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CONTENTS

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HAZELTINE LANAC SYSTEM OF NAVIGATION AND COLLISION PREVENTION

By

Knox McIlwain*

The Hazeltine Lanac System offers comprehensive facilities for all-weather air and marine navigation. It enables a pilot to navigate with respect to one or more fixed points, and it enables an airport controller or harbor master to control traffic by locating and identifying the craft in his vicinity. In addition, it has an anti-collision feature which protects the pilot from collision with obstacles and other craft. The word LANAC stands for LAMINAR NAVIGATION AND ANTI-COLLISION system, the laminar feature referring to aviation use where planes are grouped by laminas or altitude layers.

The Lanac system performs its functions by (1) automatically interchanging position and identity information between moving craft, beacons, and traffic controllers; and (2) acting as a radar. It thereby enables every pilot to avoid collision with other craft and obstacles, to fix his own position, and to proceed on his course.

A special feature of the system is that it gives each traffic-control station the identity as well as the location of craft in the area. By means of Lanac, the controller of a crowded airport can, for example, quickly identify a plane that is known to be running short of gas; he can immediately learn its location so that proper instructions can be formulated. This cannot be done by radar alone.

The Challenger and the Replier

All Lanac functions are accomplished with the aid of the two basic equipments shown in Figure 1. These are the challenger and the replier. The

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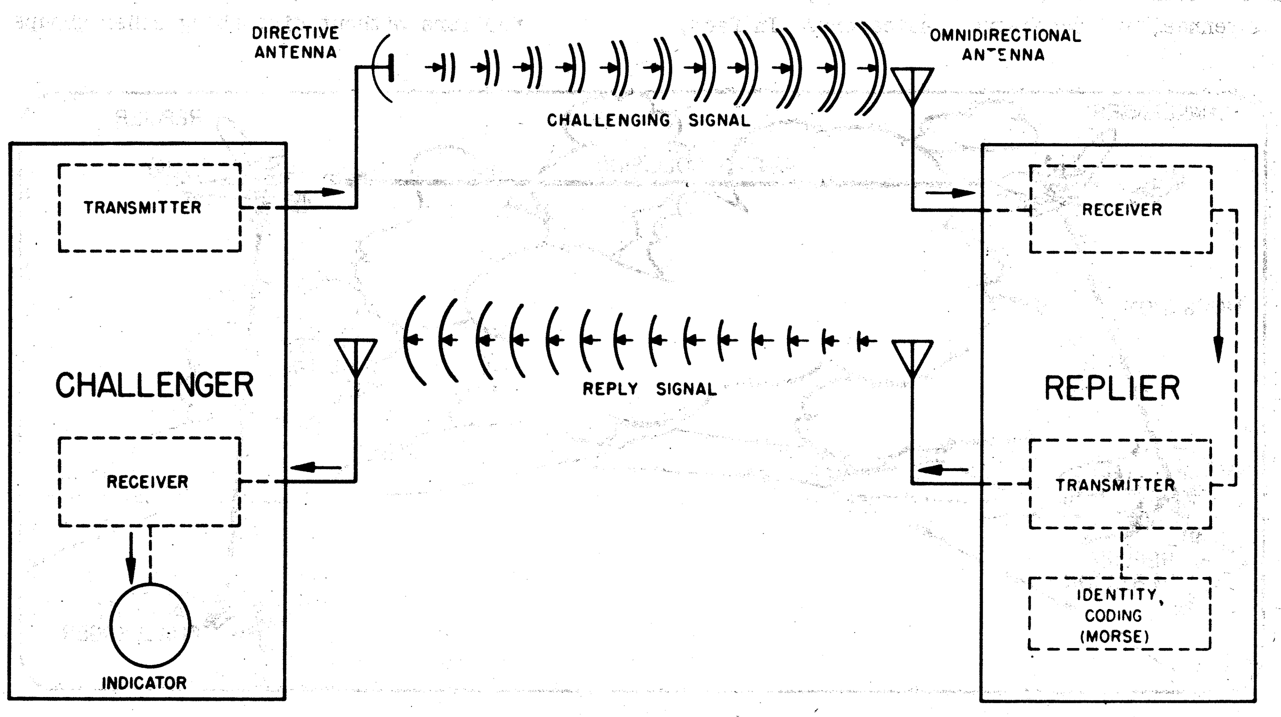


Fig. 1. Main Elements of the Lanac Challenger and Replier.

challenger is a radio set consisting of a transmitter, a receiver, and a radar-type scope or a meter. The transmitter sends out a pulse-type challenging signal; the receiver takes in the returning replies to the challenging signal; and the indicator displays them. Thus the operating cycle begins and ends at the challenger.

The challenger requires the cooperation of the replier, which is an automatic radio equipment having a receiver actuated by the challenging signals and a transmitter actuated in turn by the receiver. When the replier receives the proper challenging signal, its transmitter automatically responds by returning a Morse-coded reply signal to the challenger. The replier's automatic transmission of an automatically coded reply is a distinctive feature of the system.

When the reply signal arrives at the challenger and is displayed on the indicator unit, the challenging operator can read the distance and bearing of the replier in the same way that a radar operator reads the distance and bearing of an unknown target. The Lanac operator, however, can also read the Morse-coded reply and thereby identify the replier.

Lanac Compared with Radar

The Lanac system has much in common with radar. Both employ pulse-type signals, directional antennas, and scope-type indicators. In fact, the Lanac challenger is used as a radar for certain special navigation purposes that will be described later. The differences between radar and a Lanac challenger-replier system are, however, quite important and are as follows:

(a) With radar, a very small fraction of the energy in the original signal is bounced back to the radar receiver. The amount of the echo depends on the size of the target, being substantial for large ships and rather small for aircraft.

In the Lanac system the distant replier sends back a new signal to the challenger. This signal can be made powerful enough to meet all likely requirements for system range and reliability.

The reflection of a radar signal is like the rebound of a ball thrown against a wall, while the re-transmission in a replier is like the new drive given a ball by the bat in baseball.

(b) A Lanac challenger transmits on one radio frequency and receives replies on a different radio frequency. In this way the observer at a Lanac challenger reads the replies displayed on his indicator without being bothered by "ground return" and other interfering echoes from unwanted targets.

(c) Lanac challengers can select a group of repliers without disturbing other groups of

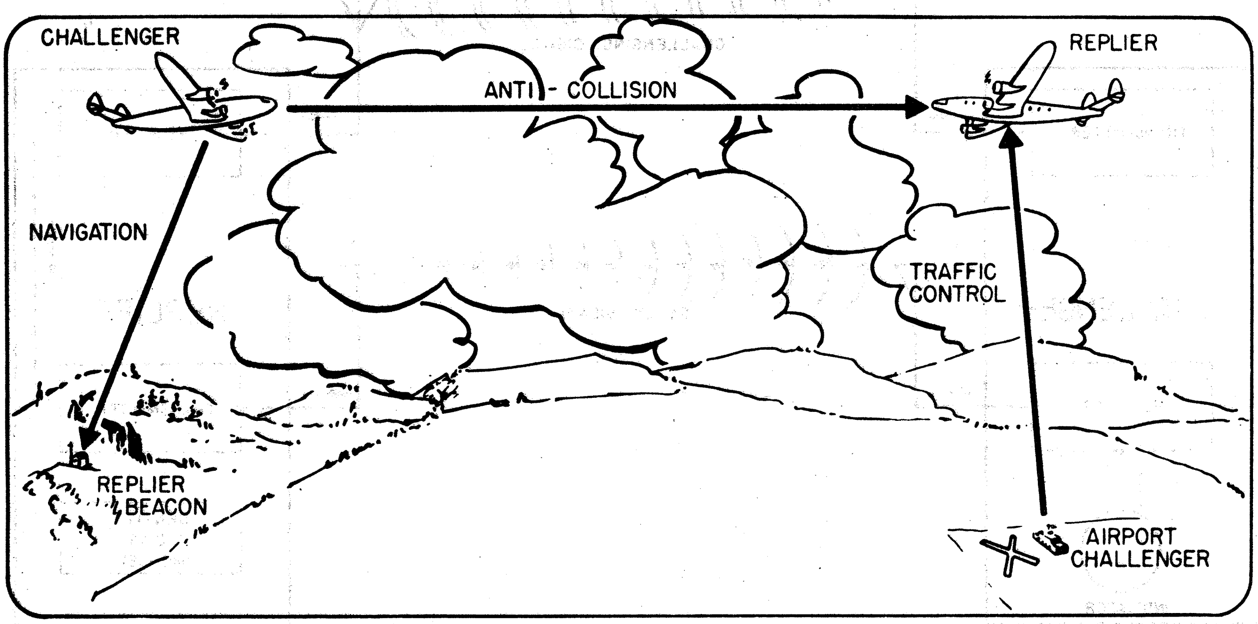


Fig. 2. Aircraft Services Rendered by Lanac

repliers. In aircraft service, for instance, a challenger can address the repliers on all planes flying in one altitude layer and ignore those at other levels. Lanac can also select traffic by direction, range, and other conventional radar techniques.

(d) Lanac repliers transmit information to challengers by means of the identity coding. Besides identity, emergency information such as "Distress" and "Obstacle Warning" can be signaled. Such features as automatic announcement of the replier craft's heading or course can be added to the basic system.

(e) The Lanac system with a challenger and a replier constitutes a two-way "radio system"; ordinary radar is, essentially, a one-way system since only one transmitter and one receiver are involved. This means that a challenger-replier system must be much more carefully engineered on an overall system basis than radar. Such considerations are the concern of the radio engineer and are mentioned here for this reason.

Lanac Challenger as a Radar

It has already been mentioned that a Lanac challenger is employed as a radar in special applications. This is done by tuning the receiver and transmitter of the challenger to the same frequency so that echoes will be shown on the challenger's display in the usual radar manner. The frequency shift requires only the turning of a single knob on the challenger's control panel. If desired, a clock-operated switch is provided to make regular transfers between the two types of operation.

The radar mode of operation is used in marine anti-collision service to warn against unequipped craft and icebergs. It is also used for harbor surveillance to show the location of unequipped vessels.

Use in Aircraft Service

In order to see clearly some of the things Lanac can do, let us examine Figure 2, which shows applications to aircraft operation. For simplicity, only a challenger is shown in the left-hand plane, and only a replier in the right-hand one. Anti-collision warning is obtained directly between planes, without the need of any assistance from the ground. The gain in range, as compared to radar, afforded by the re-transmission in the replier meets the needs of high-speed planes whose closing speeds on a collision course may be 600 or more miles per hour.

A navigational fix is obtained by the navigation challenger receiving a signal returned by the replier beacon on the ground at the left in the figure. Traffic control at airports is secured by having one or more challengers on the ground so as to maintain a complete set of data on all planes in the vicinity.

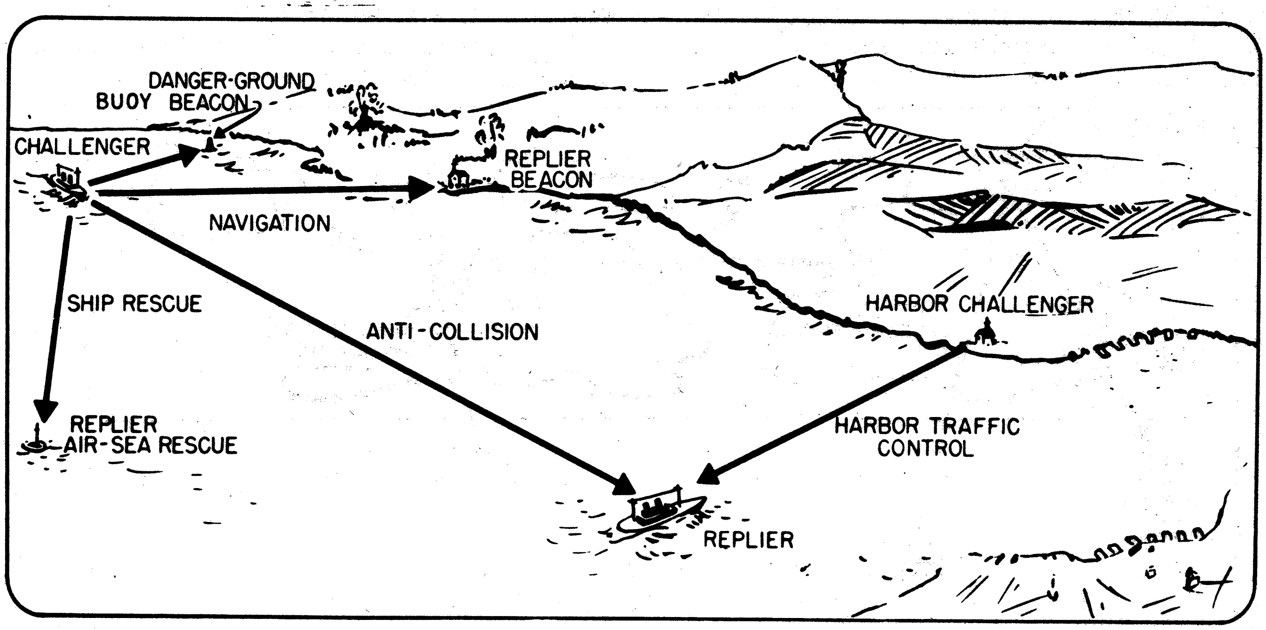


Fig. 3. Marine Services Furnished by Lanac.

An important additional aviation service rendered by Lanac is protection against crashes into mountains or tall buildings. Such obstacles are fitted with repliers having special coding of a distinctive warning character so that nearby planes are given ample notice. In addition, the identity of each such obstacle is indicated in the same way as with all repliers.

Use in Marine Service

Figure 3 shows the application of the system to marine service. The vessel at the upper left has a challenger. For simplicity we omit the replier which would normally be provided also on this ship. In the upper center of the view is a replier beacon located on the shore. The challenger of the vessel sends out a signal and receives a reply from the replier beacon, the latter thus serving as an automatic beacon by means of which the ship obtains a fix. This is possible, in the same way as with the plane challenger and replier beacon of the previous figure, because (1) the craft knows the identity and location of the beacon from the identity coding of the reply, (2) the craft also knows the distance of the beacon, which is shown on the indicator display, and (3) the bearing of the beacon is known from the direction in which the challenger antenna is pointing. Thus all desired information for a single-point fix is furnished.

Likewise the challenger will receive a reply from the danger-ground buoy beacon, thus obtaining another fix as well as a warning of danger in that direction. With two beacons thus available, the important possibility of a two-point fix arises. After the fix is obtained approximately by distance and direction with respect to one or both beacons, the accuracy can be much increased by using the two distance values only and securing a two-point fix as the intersection of arcs of circles drawn about the locations of the two beacons.

Anti-collision protection is obtained between the two vessels by virtue of the challenge and reply equipment. Should one vessel be unequipped, protection against collision would still be had by periodic Lanac radar operation of the challenger on the other vessel.

With a harbor challenger on shore, as shown, which challenges the ship equipped with a replier, we have harbor traffic control, a different kind of Lanac navigation service. The harbor challenger knows the position of the particular ship, and its identity, and can follow its movements. The harbor master with such data, supplemented by Lanac radar, is given sufficient information to plan and control all the traffic in the harbor.

A small replier, especially for lifeboats, is provided for air-sea rescue. Any vessel within 10 miles and any plane within 30 miles of a lifeboat in distress will receive the distress signal and have the position of the lifeboat displayed on the indicator of its challenger, and can therefore proceed to the location and give aid. In Figure 3 the receipt of such a distress signal by the challenging vessel at the left is shown.

Use in Joint Air and Marine Service

The correlation afforded by Lanac equipment in air and marine service is shown in Figure 4.

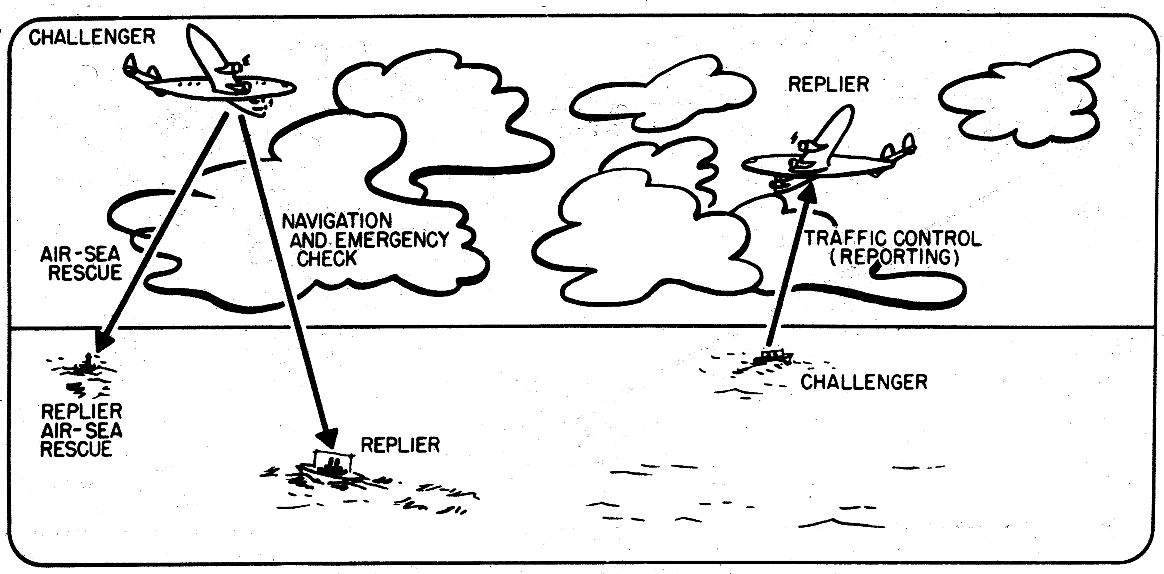


Fig. 4. Combined Air and Marine Application.

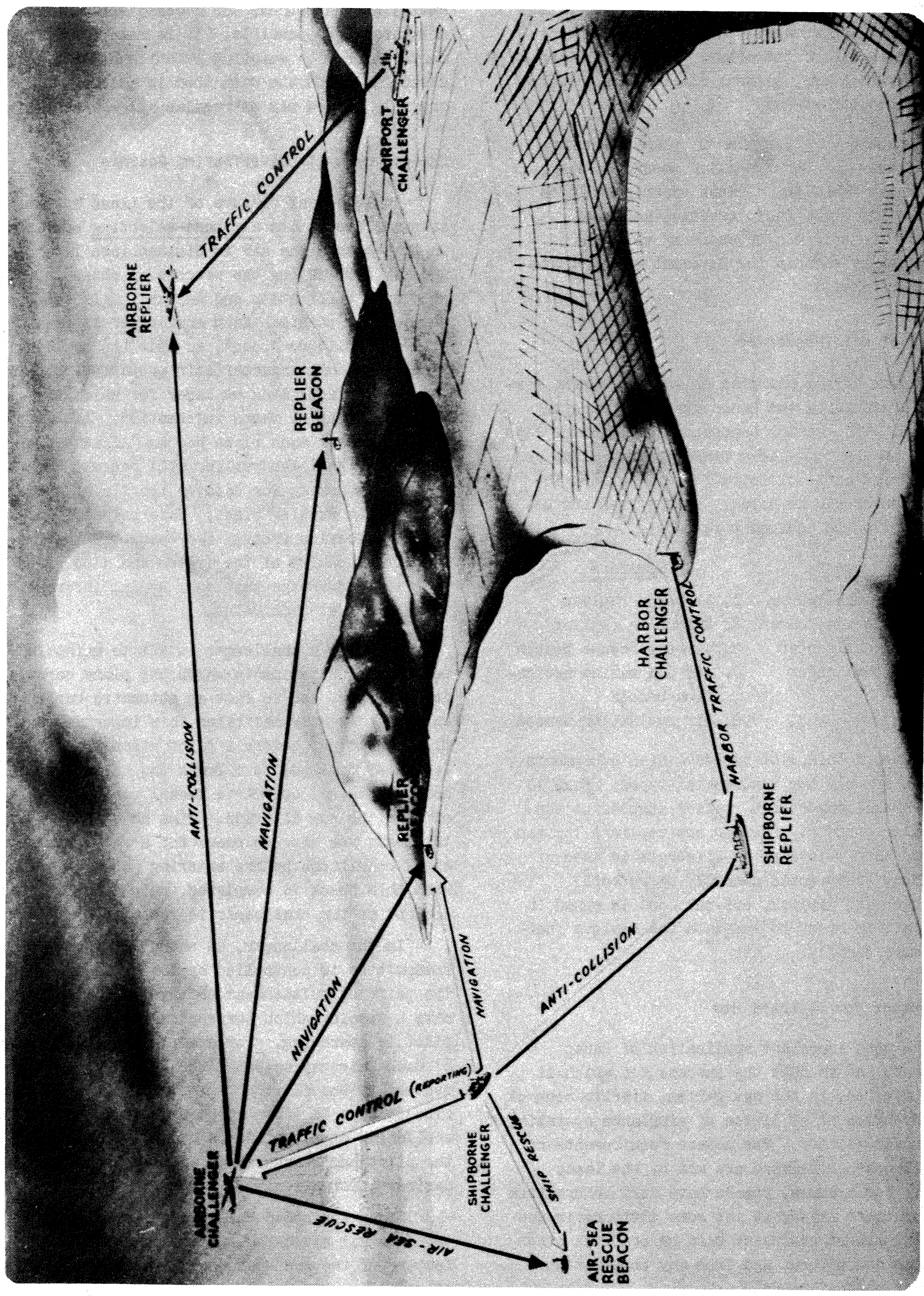


Fig. 5. Summary of Air and Marine Services Rendered by Lanac.

Far from shore, craft in one medium will know the location and identity of craft in the other to their mutual advantage. In distress either can come to the aid of the other. Although lifeboats have only repliers, without challengers, no more is required for rescue.

Reporting by vessels of planes passing nearby, another service which should develop, is shown at the right. Such reports would be handled like other radio traffic, and make possible the assembly on shore of valuable supplementary data on the movement of all trans-ocean aircraft.

Summary of Main Functions

A view giving examples of air and marine services furnished by the Lanac system appears in Figure 5. The replier beacon on the point of land jutting to the left gives fixes to both plane and vessel. The anti-collision feature between the two planes should be noted. In the view the use of the following equipment is seen:

Challengers	Repliers
1. Airborne challenger	1. Airborne replier
2. Shipborne challenger	2. Shipborne replier
3. Airport challenger	3. Air-sea rescue beacon
4. Harbor challenger	4. Air and marine navigation beacon
	5. Air navigation beacon

Although this list includes nine equipments, they are of only two fundamental types. Each is either a challenger or a replier adapted to the particular purpose. Beacons are repliers located on fixed land points or on lifeboats in need of aid. Most craft would normally carry both challenger and replier, but only one is shown in each craft in order to indicate the various functions more clearly.

Development for Aircraft Use

The most important application of Lanac equipment, and in fact the purpose for which it was originated, is the navigation, traffic control, and prevention of collision of airplanes operating in overcast weather. The severe requirements of such all-weather service are met by the Lanac system. For example, planes have full information on other craft flying at the same altitude in the locality without confusing data on craft at other altitudes and without aid from any cooperating equipment on the ground.

Broadly speaking, the Lanac system offers new equipment and methods for accomplishing results not heretofore possible. It is not therefore in competition with existing aviation aids, but instead can cooperate with them in accomplishing the urgently needed aim of regular all-weather flight.

Laminar or Altitude-Selecting Feature

An important feature of the Lanac system in aircraft use is its altitude-selecting operation. In this method the air is divided into layers, greatly simplifying the process of obtaining the necessary information and exchanging it between the various points. Each challenger is provided with an "Altitude Coder", so that its challenging signals have a characteristic property indicating the particular lamina or layer for which the challenging pilot wants information. Likewise the replier of each plane has an "Altitude Decoder", so that the replier will respond only to challenges asking for data on traffic at the altitude of the replier plane. This principle of altitude selection greatly increases the traffic-handling capacity of the system and also gives the important advantage that only useful information is received at each point.

Normally a challenger is set to maintain a search of the lamina in which the plane carrying it is flying, and in fact an automatic barometric switch ordinarily maintains this important relation. However, before a pilot rises to a higher lamina or descends to a lower one in instrument weather, he can operate a manual control to ex-explore the new altitude. Thus he can advantageously use his equipment for a short time to check conditions before entering another lamina. When this check is completed, automatic altitude control of the challenger is restored.

In the challenger, as shown in Figure 6, the transmitter is controlled by the altitude coder. The pairs of pulses sent out by the challenger have a spacing which corresponds to the lamina the pilot is searching. For example, the two pulses of each pair may be separated by, say, 10 microseconds if one altitude is of interest, and by 20 microseconds if it is another altitude. Thus the challenger at all times is under the control of the pilot and searches the altitude for which he desires information.

Since the coded challenges propagate as radio waves to all altitudes, the altitude-selecting feature of the system is completed by a discriminating altitude decoder in each plane replier.

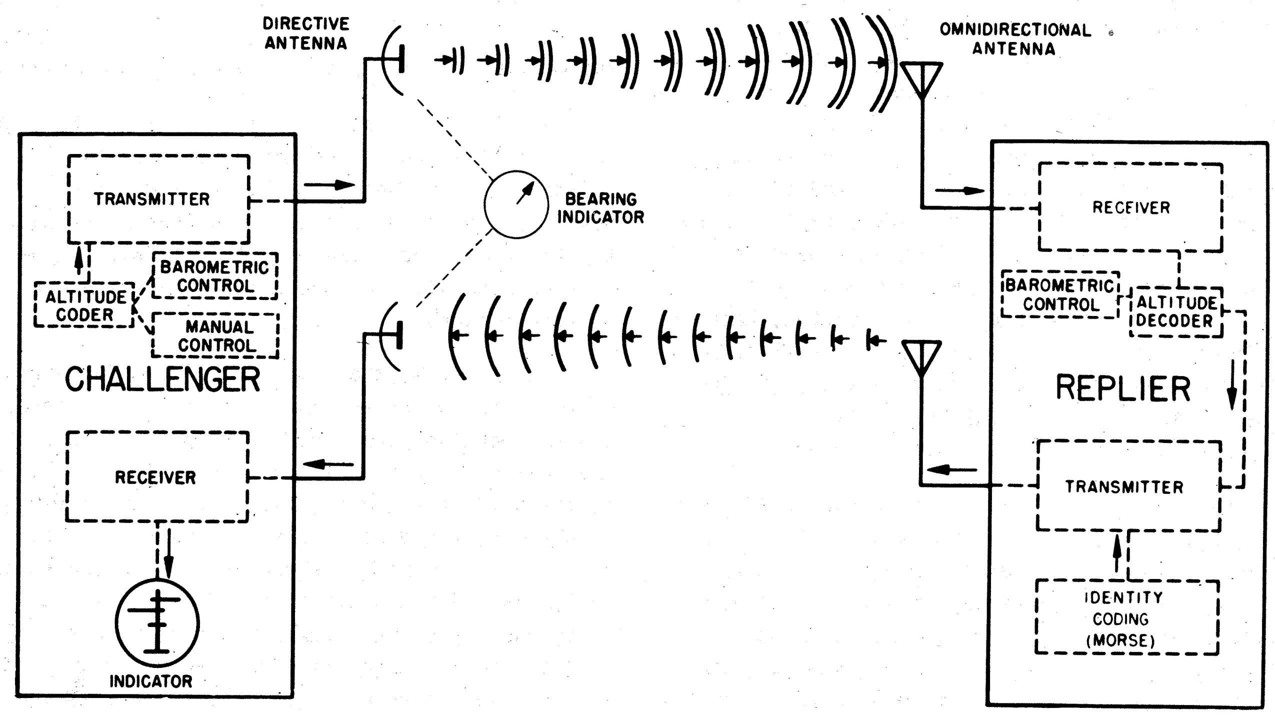


Fig. 6. Block Diagram of Airborne System Showing Challenger in One Plane Getting Answer from Replier in Another Plane

This decoder is automatically controlled by a barometric switch so that it passes on an actuating signal from the receiver to the transmitter in the replier only when the challenging signal is coded for the pressure stratum (height at which the replier is flying. This enables the replier to discriminate between challenges which it must answer and those it should ignore. With this method of operation, all planes flying in a particular lamina reply to a single type of challenging pulse. All barometric switches are adjusted to a pressure standard and sealed so that the pressure limits for each lamina are uniform for all equipments throughout the Lanac system.

Furnishing of Identification Data.

Another important feature, namely the transmission of identity information, is also shown in Figure 6. The transmitter of the replier will be seen to be under the control also of a unit marked "Identity Coding (Morse)," which alters the reply pulses, thus showing to the challenger by letters and numbers of the International Morse Code the exact identity of the plane or station in which the replier is installed. Identity data of this kind supply the information required at crowded airports where in the future dozens of planes will appear on radar scopes with otherwise no satisfactory way to tell which plane is which.

Anti-Collision Between Planes

The scene shown in Figure 7 illustrates the altitude selection, or laminar feature, of Lanac and the operation of the system to prevent collisions between planes.

Note that the double challenge pulses sent out by the rear (right-hand) plane in the 6000-foot layer look different from those sent out by the rear plane in the 4000-foot layer. They are different: the spacing between the pulses of each pair is greater at the higher altitude, as determined by the automatic altitude coder. Due to this difference in altitude coding, each challenger receives replies only from a plane or planes in its own altitude level, as determined by the altitude decoders in the repliers of the challenged planes. In effect, planes in any given altitude level are isolated from all other planes in the vicinity. This enables each pilot to concentrate his attention on the things that are vital for him to know, and avoids burdening him with information that is of no direct concern to him.

If the pilot wishes, he can manually switch his altitude coder to challenge planes in altitude levels higher or lower than his own. But in normal flight on a steady course, a pilot is concerned chiefly with what lies ahead on a possible collision course. The Lanac equipment gives him this information: it warns him instantly when there is another plane ahead, giving him its range, bearing, and identity. Brief observation of the other plane's replies also gives him the relative airspeed data he needs to overtake or follow, without delays and without danger. Independent of radio communication, Lanac supplies each pilot with complete, pertinent air-traffic information. And it does this without depriving ground controllers of full data or of opportunity to exercise their proper authority.

The anti-collision feature of Lanac is effective at good distances. Depending on weather and terrain conditions, the maximum range of an airborne radar to an airplane target varies from about 1/2 minute to one minute flying time for fast transport planes approaching head-on; the minimum Lanac range under similar conditions is from 5 to 10 minutes flying time. This corresponds to the difference between 5 to 10 miles range for radar and 50 to 100 miles for Lanac challenger-replier operation.

Prevention of Collision with Buildings and Mountains

The view of Figure 8 illustrates another anti-collision feature of the Lanac system. This is the avoidance of crashes of planes against fixed obstacles, such as mountains and high buildings. All important obstacles of this kind will be equipped with altitude-coded repliers acting as warning markers.

In the scene the lower plane is in danger of striking the mountain, which is hidden by clouds. But the warning marker on the mountain replies to the challenges from this plane and returns a distinctive identity-type danger signal which warns of the danger and identifies the particular obstacle. The warning-marker replier replies to all challenges that are altitude coded for laminas between the top of the mountain and ground level. In this way it warns all planes which are flying at altitudes where a danger exists. But it does not reply to high-flying planes, such as the one in the upper part of the illustration, which have

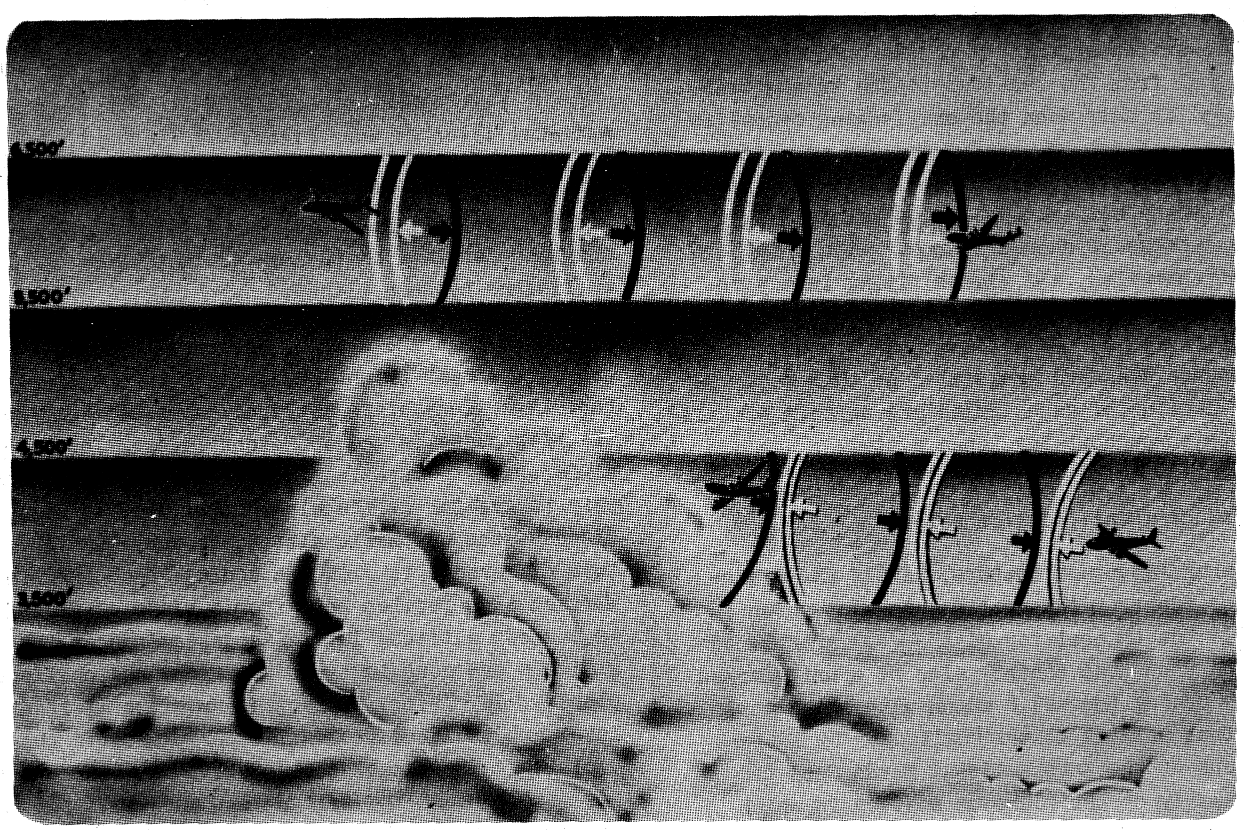


Fig. 7. Laminar Feature and its Application to Prevention of Collision Between Planes

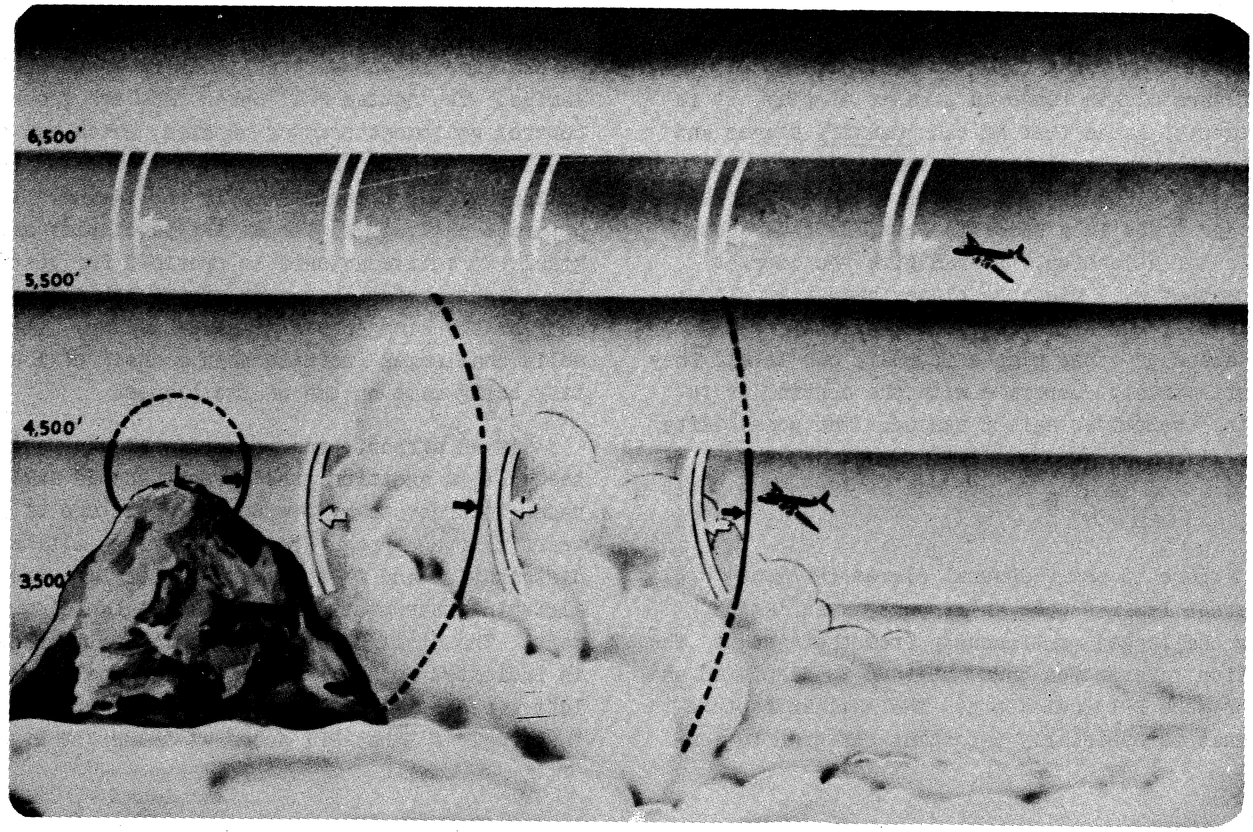


Fig. 8. Obstacle Warning by Means of Fixed Replier Adjusted To Reply to Challenges of All Altitudes Near and Below the Height of the Obstacle.

no concern with this obstacle far below them. Here again the principle of altitude selection enables danger warnings to be given only to aircraft in need of them.

Such an obstacle marker need not, as a matter of fact, be located on the actual top of the mountain. It can be replaced by one or more repliers located around the base of the mountain, provided the altitude decoder is adjusted to reply to all challenges up to the proper height. Such locations at more accessible points obviously assist in visiting the equipment for maintenance purposes.

Navigational Fixes

Figure 9 shows the use of the navigational challenger in the plane to get replies from an omnidirectional beacon on the ground. Such replies, as with the obstacle warning marker, give information of beacon identity, distance, and direction, so that a fix is obtained by the plane. The navigational challenger and its receiver constitute a distance-measuring equipment ("DME") and show on a meter or Veeder counter the distance of the plane from the beacon.

The distance, direction, and identity data from one onmidirectional beacon enable a pilot or navigator to establish his position with reasonable accuracy. Replies from two or more beacons, as would normally be obtainable, enable him to increase the accuracy. Like all repliers, these ground beacons are completely automatic and transmit replies only when they are challenged. When necessary, they can operate unattended in remote locations, requiring only monitoring and occasional maintenance attention.

Control of Traffic at Airports

The severest problem met by any system of aircraft control is the dense traffic above and around airports. Here the principle of altitude selection is a vital aid in making Lanac a practicable means of moving traffic safely and speedily.

While the air-traffic controller can "see" all planes within range on a radar display, it is by means of Lanac that he can identify planes and segregate them by altitude levels. He can challenge all planes by successive levels or he can concentrate on those in a specific level that demands particular attention. He can give the correct orders that will disperse planes evenly at different levels, and since individual pilots are always aware of other planes at their own level, they can effectively cooperate with the controller in keeping themselves safely spaced. The possibility of collision becomes negligible, and present approach and landing delays can be largely eliminated.

Figure 10 shows several planes in three different laminas over an airport, each lamina being challenged continuously from the ground. The position information thus obtained is displayed on one or more PPI indicators. The laminar feature of Lanac is especially important for traffic control at airports where large numbers of planes must be handled.

Figure 11 shows four planes in the 5000-foot lamina. The dotted challenges from the ground-control equipment produce replies, which can be displayed on a Lanac PPI scope to reveal the location of each plane flying in the lamina. A separate challenger with an A-type display and a highly directive antenna is provided for getting the identity of planes just arriving in the area and for checking others whenever needed. The solid challenges indicate such a check of identity being made on one of the planes.

At an airport, one or more challengers are needed. In addition, the airport should have a radar in order to give a complete picture of all traffic without regard for its laminar altitude distribution and to track any planes that are aloft in instrument weather without Lanac equipment. The display apparatus for a small airport is indicated in Figure 12 where a scope at the left gives a radar PPI picture of all craft in the area. A Lanac PPI scope at the right side of

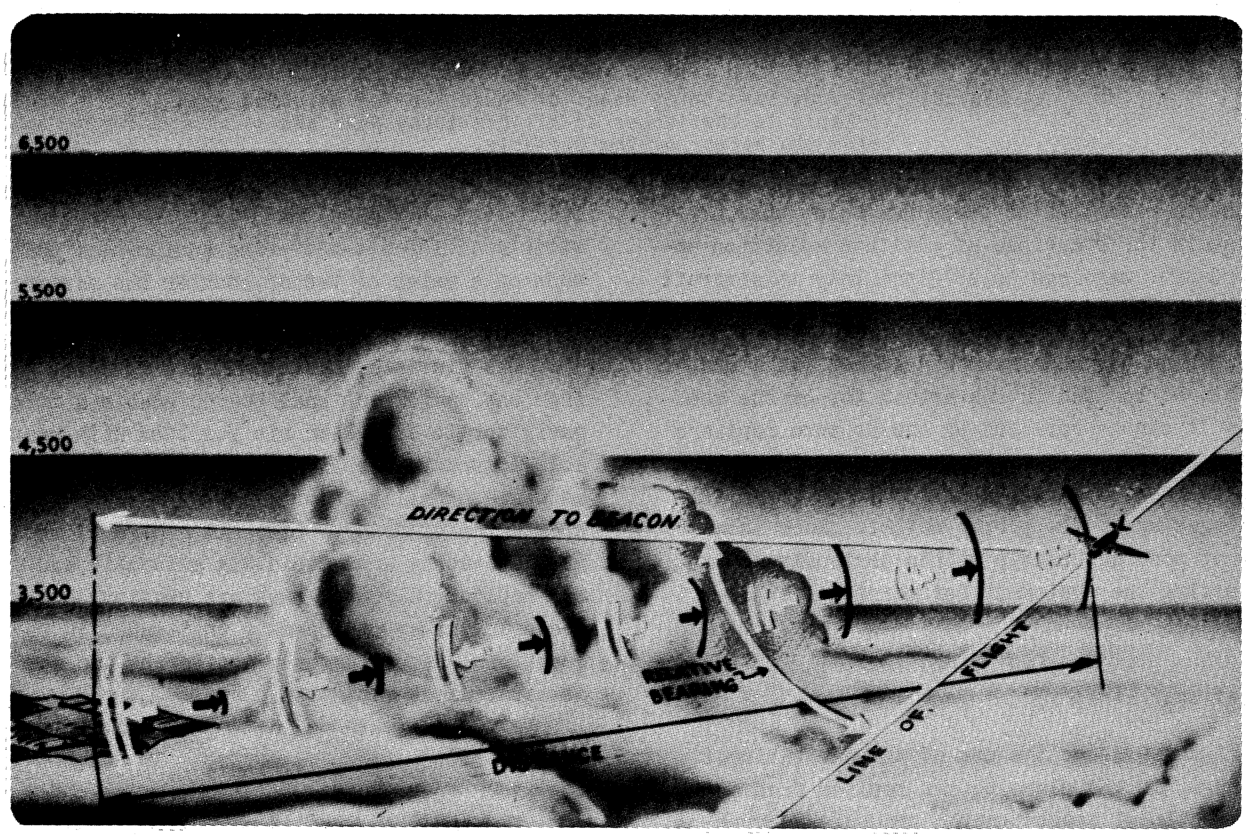


Fig. 9. Plane Getting Navigational Fix by Distance and Direction to Omnidirectional Beacon.

the main panel shows traffic in any particular lamina. This scope is switched sequentially through successive laminas or set manually to monitor the traffic in the layer which it is desired to investigate. On the shelf is the A-Type of scope for reading identification codes. This may be used with a separate challenger, or a single challenger may be used with switching for this purpose and the Lanac PPI. At airports where light traffic only is handled, one challenger would be adequate for both purposes; with heavier traffic, two or more should be provided. The plotting board shown in the illustration is sufficient with movable markers to show the traffic under light conditions. More extensive plotting facilities, with two or more tables taking the various groups of laminas, would be necessary for handling heavier traffic. At an airport serving a major city, a separate control operator would be needed for each lamina.

A complete system of centralized control also becomes possible when remote check stations (similar to but smaller than airport installations) are set up along the principal airways. These stations relay complete traffic data on their area to the central controller.

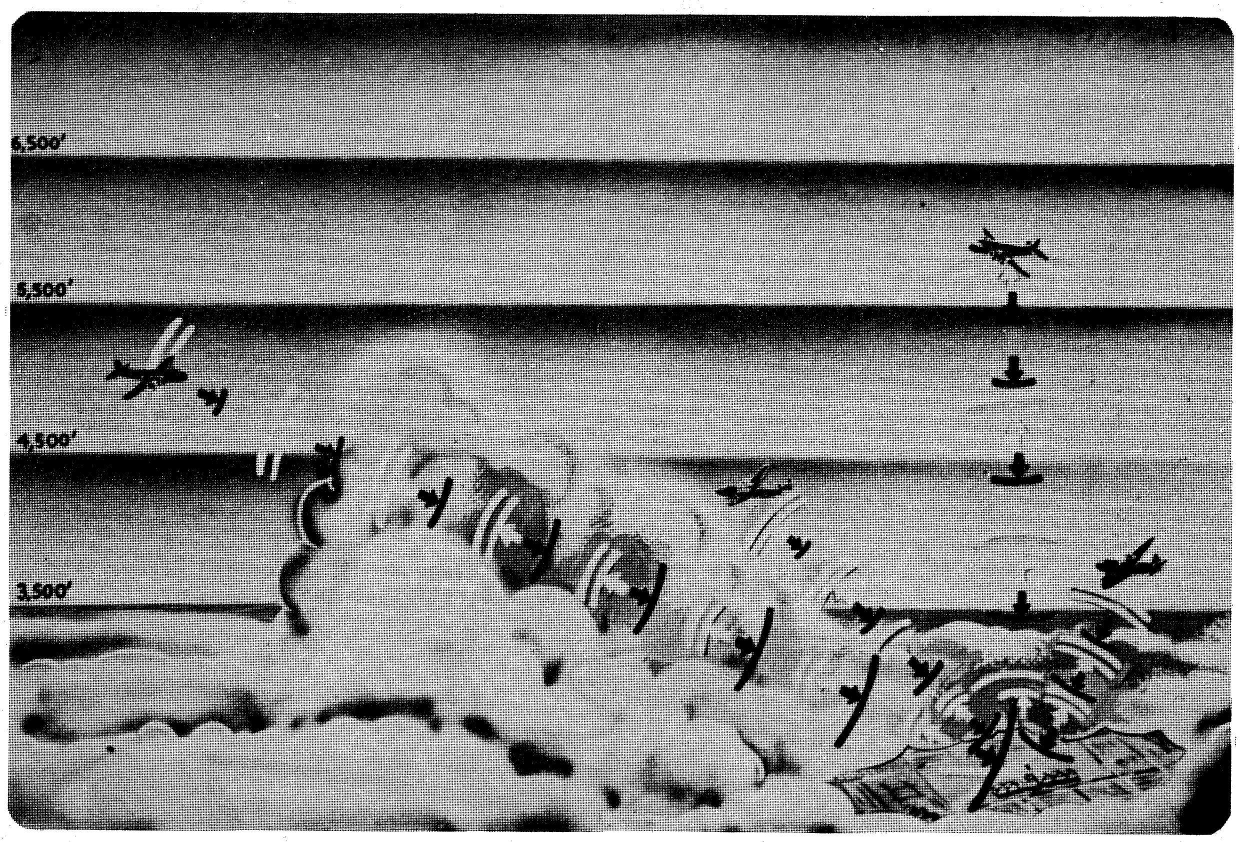


Fig. 10. The Controller at a Lanac-Equipped Airport Segregates Traffic by Altitude Laminas.

Use in Sea and Air-Sea Rescue

Figures 13 and 14 illustrate dramatically elements of Lanac's contribution to safety at sea: its unique ability to find and to mark pinpoint locations on the open ocean by means of marker-beacon repliers. One type of such beacons, shown in Figure 13, can be either hand or battery-energized, and is designed to be carried in lifeboats.

When in extreme distress, before lowering the lifeboats, any Lanac-equipped ship would of course switch its shipborne replier into Emergency operation at the same time that radio SOS signaling was begun. On all challenging ships and aircraft within operating range, the distinctive appearance of the distress replies on the scope would automatic-

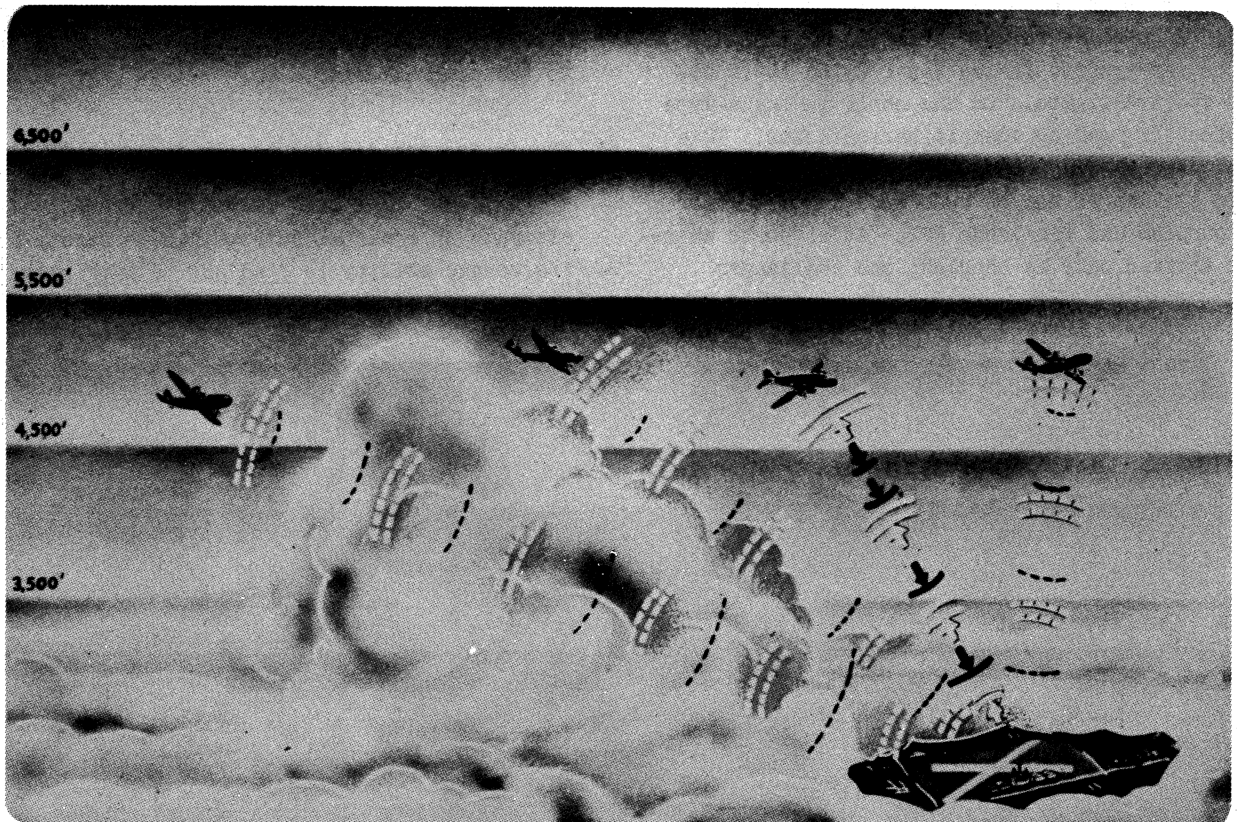


Fig. 11. Identification of Newly Arrived Plane in a Particular Lamina by Airport Controller's Directional Challenger.

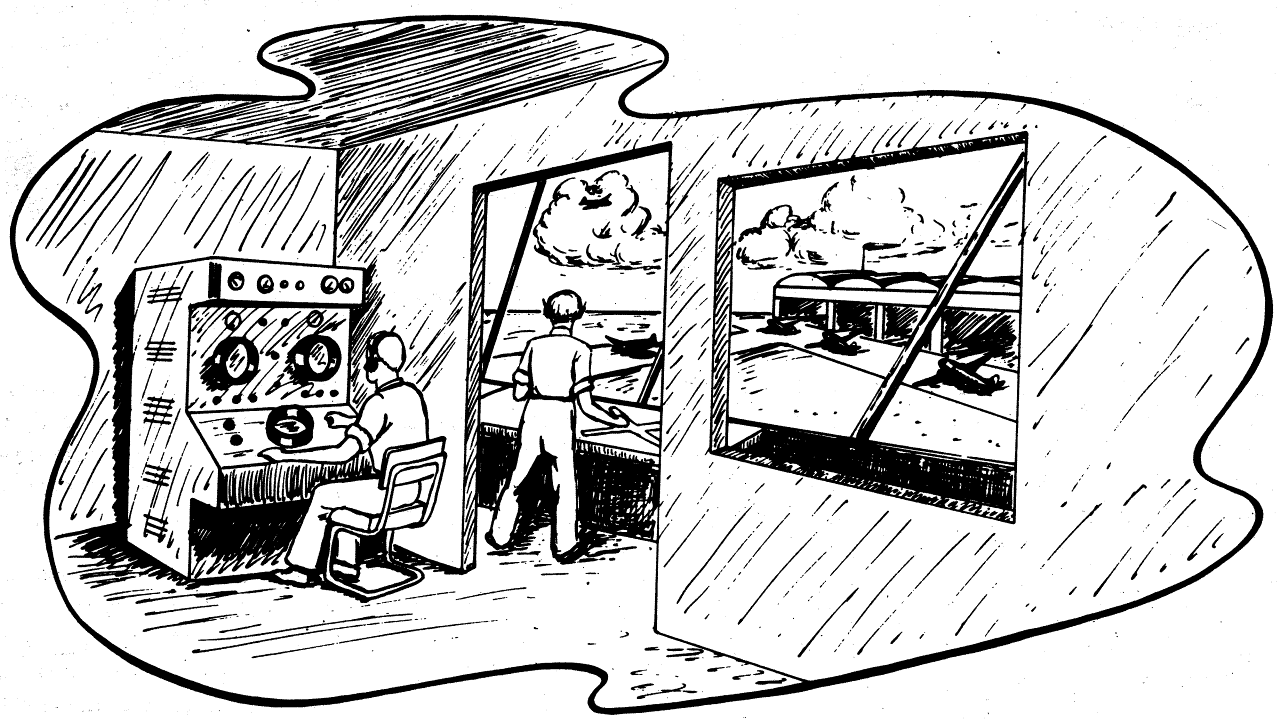


Fig. 12. Lanac Installation for A Small Airport

ally show the call for help. The vital feature of Lanac emergency operation is that these replies are not only a call for help,— they also serve as a beacon to tell the challenging ship or aircraft the exact location where aid is needed. An aircraft forced down to the sea would be given aid in a similar manner.

But whatever means are employed, a ship is not as difficult to find as a lifeboat, particularly in heavy seas. (Spotting a small boat is practically impossible in thick weather.)

Lanac Display Systems

While most of the scope display systems developed for military radar can be employed to present Lanac information, three types are particularly useful. These are the "A", the "L", and the "PPI." The one to be used in any given case is largely determined by the kind of information to be displayed.

The essential features of each display are shown in Figures 15, 16, and 17. In each, the

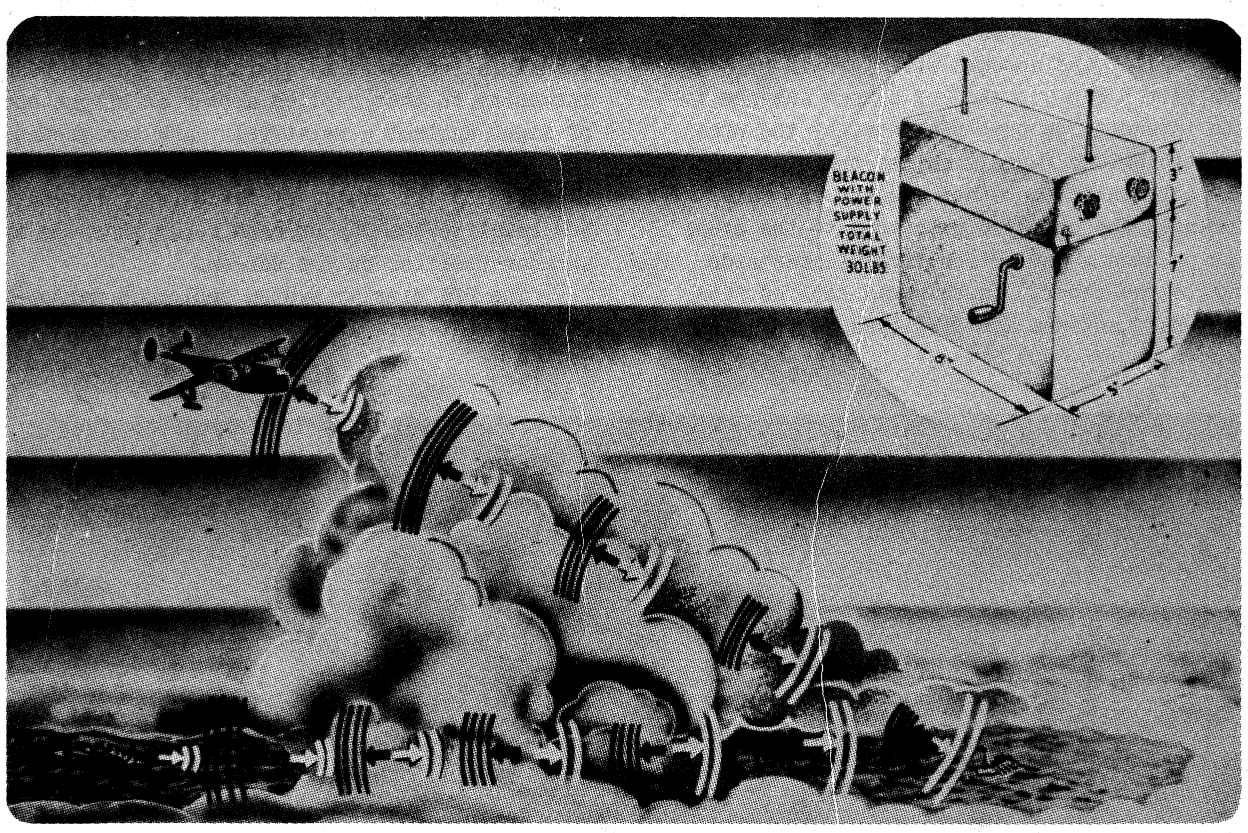


Fig. 13. Use of Lanac for Lifeboat Rescue.

The lifeboat beacon, however, enables searchers, whether in the air or on the sea, to "home" directly on a speck in the ocean that is invisible to radar as well as to eyes except at extremely close range.

The other type of emergency marker-beacon replier shown in Figure 14, is of battery-powered buoy construction. Equipped with a parachute when it is carried by aircraft, it may be dropped from a patrol plane when air search reveals an unequipped liferaft or lifeboat and when heavy seas prevent the plane's landing on the water to pick up the survivors.

diagram at the left shows the relative locations of the challenger and repliers and at the right the nature of the display which is produced. Observe that each type of indicator requires its own type of antenna.

The A-type display of Figure 15 is a well known radar display in which distance is plotted to the right along the horizontal axis and signal intensity is shown vertically.

The L-type display of Figure 16 shows distance vertically, measured from the horizontal base line at the bottom. Pips appear on either one or both sides of the vertical center trace depending on the direction in which the antenna is pointing. When the pip on the left side equals that on the right, the antenna is pointing directly at the replier. The L-type scope is essentially two A-type scopes (which display range horizontally and signal strength vertically) placed "back-to-back" and turned through 90°.

The L-type display employs two small directional antennas supported on a common rotatable mount. Each of the two antennas has the fairly broad lobe pattern shown at the left in the figure. The two lobes overlap, and in locating a replier the antenna structure is rotated until the reply picked up by one antenna is equal in intensity to that picked up by the other. An automatic switch rapidly shifts the challenger from one antenna to the other and, at the same time, changes the output connections to the scope so as to produce a deflection first to one side and then to the other. In this way replies from the right-hand antenna are displayed to the right of the vertical trace, and replies from the left antenna are displayed to the left. In the diagram the antenna is pointed toward Plane B; Plane C is to the left; and Plane A is to the right. Relative bearing indications are obtained from a dial-type indicator at the operating position which shows the direction in which the antenna is trained.

Figure 17 shows the display on the PPI scope ("Plan-Position Indicator"), and it will be seen to be a map-like representation of the zone surveyed in all directions by the challenger antenna as it rotates. The position of "our" plane is at the center. The presence of each reply signal is indicated by an increase in the beam intensity so that replies appear as bright spots of light against a relatively dark background. The distance of a reply from the challenger is measured by its radial distance from the center. The relative bearing of each reply is shown by its angular position on the screen.

The PPI display system employs a narrow-beam antenna that rotates continuously about a vertical

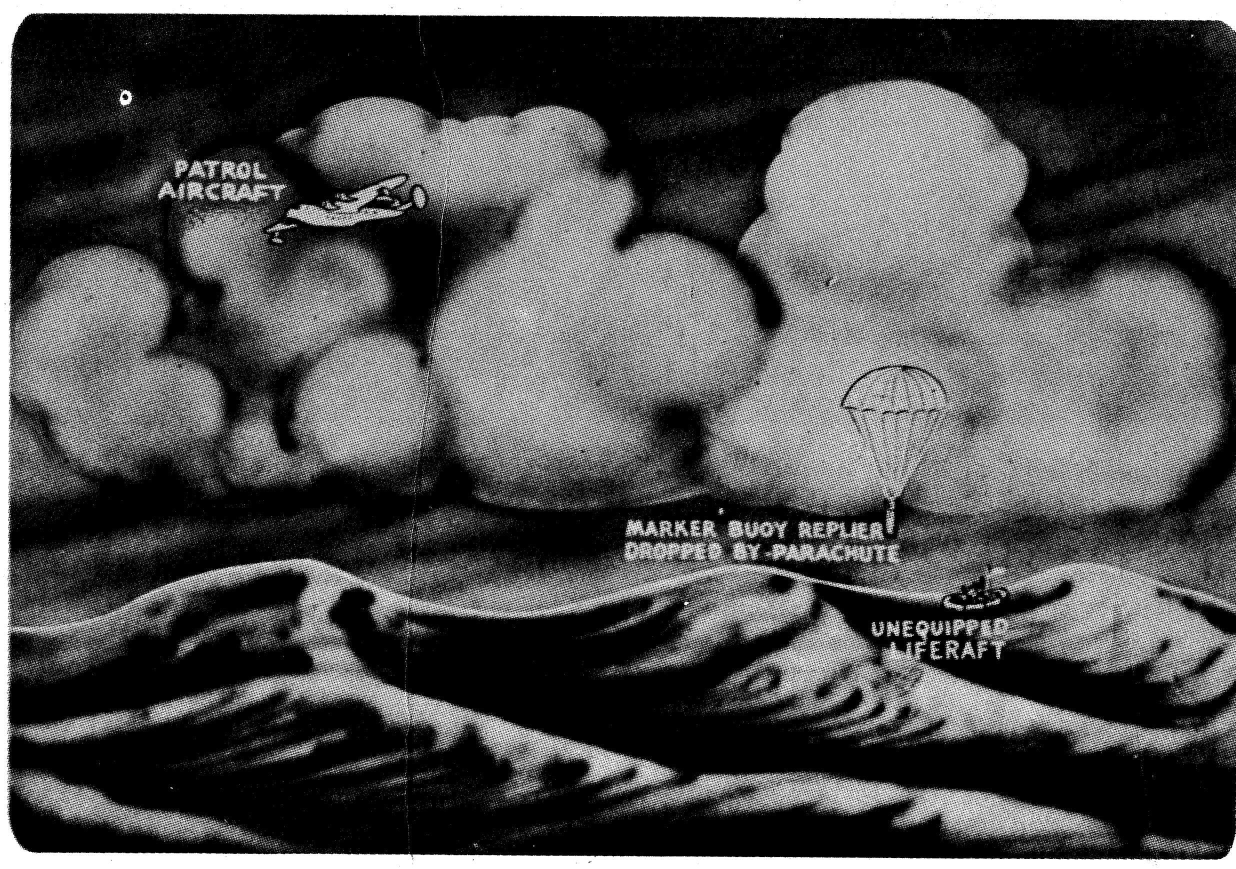


Fig. 14. Use of Lanac Marker-Buoy Replier in Air-Sea Rescue (Or as an Emergency Warning Marker for Icebergs or Derelicts).

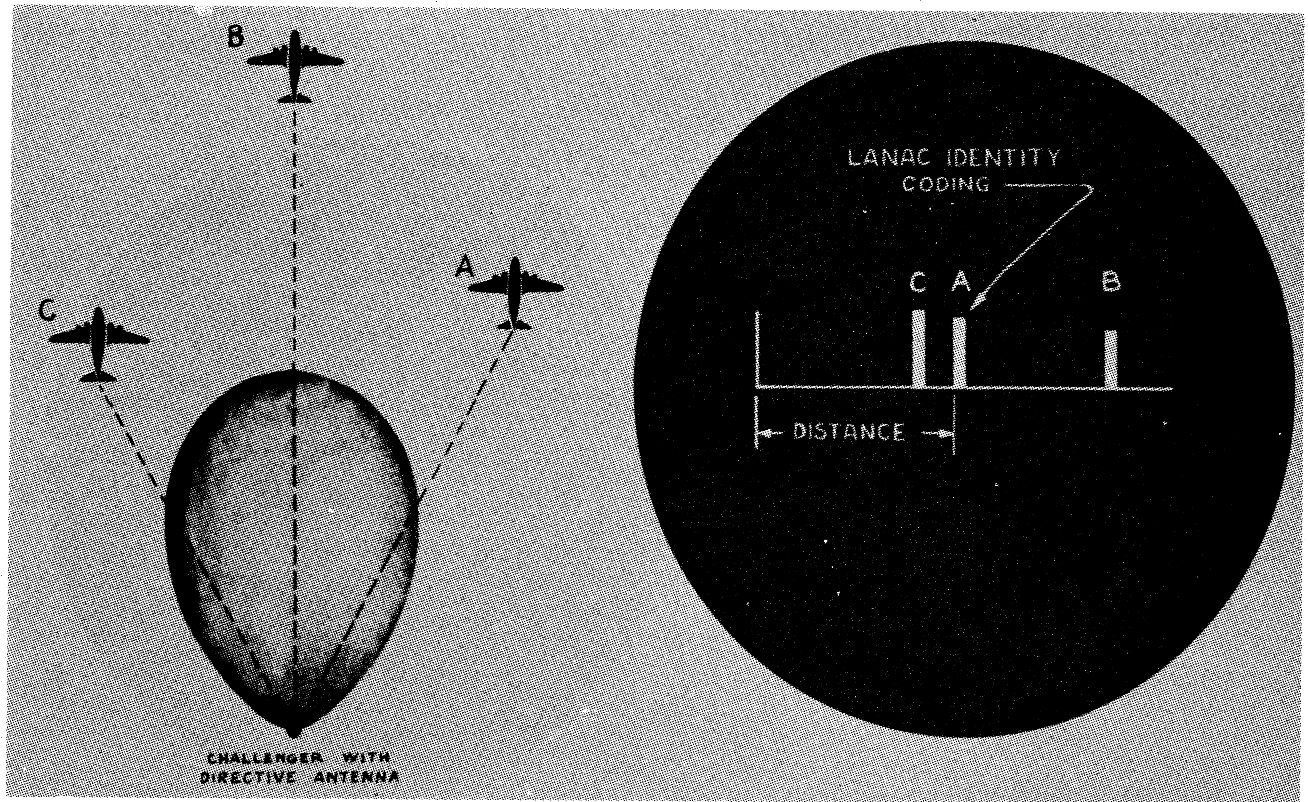


Fig. 15. Lanac display on an A-type scope

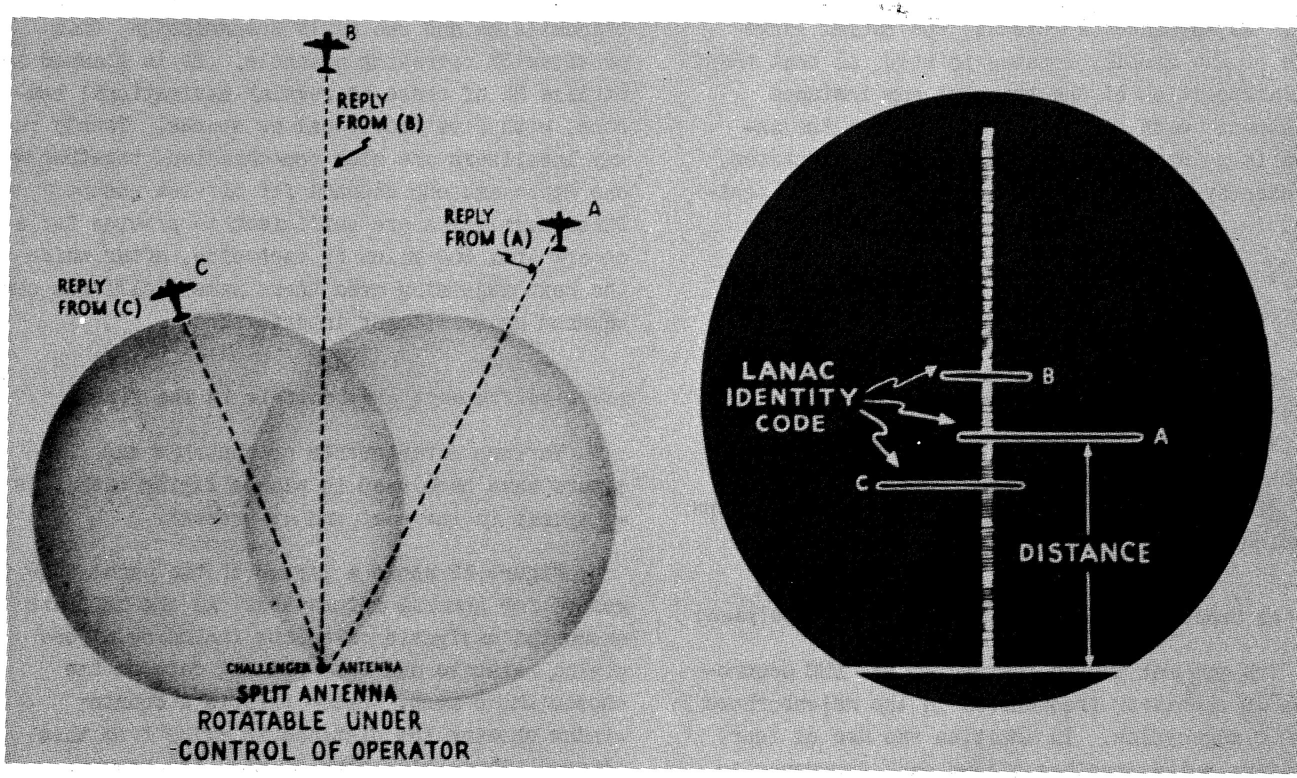


Fig. 16. Display on an L-type scope.

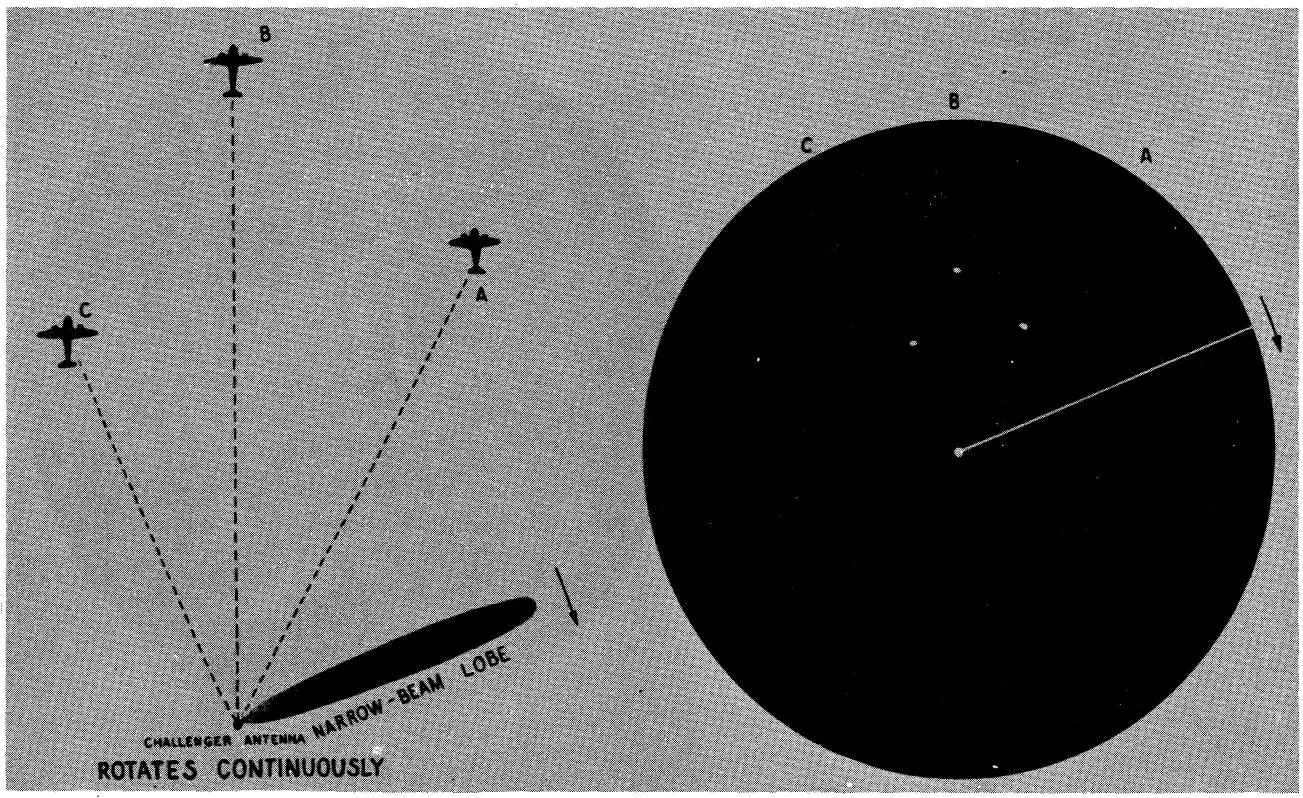


Fig. 17. Display on a PP1-type scope.

axis. As the antenna rotates, the radial range trace of the display rotates in step, so that the angular position of the trace at any instance corresponds with the direction in which the antenna is pointing. Thus, as the antenna rotates, the display shows each replier in its proper position.

Since the beam of the PPI antenna is continuously rotating and remains pointed in one direction for only an instant during any one sweep, a long-persistance screen is used. For these reasons Morse identity codes cannot be easily read on a PPI display. A surface surveillance station can provide the larger antenna required for PPI presentation and also provide an A-scope or L-scope on which to read the identity of replying craft.

Channel Capacity of the Distance-Measuring Equipment

The pre-set tuning feature of the DME accomodates 26 operating frequencies in the neighborhood of 1000 megacycles. In addition the use of four different pulse spacings allows each frequency to be used for four independent channels, so that 102 non-interfering transmissions are provided. Since each operating channel requires one challenge transmission and one reply transmission, this provides 52 operating channels. It is planned to utilize 25 of these as regular navigational beacons, with five additional as spares. Twenty runway localizers are also contemplated, together with one spare and one channel for air-sea rescue. These facilities are sufficient to provide for a square area 500 miles on each side, after which in the next adjoining area these same facilities can be used again without interference.

Panel Instruments and Controls in the Plane.

Various arrangements of controls and indicators have been used in planes flying with this equipment in the past and at present.

Figure 18 shows a layout of the panel suggested for general future use. At the left are shown the navigation elements including a rose giving relative and true bearing data on the chosen DME beacon. Below this is a counter window showing the distance in miles from this beacon. There will also be seen the beacon identity iris, behind which a lamp flashes the Morse Code verifying the identity of the chosen beacon.

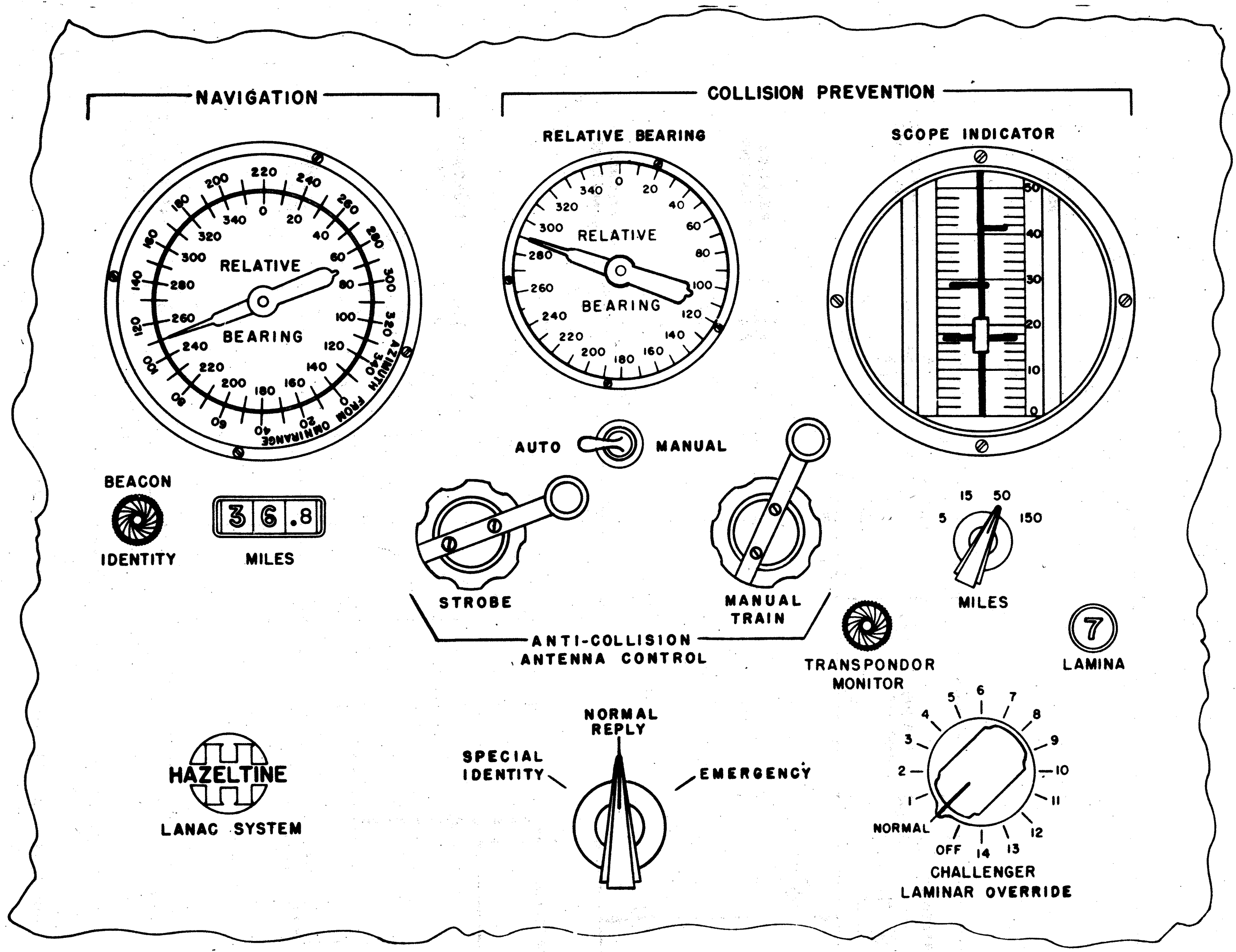


Fig. 18. Instruments and Controls on Panel in Airborne Installation

At the right side in Figure 18 are the dials and controls associated with collision prevention. The Scope Indicator shows the presence of all repliers in the lamina at which the plane is flying. With the Auto-Manual switch on the Auto side, the antenna holds the direction of the replier chosen by the position of the strobe indicated by the widened part of the central vertical line on the Scope Indicator. It is seen therefore that another plane is flying at the same elevation at a distance of 17 miles, shown on the Scope Indicator, and at a relative bearing of 290^{0}. The position of the strobe is controlled by the Strobe knob provided near the Auto position of the Auto-Manual switch. If the tracking feature is not needed, the Auto-Manual switch is thrown to the Manual side and the antenna's direction is controlled by means of the Manual Train knob. Under the Scope Indicator is the range switch providing ranges of 5, 15, 50 and 150 miles.

Should it be desired to investigate a lamina above or below that now in use before entering the new lamina, the pilot has only to operate the Challenger Laminar Override switch, moving it from Normal to the number of the lamina in which he is interested. Challenges are then sent out on the chosen lamina and the results shown on the Scope Indicator. Directions can be investigated by rotating the antenna if desired.

There remains one control and two indicators associated with the transmission of replies from "our" plane to other planes and ground stations. The window marked Lamina shows at the moment that we are flying in lamina 7 and are therefore replying to all challenges in that lamina. This number does not change except when we actually enter a higher or lower lamina. The Transpondor Monitor iris controls the intensity of light from a lamp which lights as long as our plane is

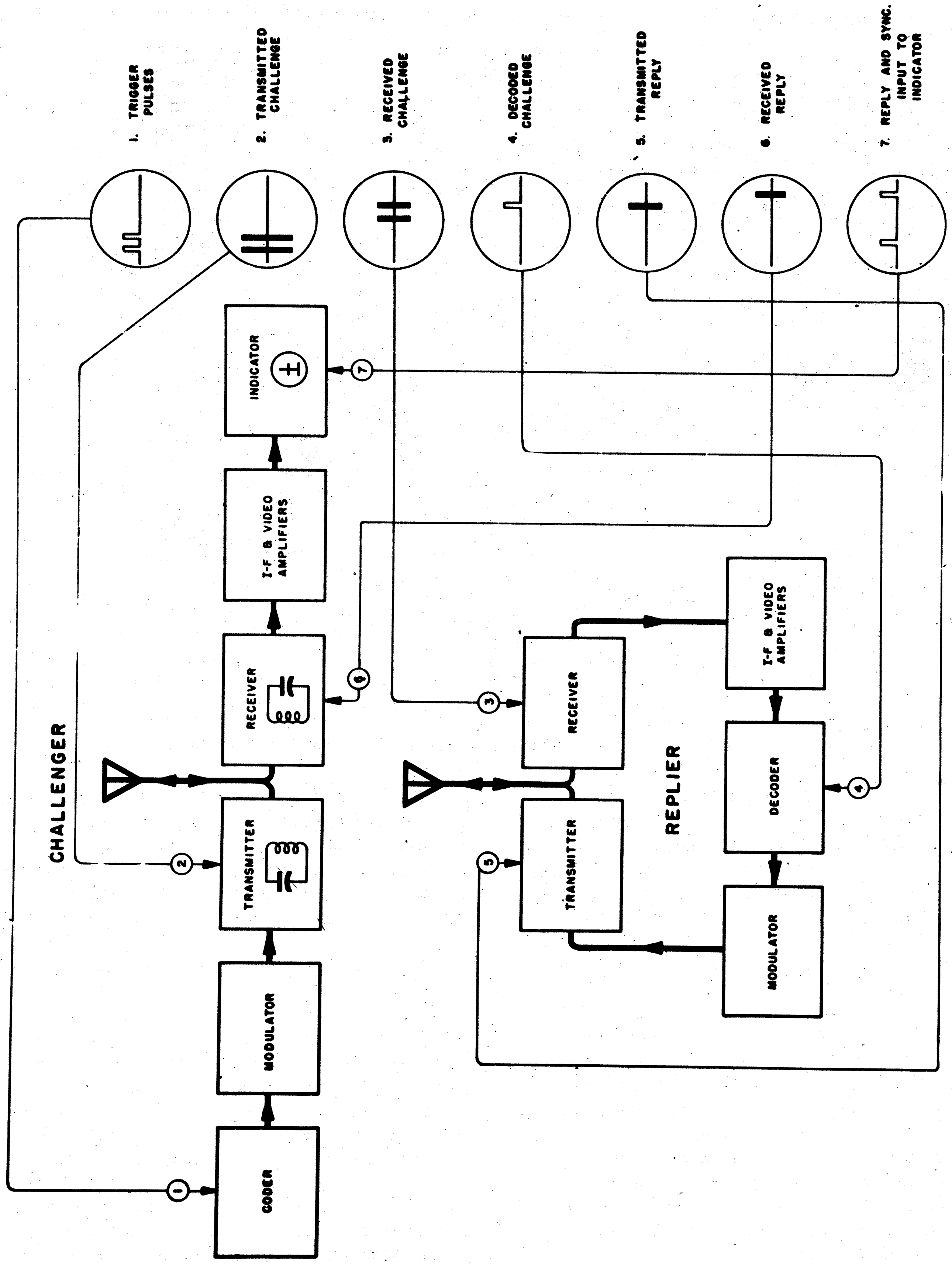


Fig. 19. Block Diagrams and Waveforms Showing Basic Operation of System.

replying to any challenge, Experience has indicated that this information is often of great value. The switch at the bottom center of the panel determines whether our plane is transmitting reply pulses of the normal character, or is sending out special-identity or emergency pulses. The special-identity pulses are switched on whenever requested by ground controllers; as a very rapid means of identification beyond that already provided. The emergency pulses are for use in distress and furnish a very distinctive pattern of 4 or 5 pulses immediately evident on all scopes.

Basic Operation of System

The main parts of the apparatus and the associated waveforms in a challenger-replier system are shown in Figure 19. Starting with the challenger, whose coder pulses are shown as waveform #1, the course of the signal can be followed through the modulator and transmitter to the antenna. The signals thus sent out, which are waveform #2, are received by the receiver of the replier, pass through the i-f and video amplifiers, and then arrive at the decoder where they are answered only if the pulse spacing agrees with the lamina at which the replying plane is flying. Assuming this is the case, the decoder actuates the modulator, which in turn radiates reply pulses through the transmitter of the replier. The reply pulses are received by the challenger antenna, go into the receiver as waveform #6, and then through the i-f and video amplifiers to the indicator. Waveform #7 shows the sync input signal to the indicator at the left and the reply pulse to the right. The indicator is an L type scope, which has distance vertically from the bottom, as already explained.

The operation of the challenger is shown in more detail in Figure 20, where the aneroid barometer normally controlling the challenge pulses is shown at the lower left. The sync connection from the coder to the i-f and video amplifiers is indicated, a connection which provides GTC, that is gain-time control, so as to increase the sensitivity of the receiver for distant replies.

The operation of the replier is shown in greater detail in Figure 21. The antenna will be seen at the upper center, and the path through the receiving and transmitting elements can be easily followed. The barometric control of the decoder is indicated. The provisions are also shown by which the modulator sends out the identity of the particular craft and can send out emergency or special identity replies when required, The various waveforms are indicated at the right.

Radio-Frequency Plumbing and Tuning

At 1000 megacycles the usual tuning reactances are replaced by transmission lines and cavities, so that the r-f portion of the challenger and replier look like, and are called, "plumbing." In a typical r-f head the plumbing includes a 2C42 tube as the transmitting power oscillator, 1B23 duplexer tube, and a 2C46 as the receiver heterodyne oscillator, together with a 1N25 crystal as modulator. The 2C46 is tuned to 60 megacycles away from the transmitted frequency so that the crystal delivers an intermediate-frequency output of 60 megacycles. Pre-set tuning is accomplished by means of a series of pins shown in Figure 22, the proper one of which in each of the three groups is chosen for the desired frequency of operation. The three sets of controls provide for (1) the transmitting frequency, (2) the two-circuit receiver input tuning, and (3) the receiver local oscillator. In this preset tuner the height of each pin is individually adjusted in advance for the required frequency, so that in operation it is only necessary to choose which pin of each tuner is to be used. One knob controls the transmitter frequency and one additional knob controls all receiver frequency adjustments.

Intermediate-Frequency Amplifier

The 60-megacycle intermediate-frequency amplifier used in the equipment has the schematic circuit shown in Figure 23. There are seven stages of amplification using 6AK5 tubes, followed by a 6AL5 double diode. The necessary wide band is obtained by staggered tuning, the various circuits being individually adjusted at 55, 60 or 66 megacycles as indicated. In this way it is possible to obtain a satisfactory transmission over the range from 54 to 66 megacycles with a gain of about 85 db.

The Decoder

The use of a delay line is the key to the operation of the decoder in each replier, as shown in Figure 24. Here it is assumed that the decoder is to accept pairs of pulses separated by 3 microseconds and to reject all others. It is therefore provided with a 3-microsecond delay line. It will be seen that the incoming pulses, delivered as

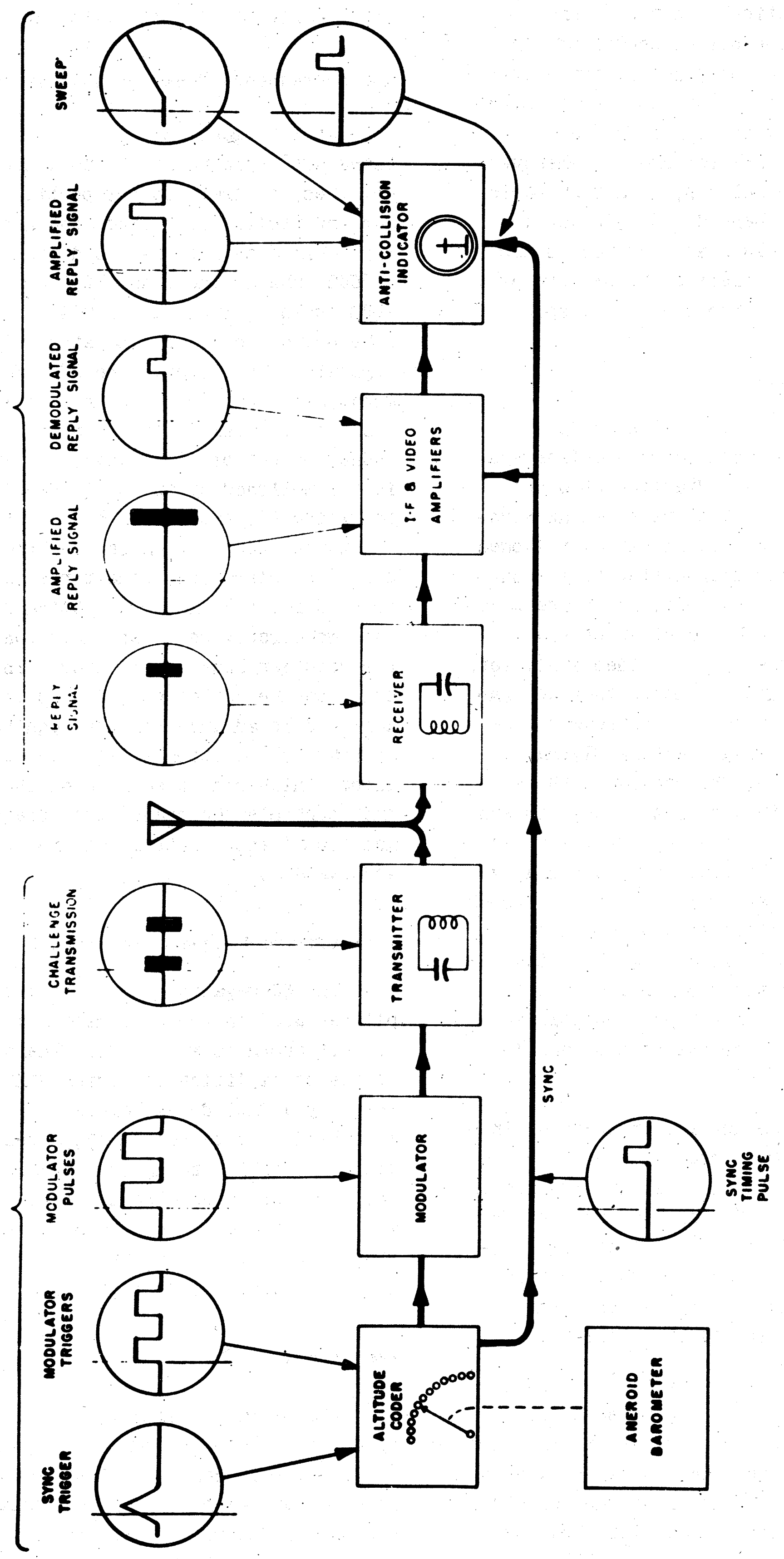


Fig. 20. Operation of Challenger

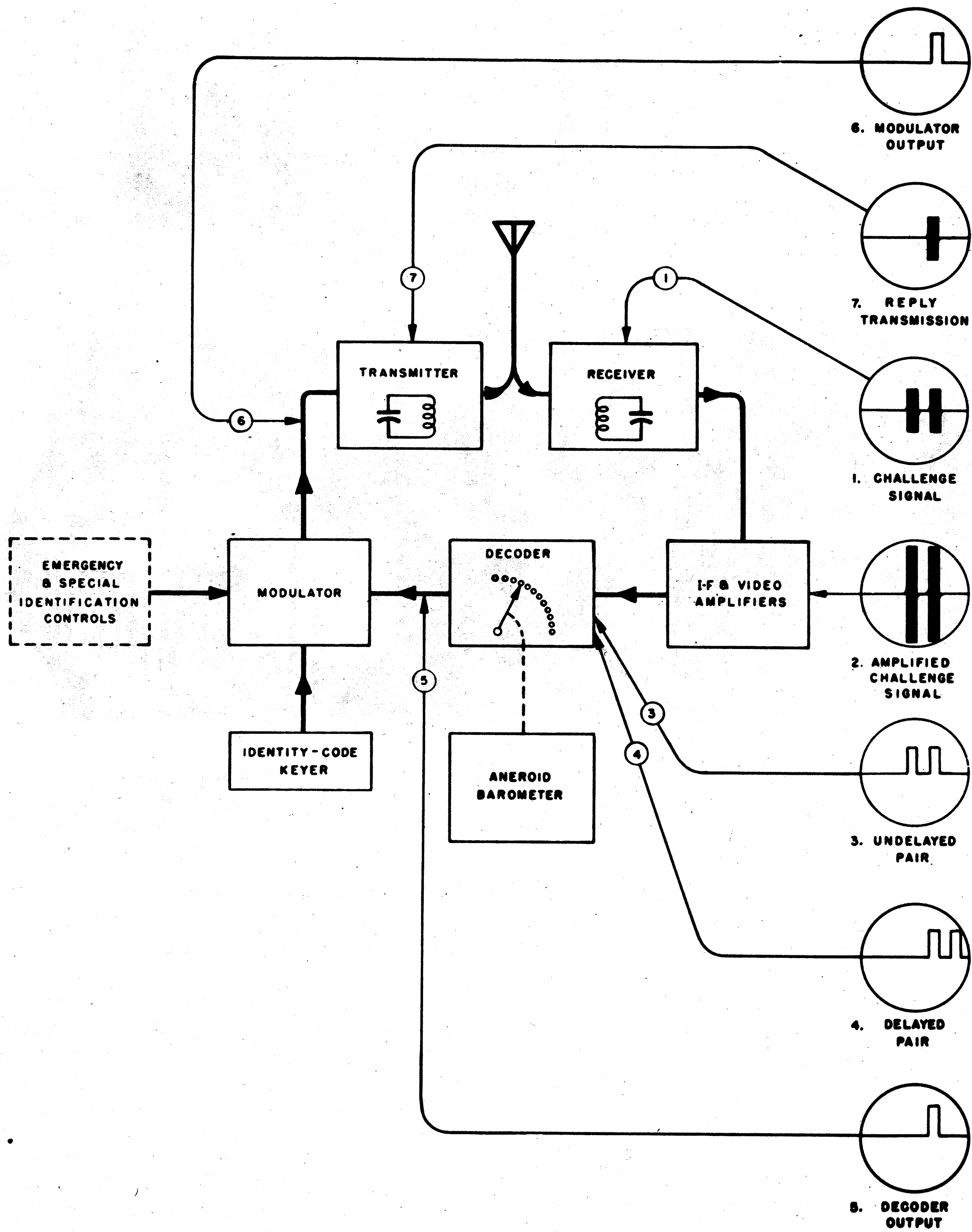


Fig. 21. Operation of Replier

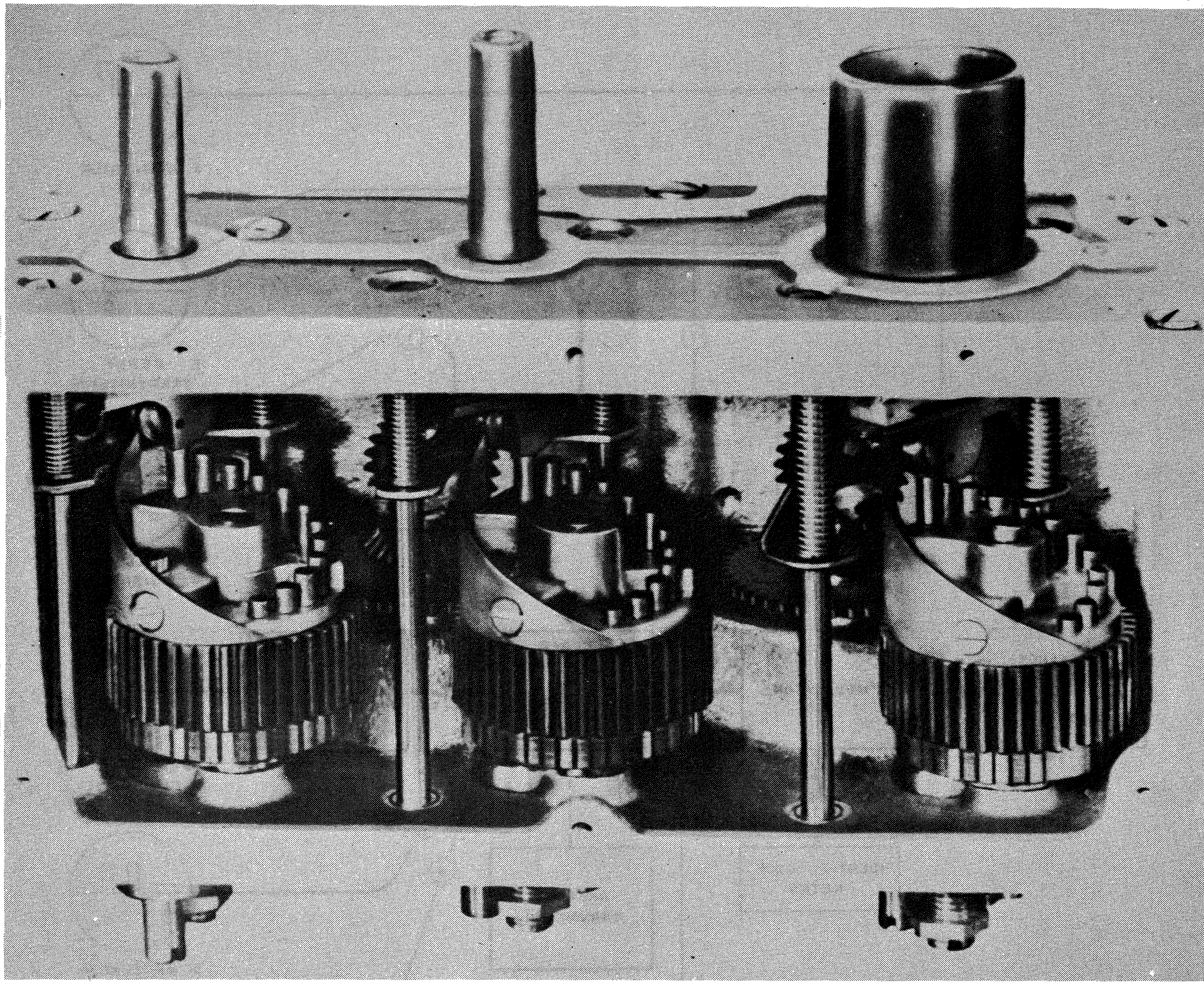


Fig. 22. Detent Tuning Mechanism of Distance-Measuring Equipment.

positive pulses from the cathode circuit of a 6AK5, proceed directly to the control grid of the 6AS6, but also proceed through the delay line to the suppressor grid of the 6AS6. The polarity of both inputs is reversed by the 6AS6 tube so that they appear as negative pulses of plate voltage. Also, a coincidence occurs at the plate between the lagging pulse of the pair on the control grid and leading pulse of the pair on the suppressor grid; this coincidence produces a large negative excursion of voltage on the plate, as indicated by the waveform at the upper right. This negative pulse is the decoder's acceptance or "O.K." to the received paired pulses. The operation in case of both acceptance and rejection is shown in the diagrams at the bottom.

Operation of Distance Computer

The circuits which produce a deflection in miles on the range meter of the DME, and thereby indicate essentially the time required for the transmitted pulse to make its round trip, are indicated in Figure 25. The main signal path starts with the decoded reply pulse at the upper left. Assuming that the wide and narrow gates are properly positioned (i.e. timed) for the particular reply pulse, the two gates deliver output to the two tracking diodes which are so connected that their effects oppose each other. The waveform sketch shows in dotted lines the positive voltage delivered by the tracking diode of the narrow gate and the negative voltage

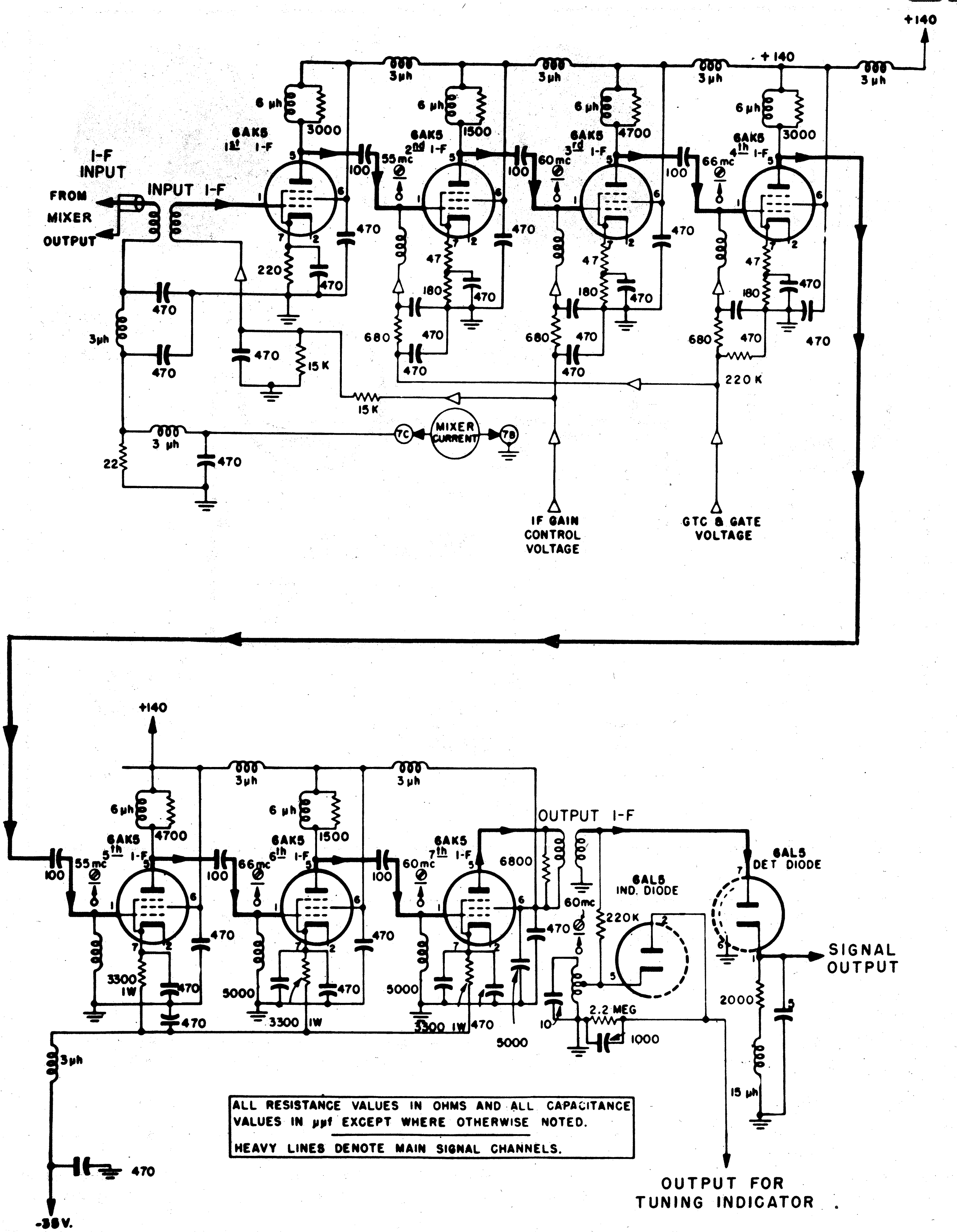


Fig. 23. Intermediate-Frequency Amplifier

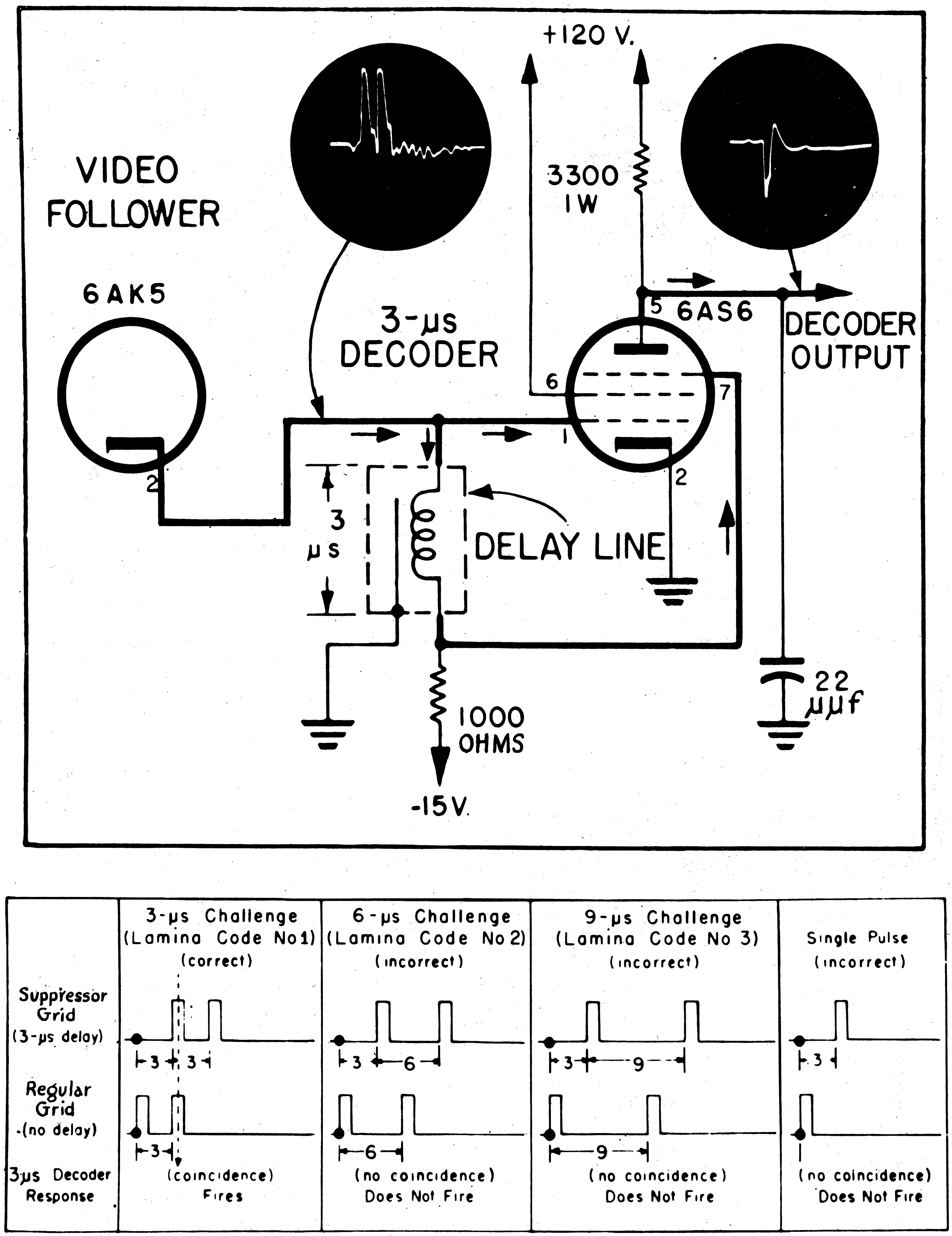


Fig. 24. Operation of Decoder.

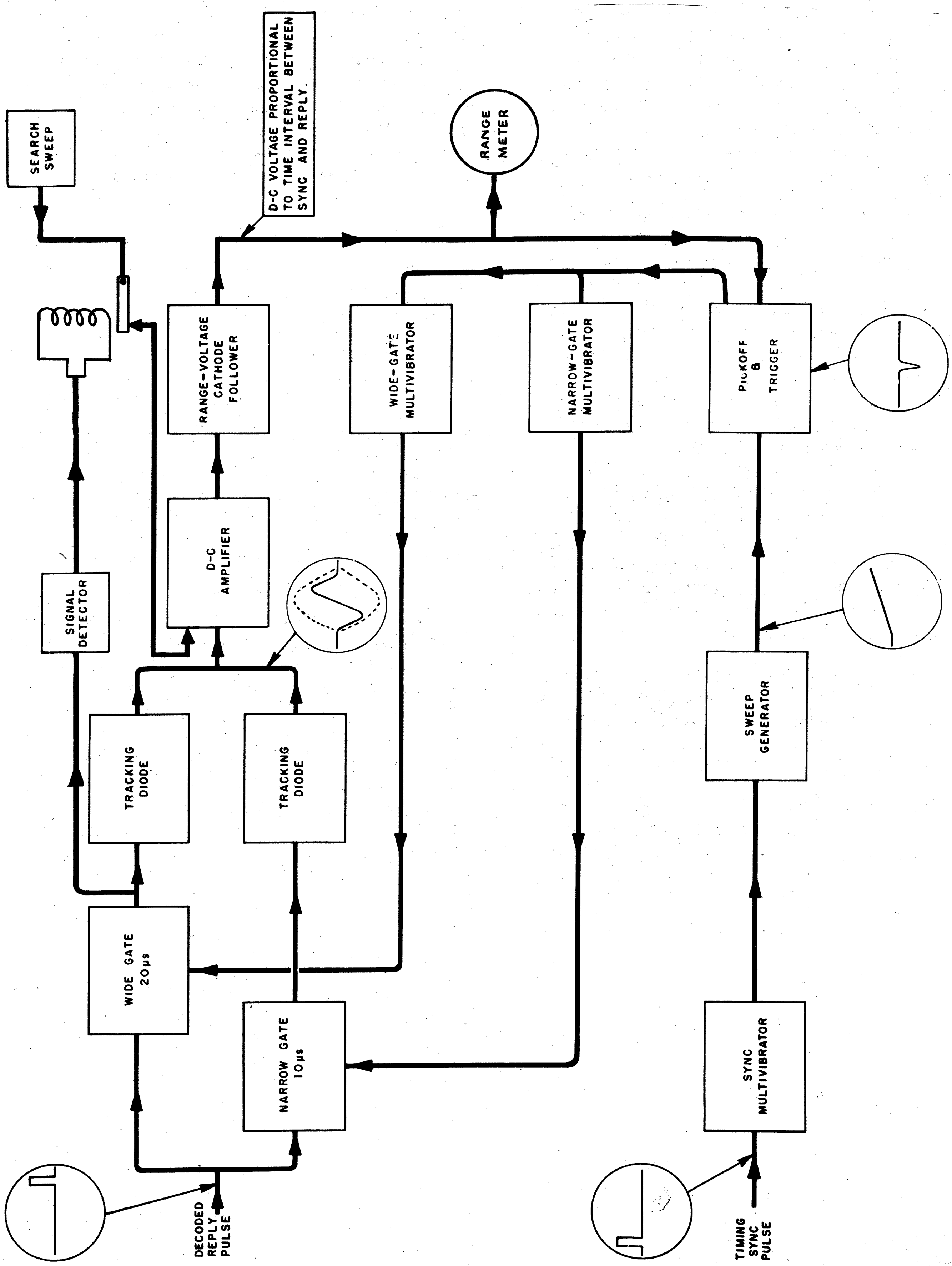


Fig. 25. Electronic Distance Computer

delivered by the tracking diode of the wide gate. Their algebraic sum determines the bias of the d-c amplifier and thereby changes the voltage delivered by this amplifier to the range-voltage cathode follower. At this point the voltage is unidirectional and can therefore operate the d-c meter used to show the range. This meter is located at the right in the diagram.

The narrow and wide gates have coincident leading edges. If the signal changes, due to the changing distance of the plane from the beacon, it will shortly be only in the wide gate, or else will be only in the part of the wide gate which is common to the narrow gate. In either case the tracking diodes deliver a correcting output which is reinforced by the d-c amplifier and the range-voltage cathode follower, goes down to the pick-off and trigger circuit and thence to the input of both the wide-gate multi-vibrator and the narrow-gate multi-vibrator. These multi-vibrators are thus caused to move the position of the two gates so that the signal is continuously held by them. In this way the DME equipment follows the changing distance during the flight of the plane. At any time another beacon can be selected, and the equipment will thereafter show the distance of this beacon.

At the lower left of the diagram is shown the time sync pulse from the transmitter, which operates a multivibrator and a sweep generator. This sweep is the main timing element of the distance computer.

When the equipment is first turned on, it searches until it finds a signal. The searching operation takes place in the absence of a decoded reply pulse at the upper left. In this case there is no output from the wide gate, and the signal detector shown at the top of the diagram has no output. Under these circumstances the search sweep is connected through the relay to the other input of the d-c amplifier. That is, the input to this d-c amplifier is varied by the search sweep to make the equipment seek a signal.

Specifications

The following are some of the leading specifications of the Lanac system:

Frequency Range	960 - 1215 Mc
Maximum Pulse Power	8000 watts for ground equipment
	1500 watts for airborne equipment
Maximum Receiver Sensitivity	96 decibels below one volt
Receiver Bandwidth	Approx. 9.5 Mc at 6 db down
Image Rejection	20 - 35 db minimum for the various models

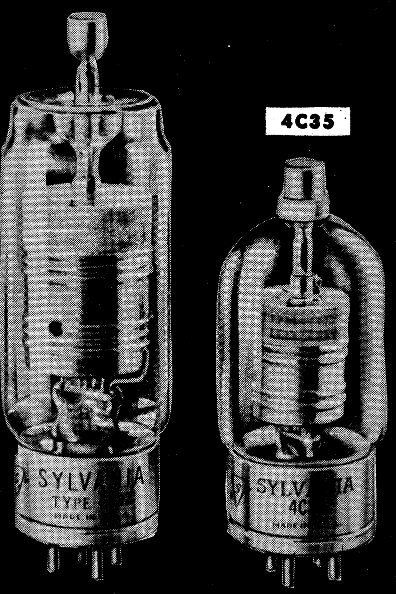
Demonstration at Indianapolis

The Lanac system with the DME feature was demonstrated at the Indianapolis convention of the Provisional International Civil Aviation Organization (PICAO) last fall, using five airplanes which made more than 100 flights totaling over 150 hours of flying time and almost 400,000 passenger miles. During these demonstrations, planes were flown safely through dense fog within one mile of each other, and were landed with a one-minute separation. This indicates the promising possibilities of the future for relieving the intense congestion now encountered at large airports in bad weather.

HYDROGEN THYRATRONS

5C22

4C35



for very high pulse repetition frequencies

ELECTRICAL RATINGS AND OPERATING CONDITIONS (TENTATIVE)

CHARACTERISTIC	4C35	5C22
Heater voltage	6.3 v $^{+5\%}_{-10\%}$	6.3 v ± 7.5%
Heater current at 6.3 volts	5.5 to 6.7 amps	9.6 to 11.6 amps
Cathode heating time	180 sec. min.	300 sec. min.
Peak anode voltage	8.0 KV max.	16.0 KV max.
Peak anode current	90 amps max.	325 amps max.
Peak inverse anode voltage (Note 1)	6.0 KV max.	16.0 KV max. 5% of e_{py} min.
Average anode current	100 ma d-c max.	200 ma max.
Pulse duration (measured at ½ amplitude)	6.0 μsec. max.	6.0 μsec. max.
Pulse repetition frequency	4000 p.p.s. max.	Note 2
Duty cycle (Note 3)	0.0008 max.	0.001 max.
Grid drive (Note 4)		
a) peak grid voltage	150 v min.	150 v min.
b) time of rise	1.0 μsec. max.	1.0 μsec. max.
c) grid pulse duration at 50 v min. amplitude	4.0 μsec. min.	4.0 μsec. min.
d) impedance of grid drive circuit	1500 ohms max.	500 ohms max.
Peak inverse grid voltage	200 v max.	200 v max.
Ambient temperature	−50° to + 90° C	−50° to +90° C

NOTE 1: In pulsed operation, peak inverse anode voltage during the first 25 microseconds after the pulse should not exceed 2.5 KV for the 4C35; 5 KV for the 5C22.

NOTE 2: Maximum pulse repetition frequency for the 5C22 (prf in pulse per second) depends on peak forward anode voltage (e_{py} in volts) and peak anode current (i_b in amps) according to formula

$$e_{py} \times i_b \times prf = 2.8 \times 10^9$$

NOTE 3: Duty cycle is defined as the product of pulse duration in seconds and pulse repetition frequency in pulses per second.

NOTE 4: Measurements at tube socket with thyratron grid disconnected.

FEATURES

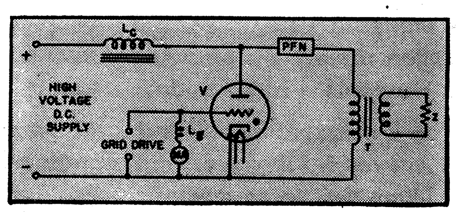
The 4C35 and 5C22 Hydrogen Thyratrons developed by Sylvania Electric are specifically designed for pulsing service at high repetition frequencies, high peak current, and high voltages.

Because of the high mobility of hydrogen, the gaseous ions are converted to neutral molecules within a very short time after tube is shut off. This feature of the 4C35 and 5C22 permits operation at exceptionally high repetition frequencies.

Tubes may be operated over a wide range of ambient temperatures without significant change in their electrical characteristics.

CIRCUIT FOR PRODUCING RECTANGULAR PULSES

The 4C35 and 5C22 were specifically developed for use in the circuit below, designed to produce periodic rectangular pulses. Pulses are formed at levels of about twice the power supply voltage, thus giving savings in size and cost of supply.



L_g Grid Choke
L_c Charging Choke
PFN Pulse-Forming-Network
T Matching or Pulse Transformer
Z Load
V 4C35 or 5C22

OTHER APPLICATIONS

Other suggested applications of the 4C35 and 5C22 include:

1. Switching in welding circuits, particularly of the capacitor discharge type.
2. Shock excitation of tuned circuit.
3. Excitation of piezoelectric crystals.
4. Use in induction heating circuits to replace spark-gap heaters, resulting in trouble-free and quieter performance.
5. Pulser for pulse time modulation circuits in which signals are produced by modulating the pulse repetition rate.
6. Servomechanisms and control circuits where relatively high a-c supply frequencies are used.

Sylvania invites inquiries on application of these tubes.

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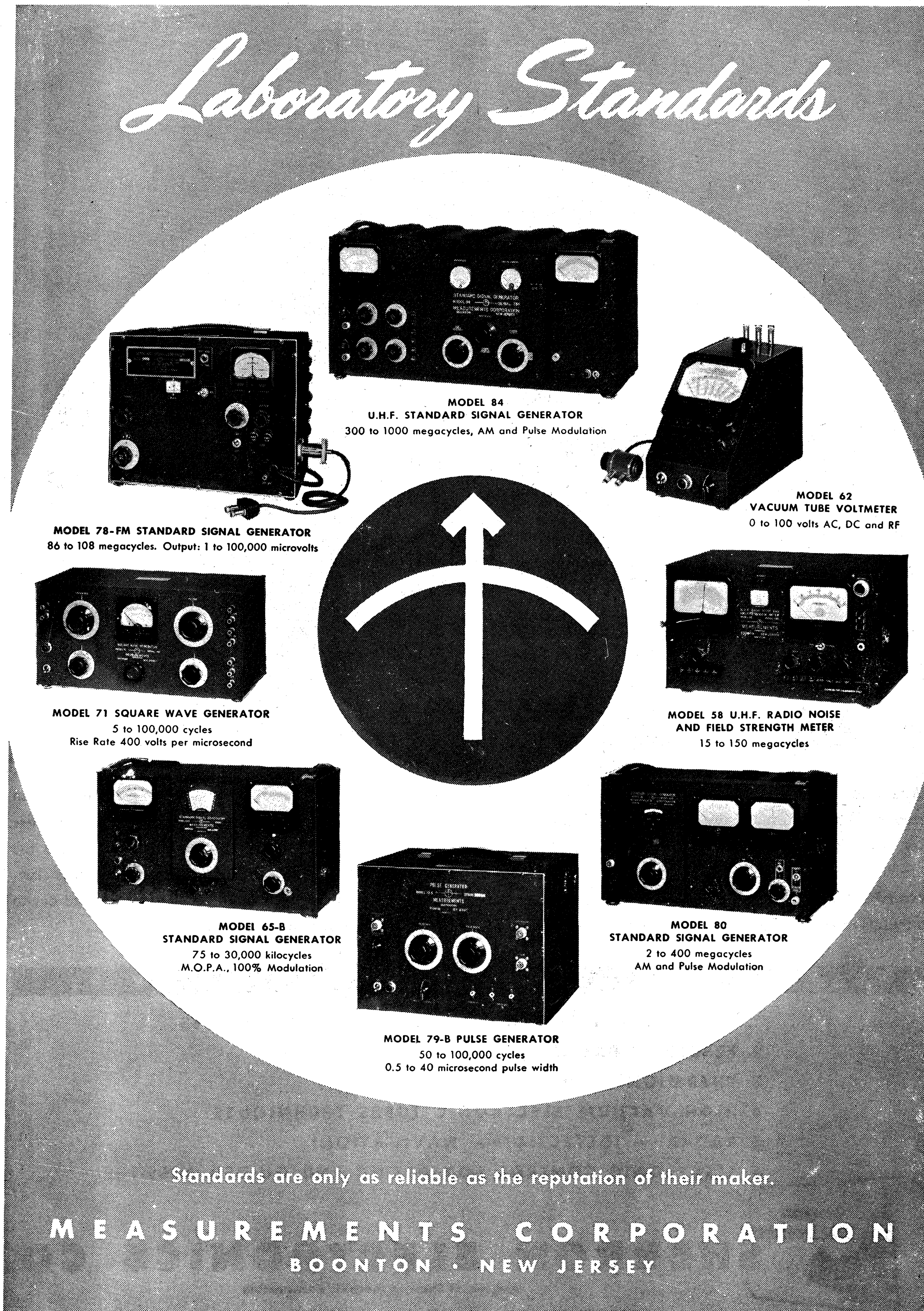
Laboratory Standards
MODEL 84
U.H.F. STANDARD SIGNAL GENERATOR
300 to 1000 megacycles, AM and Pulse Modulation
MODEL 78-FM STANDARD SIGNAL GENERATOR
86 to 108 megacycles. Output: 1 to 100,000 microvolts
MODEL 62
VACUUM TUBE VOLTMETER
0 to 100 volts AC, DC and RF
MODEL 71 SQUARE WAVE GENERATOR
5 to 100,000 cycles
Rise Rate 400 volts per microsecond
MODEL 58 U.H.F. RADIO NOISE
AND FIELD STRENGTH METER
15 to 150 megacycles
MODEL 65-B
STANDARD SIGNAL GENERATOR
75 to 30,000 kilocycles
M.O.P.A., 100% Modulation
MODEL 80
STANDARD SIGNAL GENERATOR
2 to 400 megacycles
AM and Pulse Modulation
MODEL 79-B PULSE GENERATOR
50 to 100,000 cycles
0.5 to 40 microsecond pulse width
Standards are only as reliable as the reputation of their maker.
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