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Aerial Radio Navigation

By HARRY D. ZINK, E.E. III

While everyone knows the importance radio plays in the successful operation of aircraft, few know the details involving operation and the working principles of such equipment. Since the world of tomorrow is going to be dominated by travel in the air, and most of us hope one day to own an airplane or at least to be able to fly, and all of us will be traveling by air, this article will attempt to describe some of the more common types of radio equipment one will come in contact with under such circumstances.

There has been much talk about the marvelous radio devices, including radar, used by the armed forces in aircraft work. Do not expect this type of equipment to be used commercially for a long time. Much more development will be necessary before one can expect to be able to fly through a fog and by means of radar be able to marvel over the beauty of the countryside as shown on the cathode-ray screen. It's true that all of this equipment in use by the armed forces works to one degree or another, but the operation of such equipment requires technical knowledge and skill that comes from long experience and training. The installation of such equipment in airplanes is by no means profitable from the economic standpoint; it is used because it does a job that must be done. Possibly the giant transports proposed for the future will use this equipment, but the equipment used on the family plane of tomorrow will be the same that has been used in the past plus refinements of common types of equipment which do the job of the more complicated equipment.

All radio devices installed in aircraft are essentially for the purpose of navigation. Even the small receiver in the light plane which only picks



—Courtesy General Electric.

The "Constellation" is equipped with a new type directional antenna. Note the top of the ship.

up the local control towers is for the purpose of navigating in the vicinities of the airports. The fundamental piece of equipment for aerial radio navigation is the directional loop. This consists of several coils of wire placed in a shield and mounted on the outside of the plane. This assembly acts as the antenna and the connections from the loop are brought into a sensitive receiver. The connections from the loop to the receiver are carefully protected from picking up any radio signals. This is so that all of the signals heard on the receiver will be brought in from the loop. The properties of this loop as an antenna are the reasons for its success as a direction finding device. When the plane of the loop is pointed in the direction from which the signals are coming, the signals in the receiver are approximately at a maximum. When the plane of the loop is turned approximately perpendicular to the incoming signals, the volume of the signal in the receiver sharply drops to a minimum. By turning the loop until this minimum is found and applying appropriate corrections, the bearing of the station with relation to

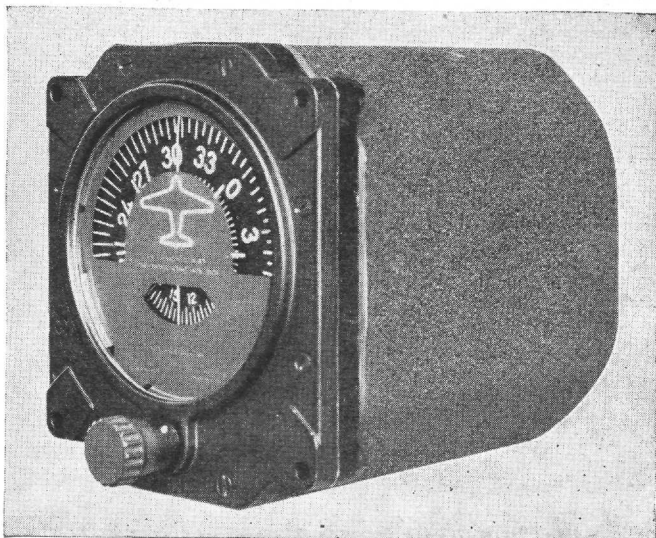
FAITH OF THE ENGINEER

The "code" presented on page 7 is the "Faith of the Engineer," presented at the Eleventh Annual Meeting of the Engineers' Council for Professional Development held in 1943. If you have been in Miss Fraser's office (Secretary to Dean MacQuigg), you may have noticed the framed copy there. We pass it on to every engineer for him to read and digest.

the plane is then found. The plane's position can be determined by taking two readings on two different stations or by taking two readings at different times on the same station. After the first reading is taken the plane flies at a known heading at a given speed for a known time until the other reading is taken.

One must be trained to successfully operate a loop because certain natural effects may make it give erroneous readings. One of these effects is known as "terrain distortion." This is due to the fact that radio waves may reflect from mountains and irregularities in the terrain. They also may be affected by large deposits of iron. When this happens to a signal it is bent, and therefore the direction from which it arrives at the plane may be entirely different from the direction of the station. A careful selection of stations from which to get a bearing by the operator will usually eliminate this effect. Another effect which makes the loop operation difficult is known as "night effect." It is most prevalent at sunset and dawn, but it may occur all during the night. Night effect causes the minimum to disappear or to shift from the normal spot. The loop works correctly only when it receives a wave directly from the station; therefore, if the loop picks up the sky wave part of the signal, which is a reflected wave, it may give wrong readings. For this reason, it works best on low-frequency stations which don't send out as much sky wave as the higher frequencies.

Besides the function of acting as a direction finding device, the loop has several other uses.



—Courtesy General Electric.

When full advantage is taken of all that is known about radio navigation, gyroscopes such as this will be obsolete.



—Courtesy General Electric.

A more complete view of the antenna installation on the "Constellation" transport.

By leaving the loop in a position such that a station straight ahead will have a minimum signal and tuning the receiver to a station at or near the destination of the aircraft, the operator can keep the plane headed toward the station by merely turning it until the station is at a minimum. This is known as "radio-homing." A device which works in connection with a gyro-stabilizer will keep the plane going toward a station automatically and relieve the pilot of the trouble. This method of homing is not the best, however, because if there is a wind blowing, the plane will follow the path of a parabola instead of a straight line in going toward the station. In an extreme case, the plane might be blown all around the station before it got there. This occurs because the loop does not keep the plane on any definite course but merely keeps it headed toward the station.

A simplified loop has been developed for use with conventional aircraft receivers. A double-ended pointer is used on the indicator at the end of the loop control shaft. One end shows the bearing to which the loop is rotated while the other end indicates the calibration correction for the bearing being taken. This type of loop will be a "must" for even the most modest private flyer in the future.

Another radio navigational device which, as far as the aircraft operator is concerned, is simpler to use than the loop, but which requires extensive ground installations, is the well-known radio beam. To fly on the beam, one needs only a re-

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ceiver tuned to the beam frequency and as long as the reception conditions are satisfactory, the plane will stay on course.

The radio beam works because of a system of directional antenna on the ground at the transmitter. These directional antenna tend to transmit their radiated energy along one line going both ways from the transmitter. If two of these antennas are placed so that their lines of greatest signal cross at right angles, then on a line bisecting this angle, both stations may be received equally well. In beam transmission, both of these transmitters are operated on the same frequency, but with different modulations. One of the stations will send out the "N" signal in Morse code, which is "dash-dot." The other station will send out the "A" signal, which is "dot-dash," timed so that it fills in the spaces left by the transmission of the "N" by the other transmitter. On the forty-five degree line between the lines of greatest intensity of the two transmitters, the signals, being of equal intensity, blend into the continuous note which is known as the beam.

There are several disadvantages to this system in that over mountainous regions, the beam may be scattered and reflected, giving rise to more than one beam being heard, or no beam at all. Also at night the sky wave from a very distant beam station on the same frequency may come in with such strength as to completely block out the local beam. The use of ultra-high frequencies has been suggested to overcome this difficulty since the sky wave of these frequencies will not interfere. The method of using a beam for navigation will be an aid to the private flyer of the future only in so far as the super-highways are useful to the automobile driver. They are fine when they happen to be on the way to one's destination, but often they aren't.

Shortly before the war, a device was developed which did away with all the above mentioned difficulties of a loop being used as a homing device. It enabled a pilot to fly from point to point in a straight line. Little has been told to the general public about this, probably because the device was made by a small manufacturing concern and the testing was not completed when the war interfered.

This new control is a small unit consisting of two radio receivers and a vacuum servo motor working in conjunction with an automatic pilot, which serves merely to keep the plane in level flight by means of a gyro-stabilizer. Two radio

stations on the intended line of flight are chosen and each receiving set is tuned to one of these stations. The signals are mixed in the control that operates the automatic pilot in such a manner that the plane is held in an absolute straight line regardless of cross wind or other outside conditions. To accomplish this, the plane will fly with its nose at an angle to the course in order to overcome the effects of wind and other outside influences. The body of the ship will follow the course exactly.

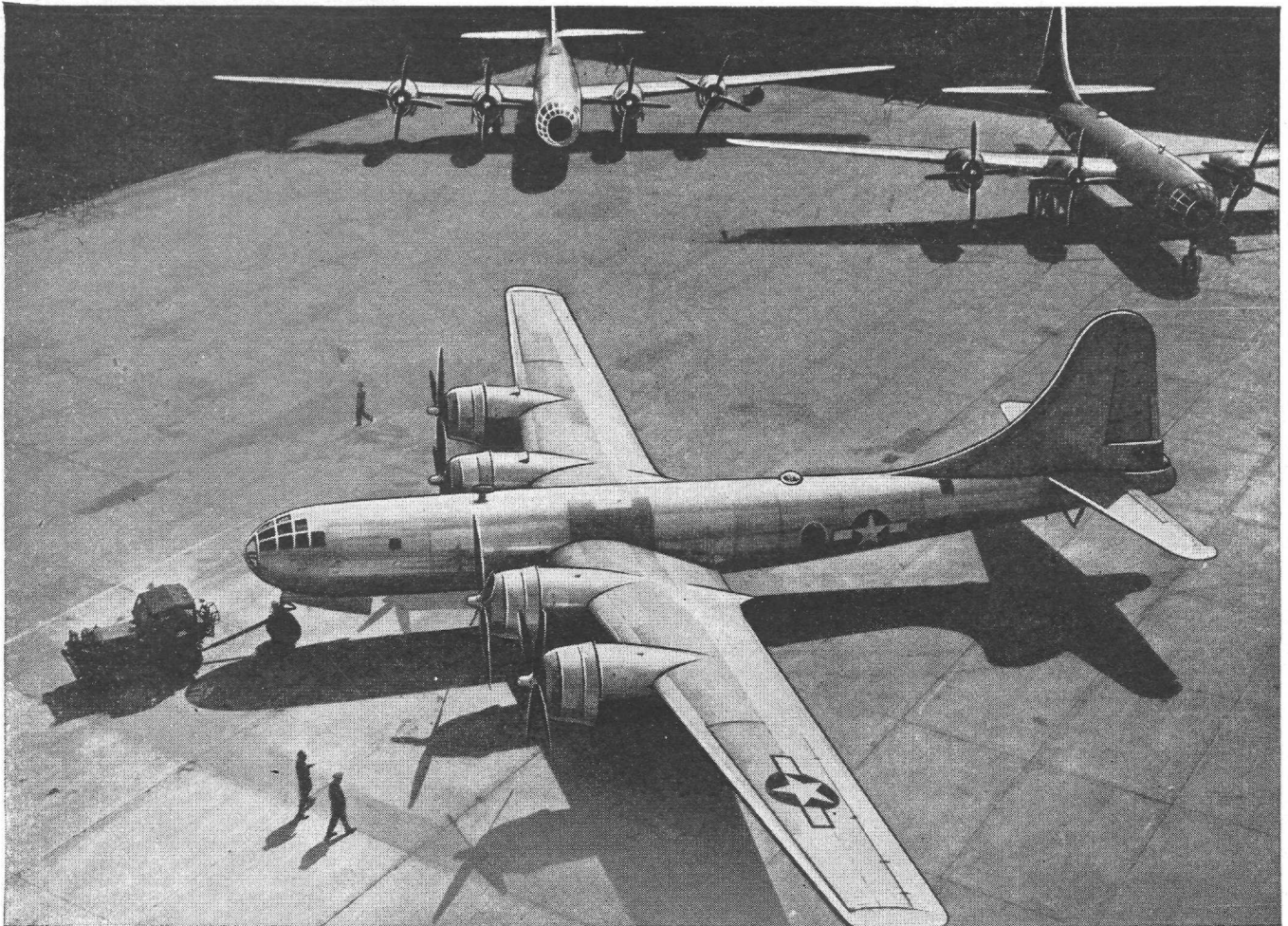
By simply throwing two switches on the panel of this sixty pound instrument, it may be made to work in a variety of ways. Two radio sending sets may be placed at one airport so that the line determined by these points will go through the destination. The dial on the control is then placed on the setting, "From 1 and 2," and the plane will be guided to its destination. If the pilot then wishes to go back from his destination to where he started, he turns the control to "To 1 and 2," and the plane turns around and goes back. Of course the most common arrangement will be that of using the positions marked, "From 2 to 1." The first two positions would be used where there was no transmitter at the destination. The second two would be used in flying between stations. There is also a provision for flying at right angles to the line between the stations in case one is lost and wishes to get quickly back on course.

Another unique feature of this control is a proportionating device. Ordinarily (with either manual or automatic pilot control) the plane, when off its course, is thrown back across the course again, and it must be *pulled* back, which causes a criss-crossing of the course. This is eliminated in this control by an automatic volume control in the two radio receivers by which the amplification of the receiver is inversely proportional to the signal strength. By this action, a plane ten degrees off course receives twice the correction that a plane five degrees off course receives. As the plane approaches the course, the control action is decreased until the plane flies exactly on course.

As can be seen, the possibilities of this device are practically unlimited. With a few simple devices, this control does what has formerly required elaborate ground and ship installations and it does this much better than has ever been done before.

Naturally, there are many other radio devices in use and many others will be developed, but the ones described above are the most logical ones to be used for aerial navigation in the immediate

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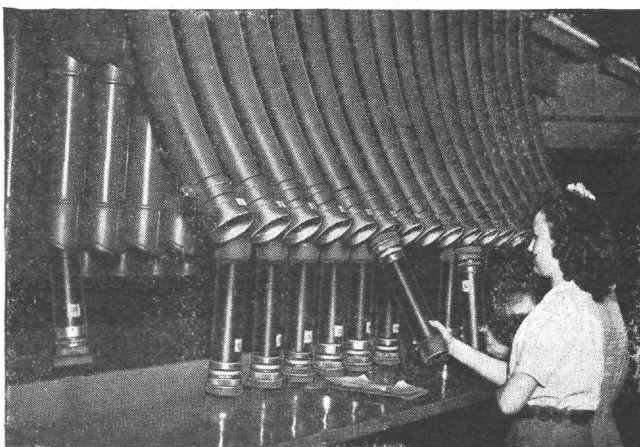
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post-war world. For those who prefer the deluxe equipment there will be sensitive radio altimeters and blind landing devices that will enable one to fly through dense fogs in comparative safety, but the ordinary pilot is not going to make a habit of flying through weather that "grounds the birds."

In speaking of aerial navigation, one must, of course, realize that there are many other ways of navigation besides radio, one of the important ways being celestial navigation. It is said, however, that when the lessons that war has taught about making simple apparatus foolproof are released to the public, radio navigation will completely supercede all other types.
