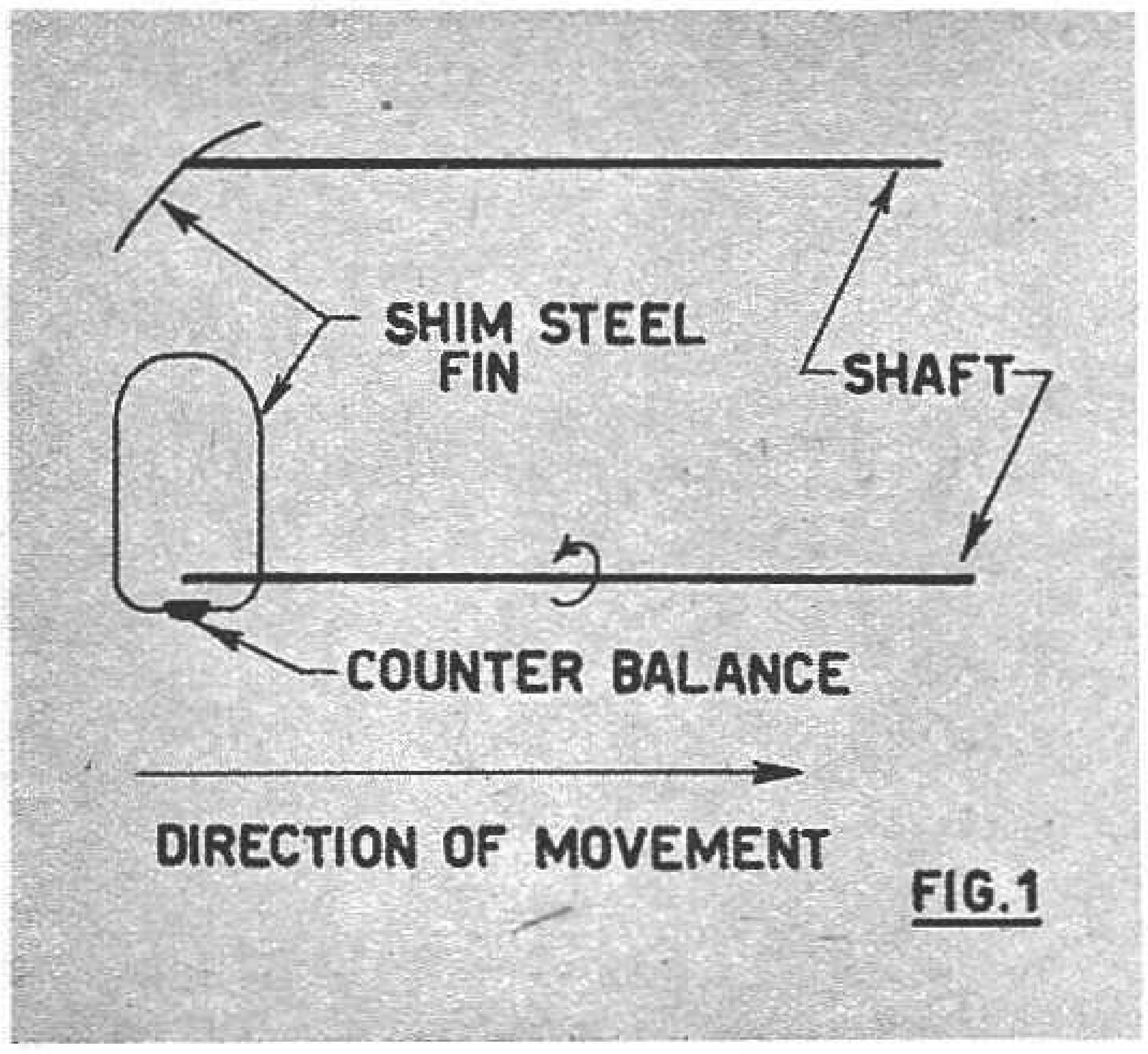


FIG. 1

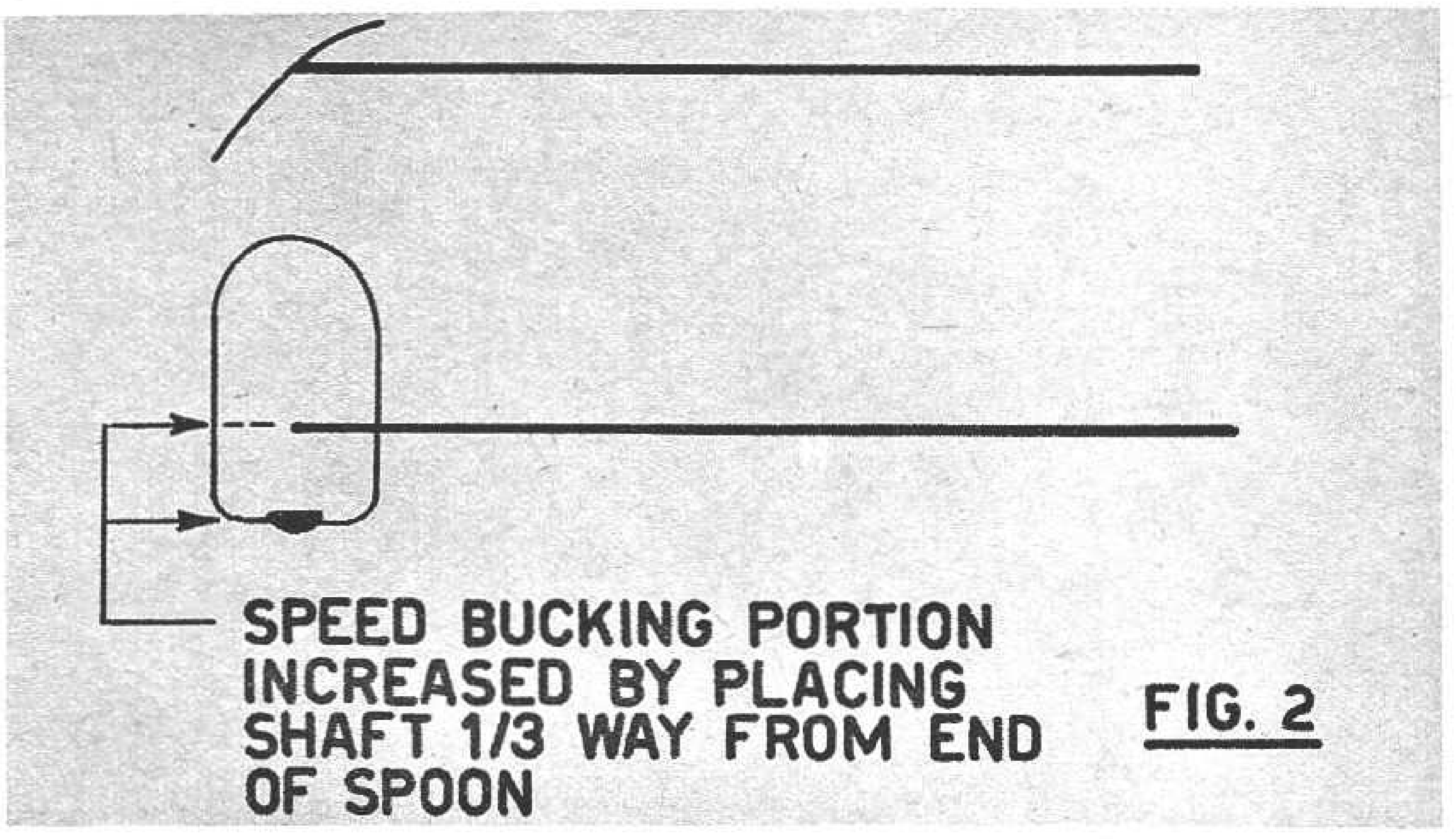


FIG. 2

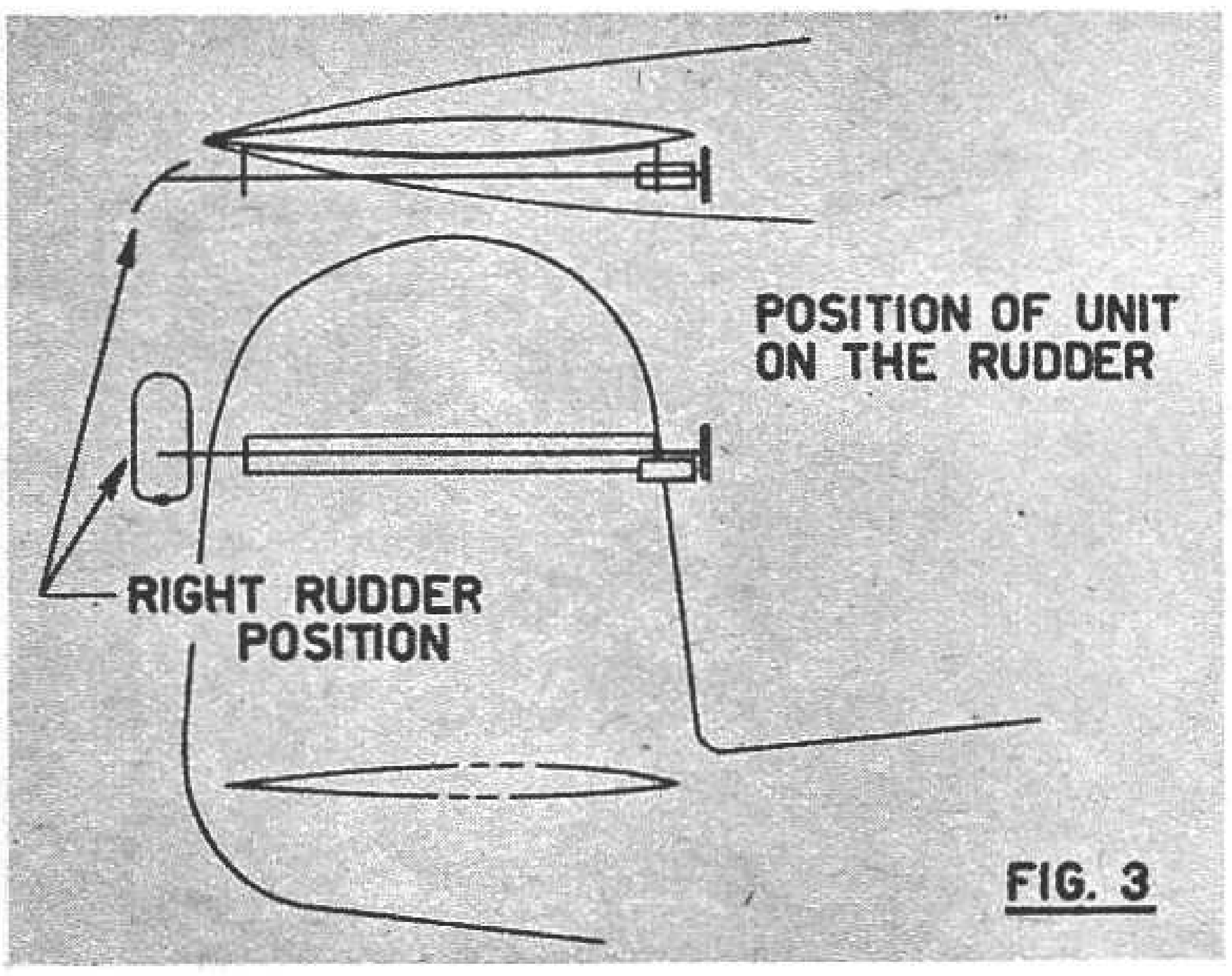


FIG. 3

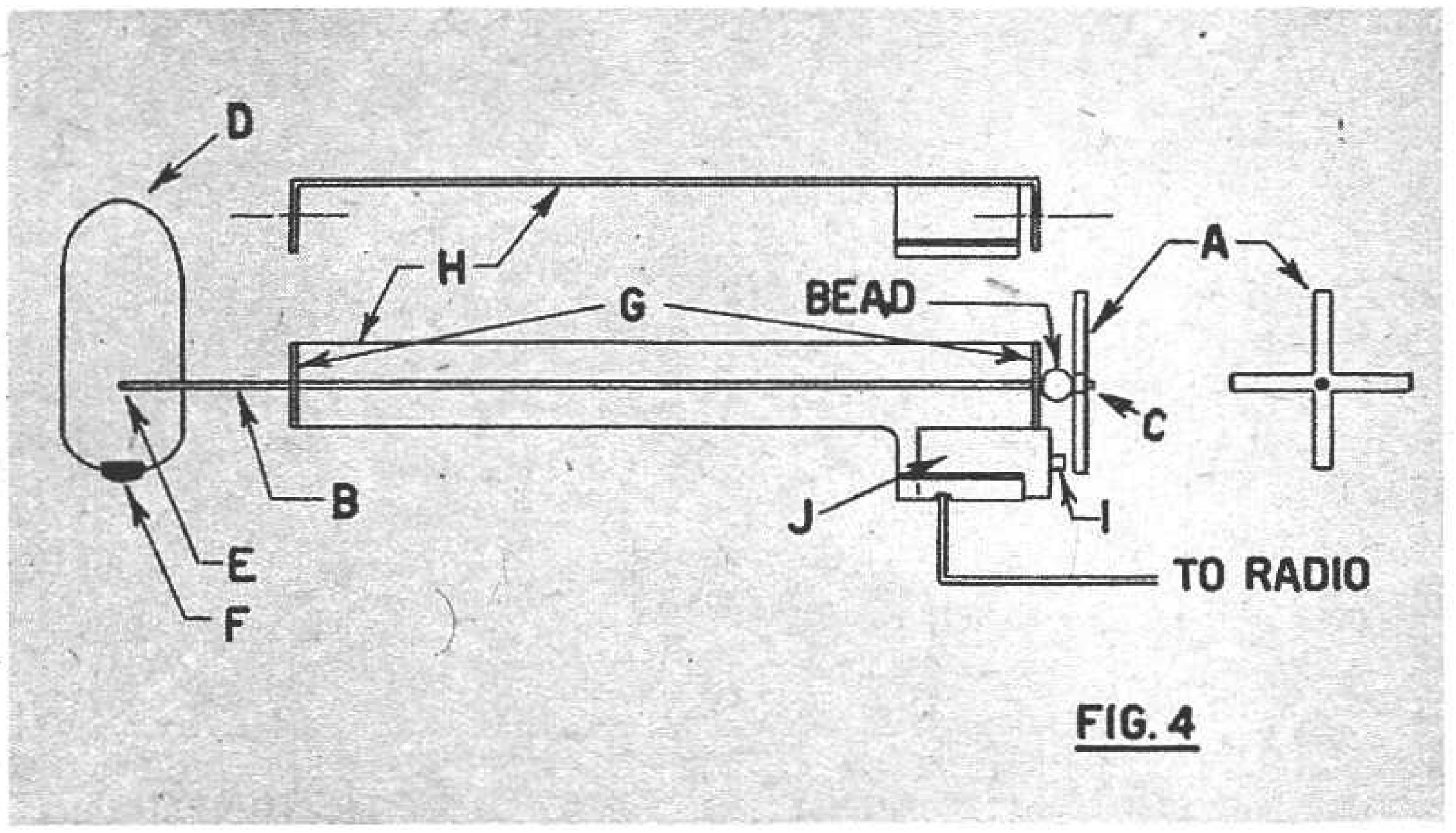


FIG. 4

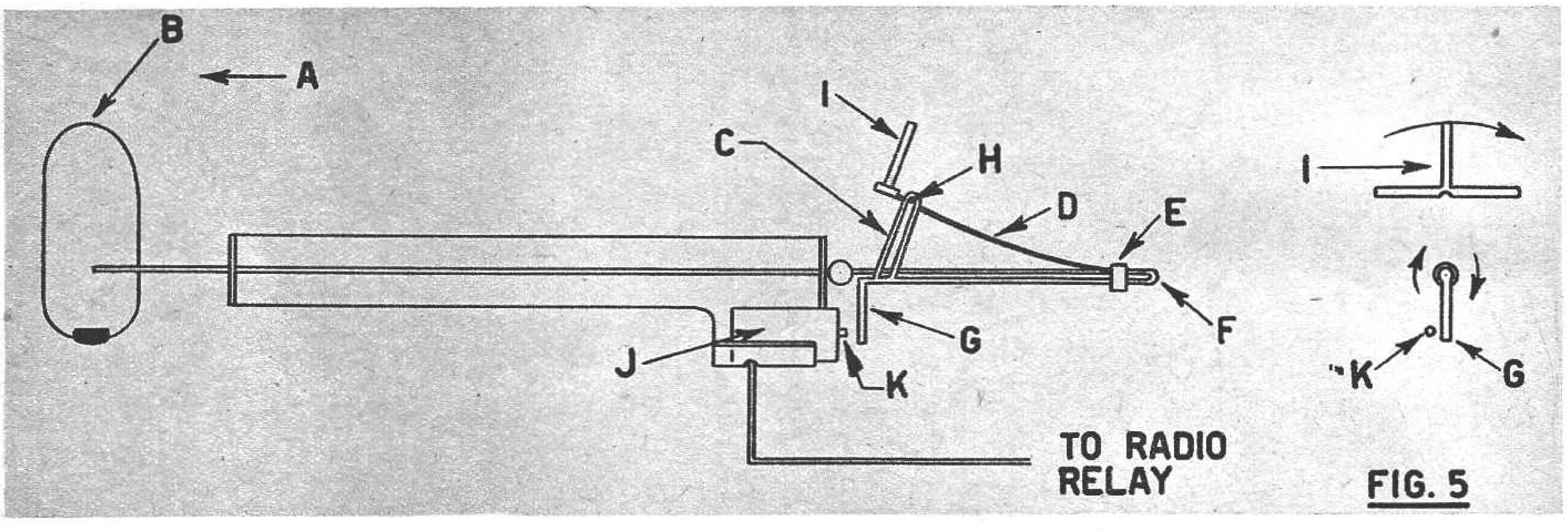


FIG. 5

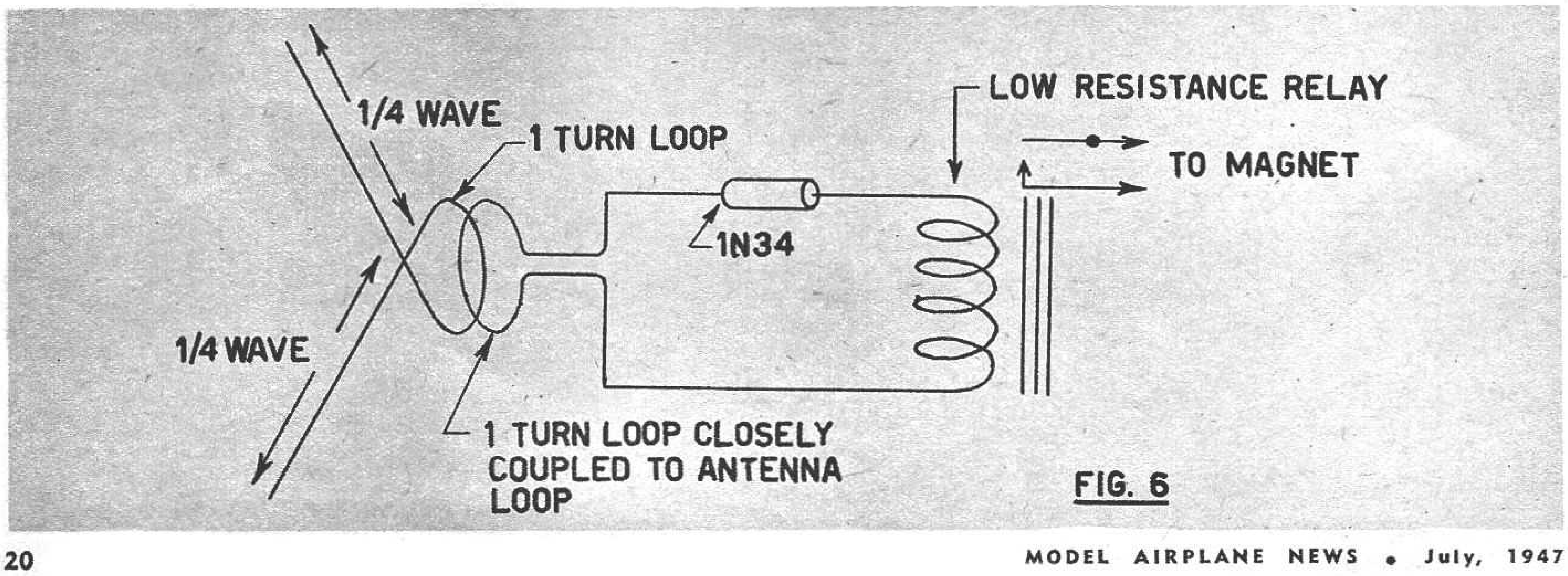
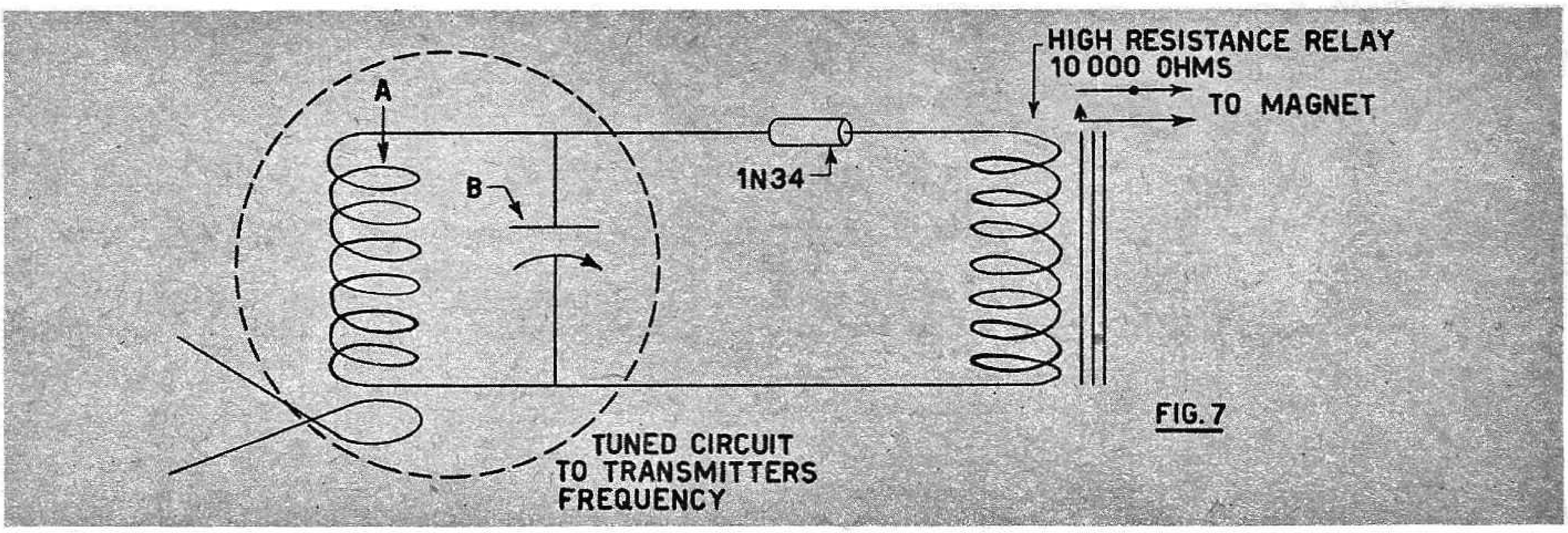
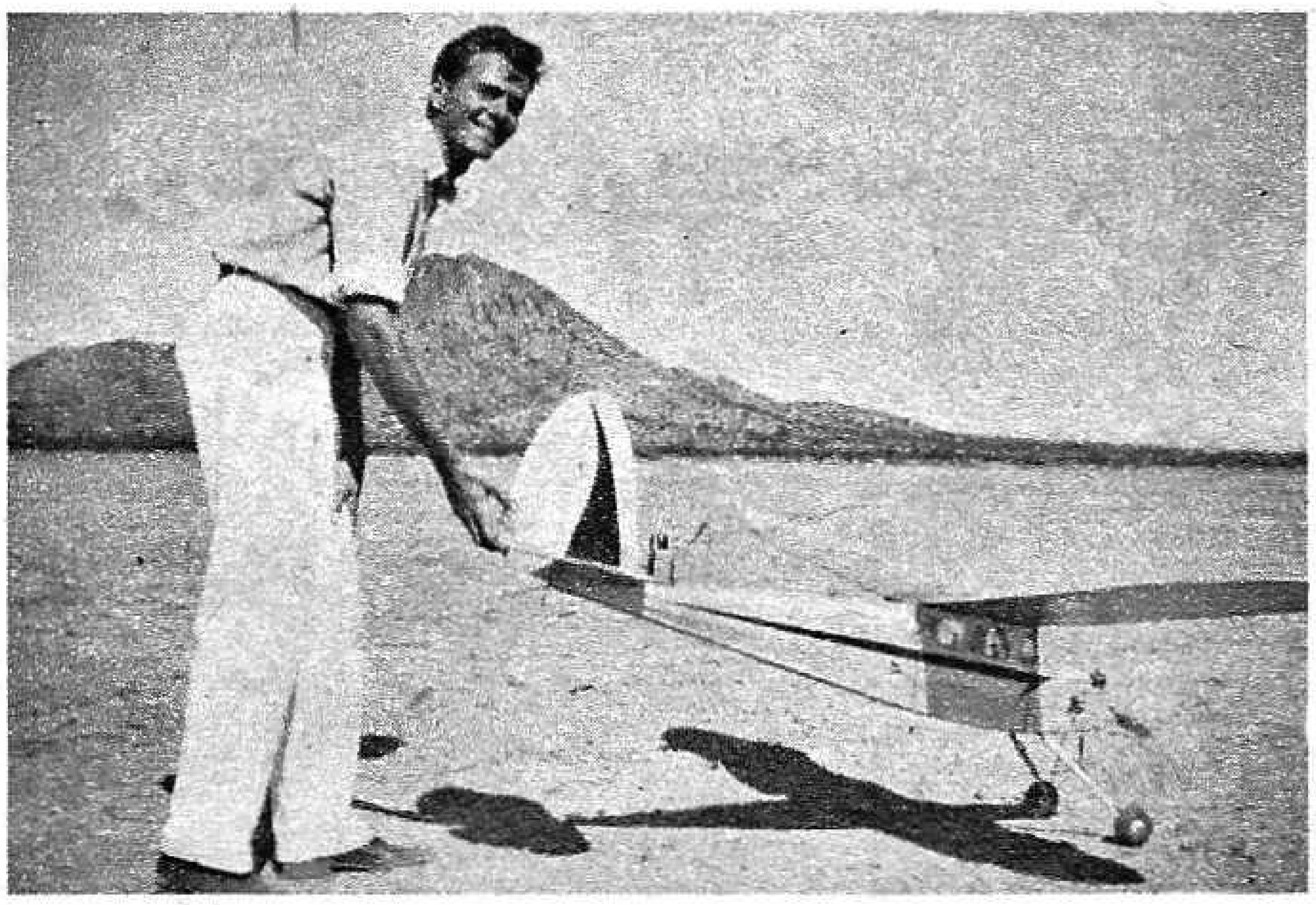


FIG. 6





SIMPLIFIED RADIO CONTROL

by **WILLIAM A. RHODES**

The equipment described is about as simple as it is possible to use, yet it gives altitude and directional control

IN THE fall of 1938 I was watching a small group of ,model enthusiasts fly their planes near Phoenix, Ariz. To see these ships wander off across the desert and lose themselves in the distance, or crash into a giant cactus just at the edge of the field when they could have been guided away from those obstructions, gave me the inspiration to construct a radio controlled craft.

Besides having the advantage of possessing an amateur radio license, I had also built quite a number of models and so had an ideal situation for constructing a radio controlled ship. As I investigated the types and methods used in radio control work, I noticed that the common trend was to manipulate the rudder and elevators and let the dihedral take care of leveling the ship when it was in neutral position. The actuation of these control surfaces is either brought about by use of a tiny electric motor with a gear train, or by using an escapement rotated by a wound rubber strand.

In either case, this demands using two of either of these control units plus two receivers to actuate them, not forgetting the installation of dual transmitters on the ground. If I wished I could have used half of this equipment and had control of the rudder only, but it seemed that this method was rather primitive. At the same time, those who have had experience tuning and operating just one of these units preparatory to flight know what kind of trouble one can give, let alone two.

After gathering information I finally decided to simplify the whole system. This simplification included: 1. Elimination of the electric motor and gear train and escapement. This would connect the receiver directly to the control surfaces, which necessitated redesigning the control surface actuating mechanism. 2. Using only one receiver and still being able to operate both elevator and rudder. 3. Eliminating the weight of B batteries by reorganizing the entire radio system. (A control receiver that uses no B batteries or tubes is described later in this article.)

The whole idea sounded impossible for one person to accomplish, but as time was something I had plenty of, I collected ideas which finally evolved into the present system. I do not contend that this unit is in its highest stage of development, but it has lots of possibilities and I hope that others will conduct further research to improve upon it, keeping in mind however not to let it grow into a nightmare of complication as have some units I've seen.

My first version of the revised controlling system was a device resembling a tablespoon (hence the name "spoon") made of balsa and rotated by clockwork inside the ship. This spoon was to stick out the rear of the tail assembly, and by stopping it in any one of four positions it would perform the duties of both elevator and rudder. Then, when released, it would whirl so quickly that it would not affect the ship's forward motion until stopped in one of the four control positions. Here again I was stuck with a cumbersome mechanism to drive this spoon, which just complicated matters—something I wanted to avoid. To be simple, this spoon had to drive itself. So, I thought, why not mount the spoon to one side of the shaft and counterbalance it so as to make the equivalent of a one-blade propeller (see Fig. 1). In this way it can rotate due to the passing airstream and will still act as a selective airfoil when stopped as previously described.

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Simplified Radio Control

(*Continued from page* 21)

This Rhodes spoon (for want of a better name) worked out very well in tests, and its only drawback was the fact that it rotated so fast that it would break the selector spokes when stopped by the radio unit.

The last and one of the most important improvements was brought about by moving the pivot point one-third of the way over from one end of the spoon as in Fig. 2. I found that thin *shim stock steel sheet* was the best to work with, being very light and strong. This steel spoon takes a terrific beating without becoming unuseable. A small drop of solder applied to the short side of the spoon counterbalanced it very well. Note that the short portion of the spoon is at the same angle as the long portion and not opposite as in an ordinary propeller. It is this short section that bucks the action of the larger section and slows the rotation to a more practical speed. The spoon has to be balanced by adding or filing the solder counterbalance on the short section, or it will vibrate slightly when it is rotating.

By placing the shaft at this one-third point on the spoon rather than having the whole blade area at one side, the following improvements were made: (1) the rotation was slowed to a reasonable speed; (2) the spoon was almost centralized in relation to the axis of the fuselage. At the same time this placed the whole control surface where it is at its most balanced position to control on a vertical or horizontal plane. This unit was built flat against the rudder and about half way up from the rudder base. The spoon stuck out in the rear of the tail assembly just far enough to rotate freely, and down far enough so that in the event the ship nosed over upon landing, the top edge of a sturdy rudder would protect it from damage (see Fig. 3).

The latest unit, including the selector mechanism (to be described) weighs only 5/8 ounce. The size of the spoon, of course, depends on the size of the ship, and the only way to determine this correlation is to start with a small size and work up. I found that the best results are obtained with a tail assembly that has about the same approximate area in the rudder as in the stabilizer. This way you don't over-control on rudder and under-control on the elevator. The larger the spoon, the more control. I found after a few trials that the smaller the tail surface, the smaller the spoon could be to get the same degree of control. Also, the most efficient angle for the spoon was about 45 degrees on the shaft and curved as in Fig. 1, end view of the spoon.

By moving the ignition batteries forward a couple of inches I compensated for the added weight on the tail. The drag of this spoon that so many modelmakers told me would affect the glide and efficiency of the plane just wasn't noticeable. Although there is no doubt that the spoon does cause some drag, it isn't serious even under conditions calculated to make it show up. You will notice in the photograph that the spoon has been placed so that it is in front of the rudder. This worked successfully, but with a marked decrease of control for a given size of spoon, due of course to its surface being closer to the ship's center of gravity (shorter moment arm). In later experiments it has been used solely in the rear of the tail assembly with much better results.

I am indebted to my friend Ted Freeman of Phoenix for his assistance in constructing and operating the *Flying Quaker,* the first of two ships built for control purposes. It was found that a spoon whose dimensions were 1 to 3 in. proved best, neither under-controlling nor over-controlling this ship. If you desire to go in for some aerobatics, however, you will merely have to increase the size of the spoon slightly and keep on your toes when flying.

The second ship was a *Commander.* It was much faster and more thrilling to watch than the *Quaker.* Its receiver used no B batteries, so the small diameter fuselage was not crowded in the least. This ship was much more successful, as the radio trouble was brought to a minimum with the new equipment, and more time could be devoted to actual flying. The use of a butterfly "V" tail section was tried on this ship with great success as one less surface had to be constructed and the control unit was mounted on the fuselage between the "V" arms.

Now for the selector. It is unnecessary to give exact dimensions here as the selector runs very well, even with a sloppy fit in the bearings, and the overall dimensions of the entire unit may be changed to suit one's taste without greatly affecting its operation. Everything can be made so small that it weighs only a fraction of an ounce, and it will still control a ship just as well as a larger unit.

There are two types of units that may be used for selection. The first is rather a hit-and-miss affair but will operate successfully if one practices a bit in order to get the sequence correct. It is made by fastening a four spoked wheel to the end of the shaft as in Fig. 4. The spoked wheel (A) is cut out of a disc of brass, a hole is bored through its center the same size as the piano wire shaft (B), and the two are soldered together at (C). The spoon which is shown at (D) is soldered at (E) to the shaft, then counterbalanced at (F). The balance doesn't have to be perfect because the weight involved is so small that the vibration produced from a slight unbalance amounts to nothing. The bearings shown at (G) were made to fit just loose enough for free rotation and are made from a piece of aluminum plate bent as shown at (H). This piece acts as a mounting bracket for the unit as well.

The only disadvantage of this unit is that one never knows what position he will come upon first when the key at the transmitter is depressed. However, the sequence will run either "Up, Right, Down, Left" or "Up, Left, Down, Right," depending on the direction the spoon is rotating. Of course the little armature (I) of the solenoid (J) will stop any one of the spokes the first time, but thereafter one has almost instantaneous control over any position. For instance, if the first position is "Left," then by making the Morse M and holding down the key on the last dash the position will change to "Right." One quickly learns to control with this system, but there is always that uncertainty about the first position.

By making the selector wheel (Fig. 5) so that one spoke remains fixed at all times and the other three (I) swing away from the shaft by centrifugal force, you have an arrangement where the fixed spoke always comes in contact with the armature rod first. This spoke can be set on any position of control by soldering the spoon on the shaft so that with the armature rod extended and the spoke against it in the direction of rotation, you have a "First" position that never fails when you press down the key the first time. Always set this spoke on the elevator "Up" position; then if the ship is coming in at a steep angle your first effort at the key will prevent a crackup and save time in getting the proper position.

Although this unit is a small, simple and light affair, it can still stand a lot of refining. As far as mechanical complications are concerned though, there just aren't any. It may be said here that the pressure and direction of the wind (A) against the spoon (B) holds the rotary system against the bead regardless of whether the fin is in neutral (spinning) or in a stopped position. The loop (C) of steel wire is soldered on the shaft to prevent the movable spokes from flying out too far from the shaft. The spring at (D) came out of a dollar watch. It is adjusted so that when the shaft and the movable spokes (which are soldered to the spring) are upsidedown it will have just enough strength to hold the spokes to the shaft against the force of gravity when the spoon is standing still. The other end of the spring is wrapped to the shaft with fine copper wire (E), then sweated into a solid piece with solder. It may be well to add here that the shaft is doubled back at (F) and then again bent at 90° to form the fixed spoke (G). The sweating of solder along this fold will add plenty of strength providing it reaches the 90° bend. Do not worry about taking the temper out of the steel parts as loop (C) will prevent too much bending in the case where a high speed spoon is used. Be sure the spring tension is such that the movable spokes will fly out with not too much speed of rotation.

To balance the unit, tie the spring to the loop at (H) with the movable spokes (I) extended as they will be when revolving. This is the position in which vibration will become noticeable and not in the still position when the spoon is stopped. Balance for running conditions and forget about balance on the stopped position, as air pressure on the spoon will insure perfect automatic operation so long as the plane is moving through the air.

The solenoid in use on this unit is one purchased from a camera shop and was originally used for electric shutter operation with a flash camera. This solenoid (J) has a little pin (K) that sticks out of one end; when current flows through the coil this pin sticks out about 1/8 to 3/16 of an inch further with considerable force, more in fact than is needed for reliable operation. Naturally, while the spoon is spinning (this is called neutral) the movable spokes are extended by centrifugal force, and the only thing the armature can contact is the fixed spoke, so the fin has to stop in that position first every time the key is first depressed. As soon as the spoon is stopped for a fraction of a second, centrifugal force ceases on the movable spokes and they are pulled back to the shaft by the springs. The key at the transmitter is again lifted for a fraction of a second and again depressed; this action causes the armature to snap back into resting position long enough to allow the wind to rotate the spoon a little past the catching point of the fixed spoke; then the armature comes out again to stop the next spoke, and so on through the four positions. When the key is released, no matter what position the selector is in the spoon quickly comes up to the speed of the neutral position. Remember that the speed of the neutral rotation depends entirely on the counterblade of the spoon (short section)—the longer it is, the slower the rotation.

Supposing that the spoon rotates in the same direction as the propeller of the ship, the sequence will be Up, Right, Down, Left; Up, Right, etc. With the fixed spoke set on the Up position, the first signal dash would start the ship climbing and the up-elevator position of the spoon will persist until the operator releases the key. If the ship has been properly adjusted, it will not be necessary to give a Down signal to level the ship. If the operator lets up the key and instantly depresses it again, the armature will catch the next tooth; but if the operator waits about a half second to one second, the spoon will assume the neutral position automatically, thus making itself ready again for the Up position upon first contract of the key.

The nice part about this system is that the operator has any position at his fingertips at any moment he desires it. Then, too, the movement of the craft drives the spoon and there is nothing to run down. For the Up position the Morse letter T or dash is used. Its length will be up to the controlling operator and will determine how long the spoon will stay on the first position. In the Right position is the Morse letter M with the last of the two dashes held down for any desired amount of right turn; and for Down the letter O with the last dash held down for as long as the operator wishes to dive the ship. Left is four dashes with the last dash as the controlling factor for that position. It is always the last dash that is held down in the sequence of four positions that holds the spoke until the operator wishes to let go.

Anyone wishing to use the plain four spoke solid selector wheel will find that with very little practice he will be able to control nearly as well as when the spring-spoke unit is used. However, he will have to guess at that first position.

This simple control unit may of course be used with any of the popular transmitter and receiver units. The solenoid is simply connected in series with a penlight cell and the contacts of the sensitive relay. After working out such a simplified control unit, however, I decided to see what could be done to further simplify the receiver, and so of course to cut the weight that had to be carried in the plane.

The first effort along these lines was what might be called a "hot wire relay," and though it worked, this was soon superseded by a much more practical hookup which represented just about the ultimate in simplicity, consisting as it did only of a 1/2 wave antenna, a crystal detector (I used the tiny 1N34 unit) and a low resistance relay, all in series. The contacts of the relay connect to the pen cell and solenoid of the spoon unit. This layout is so ridiculously simple yet it worked beautifully. There is a hitch, however! In order to operate the ship reliably up to a half mile, it was found necessary to use a transmitter of about 100 watts power, and to employ a complex beam antenna besides. Because of the necessity of the beam, the wave length should be 2 meters or less, and of course the beam antenna has to be turned to keep it pointed at the airplane.

The only tuned circuit in the plane was the antenna, which must be cut accurately to 1/2 wavelength. The "ground" part of the system included the motor plus a sheet of thin aluminum in the plane, and the antenna was fine copper wire glued to the wing trailing edge. Since this wasn't long enough, the end was allowed to hang off the wingtip and trail backwards in flight.

This gave a desirable "L" shape to the antenna which eliminated the blind spots that were noticed when I previously had the whole antenna running back along the fuselage and trailing from the tail. Some of my model building friends predicted dire results aerodynamically as a result of the trailing wires, especially that from the wingtip. Flying tests showed, however, that these wires had no effect whatever on the model's flying qualities.

An improved circuit in this simple form is shown in Fig. 6 and is recommended in place of the circuit just described. Here the half-wave antenna is split at the center with a one turn coupling loop which is closely coupled to a similar loop in the crystal circuit. The antenna must still be tuned carefully to the operating frequency, of course, but this arrangement obviates the need for a "ground" connection.

A tremendous improvement in operation may be had by using a simple tuned circuit as in Fig. 7. This tuned circuit, composed of coil A and condenser B, are coupled to the antenna by a one turn loop. In this case the relay coil should be very high resistance.

It was found possible to use greatly decreased transmitter power using this arrangement, and though it is a bit more complex than that in Fig. 6 is still eliminates the batteries and other troublesome parts associated with the usual vacuum tube receivers.

By using this simplified equipment it is possible to put radio control in the smallest powered models or even in rubber types. We have simply transferred the complications from the airplane equipment to that used on the ground, where weight means very little, and added complexity is also tolerable.