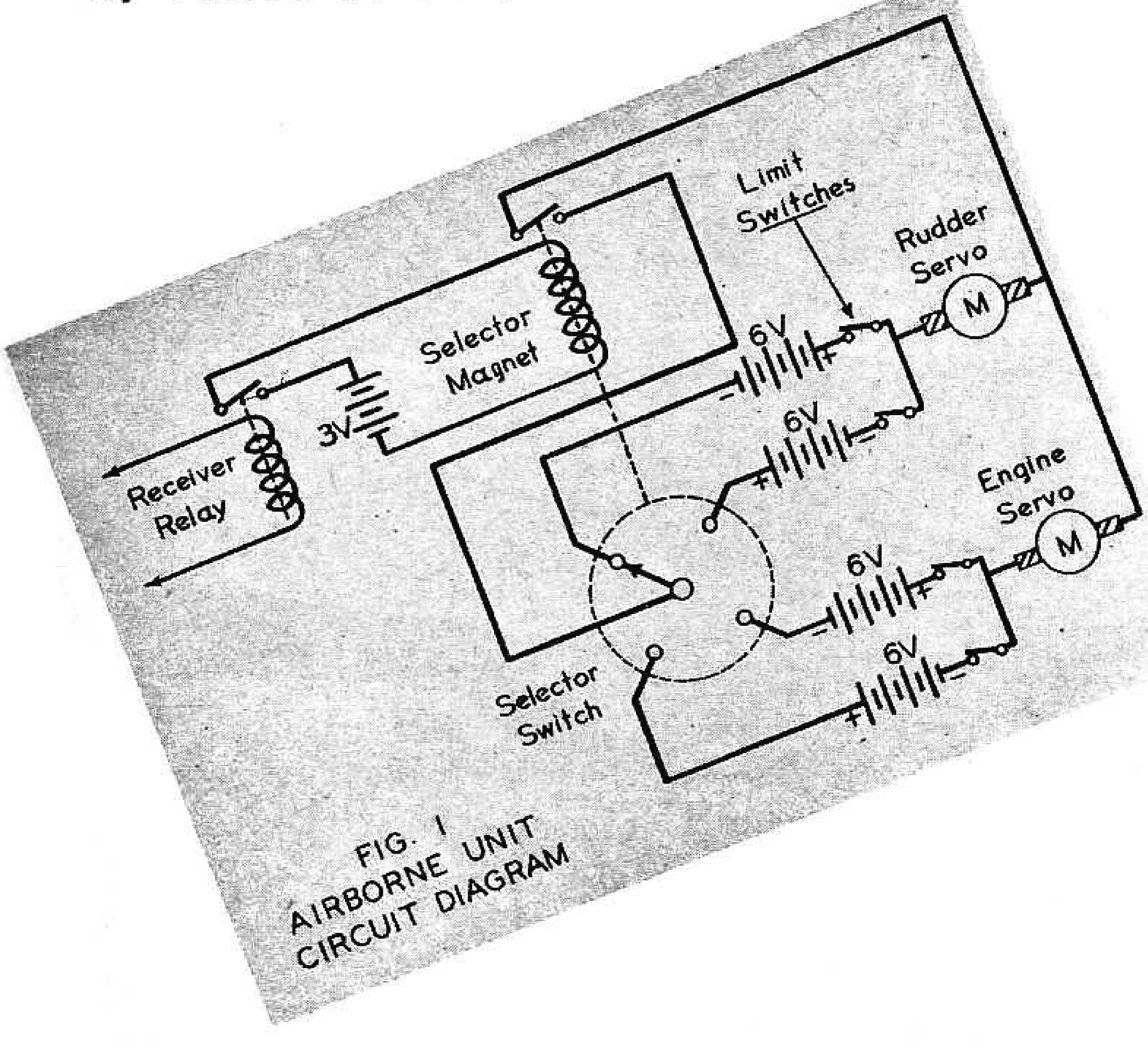
by James R. Custin



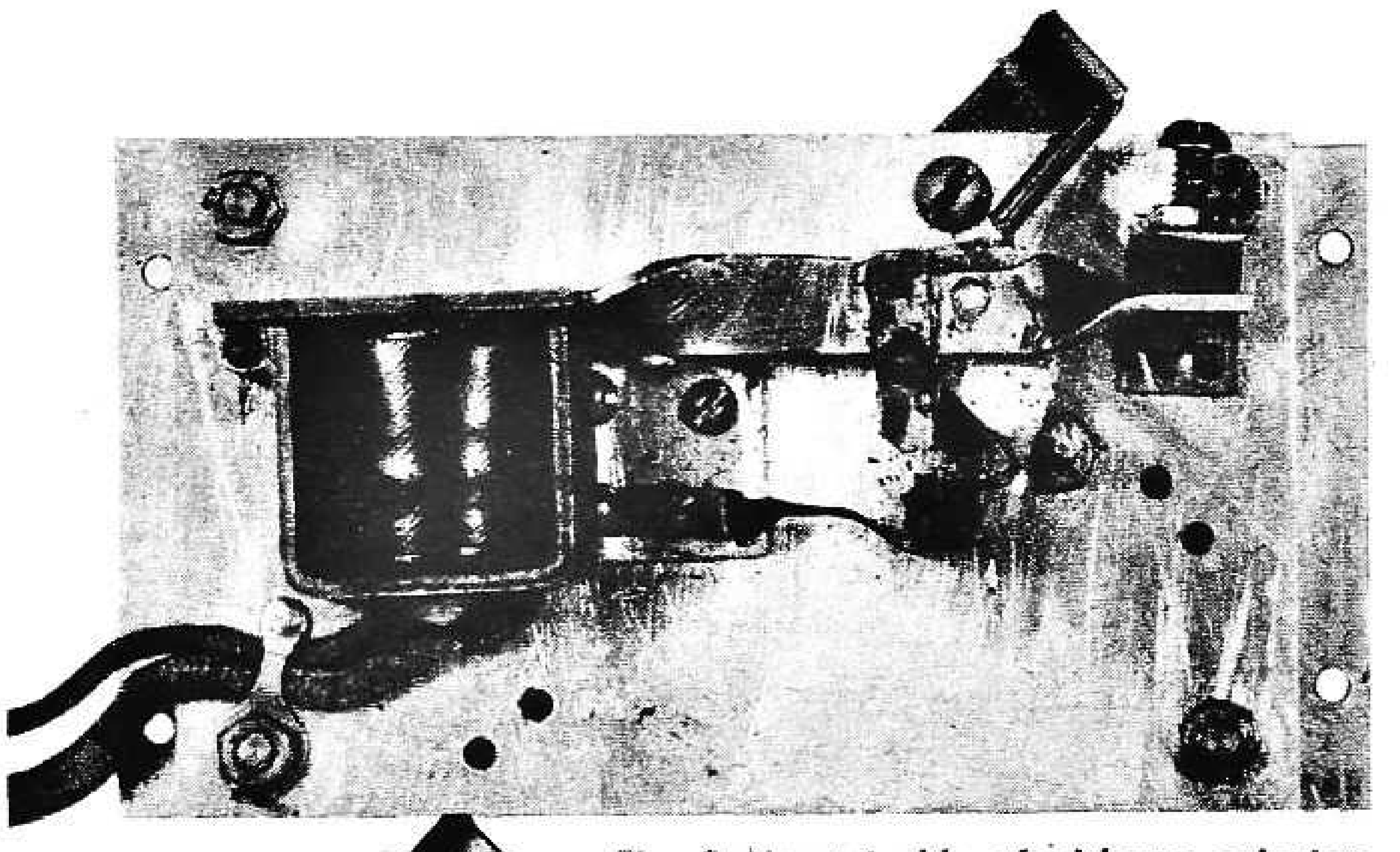


Fig. 3 Magnet side of airborne selector

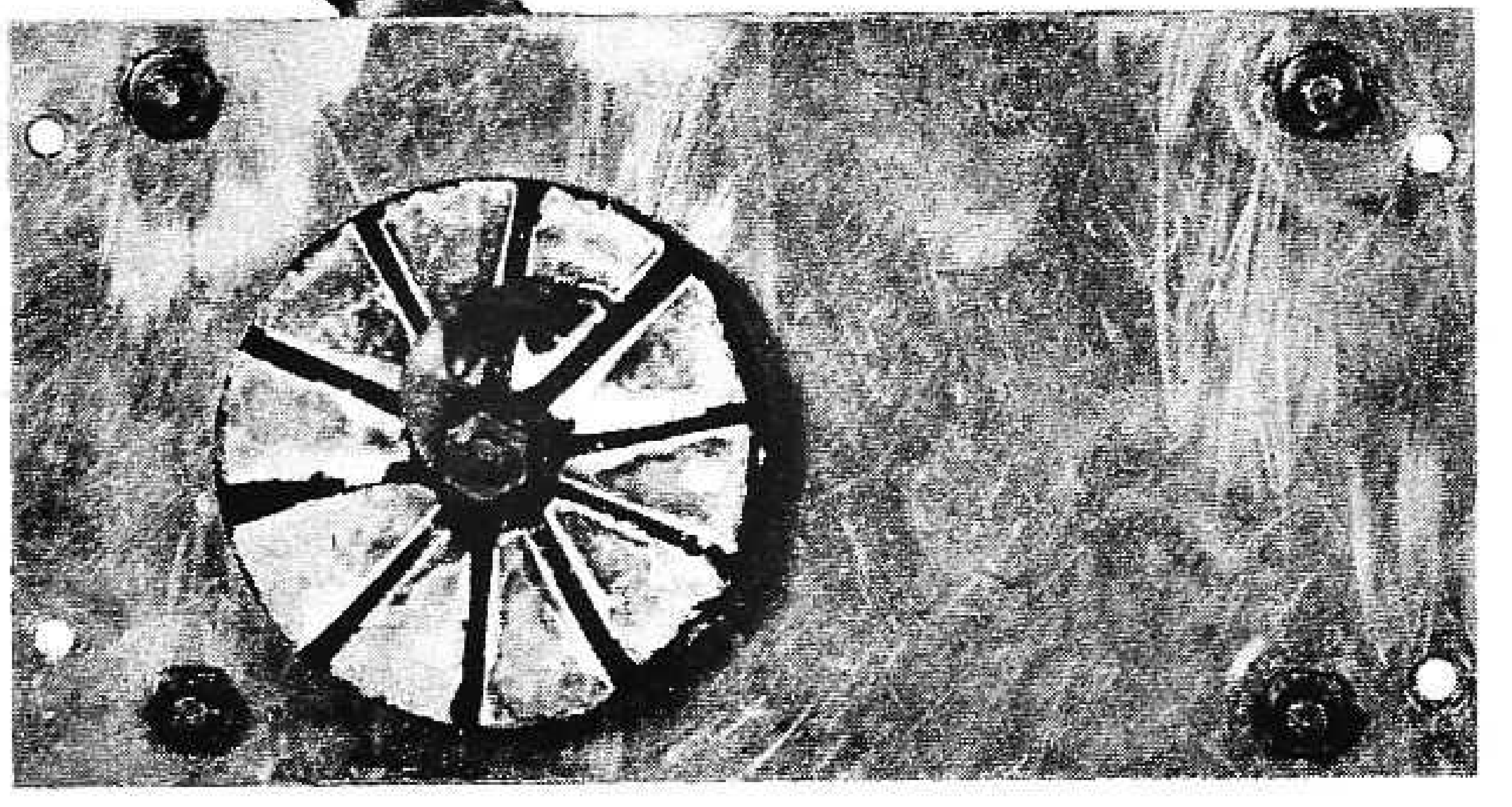


Fig 2 Top of airborne selector unit

COCKPIT RADIO CONTROL

PART I

WHEN my brother Tom and I began working on the development of a model airplane radio control system we set out to achieve the ultimate in realistic control operation—a system in which the ground control station would be in every essential respect a reproduction of the cockpit of a man-carrying ship, so that the operator could control the flight of the model with the same type of controls used on a big airplane, moved in exactly the same way.

Thus the ground "cockpit" of our control unit would be equipped with the usual joystick and throttle levers, and each control on the model would be made to follow accurately the movements of the appropriate lever of the ground control station, always taking a position corresponding exactly to that in which the lever at the "cockpit" was placed.

It is obvious that only a rather intricate mechanism will fulfill these requirements; but the problem is further complicated by stringent weight limitations. AMA rules permit a 15 lb. maximum gross weight for a radio controlled model, but 10 lbs. is the practical maximum for a model powered by any of the more popular engines now on the market.

We estimated that our airborne control unit would have to weigh less than 4 lbs. if it was to be carried by a ship built to this limitation; and 3 lbs. seemed a much more desirable figure. This would include the necessary batteries, as well as the receiver or receivers, selector, and control activator units.

Eventually we succeeded in building a fairly successful model in which the airborne control unit weighed 3-1/2 lbs., including an 8-1/2 oz. "B" battery—a compromise between what we wanted and what we could have. Although we were never completely satisfied with the system we developed, we did make a few successful flights with it. Unfortunately our "team" was separated by a matter of a thousand-odd miles before we could achieve all the refinements in the system that would bring it to a state of perfection; but we convinced ourselves that we were on the right track and that we had a cockpit type control system that really worked.

This article, therefore, is not a set of instructions that will enable the model builder to assemble a proven cockpit radio control system in a few evenings at home. Rather, it is a discussion of the systems and equipment with which we experimented, intended to point out some lines of approach and the possibilities that they present for those who are willing to do the necessary engineering to bring the radio control system de luxe to its full state of development.

As we began our preliminary design work, we decided to limit ourselves at first to a two control system, providing means for controlling only engine speed and rudder position. We reasoned that directional control of the model is obviously necessary; and since a model having a high degree of inherent stability will respond satisfactorily to displacement of the rudder alone, the additional complications entailed by aileron controls or linkages are unnecessary. It is also desirable to provide some means for controlling the ship's altitude. This may be achieved by an elevator control, but there is always the uncomfortable possibility that the control mechanism may stick when the elevators are down. On the other hand, a well designed gas model will climb under full engine power, fly level at some cruising rpm, and descend when the engine is idled or cut. We therefore decided to concentrate for the time being on precise control of engine rpm as our means for controlling altitude, adding an elevator control after we had perfected the system.

Engine speed regulation may be accomplished either by controlling the position of the spark timer lever or by means of a controllable butterfly valve on the carburetor venturi; but best results are obtained from a combination of the two. Thus the ideal two cycle engine for a radio controlled model would have a linkage connecting the timer arm with a butterfly valve on the carburetor, so that closure of the butterfly valve would be proportionate to retardation of the spark, thus simultaneously enriching the mixture and reducing the fuel charge to the cylinder as the spark is retarded. We did not do any experimental work on this feature but took the course of least resistance by providing only a control for the timer arm.

The mechanical design of the radio control system presented some additional considerations to which we gave much thought. Our first problem was to select the type of servo unit or control activator that would best suit our needs. It was obvious that the popular and practical rubberband escapement activator would not be satisfactory since it provided only a limited number of control positions.

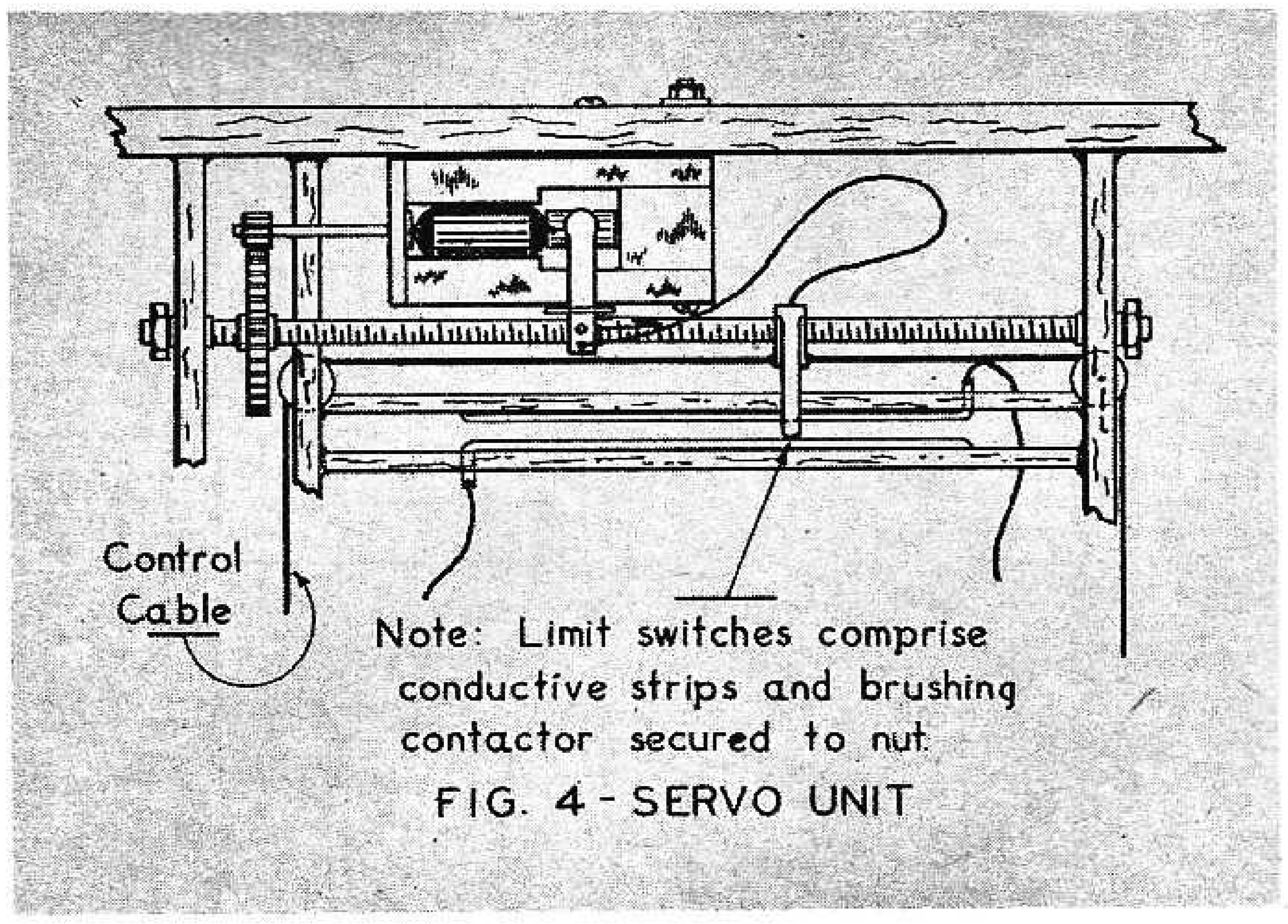


FIG. 4 - SERVO UNIT

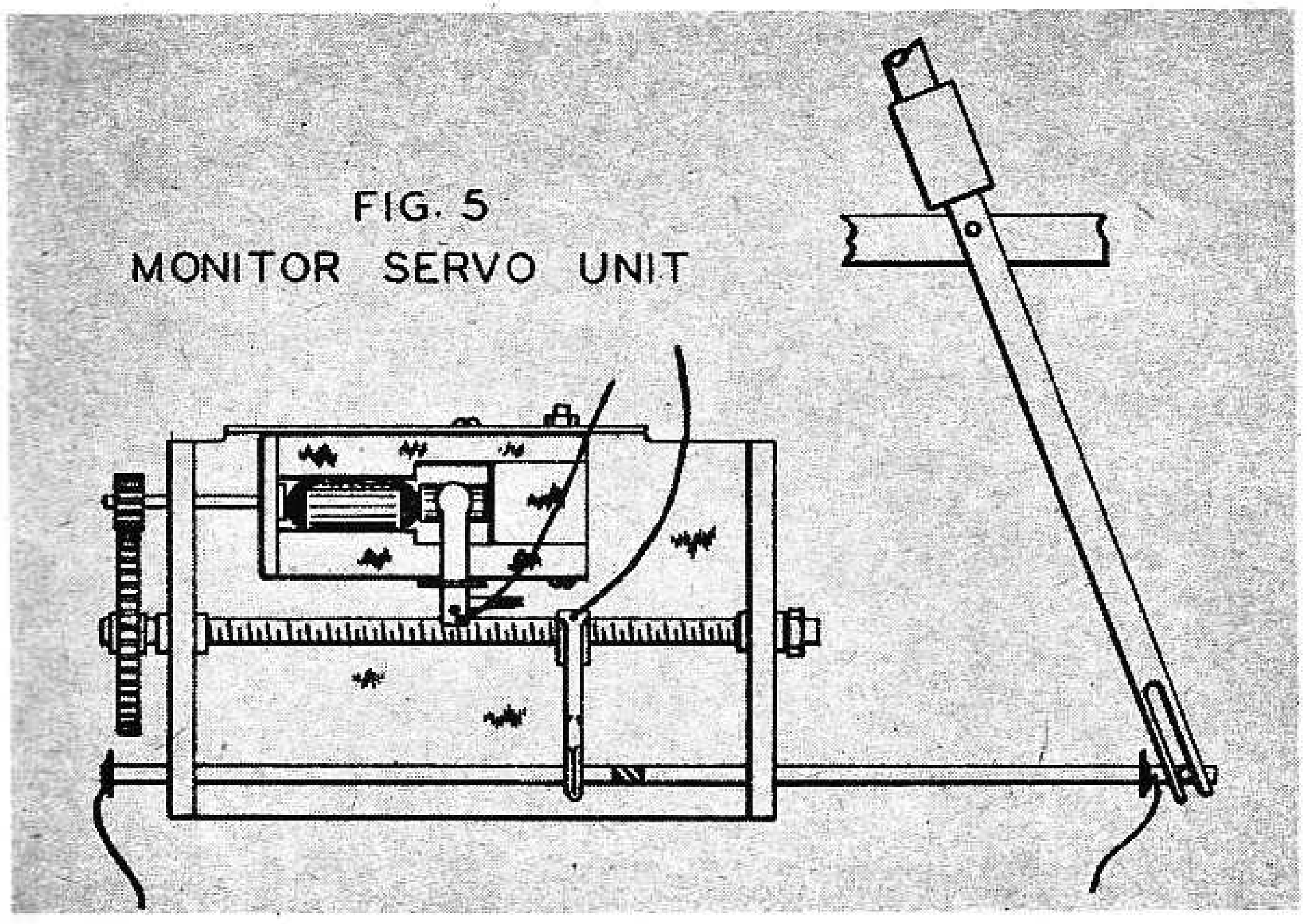


FIG. 5
MONITOR SERVO UNIT

Solenoid operated activators were also out of the question, for the same reason. We therefore concluded that the simplest device for providing the type of control activation we desired would be an electric motor driven servo unit.

Our next problem was to decide on the type of selection we wished to employ. A radio control system of any complexity requires a selector to route signals from the receiver to the activators so that the proper control will be moved in the desired direction. Although there are several devices whereby selection may be effected, all selection systems fall into either of two general types: multi-channel selection or sequence selection.

The most obvious multi-channel system involves use of several carrier frequencies, one for each control—or rather one for each direction in which each control is to be moved. A separate receiver is tuned to each carrier frequency, so that a model having only engine and rudder control would have to carry four receivers, each tuned to a different carrier—rather a large order. Moreover, multiple carrier selection requires use of as many transmitters on the ground as there are receivers in the plane; or at least some device for rapidly and automatically changing the frequency of a single transmitter to tune it to the receiver corresponding to the control motion selected. As far as we were concerned, multiple carrier selection was out of the question.

We also gave some thought to the use of a single carrier modulated with a number of audio frequencies. Control selection would be effected by feeding the audio output of the receiver to a number of magnetic reeds tuned to vibrate selectively to the transmitted audio frequencies, or to a number of highly peaked audio amplifiers. We decided against the use of tuned reeds because we felt they would be too sensitive to temperature changes and engine vibration; and we rejected peaked audio because the necessary chokes or transformers would have been excessively heavy. But recent developments in ultra-high frequency equipment point to the possibility that some form of peaked audio selection may soon be practical even for small radio controlled models.

Having decided against multi-channel selection, we turned our attention to the development of a sequence selector which would meet our requirements.

The well known rubberband escapement is really the simplest form of sequence selector, combining the functions of selection and activation in one simple unit. It serves to exemplify the one defect of any sequence selection system —there is a variable time delay involved in almost every control operation, since the escapement must frequently pass through several undesired positions before it is brought to the position selected. At first we were somewhat concerned about this time lag element, especially since the operator is unable to anticipate the exact length of the delay in any particular instance. In practice, however, we found that even a relatively crude selector will respond accurately to ten selection steps per second. One experimental escapement type selector switch, developed by Robert G. Stoneman, gave accurate selection responses at rates as high as 196 selection steps per second.

We concluded, therefore, that the advantages of sequence selection outweighed its theoretical disadvantages, and we turned our attention to the development of a selector that would be completely automatic in its operation.

The system that we designed around this device is best explained by starting with the airborne unit. (See Fig. 1.)

(*Turn to page 67*)

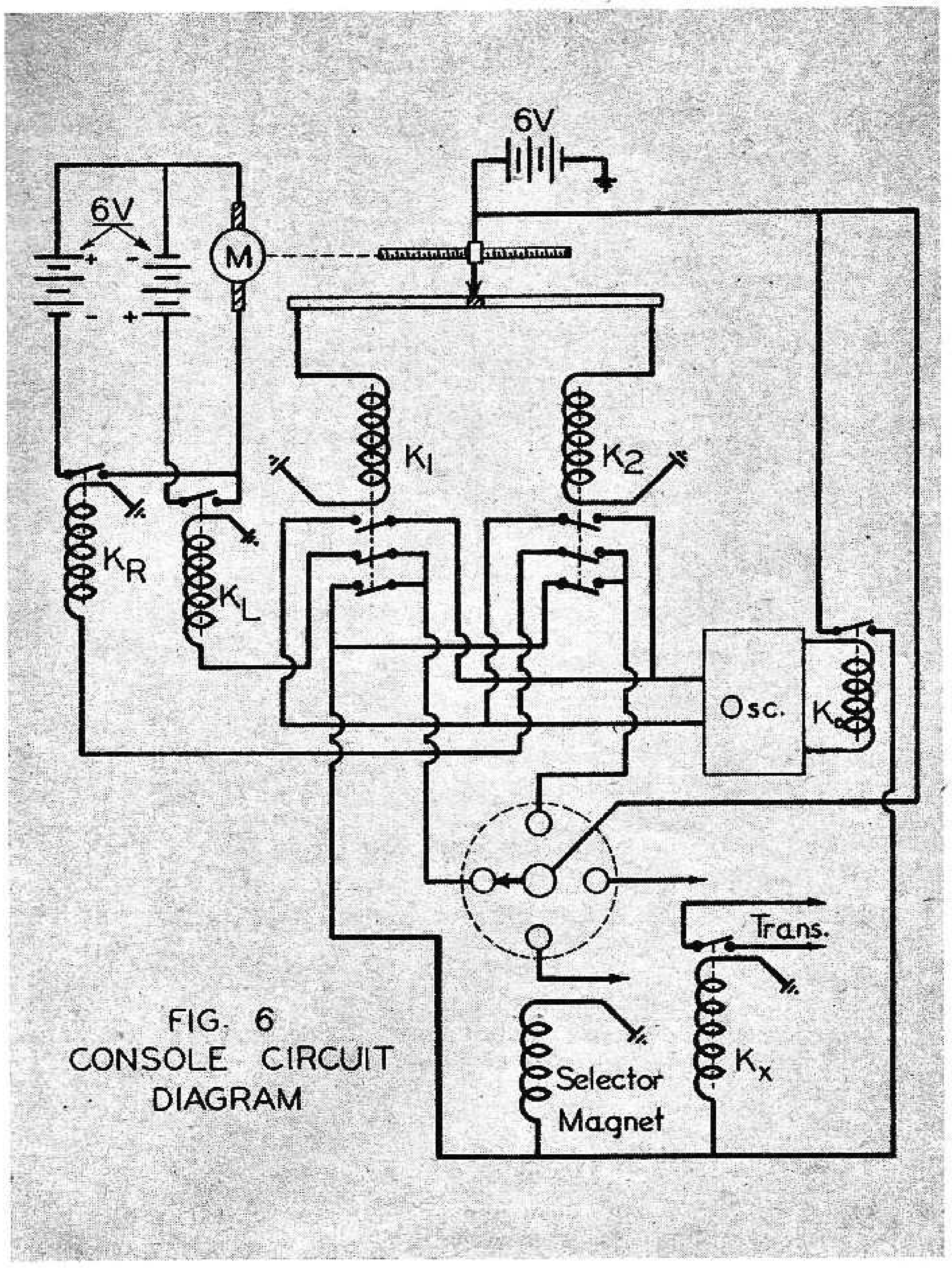


FIG. 6
CONSOLE CIRCUIT
DIAGRAM

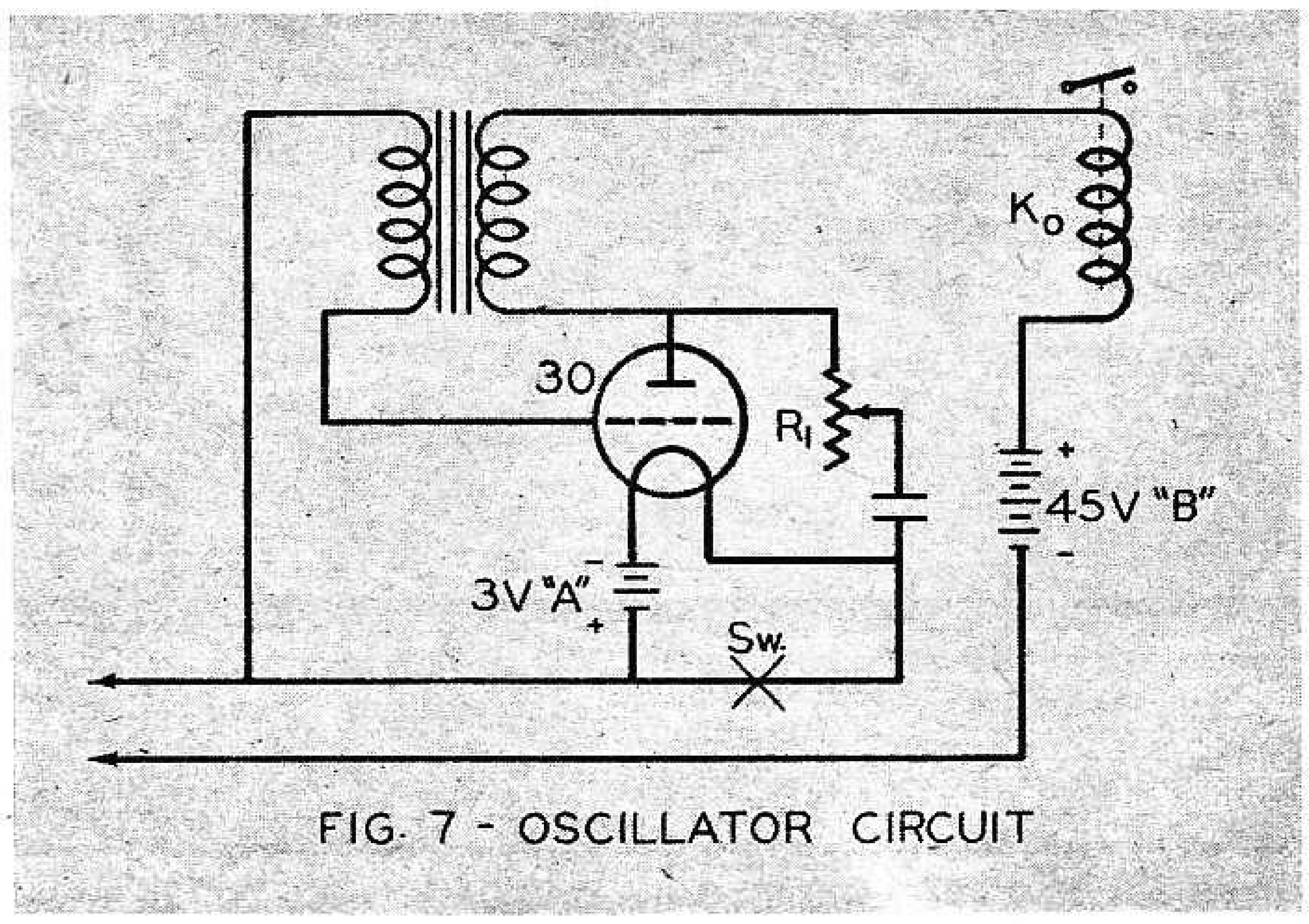


FIG. 7 - OSCILLATOR CIRCUIT

Cockpit Radio Control

(Continued from page 21)

The receiver embodies the conventional superregenerative circuit, details of which have frequently been described elsewhere. Receiver output is fed to a sensitive relay in the usual manner. We used a homemade version of Walter Good's polarized relay and found it lighter, more sensitive and less susceptible to the effects of temperature change and engine vibration than even the commercially built relays of the spring loaded type.

The airborne control unit itself comprises an automatic selector switch and a motor driven servo unit for each control—in this case one for the rudder and one for the engine spark timer arm.

The selector switch (see Figs. 2 and 3) consists of a selector magnet, a commutator disc on which is mounted a series of fixed contact points, and a rotor arranged to traverse the contact points. The rotor is mounted on a common axis with a ratchet wheel and is advanced step by step around the commutator disc by means of a pawl carried by a spring loaded armature on the selector magnet.

The fixed contact points on the selector switch are connected with corresponding control servo motors through a switch formed by the selector magnet armature and a stationary contact point with which it engages. Each servo motor is geared to a threaded shaft which serves as a lead screw to drive a nut coupled to the control cable. (See Fig. 4.) Limit switches at the extremes of travel of the nut break the motor circuit to prevent the nut from overrunning its travel range and jamming.

In operation, the transmitter is keyed so that the carrier is propagated in a series of short selection pulses, followed by a long control pulse. Each of these pulses, when detected by the receiver, causes the sensitive relay to close, and the relay in turn energizes the selector magnet so the pawl and ratchet assembly will advance the selector rotor to the next contact point on the commutator disc. The short pulses move the selector rotor around the commutator disc to the contact point corresponding to the control motion dictated by the ground control station. The last pulse in the series, the long control pulse, causes the servo motor to be energized for the period of time required to move the control to the desired position.

Since each of the servo motor circuits is completed through the selector magnet switch, the servo motor will be energized only at times when the selector magnet is energized. Thus the servo motor will stop rotating as soon as the selector magnet is de-energized at the end of the carrier pulse.

Each of the short selection pulses actually moves one of the controls a slight amount, but since the controls are connected in sequence to the selector switch, the small control travel due to any one momentary contact is neutralized as soon as the selector rotor steps to the next contact point. We found, moreover, that because of the inertia of the servo motors and the short period of the selection pulses (on the order of 0.1 second), there was no perceptible control movement during selection.

Because we used only a single selector switch commutator, it was necessary to use two sets of batteries for each servo—one for each direction of control travel—since the direction of rotation of the servo motors is determined by the polarity of the voltage applied to them. We did some experimental work in an attempt to operate all the servo motors from a single battery source by adding a second commutator disc to the selector, but the necessary machine work proved too complex for our limited workshop facilities.

The ground control station consists of a transmitter and a ground "cockpit" or control console.

The transmitter is of a conventional type, powered by a six-volt automotive type storage battery in series with a 30-watt dynamotor. We found it convenient to mount the transmitter power supply in the same case with the transmitter, connecting the control console with the transmitter by a 50 foot cable. It was thus possible to mount both the transmitter and the console for greatest convenience and operating efficiency.

The control console is the most complicated unit in the system. On it are mounted the joystick and throttle lever with which the ground pilot flies the model airplane. Its function is to translate the operator's control movements into the pulses necessary to operate the system. In effect it is an automatic device for keying the transmitter.

The control console contains a selector switch which is essentially a duplicate of the selector switch in the airborne unit, a relaxation oscillator, a monitor servo corresponding to each of the servo units in the model, and a number of relays.

Each monitor servo has an electric motor of the same type as the airborne servo motors, driving a similar threaded shaft and nut arrangement. (See Fig. 5.) Instead of moving a control cable, however, the nut on the monitor servo carries a brush which slides along a rod parallel to the lead screw. The rod compromises two electrically conductive lengths with a short insulating section between them. It is slidable in a direction parallel to the lead screw and is **mechanically linked to one of the control** levers so that movement of the control lever by the operator moves the rod a corresponding distance.

Operation of the console is best understood by reference to the circuit diagram, Fig. 6. This diagram has been somewhat simplified in that it shows connections for only one of the control units; but the other unit or units would be connected into the circuit in exactly the same way as the one shown.

When a control lever is moved by the operator, the corresponding servo monitor rod is moved with respect to the brush contact carried by the nut. Assume, for example, that the control shown in Fig. 6 is the rudder, and that the operator moves the "stick" to the left for a left rudder response. Since the "stick" is pivoted, the monitor rod is moved to the right with respect to the brush contact, thereby completing a circuit from the battery through the brush and the left-hand conductive portion of the rod to the relay K_1.

When relay K_1 is energized, the oscillator circuit is closed through one of its three poles, and the oscillator begins to energize the relay K_O in a series of pulses. The rapidity with which relay K_O is opened and closed, corresponding to the selection pulse rate, depends upon the value of resistor R_1 in the oscillator circuit. (See Fig. 7.)

Each closure of the oscillator relay K_O closes a circuit which sends a pulse of 6 volt current from the battery supply to the transmitter keying relay K_X and simultaneously to the selector switch magnet. Since the transmitter is thus made to send out a carrier pulse with each step of the ground selector, the airborne and ground selectors will step in synchronism with one another.

When the ground selector rotor arrives at the contact point corresponding to the left rudder position, it completes two circuits through the remaining two poles of relay K_1. One of these is a holding circuit which short circuits the oscillator relay K_O to keep the selector magnet and the transmitter keying relay K_X energized during the time that the brush contact is moving toward the insulated segment on the monitor rod, thus providing the long control pulse which causes the servo in the airborne unit to move the rudder to the selected position. The other circuit completed through the selector and relay K_1 is the servo monitor motor control circuit, which energizes relay K_L to supply current of the proper polarity to the monitor motor to cause it to drive the brush contact toward the insulated segment on the monitor rod.

The oscillator will of course continue to pulse, and relay K_O will continue to open and close during the long control pulse; but this will obviously not affect the operation of the remaining units in the circuit.

When the brush contact reaches the insulated portion of the monitor rod, the circuit to relay K_1 is broken and the relay is opened, immediately breaking the oscillator, holding, and motor circuits, thus stopping all operation of the console units and terminating the carrier control pulse.

(To be concluded in the next issue.)

RADIO CONTROL INFORMATION

Because of many requests we receive for information covering all phases of model airplane radio control, we have compiled a list of all articles on the subject that have appeared in Model Airplane News. The first of these articles was printed in 1937, but almost all of the issues listed, including several in 1946, are now out of print. However, most cities have second hand magazine dealers who carry these old issues, and many libraries also have files of them.

Radio Control enthusiasts may obtain a free copy of this list by writing to: Model Airplane News, 551 5th Ave., N.Y. 17, N.Y.