.—are used throughout the text. We have used them, since by far the largest use of radio-control equipment is for the control of model planes. It should be understood, however, that virtually all of the systems, equipment, and gadgets we cover may be adapted with little or no change to other classes of models such as boats, cars, and the like. In fact, Chapter 12 covers three complete control systems for boat and vehicle use.

Street & Smith Publications Inc., publishers of the magazine "Air Trails Hobbies for Young Men," have been most helpful in allowing the use of many illustrations originally appearing in articles by the author and printed in Air Trails, and the Air Trails Model Annual. We thank Radio & Television News for permission to describe and illustrate the equipment covered in Figs. 206, 208, 209, 214, 503-505, 705-707, 808-809. Thanks also go to Popular Science Monthly for use of their illustrations, Figs. 1215-1223 showing our R-C tractor. Ideas from many pioneers in the radio-control field are presented herein and we gratefully acknowledge the following. Figs. 118 and 305, John Worth; Fig. 307, Howard Bonner; Fig. 308, Al Trefethen; Figs. 310 and 311, Jim Schenck; Figs. 313, 807 and 810, E. Paul Johnson; Figs. 314 and 315, Claude McCullough; Fig. 501, John Worth and Ed Lorenz; Figs. 507-509, and 714, John Curry; Fig. 812, Bob Trainer; the sleek Porsche body in Fig. 1207, Aubrey Kochman. And lastly, the author wishes to express deep appreciation to his long-suffering "hobby widow" wife, Elinor, for help in preparation of this manuscript.

HOWARD G. MCENTEE

Chapter 1

Simple Control Systems

IN electronic model control, the simplest of all steering devices is the electromagnet. This may be linked to the rudder of the model as shown in Fig. 101. It is set up so that with no incoming signal the rudder is at one extreme of its range of

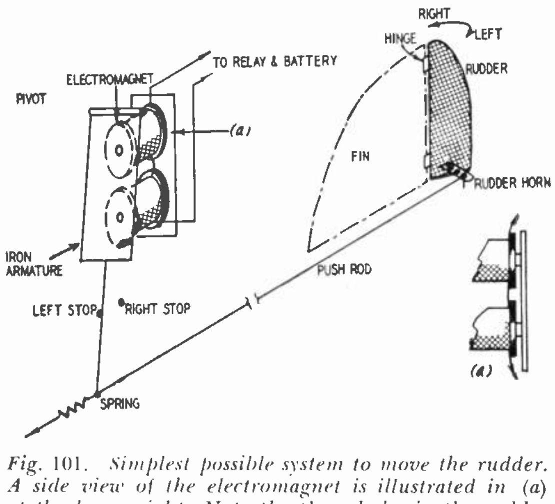


Fig. 101. Simplest possible system to move the rudder. A side view of the electromagnet is illustrated in (a) at the lower right. Note the three holes in the rudder horn.

movement. When a signal is transmitted, the magnet armature—and with it, the rudder—takes the opposite extreme.

Assume that with no signal coming in the receiver relay cuts off the current flow through the electromagnet. The armature is pulled away from the electromagnet by means of the spring. This spring action also pulls the extension arm until it reaches the left stop. The motion of the push-rod (connected to the extension arm) pulls the rudder over to one side. If, now, a signal is picked up by the receiver in the plane, the relay will put the electromagnet into operation, the iron armature will be attracted, and the push-rod (now going to the right) will force the rudder to assume the opposite position.

The push-rod is not fastened directly to the rudder. Attached to the rudder (fastened at right angles) is the rudder horn. The end of the push-rod is free to turn in the rudder horn. The motion of the push-rod is such that it moves the rudder horn front or back. Since the horn is fastened to the rudder, this results in rudder motion.

The horn usually has a number of holes. As the push-rod is

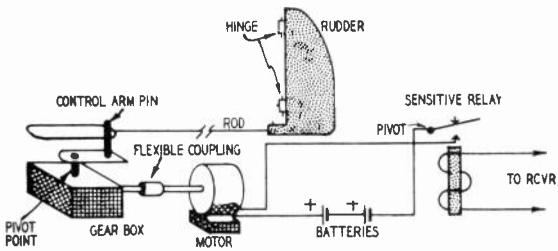


Fig. 102. The geared-down motor gives lots of power, but relatively slow rudder movement.

moved toward hole 3, rudder movement is increased, but turning force is decreased. Hole 3 in the horn is closest to the rudder.

We can thus make the model turn right or left; to get neutral, or straight flight, the operator pushes the transmitter button at short intervals, the idea being to send right and left impulses rapidly enough so that the model will follow a straight line. If the pulses are fast enough, the path will be quite direct and not a wavy line as might be expected, since the reaction of the plane to the rudder is not instantaneous. Some models react rapidly; some much more sluggishly. Therefore, this sort of control should not be employed on a fast and highly maneuverable model plane, though it is quite adequate for a slow plane or an electrically driven boat.

Simple motor rudder drive

A tiny electric motor may be used to control the steering surfaces, and since it must be geared way down, there is plenty of turning power available. In the most elementary arrangement, the motor and gear train are connected directly to the sensitive relay of the model, as in Fig. 102. When the transmitter is kept on, the receiver in the plane operates the sensitive relay shown in the illustration. The armature moves down, closing the motor circuit. The gears in the gear box are turned through a flexible coupling connected to the motor. The transmitter is kept turned on until the rudder assumes the desired angle. This means that the operator must watch carefully, and cut the signal when the turn is at the required angle. To get back to neutral, it is necessary to allow the motor-driven arm to go to the extreme position, then turn back the other way. This is certainly a rough sort of control, but a lot of fun can be had with this simple system. Furthermore, exactly the same rudder-moving system may be

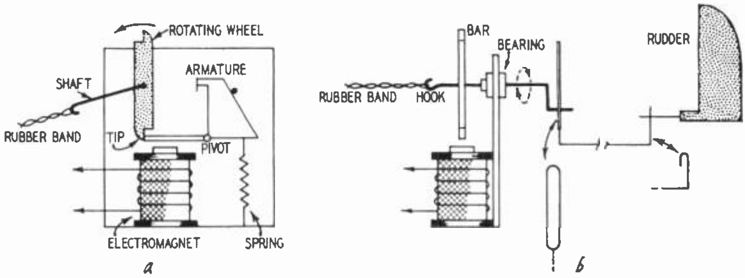


Fig. 103-a, -b. Illustration above shows a front view (left) and a side view (right) of the two-arm escapement.

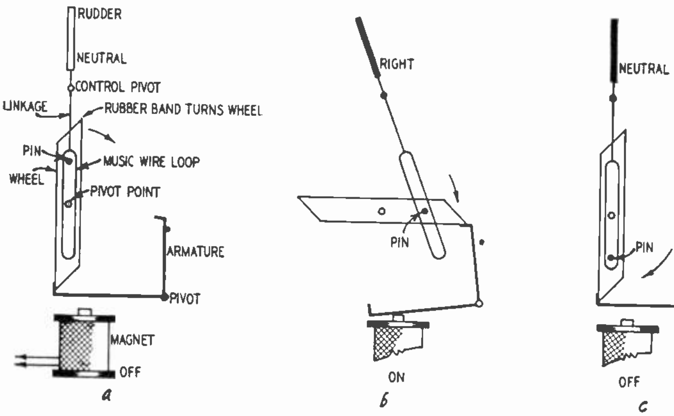
utilized, with more complex switching at the transmitter, to get a better and more precise rudder movement. Chapter 2 will explain how this is done.

Escapements

A very simple device for moving the rudder is the escapement, by far the most widely used control mechanism today. It can be made to give neutral, or right and left, and some types even can give right and left in two degrees, if desired. Escapements are generally classified according to the number of *arms* or the number of tips or points on the rotating wheel. The simplest is the two-arm style in Fig. 103. In Fig. 103-a, no current flows through the electromagnet, and the spring keeps the armature in the position shown. The armature fits into the bottom tip of the rotating wheel and keeps the wheel in a vertical position. When a signal is received, the electromagnet is energized and pulls down the armature, releasing the tip of the rotating wheel.

The rubber band forces counter-clockwise rotation. The tip spins a quarter turn and catches into the upper part of the armature. The armature will be kept in this position as long as the signal is transmitted and received. Thus, the rotating wheel will turn 90 degrees when the transmitting key is pressed down, and another 90 degrees when the key is released. Fig. 103-b shows a side view.

Rudder operation with a two-arm escapement is illustrated



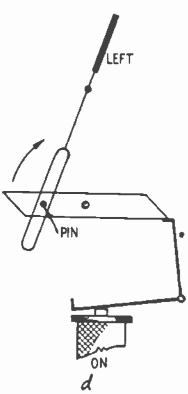


Fig. 104. In this illustration we have the successive stages of operation of a rudder using a two-arm escapement. The first picture (a) shows the rudder in a neutral or straight position. When current flows through the electromagnet, the armature is pulled down, the wheel rotates 90° and we get right rudder (b). When the current through the electromagnet is stopped, the wheel turns another 90°, returning the rudder to neutral (c). Energizing the electromagnet again gives left rudder (d).

in Fig. 104. It will be seen that the wheel can be made to take and hold any of four positions, though the rudder itself has only three positions. At (a), we start out in one of the neutrals, and the rudder is centered. At this point, there is no current going through the escapement coil electromagnet. If a steady signal is transmitted, the coil becomes energized and pulls the armature down, the bar turning 90 degrees clockwise (b). The action of this mechanism is such that the rudder is then turned to the full right position, and will stay there just as long as the signal comes in. With the signal cut off, the wheel (sometimes called a bar) rotates another 90 degrees in the same clockwise direction, getting the rudder back to neutral (c). Another signal gives a further

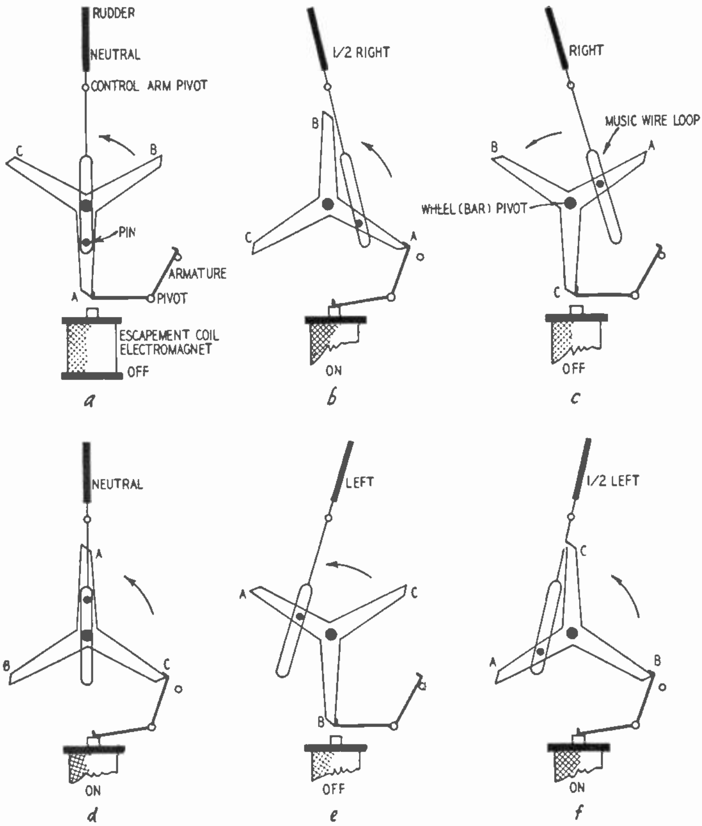


Fig. 105. Positions taken by a three-arm escapement. Such escapements are not very widely used.

90 degree rotation for left rudder (d), and when this signal is cut, the wheel returns to its first neutral position (a). It will be seen that the rudder is in turn position whenever the signal is on (b and d), and is in neutral when it is off (a and c). This is a big advantage in many ways, as the operator can always get neutral by simply releasing the transmitter button; it is generally considered that this sort of escapement is ideal for the beginner. The two-arm style is by far the most popular, even with the experts, due to its ease of operation. It has the disadvantage of re-

quiring power all the time the rudder is in a turn position. Current-savers, to be described later, overcome this objection.

You will note in Fig. 104 that right rudder actually shows the rudder moved over to the left. The term right rudder does not refer to the positioning of the rudder, but rather to the motion of the plane. Thus, left rudder means that the plane is turning to the left, and right rudder indicates a right-hand movement of the plane.

Three-arm escapement

Three-arm escapements (Fig. 105) have not been widely used, but do offer certain advantages. Probably one reason for their comparative lack of popularity is that there has never been a commercial three-arm unit made. It will be seen that the bar (or wheel) has only one neutral position (there are really two, but only one of these two neutrals may be had when the current is *off*). Thus, from neutral (a), you will always get right (b) with one pulse of signal, and left (e) with two. It is not necessary to hold the pulse to remain in a turn position (c). The rudder returns to neutral (d) when the transmitter signal goes on again. The disadvantage of this system is that current must be *on* for one of the neutrals. See Fig. 105-d. The three-arm escapement, however, supplies ½ right and ½ left rudder, useful for making shallow turns. See Fig. 105-b and 105-f.

Four-arm escapement

The four-arm escapement of Fig. 106 is in quite wide use. It takes no power to hold in the turns, and affords half positions, that may be used for shallow turns or to close contacts for other control purposes. It must be pulsed back to neutral from the turn positions. This has been found confusing to beginners. The illustrations (a, b, c, etc.) show the different rudder positions. The four-arm escapement also appears in the photo, Fig. 107.

Briefly then, the two-arm escapement is the simplest to operate (and the simplest to make, if you wish to build your own equipment), but requires that current be drawn to hold a turn. If control is lost during a turn, the rudder will be returned to neutral position; this prevents a spin-in, but may result in a lost plane. Three- and four-arm units must be pulsed back to neutral after each turn. Both allow turns without current drain, and both afford intermediate or half-control positions with signal on.

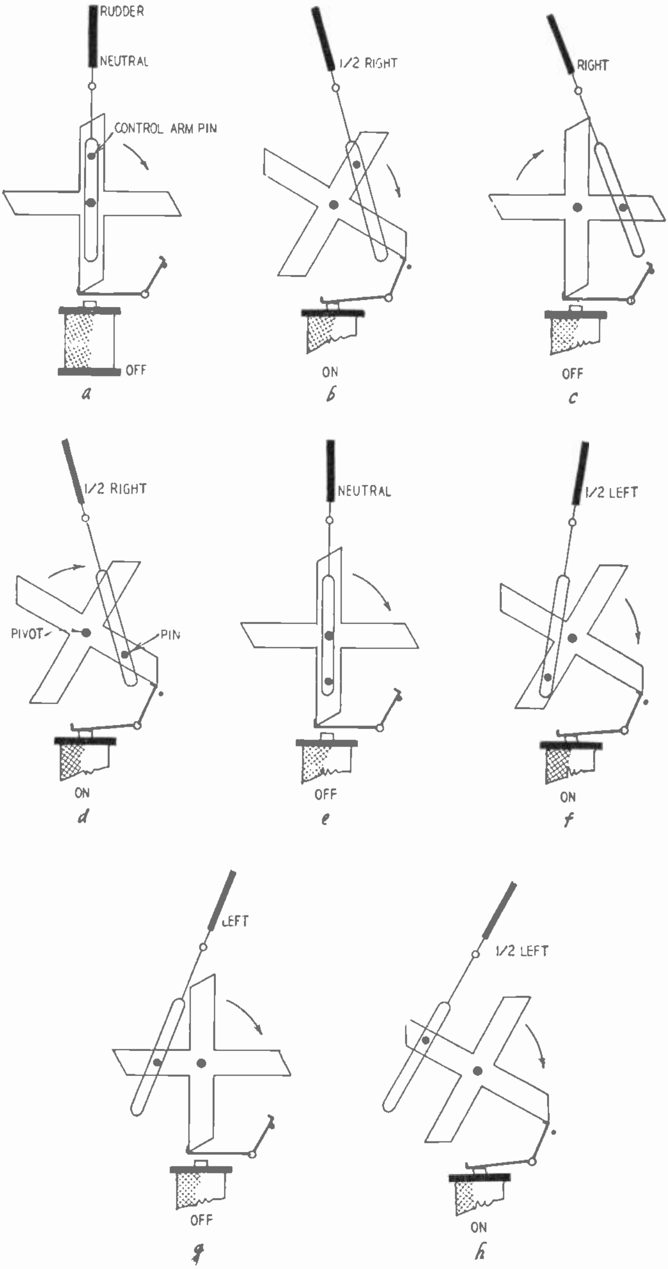


Fig. 106. The four-arm escapement shown above will hold continuous turns without current drain. Like the three-arm escapement, it can supply ½ right and ½ left rudder for making shallow turns.

Lengthy (shallow) turns would normally require the use of the rudder in the ½ or intermediate position. Thus, to fly in a large circle, the control would have to be put half-right, or half-left. Both of these positions require power to maintain the turn.

The compound escapement

This unit is a comparatively recent development. It is unique

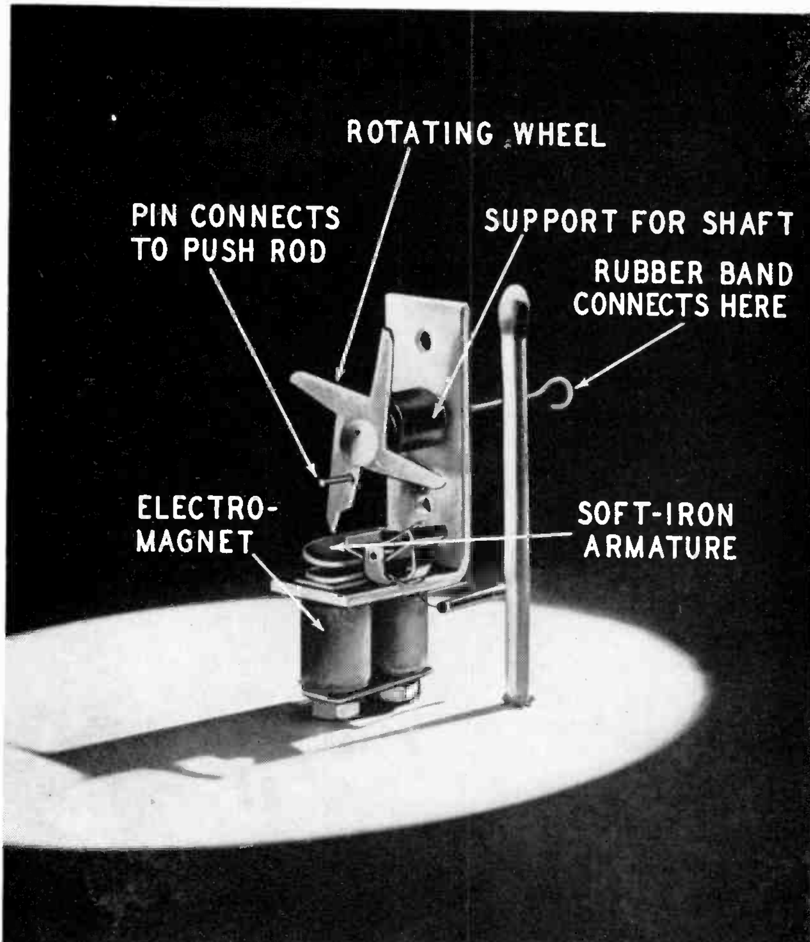


Fig. 107. Photo of a four-arm escapement. When current flows through the coils of the electromagnet, the soft-iron armature pulls down, releasing the rotating wheel for a 45° turn. The escapement is turned by a rubber band.

in that the rudder always returns to the same neutral after any turn. There is only one neutral, and as seen in Fig. 108-a, the neutral point or arm (1) engages only on armature stop B, while the other three arms (2, 3 & 4) engage only on Stop A. ·With this escapement, (as we show it in Fig. 108) one pulse always gives right rudder and two give left. Another arm (5) operates on three pulses, and is used to close a set of contacts for a supplementary control such as motor or elevator. Arm 5 is the shortest of the arms and is the only one to engage the electrical contacts. The contacts are not operated by the longer arms. Arm 5 has a step-like bend so it alone pushes the electrical contacts, the longer arms passing either over or under them. It will be noted that when the fourth arm is engaged on the armature stop (Fig. 108-d),

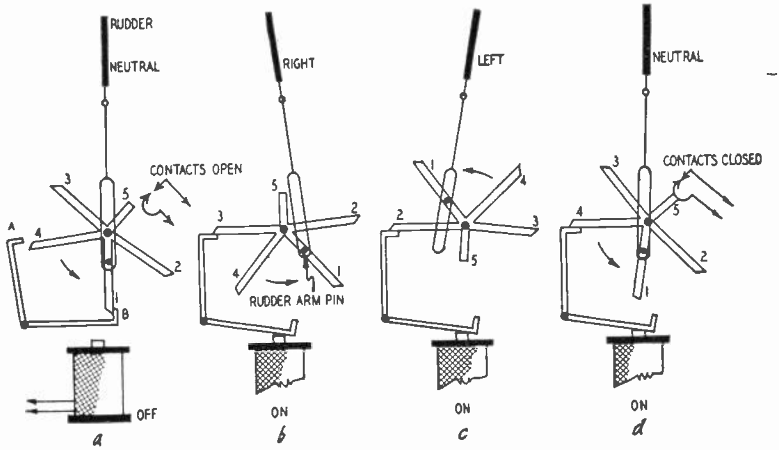


Fig. 108. Steps in the operation of a compound escapement. For the sake of clarity, the text refers to arm 5: however the compound escapement does not really have a fifth arm, the contacts being closed by a lug punched up on the ratchet wheel.

the control linkage is just about in neutral, so that if you are using this position to change motor speed for example, the rudder is essentially in neutral while the change is being made. Since the operator couldn't possibly pulse fast enough to catch the wheel at the arm he desired, this escapement must be fitted with a governor to slow the wheel. The commercial version shown in Fig. 109 has a vibrating arm and toothed wheel for this purpose.

All the other escapements we have shown require that the operator follow a fixed sequence when moving the rudder; you have to go through unwanted positions in a set sequence. Furthermore, the number of pulses will vary, according to the direction of the turn you wish, and which neutral the wheel happens to be in when you start the series. Thus, you have to keep in mind at all times which direction of turn you made last, so that you will know what direction is coming up nex'. If you wish to give three left turns in a row with a simple escapement, you still have to signal for right and neutral every time in order to get your lefts. The compound escapement is the only one that does not require this adherence to sequence—hence it is by far the easiest to fly with. One pulse will *always* give one direction of turn and two pulses will *always* give the opposite position. While the rudder does go through the undesired position, it has no effect on plane direction (since the pulses come so rapidly) and most important of all, you do not have to try to remember what rudder position

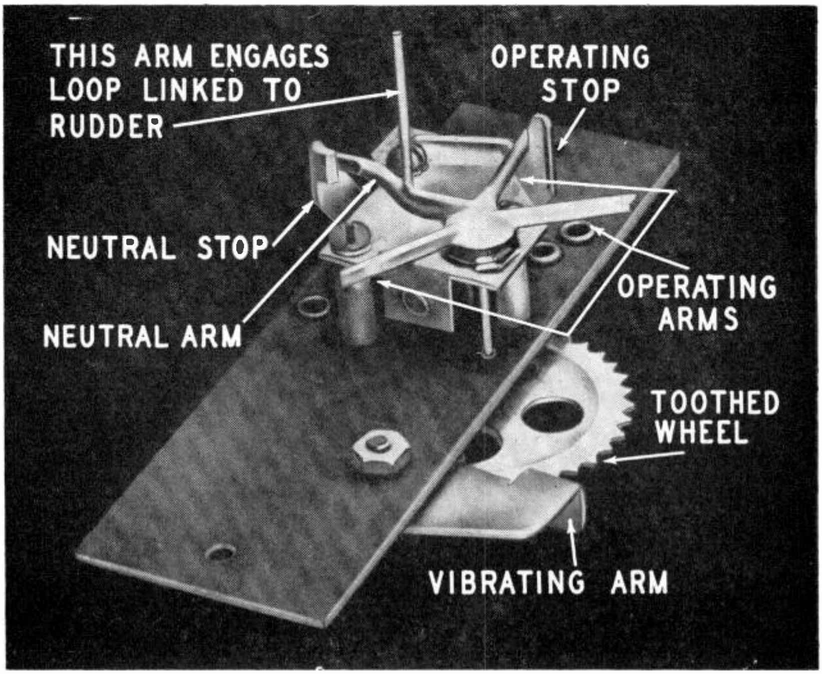


Fig. 109. Photo of a compound escapement. Note the toothed-wheel governor to slow rotor movement.

is coming up next. Current must be held on for the duration of a turn; the wheel always goes into neutral when the signal goes off.

Escapement drive power and linkages

All the escapements we have covered utilize the electric power that is sent to them by the sensitive relay of the receiver only to *control* their rotation. The mechanical energy for such rotation, and for use in moving the rudder, must come from another source. In practically all escapement operation, a twisted rubber band

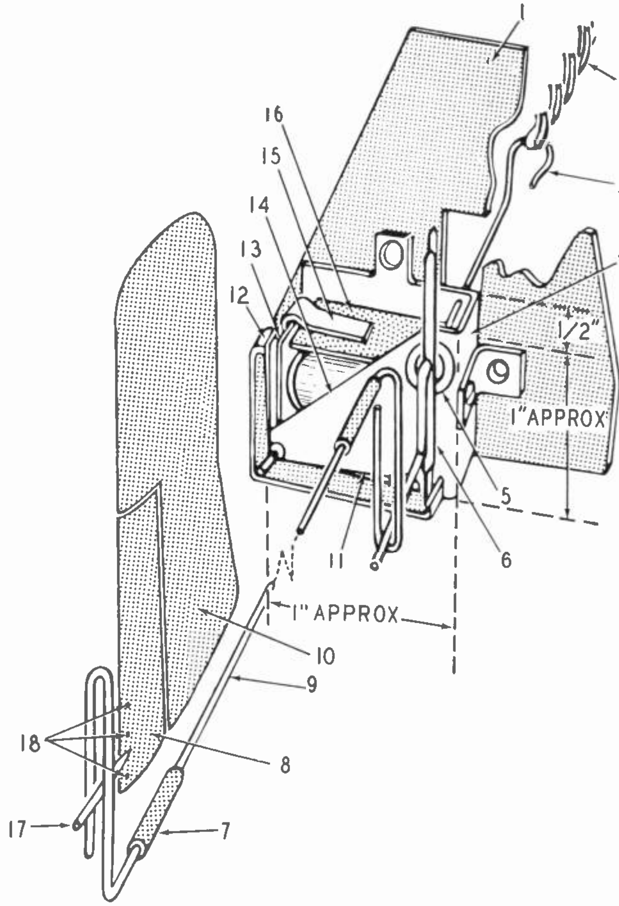


Fig. 110. The escapement mechanism. The parts are identified as follows: 1) bulkhead; 2) rubber loop, 1/8-inch flat rubber; 3) crank-pin hook, 1/16-inch music wire; 4) frame, .025-inch hard brass sheet; 5) bearing, model airplane type; 6) control arm, 1/8-inch brass rod; 7) bushing, brass tubing; 8) rudder; 9) yoke shaft, 1/16-inch music wire; 10) fin; 11) spring, .012-inch music wire; 12) pawl; 13) armature, 1/16-inch soft iron; 14) coil: 90 ft. No. 32 enameled wire (or equivalent in No. 31 to give resistance of 6-10 ohms), wound on soft-iron core, 3/16-inch diameter, 3/4-inch long. This coil draws 300 to 500 ma at 3 volts; 15) armature stop; 16) L-shaped coil bracket; 17) rudder pin; 18) extra adjustment holes for the rudder pin.

supplies this auxiliary power. Most commercial escapements are designed to operate on two strands of 1/8 inch flat rubber. The loop thus formed is run through the fuselage to a hook, and the far end must be fastened in such a spot that it may be easily reached, so that the rubber can be wound, as the turns are used up. The rubber loop must supply torque, or twisting effort, but as little tension as possible. To reach this objective, it is common practice to make the loop much longer than the distance from fixed hook to escapement—some fliers use a loop one and a half times as long. Of course, this must be wound up considerably before it contracts enough to hold securely on the hooks. Though most escapements are made without them, some experts insert tiny ball-bearing washers between the wheel and the frame, to attain as close to frictionless rotation as possible. Anything that will contribute toward this end is worthwhile, as it is an assurance

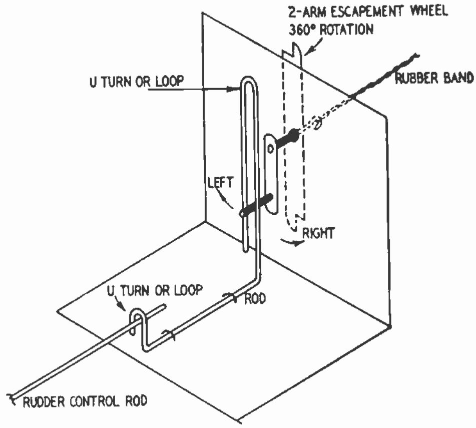


Fig. 111. Simple linkage controlled by a two-arm escapement wheel.

that the escapement will still move the rudder reliably, even though the rubber loop may be almost unwound.

The entire linkage to the rudder must be worked over until it is entirely free from binding of any sort. It has been found that the *rocking* type of linkage is easiest to set up for free operation. As illustrated in Fig. 110, the wire that runs to the rudder rocks back and forth; there are loops (U turns) at each end to engage the pin on the escapement, and another pin on the rudder. If several holes are made in the rudder for the latter, the amount of rudder movement may be controlled as required.

Details of a simple linkage are shown in Fig. 111. For the sake of simplicity the electromagnet and the armature are not shown. When the escapement wheel turns, the crank also will turn, both parts eventually going through a complete 360-degree rotation. The rod, ending in the form of an inverted U, will move to the left or the right depending on the position of the crank arm. In this way, circular rotation is changed into lateral (side to side) motion. At the rudder end, the rod terminates in another inverted U. A rudder-control rod passes through this U but is not fastened to it. As the U moves left or right, it pushes

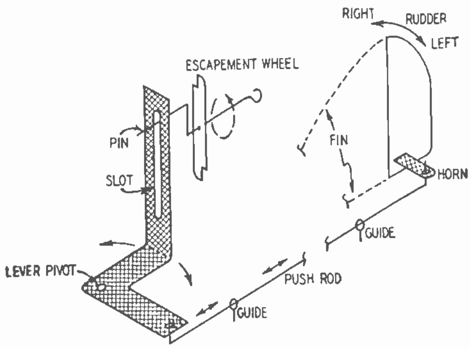


Fig. 112. The push-rod linkage is fine if carefully made and adjusted.

the rudder-control rod also left or right. Since the rudder-control rod is fastened to the rudder, this gives left or right rudder motion.

Some builders prefer the push-rod arrangement shown in Fig. 112. Since the escapement must be placed in the fuselage so that

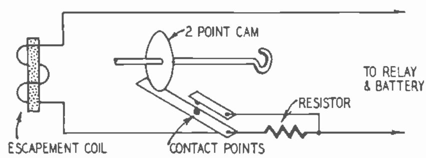


Fig. 113. Escapement gets full power to move armature. Reduced power will hold it operated.

the rubber band can run lengthwise, it is necessary to employ a pivoted arm to secure the desired fore and aft motion of the rod. A horn is then used on the rudder. The horn can be drilled with several holes so that the rudder movement can be set as required. In such a system, greatest care must be exercised to eliminate drag and binding, for in this setup there are many more points where friction can develop and hinder the control surface action.

Since many turns are required to wind up the rubber loop, it is usual to employ some sort of winder for the purpose, such as a heavy wire hook held in the chuck of a small hand-drill. The rubber should be stretched out to at least twice its normal length at the start of the winding, then gradually brought in to normal length as the end of the winding is approached. This allows many more turns to be put in the rubber without fatiguing it. If the model is to be stored for a considerable time before being used again, the turns should be taken out of the rubber.

Current savers

Some escapements are fitted with means to cut the current they require, so that lengthy turns may be held without running

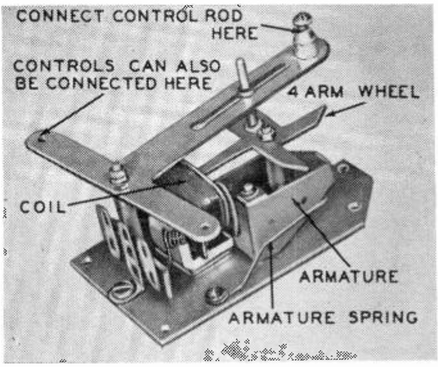


Fig. 114. A wound-up spring works this escapement. It will give about 50 turns of the rotor on a full winding.

the battery down. There are two main ways to do this; both require that the full power be fed to the escapement to initiate the movement of the armature. When the latter has come close to the pole piece, it can be held there with much less power. A set of contacts is needed to shift from high to low current drain. These may be worked by a cam on the shaft, by a projection from one of the arms, or the contact may be closed through the arm itself. Some escapements have two windings on the core, one being used for full power and the other for hold. Others simply put a resistor in series with the single winding, to get a lower current drain for hold purposes. The latter is simplest, and is of more interest, in that the arrangement may be added to escapements that have only the usual single magnetic winding. Fig. 113 gives the details.

The average escapement requires around 500 ma at 3 volts to operate. It will be found that this current can be cut in half or even further, and still retain sufficient power in the coil to hold the armature reliably. Since the coil will have a resistance of about 6 ohms to operate at these values, it will be necessary to use a resistance of the same ohmage, or higher, for the current saver. Depending upon the size of the control surface to be moved (and held), it might be found that a considerably larger resistance value would do, thus saving even more battery power.

Clockwork escapements

This is a type rarely seen, but quite useful for purposes that do not require too many operations during the flight of the plane. While it would not do for rudder actuation, it would be entirely practical for motor or elevator control. Because there

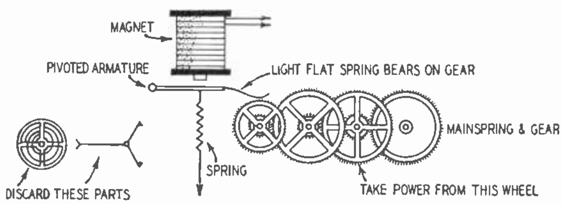


Fig. 115. Very little power is required to control this clockwork escapement which has no set stop positions.

is no stretched rubber band needed, the clockwork escapement may be mounted most anywhere in the plane, and may be oriented to suit the controlled element. In one commercial type, Fig. 114, the spring case is knurled on the outer edge, and the escapement is normally mounted in the plane so the knurled case is on the outside of the fuselage, for easy winding.

It is quite feasible to make your own clockwork actuator by a few simple operations on a small alarm clock as shown in Fig. 115. It is set into motion by energizing a small electromagnet which lifts a light spring off one of the gear-train wheels. Very little power is needed for this purpose.

The balance wheel and rocking arm of the clock movement are removed, leaving intact the entire gear train. The last gear before the rocking arm is used to control the movement, since only an extremely small amount of power applied to its rim is sufficient to stop the entire gear train, due to the great step-up between this wheel, and the main spring. It is possible to work this sort of power unit directly from a sensitive relay; this is done by attaching a tiny piece of flat spring to the armature of the relay. When the relay operates, the spring is pulled away from the gear wheel, and the gear train is allowed to turn.

This particular arrangement has no rotation limits of any kind—it just turns till you stop it. It is best therefore for operations that are required only once or twice per flight, such as retracting and lowering landing gear or flaps. The actual power is taken from the gear train at a point nearer the spring. One of the hand-shafts will normally be satisfactory.

Adding contacts to escapements

Most escapements, commercial or otherwise, are made without any sort of contacts, but these are easy to add. If the unit is a

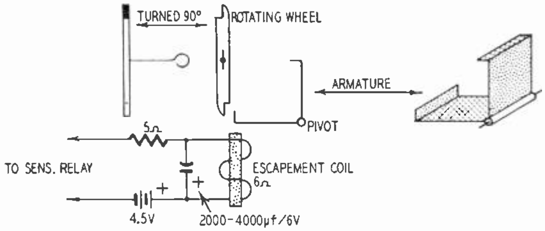


Fig. 116. Delay circuit for the escapement coil is simple, uses only a resistor and capacitor.

sturdy one, with good fit between shaft and bearings, you can solder a little cam to the shaft, and use this to work the contacts. The cam can have one or more points, depending upon what you wish to work with the added circuit. In the two-arm escapement, it is useful to have the added contacts close only in one of the two neutral positions. Thus you have one plain neutral left over for straight flight. If you have a four-arm escapement, the contacts may be placed to close in one or more of the half-positions; you can then skip through this position quickly, if you don't want the extra circuit to operate. For either of these cases, however, it will usually be necessary to include a slight delay action in the added circuit, so that the added circuit isn't actuated every time the wheel makes one rotation. If the circuit is an escapement or other magnetic device, as is most often the case, the delay may be had by the use of the simple arrangement in Fig. 116 where a low voltage, very high-capacitance electrolytic capacitor, and a low-value resistor are used.

Suppose, for example, that the relay closes the escapement-coil circuit. Without the 5-ohm resistor and electrolytic capacitor, current flowing through the escapement coil would magnetize the coil, and the armature would be attracted. Now let us see what happens when the resistor and capacitor are added, as shown in Fig. 116. When the circuit is closed, a large current flows, as the uncharged electrolytic capacitor acts almost like a short circuit: little current passes through the escapement coil. Since the current also goes through the 5-ohm resistor, a voltage drop is established which limits the voltage reaching the capacitor (and the escapement coil), thus slowing the charging of the former. However, the capacitor gradually becomes charged. As the charging current becomes less, several things take place. The voltage

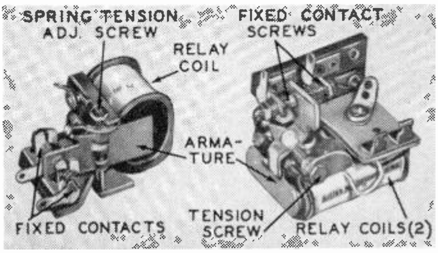


Fig. 117. These relays are tops for R-C work, but are a bit heavy.

across the resistor becomes less and that across the capacitor becomes larger. Eventually the voltage across the capacitor becomes sufficient to operate the escapement coil.

The amount of delay depends upon the values of resistance and capacitance you use. The larger the amount of resistance and capacitance, the more delay you will get.

Other simple delay arrangements are shown in Chapter 3. They may be worked from contacts on the escapement, or by other means.

Eliminating the sensitive relay

Before leaving the subject of simple control systems, it should be mentioned that it is quite practical to put a high-resistance winding on the escapement and work it directly from the plate circuit of the relay tube in the receiver. This arrangement is not too successful, however, with simple one-tube receivers, as the plate current change is not great enough to assure reliable operation. Good operation is secured with a receiver in which the plate current swings from near zero to around 2 ma; such receivers are of the multitube type described in Chapter 5. You need a very good relay for this sort of operation, and of course it must be considerably modified. The Sigma relays shown in Fig. 117 are generally considered to be tops for any radio-control purpose; the Sigma 5F is especially good for this conversion. Care is required in the construction of a high-resistance escapement, but if the job is well done, it will pay off in simplicity of installation and maintenance. There are no relay contacts to get dirty, and you don't have to worry about the escapement battery running down. In such an installation, it is usual to employ slightly larger B batteries; thus, the over-all weight saving is not a factor.

An ultra-simple rudder control method is shown in Fig. 118.

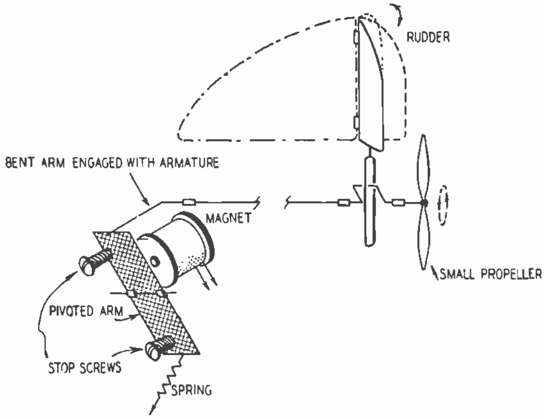


Fig. 118. In the illustration at the left we have a simple rudder control system for light-weight model planes. When the magnet is energized, the armature engages the linkage going to the rudder. The motion of the propeller (during flight) moves the rudder back and forth until the electromagnet becomes energized.

This again, is based upon using the plate circuit relay as the actuator. No rubber loop or other power is needed to work the rudder, though, for it is moved by the little propeller which turns in the wind-stream. Again, a receiver is required that will give a large plate current change, for the relay armature must be set to move 1/32 inch or so. As we show it, the rudder flaps back and forth continuously in flight, unless the magnet is energized, when the bent wire end catches on the relay armature. The plane is trimmed to fly in a fairly tight right turn (but not tight enough to develop into a spin); when the relay is not energized and the prop is spinning, the plane will turn right. With the prop stopped, the rudder is held steady in the left-turn position. To get neutral, it is necessary only to give an occasional pulse, which will stop the rudder momentarily in left and will serve to counteract the right trim. This system may be used with very small sensitive relays, and is ideal for the lightest weight planes.

Chapter 2

Complex Control Systems

MOST of the control arrangements described in Chapter 1 are the step-by-step type: they will give right or left, and neutral, as you desire, but only in one degree. If you want to make a long shallow turn to right, you have to signal for a whole series of *rights*, interspersed with *neutrals*. This is true because it is usual to set up the rudder to give fairly sharp turns, when it is held over to either side. Much smoother action in the turns could be had if there were a method whereby the rudder could

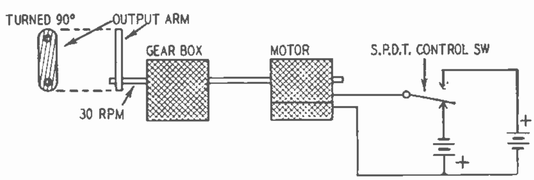


Fig. 201. Simple arrangement for demonstrating semi-proportional control.

be moved just a little bit to one side when a shallow turn is required. Actually, there is a way, and it is not too complicated at that. It is called semiproportional control. Most of the added complexity involves the transmitter, so not much extra is required in the plane. With this system you can have a shallow or steep turn just as you wish.

Semiproportional control

Let's see just what is required to get this semiproportional control action. It's more easily understood if you will try a simple experiment. Hook up a s.p.d.t. switch, two batteries, and a permanent-magnet motor geared down to a ratio such that if the switch is held closed the output shaft of the gear box will turn steadily at a speed of about 30 r.p.m. The circuit is shown in Fig. 201. With the switch in one position the motor turns steadily in one direction, and reverses when the switch lever (switch arm) is pressed to the other contact. Now try tapping the lever rapidly, so the motor receives reverse polarity in even pulses. What does it do? It wiggles energetically, but can't get anywhere —the output arm stands still—and that's the neutral of our semi-proportional system.

It's a simple matter to transfer this system of your model, for rudder operation. In the plane, instead of the s.p.d.t. switch, we will have the contacts of a sensitive relay, and the gear box shaft

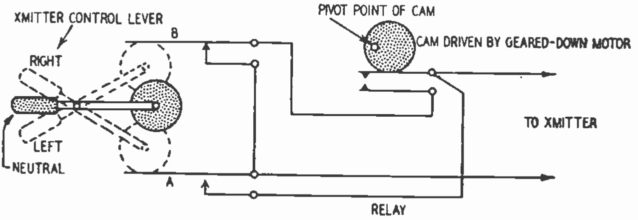


Fig. 202. Semiproportional mechanical pulser. The transmitter control lever is shown at the left.

connected to the rudder. To control the rudder, you push the button or key of the transmitter. If you push to get evenly spaced pulses, the rudder will not move; if you hold the key down, or else let it up completely, the rudder will go to either extreme position. To hold the rudder at any point of its travel either right or left, you would have to send even pulses again; this can be a nuisance (and tough on the thumb, too), so a simple keying pulser can be rigged up similar to Fig. 202. Here we have a small geared-down motor which turns a cam at steady speed. The contacts are arranged to turn the transmitter on and off, giving even on and off pulses. The actual control switch operated by you is the lever at the left; as set up here, the right position closes contact A, to give a steady signal. Left is had when contact B is opened: this cuts the transmitter signal entirely. In the center or neutral position, with contact B closed and A open as shown on the drawing, the transmitter sends out the steady series of pulses that signify neutral to the plane. Construction details of this pulser are given in Chapter 8.

This setup can give good results, but it is possible to do a lot better with a little further complication. The next step is to go back to Fig. 201, and try a further experiment. Suppose you tap the switch arm so that the pulses are *not* even; in other words, the lever is on one side longer than it is on the other. The gear-box arm will turn in one direction. Though the motor reverses each time you hit the lever, it turns more and longer in one direction than it does the other, so the net motion at the output

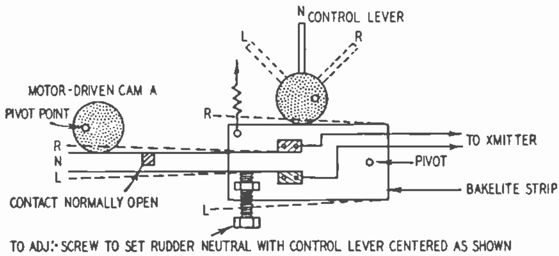


Fig. 203. This arrangement allows variation of proportion of on-to-off signals.

arm of the gear box is in one direction only. You can reverse this direction by allowing the lever to rest against the *opposite* contact for a longer period of time.

Now, we can take the geared motor and cam arrangement of Fig. 202 and add an adjusting system to the contacts moved by

Fig. 204. Types of pulses produced by the unit shown in Fig. 203.

the cam. This is depicted in Fig. 203; you can see that if the control lever is shifted from the center position, the motor-actuated contacts may be made to close for varying periods of time. Suppose the lever is shifted halfway to left; the contact strip that engages cam A will drop downward, and the cam will be able only to hold the contacts closed for a short part of its rotation. In the center or N position, on the other hand, the contacts were held closed for half of each revolution of cam A. Thus, at half left, the transmitter will be sending out pulses something like those shown in Fig. 204 (½ L). If the lever is moved full left, the signal will be cut off. Similarly, full right will be continuous signal, and half right will be long pulses with short intervals.

If you used this system at the transmitter, and had the same motor-driven rudder of Fig. 102, what sort of control could you get? Assuming that the whole layout were adjusted so that with the stick in the neutral position, the rudder would not move—if the stick were shoved half left, the rudder would move slowly to the left. To hold the rudder at any position, the stick would be pushed back to neutral. But to get the rudder back to neutral, the stick would have to be moved the other way—to the right. To make the rudder move rapidly in either direction, the stick would be pushed all the way in the desired direction.

A little reflection will show that this is pretty much the way certain controls on a full-size plane work. To get a turn in a given direction, the pilot moves his stick toward that direction (we assume that the rudder is moved in co-ordination with it) and the plane starts to roll into a bank, and to turn. When the desired degree of bank is attained, the pilot centers the stick, and the plane holds this degree of bank. To get back on an even keel, the stick must be moved to the other side for a short period, in order to neutralize the original bank. If he had held his stick in the original bank position, the plane would have continued to roll on over.

Semiproportional control of this sort has been used, but it has been found more practical to arrange things so that the rudder follows the control stick on the ground more closely, both in direction and in degree of movement. Thus, if you move the stick half left, the rudder also goes half left, and stays there as you hold the stick over. When you neutralize the stick, the rudder also neutralizes. There are several ways to acomplish this, the simplest being to put a spring loading on the rudder or its push-rod. Two springs are arranged so that they equalize in the neutral position, but build up increasing and opposite pressure, no matter which way the rudder is moved. When balanced properly, the rudder will follow the motion of the stick closely; it returns to neutral, because even with the stick in the center and the transmitter sending out evenly-spaced pulses, the unbalanced spring pressure on the rudder arm tends to force this arm back slightly toward neutral at every reversal of the motor. Worm-gear drive should be avoided in such a system; the back pressure of the springs causes binding.

A really simple proportional system may be had with nothing more than the magnet rudder actuator of Fig. 101. With the control box of Fig. 203 sending out even pulses, the rudder linkage and pull of the spring could be adjusted to give center rudder. Then any change toward longer or shorter pulses would give a deflection of the rudder one way or the other. In terms of rudder-moving equipment, you can't get much simpler than this, but it isn't a very practical arrangement, for lots of power would be required to move the rudder, and the actual movement could not be very large.

To get more movement of the rudder, some experimenters have used the little plastic low-voltage motors, of which there are many on the market. The motor is fitted with stops so that it can turn no more than, say, one-half a revolution. As the pulses come in, the motor then flips back and forth between these

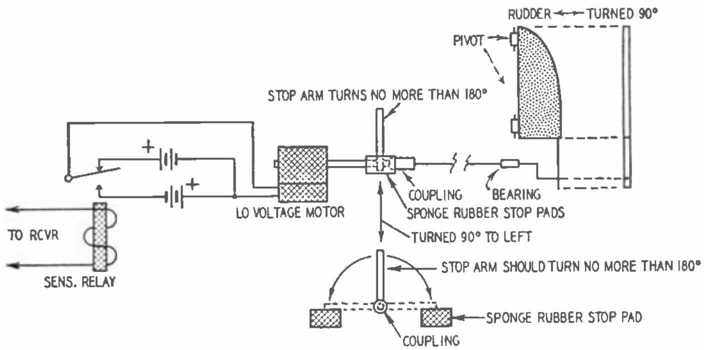


Fig. 205. A low-voltage motor can be used to move a rudder or elevator.

stops, and the push-rod works the rudder. The motor has lots of power, and can move a large rudder or elevator, but it takes a lot of current. An electric motor draws the greatest amount of current when it is not turning, and of course this system, which we show in Fig. 205, requires that the motor be stalled at the stops part of the time, and moving relatively slowly the rest. Also, it requires two sets of batteries, one for each direction. This is considered a disadvantage, since one set of batteries will almost always run down, and hence tend to drop its voltage faster than the other. Since few sensitive relays are made with d.p.d.t. contacts which would enable them to be connected as a reversing switch and used with a single set of batteries, other means are required.

Actuators

A neat way to reduce the current drain, while still obtaining plenty of push-rod movement, is shown in Fig. 206. This gadget, developed for model use by George Trammell, is generally called simply an *actuator*. It might be likened to a permanent-magnet motor without a commutator. It gives a shaft rotation of up to about 160 degrees, depending upon the power put into it and

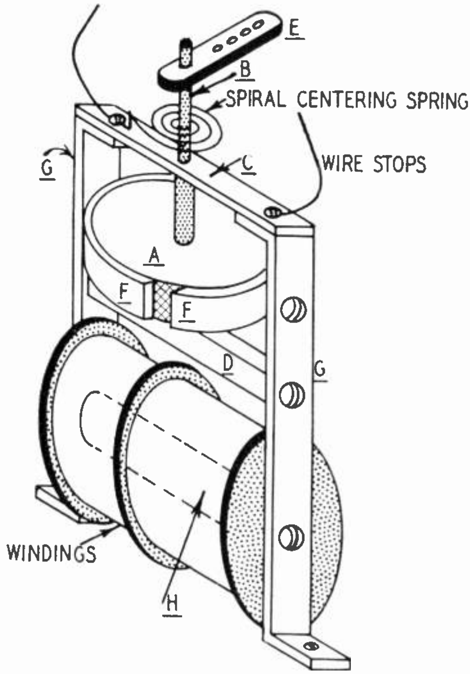


Fig. 206. Disc-magnet type rudder actuator. The letters on each part correspond to similar letters in the detail drawing of Fig. 208.

whether it is used with single or dual windings. With a single winding, it may be connected to two sets of batteries, as was the motor of Fig. 205. If it is provided with two windings, the

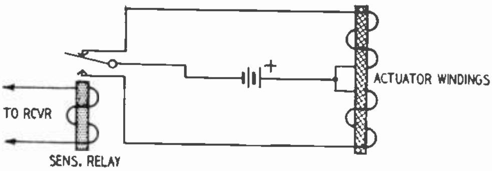


Fig. 207. Preferred actuator hookup uses only one battery.

connections are as in Fig. 207. The windings should be polarized so that shifting the relay armature from one side to the other will make the actuator move in opposite directions.

The basis of this unit (Fig. 206) is a disc permanent magnet A attached to a shaft B. The shaft turns in bearings C, D, and carries the arm E, which works the push-rod. Two semicircular

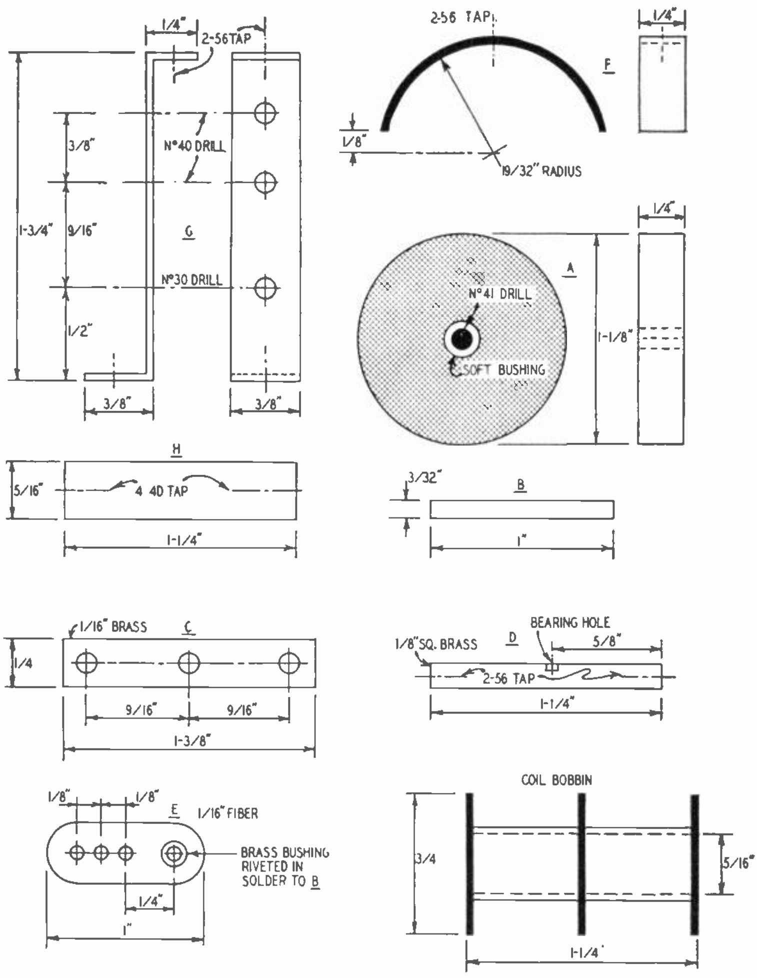


Fig. 208. Dimensions of the parts needed for the actuator illustrated in Fig. 206.

pole pieces F, and two side-frame members G of soft iron form the magnetic circuit, which is completed by the core H. These actuators have been made in many forms and sizes, depending mostly upon what the constructor could dig up for the disc magthrough them. Thus, you can get more power by increasing the number of turns, by putting more current through an existing coil, or both. If you have a big plane, and can carry plenty of batteries, you don't have to strive so hard for top efficiency. But if you want to get the most pull for the least current, it will pay you to try several different coils. As an example, the first coil used on the actuator of Fig. 209 had 780 turns of No. 32 enameled wire (on each coil), drew about 80 ma on 1-½ volts and had quite a good pull. The actuator in Fig. 209 weighs 3.4 ounces. equipped with the counterweight shown on the arm.

Another winding with 700 turns of No. 30 wire was tried. This gave considerably more pull, and a drain of 116 ma. But further

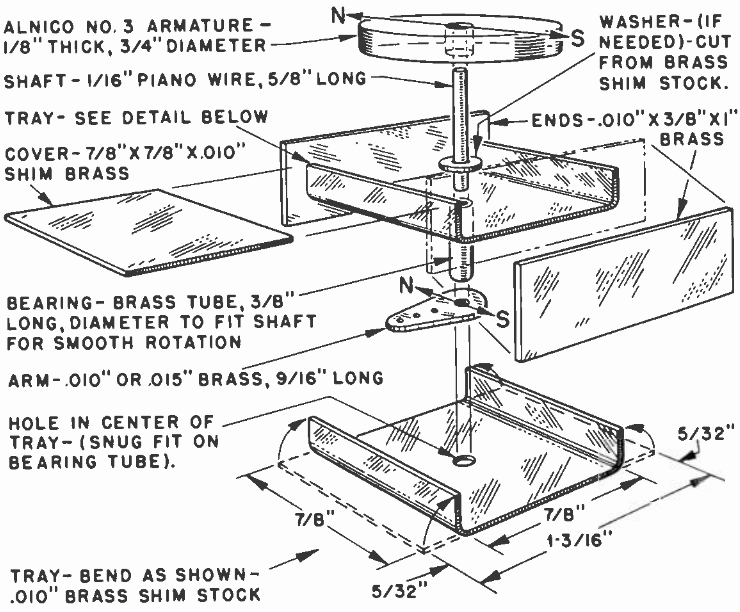


Fig. 210. Simplified style of disc-magnet actuator. This unit has no iron, except in the magnet and in the shaft.

coils with 600 and 500 turns of the same wire gave no increase in pull, although the drain went up to 170 ma in the last case. Also, cutting the size of the core H down to ¼ inch diameter reduced the pull very noticeably in every case.

In any of these magnetic gadgets, the inner turns are the most efficient, since they give just as much magnetic field as the outer turns, but do so with much less resistance, due to their shorter length. The best shape for such a coil would be long and thin. Final power available thus becomes a compromise between coil shape and size, number of turns, wire size, and the current you can afford to use.

Simplified actuator

Another type of actuator, also developed by Trammell, is shown diagramatically in Fig. 210. This is extremely simple, but has surprising pull. It can be made much lighter and more compact than the one in Fig. 209. Details of the actuator parts and

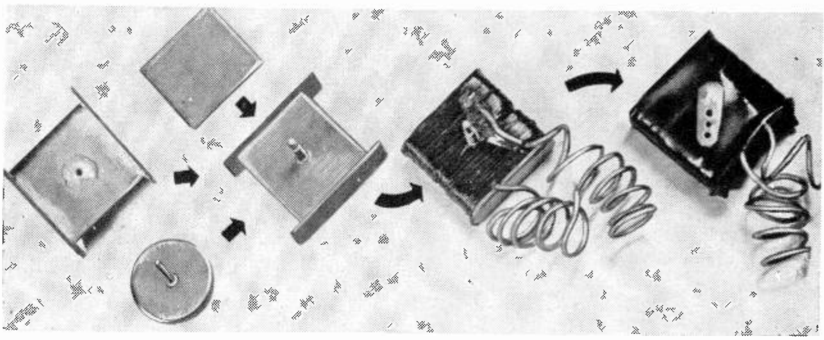


Fig. 211. Steps in the assembly of the simplified actuator. Commercial actuators are now available, although most builders prefer to make their own. Actuators are much easier to make than escapements, as the latter have tricky adjustments.

assembly are shown in Fig. 211. Actuator coil winding information and a cross-section through the assembled actuator unit are given in Fig. 212.

For the simplified actuator, it seems quite possible that bar or square magnets could be used, provided they are correctly

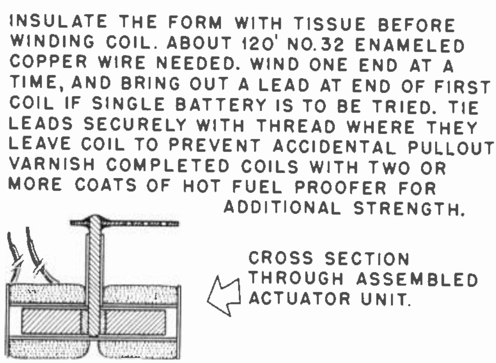


Fig. 212. Construction details of the actuator coil.

poled, if you don't require the maximum pull. This actuator has absolutely no centering action when the current is turned off; the more complex actuator of Fig. 206 does have some centering action—and this may be increased by putting a slight gap in the magnetic circuit (a thickness or two of cellophane tape between one end of H, and G) at the expense of some loss in pull. An actuator may be centered by the use of a spring, as shown in Fig. 206. A tiny bar magnet may be mounted beneath the unit of Fig. 210 centering being dependent upon how close this auxiliary magnet is to the disc magnet.

We have covered these actuators quite thoroughly since many radio-control hobbyists prefer to make their own. On the other hand, there are dozens of commercial escapements in all sizes and types. Incidentally, it is quite practical to make an actuator with a high-resistance winding, to be operated right from the last tube of the receiver without the need for a sensitive relay. Tests with the actuator of Fig. 209 showed that a very nice pull could be had when 8 ma was put through a 5,000-ohm relay coil substituted for the normal low-resistance winding. In this instance, the coil pulled only one way, against a return spring. If it were possible to use the same push-pull coil arrangement that is shown in Fig. 207, but with the high-resistance windings, the 8 ma could probably be reduced to only a few milliamperes in each coil. Such an arrangement would probably necessitate double output tubes in the receiver, and thus might add more complication than it is worth.

Preventing proportional control failure

Proportional control systems all have one failing: If you lose control for any reason, the ship goes into a hard turn to one side or the other. With a boat this would not be too dangerous, but with a plane it could—and usually does—lead to disaster. Even so most modelers (especially those who had formerly lost an escapement-equipped plane which flew off in a straight line when the radio system failed) would much rather take home the remains of a plane that would inevitably spin to ground when control was lost than lose the plane through a straight-line flyaway. Now there are ways to prevent proportional control systems from going into hard-over rudder if any part of the apparatus fails. It is probably easier to visualize the arrangement if we examine a motor-driven rudder hookup as shown in Fig. 213. This utilizes a PM motor, and two sets of cells, connected to the sensitive relay in such a manner that signal-on gives rotation one way and signal-off the other way. Let's say that with no signal, we have right rudder, with the relay on the upper contact; also, that to move the rudder arm toward right, the motor requires positive on terminal (1).

A study of Fig. 213 will show that the rudder control arm has normal R and L limits as shown by the dotted lines. A failure in the transmitter or receiver would in most cases cause the sensitive relay to assume the position shown. Tracing the circuit through you will find that this gives positive on motor terminal 1 and negative on motor terminal 2. The motor will turn right, forcing the arm past the normal right-hand dotted position and pushing the sliding yoke from stop B to stop A. This moves the

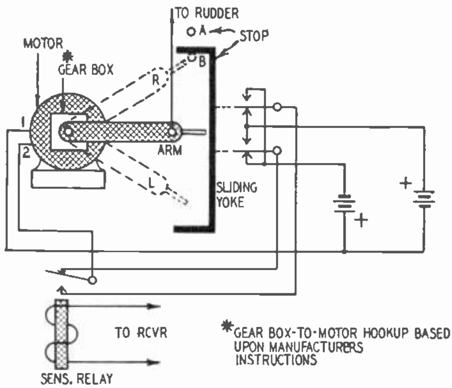


Fig. 213. Safety reverse system goes into action if radio equipment fails.

d.p.d.t. contacts to the opposite side (the sensitive relay remains nonoperated) the polarity of the motor voltage changes, and the motor reverses. Since the d.p.d.t. switch and yoke are designed to hold either position until forced opposite by the rudder arm, the motor will drive the arm to the extreme left position, pull the yoke down, and start back again. As a result, the plane will turn alternately hard right and hard left, a rather wild maneuver to be sure, but at least it won't have a chance to wind up into a screaming spiral dive, and it won't head off cross-country.

Should the breakdown occur at the transmitter and be quickly repaired, control of the ship could easily be resumed. The normal yoke position is downward (against stop B). You might have to move your ground control stick the wrong way to get the yoke back to normal. Once you did so, however, everthing would go on as before the breakdown.

Ordinary midget slide switches available in radio stores could be changed to fit this arrangement, possibly with a little alteration to make them work more easily.

The same sort of set up can be adapted to the actuator and the circuit of Fig. 207. The arrangement is shown in Fig. 214 and requires only the addition of a pair of contacts and the yoke to the actuator. Since the latter has nowhere near the power of the geared motor-driven system, the yoke and switch contacts must be made much more delicate and easy to move; however, this is possible, since only a s.p.s.t. switch is needed. The control box at the transmitter would be set up so that the pulsing would take place between the limits of, say 25% and 75%. Thus, full-on and full-off would be reserved for the safety system. Depending upon the type of receiver used, the contacts of the relay should be connected so that they would move the actuator arm up should there be failure of the equipment. Most model planes have one direction in which they spin (or spiral) much more tightly than the other, and this is the side to choose for the cutoff. It should also, if possible, be the same side to which the actuator moves the rudder when the transmitter fails. In case of transmitter or receiver failure, the actuator arm would move to the up position, but would go beyond the normal control range, thus moving the sliding yoke to open the switch, and de-energize the coil that pulled it to the up side. Air pressure would then move the arm back toward center; it would probably not go all the way to neutral, and you would thus have a wide turn—the most desirable condition. If the system failure happened to be at the transmitter, and could be quickly repaired, opposite rudder would pull the yoke all the way in the other direction (a button on the control box would be used to send 100%, or solid signal) and the switch on the actuator having been pushed to the other extreme, the entire system would be placed back in normal operation. If motor control were fitted to the plane, both the arrangements of Fig. 213 and Fig. 214 could have another set of contacts to cut the engine, or put it in low speed.

These safety systems seem quite practical, but it must be admitted that we have never seen any such system in use. Be that as it may, most users of proportional control *have* schemed out some such arrangements, and many of them—the writer included—hope *sometime* to put them into use. With the growing interest in adding other controls to our planes, such as motor speed or elevator, it is possible to incorporate safety hookups with the auxiliary controls. One such setup is described in Chapter 3.

Actuators may be connected to the rudder in the same way we have shown for escapements. The push-rod linkage is the most widely used, though the rocking arm can be rigged up to give the least friction. Some receivers are sensitive to "r.f. noise," the electrical disturbances created in the plane as pieces of metal rub together. Such interference can completely incapacitate such a receiver, as the rubbing is aggravated in flight by motor vibration. If your control system seems to work perfectly on the ground, even with the engine running, but becomes erratic in flight, it may be necessary to bond the various parts of

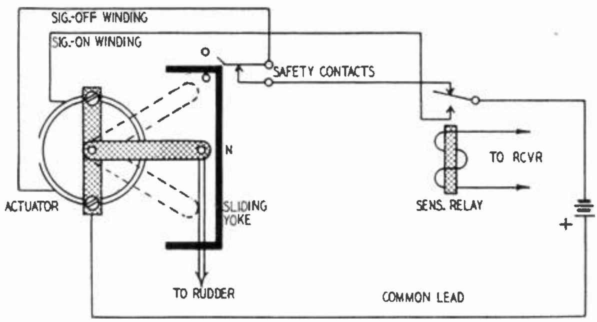


Fig. 214 Safety system that can be used with a magnetic actuator.

the rudder linkage. Some fliers use push-rods made of dowel or other insulating material to help clear this condition. Small pigtails of very flexible wire may be soldered between sliding or rubbing pieces of metal. Actuator arms may be made of fiber or bakelite. Such an arm was installed on the actuator in Fig. 209 to cure this sort of trouble. The spiral spring on the shaft was added for the same reason. The spring also serves the purpose of bringing the arm back to center, so that the neutral position of the rudder is more certain.

Chapter 3

Motor and Auxiliary Controls

MOST radio-control enthusiasts, after they have licked the problems of steering their model, develop an immediate urge to add other control actions. Some want elevator control; others prefer means to vary the engine speed. There are both simple and complex ways to effect these and other added functions. Let's see how some of the more practical systems operate.

Engine control

How, for example, can you vary the speed of your engine by radio? If you use spark ignition, it is a simple matter. The most

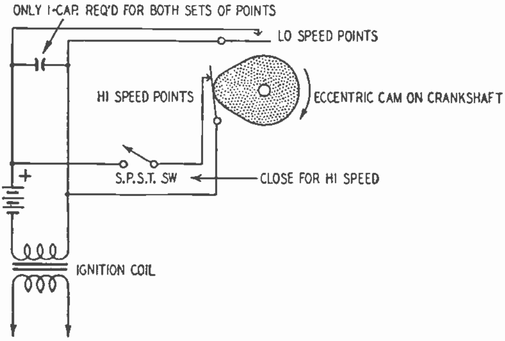


Fig. 301. Many users of spark ignition stick to this so-called old-fashioned form of ignition because it offers such a simple way to change engine speed.

common way is to use what are called *two-speed points* on the timer. One set of points runs the engine at top speed, the other slows it down, and the change between the two may be made by a simple switch. Connections are shown in Fig. 301. It will be noted that on'y a s.p.s.t. swi'ch is required. The reason for this rests in the arrangement of the points on the timer: as the cam turns, it opens the high-speed points before the low-speed points. Thus, when the high-speed points are connected in the circuit, they fire the charge before the low-speed points get a chance to operate. The latter do no work, but they do no harm either, and are always left connected. In operation, a relay would be substituted for the s.p.s.t. switch. The relay, operated by the receiver in the plane, could then be set into action by the operator on the ground. When the relay is open only the low-speed points are effective. There are commercial two speed points made, but they fit relatively few engines.

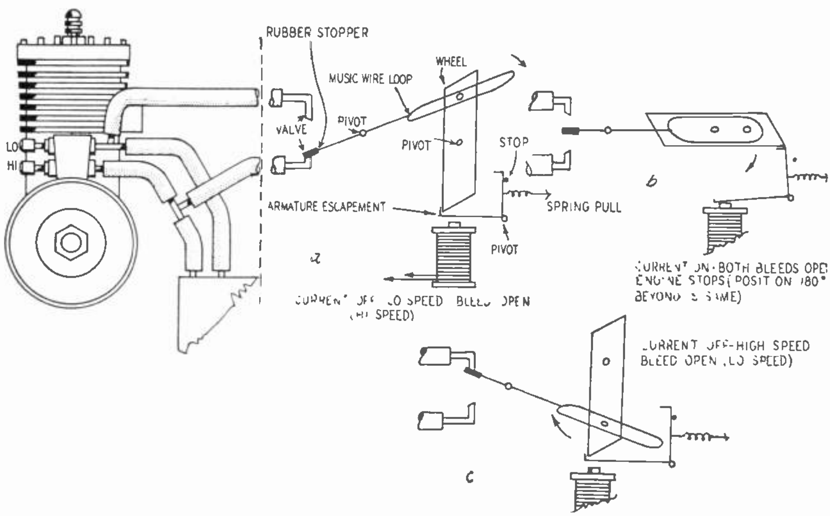


Fig. 302. (left) and Fig. 303 (right). The illustration to the left of the dashed lines shows the "plumbing" for dual needle valves. The drawings, a, b, and c, indicate the steps in motor-control escapement operation.

Speed of spark-ignition engines may also be changed by actually moving the distributor by means of a geared-down electric motor, but this idea is not in very wide use, due to the complexity and added weight. While spark ignition is in the minority, some modelers stick to it, since the fuel used doesn't harm dope, and it does offer such a simple and sure way to vary speed.

Twin-needle system

Glow-plug engines are a bit more of a problem, when it comes to speed variation, since it is necessary to alter the fuel-air mixture in some manner. Twin-needle valves, with appropriate air bleed, are usually fitted. Fig. 302 illustrates the common setup; the high-speed needle valve is connected to the tank through a tube that has a T some distance from the valve. The low-speed needle has its T right at the valve itself. When the motor is started, only the high-speed needle is utilized (the tube leading to its T is closed, while that to the low-speed T is open), and the engine is warmed up and set at the desired maximum speed with this valve. Then the T tube to the low-speed needle is closed; and that for the high-speed needle opened; this allows the low-speed valve to draw fuel. The low-speed needle is set very

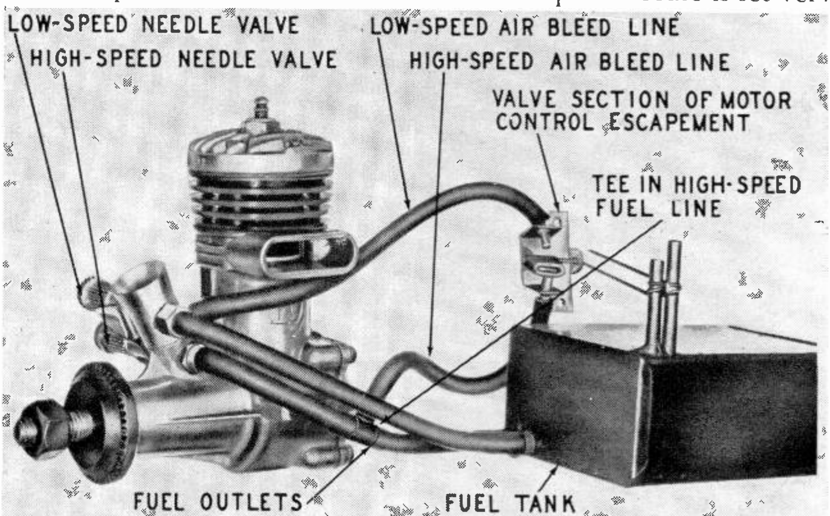


Fig. 304. Two-speed engine fitted with dual needle valves. Engine stops when both valves are opened. Wire loop on valve engages escapement rotor pin.

rich (excess fuel) and since the motor is getting an over-rich mixture, runs at lower speed. If it is desired to stop the engine, both T pipes are opened, cutting off the fuel flow entirely.

A special escapement is required to work the T pipes, or bleeds, as they are called. The two tubes are opened alternately, when the escapement is in one or the other of the *neutral* positions, that is, when the current is off. When the current is held on, both tubes are opened, the motor gets no fuel, hence stops. See Figs. 302, 303-a,-b,-c. Because the T on the high-speed fuel line is located several inches from its needle valve, opening this bleed momentarily, when changing from high to low speed, does not stop the engine, as there is sufficient fuel in the line to keep it running. To stop the engine the line must be held open till the fuel between the T and the needle is used up. Some control systems allow quite a lag between the time power is applied to the escapement, and the time it is cut off. In such cases, it may be found that the engine will stop when going from *low* to *high* speed, even though you don't want it to. This may be eliminated by connecting the T for the low-speed needle an inch or more from the needle itself so that a little fuel is stored up in the tube to maintain feed to the engine until the valve snaps over to the other side and fuel starts feeding through the high-speed line again.

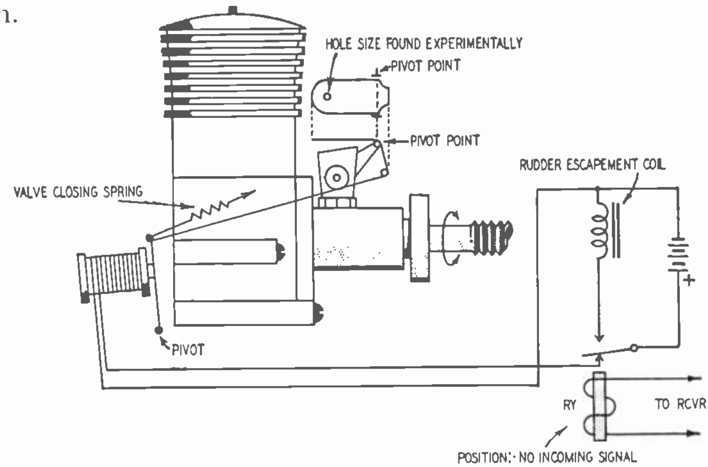


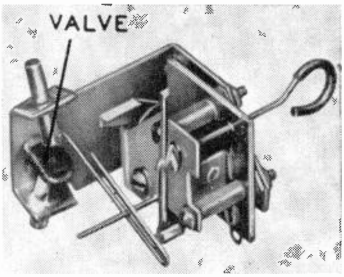
Fig. 305. A flap valve on the air intake cuts engine speed. A small hole in the flap valve permits the engine to run at slow speed.

The twin-needle system is very flexible, but in most cases the builder must adapt it to his own engine; Fig. 304 shows a commercial two-speed engine, the K & B .19, fitted with twin-needle valves.

Flap-valve arrangement

A simpler system is a flap valve fitted over the air intake. The flap must have a small hole in it to allow entrance of sufficient

Fig. 306. Photograph at the right shows a motor-control escapement used with dual needle valves. The valve is connected to a U-shaped linkage which is moved up and down by the rotary motion of a pin connected to the escapement.



air to promote slow-speed running. The engine is of course adjusted to the desired high speed first, then the clapper is closed and the hole is reduced till satisfactory low-speed running is achieved. Some engines are more adaptable to this sort of running than others; balky engines may often be made to run properly with a change of fuel. Fig. 305 shows the flap valve, and connections to the sensitive relay of a receiver for a workable two-speed system of the simplest sort. This arrangement must be used with a four-arm escapement; the latter works normally, but motor slow speed is had in each of the half positions of the wheel. The engine will give a cough each time a half position is passed through, so this system is best suited for use with a beep box (see Chapter 8), which operates the escapement very rapidly.

The motor escapement shown in Fig. 306 was developed especially for use with an escapement fitted with a pair of contact points, as is the one in Fig. 107. However, there are other ways to work it. One of these is shown in Fig. 307. The cam A is attached to the escapement shaft—it must be a shaft that fits well

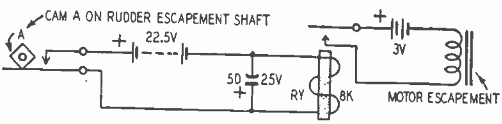


Fig. 307. Circuit to operate motor-control escapement.

and has no slop in the bearing. When the escapement is operated for normal turns, the electrolytic capacitor doesn't charge sufficiently to allow the relay to pull in. However, a series of four pulses turns the escapement wheel two complete revolutions, giving eight closures of the contact points—enough to pull the relay in for a moment and work the motor escapement. The four pulses also leave the escapement and rudder in the same position they had before the pulses came through, so the plane will not change direction when the motor speed is shifted. The cam is attached on the shaft so that it allows the points to close when the escapement wheel is between either of its two neutrals, and the two turn positions—in other words, when the armature is operated. The points should be adjusted as closely as possible, without running the risk of unwanted closing, while the 8,000-ohm sensitive relay is used with a fairly wide contact gap. The spring tension is set to give reliable closure when the four pulses come through.

Another variation of the restricted air intake system is shown in Fig. 308. This has been used effectively with the motor escapement shown in Fig. 306. The tube sizes are those found satisfactory with engines in the 0.09-cubic-inch class, and some experimentation may be required for larger engines.

Thermal control

Thermally-operated devices have been used for some years with complete satisfaction. They are based upon a strip of bimetal, and incorporate a small heating coil (see Fig. 309). The points may be either normally open or closed, as your circuit requires,

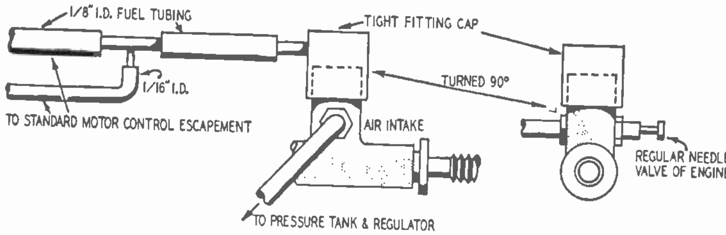


Fig. 308. This arrangement is good for small engines only, unless a special escapement with extra-large valves is used. Low speed, 1/16" line open; medium speed, 1/8" line open; high speed, both lines open; or, low speed, 1/16" line open, high speed 1/8" line open; motor cut, both lines open.

but when current is put through the heating coil, the strip bends and moves the upper contact. When the current is cut, the thermal strip resumes its original position, though a catch may be fitted which will hold it in the operated position, if this is

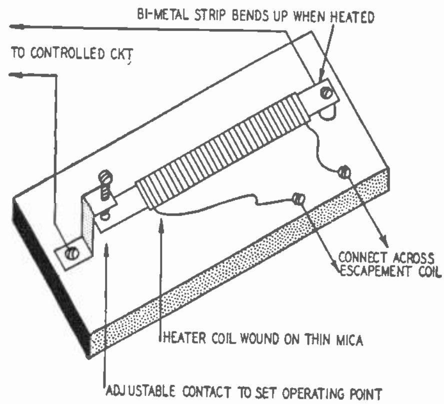


Fig. 309. Thermal release device uses bimetal strip.

desired. If used with a four-arm escapement, the heater may be connected right across the escapement coil; and since this type of escapement requires current only to turn the wheel, but none to hold it in the turn positions, the thermal unit does not receive current long enough to operate. If it is desired to work the additional circuit, the escapement is held in the half position for several seconds. The thermal unit may be used with two-arm escapements by adding a pair of contacts to the escapement shaft or wheel, that close in only one of the two neutrals. The other neutral is used in the regular manner. Some fliers object to this arrangement, since the heater coil takes quite a bit of current, and larger batteries are required in the escapement circuit.

Another auxiliary circuit, which again has been used primarily with four-arm escapements, is depicted in Fig. 310. The rudder

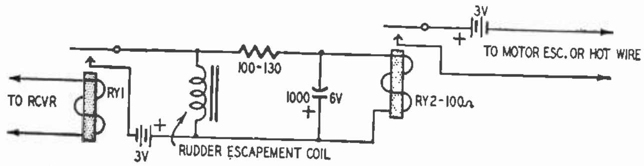


Fig. 310. This arrangement will permit you to work auxiliary circuits.

escapement works normally every time the receiver sensitive relay RY1 closes; the added relay closes only when a long pulse is received, since the resistor and capacitor constitute a delay circuit. RY2 is used to operate the motor, or any other auxiliary circuit. It can be used to drop a bomb, for example, by the simple release device in Fig. 311. The wire catch is pulled to the right by the

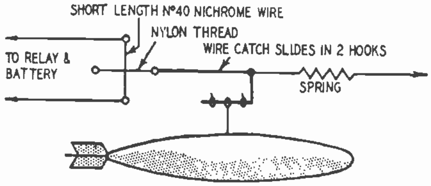


Fig. 311. This gadget will drop a bomb or a parachute.

spring; when the wire heats up it burns through the thread, and the bomb drops.

Pulse rate

The user of proportional control, or any other pulse system, has a ready means for working added circuits by the simple method of changing the pulse rate. The actual system to change the pulse rate involves the keying arrangement at the transmitter, and is covered in Chapter 8. We will describe here only the ways to utilize this change of rate. The simplest scheme makes use of a tiny transformer and an instrument rectifier in the plane.

Connected to a sensitive relay RY as in Fig. 312, there is not enough voltage built up across the electrolytic capacitor to allow the relay to work when the pulses come in at the normal rate. However, when the pulse rate is considerably increased, the capacitor becomes fully charged and the relay does operate to actuate the required auxiliary circuit. For reliable operation, the pulse rate must be at least doubled. The primary of the transformer may be connected either in series or in parallel with the

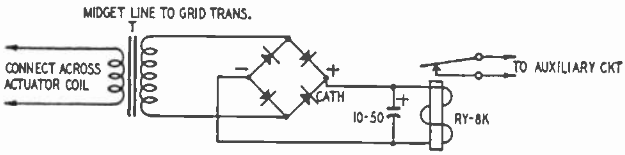


Fig. 312. Circuit for utilizing pulse-rate change.

winding of the rudder actuator. A midget line-to-grid transformer may be used for transformer T. The relay can be adjusted and a size of the electrolytic capacitor chosen so as to obtain operation of RY, when the pulse rate is increased. Various rectifiers have been used for this circuit, among them bridge-connected meter units, various small selenium types, and 1N34 crystals. As an example for the experimenter, it was found that the parallel connection of Fig. 312, in conjunction with a meter

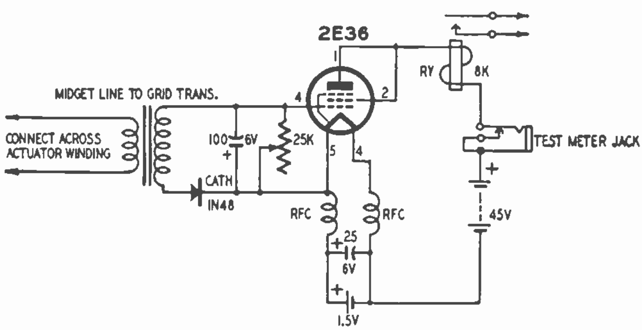


Fig. 313. The addition of a tube gives more reliable pulse-rate change operation.

rectifier, a 50-µf capacitor and an 8,000-ohm Sigma 4F relay, would operate reliably when the pulse rate was changed from 200 p.p.m. to 600 p.p.m. The current change in the relay circuit was from 0.3 to 0.52 ma. When four 1N56 rectifiers were used in a bridge circuit, the current change for the same pulse rate variation was 0.37 to 0.6 ma.

If you need more change than this, or want to get reliable relay operation with less variation in the pulse rate, you can go to a single-tube circuit, such as that of Fig. 313. Here we find the same sort of transformer connected into the actuator circuit. At low pulse rates the 2E36 tube conducts, closes the relay in its plate circuit, and keeps it closed. When the pulse rate is raised, more voltage is developed across the 100-μμf capacitor, because of rectification in the 1N48 diode rectifier. This voltage is applied to the grid as a negative bias and the tube cuts off, releasing the relay. The 2E36 uses the same A and B batteries as the receiver. It has been found advisable to include r.f. chokes in the filament leads. At low pulse rates, the plate current is around 1 ma, dropping to zero as the pulses are increased. The 25K grid resistor is varied to shift the operating point of the tube as desired.

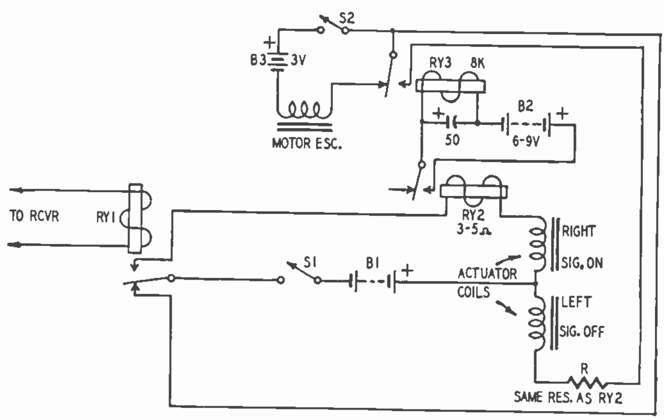


Fig. 314. Close S1 to operate rudder. After pulsing has started, close S2. Secondary relay, RY3, opens when pulses cease. All relays are shown in the signal-off position.

Versatile control system

A somewhat more flexible arrangement for gaining an added control from a proportional rudder system is diagrammed in Fig. 314. It has several added features, such as the fact that many kinds of equipment failure will cause the rudder to go into the neutral position. Also, with a bit more complexity, still a third control could be added to it! The components, including the receiver relay RY1 are shown in the no-signal, or open position. After S1 has been closed, the first pulse that comes in closes RY1 and moves the actuator to the right side; RY2 also closes. The latter then closes RY3, which remains closed for ½ second, due to the capacitor across the winding. With RY3 operated, the left actuator coil circuit is closed, so that normal rudder action may be had. The system has been set up so that pulses at the rate of 2-½ or more per second will assure that the circuit remains in this normal working condition. The pulsing unit at the transmitter is adjusted so that in the no-signal direction (which gives left rudder) the pulses never are cut off entirely, though they get very short. This makes certain that relays RY2 and RY3 remain operated in normal use. When motor-speed change is required, the transmitter is cut off for a little over ½ second, which allows RY2 to open, followed by RY3. The latter opens the rudder circuit (so the rudder won't swing hard over during this period) and closes the motor escapement circuit.

The receiver used with this hookup is of a type that puts RY1

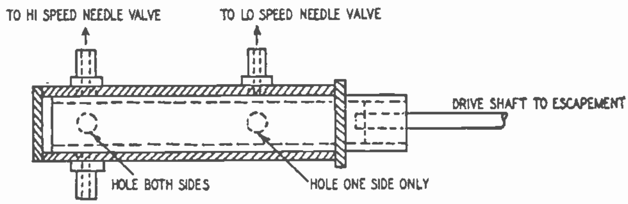


Fig. 315. Rotary-type fuel valve is made of brass tubing. Solder fuel tube fittings on before drilling holes through brass valve body. The valve is shown in the cutoff position —engine escapement energized.

in the position shown in Fig. 314, for a transmitter failure, and for most receiver failures as well. Thus, the same sequence of operations occurs if any of these elements of the entire control system fail. In addition, since the motor escapement is of the type which cuts off the engine if allowed to remain in the operated position for any length of time, a system failure not only centers the rudder but stops the engine. Should the fault be at the transmitter, and be quickly repairable, the first pulse restores normal rudder action—though of course the engine cannot be restarted. When cutting the signal purposely to change engine speed care must be taken not to hold the signal off too long or the engine will stop.

The system may be simplified somewhat by using battery B2 to operate the motor escapement as well (now worked by B3). Or with the proper resistance windings in the actuator and in RY3, B1 could be used in these two circuits.

The resistor, R, should be the same resistance as RY2. This resistor simply balances the actuator circuit so that the rudder pull is the same both right and left. Still another auxiliary circuit could be operated by replacing R with an added pair of relays similar to RY2 and RY3 . In this side of the circuit, the two relays would have to work with full-on signal, so the added relay similar to RY3 should be set to remain closed, except when the transmitter sends a steady or solid signal. Then the pulser would be limited to go only as far as 75% full signal (approximately), and the operating button for this additional operation would shift the transmitter to 100%, or full on. This particular circuit would not have the fail-safe feature of the other, however.

The fuel valve that has been used with this hookup is shown in Fig. 315. It is made from two lengths of brass tubing that will slide together snugly. The drive shaft is turned directly by the motor escapement, which is of the two-arm style. As shown in the drawing, the escapement is energized and the valve is in the shut-off position. One of the two neutrals allows fuel to both needle valves of the engine, while the other feeds fuel only to the high-speed needle.

The system of Figs. 314 and 315 is shown and described in detail, since the experimenter may be able to adapt either the whole thing or just various parts to his own uses. It is a good example of the advanced developments now coming into model use in the pulse-control field.

Chapter 4

Single-Tube Receivers

EVER since some time in 1938, when the first miniature thyratron, or gas-filled tube, was developed especially for model radio-control purposes, the single-tube receiver has been predominant. About the same time, other experimenters worked out a successful single hard tube receiver. Hard tubes are generally considered to be those which are pumped out to a high vacuum; gas tubes are similarly pumped out, but then a tiny amount of various gases are admitted to the evacuated bulb. Both the single hard- and gas-tube types continue popular today, and are used by most receivers. It should be understood from the outset that in this service we are asking the tube to do quite a lot. It must be sensitive enough to operate a relay on a rather weak signal at a distance of a mile or more. It must do this with a very short untuned antenna. It must work from very small batteries that do not have an especially long life, hence tend to drop in voltage constantly. It is expected to hold its adjustment, despite these handicaps, for sustained periods. And to top it all off, the receiver tube has to supply a relatively large amount of power to work the plate circuit relay, while subject (at times) to extreme vibration.

When these facts are considered, it is a wonder that the one-tube receivers work at all, yet work they do, and it is probable that about 70% of all radio control of models today is still accomplished with these much-maligned receivers.

Gas-tube receiver

The gas-tube receiver is certainly a simple sort of equipment, and when working right can give results out of all proportion to its elementary circuit. Yet this apparent simplicity is deceptive;

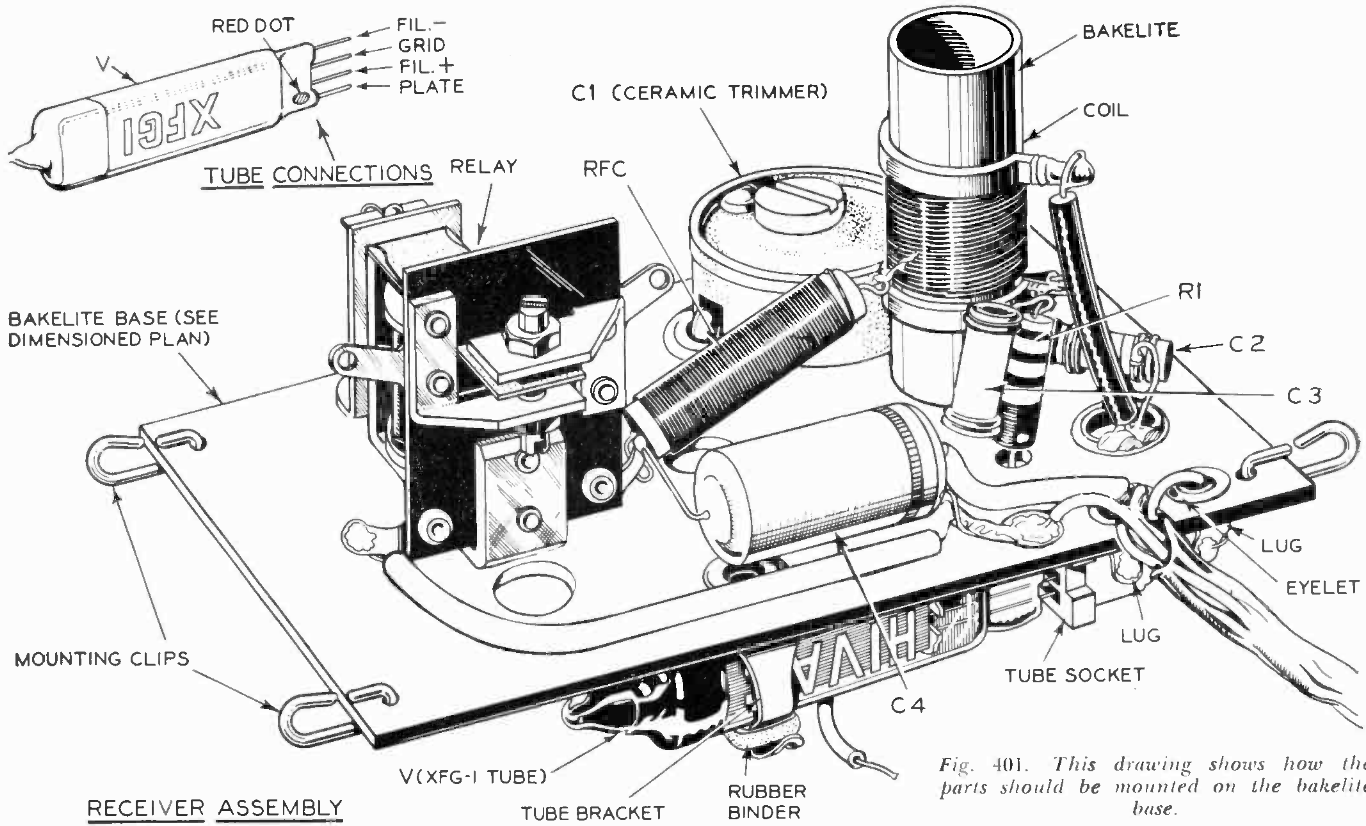


Fig. 401. *This drawing shows how the parts should be mounted on the bakelite base.*

the workings of the gas-tube receiver are still the subject of somc debate in engineering circles. The purpose of this book is not to give you theory, but the practical side of the various types of receivers, how to make them, get them in'o operation, and most important—how to *keep* them that way.

There are two makes of gas tubes now sold, the American RK-61, and the English XFG-1. Though they operate upon exactly the same principles and require the same sort of circuits and the same voltages, they are not in general directly interchangeable.

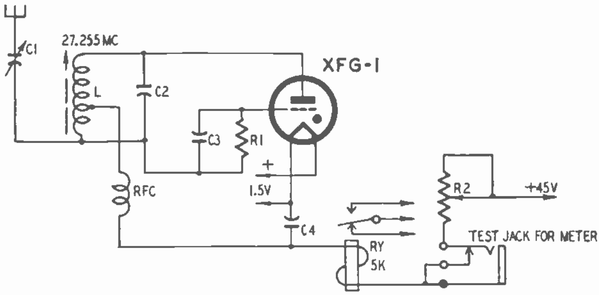


Fig. 402. Simple, but practical, radio-control receiver. Values are: C1, 4.5—25 μμf ceramic trimmer; C2, 4.7 μμf fixed ceramic capacitor; C3, 100 μμf fixed ceramic capacitor; C4, .1 μf 150-volt paper capacitor; R1, 3.9 megohm, 1/2-watt carbon resistor; R2, 25,000-ohm potentiometer, RY, 5,000-ohm E.C.C. relay, or equivalent (American Telasco, Huntington, N. Y., or any nationally-known hobby shop); RFC, 3/4" x 1/4" bakelite rod wound full of #34 enamelled wire; L, CTC LS3 coil form (see Fig. 406; Cambridge Thermionic Corp., Cambridge, Mass); tube, Hivac XFG-1 (available in most nationally-known hobby shops); socket, Cinch 2H5 five prong.

Due to variations in internal capacities, and, more important, in gas content, the two types require somewhat different circuit conditions for best results.

Gas-tube receivers are the simplest that can be built; they are the lightest and may be made the most compact. The tubes themselves have a rather limited life; an average tube might be expected to last from about four to twenty-five hours of actual use, and during this time the tube characteristics will constantly change so that circuit adjustments will be required. If this appears to paint a rather dark picture of this type of receiver, it should be emphasized that until quite recently the majority of radio-control receivers employed just a single gas tube!

Typical receiver

Let's look at a typical set of this sort. The circuit diagram is shown in Fig. 402 and the set is illustrated in Figs. 401 and 403.

An under-chassis view appears in the photo, Fig. 404. If there is need for it, the receiver could be made much more compact and still would work just as well. All gas-tube receivers idle —when no signal is coming in—at their maximum plate current, and this drops to a low value upon receipt of even a weak signal. Generally speaking, the signal-on plate current drop is more or less independent of the signal strength. That is, if the set is properly adjusted, you will get a plate current-drop of about 1 ma whether you are right next to the transmitter, or a quarter of a mile away. The dimensions of the bakelite base are given in

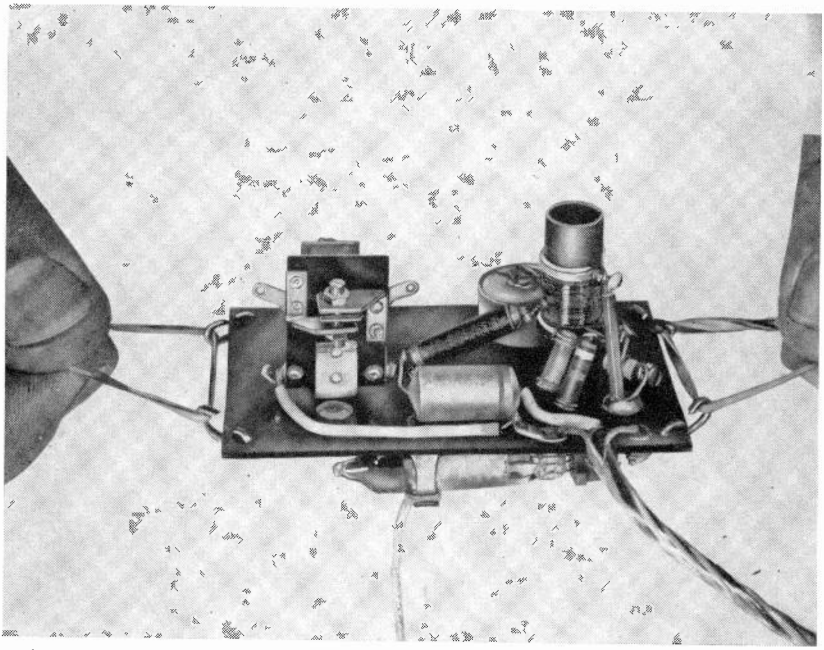


Fig. 403. Photograph of the receiver. The sensitive relay is at the left.

Fig. 405. Drill all the holes first, then mount all parts before wiring is started. As we show it, this receiver is intended specifically for the XFG-1 tube. Changes needed for using the RK-61 will be described later.

Inductor L is wound on a commercial slug-tuned form. The winding should be placed as shown in Fig. 406 in order that the core may have the proper tuning range. Most of the cores for these forms come with a brass collar in addition to the iron slug. This collar should be removed. Unscrew it with a pair of pliers while the threaded shank is held in a vise. Don't put any pressure on the black powdered iron itself—it is fragile and will crumble. A slug with a red paint mark on it was used here. A white-marked core also can be used. These marks show the permeability of the particular iron. Don't use a yellow-marked core.

No detailed instructions should be necessary for wiring. Keep the leads short and direct. Note the placement of the various small parts in Fig. 402. Do *not* use any sort of acid-core solder for connections; only *rosin-core solder* should be used for any of the radio apparatus described in this book.

The base is laid out for the E.C.C. relay, one of the most compact available. Other types that have been tried successfully in

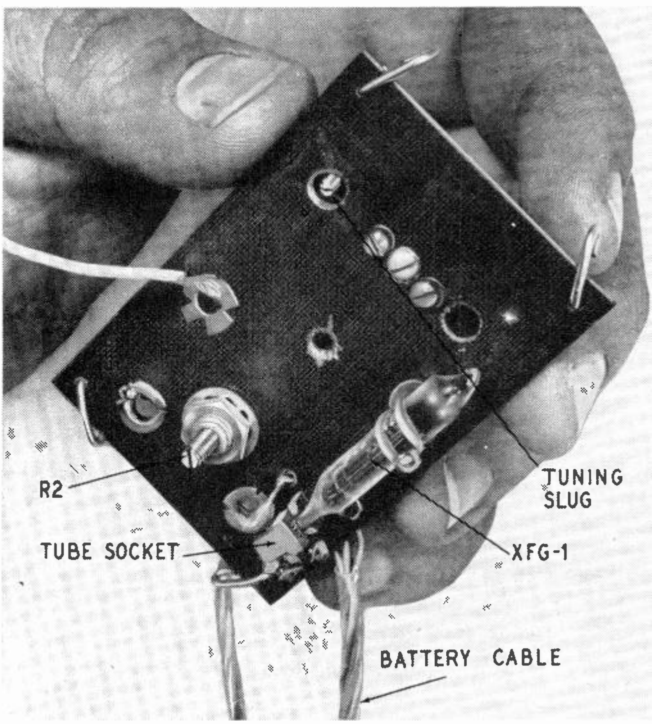


Fig. 404. The XFG-1 is mounted underneath the chassis as shown in this picture.

the set are the Kurman 13C44 and the Sigma 4F; there is room on the base for either of these. The tube socket is held on by soldering to four rivet-type lugs. These sockets come with five lugs, but only four are needed in this set, and it is wise to remove one.

The tubes are furnished with long wire leads, which must be cut down to about 3/8 inch and be well scraped with a knife or razor blade. Don't neglect this scraping; some of these tubes have a very thin transparent lacquer on the lower end of the tube and the leads. If the lacquer is not removed, very erratic operation may result. A rubber band holds the tube to the long lug, and the tube plate lead is indicated by the red dot.

Receiver operation

Check all your connections very carefully, then connect the A and B batteries, the test meter (0 to 3 ma, d.c.), and a 2½-foot length of wire for the antenna. Set R2 to bring the plate current to about 1.3 ma with C1 near its minimum capacitance (when the semi-circular segment visible on top of the movable plate is opposite the two mounting holes). Rotate the disc about 45 degrees from this position. Turn on a nearby crystal-controlled 27.255-mc Citizen's Band transmitter, but do not use any antenna on it; instead, use a lamp bulb as the antenna load. Information on this type of load for the transmitter will be found in Chapter 11. Turn the core of L in and out until the plate current of the receiver

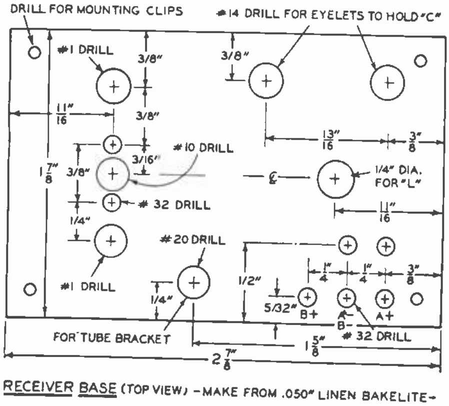


Fig. 405. You can use this drawing as a guide for drilling the receiver base.

drops sharply. If you do not get such a drop, it is evident that either the transmitter or the receiver is not covering the proper frequency. We assume here that the transmitter is working correctly, so the trouble must be in the receiver. Recheck the turns on coil L to make sure there are the specified number, and look to see that the paint on the end of the core is white (a core with red paint can also be used, but the white is preferred).

With the components called for, and a properly working transmitter, you just *have* to get some sort of current dip on the receiver within the tuning range of the core in coil L. If the dip is rather slight, say down to only 0.8 or 0.9 ma, the tube is suspect, and you should make every effort to try another, preferably one that is known to work right. The fact that you have a brand-new tube doesn't excuse it from suspicion; these gas tubes are unpredictable, and a tube that might have passed its tests at the factory may later be found to be practically useless when it is put in a receiver.

With everything working as it should, the plate current should drop to around 0.1 ma when the core is set to resonance. With the transmitter turned off, observe whether the pointer of the meter moves erratically—you should hear quite a singing sound from the relay, too. If the pointer jumps more than about .04 ma, it shows that the set is too hot, and capacitor C1 should be turned another 45 degrees toward maximum capacity. The core of L will now need retuning, and you will find that the meter pointer is somewhat steadier and the relay is not buzzing quite so loudly.

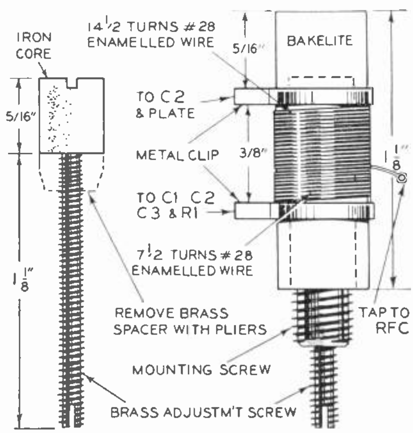


Fig. 406. This coil is designed for operation on the 27.255-mc band.

It is now time to take the receiver for a distance check, so attach all the batteries and other parts to a board, put the normal antenna on the transmitter and start walking. If at all possible go out at least ¼ mile from the transmitter and tune the receiver accurately (it can't be tuned properly when too near the transmitter). Have someone key the transmitter at your signal, and make sure that the plate current drops to around 0.15 ma and that it comes right back to 1.3 ma when the transmitter is cut off. If you don't get the proper drop, you may have to reduce the capacitance of C1, and retune, to give the receiver a bit more sensitivity. Field tests at a distance of ½ mile showed that the receiver would drop from an idling current of 1.2 ma down to 0.15 ma with signal. At the ½-mile distance, with a considerable increase in capacitance of C1 (equivalent to lengthening the receiver antenna) and retuning, the meter showed a drop only to 0.5 ma. The receiver had been desensitized too much.

As we mentioned before, gas-tube sets have quite a lot of tricks of their very own. The reason for this is that almost every gas tube is at least slightly different from every other one—each one of these tubes has an individuality all of its own. Outside of a few definitely defective ones, it is possible to make most of them serve you very nicely, if you know how to go about it. Here are some hints.

One of the first things you might find with a stubborn tube is that the plate current cannot be raised above, say, 0.2 ma, no matter where you set R2. The trick here is to increase C1 or lengthen the antenna; in some cases, both may be necessary. Add 6 inches to the antenna, then see if the plate current will come up to the desired 1.3 ma with R2 somewhat below the zero-resistance setting. If the current still stays low, it may be necessary to add a little more capacitance across L, in addition to C2. More antenna length would do the same, but you shouldn't go above about 3 feet, as the antenna would be too long to go in most planes, and much too long for boats. You can also increase the capacitance of C1, by adding a fixed capacitor of 10 or 15 μμf across it.

Suppose the plate current goes up to 1.3 ma with no signal, but will drop only a few tenths of a milliampere with signal. In the receiver shown, the first cure for this is to ground the core of L. Connect a lug under the mounting nut to A–. If this doesn't bring about the desired drop, connect a 1-7 μμf ceramic trimmer capacitor from the plate end of L to A–, and set it at minimum (with the semicircular plate away from the mounting screw holes). Keep increasing the capacitance a little at a time, till the plate current drops as required.

Trouble-shooting summary

We can summarize the trouble-shooting steps as follows:

1. If plate current without signal can't be raised above 0.2 ma or so, with R2 at zero, increase antenna coupling (by using more capacitance at C1), increase antenna length, use slightly more capacitance across L.

2. If current won't drop more than a few tenths of a milliampere with signal, ground core of L, or add small capacitance from plate to filament.

3. If step 2 gives desired plate-current drop but current is sluggish in returning to idling value or refuses to do so when signal is cut, increase C1, or antenna length.

4. Don't ground core of L, unless shown to be required, as in 2.

5. If plate current can't be raised, as suggested in step 1, increase plate voltage to 50–67½ volts, and use sufficient resistance at R2 to hold no-signal value to 1.5 ma or less.

6. If idling plate current is very erratic, increase C1 or antenna length.

A simple test of proper receiver operation is to set the receiver at the 1.3 ma no-signal plate current, and make sure the current drops properly with signal. Then recheck with and without signal, and with the idling current first at 1 ma and then at 1.5 ma. If the drop and recovery are normal at both these points you are ready for business.

As gas tubes get old, the plate current often tends to get more erratic. It may be stabilized by following step 1 or 6. If an old tube refuses to work correctly, it can sometimes be restored to usefulness by *cooking!* This is accomplished just as you would suspect—by putting it in the oven. Try one half hour at 450° F. Some tubes won't respond at all to this treatment; others will give hours more service.

Step 5 is another that may enable you to get a lot more use out of an old tube. Be sure you use enough resistance at R2 to hold the plate current under 1.5 ma. As a matter of fact, the current of these tubes should never be allowed to go above this value. The life of an XFG-1 tube is considered to be around 5 hours or so. It may be lengthened by using lower plate current, and will be drastically shortened if the plate current is allowed to go much over 1.5 ma. The 1.3 ma value we have suggested will give good life and yet is high enough for reliable relay action. Incidentally, new tubes often do not work so well with the higher voltage and value of R2; better save this trick for the older tubes.

The receiver of Fig. 401 was designed specifically for XFG-1 tubes. Some RK-61's will work in it, too, but for these it is better to increase C2 to about 10 to 15 μμf and take a turn or two off coil L, to reach 27.255 mc. RK-61's have been found to work better with a lower L-C ratio (less inductance L in proportion to capacitance C) and will have a life of about 25 hours.

Gas-tube receivers, both commercial and homemade, that do not seem as sensitive as they should be, may be pepped up by the addition of a small capacitance, as detailed in step 2. It should be noted that in the cases where the additional capacitance is beneficial, it is often not the *receiver* that is at fault—it is the particular tube in use. Some experimenters use a ceramic trimmer from plate end of the coil to ground; others simply hook in a fixed capacitance in the same location, and bring the set to proper operation by manipulation of the other variable controls of the receiver—i.e., the antenna coupling, antenna length, and the plate-circuit variable resistor.

Hard-tube receivers

Single hard-tube receivers are more difficult to get into operation, but once adjusted properly, they will hold the settings much

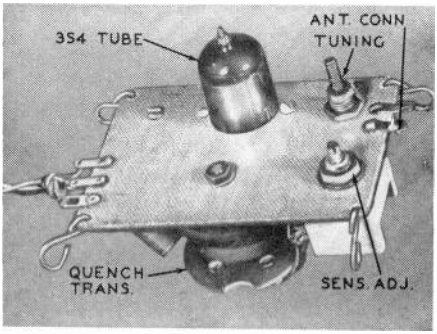


Fig. 407. Photograph of the hard-tube receiver.

longer. These sets normally use one of the miniature battery-power output tubes, the 3A5 (one section only), 3S4, 3Q4, 3V4, and 1S4 tubes being favored. Although one highly successful commercial receiver utilizes the 3A5, this tube is not being built into many receivers at present, due to its high filament drain and the fact that it draws high plate current as well. The 3-volt tubes listed all have double filaments; these filaments may be connected in parallel for use on 1.5 volts or in series for 3-volt operation. Radio-control receivers normally utilize the parallel connection, since flashlight cells, either singly or in parallel, are the preferred A-power source. The 3S4 with parallel filaments is identical to the 1S4, but the filament connections are a bit different. The 3Q4 and 3V4 have identical characteristics, but the socket connections are different, so they cannot be used as direct substitutes.

All these tubes are capable of many dozens—or even hundreds

—of hours of service. Once adjustments have been made, it is normally unnecessary to make circuit changes, except to compensate slightly for changing battery voltages; the tubes do not age as rapidly as do gas tubes, and it is this property that makes hard-tube sets of so much interest, even though they are generally heavier and more complicated and require higher battery power than the gas-tube sets.

Hard-tube receivers are set up so that there is circuit oscillation continuously on both low and high frequencies; the low-frequency oscillation is termed the *quench* frequency, while the high frequency is of course that which the transmitter radiates. When these receivers are in the idling condition, the high-frequency oscillation is extremely weak, while the quench oscillation is strong. When a signal comes in, it triggers the tube into heavy high-frequency oscillation (the quench voltage amplitude drops somewhat at the same time) and the plate current drops abruptly. Hard-tube receivers normally do not provide the high current change ratio that may be had from gas-tube equipment; the latter usually are set up to give a plate-current change of somewhere around 10 to 1, while hard-tube receivers run around 2 to 1.

Typical hard-tube receiver

A representative hard-tube receiver is shown in the photos,

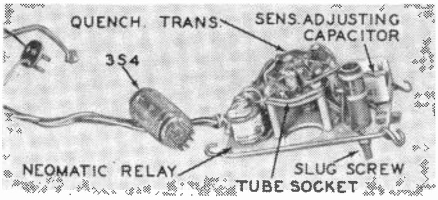


Fig. 408. Under-chassis view of the hard-tube receiver.

Figs. 407, 408, and the schematic in Fig. 409. This is about the simplest circuit that can be made to work well. Some receivers of this type utilize quite a few more small parts, but every practical hard-tube receiver requires the quench-oscillation coil or transformer. Depending upon the relay used, this receiver may be made just about as small and light as many gas-tube sets. The example shown in Fig. 407 weighs 3 ounces and measures 2 x 3 x 2½ inches over-all. The relay is about the lightest that can be had, and still give satisfactory results in this circuit. If other types are used the base may have to be enlarged a bit, although it is just as practical to mount the relay on the opposite side of the base, where a little more room is available. While the base dimensions of the prototype are given in Fig. 410, the base should not be cut out until all the parts are collected, in case the exact one specified are not available.

Lugs are provided for A and B leads, and for the antenna. It was found that the latter could be jus' a piece of wire one or two feet in length. Connections to the relay contacts are made directly to the lugs provided on this component. The capacitance range of C1 is not critical, and a padder having a lower or higher range will be adequate. If higher capacitance is found to be needed when the set is put into operation, a fixed capacitor may be attached in parallel with C1; if less capacitance is indicated, several plates may be removed from the padder. The range given was found to cover many different tubes, antennas, and battery voltages.

When the receiver has been connected to the proper batteries, and the antenna stretched away from the latter and from other

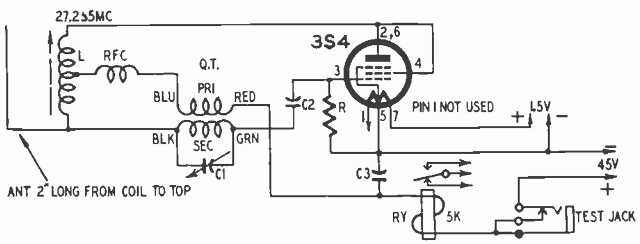


Fig. 409. Circuit diagram of the single hard-tube receiver. Values are: C1, sensitivity control, El-Menco #309 padder, 550-1600 μμf (it may be necessary to remove several plates); C2, 100 μμf ceramic capacitor; C3, .1 μf paper capacitor; R, .1 megohm, 1/2-watt carbon resistor; L, CTC (Cambridge Thermionic Corp.) LS3 coil form (see Fig. 411-a); Q.T., quench transformer, National OSR (remove shield can); RFC, 3/4" x 1/4" bakelite rod wound full of #34 enamelled wire (see Fig. 411-b); RY Neomatic 5529 sensitive relay.

nearby metal objects, the plate meter may read anything between 1 and 2.3 ma (use meter having full-scale deflection of 3 to 5 ma d.c.). If it is lower than 1.7 ma, try reducing the capacitance of C1. If higher than this value, increase C1 (capacitance increases when the screw head on the lug side of the padder is turned clockwise). A point should be passed where the plate current changes abruptly about 1 ma. This is the *sensitive spot,* and C1 should be set about a quarter turn on the high-current side of this point. Now the core in L may be adjusted in and out until a signal from a nearby transmitter is indicated by a drop in plate current. The transmitter should be used without an antenna at this stage of tune-up. You will find that there is little or no interaction between the settings of L and C1—a big advantage of this circuit over other types of hard-tube arrangements.

Here are the tune-up and trouble-shooting steps:

1. Turn C1 in or out until a point is reached where plate current changes abruptly about 1 ma. Rotate the screw a little to the high-current side of this change point.

2. Tune L to the transmitter frequency, indicated by a drop of about 1 ma.

3. If plate current cannot be raised to 2 ma or so, regardless of setting of C1, increase length of antenna 6 inches or a foot. Conversely, if plate current with no signal won't drop below 2 ma as C1 is manipulated, cut antenna length, or connect a capacitor of about 10 μμf in series with the antenna.

4. If plate current drops down 1 ma with signal, but then will not come back up to 2 ma when the signal is cut, the sensitivity

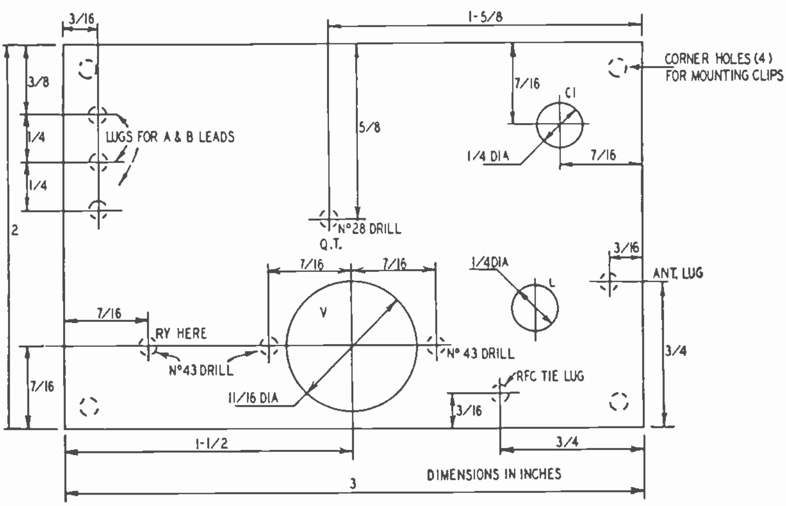


Fig. 410. Suggested layout for the base of the hard-tube receiver.

control C1 should be *reduced* in capacitance slightly. If the receiver does not have good range, C1 should be *increased* a bit.

5. If relay produces a buzzing sound as C1 is turned past the sensitive spot, it indicates too long an antenna. Either cut length or use a series capacitor. This buzzing will do no harm if the set is tuned exactly to the transmitter. However, when the receiver is working properly, the relay will not buzz this way, but will snap in and out very cleanly as the transmitter is keyed.

6. *Note carefully* that only one side of the 3S4 filament is to be used. Connect socket terminal 5 to A and B minus; use *either* 1 or 7 for A plus. The receiver will not work properly with both sides of the filament in parallel.

Be sure to obtain the specified low-frequency transformer and connect it as shown in Fig. 409. Some other makes on the market look the same but might not work well with the circuit values given. The specified transformer has colored dots on the four terminals, and these must be hooked up as shown. Other makes may be marked with the letters "G," "F," "P," and "B," which correspond to Green, Black, Blue, and Red on the unit specified. Others may not be marked at all. In the latter case, and if some other make is all you can get, connect the *larger* coil from L to the grid capacitor C2; if the receiver will not operate properly, try shorting the primary lugs with a screwdriver. This should result in quite a change in plate current. If it does not, reverse the leads to *either* the primary *or secondary.*

Coil L can be built following the specifications given in Fig. 411-a. Construction details for the radio-frequency choke, RFC, appear in Fig. 411-b. You should know that not every tube will

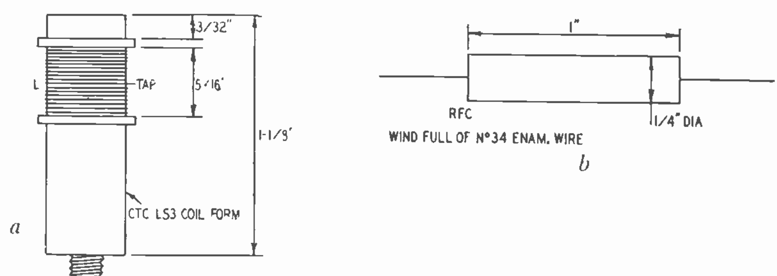


Fig. 411-a, -b. Construction details for the coil (a) and the choke (b).

work perfectly in this (or any other) hard-tube receiver. Some makes are apparently just different enough so that they fail to give the best results, even though they test perfectly and will give excellent performance in other equipment. Fortunately, most tubes of *reputable* make will do the job nicely. However, if you just can't seem to get good results, try another tube, preferably of a different make. The receiver shown was found to work well on tubes of many makes and ages, but some of them could not be set up to be as sensitive as others. However, these poorer tubes might prove to be entirely usable at rather short ranges, or with more powerful transmitters.

The sensitivity control, C1, should be set as far on the high current side of the sensitive spot as possible. The receiver will not then be triggered off by stray signals and will stay operative longer, with the normal drops that may be expected in A- and B-battery voltage.

This receiver works nicely with higher plate voltage, and in fact seems a bit smoother and more sensitive when so operated. 52½ volts (standard 22½- and 30-volt batteries in series) gives an idling plate current of about 2.4 ma. 60 volts will give an idle current of around 2.8 ma. A strong signal will drop this latter to around 1.2 ma; this current change makes it easier to set the relay, of course. With the normal 45-volt B supply, the relay should be set to pull in at about 1.7 ma and drop out at 1.3 ma.

Receiver conversion

At one time most radio-control work was on 50 mc, since the

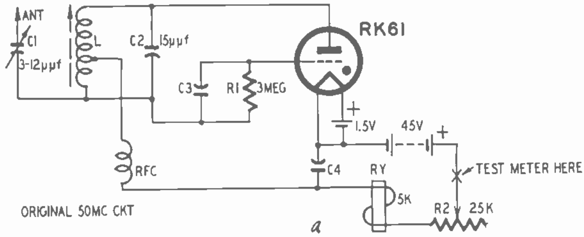


Fig. 412-a. Circuit of gas-tube receiver prior to conversion.

27.255-mc spot had not then been opened. When this frequency was made available by the FCC the large majority of radio-con-

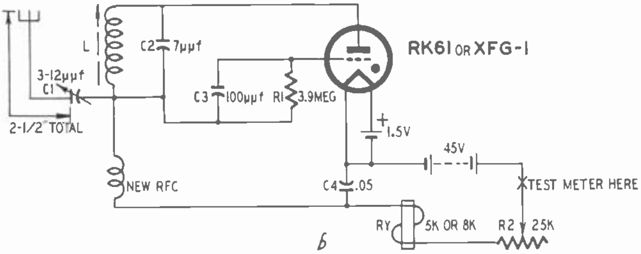


Fig. 412-b. Gas-tube receiver modified for 27.255-mc operation. RFC. 1/4" x 1" bakelite form wound full of #34 enamelled wire; L, CTC LS3 coil form with red painted slug. Remove brass ring that is threaded on the stem next to the iron slug. Use 20 turns of #24 enamelled wire, centered on the form, and close wound.

trol enthusiasts shifted to 27.255 mc, with the result that a lot of them had 50-mc receivers on hand which were of little use.

Those with the know-how changed their receivers over, but many modelers knew little of radio and could not handle this job, so the receivers were put aside and new ones for 27.255 mc were purchased.

Receiver conversion is quite a simp'e task—nowhere near as complex as changing the 50-mc transmitters to 27.255 mc, as described in Chapter 6. Most of the 50-mc receivers used a circuit very similar to that shown in Fig. 412-a which is the original circuit of the RCH receiver we converted. L was an air-core coil, but to use the same sort of coil on 27.255 mc requires a lot of heavy wire, so an iron core coil is substituted. Some of the 50-mc receivers had a variable trimmer capacitor at C2—others just had a fixed type as in this example. It was found that good results could be had with the r.f. choke at the grid end of the coil, and so no tap was used. However, a new choke was necessary. To attain enough sensitivity, it was necessary to reduce the value of C2 to about 7 μμf. The modified receiver is shown in Fig. 412-b.

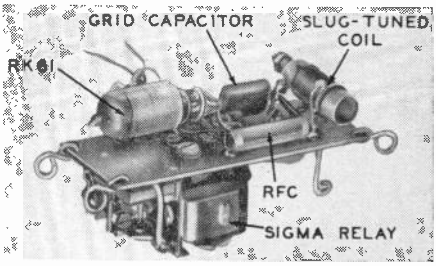


Fig. 413. Converted receiver ready for use.

All other parts were retained, as was the original RK-61 tube. Tuning and trouble-shooting is the same as for other similar receivers described in this chapter and will not be repeated. This receiver (see photo, Fig. 413) was found to work well with either the RK-61 or XFG-1 tubes; the same ideas may be used for conversion of most any 50-mc gas-tube receiver to the new 27.255-mc spot.

Chapter 5

Multitube Receivers

ALTHOUGH one-tube sets can give good results and are the most economical in first cost, they are undeniably lacking in some desired characteristics. In the search for more reliable operation, and mainly for operations over longer periods of time without the necessity for any adjustments, many radio-control builders are turning to two-and three-tube receivers. There are countless types of these, all of which are said to excel in some one or more features, such as low B-battery drain, long service possible without adjustments, large plate-current change making relay setting very simple, current *rising* with signal rather than dropping from a high value, as in the receivers described in Chapter 4. This latter action is much sought after, since it makes the entire system more *fail safe*. The reason for this is that more things can go wrong in the plane without putting the rudder into one extreme or the other. If the plate current is low when idling and rises with signal, the control surface will remain in neutral even if the A or B batteries go dead, if the tube burns out, or if most of the circuit components or wiring connections fail. With the high idling current of the single-tube receivers, any such failures will swing the rudder hard over on one side or the other.

Two-tube receiver

One of the most popular styles of two-tube receivers is a development of the single gas-tube circuit. Since gas tubes will last for many more hours if the plate current is lowered, the first tube of this style of receiver is idled at about 0.5 ma. With signal, this drops to about 0.1 ma. Such a current range is not sufficient to work a relay, therefore a relay tube must be added. Most of the gas-tube receivers may be changed over to this mode of operation by the addition of another tube and a few other circuit parts. Conversion of the gas-tube receiver described in Chapter 4 is shown schematically in Fig. 501, with the added components at the right of the dashed line. If another gas tube is used in the second socket, the largest plate current change may be had. Furthermore, it has been found that gas tubes which no longer will work in the normal single-tube hookup will give good service in this relay-tube position. If a bit less current change is satisfactory, a subminiature hard tube will serve nicely in the second position. The 1V5 and 1AC5, power pentodes, are the most widely used for the purpose. Although *no grid leak is shown for the second tube*, this is the preferred arrangement. If you find that

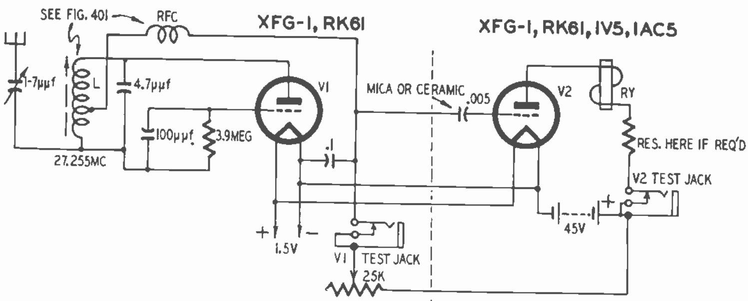


Fig. 501. The two-tube receiver can use either gas or hard tube in second position.

the relay tends to chatter a bit when idling, a leak of 1 megohm or less will cure the difficulty.

The second tube may be mounted wherever there is room, and the small components fitted in with the shortest possible leads. It is wise to install two meter jacks as shown, though it is not necessary to use two meters after the set has once been tuned up.

Let's say we have an XFG-1 in the first socket and either an XFG-1 or an RK-61 in the second. Connect the batteries, insert a 0—1-ma meter in the first test jack, and note the idling current (no signal coming in). It should be about 0.5 ma. Then turn on a nearby transmitter without an antenna, and tune in the signal; the current should drop to about 0.1 ma or less. If it does, you can turn your attention to the second tube. For this one, a meter of 0 to 3 ma d.c. range or more is needed. Without signal the meter should read zero or very near it, and with signal on the plate current should rise to 2 ma or more. If it is over 2 ma, a resistor should be placed in series with the relay (as shown in Fig. 501) or a higher resistance relay might be used. There is no need to go over 2 ma, for any small *sensitive* relay now made will work very reliably with the 2-ma current change afforded by this circuit. Such a change also makes relay adjustment very easy, and there will be plenty of spring tension to offset the vibration often found in gas-engine-powered models. A higher current than 2 ma will only run down the B battery faster, although in most installations this current will be drawn only for a very short fraction of the time the receiver is turned on.

Even though it uses one or two gas tubes, this receiver is one of the most trouble-free that can be made. One component that should be the very best—either a ceramic or mica type—is the .005-μf coupling capacitor. Any leakage here will render the receiver useless, and may ruin the second tube. If the first tube does not give the proper plate-current drop, or misfunctions in any other manner, apply the trouble-shooting steps to it that were given for the gas-tube receiver in Chapter 4. The first tube of this two-tube receiver functions in exactly the same manner, but just doesn't have to supply such a large plate-current change. With some tubes, the idling current of the detector may be as low as 0.3 ma, but it is wise to raise it to 0.5 ma and be on the safe side. Some tubes, even when brand-new, can't be made to idle as low as 0.5 ma; so if you get one of these you can make it more co-operative by *aging* it at 1.5 ma or so for 15 minutes, then re-checking it to see if the current will drop reliably from 0.5 to 0.1 ma. If not, age the tube a bit more and try again. (This treatment is necessary also on some new tubes when they won't work properly in the single gas-tube receivers.)

Relays having a resistance other than that specified in the original one-tube receiver may be used in the two-tube receiver; in fact it is possible to use certain surplus relays that are sold quite cheaply and which are not good enough for the single-tube sets. Resistances ranging from around 3,000 ohms all the way up to 10,000 ohms have been employed successfully. Because of the large current change available, it has been found entirely practical to eliminate the sensitive relay as such, and work the escapement directly from the last tube. The escapement, of course, must have a high-resistance winding, and most builders make them for this use by revamping the sensitive relay itself. The original contacts are removed, and the armature is adapted to control the escapement wheel. This mode of operation eliminates the escapement battery and wiring, removes the possibility of dirty or sticking relay contacts, hence makes the entire control system lighter, more reliable, and much simpler.

A really well-made and efficient proportional control actuator of the type shown in Chapter 2 also could be adapted to this sort of operation, the normal low-resistance actuator winding being replaced by one of 5,000 ohms or so, taken from a relay. Of course, you could get pull in one direction only, the return pull being supplied by a light spring.

Direct-coupled receiver

Another two-tube receiver that has been used with some success is diagrammed in Fig. 502. This is a form of direct-coupled amplifier. A very small current change in the plate circuit of the first tube, when a signal is received, produces a large change in the relay-tube plate circui . This receiver has not enjoyed

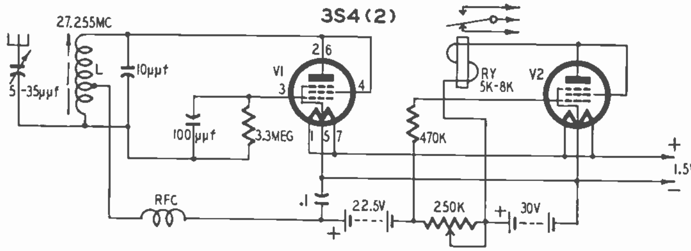


Fig. 502. This two-tube receiver uses a direct-coupled amplifier. For 27.255-mc operation coil L consists of 15 turns of #28 enamelled wire wound on a CTC LS3 coil form. (see Fig. 406). Use a core identified with a white tip. The choke is a 3/4" x 1/4" form wound full of #34 enamelled wire.

much popularity, possibly because it is not as well known as others we have covered here. Also, as shown, it requires two plate batteries, though they both may be of rather low voltage. In operation, the 250,000-ohm variable resistor is set so that the plate current of V2 is practically zero. A test jack can be put in series with the plate circuit as shown in previous schematics. When a signal is received, the plate current of V1 drops a small amount, and since this current change flows through the .25 meg variable resistor, the control grid bias of V2 is dropped and this tube then produces an appreciable current change through the relay. When properly set up, only a tiny change in V1 plate current is required to produce considerable re'ay current. Anything that will give a larger plate current change in V1 naturally will affect V2 that much more. It is therefore wise to try alterations of all the circuit components of V1, in a search for more current change. Of course V1 could be connected as shown for the hard-tube receiver in Chapter 4, but it seems a shame to install the large padder and quench coils if good results may be had without them.

Another possibility is to use a dual tube such as the 3A5, though this tube has filament current that is rather high for receiver use. It is probably advisable to stick to the 3S4's shown, or to try various subminiature tubes.

With 3S4's, the first tube can be made to change current about 0.05 ma, and the second tube will then rise to 1.3 ma. Use of higher voltage on the second tube will increase this current rise.

Three-tube receiver

There was a time when a radio-control builder would not even consider trying a two-tube receiver, because of its supposed complexity, and a three-tube receiver would have been unthinkable. However, the past several years have seen a big increase in the use of multitube sets, and today it is quite common to employ two and even three tubes in the receiver. The object is to get more reliable operation, less effect upon operation by aging of A and B batteries, longer tube life, and less critical adjustment.

A 50-mc receiver giving all these desired features is shown in

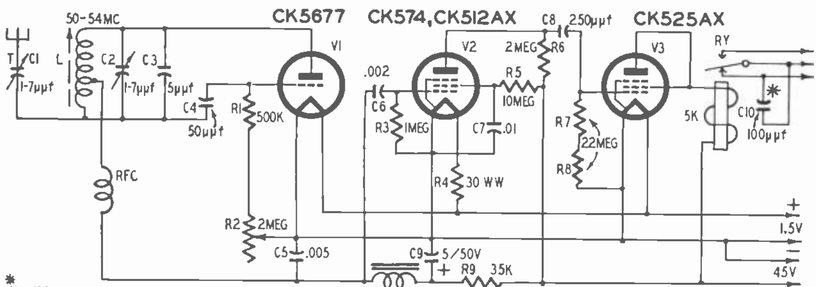


Fig. 503. Three-tube receiver. For the 50-mc band, coil L consists of 11 turns of #16 wire, center tapped, wound on a form 7/16" i.d., 1-1/4" long. The sockets are Cinch, subminiature 5 prong. The choke (RFC) is on a form 3/16" diameter and 5/8" long, wound full of #36 enamelled wire.

Fig. 503. It uses three subminiature tubes in a circuit which is essentially a superregenerative detector followed by two audio-amplifier stages. The last of these is biased so that it operates at low current when the set is idling, and a signal sends the plate current upward. The first tube is adjusted to hiss strongly when there is no signal. The second is simply a voltage amplifier which builds this hiss up to a higher value, and the amplified noise is

then applied to the grid of V3. Because of the large grid leak, the hiss voltage produces quite a large grid bias on V3 and thus holds the plate current to a low value—it runs about 0.2 ma in the set shown. When any superregenerative detector receives a signal, the noise level drops sharply; thus, with a signal coming in, the last tube receives less bias voltage and the plate current rises enough to actuate the relay.

The receiver shown was built with the smallest components that are generally available on the open market, and hearing-aid subminiature tubes were used for V2 and V3, to cut down size and filament-battery consumption. With the moderately small sensitive relay shown, the outfit weighs about 3 ounces, and measures

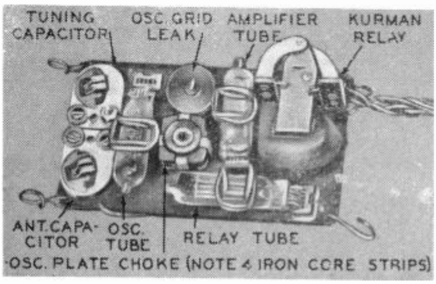


Fig. 504. Receiver occupies minimum amount of space.

3¼ x 2 x 1½ inches. Several seasons of constant use have proven this receiver to be very reliable, and since the plate current is low with no signal, the smallest hearing aid B batteries may be used safely. The entire receiver draws about 0.4 ma plate current when idling, this rising to about 1.6 ma with signal. Within normal sight ranges, the plate-current rise remains nearly the same regardless of signal strength; in other words, a model plane fitted with this receiver will show a V3 plate current rise of about 1.2

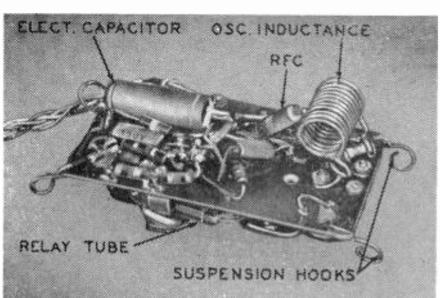


Fig. 505. Receiver parts are mounted on a bakelite base.

ma near the transmitter, and will give almost the same rise a half mile away.

As seen in Figs. 504 and 505, the parts are mounted on the usual bakelite base. The parts layout is not at all critical, though the choke coil and the relay should not be too close. Other sets of this same style have been built with the three tubes mounted right alongside each other, without adverse affects. The tubes in the set shown are held by subminiature sockets and by snapping the bulb portion into small fuse clips, which were re-formed a bit to hold them snugly. When the set is used in a plane, a small rubber band is wound tightly around the upper ends of the fuse clips, to prevent the tubes from popping out on hard landings.

The a.f. choke is of the hearing-aid type with practically all of the core removed; due to the small current, the normal core is not required, so taking most of it out saves a bit of weight and makes the unit easier to mount. Four straight core strips are bent around the winding, one on each of the four sides; then the whole assembly is attached to the base with an eyelet or small bolt through the center.

Aside from the tuning control C2, the most important adjustment on the set is R2, which might be called the sensitivity control. This is a hearing-aid type potentiometer, used here as a plain rheostat, to vary the grid resistance of V1. The little knob that was fitted to this resistor was removed and a screw put in the hole; the resistor may then be adjusted with an insulated screwdriver, the same as capacitors C1 and C2

To reduce the weight a bit, and also to lower the over-all height of the receiver, the mounting bracket of the Kurman relay was removed and mounting holes were drilled and tapped right into the iron core. Another change—and a most important one—was to add a pair of braces to the long curving arms that support the fixed contacts. This operation is shown in Fig. 506; the added pieces are simply brass strips about 1/8 x 1/32 inch and long enough to reach from the outer ends of the arms down to the lug ends. They are soldered at both points. It was found that without this modification, a strong audio vibration would be set up in the relay, which rendered the receiver completely useless. After the change had been made, no further trouble was had from this vibration.

The electrolytic capacitor C9 was installed to cure any tendency toward audio oscillation should the B battery develop high internal resistance. While a close check of the batteries is usually kept, some older ones were found to produce feedback, even though they had plenty of energy to operate the receiver.

Since electrolytics have a considerable tendency to internal leakage, (a tendency which seems to be aggravated in the miniature types), the series resistor R9 was added to reduce this added current drain as much as possible without seriously affecting the operation of the detector tube. Some electrolytic capacitors have extremely low leakage current, and are much smaller than the unit used here; if the builder can obtain one of this type, R9 might very well be eliminated.

Capacitor C4 should be a ceramic or a mica unit; due to the high grid leak, any leakage here will render the set inoperative, so it is best not to trust a paper unit in this position. The original circuit used 30-megohm resistors at R7 and R8, but these are no longer available. Twenty-two megohms seems to be the highest stock value that can now be had, but the difference in operation between 44 and 60 megohms is not enough to warrant using three of the former in series.

The receiver is simple to put into use, and has no bad characteristics. Although it is normal to put the test-meter jack in the

Fig. 506. Side view and front view of Kurman relay with braces applied to the contact arms.

plate circuit of the relay tube only, this receiver has been used with the meter in the receiver B plus lead; the current of V1, V2, and C8 hold quite constant at 0.2 ma total, so any current change observed on the meter is that produced by V3. Thus an extra meter lead from the latter is unnecessary.

Adjusting the receiver

Start with R2 at maximum resistance, a 2-foot-long antenna, and C1 near minimum capacitance. With a nearby transmitter on, tune in the signal with C2, then reduce R2 till the idling plate current (for the entire receiver) is about 0.4 ma. A strong signal should now send the plate meter up to 1.5 ma or more. It will be found that as R2 is reduced (no signal input) a point will be reached where the plate current starts to go up rather rapidly, and the resistor should always be kept well below this point. The receiver works best with very light antenna coupling;

if there is too much antenna or C1 is at too high a capacitance, the set has a tendency to whistle and several resonance spots may be found very close together when C2 is adjusted. If C1 is varied, C2 must of course be retuned; however, change of the sensitivity control R2 has no effect upon tuning.

The receiver is not swamped by a nearby strong transmitter, so once C2 has been set to resonance, a preflight check may be made right at the launching spot, after noting that the plate current rise is correct. It has been found unnecessary to make repeated distance checks; if the current rise is satisfactory right at the transmitter, it will also be good at a distance. Naturally, when the receiver is first installed, a distance test should be made, just to make sure the whole installation is in perfect working order. The receiver shown has been used mostly with an 18-watt transmitter (this is operated on the amateur 6-meter band, of

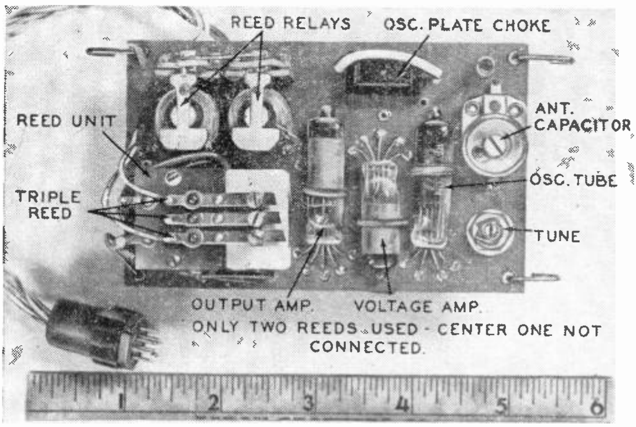


Fig. 507. Audio-tone receiver fitted with triple reed unit. Only two reeds are used in this particular set.

course), and it has been found that the plate-current rise when near the transmitter is only a few tenths of a milliampere higher than it is at a quarter-mile or more away. Also, at this distance, cutting the transmitter final plate input from 18 watts down to about 2 watts makes only a slight difference in the current rise.

Since the relay tube works between the limits of about 0.2 and 1.3 ma, the relay is set to pull in at 0.9 ma and release at 0.6 or 0.7 ma. As the batteries get older, the minimum plate current rises, and the maximum drops; thus this relay setting gives satisfactory leeway.

This receiver has been found to be the least erratic and the most reliable over a long period of any tried so far. Of course, it has a lot of parts, the A drain is higher than with either of the receivers described in Chapter 4, and the tube complement is rather expensive. However, it is thought that all these disadvantages are offset by the reliability and ease of adjustment. It works very well with a modulated signal—in this case the carrier must be left on and the audio tone keyed; we then have normal high plate current, which drops when the key at the transmitter is depressed. Heavy modulation is required, for it must be remembered that this is a "noise-operated" receiver. The stronger the modulation, the more current drop there will be; 100% modulation will drop the V3 plate current to 0.2 ma or even less.

Audio-tone receivers

With the growing interest in multi-controls – meaning the ability to operate rudder, elevator, and motor speed—the use of audio-tone receivers is becoming more widespread. The simplest

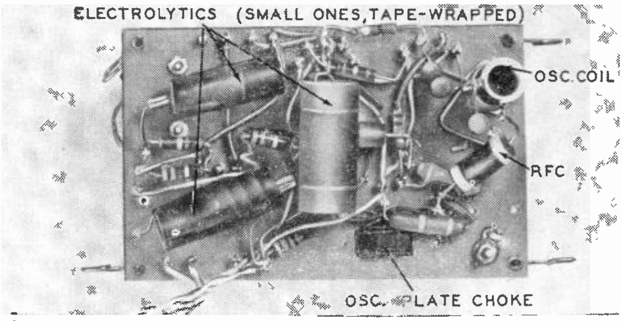


Fig. 508. All small circuit parts for this receiver are under the chassis.

way to get several control operations is through the use of tuned reeds. These reeds are so proportioned that they may be made to vibrate by sending the proper audio note from the transmitter. The notes are separated far enough so that there is no danger of one reed vibrating when the note for another reed is coming in. It has been found entirely practical to use as many as five reeds; however, most of the equipment of this type now being made by the home constructors is built around a three-reed unit that is available on the open market. A receiver based on this unit is shown in Fig. 507 and Fig. 508; the triple-reed setup in Fig. 507 is at lower left, while directly above it are two tiny relays that are operated by the vibration of two of the reeds. The third reed is not in use in this particular receiver. The circuit is shown in Fig. 509. It will be noted that it is essentially the same as that shown in Fig. 503, except that the grid leak for the first tube is fixed, and V3 has a much lower grid leak than does the carrier-operated version. The reed-unit winding takes the place of the relay coil. Reed filters are required to smooth out the pulsations of the reed contacts, since these produce a vibratory current, of a frequency the same as that of the reeds themselves. Each filter consists of a pair of resistors and a capacitor. Only

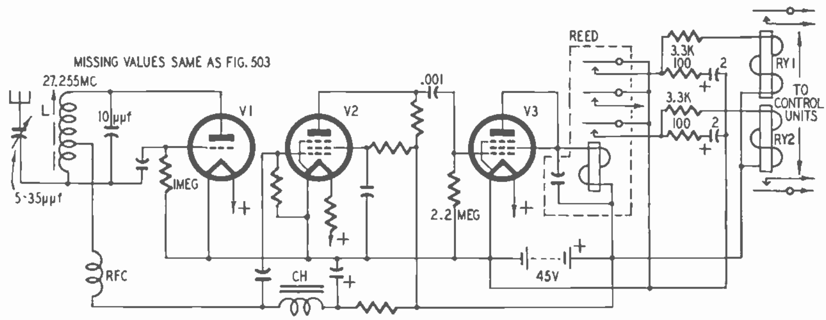


Fig. 509. Reed receiver circuit. Only two reeds are shown in use. If three reeds are required, simply duplicate the reed filter and add another relay. For 27.255-mc operation, L consists of 17 turns of #24 enamelled wire wound on a CTC LS3 coil form. Use core having a red tip. If you want to use the receiver of Fig. 503 on 27.255-mc substitute the values of L and C1 given in this illustration. The choke, RFC, is on a 3/4" x 1/4" form wound full of #34 enamelled wire. RY1 and RY2, Neomatic #5529. Reed, E.D. triple reed unit.

one tone—and thus only one escapement—may be operated at a time, of course.

The receiver is put into operation the same way as the one in Fig. 503, but of course in this case there is no interest in plate current change in V3. Here we just want to get a good, solid audio signal from the last tube for the reeds. To check on this, it might be wise to connect a pair of headphones across the reed coil, while preliminary tune-up is being accomplished. Of course, the transmitter must be in operation, so that the proper audio tones can be sent to work the reeds. With the receiver tuned to the transmitter frequency, one audio tone is keyed and the audio frequency at the transmitter is adjusted until the selected reed vibrates the strongest. Then the reed contact is set so that the highest current is passed to the appropriate relay. The reeds are not changed in tune, of course; the transmitter tones must be brought into tune with them.

As was the case with the carrier-operated three-tube receiver, parts placement is not especially critical, but the choke CH should be kept away from the relay winding, or audio feedback might result.

Chapter 6

Simple Transmitters

BEFORE launching into a description of the transmitters that may be used for radio control, it is necessary to mention the various spots and bands where radio-control transmitters may be legally operated. The most important is the Citizen's Radio spot at 27.255 mc. Though often referred to as a "license-free band," this is neither a band *nor* is it license-free. It is a spot frequency as noted above, though the FCC permits a slight deviation of about $\pm$ 10 kc to allow for the normal drift of frequency and for the use of tone modulation. A license *is* needed, but there is no exam to take; you just fill out a simple form and mail it to the nearest office of the FCC. In a week or two, your license will be returned to you, and you are then ready for legal operation. This spot frequency may be used by anyone of any age. However, the operator must have a Citizen's Radio license, or must be working under the supervision and with the consent of the owner of such a license. Anyone over the age of 18 years may obtain such a license, but again, it is entirely legal for anyone under this age to work the transmitter if the license owner is present.

The requirements for a transmitter working on 27.255 mc are simple: The transmitter must be crystal-controlled and must have a power input of 5 watts or less. That's all. Naturally, you must operate it so that it stays on frequency, and so that no interference is caused to other radio services. The license form that you will be required to fill out is known as Form 505," and may be had from any FCC office. Most transmitters that are sold for this frequency are packed with this form included.

Because many questions have been raised as to how the form should be filled out, let's go into this in some detail. See Fig. 601.

If you will follow the instructions given here and also the sample form shown in Fig. 601, you should have no difficulty. After getting your license carry it with you whenever you work the 27.255-mc spot. To get your license, first fill in your name and address at *two places* on the top front of the sheet. The right-hand top section is the part you will later receive as the license. Fill in the top left- and right-hand sections the same way. Under "Class of station" write C, "Number of transmitters" one, and put a dash under the heading, "FCC type-approval No." This completes the two top sections. Now come down along the right-hand side to the numbered lines and fill out as follows: 1—Write your name and address. 2—Don't put anything here. 3—Write "none." 4—Put an × in the right-hand box. 5—Put an × in the right-hand box. 6—Under "Class of station" write C, under "Number of transmitters" write one, and put a dash under "FCC type-approval No." Put an × in box marked "Yes." Sign your name on the front of the form and have it notarized. That's all there is to it. Although under "Number of transmitters you write *one*, the license covers any 27.255-mc equipment you may have.

This form is used whether you buy a ready-made transmitter, build up a kit job, make one from the data given here or from your own ideas.

There is another Citizen's Radio frequency that may be used for radio control; it is also a spot frequency, this time at 465 mc. You are not allowed to do any service work on the transmitter, not even to the extent of replacing a defective tube. However, you can replace batteries as needed. Since it is not legal to build your own transmitter for 465 mc, such equipment will not be covered in this book. As on the 27.255-mc spot, FCC Form 505 may be used for the license on this frequency, but here the transmitter has a type-approval number. There is only one such type-approved unit on the market; it comes with the correct form for you to fill out.

A great deal of radio-control work is done on the various amateur bands, and indeed some amateurs have taken out licenses for the sole purpose of undertaking model-control by radio. It is not necessary to go into the requirements for the various types of amateur licenses here. Full information on such licenses may be had in other publications. The 50-mc band is the most widely used, probably because the pioneers of radio control settled in this vicinity long before the war. The so-called 11-meter band is also popular, and the same equipment to be described for 27.255

FCC
Form 505-3

CITIZENS RADIO

FCC Record Copy

Licensee and P O Address (Print): JOHN DOE (Name)

1200 FULTON ST.

(Number) (Street)

NEW YORK 77 N.Y.

(City) (County) (State)

Class of station	Number of transmitters	FCC type-approval No
C	ONE	–

Not to be filled in by applicant 16—58488-2 GPO

Call Sign ....

Issue date

Expiration date

Part II

(To be completed only by applicants which are corporations or associations)

7 If applicant is a corporation or association—

Under the laws of what State is it organized? | Purpose for which organized

Is more than one-fifth of the capital stock of the corporation either owned of record or may it be voted by aliens or their representatives or by a foreign government? ☐ No ☐ Yes

Is any officer or director of such corporation an alien? If so, state name and position of each, and state total number of directors

8. Is applicant directly or indirectly controlled by any other corporation? If so, what is the name and address of the controlling corporation? ☐ No ☐ Yes

Under the laws of what State is it organized?

FCC
Form 505-2

United States of America
Federal Communications Commission

Not Transferable

CITIZENS RADIO STATION LICENSE

Licensee and P O Address (Print): JOHN DOE (Name)

1200 FULTON ST.

(Number) (Street)

NEW YORK 77 N.Y.

(City) (Zone) (State)

Class of station	Number of transmitters	FCC type-approval No.
C	ONE	

Not to be filled in by applicant 16—58488-2 GPO

Call Sign ....

Issue date

Expiration date

Secretary.

FCC
Form 505-1
Rev 12-52

Form Approved.
Budget Bureau No 52-R123.3.

United States of America
Federal Communications Commission

Application for
Citizens Radio Station Construction Permit and License

(Read Instructions on Reverse Side)

1. Name of applicant (Print) (If corporation or association, see Part II)

JOHN DOE

Post-office address (number, street, city, county, State)

1200 FULTON ST. NEW YORK 77 N.Y.

2. If you now hold a valid authorization, what is the purpose of this application?
   a. Change of permanent address ☐
   (If so, give former address)
   b Other ☐ (state)

3. Present call sign

NONE

Is more than one-fourth of the capital stock of the controlling corporation either owned of record, or may it be voted by aliens, their representative, or by a foreign government or representative thereof, or by any corporation organized under the laws of a foreign country? ☐ No ☐ Yes

Is any officer or director of such corporation an alien? ☐ No ☐ Yes
If so, state name and position of each, and state total number of directors

Is the above described controlling corporation in turn a subsidiary? ☐ No ☐ Yes
If so, attach additional sheets answering the items in this paragraph for each company to and including the organization having final control

9. If an unincorporated association—

Number of members	Are any members aliens? ☐ No ☐ Yes	Number of aliens, if any

Name and position of alien officers or directors, if any

4. Type of use—

Radiotelephone ☐ Radiotelegraph ☐ Radio control of devices or objects, etc. ☒

5. Is equipment type-approved by FCC? Yes ☐ No ☒
If answer is "No," furnish the data required by Item 10 on the reverse hereof.

6. Transmitters—

Class of station	Number of transmitters	FCC type-approval No.
C	ONE	-

If for Class C, are transmitters crystal controlled? Yes ☒ No ☐

Not to be filled in by applicant

Call Sign ....
Issue date Expiration date

I hereby certify that I am (if a partnership, that each partner is) a citizen of the United States, eighteen or more years of age; that I am (if a partnership, that each partner is) not the representative of any alien or any foreign government; that I accept full responsibility as licensee for operation of a Citizens Radio Station in accordance with law, treaty, and Rules and Regulations of the Federal Communications Commission; that I waive any claim to the use of any particular frequency or of the ether as against the regulatory power of the United States because of previous use of the same, whether by license or otherwise; (if a partnership) that I am a partner; (if a corporation or association) that I am an officer; and I request an authorization in accordance with this application.

Subscribed and sworn to before me this 7TH day of October, 1954 [Seal]
(Notary public's seal must be affixed where law of jurisdiction requires, otherwise state that law does not require seal.)

Richard Roe
Notary Public.

My commission expires March 8, 1956

16—58488-2

John Doe
Applicant (Must correspond with Item 1))

By ....
(Name and title)

Fig. 601. Actual reproduction of Citizens Radio Station License. This license is necessary for operation on the 27.255-mc spot. An examination is not required, but it is essential that the license be filled in properly. Copies of this form can be obtained by writing to the Federal Communications Commission, Washington 25, D. C. or secured from your local F.C.C. office. Write your full name and address three times as shown, and then sign the license at the lower right-hand corner. The license must be notarized. The same type of license form can also be used for operation on 465 mc, except that in this case the transmitter must have a type approval number. All 27.255-mc transmitters working on the Citizens Radio spot must be crystal-controlled. The input power to the transmitter must not be more than five watts. The license shown here is Form 505. An older license application, on which the upper right section is labeled "Form 555", may still be seen; it is very similar to the one shown except that part of item 6 is on the reverse side.

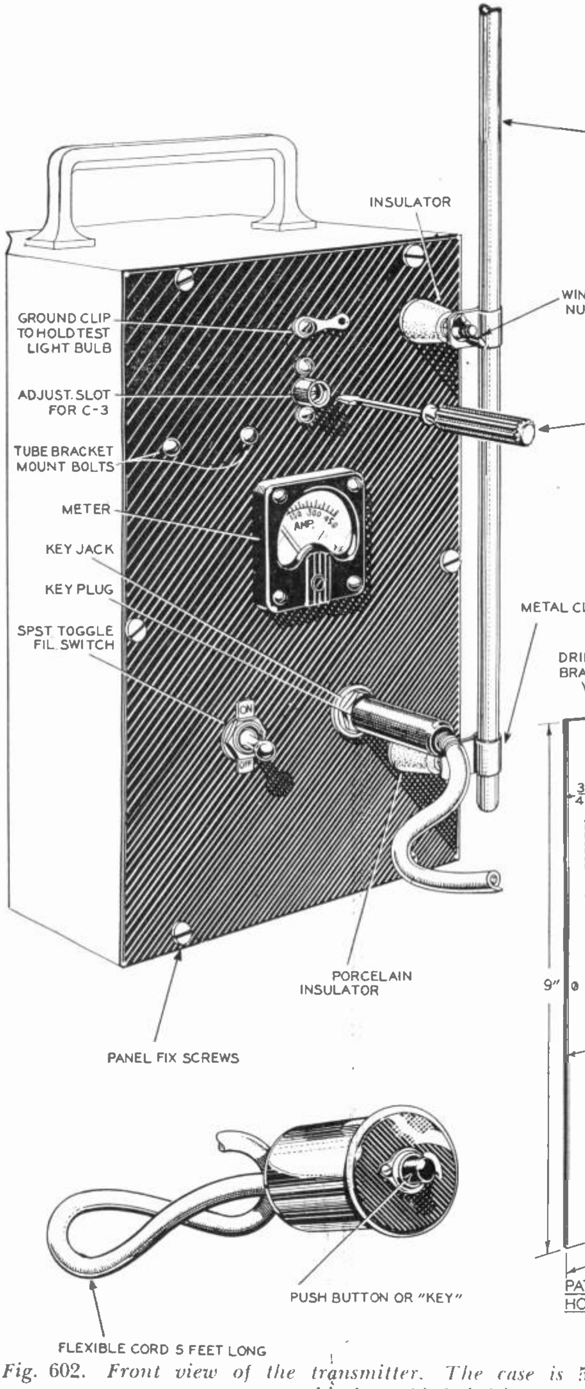
mc may be utilized here; the band runs from 26.960 mc to 27.230 mc. Amateur licensees may use self-excited transmitters on 11 meters if they wish. There is a scattering of radio-control work on other amateur bands, but the ones mentioned are the most important for this activity.

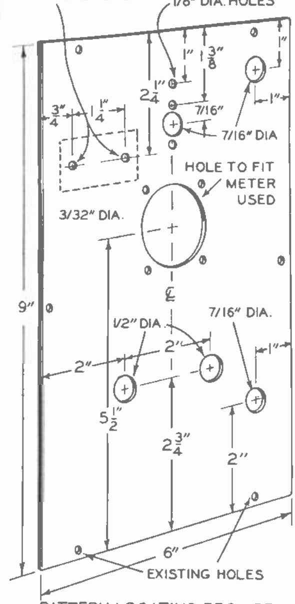
Crystal-control transmitters

Now that the legal angles have been covered, what about the actual equipment itself? Fortunately, it may be simple, and of very low power. The majority of radio-control transmitters work at an input of around 2 or 3 watts, which is adequate for any distance at which you can see a model boat or plane. A transmitter that has been widely used is shown in Fig. 602. It utilizes a single 1S4 tube connected as a pentode, and has a power input of about 1.7 watts. The parts are mounted in a standard 5 x 6 x 9-inch metal box, which carries all necessary batteries, and also supports the antenna.

All crystals that are usable in simple transmitters for this purpose are of the overtone type, and most of them require considerable regeneration, for good output. In this transmitter, the regeneration is furnished by the grid coil, and the circuit has been found to work well with practically all makes of 27.255-mc crystals. Also, it is very easy on the crystal (some circuits are not, as will be explained later). Some crystals for this frequency are marked "9.085 mc," but these too, will work in many of the circuits to be shown. Crystals marked "27.255 mc" are actually 9.085-mc units especially processed to be active on the third overtone. When utilized this way, the fundamental cannot be detected.

The transmitter parts are all mounted upon the front panel of the case; the tube and crystal sockets are held by a small metal shelf. A meter is absolutely necessary to tune up one of these transmitters, and while modelers employ a separate meter just for initial tuning, it is strongly advised that the meter be built right into the case as shown in Fig. 602 and in the inside view, Fig. 603. This allows a constant check upon the working of the equipment, the antenna loading, condition of the batteries, etc. If a moderately shallow meter is used, the case shown is big enough to hold three 45-volt B batteries, and a plug-in type 1½-volt A unit. The A battery will run down first, of course, but the B's will last several months, with average use, since they are under drain only when the transmitter button is pressed.





PATTERN LOCATING REQUIRED HOLES IN TRANSMITTER PANEL

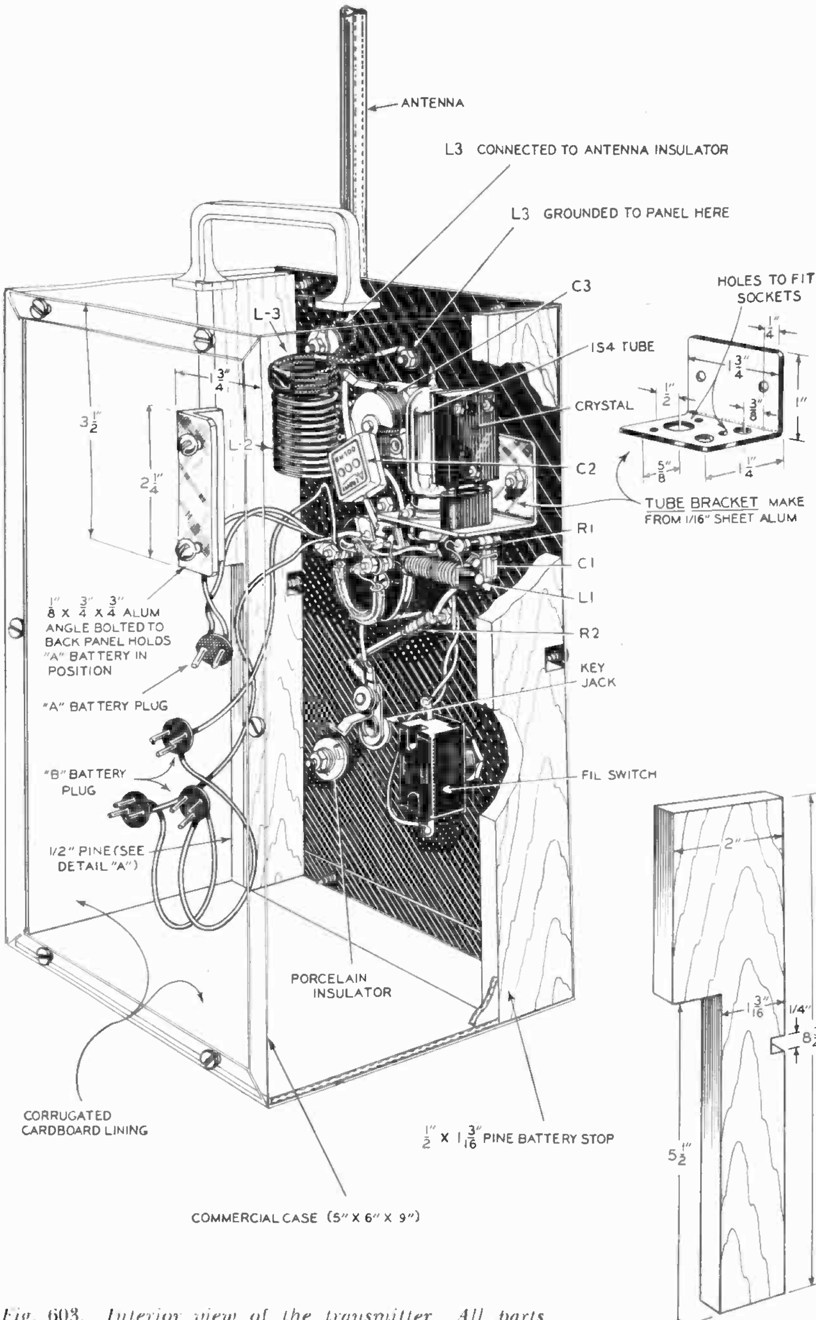
Fig. 602. Front view of the transmitter. The case is 5 x 6 x 9 inches, steel, black-crackled finish.

Wiring of components in the high-frequency circuits of this transmitter, Fig. 604, should be as short and direct as possible. The ground end of coil L3 is soldered to a lug on the panel (scrape the paint away under the lug) and the other end goes to the upper antenna insulator. The antenna must be about 10 feet long, since the lower 6 inches or so is inactive. If you will examine Fig. 602 again you will see that the lower six inches (approximately) of the antenna is just used as a support. A 9½ foot antenna has been found about right for this frequency; this length acts as a quarter-wave radiator, and must be operated against ground for efficient radiation. In other words, the transmitter must be standing on the ground, not raised up in the air on some nonconducting medium such as a wooden chair, box, or table. Some users set the transmitter on the hood of their car, which works very well. Actually, the simplest good antenna is a half-wave length long. When a quarter-wave length vertical antenna is used, as is the case here, the ground acts as the other quarter wave. The loading on the transmitter will change somewhat, depending upon what kind of ground it is set upon. In most cases, even fairly light loading will still allow plenty of signal to go out for good control.

Tune-up procedure

To tune up: Connect a No. 47 pilot-lamp bulb to the upper antenna post and to the case. Turn on the filament switch, and press the key. Quickly tune capacitor C1 and note if the plate current takes a sharp dip. The coupling coil L3 should be about ¼ inch away from L2 at first. If the plate current dips below 12 ma, push L3 closer to L2. The action of the meter as the tuning capacitor C1 is rotated through its full range should be fully understood. Start with the plates fully meshed, and turn toward the low-capacitance setting; at a point near mid-capacitance, the plate current will take a sharp dip, then will gradually rise as capacitance is further reduced. Highest output is had right at the greatest current dip, but the transmitter should never be used in the field with this setting, as slight changes in loading might pull the circuit out of oscillation. Instead, rotate the capacitor toward the *low-capacitance* side a few degrees; experience will show how far to go in this operation, but the point to remember is that you *must* tune away from the point of maximum current dip a small amount.

One other point should be checked. As noted previously, this



DETAIL A - 1/2" PINE

Fig. 603. Interior view of the transmitter. All parts are mounted on the front panel.

and most other 27.255-mc crystal oscillator circuits utilize considerable regeneration; in Fig. 604 the grid circuit is actually resonated somewhere around 35 mc and it is possible to get self-oscillation of the circuit near the minimum capacitance side of C1. This self-oscillation will naturally vary in frequency as the capacitor is rotated, and it will have no sharp point of plate-current drop, as has the correct crystal oscillation. Also, the bulb will not show as much output, though it might light dimly.

After the circuit has been checked for proper operation with a bulb load, the transmitter should be taken outdoors and set upon

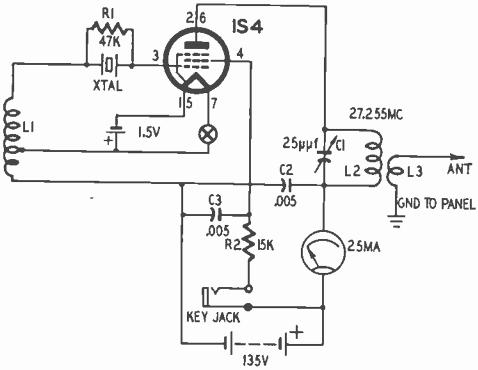


Fig. 604. Crystal-control transmitter is simple, uses few parts. L1, 30 turns, #22 d.c.c. wire close wound on 1/4" diameter bakelite rod. Tap 3 turns from lower end. L2, 11 turns #14 wire on form 1-1/8" long, 3/4" i.d. L3, 5 turns #14 wire close wound on form 3/4" i.d. Use insulated wire.

the ground, and an antenna should be attached. The bulb is removed, of course. The resonance point of plate-tuning capacitor, C1, may be a bit different with the antenna than it was with the bulb, but the same tuning procedure should result in the same sort of meter action—a sharp drop around mid-scale as you rotate from maximum to minimum, then a gradual rise of current. You can also get self-oscillation with the antenna, and it will show the same characteristics.

The coupling coil, L3, should be adjusted till the plate current is about 12 ma when the transmitter is on the ground. If always used sitting upon the ground thereafter, the meter should indicate about the same loading, varying a milliampere either way. If it does not, and the meter is way down the scale, you will know the ground is radically different from that where you did the initial tuning, and you can try putting the set in a different location. Incidentally, concrete runways, paved roads, macadam driveways, etc., are not good "ground" locations for the transmitter.

You will probably find that the meter reading will vary a bit as you move the keying lead around. with the key depressed. This is normal: in this instance the lead is changing the radiating system, and this alteration in loading is one of the main reasons for not tuning to the point of greatest output—that is, where the meter dips the lowest. When not oscillating, the plate current will be around 24 ma.

Higher-power transmitters

Those who want a bit more power may try the circuit in Fig. 605. This is just the same basically as the one in Fig. 604 but

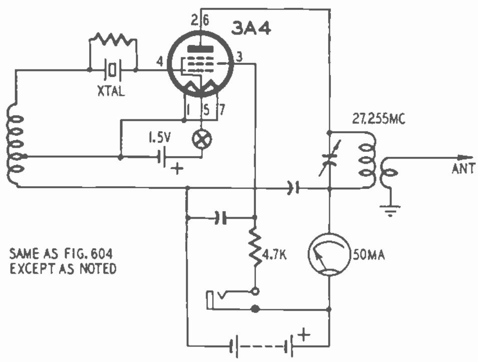


Fig. 605. This circuit gives about 30% more power than that illustrated in Fig. 604. Coils same as Fig. 604.

will handle somewhat more plate input. When not oscillating, the current may go up near 50 ma so the tuning capacitor should be turned quickly to the point where oscillation starts and this current drops. When loaded to capacity with either bulb or antenna, the plate current may be run as high as 17 ma. This circuit was installed in the same transmitter shown in Fig. 602, and has proven very satisfactory. The only changes required are in the plate and coupling inductances and the screen-grid series resistor.

For still more output from the same sort of circuit, try Fig. 606. This must be used with more care, for it is possible to damage the crystal if the circuit is tuned to resonance with no load. As a matter of fact, no crystal oscillator should be tuned up without load, since the crystal current goes way up when you reach resonance.

Also, in the case of screen-grid tubes, the screen current can rise to damaging values if the tube is allowed to operate for any length of time with no plate load. So make that first tuning test as fast and brief as possible. When you have the loading correct and the plate current as specified (or a little lower) everything will work with no possibility of damage.

It will be noted in Fig. 606 that the 3A4 is connected as a triode,

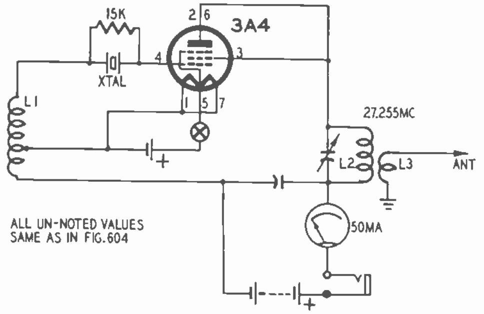


Fig. 606. This transmitter circuit gives still more power, but is trickier than that shown in Fig. 605. L1. 22 turns #22 enamelled wire close wound on 3/8" diameter rod, tap at third turn. L2, 8 turns #14 enamelled wire, wound on form 3/4" i.d., 3/4" long. L3 same as in Fig. 604.

with the plate and screen tied together. Thus, the power that was "wasted" in the screen, in Fig. 605, is put to good use. This connection will light up a No. 47 bulb to almost full brilliance,

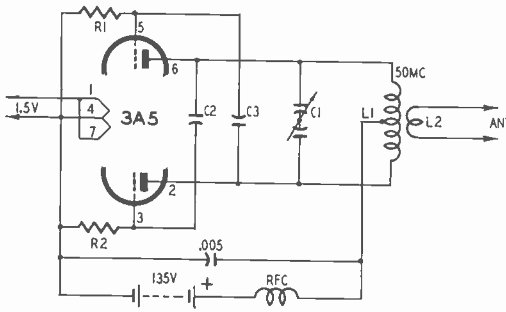


Fig. 607. Conventional 3A5 push-pull 50-mc transmitter. This circuit is a self-excited oscillator, but it can be converted to a crystal-controlled transmitter for work on the 27.255-mc spot, as shown in Fig. 608.

if you have a good active crystal. However, certain crystals now on the market will not work well in it, so unless you have a type that you know will do the job, better stick to one of the pentode circuits, which are generally much easier on crystals, and will give good results with crystals that would oscillate poorly when used in the circuit of Fig. 606. In the early test stages, it is wise to feel the crystal frequently; if it seems more than just slightly warm, cease operations till you find out why. Crystals at five dollars or more each are not to be taken lightly.

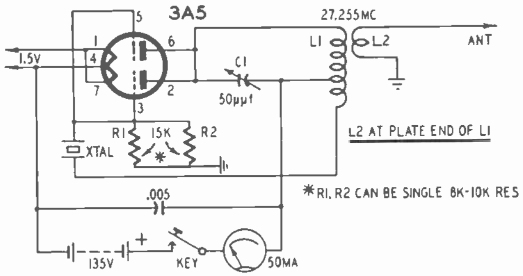


Fig. 608. Transmitter circuit after modification for 27.255 mc. L1, 12 turns #16 enamelled wire, on form 1-1/8" long, 5/8" i.d. Tap at second turn. L2, 4 turns #16 enamelled wire close-wound on form 5/8" i.d.

Push-pull transmitters

For years, the standard radio control transmitter on six meters has been a 3A5 push-pull self-excited oscillator. The circuit normally operated at about 30 ma input and on a 135-volt B supply. When the 27.255-mc spot was opened, early in 1952, a lot of these

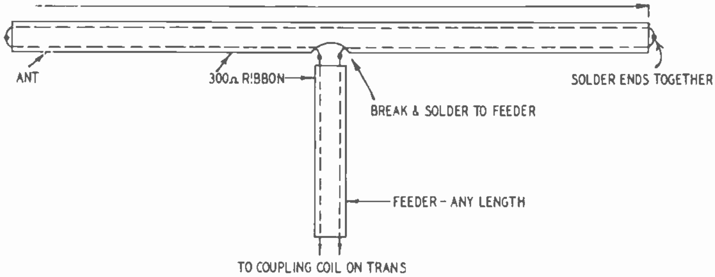


Fig. 609. Half-wave horizontal antenna for use on 27.255 mc. The total length of the antenna, as indicated by the solid arrow, should be 16 feet, 11 inches.

units were put aside, but with a little work they can be converted to the new spot and crystal control, with little added expenditure except for the crystal itself. The original circuit of a typical commercial unit of this type is shown in Fig. 607 and the converted circuit in Fig. 608. Some alteration of parts is needed, since the 50-mc version utilized a double-section capacitor, C1, to tune the coil. In this case, the entire rear section of the capacitor was removed, and two semicircular plates from the discarded half were slipped on the remaining shaft in place of the two disc plates that were found there; this change just gave a bit wider tuning range. Many 50-mc transmitters have two grid leaks of 15,000 or 20,000 ohms; the former size was found here, and the two, R1 and R2, were connected in parallel, for the final job. A single resistor of 8,000 to 10,000 ohms would do just as well. The two little capacitors C2 and C3 were discarded, since no grid capacitor is required in the converted circuit.

While both halves of the tubes are shown connected in parallel —and this arrangement gives the greatest output—you can get

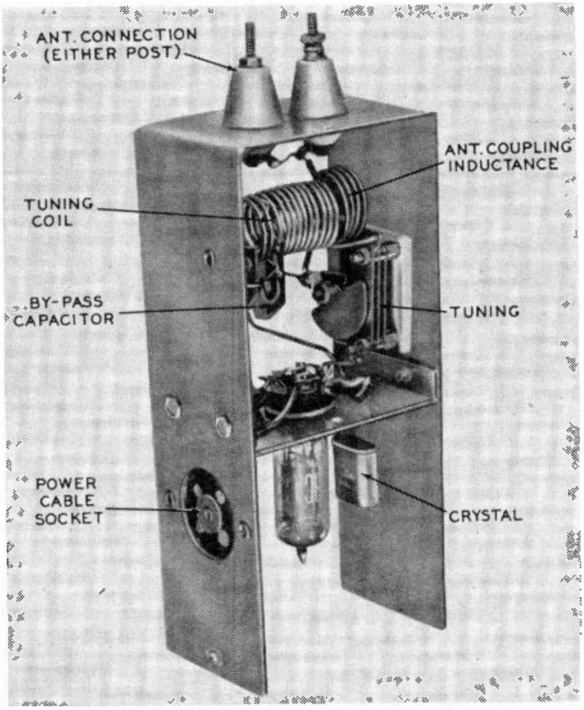


Fig. 610. Photograph of the rebuilt transmitter. Upside down mounting of the tube permits use of shorter leads, makes for more compact equipment.

along nicely with only half the 3A5, and this connection will be a lot easier on the crystal. It will save battery power, too.

The crystal socket was mounted on the tube shelf, and a tie lug on the rear of the aluminum case allows a firm point to attach the lower end of the coil, L2.

Most 50-mc transmitters used ordinary 300-ohm ribbon line for the antenna, and this one is no exception. The Twin-Lead was employed both for the antenna itself—which was supported horizontally on poles—and for the feeders. The half-wave antenna becomes rather bulky on 27 mc, though it must be admitted that it is very efficient and won't give the coupling and loading problems that you have with the simpler quarter-wave vertical antenna. You do not ground one side of the coupling coil as you must with a quarter-wave type; the antenna itself should be about 14-½ feet long, and the ends of the twin-lead are soldered together as shown in Fig. 609.

With either style of antenna and feeders, the coupling coil should be at the plate end of L1, since placing it there tends to

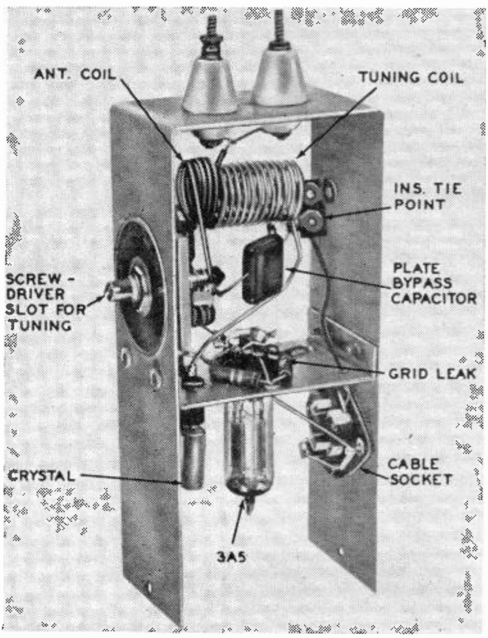


Fig. 611. Another view of the modified transmitter. The unit is connected to the power supply by means of a cable.

lower the crystal current. The photos (Fig. 610 and 611) show how the rebuilt unit will look. Getting it into operation is just the same as described for the 1S4 job. Start tuning from the high-capacitance position of C1 and move quickly toward low capacitance until the plate current takes a sudden dip. Use the bulb load at first until you are sure the circuit may be tuned to to the correct frequency, then take the outfit into the open where it may be tested with an antenna. With this transmitter (and in fact, with any of the others described) it is a good idea to make the preliminary checks with only 90 volts on the plate; this is much easier on tube and crystal, and will conserve the B batteries too. When you are sure of proper operation you can add the third 45-volt battery.

A transmitter of the size shown is really too small to use with a quarter-wave antenna, since, even if it is resting on the ground there is too little capacitance to allow a quarter-wave antenna to load well. However, if the batteries are put in a metal case and the transmitter unit fastened to this, you will probably be able to load up well enough. Remember, to use a quarter-wave antenna with any sort of efficiency, you *must* have considerable capacitance between ground and the transmitter case.

The conversion job shown here may be followed for any other 50-mc outfit you have. In any such job, try to keep the leads that carry r.f. (those from grid and plate of the tube, the crystal connections, etc.), as short as possible. This should not be difficult, as there are few parts, and these may be mounted in a compact manner.

The converted 3A5 transmitter of Fig. 608 will run at about 20 ma plate current, with 135 volts on the plates; this current is for both halves of the tube. Never operate a triode-connected circuit of this type at higher than 135 volts—and don't forget to keep a load on the circuit at all times.

Chapter 7

Complex Transmitters

THE transmitters described in Chapter 6 are all for the Citizen's spot at 27.255 mc and are of the simplest construction.

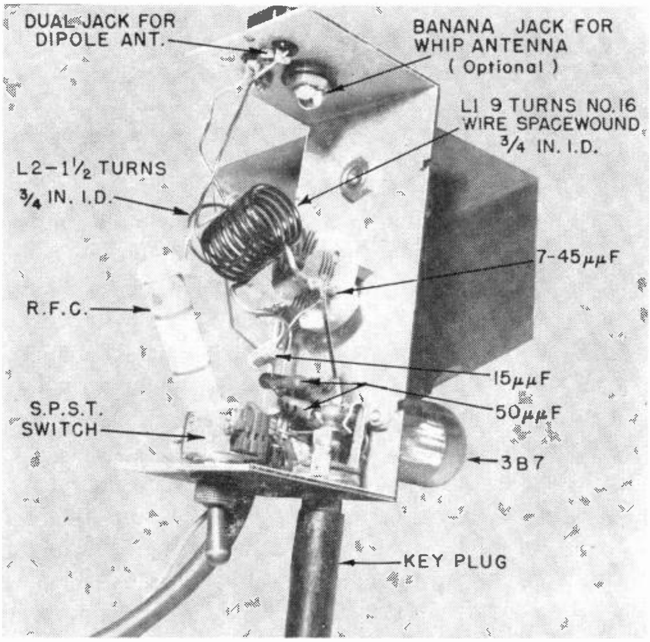


Fig. 701. Photograph shows under-chassis view of push-pull transmitter.

Here we will go into outfits for other frequencies and more complex or higher-powered units.

Push-pull transmitter

The basic radio-control transmitter has been the simple push-pull 3A5. Figs. 701 and 702 show a design of this style, using a 3B7 tube (a double-section triode, something like an overgrown 3A5). This unit *cannot* be used on 27.255 mc as it is not crystal controlled, but can be legally operated by regularly licensed amateurs on the 11-meter band. The circuit values are for such use. A 3A5 can be used with the same circuit values, but the socket will have to be changed, as the 3B7 requires a loctal socket, while the 3A5 takes the 7-pin miniature size. The set can be used

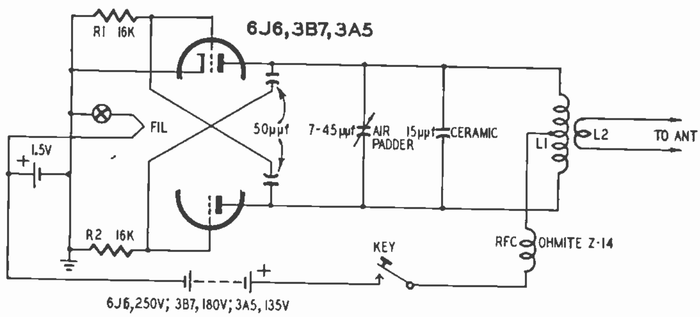


Fig. 702. Circuit of push-pull radio-control transmitter for use on 11-meter band. This unit can only be operated by licensed amateurs. For a 6J6, heater battery should be 6.3 volts. Do not use this transmitter on the 27.255-mc spot. See Fig. 701 for coil values.

also with the 6J6 tube and operated from a 6-volt car battery. In this case, it is usual to employ a vibrator or dynamotor high-voltage system, also working from the car battery. With the 6J6, the grid leaks, R1 and R2, may be changed to 6,800 ohms each, for greater power output, and the plate voltage can be as high as 250 volts. This will give quite a good signal, and a good long operating range. The coupling coil should be meshed at the center of L1. It is generally considered good practice to spread the center turns a bit, so that L2 may be slid in; this way, the loading on the two sections of the tube is more uniform. Well-insulated wire should be used for L2, of course. If the transmitter is used with a quarter-wave vertical antenna, it is likely that more turns will be needed in L2; try 4 turns here, for a start. With any of the three tubes suggested, the loaded plate current should not exceed 30 ma, and the coupling coil must be adjusted to attain this value. Since this sort of transmitter will operate over a wide range of frequencies, make certain you are in the desired amateur band.

This circuit will also operate on the ham 10-meter band, but radio control is not used often here, for 10 meters is a very busy spot, with many high-power stations. It is quite possible to operate radio control on *any* of the ham bands, but at wavelengths higher than 11 meters the antennas become a problem. There is also the difficulty of competing with large numbers of high-powered stations, and the possibility of some amateur a thousand miles away inadvertantly taking over control of your model, through *skip effect!* All in all, therefore, it is wise to keep on the high-frequency side of 11 meters. Up to the present time there has been little radio-control work done on bands higher than 50 mc (aside from the 465-mc Citizen's spot), but this is useful territory for control work. The antennas are very compact, the bands

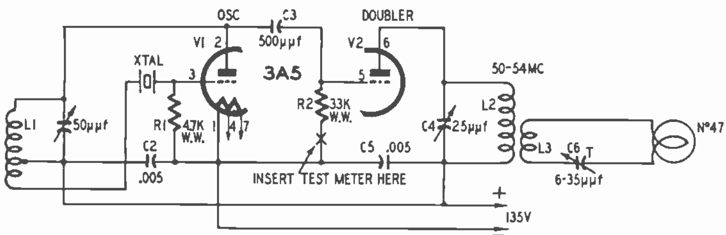


Fig. 703. Transmitter for operation on the 50 to 54-mc band. The fundamental frequency of the crystal should be between 25 and 27 mc. L1, 17 turns #18 enamelled wire on form 1/2" i.d., 1-3/8" long; L2, 9 turns #16 enamelled wire on form 1/2" i.d., 3/4" long; L3, 3-1/2 turns #16 enamelled wire on form having 3/4" i.d.

are not too heavily populated, and there are few dx signals to bother you. A few regular amateur and Technician licensees are giving the 144-mc band a tryout and find it very satisfactory. About the only drawback is that typical, simple gas-tube receivers are not reliable higher than about 75 mc, (considering the distances required for trouble-free radio-control flying) so new receiver techniques must be developed.

50-mc transmitter

For those who wish to use 50 mc, and are looking for a simple transmitter, the circuit of Fig. 703 will give very nice results if used with an active crystal. The output is ample for any control work within the range of sight, when the circuit is correctly tuned. The crystal oscillator must be in the range from 25 mc to 27 mc. In general, it has been found that the crystals in small sealed metal cases are the "hottest." An overtone-type crystal is recommended. The second half of the 3A5 acts as a doubler, making neutralization unnecessary. The grid resistors R1 and R2 should both be of the wire-wound type, as these act as r.f. chokes. If you can get only carbon resistors for these positions, small r.f. chokes should be inserted in series with the resistors. The wire-wound resistors may be of any wattage up to 10-watt size; higher wattage units are too bulky.

Transmitter adjustments

To put the circuit into operation, connect the usual bulb load to L3; a milliameter of about 0–5-ma range should be connected temporarily between the ground end of R2 and B minus. This meter will indicate grid drive on the second section of the 3A5. Rotate the 50 μμf capacitor till the meter reads maximum. It

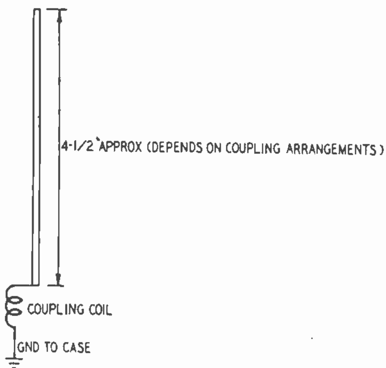


Fig. 704. Simple 6-meter band antenna is only four and one-half feet in length.

should go to at least 2 ma for good efficiency in the doubler. Then tune C4 for the best output. When working correctly, the plate current of V1 will be about 8 ma and that of V2 will be about 16 ma. A good deal of regeneration has been used in V1, to assure high output, so use care when tuning to be certain you are on the correct frequency.

It may be difficult to get enough coupling between L2 and L3 to load V2 properly when a bulb is being used. Hence, a tuned output circuit is shown, composed of the No. 47 bulb with L3 and C6. This circuit is tuned to the output frequency of V2, or very near it, and will then be found to take as much power out of L2 as you wish, depending upon how close L2 and L3 are coupled. With this sort of tuned-output circuit, it is easy to overload tube V2, so adjust coupling with care. The plate current of V2 was found to go up to about 25 ma with L1 tuned to the point of best output, but with C4 off resonance. If C4 is then tuned to resonance with no plate-circuit load, the plate current will drop to around 4 ma.

This makes a very nice little transmitter, since the crystal oscillator is not affected by anything that happens in the antenna circuit. Thus, if someone leans against, or grabs, your antenna, there will be little effect, aside from a slight reduction in output. If this were done with a self-excited circuit such as the one in Fig. 702, the frequency would vary widely, while the same treatment to a crystal oscillator coupled directly to the antenna, as in the circuits of Figs. 604 or 606, would probably throw the crystal out of oscillation, and put the transmitter off the air.

For the 6-meter band, the antenna should be about 4½ feet long, if of the quarter-wave vertical type. A half-wave horizontal antenna made of 300-ohm Twin-Lead will measure about 8¾ feet long, with feeders of the same material. Fig. 704 shows these dimensions clearly.

High-power transmitter

For those who want a higher-power transmitter of the deluxe

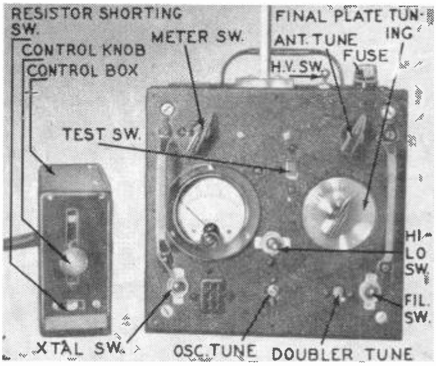


Fig. 705. Front view of high-power transmitter.

type for 50 mc, the one shown in the photograph in Fig. 705 is highly recommended. This unit has been in operation for several years without trouble of any kind, and will keep right on going hour after hour—as long as your car battery holds up! An inside view is pictured in Fig. 706. The outfit shown was made almost entirely from surplus parts, but *new* components of standard make may be fitted in. Normal ham practice was followed throughout. The circuit in Fig. 707 starts off with a crystal oscillator and a doubler stage (very similar to the circuit of Fig. 703, but using a 6J6 tube) that furnishes 50 mc output to the 832. This tube, which is operated far below its maximum rating, serves as a push-pull final amplifier on 50 mc. It works very smoothly, without the necessity for neutralization. A 3-position metering switch S1 allows the circuit to be tuned up and monitored constantly, while S2, when open, inserts a large resistor in the cathode lead of the 832, thus reducing power for tuneup with the receiver nearby.

It was found necessary to key the B plus to the entire transmitter; even allowing just the crystal oscillator to run continuously provided enough signal on 50 mc to affect a sensitive receiver at quite a distance. Keying is accomplished by the relay RY. A push-button S5 on the panel makes it convenient to run tests without having to plug in the regular control box.

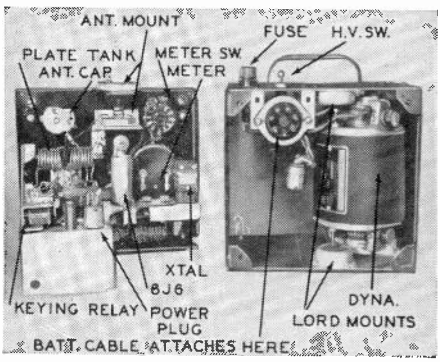


Fig. 706. Inside view of high-power transmitter.

The transmitter was fitted with two crystals and a switch to change the two, on the theory that interference might be encountered. If this should happen, it is simple to change to another spot in the 50-mc band. Actually, this switch has never been used, the transmitter always working on a frequency of about 53 mc. For this reason, the switch and extra crystal are not shown on the diagram.

M is a 1.5-ma meter, and this range is used in the No. 1 position of S1, to measure grid current to the doubler section of V1. Position 2 shunts about 47 ohms across the meter to make it read 3 ma full-scale (meters other than the one shown might require a different shunt value) for grid current in the 832; the final position connects another shunt on the meter, so that it reads 75 ma full-scale. Here it is connected into the cathode of V2 and thus indicates the total of control grid, screen grid, and plate currents for the 832.

Frequency-tuning capacitors C1 and C2 just have screwdriver slots on their shafts, as they are never shifted after the first tune-up, but C3 and C4 (final tank and antenna) are fitted with knobs. These two require touching up when the transmitter is moved from one location to another. The transmitter is normally placed on the hood of the car, and of course if never used in any other location C3 and C4 would never need changing either.

It will be noticed that all the d.c. grounds in the transmitter are isolated from the chassis and case; some cars have the positive lead of the battery grounded and some have the negative

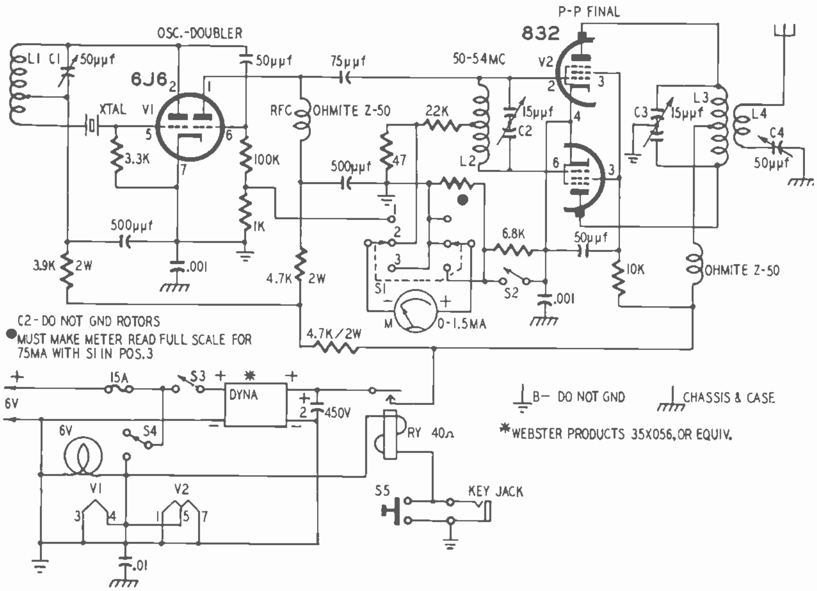


Fig. 707. The transmitter uses a 6J6 as an oscillator-doubler and push-pull 832's in the final. A single meter is switched to check three different circuits. L1, 18 turns #16 enamelled wire on form 1/2" i.d., 1-1/2" long. Tap at 6-1/2 turns from crystal end. L2, 12 turns #16 enamelled wire on form 1/2" i.d., 1" long. Coil is center-tapped. L3, 14 turns #14 enamelled wire on form 3/4" i.d. Each half of coil 7/8" long, 3/8" apart in center. Note center tap. L4, 3 turns #16 insulated wire on form 3/4" i.d. All variable capacitors receiving type.

grounded. Isolation of the d.c. leads from the case prevents possible fireworks if the set is used on a car with the wrong side of the battery grounded. There are several capacitors in the circuit that actually attach to the chassis to take care of r.f. grounding.

The outfit has always been used with cheap surplus crystals in the range from 8,800 to 8,900 kc and for these quite a lot of regeneration is required. Thus we show 6½ turns in the crystal end of LI (below the tap). If good amateur-band crystals in the range from 25–27 mc are used, this section of L1 can be reduced to two or three turns with less likelihood of the circuit taking off on the wrong frequency by self-oscillation.

The dynamotor is a 9-volt job, which gives about 275 volts at about 80 ma d.c. with 6-volt input, at the drain of this transmitter. It is suspended vertically on four Lord Mounts. The case is 7¼ inches wide, 7½ inches high, and 6½ inches deep. An aluminum chassis was made to fit around the dynamotor, and the other parts were disposed for the shortest leads. V2 is mounted so that the socket is about ⅞ inches below the under side of the chassis; a section cut from an old r.f. coil can is clamped between the socket and the chassis to shield the tube. The two plate pins of this tube are on the top and connect to the two halves of output tank coil L3 by means of tiny bronze clips.

Operating values are as follows: Oscillator, 155 volts at 10 ma; doubler, 180 volts at 8 ma, 1 ma grid current; final cathode current is about 50 ma and grid current 2 ma. When fully loaded, the drain on the battery is around 9 amperes. Power output is about 8 watts.

It will be noted that there is a capacitor (C4) in series with the ground end of L4; this makes it simple to change loading, no matter where the transmitter is located. Once the antenna coil L4 has been properly set, it will never need changing—all variations in loading may be handled by C4. This system may be adapted to any of the transmitters that have been shown, of course, but is considered rather a luxury, and is not generally fitted to the simpler transmitters. In practice, C3 is tuned to resonance with C4 near minimum, then C4 is varied to bring the cathode current of V2 to the desired point. There is a little interaction between the two, so C3 must then be touched up again.

No lineup directions will be given for this transmitter, as it is not a job for the beginner to tackle, and the more advanced amateur operator will know how to go about it.

5-watt Citizen's Band rig.

Since the FCC allows 5 watts input on the 27.255-mc spot, many modelers feel they should have this much power. Actually, if the transmitter and receiver are properly made and tuned up, a fraction of a watt will give reliable control at any distance within the range of sight. However, more power into the transmitter *does* provide a margin of safety, so the equipment required for such power may be justified from this angle.

Fig. 708. The author, Howard G. McEntee, operating the Citizen's transmitter.

Transmitter using vibrator supply

The front view of an outfit (a Citizen's Band rig) that may be run at about 4.8 watts input is shown in Fig. 708. A rear view of the same transmitter is shown in Fig. 709-a This is a self-contained piece of equipment, which includes within the case the r.f. unit, a vibrator power supply, and a storage cell to run them.

The case itself and the entire power supply are surplus items: the vibrator unit is similar to that used in some types of deluxe broadcast-band portable receivers, as is the 2 volt, 20 ampere-hour storage cell. It is possible that one of these broadcast-band

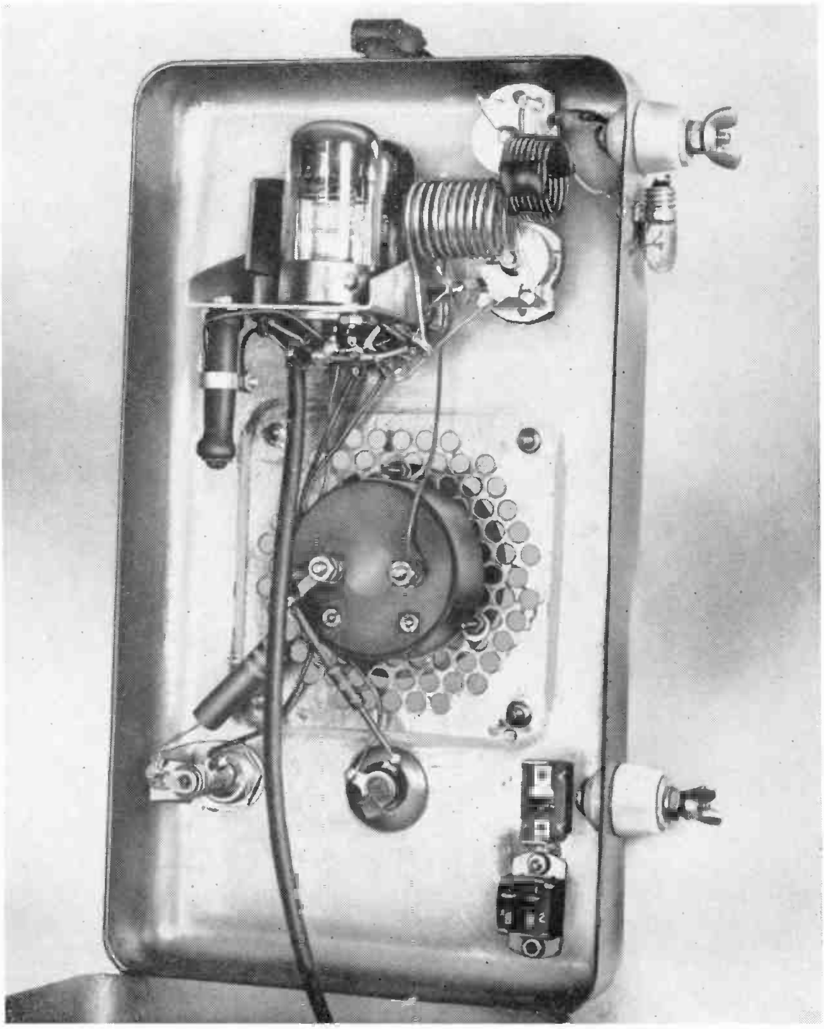


Fig. 709-a. Inside view of the r.f. portion of the 27.255-mc transmitter.

portables might be picked up in the second-hand market, if the PE-157 unit used here cannot be located. Actually, the transmitter may be run just as well from dry cells; a standard 1.5-volt A unit and 180-volt for the B would do the job. Some builders might prefer this, since there is a fair amount of work to converting the PE-157. For those who like the 2-volt power supply, but don't want to bother with the PE-157, the essential power supply elements—2-volt storage cell, synchronous vibrator, and special vibrator transformer—may be purchased separately. The other parts are standard.

A survey of tubes that might be used showed that the 3D6 was the best prospect. This tube is designed for r.f. purposes, and

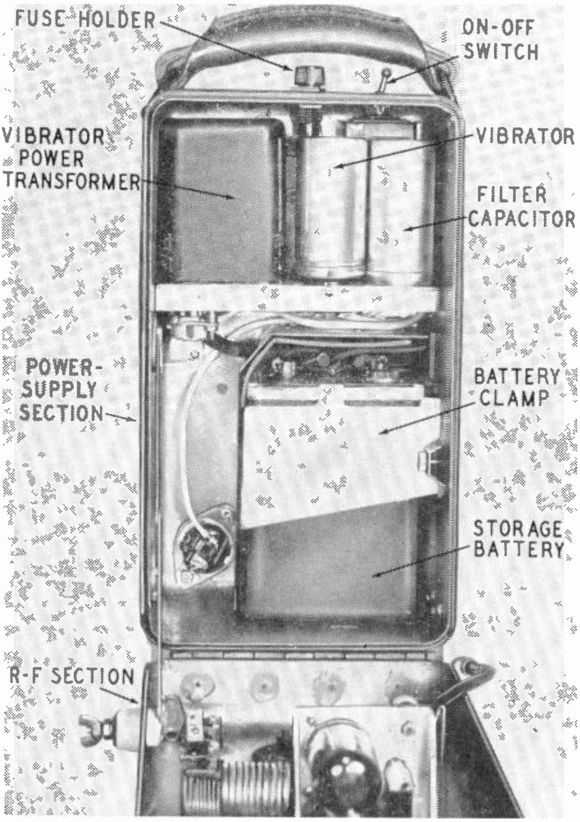


Fig. 709-b. Vibrator-power supply for the Citizen's transmitter. The battery, a 2-volt storage cell, is held in place by a clamp. The fuse holder is not used.

is considerably more rugged than the more or less standard radio-tubes, such as the 3A4 and 3A5. It is a loctal base type, and has a beam-power element arrangement, which means that it will not use as much screen-grid current as a 3A4. Though tests showed that a single 3D6 would take the full 5 watts input, this required higher plate voltage than the vibrator unit would supply. Hence, two of these tubes were connected in parallel, and in this way did a fine job. No parts of the unit are strained, and everything runs cool and safe. Aside from the use of two tubes in parallel, the r.f. circuit will be seen to be about the same as that shown for several other transmitters. The antenna is of the quarter-wave vertical type, and the coupling system includes an adjusting capacitor C2 (it was put on the antenna side of the coupling coil in this circuit merely for convenience in connections). The power supply is shown in Fig. 709-b.

The PE-157 includes all parts needed for the power supply of this transmiter. There are a lot of extra parts that aren't needed, so the first job is to disassemble the entire unit and take inventory. The circuit in Fig. 710 shows the parts that are used; those

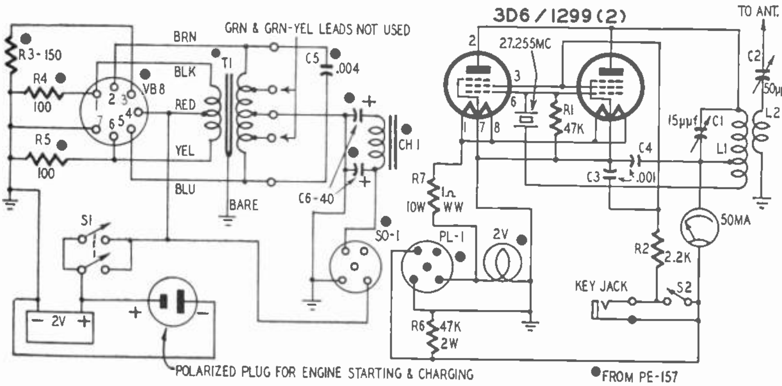


Fig. 710. Circuit diagram of the transmitter, popularly known as the Mac II. L1, 10 turns #14 wire. Tap at second turn. L2, 8 turns #20 insulated wire. See also Fig. 711-C. All variable capacitors receiving type.

from the PE-157 are dotted and are indicated by the same numbers that they have in the original power supply.

The case was stripped of paint and refinished after the necessary holes had been drilled. The meter was mounted in a hole cut in the area where a loudspeaker originally was placed: the hole was made by snipping out part of the perforated grill with a pair of diagonal cutting pliers. The mounting provisions for the storage cell were hacksawed from the original chassis and refastened in the same location in the case.

A small chassis of aluminum holds the entire power unit, but the transmitter r.f. parts are attached directly to the front panel, with the tube and crystal sockets held on an aluminum bracket.

When wiring, heavy connections should be used between the cell and the vibrator and power transformer T1. Since this is a 2-volt circuit, it doesn't take much resistance to give considerable voltage drop; any drop here is multiplied many times and will cut down your high voltage. The on-off switch S1 should be a heavy-duty style. A d.p.s.t job with two sides in parallel is required. No fuse should be used, as it will give too great a voltage drop. The high-current leads were made of No. 10 flexible wire in the outfit shown: the leads to the tube filaments may be of more normal size hookup wire, of course. Since the tubes require only 1.5 volts, it is necessary to use a series resistor R7, of about 1 ohm. In the outfit illustrated, the resistor is a 2-ohm, 10-watt unit of the slider type: it was adjusted to give just 1.5 volts on the filaments.

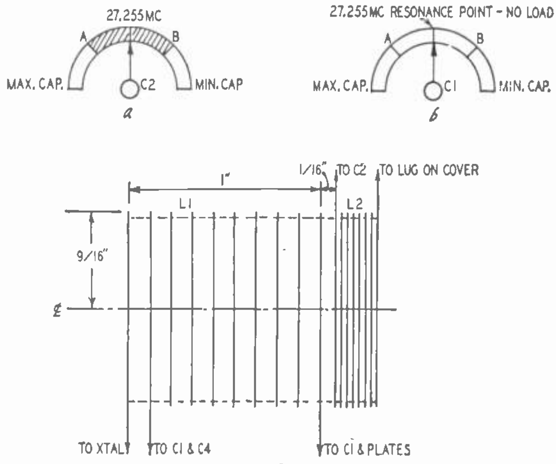


Fig. 711. Tuning procedure (a and b) and coil data (c). Proper loading may be had with C2 near either A or B; C1 will resonate near corresponding A or B.

Insulators for the 10-foot-long antenna (only the upper 9½ feet are active) are attached to the side of the cover. The cover is hinged at the bottom and may be opened for access to the works; a folding brace limits the outward movement of the cover.

Due to the rather poor regulation of this sort of power supply, the voltage goes up to about 230 volts when the key is open. When the key is closed, the plate voltage drops to 155 volts. This sudden drop gives rise to a very slight shift in frequency. The resultant note, as heard in a communications receiver, is not what a normal ham operator would be proud of, but this effect does not bother the average radio-control receiver a bit. The result would probably be serious if it were not for the fact that the crystal holds the transmitter on frequency.

Tune-up is the same as for any other crystal oscillator transmitter; the usual bulb load is needed. but in this case use a No. 44 or 46 bulb which will take up to about 1.75 watts of power. The bulb is simply attached from the upper antenna insulator to a lug on the cover of the case. With L2 about as shown in Fig. 711-c

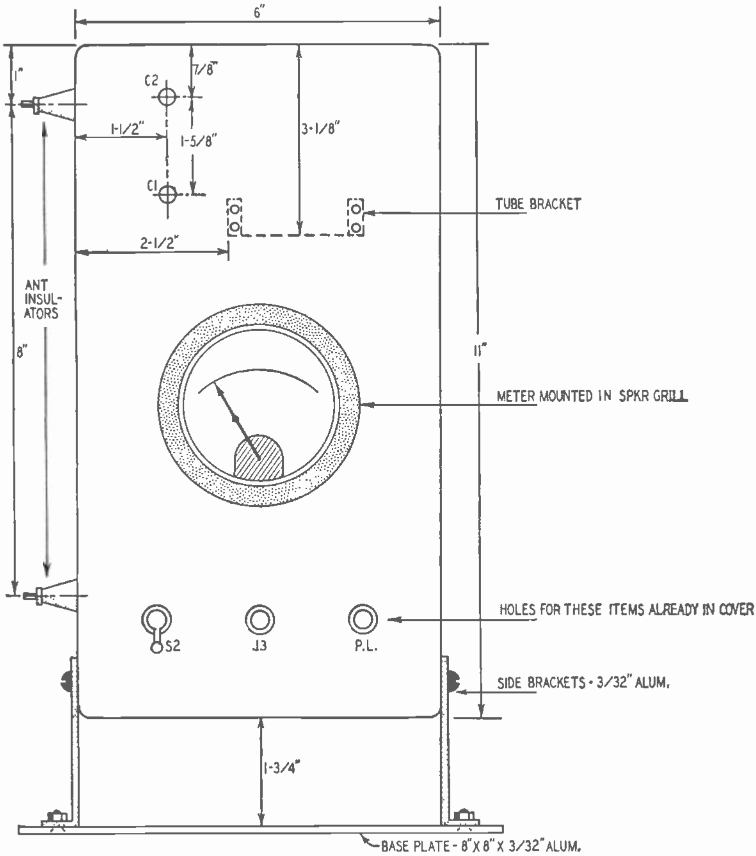


Fig. 712-a. Suggested front-cover layout for the transmitter whose circuit is shown in Fig. 710. In order to carry the unit around, mount a handle on top of the transmitter.

and with C2 near minimum, turn on the power and quickly rotate C1. The plate current should be about 35 ma with the circuit out of oscillation, and this will drop as resonance is reached. The set is usually run with a plate current of about 25 ma, but it may be raised to 28 ma or so for top output. If the current drops lower than 25 ma the coupling may be increased. However, try varying C2 before you do this. As seen in Fig. 711-a, there are two spots where maximum loading may be had. If you tune the output circuit to exactly 27.255 mc and the coupling is just the right amount, you will have only one spot of resonance on C1. However, overcoupling is usual practice so that there may be enough coupling for all conditions found in the field. Depending upon

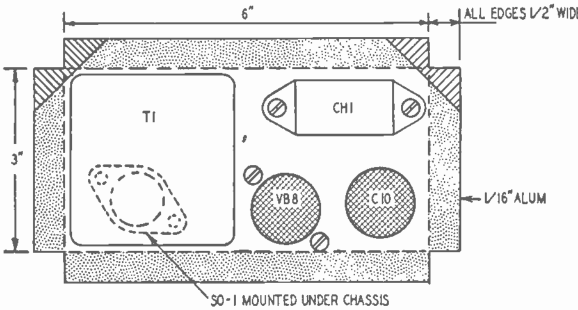


Fig. 712-b. Recommended chassis layout for the vibrator power supply. Bend edges down on dotted lines. Cut off shaded corners. Power supply mounted with 3-3/4" between upper surface and top of case.

whether C2 is higher or lower than the exact spot of 27.255, the plate capacitor C1 will be pulled away from this exact 27.255 spot also. This effect is particularly noticeable with an antenna load, but does no harm and does not reduce the power output to any significant extent. See Fig. 711-b.

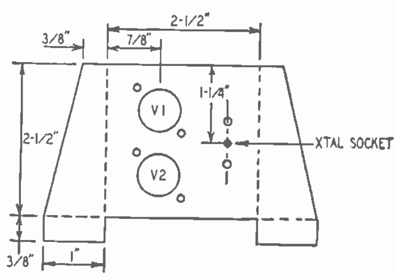


Fig. 712-c. Tube and crystal socket shelf. Bend up on all dotted lines. Cut holes to suit sockets used.

When using a bulb load, C2 will be near minimum capacitance, but it will have to be near mid-scale with an antenna. When correctly tuned, the entire series circuit of L2, C2, and antenna (and the capacitance of the case to ground) is tuned close to 27.255 mc. Construction details of L1 and L2 are shown in Fig. 711-c.

Use the front-cover layout and chassis details as shown in Figs. 712-a,-b,-c for case and chassis construction.

Most users of miniature internal-combustion engines use glow-plug ignition, and the storage cell may be used for heating these plugs. A regular 2-prong appliance power socket is fitted at the rear of the case, and clip leads may be attached to this for the glow plugs. The same socket makes a handy place to plug in a battery charger. The PE-157 unit has a double-section rectifier in it; if this is attached as shown in Fig. 713, to a 6.3-volt filament transformer having a 3-ampere rating, you will have a simple and effective charger. The cell is normally charged at 1- to 1.5-ampere rate. The transmitter takes around 5.5 amperes when in operation, so the cell will allow at least 3 hours use on a full charge. There is a set of 3 colored balls in the cell to show the condition of charge; the green one sinks when the cell is down to 75% of full charge. At 50%, the white one goes down, and the red sinks when down to 25% capacity.

It is quite practical to charge the 2-volt cell from a 6-volt car battery. This is often a useful method if the charge is found to be dropping from extended use while you are at the flying field. Just make up a lead to plug into the cigarette lighter on

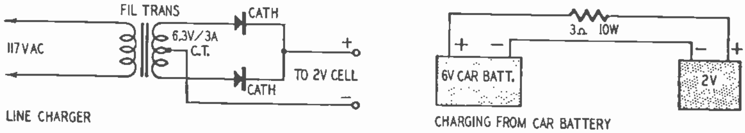


Fig. 713. Techniques for charging the 2-volt cell. The power supply at the left uses a magnesium-copper sulphide full-wave rectifier that was removed from a PE-157 unit.

the dash (regular plugs for this purpose may be had at auto-supply stores for less than a dollar) and use a series resistor of about 3 ohms, 10 watts. A polarized plug to fit into the transmitter will keep you from making the connection backward.

If the reader desires to use this transmitter with dry-battery power, it will be necessary to go up to 180 volts. The screen series resistor R2 shou'd then be raised to limit the plate current at full load to about 26 ma; start with a value of about 10,000 ohms for this and cut it down as needed.

Tone-modulated transmitter

More and more builders are turning to audio-tone operation, since it affords a simple way to get multichannel control from a single set of r.f. equipment. In general, tone work is not too satisfactory with the plain crystal-controlled oscillators which have been described, for the simple reason that they cannot be modulated to a high enough percentage; tone operation, especially when tuned reeds are used, requires full 100% modulation. This is difficult to get with a modulated crystal oscillator. It is therefore preferable to go into some sort of oscillator-amplifier transmitter. The single 3A5 outfit shown in Fig. 703 would be a good basis for this if you wish to work on 50 mc, or the circuit in Fig. 714 may be used for 27 mc. The latter covers a complete modulated transmitter that has been used successfully to operate the receiver shown in Fig. 509. Only two tones are generated

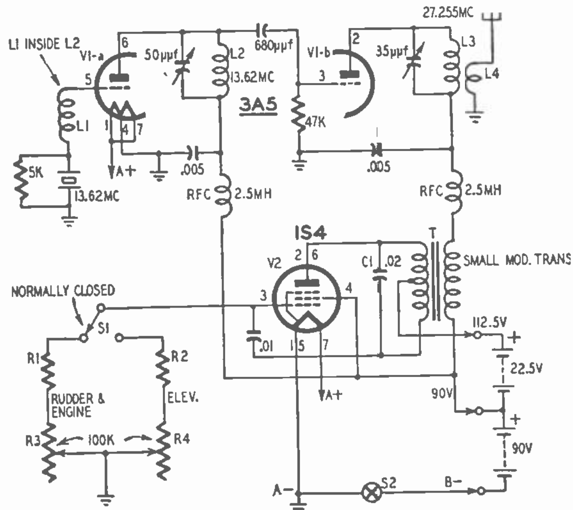


Fig. 714. This transmitter is for use with a reed receiver. The unit modulates with two different tones, depending upon the position of S1. A third audio tone can be easily added. The tones can be varied by adjusting the setting of potentiometers R3 and R4. L1, 20 turns of #22 enamelled wire on form 3/8" o.d.; L2, 24 turns, L3, 10 turns, L4, 4 turns, #22 enamelled wire on 1/2" dia. form. For L2, L3, and L4 you can use B & W Miniductors, #3004. All variable capacitors receiving type.

by this equipment, but any number could be added by simple duplication of the switching system and control rheostats attached to the grid of V2.

The r.f. section is something like that of Fig. 703, but here an overtone or harmonic type crystal of 13.62 mc is employed, and the oscillator produces 13.62 mc in its plate circuit. The second section of the 3A5 then doubles this to 27.255. Tuned-reed receivers do not require a very strong signal for good operation at reasonable distances, so the doubler section of the 3A5 is supplied with only 90 volts. Another 22½-volt B battery is added to this for the modulator plate supply.

The transformer T must have two high-impedance windings, but the smallest modulation transformer you can buy is still much larger than is needed for this outfit. Experiment might turn up something you can use, such as a small class-B driver transformer, that will be compact and cost less. This unit acts as both modulation transformer and oscillator inductance for V2. Depending upon the type you employ, it may be necessary to pick a value other than the 0.02 µf shown at C1.

The control system consists of the two switches S1 and S2. Both are Microswitches, and one is held in each hand. With S1 in its normal position (not depressed) as shown in Fig. 714, S2 is given one push for right turn, two for left, and three for engine-speed change. At the plane, these pulses are translated into action by a compound escapement, the third pulse closing a pair of contacts to step the engine-speed escapement one notch. Another compound escapement is attached to the elevator; if S1 is depressed, then pulses on S2 will operate the elevator, with the rudder and engine remaining as they were. Resistors R1 and R2 are chosen so that the proper tones to work the reeds in the receiver will be had with R3 and R4 near the center of their ranges. The electrical contacts on the elevator compound escapement could be used for some purpose such as working flaps or dropping a bomb.

Chapter 8

Keying the Transmitter

FOR years the accepted means of keying has been a simple push-button at the end of the key leads to the transmitter. Some operators favor a Microswitch, as they find the snap action which can be felt as it operates gives assurance that the command has been transmitted to the model. With the advent of higher-speed planes, more complex maneuvers, and multicontrols of one sort or another, various types of automatic keyers have been developed. Such keyers are not really new. Experimenters used mechanical selector switches long before the war. However, they did not attain wide use at that time.

Rotary selector

The simplest style of semiautomatic selector you can make is just a rotary switch. If one is chosen that will allow 360 degrees of rotation, and the contacts are arranged correctly, the escapement may be made to turn in sequence as you advance the switch. For this use, the switch knob must always be turned in the same direction; some users have fitted a ratchet so that the wheel cannot be turned backward, which would get you out of step with the escapement. Choose a switch that has at least four contacts at 90 degree intervals; any extra contacts may be ignored. With a two-arm escapement, the contacts could be arranged as in Fig. 801. There are only two live contacts in this case; from the straight-up neutral position, if the switch were stepped 90 degrees to the left, you could have left turn, while right would be signaled, if the switch arm were turned 270 degrees from the straight-up position. The arm should always be returned to the straight-up position after either a right or left turn. While right, left, and the single neutral could be marked on the face of a small box holding the switch, many users prefer to make plain lines at all four of the 90 degree positions. Then, if the plane escapement is found to have gone out of step with the switch for any reason, the box is just turned in the hand till the usual rotation (say, 90 degrees for left and 270 degrees for right) positions are regained.

The same sort of switch box may be rigged up for any type of escapement, whether it be two, three, four, or any other number of arms. Such a switch is of little use with the compound escapement, of course, since this unit has no sequence, and a simple push-button will do just as well.

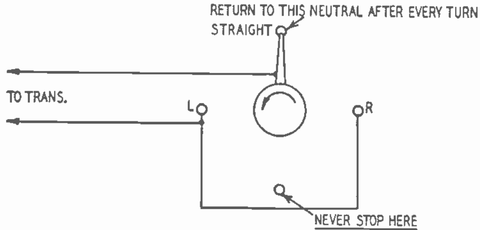


Fig. 801. Rotary switch helps keep escapement pulses in order. Rotate only in direction of arrow on knob.

Beep box

The most widely used type of automatic keyer is known as a beep box, and most of these in use today are driven by small battery motors. If it has the proper voltage rating, the motor may be driven by the same battery that is used for the filaments of the transmitter tube. The motor drives a drum through a simple form of clutch; the unit shown in Fig. 802 uses an HO train worm and gear set of about 32 to 1 ratio. The clutch is a disc cut from an old leather glove. A small spring holds the gear in contact with the end of the bakelite drum. When the latter is stopped (by the stop arm) by engagement of any of the stop screws on the drum, the clutch allows the worm gear to continue turning, and the motor is not stalled. Since there are four stop screws, the drum may be halted in any of four positions. These positions are the same whether the unit is used for two- or four-arm escapements. The only difference in the setup for these two types is in the placing of the cam screws (holes 1–6) that actuate the contact points. Thus by just changing the setting of these screws, the beep box may be used for either design of escapement.

The unit shown was built up in a small commercial radio box measuring 4 x 2$\frac{1}{8}$ x 1$\frac{5}{8}$ inches, and all parts are put in one half of the box; the other half just goes over the top to protect the mechanism and keep out dirt.

No precision work is required, though the smoother you can get the drum to turn, the less trouble you will have in setting the stop screws and contact-lifting screws. Most of the mating parts were made so that they would have some leeway in mounting; it was thus easy to bring all parts into adjustment and attain smooth operation.

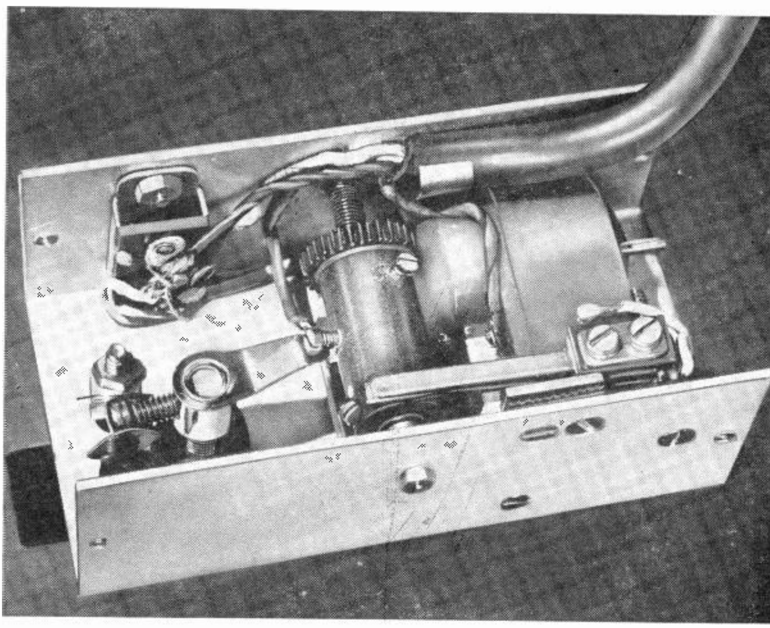


Fig. 802. This beep box utilizes a small motor geared to a drum having stop pins.

A look at the exploded view, Figure 803, will show that the heart of the mechanism is the drum: this revolves on a steel shaft, which is threaded at each end so it may be held in the case with a pair of 2-56 nuts. The groove in the shaft and the C washer make it possible to get the shaft into place. With the shaft in position, the right-hand nut clamps the C washer against the side of the case. The nut is then turned up against the other side of the case to clamp the shaft tight.

The parts that go on the shaft must be put in place on the shaft as it is pushed through the $\frac{1}{8}$ inch hole in the case. The

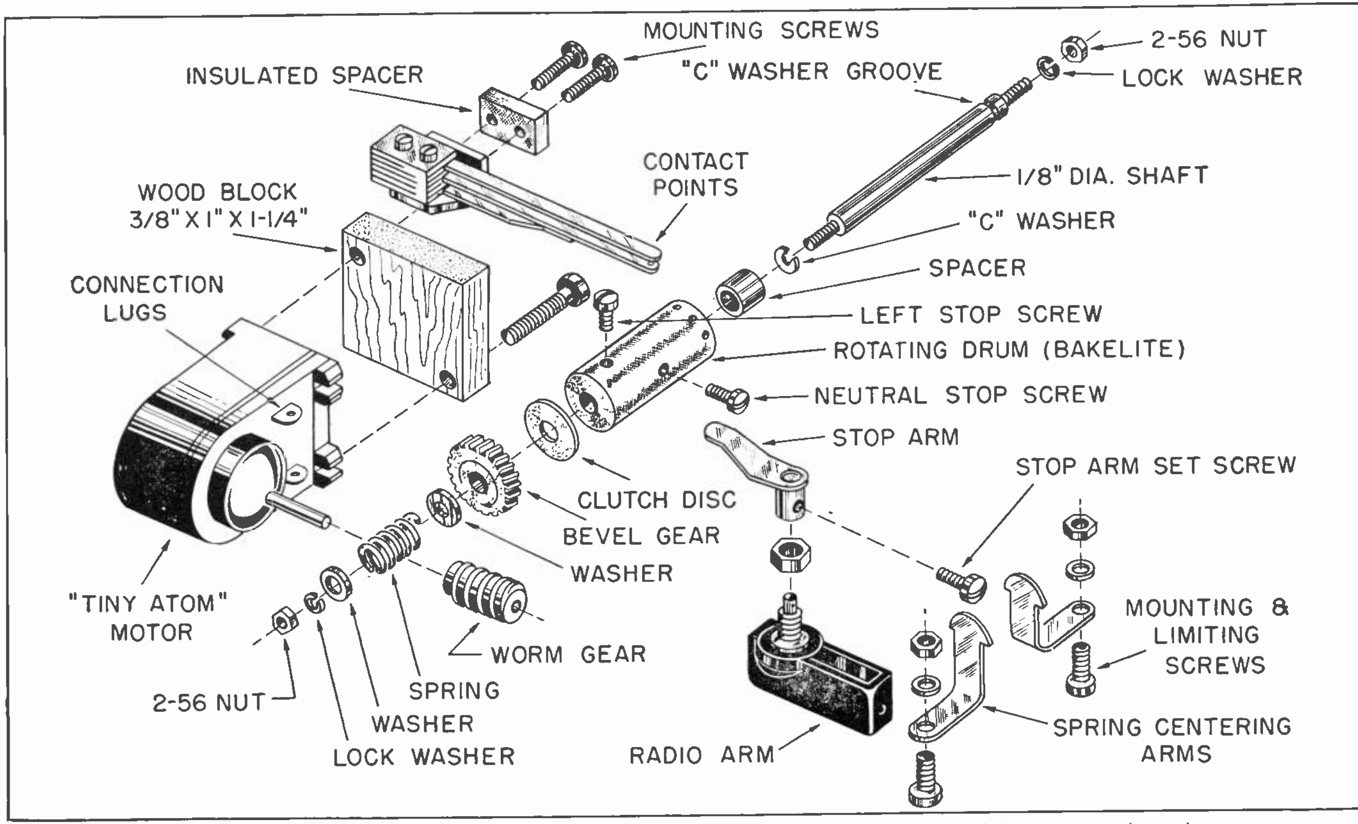


Fig. 803. Exploded view showing parts and assembly of beep box. The drum is operated by a motor through a worm gear.

only adjustment that is at all critical is that of spring tension on the clutch; this must be great enough to drive the drum reliably at all times, but not sufficient to slow the motor greatly or to stall it when the drum is not turning.

The stop screws are 2-56 filister head type, and are installed

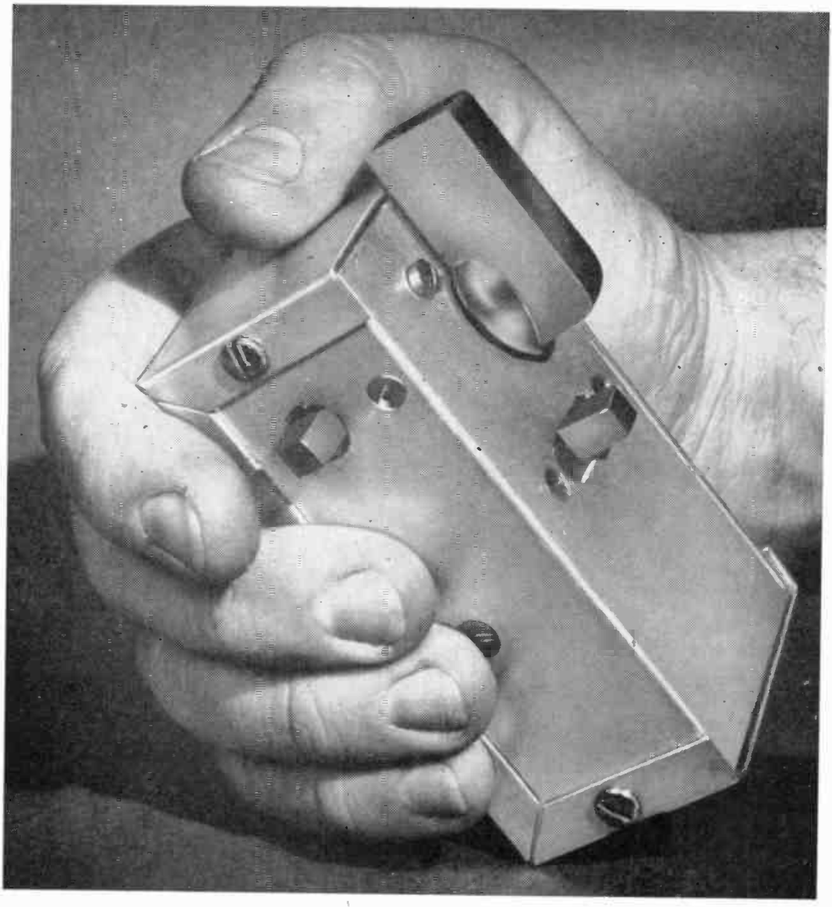


Fig. 804. The beep box is compact, easy to handle, fits snugly into palm of hand.

in tapped holes in the drum. A drop of model cement in each hole will keep the screw in place. 2-56 tapped holes are also used for the cam screws, but since these may have to be changed for different escapements, they are not put in with cement, but just turned up tight. An outside view is shown in Fig. 804, above.

You can get all the parts of the stopping mechanism, including the arm, spring-centering arms, control knob, etc., from old radio rheostats. The end of the stop arm must be wide enough so that when it is moved from the center (neutral) position to either side, the right- and left-turn stop screws are engaged reliably and cannot slip past.

The contacts, taken from a discarded radio jack, are normally open, and are closed every time a cam screw passes beneath them. For a two-arm escapement, this is twice for every revolution of the drum; furthermore, the cam screws must hold the contacts closed when the drum is in either turn position. For a four-arm escapement, there are four contact closures per revolution, and the cam screws do *not* hold the contacts closed in the turn positions. See Fig. 805.

In the end view of the drum, Fig. 806, holes numbered 2 and 5 are used for two-arm escapements, and those numbered 1, 3 4 and 6 for the four-arm jobs. Holes 7, 8, 9, and 10 are for the stop screws. Fig. 806 also shows stop arm detail.

A little thought will show how the device works. The motor turns continuously, of course, but the drum is held in neutral by one of the neutral stop screws (8 or 10). When the lever is swung to one side, the drum turns till either of the outer stop screws engage, then holds there till the lever is released upon which it rotates again to the other stop screw. If, in your particular installation, left turn calls for one pulse and right turn for two, the beep box will give that single pulse in a quarter turn from neutral—and will hold there with the contacts closed (assuming you are using a two-arm escapement) till you release the lever. The drum then turns to the other neutral stop. In other words, it has turned a total of 180 degrees so far. However, if you want right turn, the drum is allowed to turn 270 degrees before it hits the right stop screw; on the way around, the contacts close once and open again. This steps the escapement through the unwanted left position, and it is then ready to operate and hold in right turn. Release from this position allows a further rotation of 90 degrees to the stop position. All this sounds rather complex, but it is really very simple. With reasonable care in construction, the beep box simply never misses; any wrong positions you might get are the fault of other parts of the control system, such as an escapement that skips.

It is virtually impossible to fool the beep box; you can swing the lever wildly back and forth as much as you want. When you stop, the escapement will be found right where it should be, ready to obey your commands!

The clutch disc that was found best came from a worn-out pigskin glove. Felt, from an old hat, and cork also work fairly well.

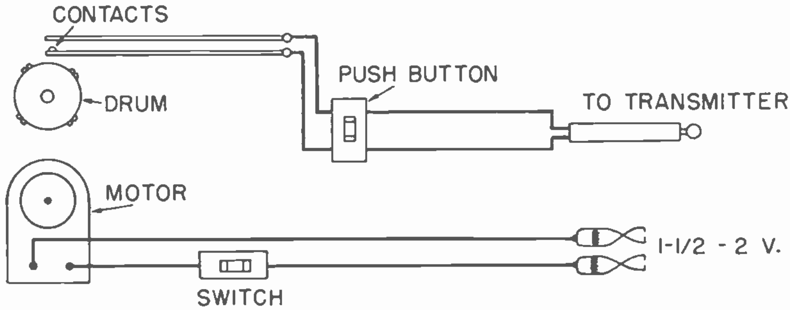


Fig. 805. Top view shows how stop screws on drum push contact points. Lower view illustrates how motor is connected to low-voltage source through a switch.

The gear set to use, from the point of suitability, depends upon your motor; the one employed here turned about 4,500 r.p.m. on

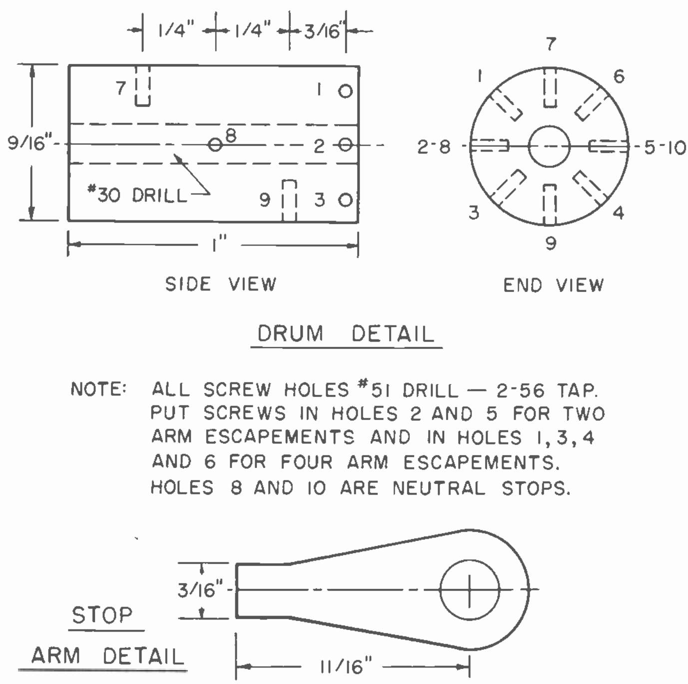


Fig. 806. Physical details of the drum used in the beep box.

the transmitter A battery, with no load, and a 32-1 worm set was chosen. With the drum held at a stop position, the motor slows down to about 3,500 r.p.m. so the average drum speed is about 125 r.p.m. This gives very fast escapement action; if the motor is operated from a 2-volt storage cell, the drum speed goes up to about 200 r.p.m., but even at this speed the escapement follows perfectly. This is probably because the beep box keys the transmitter much more accurately and cleanly than you could do it by hand at such a speed. The worm and gear are standard HO gauge model train parts.

A push-button is fitted to the case to get the escapement in step with the box, prior to a flight. The button can also be used to restore synchronization, should the escapement skip, or should stray signals cause the equipment to get out of step.

Relay pulse sender

The beep box may be used with a compound escapement by alteration of the stop and contact screws. However, some fliers who

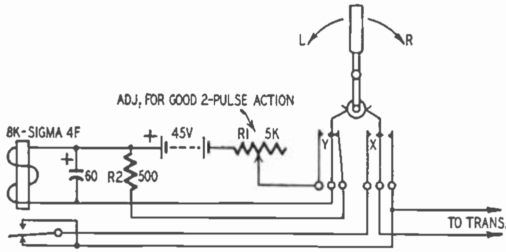


Fig. 807. Relay pulse sender for the compound escapement. Adjust the potentiometer, R1, until you get the desired pulse action. Lever to L gives one pulse and hold for left turn; lever to R gives two pulses and hold for right turn; lever to R, then to L, gives three pulses for motor escapement actuation. Points X should close before points Y in the R position.

prefer making electrical rather than mechanical gadgets are using a system as shown in Fig. 807. It will be seen that a single relay is employed, while the actual control is a three-position lever switch which will give a single pulse (and hold) when moved one way, and two pulses (and hold) the other. Rheostat R1 is adjusted to make the second pulse come at the proper interval so that the escapement catches correctly on the second arm. If motor control is desired—which calls for three pulses—the control lever is pushed rapidly to right and then left; this transmits the required triple signal. The relay should be adjusted with large spacing between the contact points and with weak spring tension.

Pulser for proportional control

For true proportional control, it is necessary to have some means for changing the contact settings, so that pulses from long to short may be transmitted. A box that does this is shown in Fig. 808; this one has been used regularly with the transmitter of Fig. 705, and so is fitted with a motor that will give the desired speed on 6 volts. The motor is actually a surplus item intended for 27-volt operation, but it is fitted with a governor which holds the speed constant at any input voltage from about 10 volts and more. It runs amply fast at 6 volts for the purpose intended; in fact a slider type resistor is in the control box to slow it down even more. Input voltage is normally about 4½ volts, and due to the built-in gears this means a cam speed of around 350 r.p.m.

A simple off-center disc cam was used with this unit for some

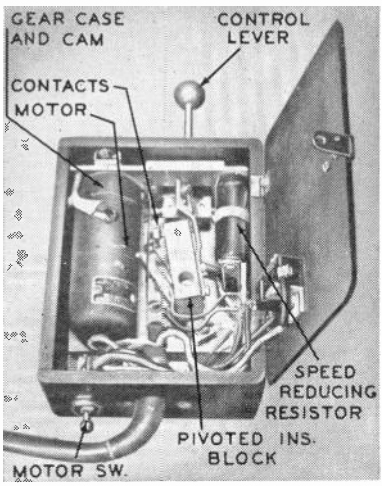


Fig. 808. Complex proportional pulser has stick control.

time, and while it gave fair results, the resultant rudder action was quite abrupt on one side, though action the other way was very smooth and gradual. This was found to be due to the shape of the cam. A later one of heart shape was made that proved much better. The latter is what is called a "constant-speed" cam, and is of the same shape as you will find on the bobbin-winding mechanism of a sewing machine. It gives a more steady speed to the contact over the entire 360 degrees of rotation—something that could not be had with the semicircular cam used at first.

The pulser construction details are shown in Fig. 809-a. The

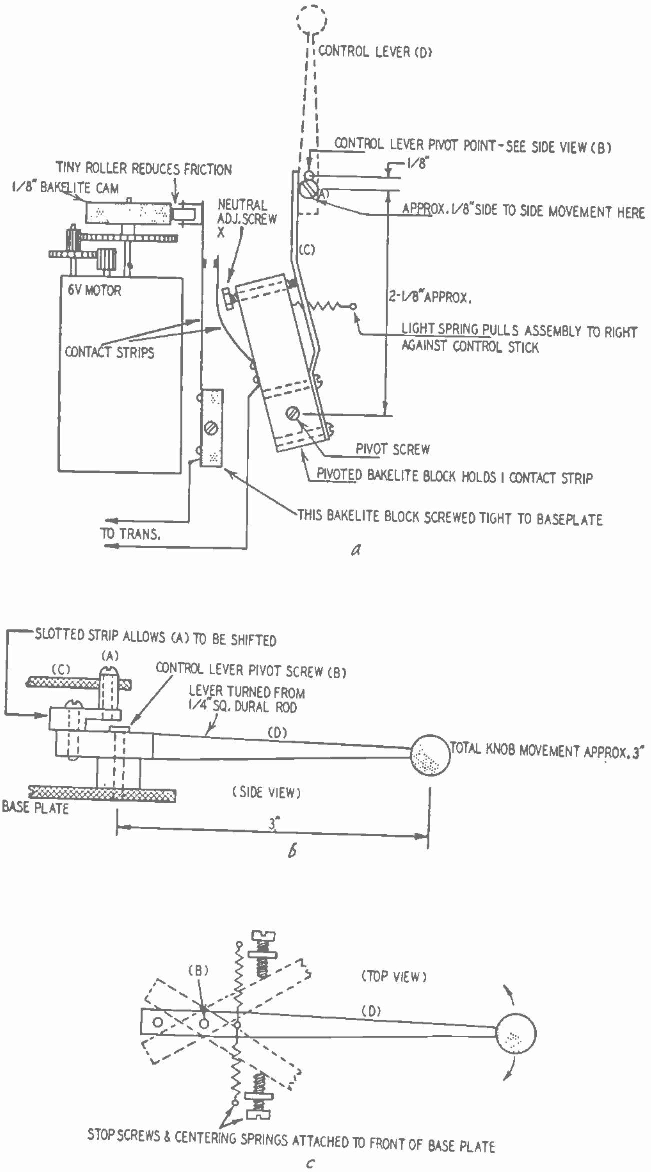
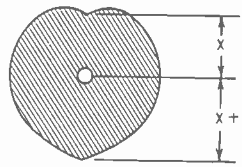


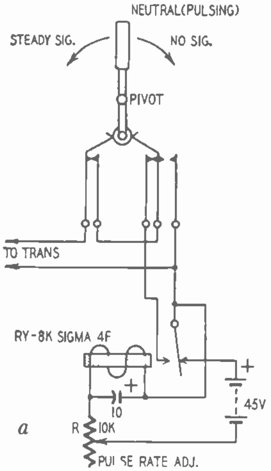
Fig. 809-a. Complete mechanism (a), side view (b), and top view (c) of the control lever. The stops for the lever should be set so that the total movement of the control knob is approximately three inches, or less.

contacts are mounted on a block of bakelite that may be moved back and forth at will by motion of the control lever. The lever itself has adjustable stops at each side, and the knob may be moved a total distance of about 2¾ inches, which shifts the contacts enough so that in one extreme they remain closed all the time, while at the other extreme they are open. At dead center, the contacts should theoretically be open and closed exactly half the time. In use it doesn't work out quite this way,

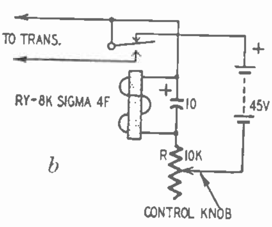
Fig. 809-b. In the illustration at the right we have the physical dimensions of the constant lift cam. The cam should be made of 1/8-inch thick bakelite The cam is operated by a geared-down 6-volt motor and is used to open and close the contact strips.



due to various lags in the entire radio system, particularly in the receiver. Therefore, it is usual to adjust the center or straight-ahead setting while the plane is in flight, by varying the neutral adjustment screw X, until straight flight is had. Once set, this adjustment seldom needs change. Although the neutral does tend to creep a bit one way or the other, in actual use this is never noticed.



a



b

Fig. 810-a, -b. Here we have a simple relay proportional pulser. In the illustration (a) a three-position lever switch is used while knob control is used in the schematic at the right (b).

since flight is accomplished by watching what the *plane* does, not by where the control lever may be. The two centering springs on the stick do give a feeling of true airplane control however, and when the plane has at times been put into some wild maneuver, it is often allowed to recover by itself, simply by permitting the stick to snap back to center.

Needless to say, the better the unit is constructed the smoother it will operate, though there is no need to go into precision workmanship on it. See Fig. 809-b for details of the cam.

At the pulse rate mentioned, the rudder is seen to just wiggle a bit in the center of its travel. The system is used with the receiver shown in Fig. 503, a type that will stand fairly high pulse rates.

Simple relay proportional pulser

For those who desire a simpler type of pulser, the circuit shown in Fig. 810-a is just the thing. This is rigged up, as shown here, to be used with the same sort of control system that the motor-driven job of Fig. 818 (and Fig. 202) could handle. The three-position lever switch works the same in both cases. However, if the switch is eliminated as in Fig. 810-b, and a control knob fitted to the variable resistor R, you will be able to control the length of the pulses much as you can with the mechanical pulser of Fig. 808. Actually, this control varies both the speed and length of the pulses, but in most cases this will do no harm.

Twin-relay pulser

If for a certain control system you want a unit that has independent pulse speed and pulse-length controls, try the system

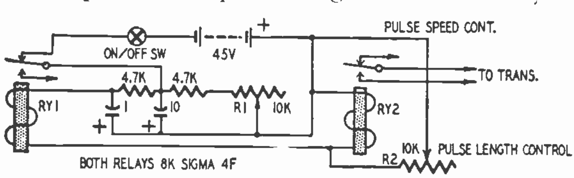


Fig. 811. The twin-relay pulser is more satisfactory for some uses.

shown in Fig. 811. Here there are two relays of the same type, RY1, being the *timing* relay, which works continuously at the same speed (unless the setting of R1 is changed), while RY2 is the *keying* relay that actually operates the transmitter. Though there is a slight change in pulse rate as the pulse length is varied by R2, it is far less than in the circuit of Fig. 810-b. Since some control systems require that the pulse speed be changed abruptly —for example, to operate a motor-control escapement—a switch may be arranged to shunt R1 with a fixed resistor. This will give instantaneous pulse-speed change.

Multivibrator pulser

Still another method to get the required proportional control pulses is shown in Fig. 812. This is a true electronic system. The two sections of the tube function as a multivibrator oscillator. The control lever is attached to the shaft of R1. While two relays are required for this circuit, they may be cheap units of most any sort, as long as the resistance is as shown. Note that one

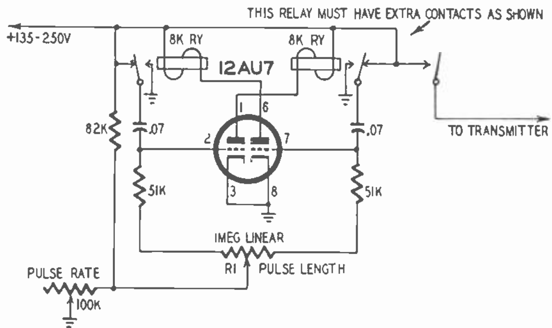


Fig. 812. Multivibrator-type pulser. Control knob or lever can be used to operate R1.

must have extra contacts to control the transmitter; the circuit will not work well if the transmitter is simply connected to the s.p.d.t. contacts. A linear potentiometer must be used in order to have the control action the same on both sides of the center or straight-ahead setting.

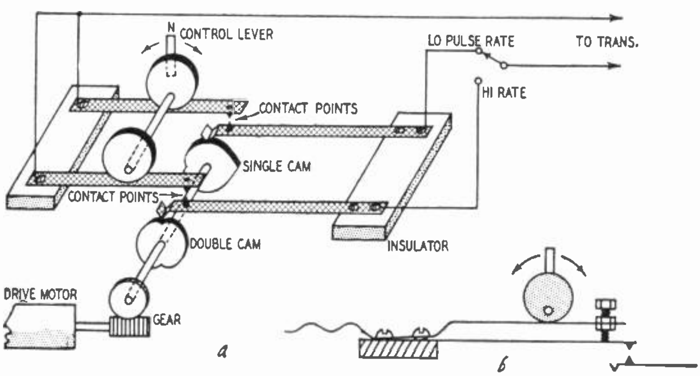


Fig. 813. Mechanical system for producing independent pulse rates. The use of two cams allows instant selection of two pulse rates (a). A fine adjustment for neutral can be added to the left-hand contacts as shown in lower right (b).

Independent pulse rate

It is sometimes desirable to have a pulser that will supply two different pulse rates, as needed, yet be able to adjust the neutral position at each speed independently of the other. Many proportional control systems will give almost as much movement of the rudder with a change in pulse rate as they will with changing length—at least in some rudder positions. It is probably easiest to make such a double-speed system of the mechanical type since it is so easy to adjust each set of points exactly as desired. In practice, there are two cams required, one of the type shown for the unit in Fig. 809, and another with two or even three lobes on the cam. There will be two sets of points, of course, and each set should have a screw to set the neutral position when the stick is centered. A s.p.d.t. switch then shifts the transmitter from one set of points to the other as needed, the change giving no adverse rudder movement as will be the case if the motor of a single-contact pulser is speeded up or slowed down. The general idea is shown in Fig. 813. All sorts of mechanical arrangements may be worked out to accomplish this result, of course; the one shown is just one of many ways.

Knupple pulser

A very simple type of pulser is shown diagramatically in Fig. 814. This design was said to have been worked out by the Germans during the last war and used for proportional rudder con-

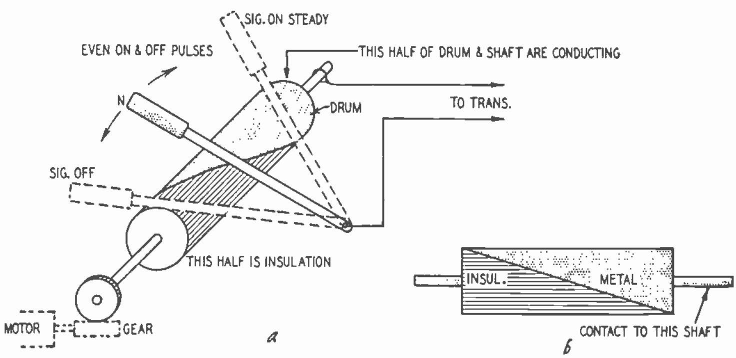


Fig. 814. The Knupple pulser. Essentially the pulser is a drum, half of which is conductive, the other half insulated.

trol on glide bombs. The drum is made up of sections of insulation and conducting material, with the junction between them splitting the drum diagonally. If the drum is carefully made, the pulses will be absolutely uniform. Aside from the drum itself, the rest of the mechanism is much simpler than that of the pulser shown in Fig. 809. Of course, for best results both the metal portion of the drum and the section of the arm that makes contact with it should be of silver, or at least heavily-plated. However, plain brass will do if the surfaces are cleaned occasionally; some substance such as Lubriplate should be applied to the surfaces.

This gadget is called a "Knupple" by the originators. The drum-speed considerations are the same as for the pulser of Fig. 805, and 200 r.p.m. could be considered average. Some receivers will not handle this speed, while if you go a great deal slower the rudder movement may become slow enough to allow the ship to wobble in flight, as it responds partially to each rudder movement.

Practical pulse rates

In general gas-tube receivers have been found reluctant to operate with high pulse rates. Hard-tube receivers are the best for fast pulsing, but even some of these cannot be pulsed very

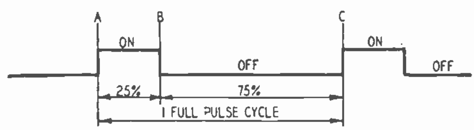


Fig. 815. Loss of pulse range at high rates.

rapidly. The receiver in Fig. 503, for example, has been used regularly at a rate of about 400 p.p.m. and at this speed, the rudder just floats—that is, it doesn't flap back and forth between the two stops. Such operation is much smoother than if the rate were lower. The faster the pulse rate, the more of the total range of pulsing you lose; with the receiver circuit of Fig. 503, it was found that at a pulse rate of 370 p.p.m. the receiver relay would not operate unless the pulses were on at least 25% of the time. To make this clear, refer to Fig. 815. One pulse cycle should be considered the total time between A and C; this includes an on-signal period (A-B) and the off period (B-C) until the transmitter is turned on again. Thus if the pulses were as shown in Fig. 815, the receiver would not respond at all. This has not been found any great disadvantage in actual use. However, some of the more complex pulse-control systems require full-on and full-off signal for certain auxiliary operations such as motor and elevator control. In cases of this sort, the fact that you start out with only 75% of the total pulse range might become troublesome. On the same receiver, raising the pulse rate to 620 p.p.m. increased the useless portion of the total pulse length to about 40%, while lowering the rate to 225 p.p.m. cut this unusable area to about 18%. When the grid leak was cut to only 10 megohms, the receiver relay would follow the pulses down to about 15% on-signal, at a pulse speed of 370. With this lower grid leak, of course, it is not possible to get as large a plate current change in V3, from no-signal to full signal as may be had with the specified leak (A receiver of the type in Fig. 407 is capable of extremely high-speed pulse operation).

Other elements in the system might also contribute to this apparent loss of usable pulse length. If the transmitter is relay-controlled, as is the one in Fig. 707, you may get an appreciable lag in operation at high rates. Also, some crystals and certain oscillator circuits are rather sluggish in action and can contribute to delays in fast pulse action. In most cases this will do no real harm, but it is just as well to understand these limitations if you intend to work with pulse systems.

Key lead chokes

Though it is not exactly involved in the subject of keying the transmitter, the use of r.f. chokes in the key leads might be

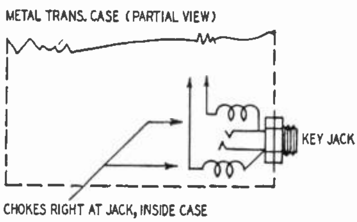


Fig. 816. The use of radio-frequency chokes as shown in the illustration at the left will keep the signal inside the metal case, minimizing the possibility of throwing the transmitter out of oscillation.

considered here. The reason these are needed is simply that the key leads act as part of the antenna system (when any sort of simple antenna such as the popular quarter-wave type is used)

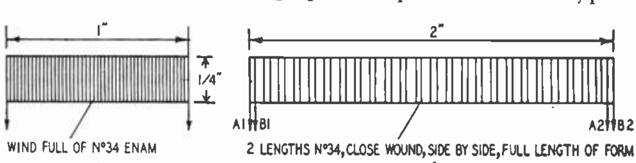


Fig. 817. To keep r.f. out of the pulser you can use individual chokes of the type shown at the left (a) or you can wind two chokes on one form as shown at the right (b).

and moving the lead around—or even holding it in your hand changes the loading, and in turn varies the transmitter output. Normally this does no harm, but if the transmitter is tuned too near the peak of output, that is, just below the point where the crystal drops suddenly out of oscillation, movement of the key lead is apt to put the transmitter off the air completely, with possible disastrous results to the model under control.

Fortunately the remedy is very simple, and has been used in a few commercial and homebuilt outfits. It should be more widely used, and in fact should be applied to every transmitter which is operated with a quarter-wave antenna. The solution is shown in Fig. 816, and consists of installing r.f. chokes in each of the key leads. Note that if a hand-held pulse box is used, chokes must be in the wires that go to the motor too—in other words, everything in the keying system outside of the transmitter case must be isolated r.f.-wise. Suitable chokes are shown in Fig. 817-a. These might be satisfactory to carry motor current unless the motor is a very greedy one, in which case larger wire will be necessary. The chokes may be individual ones for each lead, or you can wind them all together on one form, as in Fig. 817-b.

Pulser for semiproportional control

For semiproportional control, a simple pulser is needed as described in Chapter 2, Fig. 202. This takes the form of a motor-driven cam and a single pair of contacts. One that has proven

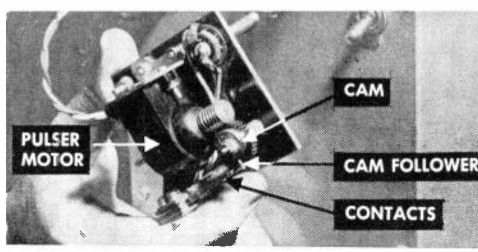


Fig. 818. Photo of pulser for semiproportional control. Pulser motor speed is stepped down through a 30-1 gear ratio.

satisfactory is shown in Fig. 818. It utilizes the same sort of motor and HO worm and gear set that were used in the beep box. Here, though, the cam and contacts are in continuous operation. The lever switch has three positions, and is in neutral when it is centered. The cam is just a disc of brass filed off on one side so that the contacts are held shut approximately half of each revolution. The unit shown was made to plug right into the key jack of a transmitter (the plug is attached to the bakelite base) and another lead connects to a battery to run the motor. The lever switch is the actual control unit; it is normally used fitted inside a small shield can, upon which are marked the rudder movement positions of left, neutral, and right. The gears are 30-1, and speed of the cam is about 150 r.p.m.

Chapter 9

Installation of Parts

CONTRARY to general belief, there is more to putting the various components of a radio-control system into a model than just stowing them in the most convenient spots. There are many factors to consider, depending upon what type of model we have, how it is powered, what sort of receiver and actuator is to be employed, and so on. Because they have limited space and because of the necessity for watching weight distribution, most of our remarks on location of parts will be directed to model airplanes.

Linkages

Let's start with the gadget that moves the rudder; since this is an item of moderate weight it may be put in the most con-

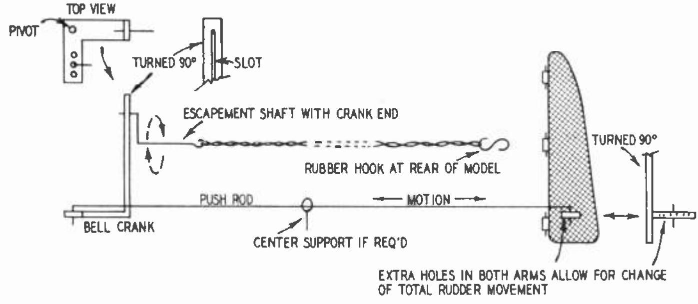


Fig. 901. There are two techniques for getting rudder motion—push rod and torque rod. Illustration above shows push-rod method.

venient spot, considering that there has to be a link to the rudder itself, and wires running to the receiver and actuator battery. Let's say further that an escapement is to be used to move the rudder. This means we must have space to string out the rather lengthy rubber that turns it. If the escapement is located at the rear wall of the cabin, we will need a rod of some sort back to the rudder. There are two main methods of rudder-moving—by push-rod and by torque-rod. These are shown in Figs. 901 and 902. If a torque-rod is employed, and is made of a length of music wire, there is often so much twist in the wire that the rudder will not turn sufficiently when the plane is in flight, even though the escapement has plenty of power to move it. The wire just winds up a bit, but the slip-stream of air keeps the rudder from turning as much as desired. Some builders over-

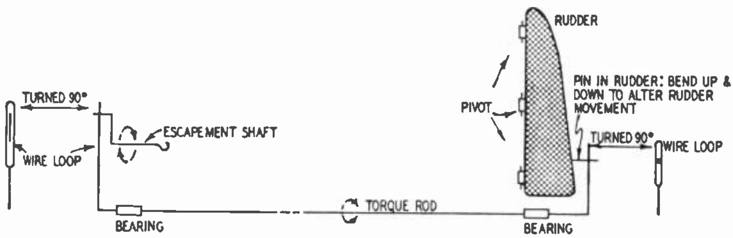


Fig. 902. The torque-rod method for getting rudder motion.

come this by making the main portion of the torque-rod from square balsa, with wire ends bound on to fit in the two end bearings. See Fig. 903.

If a push-rod is utilized, it is often necessary to put at least one extra support between the two end supports, or the wire may tend to bow when the rudder is moved in the direction which puts the push-rod in compression. The center bearing may be very loose, and in fact it should be, so that it adds very little to the over-all friction of the system.

In order to use an escapement with a push-rod it is necessary to start the linkage with a bell-crank, since the escapement has to be mounted so that the rubber band may be run the length of the fuselage. When this arrangement is in use you must take care to have every moving part as free of friction as possible, since the motive power of the escapement (usually a single loop of 1/8-inch flat rubber) is not very potent. There is far less chance of excessive friction in the torque-rod method of rudder drive.

Proportional actuators are linked to rudders or other control surfaces in the same manner as escapements, but here there is more leeway in mounting and placement, since there is no need to consider the positioning of a rubber band. Both actuators and escapements have been mounted in the cabin of the plane and in the tail section, right adjacent to the rudder. In the latter case, the effect of the lumped weight so far from the center of gravity must be considered, of course.

The rear mounting does simplify the linkage problems. In this case the rubber motor terminates in the cabin and is reached

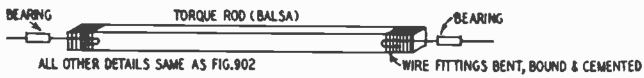


Fig. 903. A wooden torque rod is preferred.

through one of the hatches. If the escapement is forward. the rear end of the rubber may be fastened to a plug that fits into the side of the fuselage. When the rubber is to be wound, the whole plug is pulled out and the loop of wire (the rearmost end of the rubber hook) is attached to the winder. Incidentally, it is very wise to unwind the escapement rubber after every flying session, rather than to leave it wound tightly till the model is taken out again. Also, a bit of lubrication on the rubber will preserve it and allow you to put in more turns. Just rub in a little glycerin thoroughly, then wipe off the excess. When winding, stretch the rubber out to about twice its normal length. The

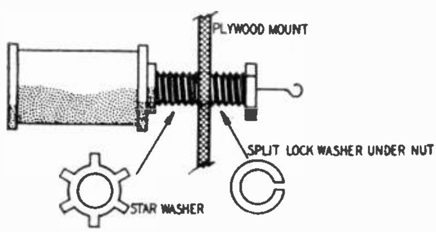


Fig. 904. Single-hole mount escapement must not turn.

rubber loop should be about a quarter again as long as the length between the two hooks that hold it; what we want here is not tension but torque.

Escapements, or any other form of actuator should be firmly mounted on a strip of plywood. Some escapements are so constructed that if they are screwed up tight against some rather yielding backing—such as balsa wood—they will be pulled out of shape enough to render them inoperative. Escapements that use only a single hole for mounting should have a star-washer between them and the mounting surface, and a spring type washer on the other side of the mount, under the nut, as in Fig. 904.

Batteries

Batteries, since they are a concentrated weight, should be located with great care. It is best to place them against the rear face of a sturdy bulkhead, to prevent them from flying forward in case of a crash or hard landing. In any case, they must be

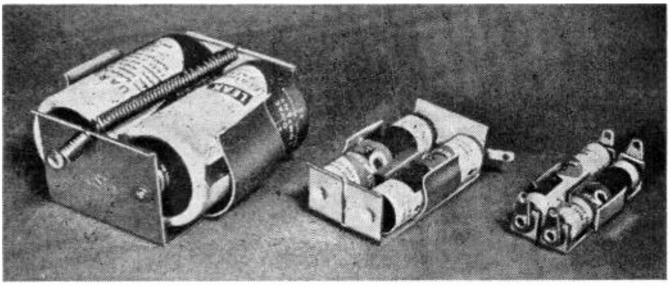


Fig. 905-a. Commercial battery cases come in many sizes and shapes.

fastened down most securely. The damage done by a flying battery must be seen to be believed! The universally-used flash-light cells can be fitted into one of several sorts of holders. See Figs. 905-a,-b. The open holders, made of sheet aluminum, have a reputation of doubtful contact due to corrosion; the contact points must be checked frequently and both the holder and the cell ends cleaned off with fine sandpaper. Many fliers prefer to

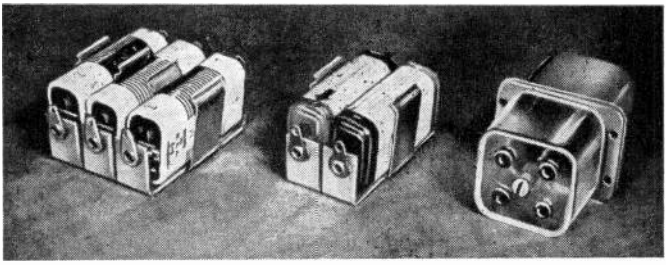


Fig. 905-b. Additional types of batteries and battery holders.

solder directly to the cells. Although this makes it much more of a problem to change cells it clears up a potential source of trouble through the poor friction contacts that are found in some holders. In soldering to cells, the ends should be cleaned carefully with fine sandpaper, then tinned with a hot iron. Try to do the soldering just as quickly as possible, so as to limit the heat applied to the cell.

When you purchase flashlight cells, remember that they tend to lose power, even though they are not in use. If you can do so, check your dealer's stock, and pick out the cells with the date farthest in the future, for these have been on the shelves the shortest time, and will give you the most service.

The small 22½-volt and 30-volt hearing-aid B batteries, popular for the high-voltage supply in smaller planes, usually have plain contact ends, and you will have to solder leads to them or make spring contact holders for them in the model. Larger types have either plug or snap fasteners both of which are reliable and handy to use. Hearing-aid A cells are used by many modelers, because some of them also have these handy plug connections.

The main points to remember when installing your batteries is to place them toward the front of the cabin—against a bulkhead or heavy former, if possible—and to fasten them down securely and make good reliable connections. Also, try to make them easy to reach for test or replacement, without the necessity for taking the whole model apart; in other words, make your installation handy.

Mounting the receiver

It has long been the practice to mount receivers by means of four rubber bands, from hooks at each corner of the receiver base. This makes sure that motor vibration will not bother the relay or other parts, but it allows the set to bounce around unmercifully when the plane lands heavily. It is good practice to make the rearmost two support bands about twice as heavy as those at the front. See Fig. 906. It is also wise to place an inch or more of sponge rubber directly in front of the receiver, to act as a buffer in bad landings. More and more modelers are mounting the receiver on sponge-rubber pads, eliminating the rubber bands entirely. This makes sense, as the mounting is much more secure, and the receiver can't fly back and forth in the cabin. Another trick coming into more use is to mount the sensitive relay separately from the rest of the receiver. The relay constitutes between a third and a half of the weight of most receivers; if this weight is taken off the receiver chassis, the latter is much less likely to be damaged. The relay may be mounted as necessary to protect it from motor vibration (the only reason it can't be attached firmly to the fuselage) while the rest of the receiver may be packed in sponge rubber for protection.

In mounting the receiver, then, the rules are these: Put the unit *behind* the batteries, if possible. Mount the receiver flexibly enough to prevent erratic operation from motor vibration, but not loose enough so that it can bounce around in the cabin. Make the leads to the receiver long enough so that they will not be yanked loose if the receiver is jounced forward. Put a sponge-rubber buffer in front of the receiver, if you can. Make all the receiver controls (such as tuning and relay adjustments) easily reached—from the outside of a model plane, if possible, so you won't have to take the wing off to work them. Some builders use the smallest size of clear fuel tubing to suspend the

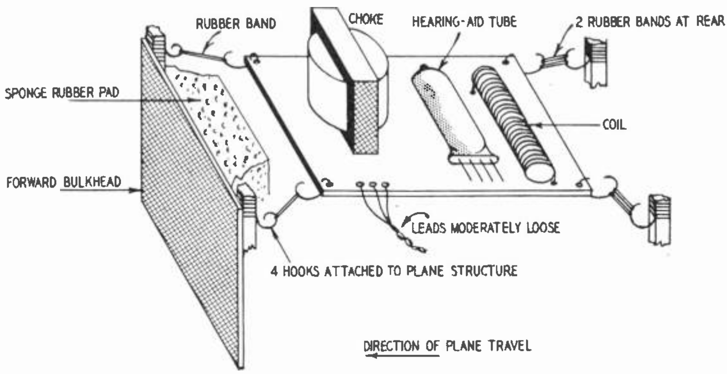


Fig. 906. Technique for mounting the receiver and protecting it.

receiver (if it is large) instead of rubber bands. This material has the advantage that it is flexible enough to absorb motor vibration but does not have much snap, and the receiver will not bounce forward then or be jerked way back, if the plane comes down hard.

Switches

The various controls that must be reached from the outside of the plane in normal use, such as battery switches and meter jack, should be mounted where they are most convenient for the owner to use. Switches are usually placed on the side of the plane, and if possible should be on the side away from the exhaust of the engine. Any exhaust that gets into the meter jack opening can render the installation inoperative due to dirtying of the contacts. The average installation requires two switches and a meter jack. The former should be placed where there is little chance that they will be accidentally flicked off as the plane is hand-launched.

There is a big difference between switches. The slide type of switch is widely used today, due to its light weight and small size. However, some types of slide switches are very unreliable, and if used make sure that your switches are of the knife type. Fig. 907 illustrates how these look, from one end. The knife style of contacts are self-cleaning and make very good contact. Other types of slide switches that appear something like Fig. 908 and have ball or rocking contacts have been found dangerous for model uses. Most toggle switches seem to work well, though they are a bit on the heavy side for small models.

Wiring

All wiring in the model should be done with flexible conductors; solid wire has a bad habit of breaking under heavy motor vibration. The wire may be quite small, except in the case of

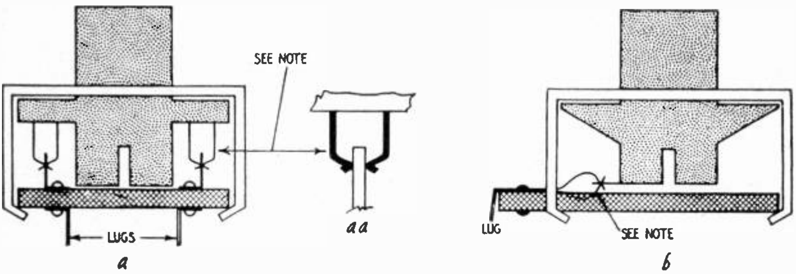


Fig. 907. Cross-sectional views (a and b) of reliable slide switches. Note: Detail (aa) shows how double sliding contact is obtained by using both sides of a fixed contact. The same sort of double contacts are used in the illustration at the right (b) but they are stationary in this type.

escapement leads which have to run all the way to the tail of the ship; escapements often draw a relatively heavy current, and if leads to them are long and light the voltage drop can lead to weak operation. In general, flexible wire as small as No. 24 may be used for A and B battery attachment, and for escapements, if they are close to the receiver. Long escapement leads should be no smaller than about No. 18 flexible wire. It is highly desirable to terminate the receiver leads in a plug, with a socket in the plane, to connect the batteries. This allows easy removal for adjustments, and is much better than having to unsolder all the leads when work has to be done on the set. Use wire of various colors and fasten the wires down so you have a neat job. It will then be much more simple to trace wiring in case of trouble than if the cabin of the plane is filled with a tangle of leads running in all directions. A good escapement carefully mounted. has been known to require no major attention for several years, so there is not much use in connecting them with plugs and sockets.

Model planes are now being built with more thought to the factor of convenience in use. For example, many builders put a hatch on the bottom of the fuselage, and under it install all the batteries for the entire installation. This makes test and replacement an easy matter, and the wing doesn't even have to be removed to do it. As an aid to ease of use, some larger planes are even fitted with miniature milliameters which are thus always handy to measure receiver current. Such meters are only about 1¼ inches in diameter and weigh an ounce or so. They allow

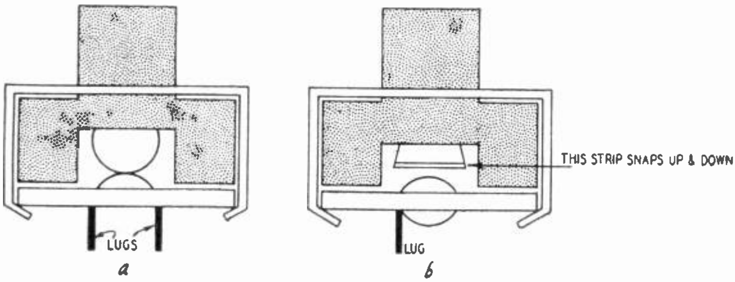


Fig. 908. Cross-sectional views of ball and snap switches. Avoid these. In the illustration at the left (a) the contacts are in the center of the slide and are hemispherical, ball bearing type. Snap switch (b) also has small contact surface area.

continuous check of the receiver operation right up until the moment the plane leaves the launcher's hand.

Though it is more a matter of plane design than of radio installation, be certain that the receiver controls, and batteries are not mounted where they may be affected by fuel seepage from the tank, or by oil from the engine exhaust. If it is necessary to run the engine with the cabin open or the wing removed in order to make vibration tests, be sure that the exhaust cannot get into the cabin or come in contact with any other parts of the electrical installation. Nothing will gum up relay contacts and cause defective switch and escapement operation quicker than model-engine fuel, either fresh or out of the exhaust!

Antennas

The type of receiver antenna depends upon that working at the transmitter. In general, it is preferable to use a vertical antenna on the model if that sort is fitted to the transmitter. The majority of present-day radio-control activity is on the 27.25-mc spot. Virtually all transmitters for this frequency utilize some sort of vertical antenna, from 1/12 to ¼ wavelength long. Hence, practically all models will be fitted with verticals as well. A length of about 2 feet will do for most receivers; it should be remembered that the length of wire from the tank coil to the base of the vertical antenna rod must be figured in as part of *antenna length.*

The diameter of the antenna is not critical; most builders use music wire of about 1/32-inch diameter. This is strong enough so that it doesn't bend back too much on a plane in flight, yet it is springy enough to flex if it hits an obstruction. When the model is not in use, the wire may be pulled back and held to

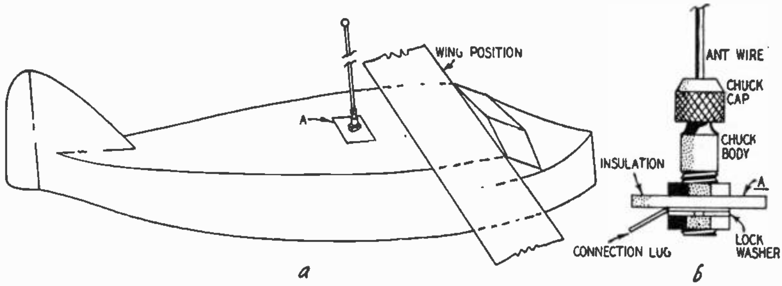


Fig. 909. The chuck from a radio test prod makes a good mount for the antenna (a). A small square of insulation can be set into the fuselage top as shown at A. Illustration at the right (b) shows mounting details.

a clip on the rudder, or, in a boat at the stern. Always bend a loop about ¼ inch in diameter in the upper end of the wire, so it will not poke through objects when the model is being handled.

On planes, the antenna is usually located to the rear of the wing, for convenience. It should be at least several inches back, for if it is directly back of the trailing edge, it will probably get torn off, should the wing (most of which are fastened to the fuselage with rubber bands) get knocked off in a bad landing.

A simple and convenient antenna mounting may be made as shown in Fig. 909; the wire is held in a chuck from a radio test prod. The best type to get is that made to hold phonograph needles. The metal end of the prod will be found already threaded 1/4-32. This end is fitted with a pair of nuts to clamp it to a small block of insulating material such as linen bakelite.

Many users of 50-mc radio equipment fit their transmitters with half-wave horizontal antennas, in which case the plane antenna should also be horizontal. Here it is practical to run a wire out on one wing or the wire may be stretched from the rear of the cabin to the tip of the rudder. If it is found that more length is required, a foot or so of flexible wire may be allowed to trail back from the rudder antenna fastening (See Fig. 910-a). Some builders feel that the antenna is less directional if it is in the form of an L as in Fig. 910-b,-c.

All antennas are directional to some extent. However, antennas on the model (boat, plane, etc.) are usually not of the resonant

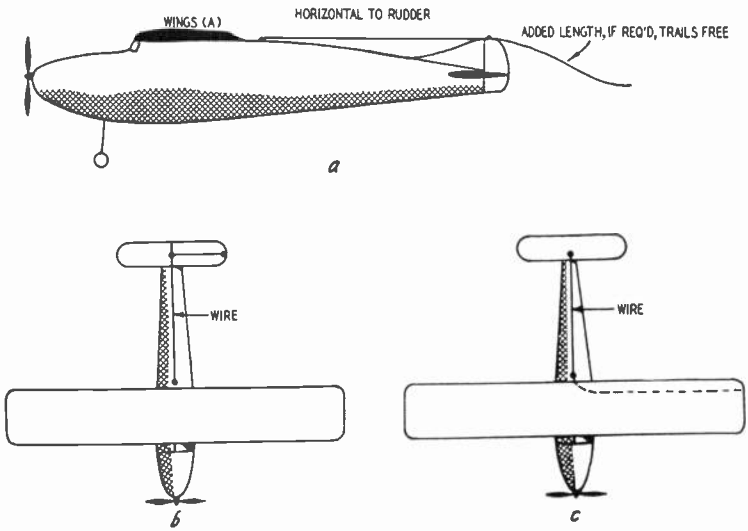


Fig. 910. The antenna can be a single length of wire with a trailing length (a) or it can form an L (b and c). In the illustration at the lower left (b) the wire runs to the top of the rudder, then out to the stabilizer tip. In the picture at the lower right (c) the wire goes to the rudder. Another wire is cemented to the trailing edge or is placed inside the wing, as shown by the dashed lines.

type (as are those on transmitters) and the rules for directional behavior do not apply so exactly to them. Also, other wiring, such as leads running to an escapement in the tail, will greatly modify the directional pattern, so that it is practically impossible to predict what it might be. Needless to say, the ideal—for both transmitter and receiver antennas—would be to have no preferred direction at all. That is, to have them operate uniformly in every direction.

Theoretically, vertical transmitting antennas put out the strongest signal at a fairly low angle toward the horizon in every direction while there is a dead spot right overhead. See Fig. 911. In actual use, the mounting of the antenna, the surroundings, the key lead held by the operator, and many other factors all work to upset this theory, so we need not generally worry too much about direction of signal propagation or dead spots. Horizontal half-wave transmitting antennas are better balanced, and might show a decreased signal off the ends (their direction of poorest propagation) if the model is a long distance off.

One last word on antennas in the model: It must be remembered that the other wiring in a plane acts as part of the antenna

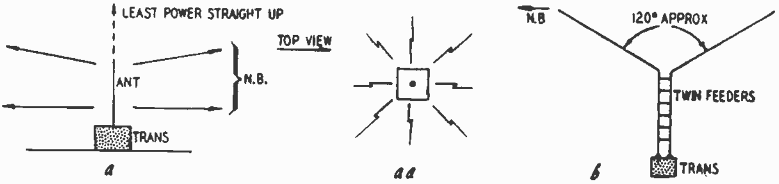


Fig. 911. Quarter-wave vertical antenna (a). N.B. Power is concentrated toward the horizon, and 360 degrees around the antenna (aa). The horizontal half-wave doublet is shown at the right (b). N.B. Least signal is off ends, maximum signal broadside to antenna. Halves of antenna are often inclined upward to give more uniform output signal pattern.

system. For this reason, a receiver that has been tuned up and found to work perfectly on the bench might be very balky when installed in the model. You will very likely find that the antenna coupling will have to be considerably different for you to get the receiver working as it did before installation. If you later change some equipment in the plane, such as using a metal pushrod to the escapement in place of a wooden one, this again will alter the receiver operation until you have compensated by changing antenna length or coupling to get things back the way they were.

Chapter 10

Adjustments

AT this point, let us assume that the entire radio installation has been made, and we are ready to find out if it works. What next? Well, the first thing is to move your model and equipment outdoors (after having first tried the various circuits to make sure they are connected correctly), since it will now be necessary to make field or distance tests.

Preliminary tests

Set up the transmitter, tune it according to the sort of ground upon which it rests, then take the model about 100 feet away and turn on the receiver. A test meter must be plugged into the jack on the receiver in the model, of course. Have someone push the transmitter button at your signal, and observe if the receiver plate current acts as it did when the receiver and transmitter were tested in your shop. A bit of retuning on the receiver will probably be required. After this is done, continue to walk away from the transmitter (if possible, in a direction so that there are no hills, houses, or trees between the two radio antennas), and make another check at 500 feet, then at 1,000 feet. Always make the final tuning of the receiver at least 500 feet from the transmitter, and preferably at twice that distance. If everything looks O.K. at 1,000 feet, you can be sure that the model will be under good control as far away in the air as you care to let it go.

Some receivers do not work too well (or might even refuse to operate at all) when very close to the transmitter. They are said to *overload*. As soon as they are 50 feet or more away, they work as they should. This will do no harm, as long as you are aware of it, and don't count on controlling the model as it comes in for a landing right past the transmitting antenna.

Remember—*don't* launch your model until you have checked the receiver tuning at least 500 feet from the transmitter. The next step is to check operation of the plane equipment with the escapement turned on. Due to the additional circuit in use, some receivers require resetting of the sensitivity control when the escapement is operating, or it may be necessary to recheck the antenna coupling. If all is well at this point we come to the final test that must be passed successfully before the plane is launched. This is just to see if the equipment will work as well with the engine running as it does without; this is a tough test, for engine motion can cause relay vibration, escapement skipping, and so on. If the relay seems to be the culprit (you can check this by unhooking one wire at the escapement and using a voltmeter to see if the relay contacts are closing when they shouldn't), then you will have to either alter the relay adjustment (for larger contact spacing or more spring tension) or perhaps rearrange the shock-mounting setup. In some cases it is not actually the relay's fault for certain motors just are naturally rough at certain speeds. Also, make sure that your prop is correctly balanced before you tear out the receiver or relay.

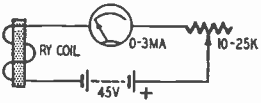
To check if it is the escapement that is being affected by vibration, turn off the switches to both escapement and receiver; if the escapement still turns erratically, it is here that you must do your readjusting. Some escapements will not take more than one loop of ⅛-inch rubber; even a strand of 3/16-inch will cause them to skip with vibration (and sometimes even without). See if you can give the armature spring a bit more tension and still retain satisfactory operation when the relay operates. If the escapement normally works on 3 volts but you just can't get it to stop skipping unless the spring is tightened to the point where normal operation is not dependable, you might consider using 4½ volts on it. Check the directions that come with it to see if this is permissible. On most escapements it is, but at the expense of higher current drain. From the viewpoint of economy of operation, it is certainly better if you can use the lower voltage.

When things are adjusted so that you can work the escapement with the plane 500 feet from the transmitter and with the motor running, try pushing the button, say, a hundred times, and see if the escapement follows *perfectly*. If it misses just once during this test, either not working when you signal it to, or vice versa, *don't try to fly until you have found out why,* for it will invariably fail just when you need it the most.

Relay adjustments

The ability to adjust your relay (and know what you are doing) is an absolute necessity, if you wish to get the most out of your receiver. Some relays are rather easy to handle, since adjustments are made by turning screws. Others have to be set up by bending various parts. The process is the same for all types, though, and you should follow a definite routine when doing it.

Fig. 1001. Simple relay test circuit. With this arrangement the relay can be adjusted until it supplies the desired operation.



The only electrical equipment needed is a 45-volt battery and a variable resistor (connected as in Fig. 1001). It is even possible to use the resistor and B battery of your plane installation; for example, see Fig. 1002, which shows part of a typical receiver circuit. By simply connecting a wire from A to B, you get a fine relay test circuit. Don't try this unless you are sure of all the

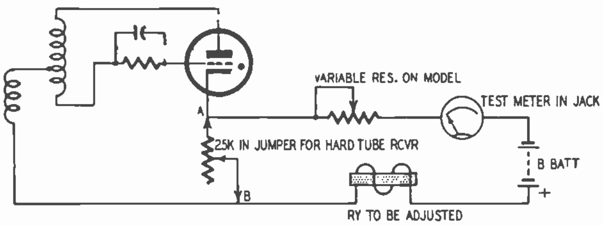


Fig. 1002. The B battery and variable resistor mounted in the plane make a good test circuit if the resistor is of high enough value. Most hard-tube receivers do not use this resistor. Put it in the connection from A to B.

connections in the receiver, though, for a misstep can result in a burned-out tube, and perhaps even more serious damage.

Some modelers who are very active in radio control have built up permanent relay adjusting equipment, based upon the simple circuit of Fig. 1001. They add switching so that the meter will have several ranges, and include a low-voltage cell and a couple of pilot lamps which are connected to the contacts, so that they can be absolutely certain when the relay armature moves. Clips are usually attached to all leads that go to the relay.

Practically all relays used in radio-control work have two fixed contacts, that is, they are single-pole, double-throw. We normally use only one of the fixed contacts for escapement installations; proportional control ordinarily requires both. When there is no current through the relay, the armature will be against what is usually termed the back contact, and the relay is open, or non-operated. Current that is high enough will make it operate, or close. See Fig. 1003.

When the relay is closed, there must be a noticeable gap between the core and the armature; if the latter can touch the core, relay operation will be very erratic, so the first step is to make sure you have this gap. On most relays it need not be large, and in fact you can set it with a piece of thin paper held between the armature and core. Decrease the gap till you can feel the paper bind a trifle as you try to pull it out.

Differential

All relays take more current to pull in or operate than they do to release. Connect the unit to the test battery and resistor and reduce the resistance till the armature is pulled in; note the current at this point and check it with the current you know is required for your particular receiver. Without making any change in the relay, increase the resistance in the circuit to reduce the current, and note the point at which the armature opens. Suppose you have a gas-tube receiver similar to that in Fig. 401; this will normally work at around 1.3 ma, and the current will drop to around 0.1 ma with signal. You therefore have to have your relay pull-in at less than 1.3 ma and release at greater than 0.1 ma. Actually, it should be set to pull-in at about 1 ma and release at perhaps 0.7 ma. This means that you now must decrease the spring tension till the armature will close at 1 ma. When this is accomplished, you must set the *differential,* which is the difference between the current points where the armature closes and opens. Differential is controlled by the spacing between the two relay contacts. As we mentioned before, most relays used for radio control have two fixed contacts, even though only one need be used in the circuit; those that do not have two require a stop of some kind, since it is essential to be able to set the limits between which the armature moves in both directions. The farther apart the contacts are, the greater will be the difference between the operate and release currents of the relay. So, having set the armature tension spring to give us a pull-in at 1 ma, adjust the contact against which the armature rests when the relay is not energized to get the required differential of 0.3 ma. It will be found that the various adjustments interact to some extent; when you change the differential, the armature will no longer pull-in at the previous value. It is therefore necessary to change first one adjustment, then the other, till both are as needed. But remember—*do not* change the distance between the armature and the core piece once you have set it initially.

It is naturally desirable to have the greatest spring tension possible while still having the relay work at the required current limits, and the widest gap between the contact points, for the relay will then be least sensitive to vibration.

On some types of relays in wide use today, the adjustments must be made by bending contact arms or springs, but the procedure is exactly the same as for a relay with screw adjustments —though it is naturally a bit more tricky.

Polarized relays are a bit different in adjustment procedure, since most of them do not have a spring or tension adjustment on the armature; the pull of the permanent magnet with which they are fitted does the job accomplished by the spring in non-polarized types. If the armature of a polarized relay is set exactly

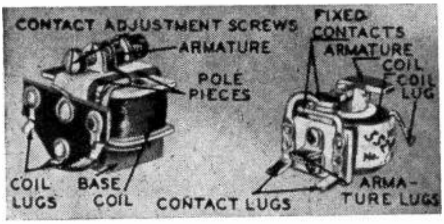


Fig. 1003. E. D. polarized relay is at left. Neomatic relay at right weighs about 1/2 ounce.

between the pole pieces it will snap either way if you push it. The first step therefore is to put it off-center (either way) a bit. The most sensitive position of the armature, the position at which it will operate with the least current, is just off-center. The farther it is moved toward one pole piece, the more current it will take to operate, since the magnetic field will hold it tighter. The differential setting is the same as for a nonpolarized type, however, and is made by adjusting the distance between the contacts. The armature of a polarized relay should never be allowed to touch a pole piece, or it will have to be practically pried off. Note carefully that you must observe polarity when hooking a polarized relay to your receiver; usually one coil lead will be marked with red paint, and this one should go to the B+. If hooked up the wrong way, relay action will be off.

Soldering

The building and operation of radio-control equipment makes essential a fair knowledge of soldering, plus a certain amount of skill. *All* joints and connections must be soldered for maximum reliability, unless of course, they are made by screws or binding posts. Twisted unsoldered leads are a sure source of grief. Needless to say, only rosin-core solder should be used in any radio equipment; never use soldering flux or acid-core solder, for these substances are conductive.

In making model receivers, which are usually small and rather delicate, a tiny pencil type iron is a great help. Some of these have a socket arrangement, so you can change the tip as desired. When making field adjustments and repairs, it is very handy to have a 6-volt iron which works from an auto storage battery.

Meters

It has been mentioned previously that the test leads to a meter used to check receiver operation in the field should be kept very short. In fact, they should be nonexistent, for best results. This means that the meter should be attached right to the test plug itself, as shown in Fig. 1004. This is entirely practical. If an ordinary radiophone plug and jack are used in the plane test circuit, the meter may be mounted on the jack with

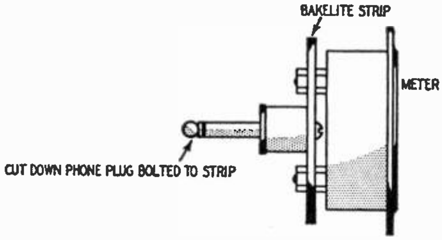


Fig. 1004. Keep receiver test-meter leads short. Mount the meter right on the plug.

a couple of heavy wires, or perhaps with a piece of bakelite to hold both meter and plug. A meter rigged up this way is normally used for no other purpose, but is kept strictly for receiver testing.

Radio-control builders often use what are known as *phono* jacks and plugs for their test meter. If the latter is small enough it may be attached to the plug, but this is practical only for the tiny 1½-inch meters, since these plugs and jacks are not as rugged as the radio plugs and jacks mentioned earlier. It is usual to have a shorted plug inserted in the jack at all times, except when the meter is in use. This is necessary since these jacks come only in single open-circuit construction. It is not difficult to

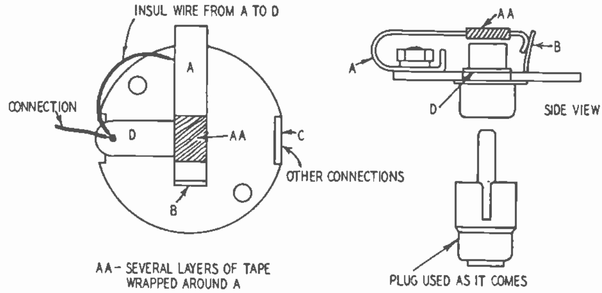


Fig. 1005. *Popular phono jack can be converted into closed-circuit type.*

transform one of them into a closed-circuit type, however, as shown in Fig. 1005. This is much more convenient, and obviates the chance that the shorted plug will be forgotten or mislaid.

It is necessary to make another piece, A, from good spring brass

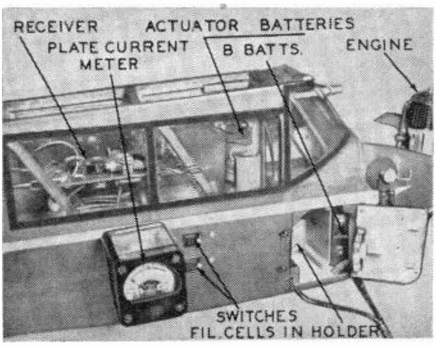


Fig. 1006. *The 1-1/2-inch test meter is convenient to use, can be carried in your pocket.*

or bronze (taken from a discarded radio jack or leaf switch), which is attached to the jack base with a 2-56 bolt. The end is bent to make good contact with the lug B that was intended for connection to the outer portion of the jack; the new connection to this part is made to one of the bent-over ends C that crimp the metal to the jack base.

The lug D for the center connection of the jack is bent outward to clear piece A. The latter must have insulation on it at point AA. You can cement on a piece of bakelite, or just wrap it with tape. Properly made, a jack of this sort will prove absolutely reliable; since part A makes a wiping contact on the lug B, it tends to keep the contacting areas clean and no maintenance is required.

The meter in Fig. 1006 has a phono plug attached right to the case, by means of a soldered-on flat washer. This is a very convenient setup, since the meter can be tucked in a pocket when not in use.

Field tests

Escapements have been described in Chapter 1; testing consists simply in making sure the escapement follows the keying button (or beep box) perfectly, and does not skip or jump when the motor is running. A little different technique is required to field-check a proportional control system. There won't be any skipping here, but the neutral setting may wander. If everything is working right, the neutral should always be just about in the same place, that is, you will not have to readjust to get the rudder into center position when the pulser is at center. Therefore, whenever you are ready to fly the plane, have the launcher hold it with the motor running so you can see the rudder. Move the control lever to both extremes from neutral to make sure the rudder follows exactly. If it doesn't, or if the neutral seems to be lopsided, halt operations till you have found out why. The trouble may be due to relay vibrations, a loose connection in the plane, or some other cause. If you experience trouble when flying a proportional plane, always note carefully in which direction the plane will, or will not, turn. This will help you determine what sort of failure led to the loss of control.

Because capacitance to ground is so important, it is always wise to make final tests with a radio-controlled model in the same position relative to ground as it will have when it is actually operating under control at a distance from you. This means that a plane should be checked by having two persons hold it up in the air at arm's length by the wing tips, while keeping away from the fuselage and antenna as much as possible. Similarly, a model boat should be checked while it is sitting on the water, and a car while on the ground. If the plane equipment works when it is held in the air as suggested, you may be fairly certain it will work well when 100 feet in the air—or when 1,000 feet up.

Chapter 11

Test Instruments

THE most elementary test instruments, of course, are a low-range milliammeter to check the receiver and one of higher range for the transmitter. Some radio-control builders have operated without either of these essentials—but not for long. You simply cannot tell what is going on inside your equipment without meters to take its pulse.

Milliammeters and Voltmeters

The cheapest type of milliammeters are those known as the *iron vane* type. These can give good service if you understand their shortcomings. They are relatively high in internal resistance. In the transmitter this doesn't mean much, but it can cause trouble in the receiver. A 3-ma iron-vane meter has sufficient

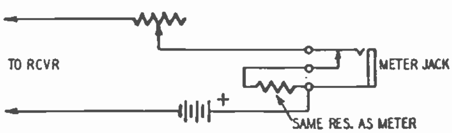


Fig. 1101. Iron vane meters require compensating resistor across meter test jack.

resistance to throw a receiver off adjustment when it is removed from the circuit. Therefore, it is necessary to connect a resistor across the meter test jack, so that the total resistance in the plate circuit will not be radically different with the meter in or out of use. The resistor is hooked in as in Fig. 1101, and should be of a value as near to that of the meter resistance as you can get. A representative 3-ma meter of this sort has an internal resistance of 4,000 ohms, so that is the required value of the carbon resistor to attach to the jack. Most meters of this type have an accuracy of 5%; the needle tends to oscillate back and forth a lot more than that of the moving-coil type meter. However, as noted, iron-vane meters are cheap and they are rugged; they are certainly a lot better than none at all.

The moving-coil meters cost about two to three times as much but are handier to use and more accurate (usually within 2%). They are somewhat more delicate, though in the ranges needed for radio control, they are well able to tolerate field handling and use. Their internal resistance is low enough so that there is no necessity for using a resistor across the receiver test jack.

For gas-tube receivers, a meter range of 0–2 or 0–3 ma is best, though meters up to 10 ma full-scale may be used if you can get nothing better. Hard-tube receivers have a somewhat higher plate current, but a 0–5 ma meter will take care of most of them.

Most of the transmitters we have described can be checked by a 0–50-ma meter. It is strongly advised that the transmitter meter be built right into the case, since it gives a constant check on operation of the unit, showing condition of batteries, antenna loading, tube condition, whether the crystal is oscillating, and so on. If it were not for the undesirable weight, it is certain that most model planes would have a meter built right in to give a constant check of receiver operation. Many boat and car builders do install permanent meters, and find them far more handy than the plug-in style that the plane operators have to use.

While the basic meters for transmitter and receiver will show in a general way what condition your batteries are in, you can learn a lot more about the individual cells with a meter made for the purpose. Fortunately, this does not have to be an expensive one, and, in fact, the cheaper ones are actually better. Small iron-vane meters are sold that have two scales, one for volts and one for amperes. A handy combination is 0–50 volts and 0–35 amperes. The former range is used to test B batteries, and also A batteries of more than 1.5 volts. For single flashlight and dry cells, the ampere scale is used. A meter of this type puts quite a load on the cell or battery under test, which is just what we want. High-grade voltmeters are not of much use for battery test purposes, since they take very little current. If they are used, the battery being tested should be connected to the radio equipment and the latter turned on to give a voltage reading under load.

Field-strength meter

Once the radio-control enthusiast gets beyond the very elementary stages of his hobby, he will feel the need for a little better equipment. A combination test meter that was designed expressly for radio-control field testing is shown in Figs. 1102 and

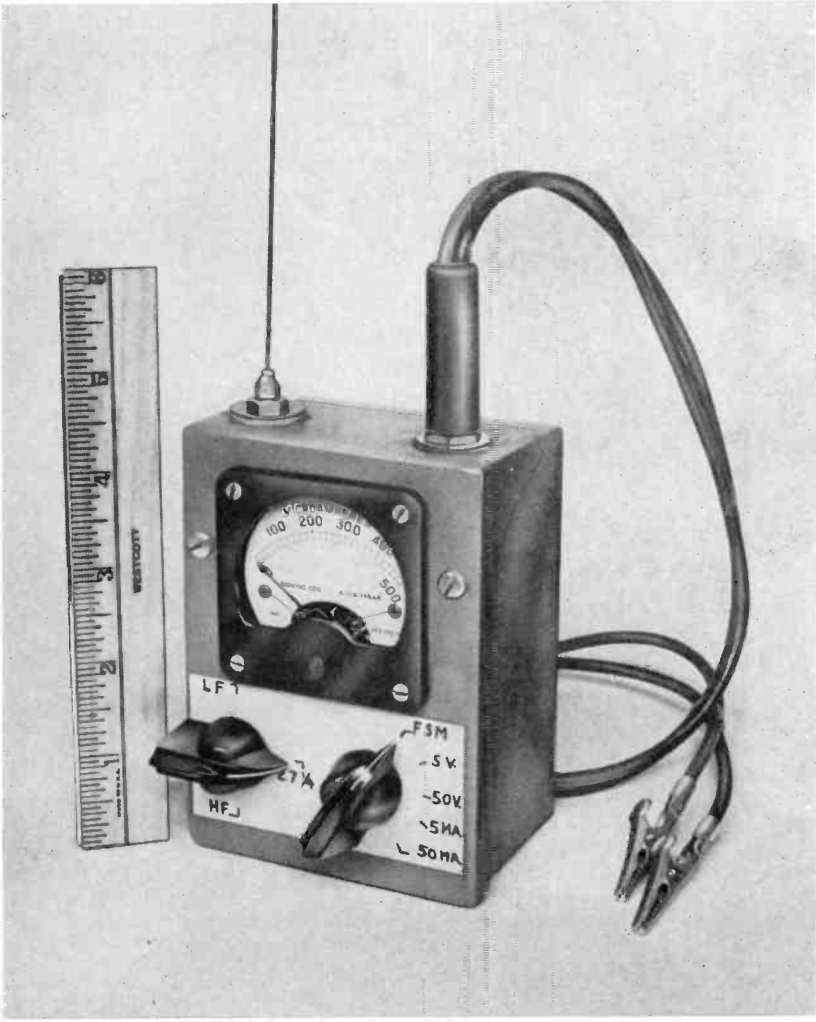


Fig. 1102. Combination test meter can be used for checking transmitter, receiver, or batteries. It can also be used for testing the field strength of the transmitted signal.

1103. Besides several voltage and current ranges, it has built in what is called a "field-strength meter," a circuit that is used to check the actual output of the transmitter *after the signal leaves the antenna.* This is most important, of course, for it shows the over-all efficiency of the whole transmitting system. It is quite possible for a transmitter to tune up correctly and appear to be working fine when actually very little of the signal is getting out into the air where it will do the most good. The circuit is shown in Fig. 1104.

The same meter is used for all functions and is switched among the different circuits as required. The only other control is a

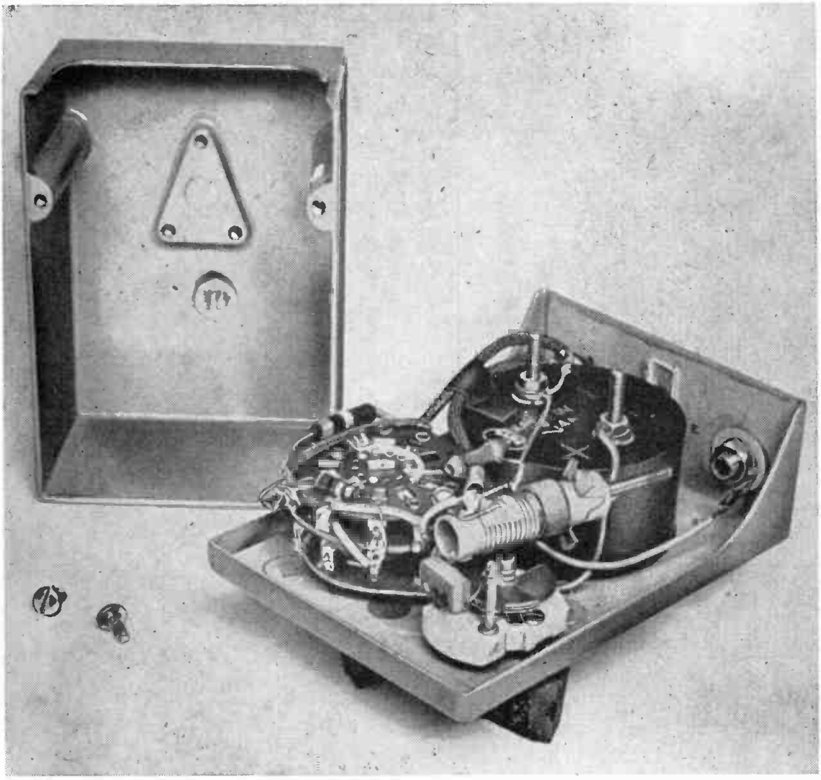


Fig. 1103. Inside view of the combination test meter. All the parts are mounted on the cover.

variable capacitor to tune the field-strength circuit, but there is a phone jack at the top of the case for battery and circuit test leads, and a small single jack for a 2-foot test antenna. The meter is a sensitive one, principally to make the field-strength meter sensitive enough to be worth while. A 500-microampere meter is shown, and is recommended, although a 1 ma meter will cost a little less and will still give good results.

Since there are thousands of them still available, a surplus jack box (BC-366) was used for the case. This box also has other parts that are needed, such as the rotary switch, and a jack for the test-lead plug. The meter in this particular unit is also a surplus item, but a standard 2-inch round or square 500-microampere meter will do as well. The first task is to disassemble the surplus unit, removing all internal parts with care, A couple of long studs found in the case must be cut down as short as possible with a hacksaw, and the rib where the meter is to mount must be filed down a bit. These jobs are easy, since the cast aluminum cuts easily. Dimensions are given in Fig. 1105.

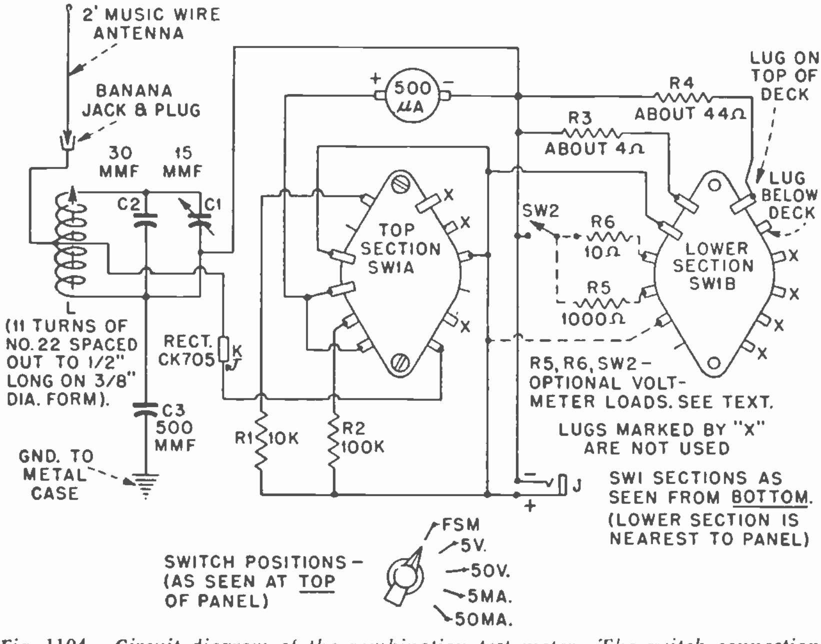


Fig. 1104. Circuit diagram of the combination test meter. The switch connections are tricky, so follow the diagram closely.

The two holes for the jacks must be insulated from the case, a job accomplished with bakelite washers. The meter hole can be made with a hole cutter, but can also be hacked out by drilling a ring of small holes and then filing out the center piece. A few extra holes that are in the case may be plugged with plastic wood or other filler.

For the five functions we need a 5-position, 4-circuit rotary switch; the one in the BC-366 actually has more circuits than are needed, but they are arranged in an odd pattern, so the circuit diagram should be followed very closely. The switch needs a bit of work done on it: The heavy spring that comes into play at one end of the rotation should be removed and the detent disc should be cut down with a hand-grinder so that the last two positions may be located reliably.

Resistors R1 and R2 (see Fig. 1104) may be ½-watt carbon units, if you can choose them carefully and be absolutely certain of their value. Otherwise, use precision carbon-film type resistors, which are small, accurate, and cheap. The current shunts R3 and R4 must be made to fit. The approximate values are given on the schematic diagram, but these will hold true

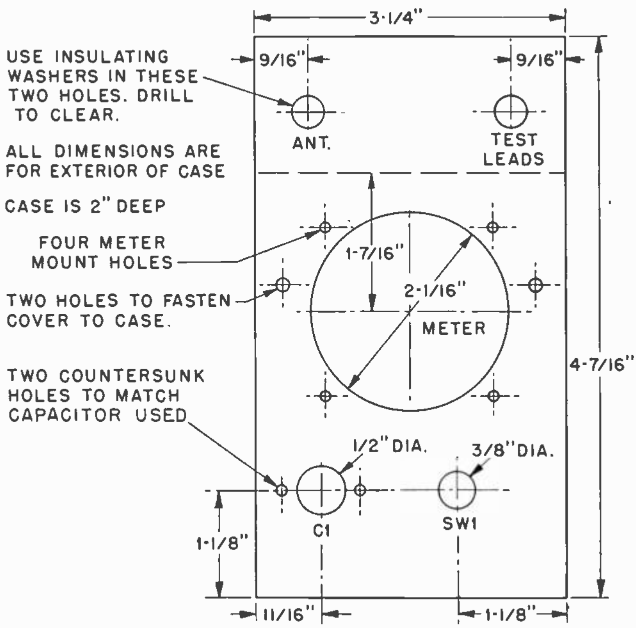


Fig. 1105. Dimensions of the front panel of the combination test meter.

only for the meter used here. If another make of microammeter is employed, these may be somewhat different. It is not difficult to make these resistors, however, using the circuit in Fig. 1106. This requires the use of another meter of known accuracy and some resistance wire; the latter may be taken from old wire-wound resistors. When the test circuit is set up, slide the clip along the resistance wire till the test set meter reads full-scale at the required input of 5 ma (or 50 ma, as the case may be). *Open the battery circuit* before you shift the clip along the resistance wire, or the 500-microampere meter may be damaged. When the proper length of wire has been ascertained, it may be wound around a length of insulating rod and soldered into the circuit.

As originally made, the voltage ranges do not apply an appreciable load to the batteries under test, which condition, as has been stated previously, does not give a true picture of battery condition. By use of resistors R5 and R6, these ranges have loads cut in that will give a better check of the batteries. If desired, switch SW2 may be incorporated to cut out these load resistors when the meter is used for other voltage-checking purposes.

The tuned circuit is selected to cover the 27.255-mc spot and a bit on each side. The field-strength meter may thus be used as a rough check of frequency as well as of strength of transmitter

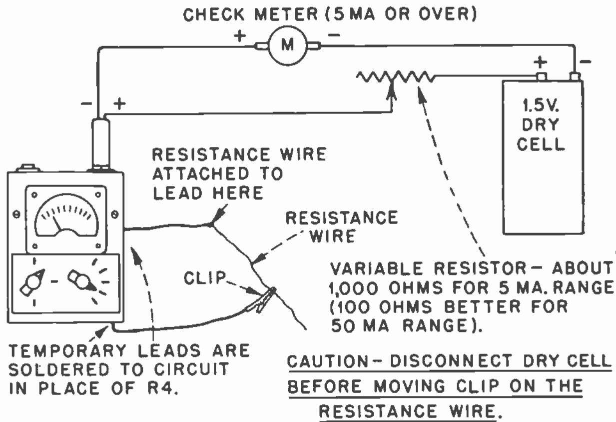


Fig. 1106. Circuit to be used when making your own meter shunts.

signal output. A 2-foot length of music wire is used as the normal antenna, and this much antenna will give a good reading when the field-strength meter is placed about 10 feet away from a properly tuned 5-watt transmitter. For transmitters of lower power input, you can use a longer antenna, or put the meter closer, or both. A more true reading will be had with the meter as far away from the transmitter as possible, however. The fie'd-strength meter will give a fairly accurate indication of the amount of power the transmitter is putting out, but to use it this way you should always utilize the same length of antenna and hold the meter the same distance from the transmitter antenna. Also, the field-strength meter should be held in the same manner (for instance, hold it in one hand, with the other on the tuning knob, and with the antenna vertical), to get a reasonably true indication of power output. A higher reading will be had if the field-strength meter is placed on a metallic surface, such as the top of an auto.

Frequency checks should also be made with the meter held in the same manner, and with the *standard* length of antenna.

When using this meter to check the plate current of a receiver in a model, try to keep the meter off the ground; set it on the model if you can, and keep the connecting leads short.

The voltage and current ranges were chosen to cover most receivers and transmitters, also most cells and batteries used for radio control. Needless to say, other ranges may be picked, but

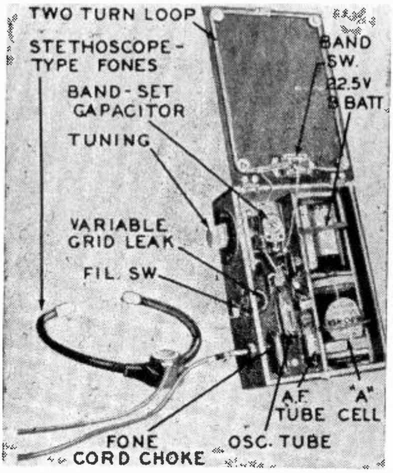


Fig. 1107. Direction finder with cover in operating position.

will necessitate resistor alterations. The ranges we have used also are easy to read on the 0–500 scale of the particular meter chosen.

Direction-finding

What do we do if a radio control plane gets out of hand and is lost?

If the general vicinity is known, and the plane came down intact, it is quite possible to locate it with a miniature direction-finder. It is not generally known that radio-control receivers also act as very low-power transmitters all the time they are turned on, and a sensitive receiver may be used to track them down. A direction-finder for such use is shown in Fig. 1107. It is small enough to be carried in the tool kit, or even the pocket, and incorporates a two-tube circuit with a superregenerative detector and one-stage audio amplifier. It will put quite a good signal into the earphones. Use earphones having an impedance of 2,000 ohms or more. Lower impedance earphones can be used, but will not be as sensitive.

The direction-finder shown is made for use on both the 27.255 mc spot (actually, this range also covers the ham 10- and 11-meter bands as well) and on the 50–54-mc ham band. A loop antenna is in the cover and acts as the tuning inductance for the detector. The unit is also handy for checking on interfering signals and may be used as a low-power test transmitter for checking radio-control receivers.

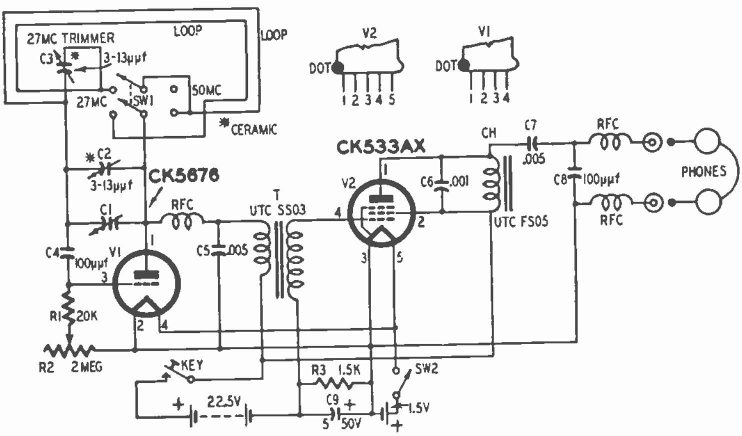


Fig. 1108. *Circuit diagram of the direction finder. The radio-frequency chokes are made of* 135 *turns of no.* 34 *enamelled wire wound on a form,* 1/4" *in diameter and* 1" *long. The antenna is a double loop* (3-1/2" x 5") *of no.* 22 *double-cotton covered wire. The outer turn is used for* 50 *mc, both turns in series for the* 27.255-*mc spot.*

The case is of cigar-box wood, with the loop on a cover of 1/16-inch thick linen bakelite. Room is provided for several different sizes of A cells and B batteries, connections to them being made by spring clips; the batteries are held in by rubber bands.

To reduce hand capacitance, the tuning capacitor, C1, is a split-stator type, made from a standard 25-µµf variable. There are four fixed plates on each side, while each rotor is composed of three plates. The two sets of rotor plates, of course, must be on the shaft, 180 degrees apart. This can only be done easily on capacitors with plates held by nuts, on threaded studs, such as

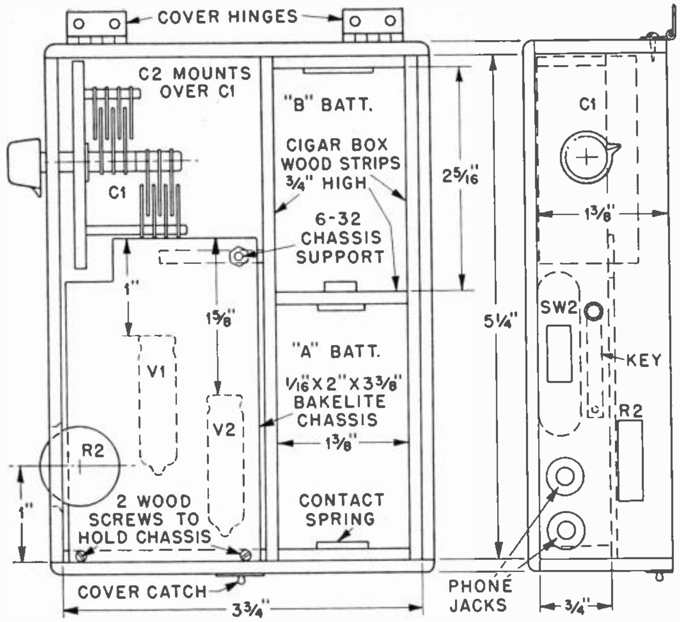
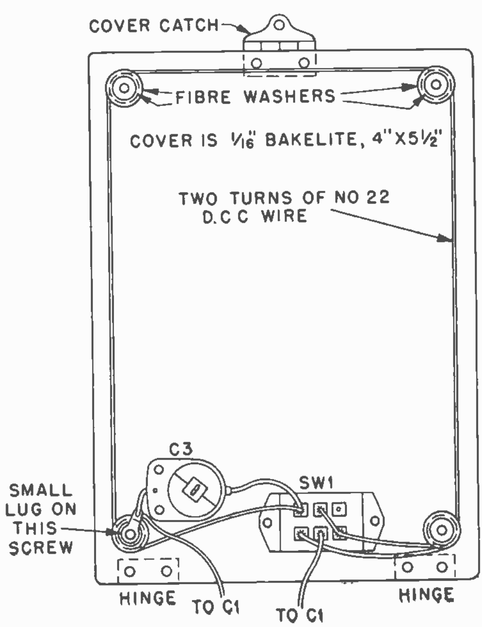


Fig. 1109. The two views (front and side) of the direction-finder case, shown above, give the required dimensions. The two tubes, the two-megohm potentiometer, R2, and the transformer, can be mounted on a bakelite chassis. The case itself is made from a cut-down cigar box. The space shown for the B battery will accommodate a 22-1/2-volt battery, in any of several sizes. The A battery can be any flashlight unit, D size or smaller. The cover, shown in the illustration at the lower right, is made of bakelite. The two-turn loop is supported by fibre washers held into the cover by machine screws. The ends of the loop are connected to switch, SW1. The setting of this switch helps determine the tuning range of the direction finder.



the National UMA-25. All rotor plates are in line (zero degrees apart) when you buy the capacitor. You have to split them into two equal groups, 180 degrees apart, to make a two-section variable.

Tubes, transformers, and R1 are on the chassis of bakelite, and may be wired up completely before assembly in the case. Midget sockets were used for the tubes in the direction-finder shown, but the tubes could be soldered right into the circuit if desired.

The loop is composed of two turns of No. 22 flexible hookup wire. The turns are held on bakelite washers attached to the bakelite cover by 2-56 bolts. The ends of the turns go directly to the band-switch, with the 27-mc trimmer also mounted on the cover. The trimmer for 50 mc is mounted on the tuning capacitor.

R.f. chokes in the phone leads make direction-finding easier, since without them the phone cord acts as an antenna. Several circuit improvements have been made since the original unit shown was photographed; among them are the addition of the

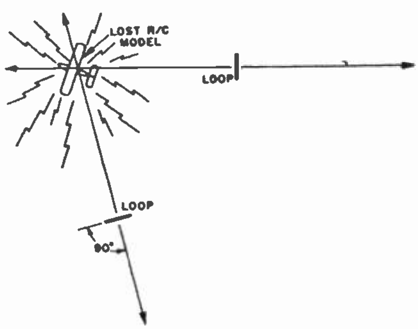


Fig. 1110. A double "fix" is needed for proper operation of the direction finder. With only a single "fix" the model could be in either direction. A second "fix" (from a different point) makes direction certain.

output choke CH and the shifting around of some of the parts. The final design is shown in the circuit, Fig. 1108, and the drawing, Fig. 1109.

When the direction-finder has been wired and checked, there is very little to putting it into use. With the band-switch on 50 mc, turn R1 to about mid-range and rotate C1 till you can tune in a 50-mc signal. Then set the band-switch at 27 mc and tune in a 27.25-mc transmitter. If you want to cover the ham bands mentioned, the trimmers will have to be set with care; ranges of the direction-finder are about 49.5 mc to 54.5 mc on the high band and 26.9 mc to 29.2 mc on the low band.

When used as a finder, it will be found that it is possible to bring up the squeal of the plane receiver by varying R1. Test this with a few planes at a distance of several hundred feet, before you lose one, so you will know what they sound like. To use the unit as a finder, the cover is opened and held vertically, then rotate a full 360 degrees until the desired signal is heard. To get a sharp line to the signal, turn the loop till the signal *disappears*. The so-called *null* is much sharper than the direction of maximum signal. When you have gotten the null point, you still won't have an accurate fix on the plane, for it could be in either of two directions from the loop. With an elementary finder of this sort, it is necessary to take a bearing on the lost plane in several locations, then note which way all the lines point. They will intersect at the spot of the plane, as shown in Fig. 1110. The same procedure is used to locate an interfering station.

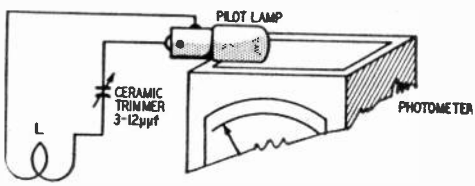


Fig. 1111. *Simple transmitter-output tester. The coil, L, is wound flat, so that it can be slipped between turns of the transmitter plate coil. L consists of 4-3/4 turns of no. 24 insulated wire, 1" in diameter, air wound. In use, a cover is put over the bulb and the top of the meter to keep out stray light.*

To use the finder as a transmitter, turn R1 to zero resistance, and you will get a signal strong enough to operate a plane receiver several hundred feet away. When in use this way, the phones are not needed, of course, nor is V2.

When tuned to any signal, you will find that the strength increases and decreases as you walk toward or away from it. The weak points will be roughly 16 feet apart on 27 mc and 9 feet on 50 mc. Therefore, when you first turn on the receiver to find a lost plane, move around in a circle. If you don't hear it at first you might be standing at a dead spot. Once you have the signal, you will find that you can get a more accurate null if you move to one of these points of weakest signal.

Transmitter output

It is sometimes desirable to be able to check the output of a transmitter quite closely when various circuits are being tried, or to compare different crystals, tubes, etc. A simple means to do this is shown in Fig. 1111, and is based upon the use of a photoelectric exposure meter. A pilot lamp of selected size is coupled to the plate coil of the transmitter, and the lamp is placed near the photoelectric cell. The lamp loads the transmitter to the desired level, and the power put into the bulb is

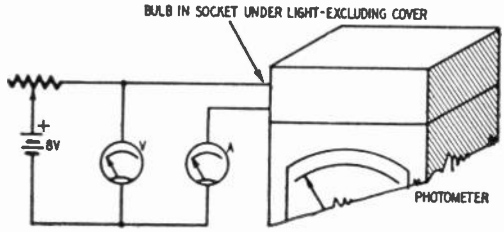


Fig. 1112. Circuit diagram for calibrating the test unit.

indicated on the meter. The bulb and meter have to be calibrated, of course, but this is not difficult, since the job may be accomplished with a d.c. power supply and meters. The resultant readings are close enough for all practical purposes.

The calibration circuit is in Fig. 1112. It is necessary to multiply the readings of the two meters together to get the power going

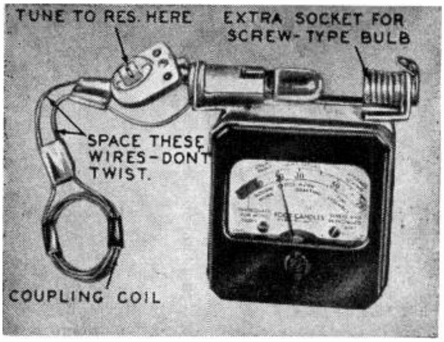


Fig. 1113. Photograph of the completed tester. The cardboard cover for the bulb is not shown.

into the bulb. For the unit shown, it was found that No. 47 bulbs could be used up to about 1.4 watts input, No. 44 up to 2 watts, and Mazda 53 bulbs (an auto instrument bulb) would go up to 3.5 watts. For convenience in reading the meter scale, which is cali-

Many radio-control experimenters are turning to boats as a most valuable test bed for radio-control equipment that might eventually be installed in a plane; boats do not "fly away" nor do they suffer disastrous vertical-dive crackups, as do planes with malfunctioning radio equipment. Thus they offer the beginner as well as the more advanced hobbyist in radio-control, an invaluable means whereby they can learn to handle equipment, make tests and adjustments, and yet not stand to lose valuable apparatus if things go wrong.

Radio-control boat

A very elementary boat installation is illustrated in Fig. 1201. The transmitter is shown in the background, to the right. For simplicity and cleanliness, the boat is electrically propelled, the motor being an extremely economical type taken from an imported German toy auto; the current drain is low enough so that the eight pencells (#7 penlight cells, 1.5 volts) connected in series-parallel to give 6 volts, will afford reasonable life. If longer life is wanted, the builder can install cells made for hearing aid use. These cost a little more, but give greatly improved service.

The boat is made from a Sterling B3 kit, and is about 19" long; the equipment it carries weighs it down to a bit more than scale depth, and any heavier apparatus would make it sink still lower, destroying the scale illusion and making it harder to drive. For small boats of this sort, where the drive power is a real problem, an ideal solution is the use of ultra-light rechargeable storage cells, the lightest available being the Silvercels. Four such cells in the nominal .5 AH size would drive this boat for at least half a dozen hours, and weigh lots less than the flashlight cells shown. The first cost, of course, would be rather high, though.

The receiver

The receiver is a subminiature version of the single hard tuber described in Chapter 4, and the circuit is given in Fig. 1202 for those who might wish to try it. It uses a hearing-aid tube which draws only 20 ma, so the single cell A supply will be good for a number of hours of use. The B current drain is about 1.8 ma with no signal coming in, and drops to about .5 ma with signal. Never run the plate current above 2.0 ma. It should preferably be kept less than 1.8 ma.

The eight pencells which run the drive motor and the rudder actuator are carried in two plastic holders, while the A and B batteries for the receiver go in aluminum holders that are attached to a strip of plywood, and held down just in front of the motor. The receiver is held on sponge rubber with a rubber band over the top of it; the rubber mounting is not used because of vibration when the boat is in action, but rather to give a bit of protection when the craft is being transported to and from the pond.

There are only two control switches; one turns on the receiver and the actuator, the other controls the motor. These are S1 and

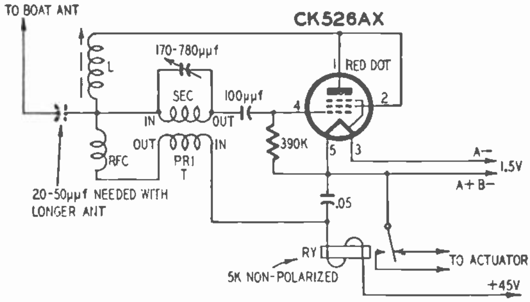


Fig. 1202. Circuit diagram of the single, hard-tube receiver. Special parts needed are: L, CTC type LSM form with red core. Wind 25 turns of no. 34 enamelled wire; RFC, form 5/32" dia. x 3/4" long, wound full of no. 38 enamelled wire (or commercial 10-μh unit); T, ESSCO subminiature quench transformer; trimmer capacitor, Arco #469; RY, E. D. 5,000-ohm non polarized; tube is Raytheon CK526AX; base plate, linen bakelite 1-1/2" x 2-1/8" x 1/16"; socket, Cinch subminiature 5 prong.

S2 in Fig. 1203. A closed-circuit phono jack (marked test jack in the diagram, Fig. 1203) is provided for checking the receiver plate current.

For short range work it is sufficient to connect the antenna lead from the receiver right to the wire rigging on the stubby mast. Longer range can be had if a vertical wire of 15" or so is installed.

The control system is what we have called "semi-proportional," that is, the signal from the transmitter is pulsed continuously to give neutral for centering the rudder. To get left or right turns, the signal is cut off completely, or sent out continuously. If a true proportional pulser is used at the transmitter, the boat rudder can be operated proportionally, turning only as far from center as you wish; however, the control system shown is very fast, and if wide turns are desired, the steering lever is just flipped on and off in the desired direction, the boat then making a fairly smooth wide turn.

The rudder is operated by an economical commercial make of actuator, but it was found possible to cut down the current drain still further with a 100-ohm series resistor. This is shown in the wiring diagram of the complete boat system, Fig. 1203. A tiny bar-type permanent magnet is held to the deck of the boat near the actuator with adhesive tape; it serves to provide a definite neutral position for the rudder when the current is turned off. The particular style of actuator used doesn't have any centering action, and without this magnet, steering is a bit erratic. The rudder is of the balanced type, that is, about 25% of its area is

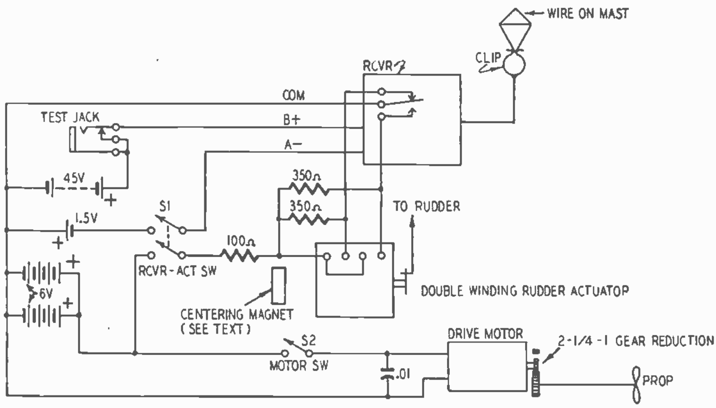


Fig. 1203. Complete electrical diagram of the boat installation. Note that the drive-motor batteries are connected in parallel. Make sure these are of equal strength. Never parallel a good battery with a weak one. The tuning meter should be a 0-3 ma d.c. milliammeter. Keep the receiver plate-current drain below 2 ma.

in front of the pivot line. Note carefully the *arc suppressors* across the actuator windings in Fig. 1203. They are merely 350-ohm, ½-watt carbon resistors of about 10 times the resistance of the actuator windings. They keep the relay contacts from sticking by greatly reducing the arc formed as the contacts open.

The boat does not travel at a high rate of speed, but at that it probably goes at more than scale speed. It can be guided in

List of parts for radio-control boat

1-Mini-Mac single hard-tube receiver; 1-Southwestern R/C proportional actuator; 1-d.p.s.t. slide switch; 1-s.p.s.t. slide switch; 1-Distler Electromatic drive motor; 1-Sterling nylon 1" dia. propeller; 1-closed-circuit meter jack; 2-Hillcrest 4-cell battery cases; 9-Eveready #1015E hearing-aid style pencells; 2-Eveready #412 22½-volt batteries; 1-Acme holder for B batteries; 1-Acme holder for A batteries; 1-100-ohm resistor; 2-350-ohm resistors (all resistors, ½ watt); 1-.01-μf ceramic capacitor.

and around buoys and obstacles in its path with real precision, and the only thing missing is means to start and stop the engine by radio. Such equipment could easily be added, but this was intended to be an ultra simple job so we have stuck to just steering. The transmitter normally used with it is the same one described

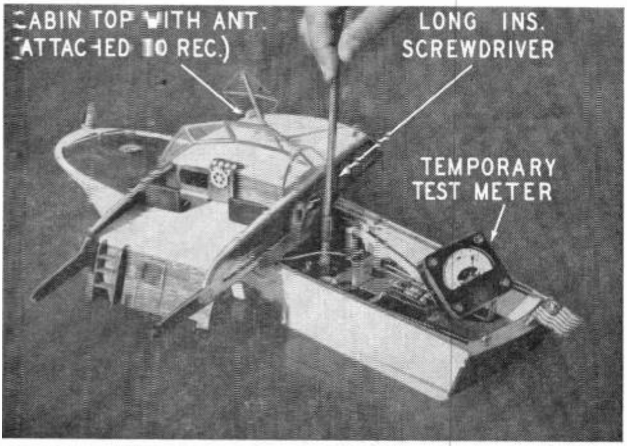


Fig. 1204. This photo shows the boat in the water and the receiver in process of adjustment. The cabin is placed across the hull, and the test meter is plugged into the closed-circuit jack. The boat should always be on the water when the receiver is tuned.

later in this chapter for operation of the radio-control tractor, and will not be covered now. Even though the transmitter works at very low power, it will control the boat up to a hundred feet or so, and with careful tuning, lots more range may be had.

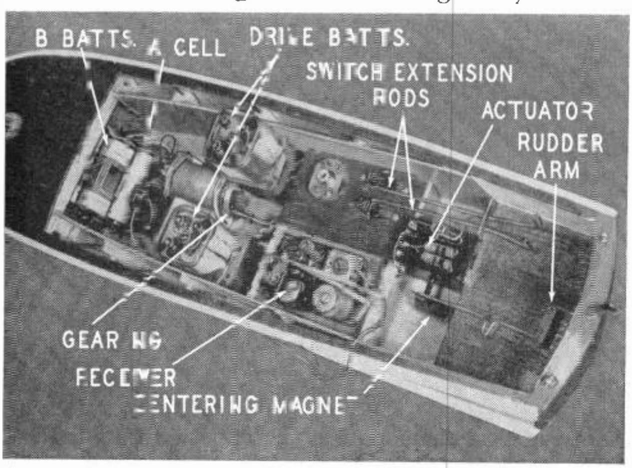


Fig. 1205. Photo of the interior of the boat. The small bar magnet is located to the left of the actuator. This magnet is shifted around until the rudder is centered with the switches off.

Tuning the receiver

Tuning of the receiver should be done with the boat setting on the water. See Fig. 1204. The cabin comes off for access to the equipment; when the set is being adjusted, the cabin top is set crosswise on the hull sides, so that the antenna is in about the same position it normally occupies, and a very small test meter is plugged into the test jack. The sensitivity adjustment of the receiver is set first, then the tuning may be touched up, with the transmitter on, and at least 100′ away. It has been found that the receiver can't be used in its most sensitive condition, due to interference created by the brushes on the motor commutator. The .01-μf capacitor across the brushes (in Fig. 1203) helps reduce this. It probably would be even better to put a small metal can

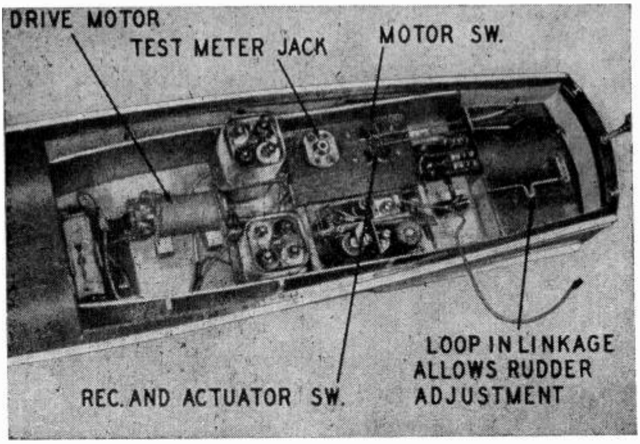


Fig. 1206. Another interior photo of the boat. The motor is held on two wood blocks by rubber bands, has small gear on shaft. Note the details of the rudder linkage. The A and B batteries of the receiver are located in front of the drive motor.

over the brush end of the motor, and ground this and the motor metal frame to B minus. Interior views of the boat installation are shown in Fig. 1205 and Fig. 1206.

Radio-control car

If you wish to conduct your radio control experiments on dry land (and not above it) the little car shown in Fig. 1207 may give you some pleasure. Though the mechanism of the car itself is rather complex—at least if it is compared to the boat we have just described—the transmitter can be any at all, since just a plain pushbutton is needed, there being no pulsing requirements. The car was originally fitted with a box truck body, painted and lettered to represent a TV truck. This body was made out of sheet balsa and was a good quicky, to cover up the works on the chassis. To dress the project up more, a scale Porsche sports car body was built (the chassis having been designed to accommodate this at the start). The Porsche body was built over a clay form, by laying on strips of fabric soaked with Weldwood. After this was built up to

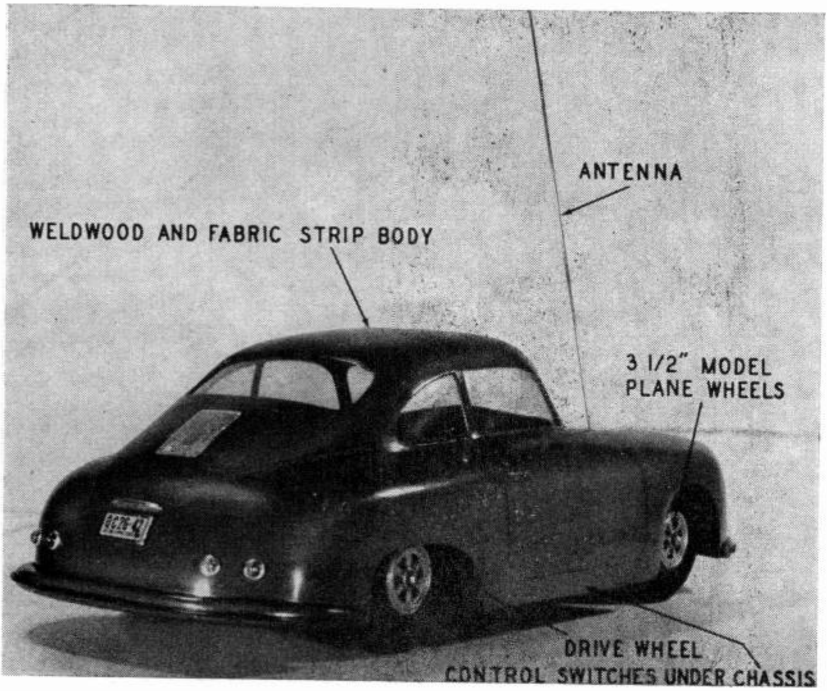


Fig. 1207. This is a close scale copy of a real Porsche Sports car. Standard 3½-inch diameter model-plane wheels are used. Careful sanding will produce a fine finish on the car.

the desired thickness it was allowed to dry thoroughly, then removed from the form, and finished off with much sanding, followed by sealer and colored dope.

The chassis is a piece of ⅜" plywood which makes an ideal base upon which to mount all the parts. Details of the running gear are shown in Fig. 1208 and Fig. 1209; the motor drives one rear wheel by friction, the rubber tubing diameter being chosen to give the car the speed desired (better start off with small diameter tubing, till you have mastered the trick of steering!). The motor is hinged from two brackets so that most of its weight is on the drive shaft; a piece of sponge rubber at the free end regulates the actual friction on the wheel.

The steering mechanism, shown in Fig. 1210, is patterned after that found in large cars; each wheel is held on a pivoted stub axle, and the two are linked together in such a manner that they track quite well whether going straight or turning at any radius. The entire front wheel assembly is moved from side to side by a geared-down electric motor. The motor may be stopped at any position, to allow the car to make constant large- or small-radius

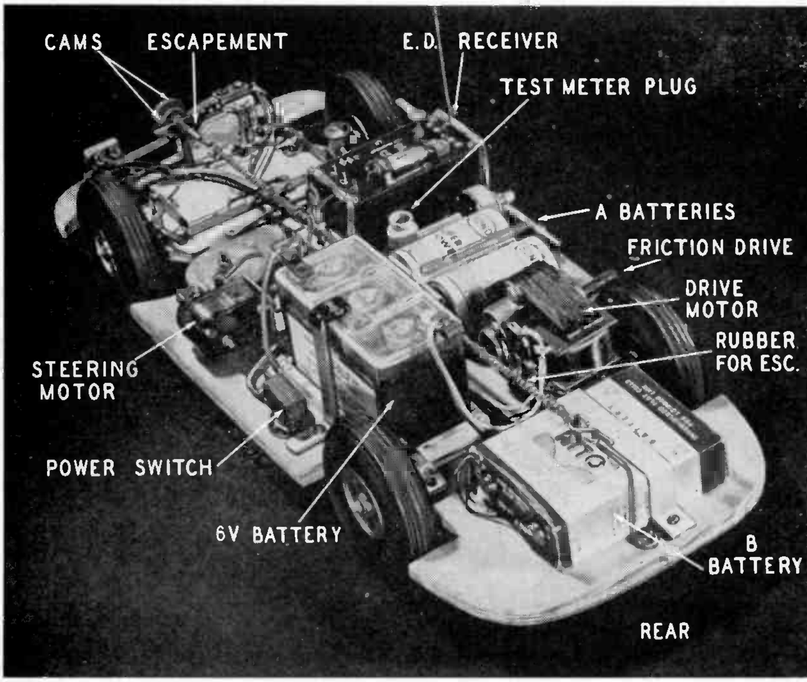


Fig. 1208. Photo of the inside of the Porsche car. All the works are below window level, adding to scale effect. The antenna is an elongated whip. The rubber band for the escapement runs practically the complete length of the car.

turns. Since the steering is too fast if the full 6 volts is put on the motor, an adjustable 10-ohm wire-wound resistor is provided to slow it down somewhat. This is shown in the top view chassis layout, Fig. 1211. Limit switches are positioned so that they will open and cut off the current to the steering motor if a steering signal is held too long; however, the opposite steering signal will immediately start the wheels back toward center. You have to learn to anticipate a bit, since the motor coasts somewhat after the turn signal is stopped. After a good amount of practice, though, you can pilot your car almost as well as you might be able to drive a full-sized one.

The steering motor is of the PM type, and gets its power through a reversing switch operated by an ordinary 2-position self-neutralizing escapement. The double-pole, double-throw switch contacts are moved by a cam (see Fig. 1212) that is fastened to the escapement shaft. The cam is sort of an egg shape, so that in the two neutral escapement positions the contacts are in mid-position, and open. One *operate* position then drives the steering

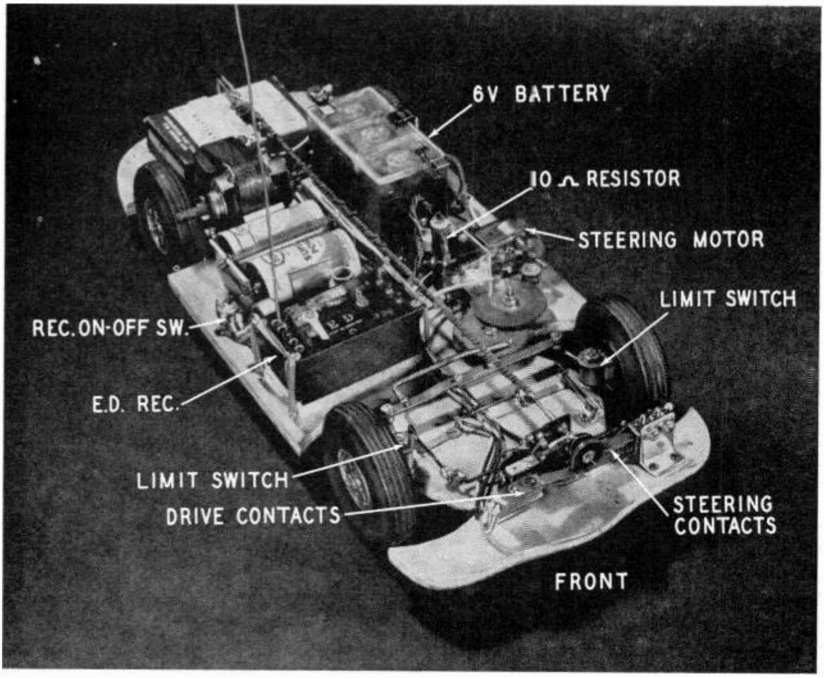


Fig. 1209. This is a photo of the chassis taken from the front. The drive motor is used to operate one of the rear wheels. Running this car will require some practice. The 10-ohm resistor is used to slow down the speed of the steering motor.

motor one way, the other moves it the opposite way. Since the escapement is a sequence device, you have to learn an entirely new manner of driving—you can't do it as you drive your own car!

The escapement also controls the driving motor through another cam which opens the circuit in one of the two neutral positions; the drive motor thus functions in the other neutral, and in both turn positions.

The entire radio installation in the car is a commercial job that comes all wired up and ready to use. It was put in just this way, with no changes whatever, except to add the cams to the escapement shaft. The receiver is held on a piece of sponge rubber by elastic bands, the two sockets (one for the test meter and one for the cable from the receiver) were raised above the chassis top by brass spacers and round-head wood screws. A small bracket

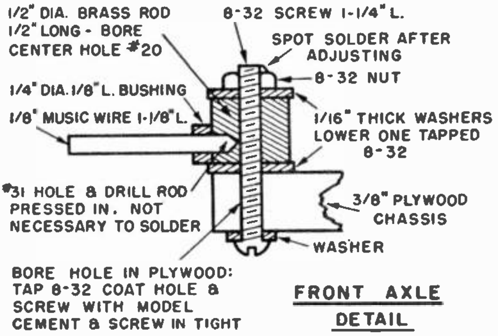


Fig. 1210-a. *This illustration shows the detail of the front axle.*

holds the variable resistor and the on-off switch goes through a hole in the chassis, with the knob under the edge of the chassis. This equipment can be had with either a hard-tube or gas-tube

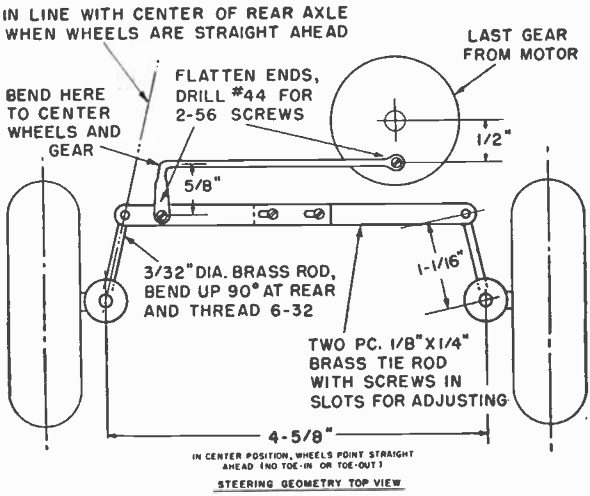
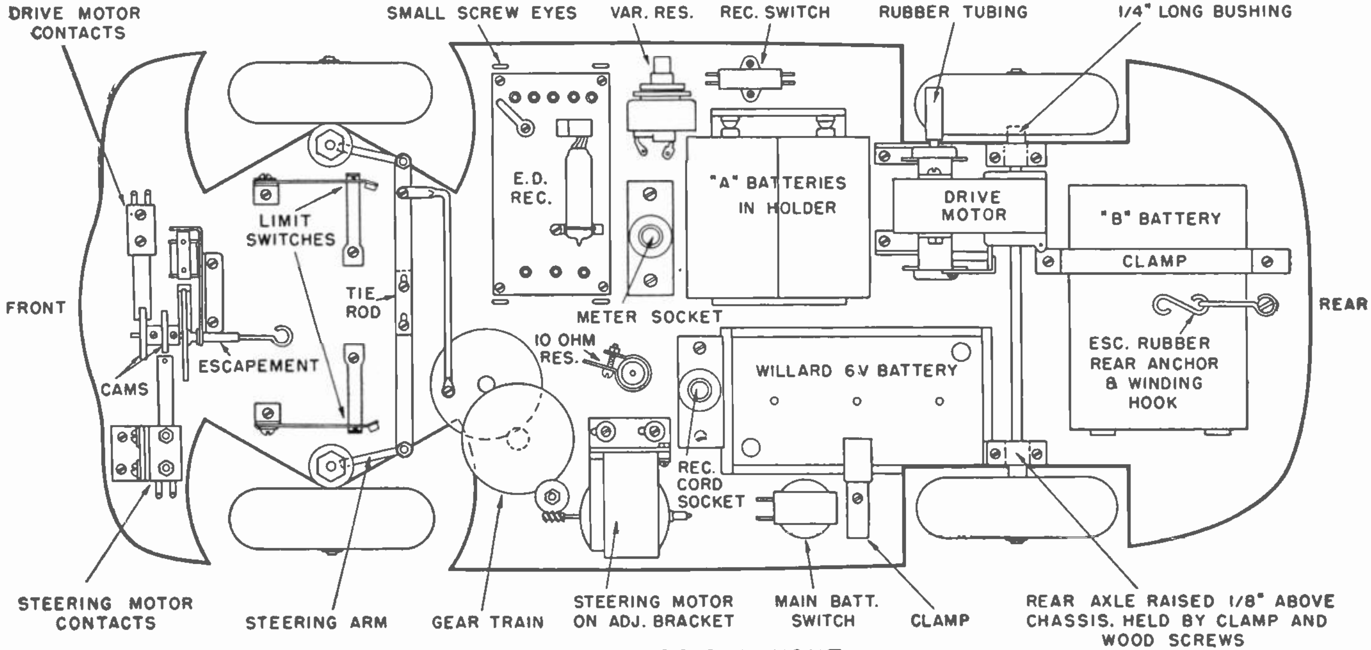


Fig. 1210-b. *Top view of the steering-wheel mechanism. With the steering gear in the center position, the wheels are set for the car to move straight ahead.*

receiver; we chose that latter, since gas tubers are much more tolerant to *electrical noise* made by opening and closing contacts, motor commutators, and the like, than are hard-tube receivers,



TOP VIEW CHASSIS LAYOUT

Fig. 1211. This chassis drawing shows the exact location of all the parts. The A batteries are mounted in a holder while the B battery is kept in place by a single clamp. The anchor for the escapement rubber band is fastened to the rear of the chassis. Since the rubber band for the escapement extends the entire length of the chassis, the parts must be mounted in such a way that there is no interference. The radio receiver used in this installation is a commercial type requiring no wiring and ready for immediate use.

It was found that the receiver was unaffected by any of the contacts, and neither motor, nor r.f. filters or noise suppressors of any kind were needed. The chassis wiring diagram is shown in Fig. 1213.

The antenna is a one-foot length of music wire attached to the body. The receiver has a variable antenna loading system that makes it possible to provide proper loading by shifting a tiny plug to any of five different sockets.

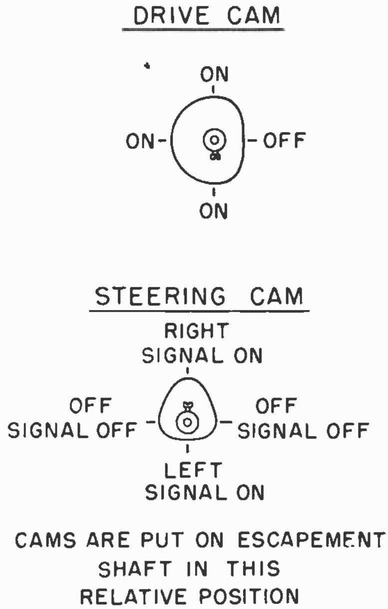


Fig. 1212. Drive cam and steering cam details. Note how the cams are positioned on the escapement shaft.

In view of the initial difficulty in learning to operate the car, it might be worthwhile to install a compound escapement; then you would always have, say, left with one pulse and right with two. The third position on the compound escapement could be wired to a second escapement to control the drive motor; if this second escapement were fitted with d.p.d.t. contacts as is the steering motor, you would be able to run the car forward or back, and stop it at will. You could also use one of the neutrals of the second escapement to cut in a resistor, for slow speed operation!

As noted previously, any CW transmitter of the proper frequency and a plain pushbutton will be usable with this car. However, "driving" it would be a lot easier, if the transmitter were fitted with a Beep Box to send the desired pulses automatically.

There is plenty of room on the car chassis for a good sized B battery, and the A supply is two large flashlight cells in parallel.

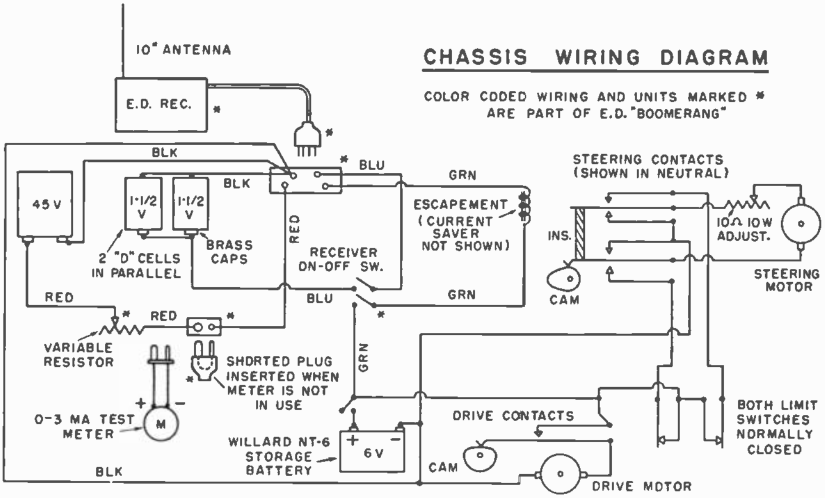


Fig. 1213. Wiring diagram of the chassis. You can control the speed of steering by experimenting with the setting of the slide on the 10-ohm resistor.

The fairly high current drain of the drive motor is handled by a tiny 6-volt storage battery which also runs the escapement and the steering motor. There is only a single switch for all these, since, if the escapement is stopped in the correct position, the drive and steering motors will be off when the receiver is turned on. Then, the first pulse you send starts things going.

The storage battery, available from most radio-control suppliers, must be charged at a rather low rate, to prevent damage;

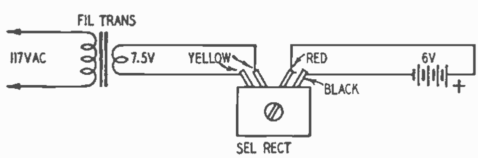


Fig. 1214. This very simple circuit will help you keep the storage battery fully charged.

don't hook it up to a regular car-battery charger, unless you use a series resistor to limit the current to about 500 ma. A diagram for a charger using an ordinary 7.5-volt filament transformer is shown in Fig. 1214.

Radio-control tractor

Another radio-controlled vehicle is shown in Fig. 1215. It is a caterpillar tractor, built up from a heavy-duty toy carried in most large toy stores. This is a rather ambitious project, if only because the tractor is rather small, and everything has to be crammed in; the tractor can be made to start, stop, go forward or reverse, and can be steered in either direction instantly and without any sort of sequence—a lot of control to be crammed in such a small package, and handled over a single radio channel.

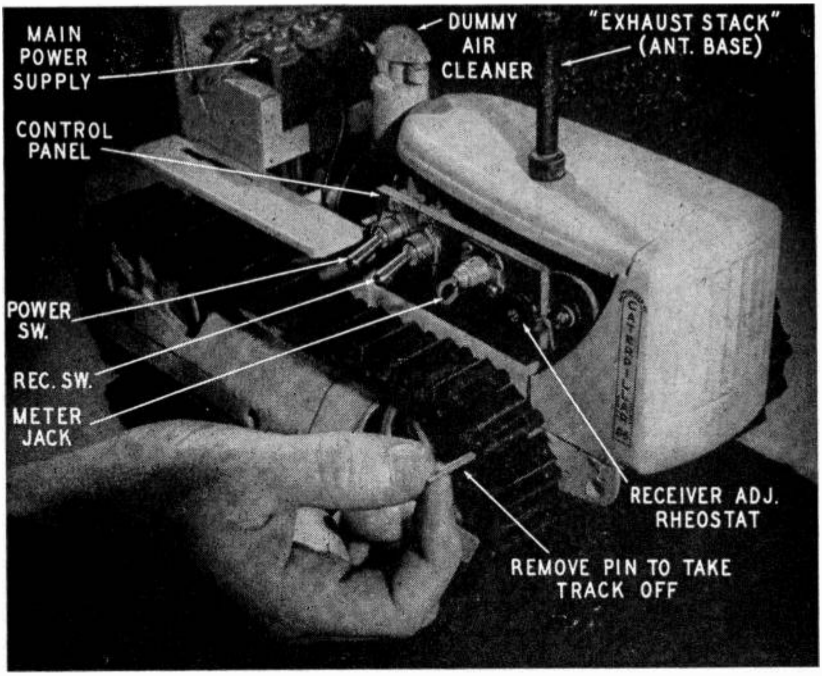


Fig. 1215. Photo of a tractor operated by radio control. A dummy exhaust stack is fitted to the top of the tractor and serves as the base for a vertical antenna. Commercial receiver and transmitter kits are used in this radio-control job.

Here again, commercial equipment was utilized, in the form of a radio-control transmitter and receiver kit. And for the same reason as in the radio-control car, a gas-tube receiver was fitted. It just isn't bothered by all those snapping relays and sparking motors. Just as insurance, a 100-μμf ceramic capacitor was connected across each motor, but it is believed that they are not really necessary.

Unlike the car, steering a unit of this sort is somewhat of a problem, unless you want to do it as they do in the big Cats, by stopping one tread or the other. That's just what we do, and the little tractor slews around on the stopped tread in most realistic fashion. It is lots of fun to run, and since you have full steering control whether it is going forward or back, it can be maneuvered into unbelievably tight places.

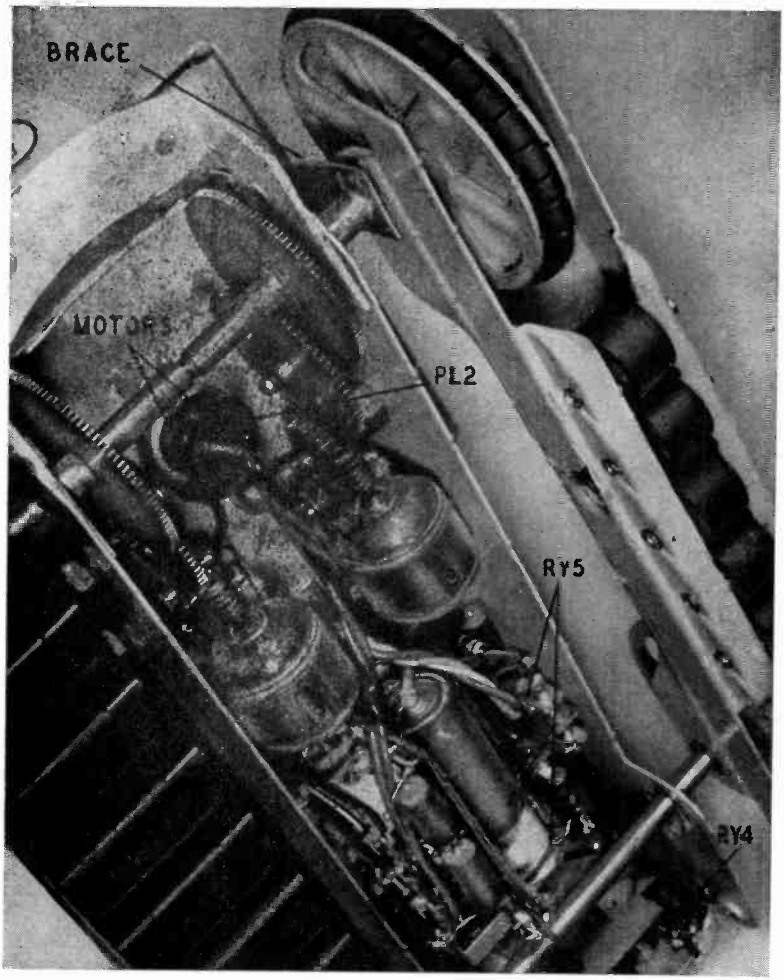


Fig. 1216. Details of the drive system. Each rear wheel of the tractor is operated by a separate motor. The front wheels are free turning. The motors are geared way down, so there is more than enough driving power.

As the tractor is purchased, it has no drive mechanism, and the first task is to install the motive power. The front wheels turn freely, while each motor drives one rear wheel. See Fig. 1216.

Tractors are supposed to move slowly, so we geared the drive about 800 to 1. A worm gear from an HO locomotive goes on the motor shaft, while the matching worm gear is attached to a small pinion. The worm and its gear have a 30-1 ratio, the next pair of gears are 4½-1, while the final set are 6-1. Any combination that will give the desired overall 800-1 reduction will do.

It is necessary to fit better axles for the wheels, and small rollers were installed in the bottom of each track frame, so the tractor can climb over books and other objects placed in its path, without stalling. The two rear wheels have plywood centers added; these were split in half and forced in between the wheel sides, with a

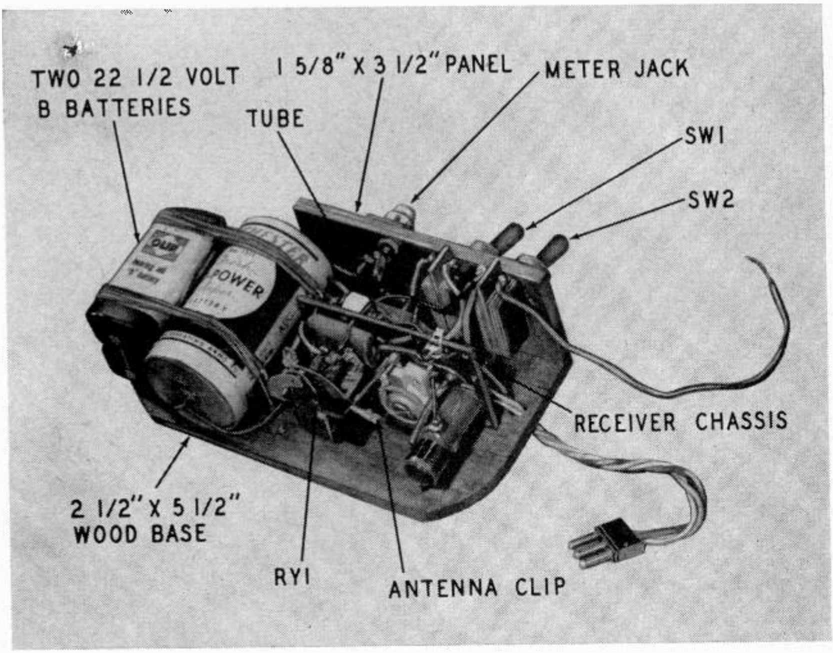


Fig. 1217. Photo of the receiver chassis with the batteries attached. The A and B batteries for the receiver are mounted on the wooden base. The receiver is mounted on edge so that the tuning controls can be reached from the side of the tractor hood.

generous application of model cement. When dry the wheels were chucked in a lathe, and the wood centers trued up, and grooved to fit the rubber tires. The latter were attached with heavy-duty rubber cement, and after installation, the outer surfaces were cut crosswise with a high-speed hand grinder. All this work on the rear wheels is for the purpose of assuring a good grip on the inside of the articulated plastic treads; if the wheels are found to slip in use, the front axle should be moved forward a bit more, to tighten the treads on the rear-wheel tires.

Tractor motors

The motors were found to be somewhat of a problem, since it is necessary to pick two that run at about the same speed. It is possible to insert a small resistance in series with one motor, if it is found to run faster than the other, but too much resistance will make the motor sluggish in starting. The holes in the HO model train worms are fortunately a bit too small to slide on the motor

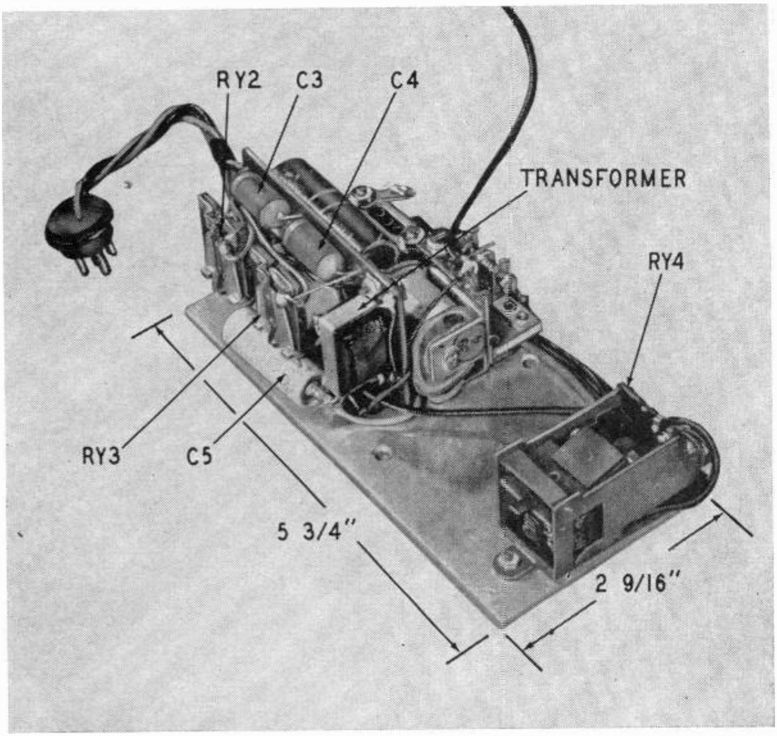


Fig. 1218. Photo of the control chassis. Note RY4 at the lower right. The control chassis, made of aluminum, is held to the underside of the tractor by three screws, two of which are wood screws and run into the receiver base.

shafts; each motor was run on 3 volts, and a very fine file held so as to slightly taper the outer end of the shaft. Then the worm was slid on and given a slight tap to seat it firmly. 2-56 screws hold the motors to the chassis, and allow a bit of movement, so the gears can be meshed properly. In addition, the chassis side holes through which the axles of the intermediate gears pass are made somewhat oversize, again to allow adjustment. There should be a slight amount of play between the teeth of all gears, when final adjustments are finished, and the tracks must turn without any binding whatever.

The space beneath the hood which was occupied by a plastic copy of a diesel motor when we got the tractor is filled by the receiver and its batteries, as shown in Fig. 1217. In addition, there is an instrument panel holding two switches, a rheostat and

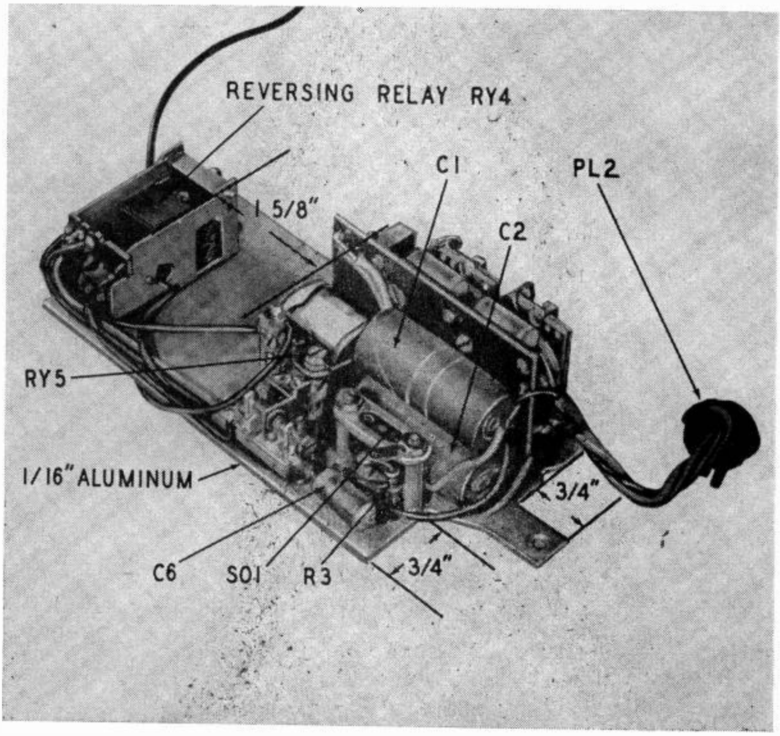


Fig. 1219. Another view of the control chassis. The reversing unit RY4 is mounted as far as possible from RY5, since its heavy magnetic field leads to erratic operation of the sensitive relay, if mounted too close to the latter.

a meter jack. The panel and base are cigar box wood, and the batteries are held by rubber bands. The receiver is mounted with the bakelite base vertical, so that it can be tuned up when in the tractor. It takes a bit of juggling to get the receiver unit in and out, when the batteries are in it, but it can be done once the trick is learned.

The antenna is a 14" length of music wire, that is held in a piece of black-bakelite rod, turned to represent an exhaust stack. A tiny clip on the antenna lead of the receiver enables quick detachment of the antenna connection. There are three leads from the receiver to the control unit under the chassis, and they terminate in a tiny 3-prong plug.

The control system is mounted on an aluminum plate, with many of the parts attached to a small bakelite panel. Note that the reverse relay RY4 (see Figs. 1218 and 1219) is mounted as far from RY5 as possible; this is necessary to prevent interaction.

Operation of equipment

Before going further with a description of the construction, let's see how the equipment functions, since it is quite different from

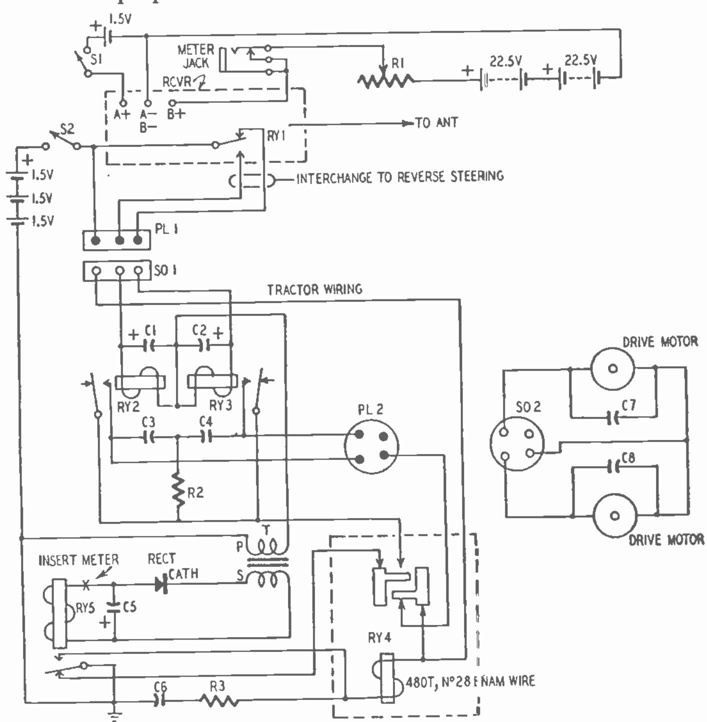


Fig. 1220. Wiring diagram of the entire control system of the tractor. Power for the entire unit (except the receiver) is obtained from three 1.5-volt storage cells. Storage cells can be recharged, but are much heavier than other types.

anything covered in this book previously. For normal straight ahead running, the receiver gets a series of rather slow pulses, and the receiver relay RY1 therefore continuously opens and closes. Each of the contacts of RY1 (see Fig. 1220) connects to an auxiliary relay (RY2 and RY3); since there are large electrolytic capacitors (C1 and C2) connected across each of these windings, they stay closed as long as pulses above a certain rate are received. When both are closed, the two drive motors run steadily. Thus each auxiliary relay governs the operation of one drive motor; when a solid signal comes in only one motor can run, while with no signal at all, the other motor runs.

The common return lead from the relays RY2 and RY3 goes through the primary of a transformer T, before getting back to the minus of the 4½-volt battery. Every time RY1 opens or closes, therefore, a pulse of d.c. goes through the primary of this transformer, where it is stepped up and put through a rectifier. The resultant d.c. goes to a very sensitive relay RY5, which also has a capacitor, C5, across it to slow its action. Now we don't want this relay to operate when the straight-running pulses are coming, so its spring tension is such that it will not pull in no matter whether pulses or solid signal come in, as long as those pulses are slow. To work RY5, we must send rapid pulses; RY2 and RY3 will close as we want with either slow or fast pulses, so fast pulsing affects only RY5. Normally, RY5 gets a current of about .5 ma, and the spring is set so that this will not pull it in. When pulses of about three times normal speed come in, RY5 gets about 1 ma of current and closes. This action sends current to RY4, which is a model-train reversing switch, and the two drive motors are stopped or reversed.

RY4 must be rewound to work on our low voltage. 480 turns of No. 28 enameled wire allow it to work with a real kick on the 4½-volt supply. RY5 is wired to cut the power to the two motors as soon as it is actuated, so there is no arcing whatever on the drum and brushes of RY4. The armature of the latter is held open by its own weight. The unit will not work correctly unless it is turned with the armature downward, a point to remember when you are first checking operation. It is a sequence device, giving two off positions, a forward and a reverse.

To facilitate easy removal of the various parts, two sets of plugs and sockets were used; the motor leads connect through PL2 and SO2, while PL1 and SO1 make connections between the receiver and the control unit. The battery plus lead also goes through PL1, to the control unit, while the negative lead from the latter connects directly to the battery.

Since it was expected that the tractor would be run for considerable periods of time, it was felt advisable to fit it with storage cells that could be recharged; the power for all circuits except the receiver comes from three type 3 AH Silvercels connected in series. They are just the right size to fit into the space occupied by the seat, which was removed. They are held firmly by rubber bands, so they will not drop out if the tractor is turned upside down. If you want a lower cost power supply, you could use six or more size D flashlight cells connected in series-parallel; even larger dry cells could be carried in a small trailer, which the tractor has plenty of power to pull.

The receiver relay is set to about the right adjustment as it comes in the kit, but some adjustments are needed for RY2 and RY3. They should have the armature spring tension reduced, till

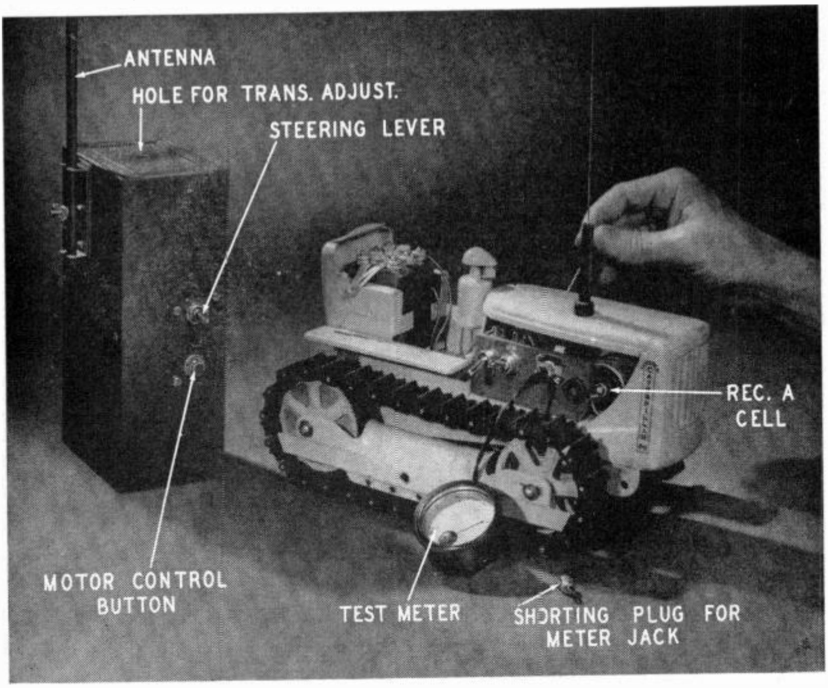


Fig. 1221. Photo of the tractor with receiver in process of adjustment. The transmitter is contained in the box at the left.

the armature will just snap reliably open when the coil is not energized. The upper contact should be bent down so that there is a gap of .006-inch, between the armature and lower contacts, when the coil is not energized.

RY5, as mentioned before, must work on very little current. Turn the normally-open contact so that there is a gap of .010 inch between the armature and core, when the former is held in by hand. Then set the other contact to give a spacing between contacts of .0025 inch with no current. The final adjustment of the tension spring must be made after the equipment is set up for test.

To get the entire tractor ready to go, tune the receiver to the transmitter, according to the directions in the kit, and set the receiver plate current to about 1.3 ma with the variable resistor on the control panel. Pull PL2 from its socket, so the motors won't run, and turn on the receiver and transmitter; with the latter pulsing steadily (neutral, or straight-ahead position of the

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List of parts for receiver and control unit

1-Super-Aerotrol receiver kit with relay RY1; 1-XFG-1 tube; 1-half-wave rectifier, Raytheon CK705.

Switches: S1 and S2, s.p.s.t. toggle.

Plugs and sockets: Miniature 3-prong plug and socket (PL1, SO1); miniature 4-prong plug and socket (PL2 and SO2).

Relays: Price midget 6-volt, 80-ohms (RY2, RY3); reversing switch (RY4); 8,000-ohm Sigma 4-F (RY5).

Capacitors: 250-μf, 6-volt electrolytic (C1, C2); .1-μf midget, paper, (C3, C4, C6); 50-μf, 12-volt electrolytic (C5); 100-$\mu\mu f$ ceramic (C7, C8).

Resistors: 47-ohm, ½-watt, carbon (R2, R3).

Batteries: 4-½-volt power battery, 3 Silvercel LR3 midget storage cells or D-size flashlight cells; 2 22½-volt hearing-aid B; 1-D-size flashlight cell.

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control lever) both RY2 and RY3 should hold steadily in the closed position. When the steering control lever is moved first one way, then the other, first one relay, then the other should open. See Fig. 1221.

To check the stop and reverse circuits, connect a milliameter at point X, in series with the winding of RY5, and turn on the transmitter and receiver: you should get a reading of about .5 ma. If it is much less than this, try reversing the leads to the primary of T. Now push the forward-reverse button on the transmitter. The relay current should raise to .9 ma or more, causing RY5 to close, and in turn, operating RY4. If RY5 doesn't release as soon as the transmitter button is released, a quick flip of the steering lever to either side will make it do so.

The transmitter and pulsing unit

The transmitter is built up just as the kit directions specify, but only one 67½-volt battery is used. In place of the second one, a small aluminum chassis is bent up and attached to the cover. This chassis holds the pulsing relay RY, plus C1, C2 and R. SW2 and SW3 are attached directly to the cover, while SW1 is a d.p.s.t. unit that replaces the original on-off switch of the transmitter. The contacts of SW2 must be bent so that they are as shown in Fig. 1222, when the lever is centered; then *right* will close the lower contacts and give a solid signal, while *left* will open the upper pair, giving no signal.

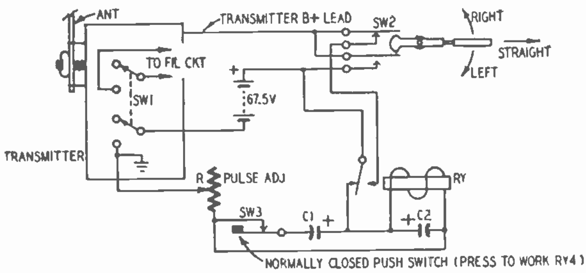

Fig. 1222. Pulsing control unit used for the radio-controlled tractor. Details of the transmitter circuit are not shown since this is supplied with the kit.

When SW3 is depressed, C1 is removed from the circuit, and the relay pulses at a high rate. RY is adjusted the same as described for the pulser in Fig. 807; be sure this relay is mounted

List of parts for transmitter and pulsing unit

1-Super-Aerotrol transmitter kit; 1-3A5 tube; 1-1½-volt A battery; 1-67½-volt B battery; 1-8,000-ohm Sigma 4F relay; 1-d.p.s.t. switch (SW1); 1-Switchcraft 3037 steering switch (SW2); 1-Switchcraft 103 normally-closed push-button switch (SW3); 1-25,000-ohm potentiometer (R); 1-20-μf, 150-volt electrolytic (C1); 1-5-μf, 150-volt electrolytic (C2).

on a piece of insulation, since the entire frame is "hot." Potentiometer R serves to vary the pulses, best results being had when the pulses are roughly 50% on and off. R also changes the pulse speed, which is handy to get a close setting for operating receiver relay RY1.

This same transmitter was used to work the little boat described at the beginning of this chapter. As shown there, SW3 is not needed. When used with the boat, R is turned till the boat follows a straight path. It was found wise to reduce the value of C1 to 10 μf to speed up the pulse rate a bit; for the boat, SW3 and C2 could be omitted, with C1 connected right across the relay winding. The transmitter is illustrated in Fig. 1223.

The three complete control systems shown in this chapter can be varied, to make up an arrangement to suit your own purposes. And by addition of circuits shown in other parts of the book, you

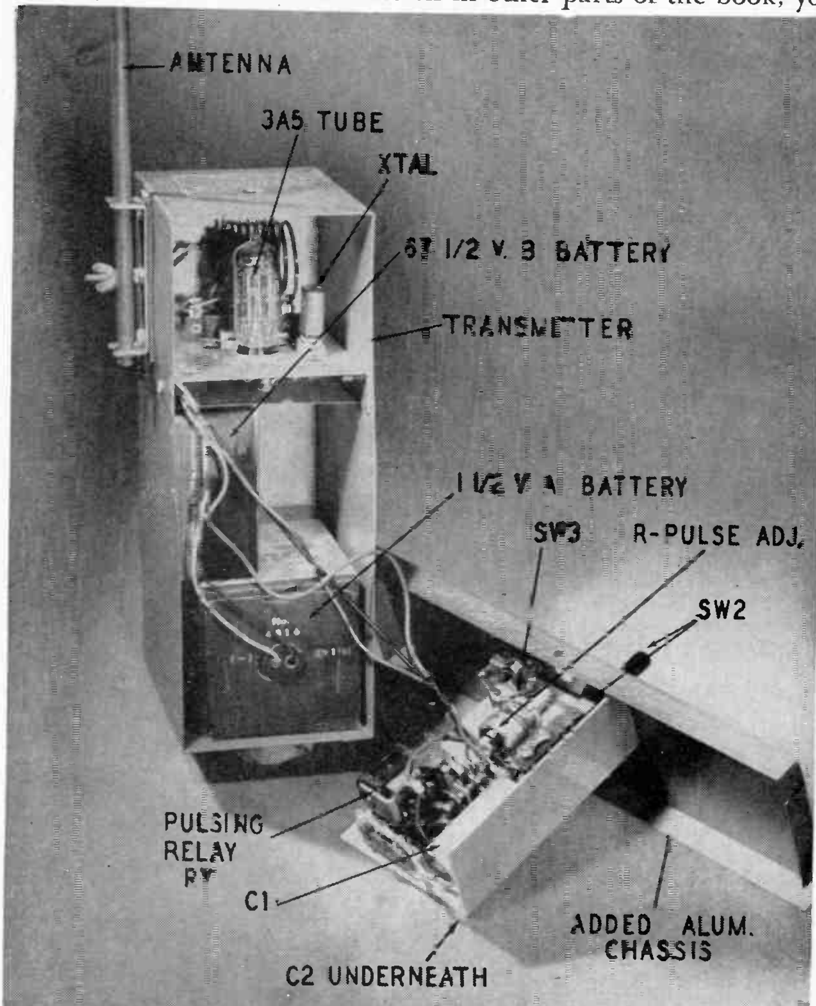

Fig. 1223. Photo of the transmitter and its associated control unit. When assembled, the control unit fits the space immediately above the 1½-volt cell shown at the bottom of the transmitter case. The transmitting antenna at the upper left of the transmitter case, is held in place with a single wing nut. The pulsing relay, RY, is mounted on a piece of insulating material.

can scheme up a bewildering array of control systems. It is the working out of complete control systems—and making them operate as you intended—that is the real fun of radio control modelling!

Relays

A brief description of relay adjustment has been given in Chapter 10, and the use of relays has been mentioned in many spots throughout the book. Simple radio-control equipment requires but one relay—the sensitive relay in the receiver; but radio-control equipment is getting more and more complex, and relays are now used for many other purposes than this. In order to give the reader a few more ideas along this line, we are adding this material, hoping that the information will enable the experimenter to do more with the relays he may have at hand.

Hobbyists and experimenters, needing a relay for a special control setup, must make a selection from the comparatively few "stock" items offered to the general public. When a desirable item is listed in a manufacturer's catalog, you may find that local

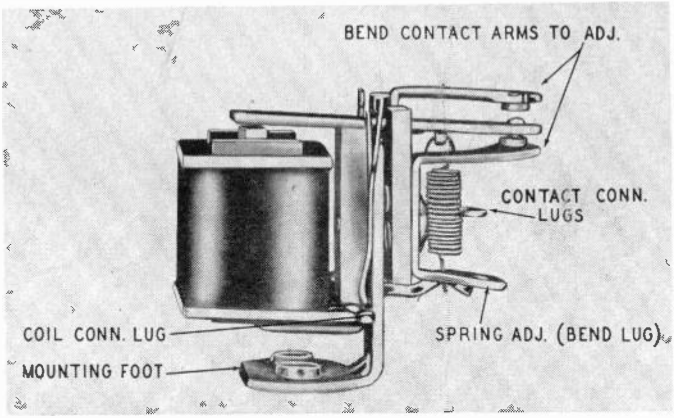

Fig. 1224. Picture of a sensitive relay. A spring, one end of which is connected to the armature, controls the sensitivity of the relay. The greater the spring tension, the less the sensitivity will be. In some relays the spring is connected to an adjustment screw. If there is no such adjustment, it will be necessary to stretch the spring to increase sensitivity. Do this carefully; avoid overstretching.

distributors and retailers, catering primarily to the service trade, do not carry the item in stock.

On the other hand, a factory design engineer does not hesitate to specify a special relay for a new piece of equipment because he can be sure of getting it. Many manufacturers make only a few stock relays, with the major portion of their business represented by relays designed for special applications and supplied in quantity on special order. These special relays are usually made by modifying the number of contacts, coil resistance, contact arrangement, and other characteristics of a standard model.

If you have a relay problem, you may find the solution in this description of the more common techniques which may be used to adapt a common relay for specific applications.

Increasing sensitivity

Since proper relay operation is vital to the functioning of any radio-control system, let's briefly consider again the problem of adjustment.

Relay sensitivity is determined by a number of factors, including weight of the armature, spring tension, spacing between the armature and core, and coil characteristics. Many of these factors are beyond the control of the experimenter unless he is willing to actually rebuild the relay. However, the sensitivity of small relays may be increased by either of two methods.

The first is to reduce the spring tension. Do this by stretching the spring slightly or by bending either of the hooks holding the spring. See Fig. 1224. In some relays, one end of the spring is attached to an adjusting screw, and spring tension may be changed easily . . . either by adjusting a nut or turning a screw. *If it is necessary to stretch the spring, it should be done very carefully. Take special pains not to overstretch the spring or to deform its shape.*

The other method of increasing sensitivity is to move the armature closer to the coil core. The best way to do this in the type of relay shown in Fig. 1225 is by adjusting the back contact to move the armature down toward the core so the contacts are brought closer together. This technique is limited by the current and voltage at which the contacts make or break. Where the voltages are low, as is the case in most radio-control applications, very close spacing may be used. If any amount of current is to be broken, it is always wise to use an arc suppressor; if this is done, some of the smallest and lightest relays used in radio-control work may be set so that there is a gap between the contact points of only one- or two-thousandths of an inch.

Reducing relay sensitivity

All you have to do is to reverse the techniques described earlier to reduce relay sensitivity. That is, increase the spacing between armature and core or increase spring tension, or both.

In addition, resistors may be used either in shunt or series with the relay to change the sensitivity. Where the relay is operated by a current change, which is the case with relays used in the plate circuits of vacuum tubes, a shunt resistor may be used. Such a resistor is also sometimes used when a relay has too high a resistance for the circuit and plate voltage that is available. Where control depends on a voltage change, a series resistor is used. Both methods are illustrated in Fig. 1226-a. -b.

Since the resistor size is determined by the control voltage (or

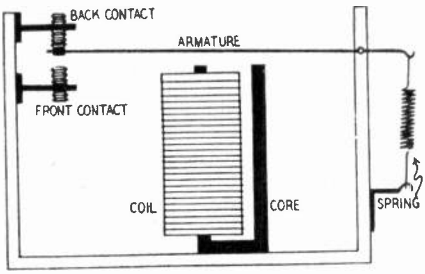

Fig. 1225. This drawing shows the construction of a typical double-throw type of relay. A single armature may carry several independent moving contacts.

current), the change in sensitivity desired, and the coil characteristics, it is generally difficult to specify the size beforehand. In most cases the resistor size is determined experimentally. For variable sensitivity, use a variable resistor.

Self-latching relay

More power is required to close a relay than is necessary to hold the relay in, once closed. This fact may be used to advantage in designing a self-latching relay circuit. The circuits for both current-controlled and voltage-controlled relays are given in Figs. 1227-a and 1227-b respectively. In Fig. 1227-a, the resistor is adjusted to bypass sufficient circuit current so that the relay is held closed, but so that there is not sufficient current through the coil to pull the relay in, once opened. When the control current is stopped (or reduced sufficiently), the relay opens, and will remain opened even though the control current is restored to its normal value, until the RESET SWITCH is pressed to open the shunt circuit and permit the relay to pull in again.

The circuit in Fig. 1227-b operates in a similar fashion, except that a series resistor rather than a shunt resistor is used. This circuit is suitable for voltage-controlled relays. In this circuit. the variable resistor is adjusted so the current through the relay is too weak to close the relay but it is strong enough to hold it closed if the armature is depressed manually. Interrupting or reducing the voltage will cause the relay to open. It will not close—even though the normal voltage is reapplied—until the

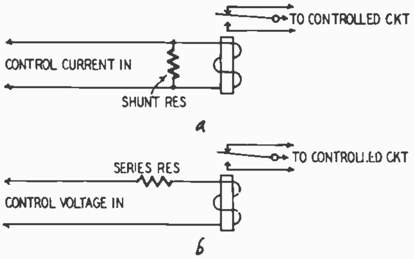

Fig. 1226-a, -b. The shunt resistor (in the illustration at the top) reduces sensitivity and adapts a low-current relay to a high-current control circuit. The series resistor (bottom illustration) reduces the sensitivity and prevents voltage breakdown in the coil of the relay.

RESET switch is closed momentarily to short out the variable resistor.

Sensitive a.c. relays

Extremely sensitive a.c. relays are not generally available except on special order. The circuit shown in Fig. 1228 will give satisfactory results as a substitute for an a.c. unit. A small instrument rectifier (such as used in multitesters) and a sensitive d.c. relay make up the circuit. These small rectifiers cannot deliver more than a milliampere or two (depending on the type employed) and are limited as to maximum voltages. However, sensitive d.c. relays requiring only a milliampere or two are easily obtained at reasonable prices.

Time-delay relays

Three different time-delay circuits are shown in Fig. 1229. Each is designed for a different application, and all may be used to give a wide range of time delay. In each case, C1 is generally an electrolytic, with the values of both C1 and R1 chosen experimentally to give the desired time delay. The exact values depend on the resistance of the relay coil, the control voltage, and the delay time. The relay is generally a high-resistance (5,000-ohm to 10,000-ohm coil) unit.

The circuit in Fig. 1229-a is designed to hold the relay closed for a given time after the control voltage is removed. In operation, closing S1 charges C1 and pulls in relay RY1. After S1 is opened, the capacitor C1 discharges slowly through R1 and RY1. RY1 stays closed until the discharge current drops below the hold-in

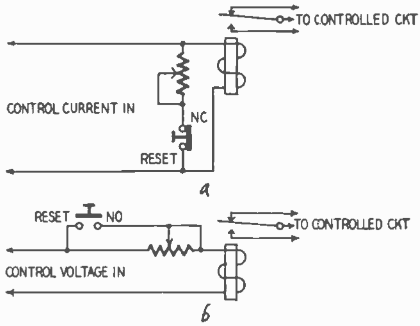

Fig. 1227-a, -b. Two types of self-latching relays. In the upper illustration, the circuit is controlled by a change in current. In the lower illustration, the circuit is controlled by a variation in the applied voltage. (NO-normally open; NC-normally closed)

current for the relay. In this circuit C1 may be either a paper or an electrolytic capacitor.

When the circuit shown in Fig. 1229-b is used, the relay closes immediately when S1 is closed, but opens automatically shortly after, even though S1 remains closed. In operation, closing the

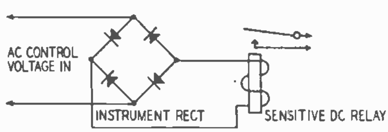

Fig. 1228 The use of an instrument-type rectifier adapts the sensitive d.c. relay to an a.c. circuit. This rectifier is a full-wave bridge type, supplies fairly uniform d.c. output. The rectifier is small and is very light.

switch permits C1 to charge from the control voltage. As long as C1 is charging, current flows through the circuit to pull in RY1 and hold it closed. When C1 approaches maximum charge, the charging current drops, permitting the relay to drop out. If it is desired to open the relay at any time before the end of the delay period, it is necessary only to open S1, in which case RY1 opens immediately.

An electrolytic capacitor is preferred for C1 (in Fig. 1229-b) because its internal leakage will permit it to discharge completely

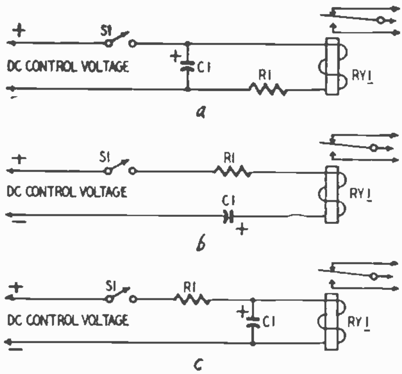

Fig. 1229-a, -b, -c. In the illustration at the top, RY1 remains closed for a short interval after the opening of S1. In the center illustration (b), the relay closes when S1 is closed. It then opens automatically after a timed interval when capacitor C1 is charged. In the illustration at the bottom, the operation of RY1 is delayed on opening or closing control switch S1.

between operating cycles. However, a paper capacitor may be used if shunted by a high resistance to provide the necessary leakage.

The circuit given in Fig. 1229-c closes the relay at a predetermined time *after* the control voltage is applied. In operation, when S1 is closed, C1 charges slowly from a voltage divider consisting of R1 and the relay coil resistance in series. The current through R1 is the sum of the capacitor-charging current and the current through RY1. The current through RY1 does not reach a level high enough to pull in the armature until C1 is nearly charged.

This circuit also has a slow-opening time-delay characteristic. When S1 is opened, C1 discharges through the relay coil. The relay stays closed until after the discharge current has dropped below the relay hold-in value. However, proper choice of components will keep the drop-out time down to a fraction of the pull-in time. Either a paper or electrolytic capacitor may be used for C1 in Fig. 1229-c.

Increasing contact current

Very often the problem of controlling an extremely heavy current with a small control current arises in design work. Unfortunately, the most easily obtainable sensitive relays cannot handle large currents because the contact must be small to keep the armature weight as low as possible. In such cases, the usual technique

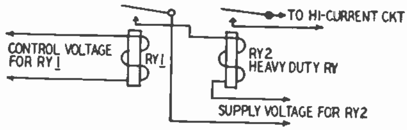

Fig. 1230. The sensitive relay RY1 controls the coil circuit of heavy-duty relay RY2.

is to use one relay to control another. See Fig. 1230. The sensitive relay, RY1, is operated by the weak control current, and, in turn, controls the heavier current required to operate the heavy-duty relay, RY2.

Series and parallel relays

The number of contacts and the contact arrangement may be modified easily in some types of commercially available relays. In others, especially the more sensitive types, changing the number of contacts is difficult. In addition, it may prove next to impossible to obtain a stock relay with the desired contact arrangement. In such cases, two or more relays may be connected in series or in parallel to give the desired circuit arrangement.

Two s.p.s.t. relays are shown connected in parallel in Fig. 1231-a to provide the equivalent of a d.p.s.t. relay. In Fig. 1231-b a single-pole, normally open and a single-pole, normally closed relay are used together to provide s.p.d.t. action. Although the relay coils have been shown connected in parallel in both cases, they could just as well have been connected in series. The method of connection depends on the control voltage (or current) available. When using two or more relays together as outlined here, it is important that the relays have similar characteristics (coil resistance, armature tension, and size), regardless of individual contact arrangement. This is necessary if the relays are all to operate simultaneously. There is a ways a slight variation in pull-in and drop-out time for different types of relays.

Relay techniques

While the methods outlined represent the more basic techniques of adapting existing relays to specialized applications, they

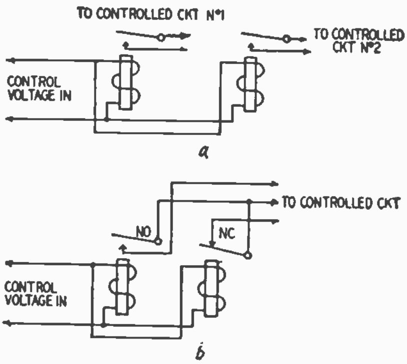

Fig. 123-a, -b. In the top illustration we have a common method of adapting two s.p.s.t. relays for d.p.s.t. use. In the figure at the bottom we have two s.p.s.t. relays (one normally closed) in a s.p.d.t. application. (NO-normally open: NC-normally closed).

by no means represent all possibilities. It is perfectly feasible to combine two or more of the techniques described for special jobs. For example, one of the time-delay relay circuits might be used not only to operate equipment, but also to switch on, in turn, a different type of time-delay relay which is used to control still another piece of equipment.

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