THE COMMERCIAL AIRCRAFT AND ITS RADIO INSTALLATION

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For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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THE COMMERCIAL AIRCRAFT AND ITS RADIO INSTALLATION

Description of Commercial Aircraft

PRIMARILY, the mechanical and electrical design of aircraft radio equipment is governed by the specialized nature of aircraft radio communications systems and by the fact that the equipment must be installed aboard a highly mobile craft whose design is, in turn, governed by aerodynamic considerations. No new principles are involved; standard radio engineering practices are merely adapted to the special requirements of aircraft. The paramount consideration is, of course, reliability of operation under all flight conditions. Other important factors are simplicity of operation, weight and space considerations, operating safety (elimination of fire hazard), and accessibility for inspection and maintenance.

However, an aircraft radio set—no matter how well designed—will op-

Courtesy American Airlines

This picture of an American Overseas Airlines DC-4 shows the large number of antennas used on such aircraft. Four are visible above the fuselage and five below.

erate efficiently only if it is properly installed; therefore, such considerations as location of equipment and proper wiring, bonding, and shielding become important. Also, since the radio installation to some extent depends upon the design of the aircraft itself, the radio man should have some knowledge of aircraft structures, nomenclature, and the principles of flight. It is the purpose of this Lesson to provide this necessary background information.

THE AIRCRAFT

Like other professions, aviation has developed its own specialized terminology. Learning to speak the language of aviation is important not only to the flight radio-operator, but also to the ground-crew radio mechanic, who must be able to converse intelligently with flight personnel. Therefore every aviation radio man should know the name, purpose, and location of the major structural components of aircraft and should understand the standard flight terms and professional "jargon" used by airlines personnel.

Principles of Flight. The aircraft sustains itself in flight because of the magnitudes and directions of the forces acting upon various portions of its structure. For example, the propeller (literally an airscrew) imparts a forward force known as thrust, a portion of which is converted by the wings (airfoils) into an upward force (lift) because of their shape. The total lift of a wing is a combination of the upward force of airflow against its underside and an additional upward force due to formation of a partial vacuum above the wing. In general, high lift is associated with thick airfoils and high speed with thin airfoils. However, lift is not synonymous with climbing ability; a thin-winged fighter, for example, gets its climbing ability from its powerful engine. Thrust and lift are positive forces tending to maintain

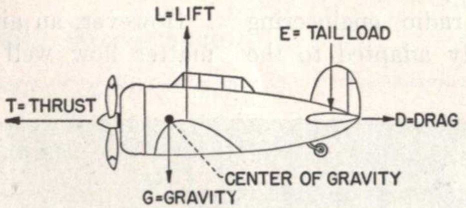
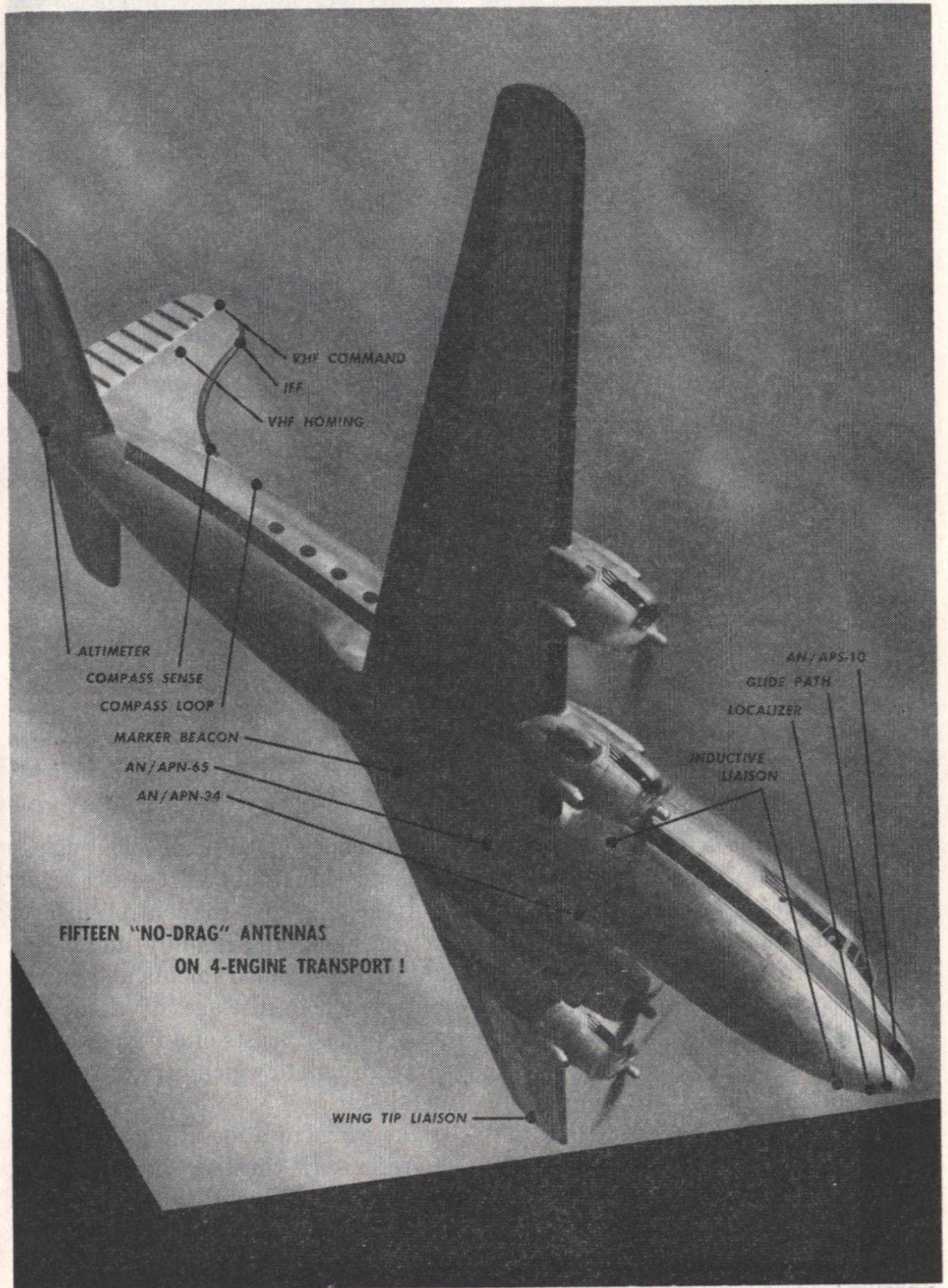


FIG. 1. The forces acting on an aircraft in flight.

flight. They are opposed by two negative forces—the downward force of gravity and the retarding force of friction known as drag. In order to maintain flight, thrust and lift must always exceed drag and gravity, respectively. Fig. 1 shows how these forces act on a plane in flight.

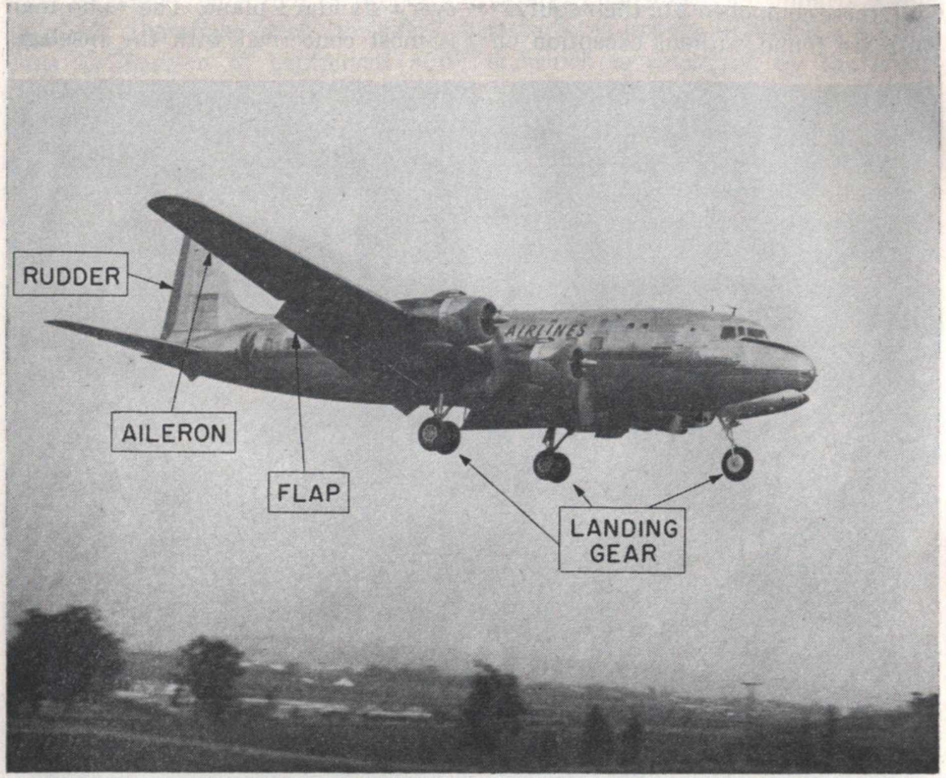
Essential Parts. The essential parts of an aircraft (see Figs. 2A and 2B) are the propeller, engine, wings, fuselage, landing gear, and control surfaces (ailerons, elevators, rudder, and stabilizers). Although aircraft differ widely in design detail (such as number of wings, number and type of engine, type of fuselage and tail structure,

etc.), these components or their equivalents are found without exception on every standard plane. The radio man is most concerned with the fuselage,



Courtesy Caldwell-Clements, Inc.

FIG. 2A. Transport plane with antennas labeled.



Courtesy American Airlines

FIG. 2B. An American Airlines DC-4. This aircraft is landing, shown by the fact that its wheels and flaps are down. In normal flight, the wheels are drawn up into the body of the craft and the flaps are level with the rest of the wing.

wings, and tail surfaces, since these structures support antennas and antenna fixtures and are electrically bonded together to serve as a ground for the aircraft's electrical system and a counterpoise for the radio equipment. The engines are of concern only as a source of radio interference if their igniton systems are improperly shielded.

The fuselage is the main body of the plane and houses the crew, equipment, and sometimes the engine (if mounted in the wings, engines are installed in nacelles). The fuselage directly or indirectly supports all other structural components of the plane. Through it to the cockpit pass all the necessary control cables from the control surfaces on wings and tail assembly, and piping and wiring for instruments and engine controls. The fuselage of a modern metal plane consists of a framework of metal girders to which is riveted a thin metal skin.

The wings of a metal plane are also of framework construction, consisting of stamped-out metal ribs mounted on transverse girders known as wing spars and covered with a thin metal skin. The wings are rigidly attached to the fuselage. Ailerons are movable parts

of the trailing edges of the wing structure; these control surfaces maintain lateral stability in flight and control the "banking" movement of the plane. Ailerons are controlled so that when one is elevated the other is depressed. The tail structure of the aircraft is also of metal framework construction, and supports the tail control surfaces, consisting of a fixed horizontal stabilizer to which are hinged the elevators (sometimes called "flippers") and a vertical stabilizer to which is hinged the rudder. The elevators control the angle of ascent or descent and the rudder normally controls the direction of flight.

Use of Flight Controls. When a pilot takes off, he first pushes the control stick (or wheel) forward; this depresses the elevators and lifts the tail while taxiing to gain speed on the ground. As the speed increases, he slowly pulls the stick back so that air pressure on the elevators will not keep the nose of the plane down. As the speed increases, the wings continue to develop lift until flying speed is reached. After take-off, the pilot gains altitude by raising the elevators and descends by depressing the elevators. Other maneuvers (turning, banking, etc.) are accomplished by various combinations of aileron, elevator, and rudder action.

NAVIGATING THE AIRCRAFT

Handling flight controls, however, is only a part of the duties of a pilot or flight crew. In fact, once a course has been set after take-off, much of the mechanical job of flying a modern transport is done automatically by a robot "gyro-pilot," leaving the pilot comparatively free to navigate and plan his flight. Many instruments must be observed periodically to check such items as engine performance, fuel consumption, speed, course, drift, altitude, etc. Radio contact must be maintained with ground stations, and, of course, the inevitable paper work and flight records must be handled.

On airlines operating within the continental limits of the United States, these duties are usually shared by the two pilots. However, the size, complexity, and diversity of instruments and equipment carried by large trans-oceanic aircraft require a flight crew composed of several highly trained men. For example, the flight crew of a trans-oceanic flying boat may include a flight captain, two pilots, a navigator, a flight engineer, a flight radio operator, and one or more stewards. Each member of the crew has specific duties to perform, and in most cases much of the work involves the use of highly specialized equipment and instruments. A few of the more important of the scores of instruments needed to operate efficiently a modern airliner are described in the following section.

AIRCRAFT INSTRUMENTS

Instruments are essential to safety of flight. Instruments are required for safe navigation, for the proper utilization of aircraft engines, for electrical and radio equipment, and for accessory equipment such as intercommunication, signal, and indicating systems. The aviation radio man is frequently required to use and maintain certain of these instruments.

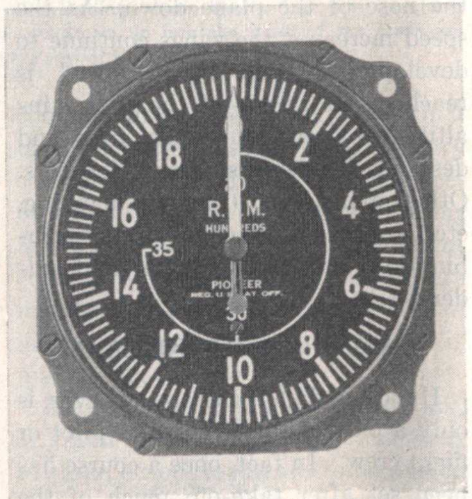
All instruments carried aboard small aircraft (including continental air transports) are mounted in the cockpit, where they are immediately accessible to the pilots. Because of the diversification of duties on larger planes, the instruments carried by these aircraft are not all mounted in the cockpit but are distributed in various compartments according to their functions. For example, the radio instruments are housed in a radio or radio - navigational compartment in charge of the radio operator. Engine instruments, and possibly a set of flight instruments, are in the flight engineer's compartment, and the cockpit, of course, contains the necessary engine and flight instruments used by the pilots.

Flight and Engine Instruments. The basic flight instruments are: (1) Magnetic and gyro compasses; (2) airspeed indicator; (3) altimeter; (4) rate-of-climb indicator; (5) turn-and-bank indicator. These instruments, together with a clock and a radio, are all essential to "instrument" flying. The rest of the instruments are either engine, airplane, or special instruments whose functions are apparent from their names. The engine instruments enable the pilot to operate the engines most efficiently and also warn him of impending engine trouble. For example, engine trouble is usually first indicated by changes in engine speed (R.P.M.) or temperature. The tachometer (Fig. 3) measures the engine's R.P.M., and various thermometer instruments measure the temperature of the cooling liquid, oil, cylinder walls, etc.

The aviation radio man should know the approximate location of these instruments and something of their operation and use. Fig. 4 shows a typical instrument panel arrangement. Note particularly that important instruments are duplicated and that for convenience of use engine and flight instruments are grouped separately.

Functions of Flight Instruments. The basic flight instruments are the most important single group of instruments in an aircraft, and are therefore selected for further consideration in preference to the multitude of other important instruments. These instruments—the compasses (magnetic and gyro), airspeed indicator, altimeter, rate-of-climb indicator, and turn-and-bank indicator—are essential to efficient air navigation, whether "instrument" or "contact."

A plane must be kept on course, and therefore the magnetic compass (Fig. 5) is perhaps the most important single instrument in the plane. However, the magnetic compass is difficult to use for



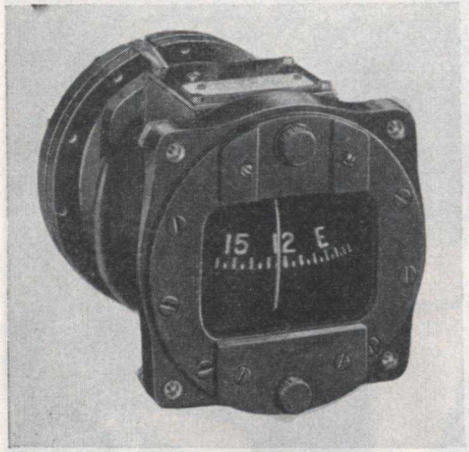
Courtesy Bendix Aviation Corp.

FIG. 3. This is a typical tachometer, an instrument that measures the number of revolutions an engine makes per minute.

Courtesy Pan American World Airways

FIG. 4. Instrument panel on Pan American World Airways Strato Clipper.

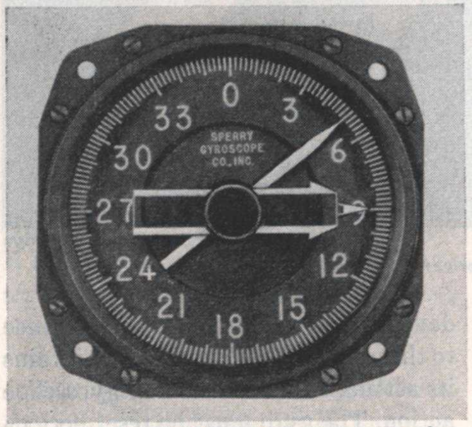
steering purposes since it is constantly oscillating, and therefore the directional gyro is usually used as the "steering" instrument. The directional gyro (Fig. 6) is not a north-seeking device; rather, it is set with reference to the magnetic compass and maintains its setting for some time by gyroscope action. The gyro must be reset periodically, usually every 10 or 15 minutes.



Courtesy Bendix Aviation Corp.

FIG. 5. Magnetic compass.

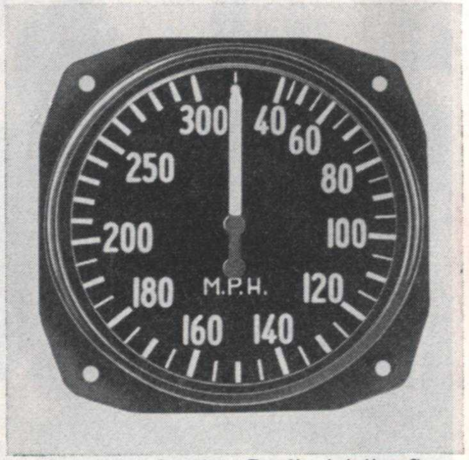
Every aircraft has a minimum safe airspeed below which it will stall, a rated maximum speed (in dives) beyond which it is unsafe, and a rated cruising airspeed for most efficient engine operation. The airspeed indicator (see Fig. 7) shows how fast the aircraft is flying with reference to the air surrounding it. Airspeed and ground speed, therefore, are the same only in perfectly calm air. A plane having an airspeed of 200 miles per



Courtesy Sperry Gyroscope Co., Inc.

FIG. 6. Directional gyro.

hour with a tail wind of 50 miles per hour would have a ground speed of 250 miles per hour; the same airspeed would be indicated with a headwind of 20 miles per hour and a ground speed of 180 miles per hour. For navigational purposes, the indicated airspeed must be converted to true airspeed. Since the airspeed indicator is a pressure-



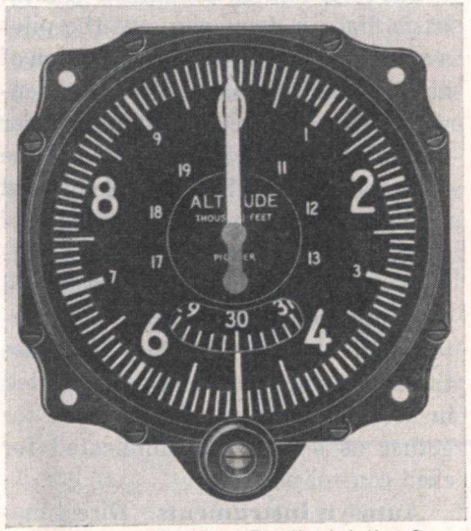
Courtesy Bendix Aviation Corp.

FIG. 7. Airspeed indicator.

operated device, its reading depends upon the altitude, and the required correction may be closely approximated by adding 2% to the indicated airspeed for each thousand feet above sea-level.

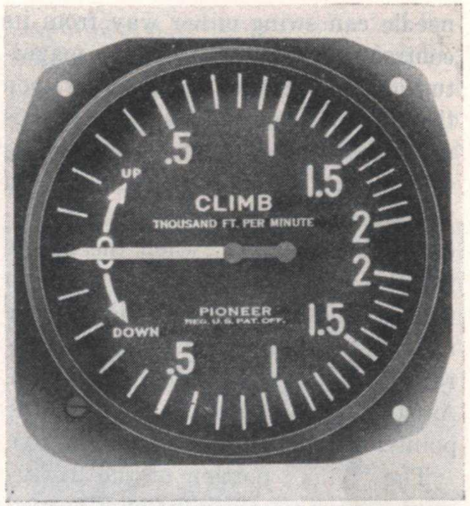
An aircraft must fly at certain altitudes to avoid obstructions and to comply with air traffic control instructions. The altitude-indicating instrument is called an altimeter; it is essentially an aneroid barometer (Fig. 8) that translates air pressure into feet of altitude. The instrument is set barometrically in accordance with the distance above sea-level of the terrain over which the plane is flying. These barometric pressures are radioed periodically to the pilot by airways ground stations so that he can keep his altimeter properly corrected. When an aircraft lands, its altimeter should read the altitude of the field above sea-level plus the distance of the altimeter above ground. Altimeter accuracy is of great importance in making instrument landing approaches, since an appreciable altimeter error may contribute to a crash landing. For this reason, most airline companies specify that altimeters must not be in error more than ±50 to ±75 feet (at sea level). Altimeters may be easily checked by setting them accurately in flight and comparing their readings after landing with the known altitude of the field.

The rate-of-climb indicator shows the rate at which an aircraft is ascending or descending. Its dial (see Fig. 9) is usually calibrated in thousands of feet per minute; as long as the pointer remains at zero, the altitude of the



Courtesy Bendix Aviation Corp.

FIG. 8. Altimeter.



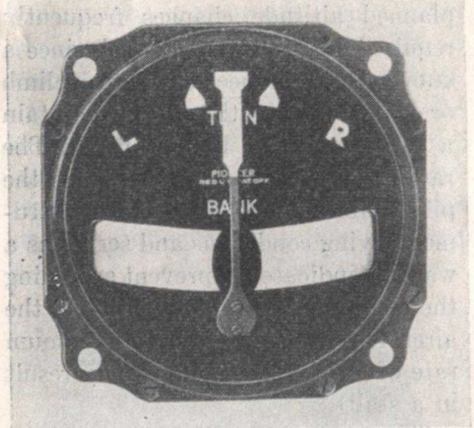
Courtesy Bendix Aviation Corp.

FIG. 9. Rate-of-climb indicator.

plane is unchanged. This instrument is particularly useful when making the planned altitude changes frequently required by air traffic control, since a knowledge of airspeed and rate of climb or descent enables the pilot to maintain a pre-established line of flight. The rate-of-climb indicator also helps the pilot maintain level flight under instrument-flying conditions and serves as a warning indicator to prevent exceeding the maximum safe rate of climb of the aircraft (each aircraft has a maximum rate of climb; exceeding it may result in a stall).

The turn-and-bank indicator (Fig. 10) is, as its name shows, a combination of two instruments. Each instrument operates independently of the other; however, because their combined indications are used to coordinate turn and bank maneuvers, they are mounted together in the same case for ease of observation. The "turn" portion of the instrument shows both the direction and rate of turning. The indicator needle can swing either way from its central zero position, and the magnitude of the deflection is dependent upon the rate of turning. Also, the dial is usually equipped with reference marks to facilitate making certain standard turns used in range orientation procedures. For example, when the needle lines up with either reference mark on the instrument shown in Fig. 10, the aircraft is turning in the indicated direction at the rate of 180° per minute. As soon as the turn is completed the pointer returns to its central position.

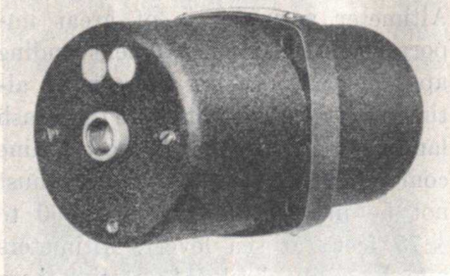
The "bank" portion of the instrument consists essentially of a curved glass tube containing a damping fluid and an "inclinometer" ball. The ball



Courtesy Bendix Aviation Corp.

FIG. 10. Turn-and-bank indicator.

is free to roll in the glass tube. During level flight, the force of gravity keeps the ball centered between the reference wires, but, when one wing is lower than the other, the ball rolls toward the lowest portion of the tube. When a banked turn is made, the ball is acted upon by both gravity and centrifugal force; gravity tends to make the ball roll toward the low wing and centrifugal force tends to force it toward the high wing. These forces just balance each other in a perfectly executed banked turn,



Courtesy Bendix Aviation Corp.

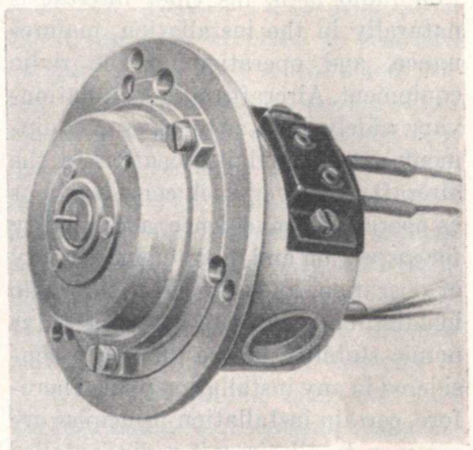
FIG. 11A. Autosyn transmitter.

and the ball remains in its central position between the reference wires. If the bank is too steep, gravity predominates and the ball rolls toward the low wing; if the bank is not steep enough, centrifugal force predominates and the ball rolls toward the high wing.

The co-ordinated indications of these basic flight instruments give the pilot a continuous picture of the operation of his aircraft and enable him to maneuver it with precision and safety. For example, the directional gyro and the turn-and-bank indicator would be used in executing a planned change of course, while a planned change of altitude would co-ordinate the directional gyro, altimeter, rate-of-climb indicator, and airspeed indicator. Because these instruments are so closely related in use, they are usually mounted together as a unit and duplicated for each control position.

Autosyn Instruments. Direct mechanical coupling between an instrument mechanism and its indicating dial is satisfactory for small aircraft but becomes impracticable for larger aircraft requiring duplicate indicators at more than one station or where the measuring point and the place where the reading is desired are widely separated. To eliminate the necessity of using mechanical coupling in such cases, the autosyn system of remote indication is used to convey the motion or deflection of an instrument mechanism to its indicating dial electrically rather than mechanically. The system is composed of two units, a transmitter and a receiver (indicator), connected electrically. Fig. 11 illustrates typical autosyn transmitter and receiver units.

Essentially, the autosyn system is an adaptation of the self-synchronous motor principle, in which two widely separated motors operate in exact synchronism without mechanical connection. However, the autosyn rotors do not rotate continuously, but are so arranged and connected that if the rotor of the transmitter is moved with respect to its stator, the rotor of the receiver immediately assumes the same position with respect to its stator, exactly duplicating the motion of the transmitter rotor. The transmitter rotor is mechanically moved by the measuring device, which may be a Bourdon tube, a pressure differential diaphragm, a governor mechanism flyweight, or other instrument mechanism; the indicator pointer is attached to the autosyn receiver shaft, which moves the pointer over a calibrated scale.



Courtesy Bendix Aviation Corp.

FIG. 11B. Autosyn indicator.

The autosyn system may be used to indicate two related functions on a single dial. A tandem indicator is used for this purpose; it consists of two autosyn receiver units with the shaft of one extending through the hollow shaft of the other. Each receiver unit operates independently of the other, but their indications may be conveniently compared since the pointers move over the same scale.

Aircraft Radio Installations

Although a general knowledge of aircraft instruments and electrical indicating systems is useful to the aviation radio man, his chief interest is naturally in the installation, maintenance, and operation of the radio equipment. Aircraft radio installations vary widely, both as to types of equipment carried and its location in the aircraft. However, such considerations as operating convenience, accessibility for inspection and maintenance, safety of operation, and any effect the radio installation may have on the aerodynamic stability of the plane are considered in any installation plan. Therefore, certain installation principles are common to all aircraft radio installations. It is these principles, and not any specific plan, that are important. The Civil Aeronautics Administration specifies what equipment must be carried by "air carrier" aircraft and also issues certificates to manufacturers of approved radio equipment. The radio installation plan for each aircraft is approved by the CAA and, once the plan has been approved, no alterations are permitted that might unbalance the aircraft or affect the performance of the equipment. Aircraft carrying transmitting equipment must be licensed as mobile radio stations by the Federal Communications Commission.

Location of Equipment. One of the first considerations affecting the placement of radio equipment in an aircraft is its convenience of operation and adjustment in flight. Also, although many of the units do not normally require adjustment in flight, they must be readily accessible for adjustment or replacement on the ground. Radio maintenance procedures usually specify that defective units be replaced rather than serviced in the plane, and therefore components should be located so that they can be inspected or removed without disturbing adjacent equipment. Also, the placement of equipment should take into account the location of controls, screwdriver trimmer openings, access doors for coils, tubes, fuses, etc., so that these may be used without interfering with other units. Units should not be "stacked" one upon another or secured with common mounting devices.

Mountings. Because air - borne radio equipment is subjected to a certain amount of shock and flight vibration, all equipment containing vacuum tubes or delicate instruments should be mounted on vibration-absorbing devices. These devices—known as "shock mounts"—damp shocks and vibrations enough to protect the equipment. Shock mounts are usually incorporated in the mounting bases, which are rigidly attached to the airplane structure. The chassis and the case of the unit are then secured to the shock-mounted base with easily operated devices such as slide-fasteners. Sometimes the case is also attached to the base and only the chassis and front panel of the unit are removable. Plug-type wiring receptacles are frequently made part of the fixed mount, so that the unit is automatically disconnected when it is removed from its mount. Some installations mount all equipment rigidly in racks and shock-mount either the racks or the individual shelves in the racks. These installations are extremely compact and, when properly designed, provide better protection for the equipment than individual mountings.

Shock mounts should theoretically be distributed equally about the center of gravity of the mounted unit so that a force in any direction could not produce rotation. As this is seldom practicable, the shock mounts should be spaced as far apart as possible to reduce rotational forces. It is often necessary to use stabilizing shock mounts or snubbers near the top of a tall unit that is shock-mounted only at its base.

A properly designed shock mounting incorporates the following features:

(1) The ratings of the mounts should be chosen so that the load is evenly supported. Better vibration damping results if the mounts are slightly overloaded rather than underloaded.

(2) The shock mounts should be spaced as far apart as possible and should be located so that a shock from any direction produces a minimum rotational force.

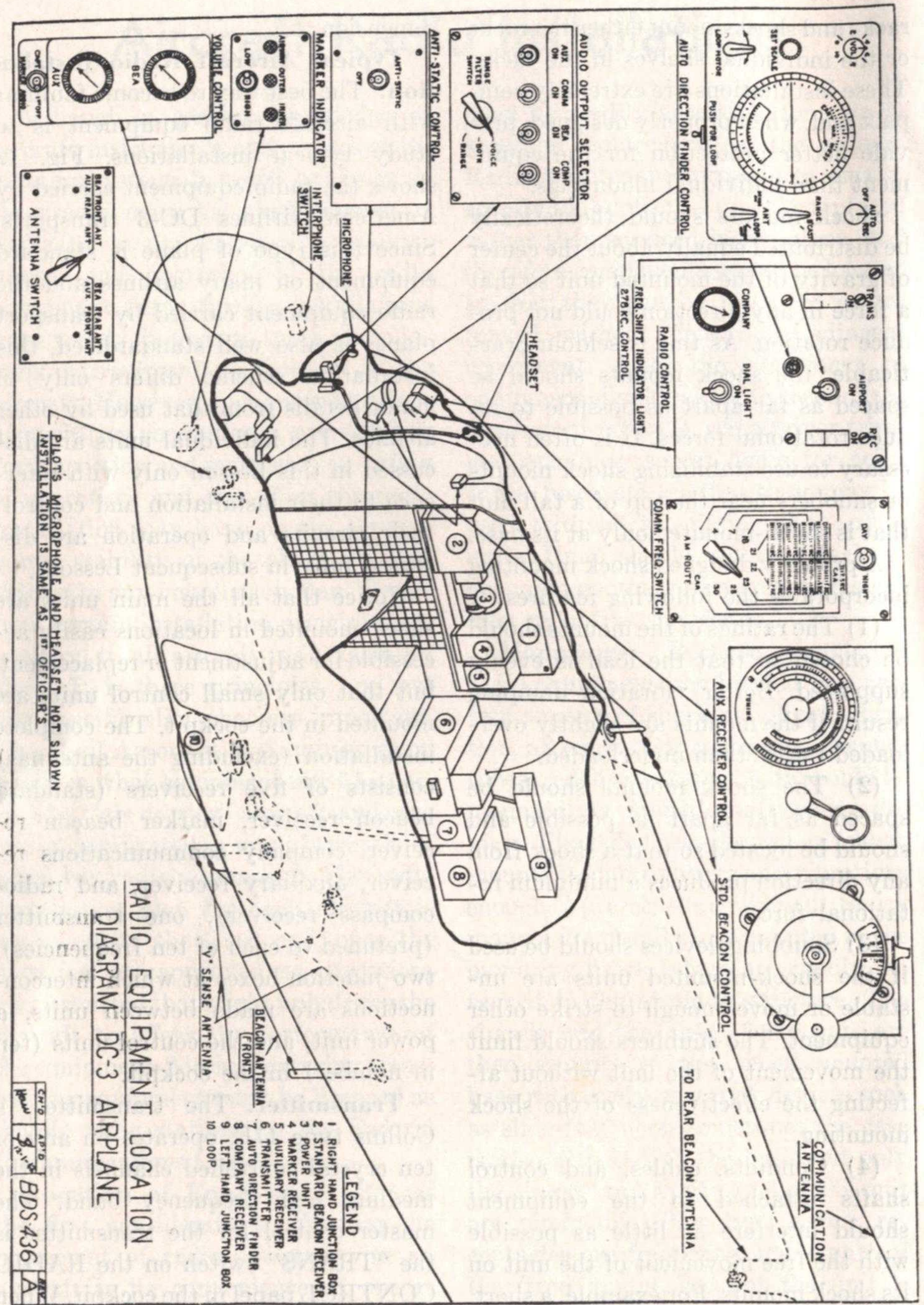
(3) Snubbing devices should be used if the shock-mounted units are unstable or move enough to strike other equipment. The snubbers should limit the movement of the unit without affecting the effectiveness of the shock mounting.

(4) Conduits, cables, and control shafts attached to the equipment should interfere as little as possible with the free movement of the unit on its shock mounts. For example, a short, straight section of flexible conduit or control shaft may be practically inflexible in the direction of its long dimension.

Typical Aircraft Radio Installation. The best way to become familiar with aircraft radio equipment is to study typical installations. Fig. 12 shows the radio equipment carried by American Airlines DC-3 transports. Since this type of plane is standard equipment on many airlines and the radio equipment carried by transport planes is also well standardized, this installation scheme differs only in minor details from that used by other airlines. The individual units are discussed in this Lesson only with reference to their installation and control; their circuits and operation are discussed fully in subsequent Lessons.

Notice that all the main units are shock-mounted in locations easily accessible for adjustment or replacement, but that only small control units are mounted in the cockpit. The complete installation (excluding the antennas) consists of five receivers (standard beacon receiver, marker beacon receiver, company communications receiver, auxiliary receiver, and radio-compass receiver), one transmitter (pretuned to each of ten frequencies), two junction boxes at which interconnections are made between units, a power unit, and the control units (ten in number) in the cockpit.

Transmitter. The transmitter, a Collins type 17F, operates on any of ten crystal-controlled channels in the medium high frequency band. The master control for the transmitter is the "TRANS" switch on the RADIO CONTROL panel in the cockpit. When this switch is "ON" the transmitter may be operated by pressing the "press-to-talk" button on the micro-



Courtesy American Airlines

FIG. 12. This sketch shows the arrangement of the radio equipment carried by American Airlines DC-3 aircraft. This can be considered to be a standard installation, since most other airlines using his ship install about the same equipment arranged in about the same way. The equipment shown here is described in this Lesson.

phone. The only other transmitter control is the "COMM. FREQ. SWITCH," with which the transmission frequency is selected.

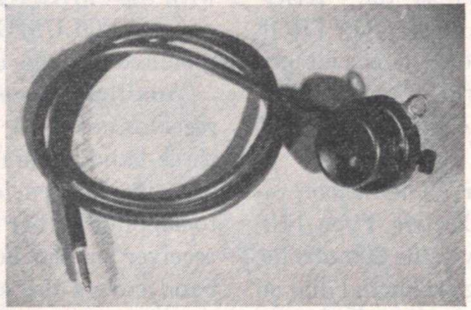
Communications Receiver. The communications receiver, a Western Electric Type 29, is pretuned to receive on each of the ten frequencies allocated for transmission; it receives whichever frequency is selected on the "COMM. FREQ. SWITCH." The output volume is controlled with the "COMPANY" control on the RADIO CONTROL panel. The master control for the communications receiver is the "REC" switch on the RADIO CONTROL panel; the receiver output is switched to the headset with the "COMM. ON" toggle switch on the AUDIO OUTPUT SELECTOR.

Beacon Receiver. The beacon receiver, a Western Electric Type 14B, is manually tuned over the 200-400 kc. band with the tuning crank and dial on the STD. BEACON CONTROL located just above the windshield "V" in the cockpit. This receiver is used to receive radio range signals, weather broadcasts, and airport control tower stations. Its master control is the "REC" switch on the RADIO CONTROL panel; its output is switched to the headset with the "BEA ON" switch on the AUDIO OUTPUT SELECTOR. The output volume is adjusted with the "BEA" control on the VOLUME CONTROL panel mounted on the control pedestal. A toggle switch labeled "AIRPORT" on the RADIO CONTROL panel automatically sets the beacon receiver on 278 kc.

Marker Receiver. The marker receiver, a Western Electric Type 27B, is a fixed-frequency receiver operating only on 75 megacycles. It is used for reception of Z marker signals over radio ranges, fan marker beacons along range courses, and outer and inner markers of low approach and instrument landing systems. The receiver is turned on with the "REC" switch on the RADIO CONTROL panel. Marker beacon signals are indicated visually on the MARKER INDICATOR panel mounted on the Captain's side of the instrument panel. Marker signals may also be received aurally if desired, and are switched to either pilot's headset with the "MARKER AUDIO" switch on the VOLUME CONTROL panel mounted on the control pedestal.

Auxiliary Receiver. The auxiliary receiver, an RCA Type AVR7H, is a three-band, manually tuned receiver used in emergencies to supplement or to supplant either the communications receiver or the beacon receiver. One band covers the communications frequencies, the second band covers the range frequencies, and the third band covers the standard broadcast frequencies. The band-selector switch and a C.W. switch for reception of continuous wave telegraph signals are located on the panel of the receiver. The receiver's master control is the "REC" switch on the RADIO CONTROL panel; the output is switched to the headsets with the "AUX ON" toggle switch on the AUDIO OUTPUT SELECTOR. Tuning is accomplished with the tuning crank and dial on the AUX RECEIVER CONTROL panel mounted just above the windshield V. The output volume is controlled with the "AUX" control on the VOLUME CONTROL panel mounted on the control pedestal.

Radio-Compass. The Sperry-RCA automatic direction finder may be used for visual or aural direction finding or homing, as an additional auxiliary beacon receiver, or as a general utility receiver with a loop antenna to reduce noise pickup. All controls for the radio compass receiver are located on its control unit — the AUTO DIRECTION FINDER CONTROL panel—located on the control pedestal. The audio output of the compass receiver may be switched to the headsets with



Courtesy R.C.A.

FIG. 13. The RCA AVA-31A carbon-button microphones.

the "COMP ON" switch on the AUDIO OUTPUT SELECTOR.

Radio Control Panel. The RADIO CONTROL panel is mounted in the center of the cockpit ceiling. As we have already said, this panel is equipped with the master transmitter and receiver switches, the communications receiver volume control, and an "AIRPORT—ON" switch to set the beacon receiver on 278 kc. In addition to these controls, the RADIO CONTROL panel also has a dial light toggle switch and an amber indicator light that lights whenever the frequency shift is operating. When this light goes out, it indicates that the frequency shift has operated and that the transmitter and communications receiver are set on the desired frequency.

Comm. Freq. Switch. The COMM. FREQ. SWITCH panel is equipped with a ten-position rotary switch (for route frequency selection) and a DAY-NIGHT toggle switch. A placard on the panel shows the switch positions and frequencies for each route. For example, night frequency for route 7 would be selected by placing the rotary switch on "7" and the toggle switch on the "NIGHT" position. This control automatically sets both transmitter and communications receiver to the selected frequency.

Audio Output Selector. The AUDIO OUTPUT SELECTOR is equipped with four toggle switches to connect the outputs of the communications, beacon, radio-compass, and auxiliary receivers to the headsets. One of these units is mounted on each side wall of the cockpit so that both pilots may listen simultaneously to different receivers. A range filter and switch are incorporated in each box; the filter

switch has three positions, labeled "RANGE," "VOICE," and "BOTH." When this switch is on "RANGE," only the range signals are received; the "VOICE" position eliminates the range signals and permits reception of voice broadcasts; the "BOTH" position provides for simultaneous voice and range signal reception.

Marker Indicator. The marker indicator is equipped with three signal lamps, labeled "AIRWAY," "OUTER," and "INNER." These lamps operate on Z and fan markers, and on the outer and inner markers of instrument landing systems, respectively. A LOW-HIGH switch provides for changing the light intensity of the signal lamps.

Antenna Switch. The ANTENNA SWITCH, located on the cockpit sidewall, switches either beacon antenna (front or rear) to either the beacon or auxiliary receivers.

Jack Boxes. A jack box to receive microphone and headset plugs is mounted on either sidewall of the cockpit, one for each pilot. Two auxiliary headset jacks are mounted on the underside of the ANTI-STATIC CONTROL located on the cockpit bulkhead behind the Captain's seat. One of these jacks is connected to the Captain's jack box and the other is connected to the First Officer's jack box; they are provided for use by jump seat occupants for checking and observation purposes.

Anti-Static Control. The ANTI-STATIC CONTROL is equipped with a toggle switch having two positions—"OFF" and "ANTI-STATIC." This switch is normally in the "OFF" position and is turned to "ANTI-STATIC" only when it is desired to release a static discharge system (described later in this Lesson) from its cartridge in the tail of the plane.

Microphone and Headset. The microphone (Fig. 13) is usually a carbon-button type contained in a molded plastic case and equipped with a "push-to-talk" button, a rubber-covered cable terminating in a plug that fits the microphone jack on the jack box, and a ring by which it is suspended from a hook on the cockpit sidewall when it is not in use. Its frequency response (about 700 to 5000 cycles) is sufficient for speech transmission and prevents transmission of much engine, propeller, and vibration noise (noise frequencies of these types are mainly below 600 cycles).

The headset is usually a standard type equipped with sponge rubber earcups for wearing comfort and reduction of extraneous noise.

Aircraft Radio Interference

The ratio of signal to noise energy in a receiver output determines the intelligibility of the received signal. Therefore, anything that can be done to increase this ratio by reducing the noise level results in increased receiver efficiency. Aircraft radio receiver noise (other than noises inherent in the receivers themselves) arises from natural atmospheric disturbances (static), generation of static by the plane itself under certain flight conditions (precipitation static), and "man-made" interference originating in the aircraft's electrical system.

STATIC

The radio interference usually referred to as "static" consists of the crashing or crackling noise associated with lightning discharges during electrical storms, and is troublesome on all aviation frequencies except the v.h.f. channels. Static consists of electromagnetic energy pulses propagated as radio waves and containing energy components distributed over a wide range of frequencies. Since static propagates as a radio wave and is received by the antenna, little can be done to reduce such interference with amplitude-modulated signals. The two most effective means of reducing static pickup are the use of directional receiving antennas to reduce the static pickup from all directions and the use of highly selective receivers to decrease the amount of static energy included with the desired signal. However, since this kind of static is an intermittent disturbance, it is usually possible to receive signals through it unless the disturbance is unusually severe. Frequency-modulated signals are relatively immune to static disturbances, as are amplitude-modulated signals above about 30,000 kc. (most static energy is concentrated in the lower frequencies). For example, a nearby lightning discharge will produce only a slight click in the output of the v.h.f. beacon receiver.

PRECIPITATION STATIC

The second type of interference is the so-called "precipitation static" attributed to the charge and discharge of the aircraft itself when it flies through precipitation or electrostatically unstable cloud areas. This interference is more serious, because it can completely blanket all reception for long periods of time. It is particularly noticeable in meteorological disturbances of the "frontal" type, particularly in the southeast sector of low-pressure areas. Precipitation static is characterized by continuous frying and crying sounds, whose pitch varies up and down the musical scale. It occurs mostly during flights, although it is occasionally noticed at ground stations under conditions of precipitation and high wind. Flight research has established that precipitation static results primarily from the charge and discharge of the aircraft itself, particularly if it becomes charged to such an extent that corona discharges occur. The charging of an aircraft is a combination result of several factors:

(a) If water drops are mechanically split up, the resulting droplets are found to be electrically charged; in general, the larger droplets are positive and the finer spray is negative. The churning action of the plane's propellers and impact with wings and fuselage break up raindrops, and the resulting charged particles that strike the antennas, wing surfaces, and fuselage give up their charges to the aircraft. Frictional electricity and small piezo-electric voltages due to impact of snow and ice crystals may also be contributing factors.

(b) An aircraft flying through an electrostatically unstable area may proceed rapidly through local areas whose potentials differ by many thousands of volts, or different portions of the aircraft may be simultaneously in differently charged cloud regions. This results in a continual transfer of charge between the aircraft and the surrounding atmosphere or in a flow of current through the aircraft itself. Electrostatic charges tend to accumulate on and discharge from sharp points or portions of a charged body having the smallest radii of curvature. If the body is highly charged the discharging action forms a "corona" or "brush" discharge, sometimes visible as a bluish ionization glow or haze surrounding the discharge point. Corona discharges from a highly charged aircraft occur from the trailing edges of wings and propeller blades, sharp corners of rivet heads, antennas and antenna supports, or other surfaces having small radii of curvature, and the characteristic precipitation static interference is most noticeable when such discharges occur. The corona discharge, if "hard" enough, generates an audio-modulated electromagnetic disturbance that is picked up by the antennas; the audio component increases in frequency as the discharge potential increases (accounting for the characteristic "crying" sounds of precipitation static). However, the disturbance field radiated by a corona discharge is rapidly attenuated with distance.

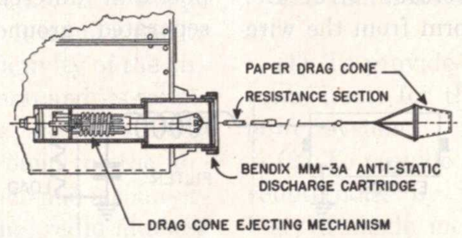


FIG. 14. Cutaway view of a trailing wire static discharge system in use. The paper drag cone and the trailing wire are contained within the cartridge when the aircraft takes off, and are ejected in flight when the pilot throws a switch in the cockpit.

An effective device for reducing the severity of precipitation static caused by corona discharges is the trailing wire static discharge system, consisting of about five feet of high-resistance conductor (such as graphite-impregnated rope) followed by five feet of thin stranded wire and terminated with a paper wind-cone. Fig. 14 illustrates the device. When it is not in use, the discharge system is contained in a cartridge. The discharge wire release is controlled by a switch in the cockpit; when the switch is thrown, current is passed through a fusible link in the cartridge, releasing a spring that ejects the drag cone which pulls out the discharge wire.

The discharge system reduces the severity of precipitation static interference for two reasons:

(1) Since the discharge wire consists of a series of points sharper than any portion of the aircraft's structure, corona discharges form from the wire rather than from the aircraft. This removes the discharge from the immediate vicinity of the antennas, thereby reducing static pickup because of the rapid attenuation of the interference field.

(2) The high-resistance conductor portion of the system acts as a suppressor that tends to prevent formation of oscillatory corona discharges and isolates the plane structure from transient radio-frequency currents in the discharge wire. The system therefore acts as a continual "leak" that prevents the static charge on the aircraft from accumulating to high values. The aircraft's bonding system must be good if the static discharge system is to be effective.

Man-made radio interference usually originates in the aircraft's electrical system. Transient noise fields containing radio-frequency components distributed over a wide range of frequency are generated by the engine's ignition system, sparking at switch, vibrator, and relay contacts, electro-static discharges between poorly bonded portions of the aircraft, circulating currents in the metal structure due to potential difference between widely separated grounds (poor bonding), commutator ripple and sparking, and other transient conditions normally existing in the electrical system. (Transient fields may be generated without visible sparking.) Noise energy may be fed to a receiver through its power leads (conduction) or may be introduced into antenna lead-ins or receiver circuits and wiring by induction or radiation.

Interference conducted to receivers via power feeders is eliminated by low-pass filters (sometimes by-pass condensers alone are sufficient) installed near the source of interference or, in some cases, at the receiver. Fig. 15 shows a typical "noise filter" arrangement. Such filters are used in most motor, magneto, dynamotor, inverter, and generator circuits to attenuate ripple voltage, commutator noises, etc.

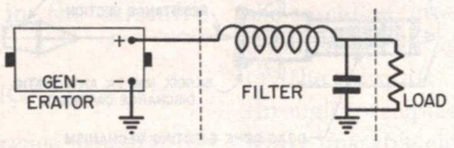


FIG. 15. This simple filter network is usually enough to prevent radio interference from generators, etc.

Radiation and induction interference are eliminated by proper bonding and shielding, which effectively isolates the receiver circuits from the noise field. Bonding and shielding are discussed in detail in the following sections.

Electrical Bonding of Aircraft

It is most important that all metal portions of an aircraft be electrically "bonded"—that is, connected with low-resistance conductors so that electrically the entire aircraft is a single metallic mass. This is equivalent to saying that the conductivity of the aircraft must be maximum and its resistance minimum. The aircraft's body then constitutes a ground for the aircraft's electrical system and a counterpoise ground for the radio-antenna system.

Two-wire power distribution circuits are not ordinarily used in aircraft; instead, one side of the circuits is always grounded to the plane's structure. The aircraft's body is therefore the return or ground circuit of a two-wire power distribution system. For this reason, the resistance of the bonding must be as small as possible. This is accomplished by connecting metal portions of the aircraft with bonding conductors having less resistance than the plane parts, both to decrease the total resistance of the aircraft and to shorten the ground return path for the electrical system.

Since the condition of the bonding affects to some extent the operating efficiency of an aircraft radio installation, the aviation radio man should have a thorough knowledge of bonding principles so that he can efficiently trouble-shoot radio disturbances caused by defective bonding. Further, local radio interference is many times the first symptom of defective bonding.

The functions of a bonding system are:

(1) To provide a low-resistance return circuit for the aircraft's electric power system.

(2) To provide an effective antenna counterpoise by making the plane's body a single metallic mass of high conductivity.

(3) To minimize the possibility of lightning damage by providing low-resistance paths around parts (such as control-surface hinges) that are susceptible to damage by lightning.

(4) To decrease radio interference (and fire hazard) caused by static discharges between various parts of the aircraft structure. The function of the bonding in this case is to maintain all portions of the plane's structure at the same static potential.

(5) To insure the effectiveness of shielding by connecting the shielding elements to the aircraft body through a path having low radio-frequency impedance.

(6) To make it possible to reduce the electrostatic potential of the entire aircraft quickly to ground potential by connecting a ground wire to any portion of the aircraft structure after it

has landed. This is particularly important as a means of reducing the fire hazard of electrostatic discharges when the aircraft is being fueled.

Resistance of Bonded Aircraft Structures. Tests, research, and experience have established certain maximum resistance standards for bonded aircraft structures, and these maximums must not be exceeded if radio equipment is to operate at best performance levels. The generally accepted maximums for various plane structures are listed below.

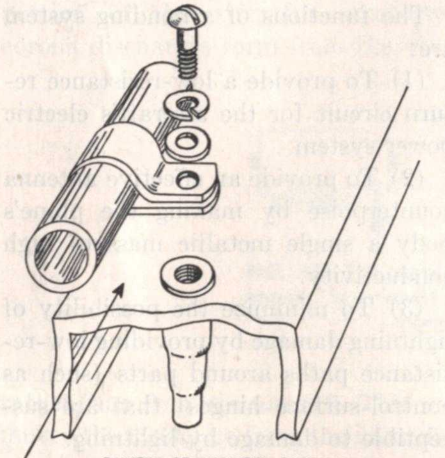


FIG. 16. How a tubing clamp is bonded to an aircraft structure with a Rivnut or Dill lock screw.

Conduit, connector panel shields, electrical and radio equipment and mounts: .001 ohm

Engine, engine mount, firewall, flooring, tubing and valves (plumbing), control surfaces, fins and stabilizers, and instrument panels: .002 ohm

Nacelle cowling, doors (closed), tanks (fuel and oil), control rods, seats, chairs, tables, control columns, ignition manifold assembly, and rudder pedals: .004 ohm

Manufacturers of aircraft furnish a table of bonding resistances similar to that shown above as a guide for checking and bonding of new or repaired aircraft. An ohmmeter continuity check is an easily made test that gives a rough indication of the condition of the bonding.

BONDING METHODS

Bonding may be accomplished by any of the following methods: (1) connecting aircraft structural members with flexible braid pigtails; (2) using metal ribbon inside fairleads to connect plumbing lines, conduits, etc. to their supporting structure; (3) removing paint and anodization from surfaces in contact; and (4) removing finish on solid tubing supported by solid tube clamps. With regard to the last type, the finish on tubing need not be removed if the "Adel" clamp is used. Piano-type hinges and riveted joints are considered to be self-bonding. Figs. 16 and 17 illustrate bonding methods and materials.

Engine mounts must be thoroughly bonded to the fuselage framework at one of the suspension points. The bonding strip is usually a flexible stranded copper braid tinned to prevent corrosion. If a flexible mounting suspension material is used to support the engine at the mount, at least four 25/32-inch inside diameter braid bonding jumpers (or other conductors having the current-carrying capacity of 6-gauge copper wire) are used to connect the engine to its mount, and if additional shock-

absorbing units are used at the firewall, similar jumpers are installed across each unit. Engine cowling sections making poor contact are connected to the engine nacelle or aircraft structure with ⅛-inch braid bonding jumpers or other conductors having the current-carrying capacity of 16-gauge copper wire. Engine cowling bonding is very important, since the cowling lies between the engine's ignition system and the antennas.

All tanks are bonded to the main metallic structure of the aircraft; flexible pigtail connections are used unless the tank is mounted so that it makes a strong pressure contact with the aircraft's structure. Tanks containing inflammable fluid are bonded with at least one 3/64-inch inside diameter braid bonding jumper connected as close to the filler hole as possible. Large tanks should have a second jumper of the same size connected as far as practicable from the first. Gas, oil, and hydraulic lines are bonded wherever they intersect any major portion of the aircraft's structure. If the lines are broken by flexible connections, the connections are bridged with flexible pigtail jumpers.

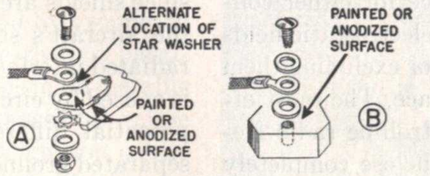


FIG. 17. Methods of securing a bonding jumper to a painted or anodized surface. In A, a star washer is used to secure good electrical contact to the surface; in B, the self-tapping screw makes the contact.

All structural members having areas of more than 1.5 square feet are bonded. Conduit is bonded every 18 inches; if the conduit is flexible it is bonded by soldering a pigtail directly to the external braid. Metallic tubing and rigid conduit are bonded only through supporting attachments. The normal spacing of tubing and conduit supports is generally satisfactory even for conduits carrying ignition circuits. Unanodized conduit and plumbing fittings are considered to be self-bonding. Movable control surfaces are bonded across their hinges; control cables may be bonded, but their normal range of movement requires bonding jumpers of such length that the bonding may be ineffective. Control surfaces are bonded with one 3/64-inch braid jumper across the hinge nearest each end of the surface (the distance between these bonds should not be more than 15 feet). Elevators are frequently interconnected with a torque-tube, and if the distance between outboard hinges is less than 15 feet, only these hinges need be bonded. Exterior doors that do not make good contact when locked should be bonded with ⅛-inch braid jumpers across two widely separated hinges. Pigtails and jumpers should in every case be long enough to permit normal movement and vibrating of the connected parts.

Shock-mounted electrical and radio equipment is usually insulated from the aircraft structure by the shock mounts, and therefore at least one ⅛-inch braid jumper should be connected from the case of each shock-mounted unit to the main structure of the aircraft. Since the cases are frequently grounded, the jumper should be large enough to carry the ground return currents. For example, junction box ground posts frequently carry relatively large currents that must be conducted to the main structure of the aircraft through a low-resistance path. Shock - mounted instrument panels should be bonded with at least two ⅛-inch braid jumpers.

Aircraft Shielding Systems

A shield is a device for either confining magnetic and electrostatic fields to a restricted space or excluding them from a particular space. The most effective means of controlling radio-frequency fields is to enclose completely the space within which the field is to be confined or from which the field is to be excluded, using a metallic shield of high conductivity, such as copper or aluminum. Magnetic flux penetrates a high-conductivity shield only with great difficulty because eddy currents set up in the shield oppose the penetration. Electrostatic lines of force do not penetrate a conductor, but terminate at its surface.

Both "confinement" and "exclusion" shields are used in aircraft radio and electrical systems. Sources of interference, such as the engine's ignition system and equipment using vibrating contacts or commutators, are completely enclosed in metallic shields to prevent radiation, and wiring or circuits in which noise pickup occurs (such as antenna lead-ins and interconnecting wiring) may be shielded to isolate them from any radiation noise fields present. The shielding system is closely allied with the bonding system, since shields are electrically bonded to the aircraft's structure. For example, radiated interference from the fuselage is caused by circulating currents due to potential differences between widely separated grounds. This interference is minimized by frequent bonding to the fuselage of all shielded leads.

SHIELDING THE IGNITION SYSTEM

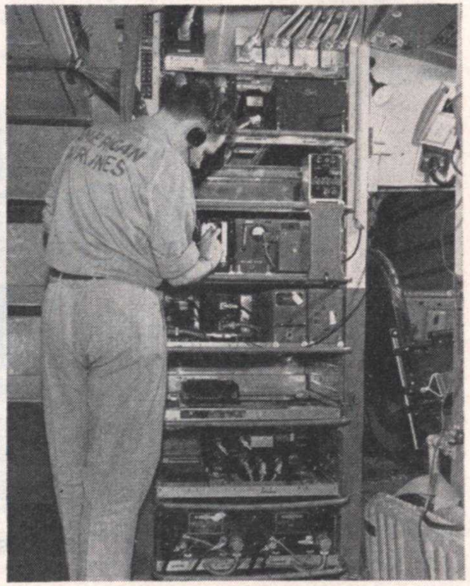
The engine's electrical ignition system is perhaps the most troublesome source of radio interference. The interference set up in a radio receiver by an unshielded ignition system is usually so intense that reception is impossible until the disturbance is suppressed by adequate shielding. Ignition sparking generates a series of damped electromagnetic waves similar to those produced by a broadly-tuned spark transmitter (containing energy components distributed over a wide range of frequency). The radiated noise field is picked up by the antennas and wiring, causing a loud buzz in the receiver output each time a spark plug fires and at every opening of magneto and distributor breaking points.

To obtain effective shielding, the en-

tire ignition system must be enclosed in metallic shields having high conductivity. This requires shields for the magneto distributor heads, booster magneto (a special auxiliary magneto providing a hot spark desirable for starting a cold engine), ignition distributing wires to the spark plugs, the spark plugs themselves, the ignition switch, and the switch and booster magneto wiring. High conductivity is obtained by using shields of good conductors such as copper or aluminum, by making good electrical contact at all joints in the shields, and by grounding the shields to the engine, thereby paralleling the shields with the main metallic mass of the engine. Because of the close proximity of shields to ignition cables and spark plug terminals, the insulation between the shields and the ignition system must be good. Ignition cable insulation must be moisture-proof, mechanically strong to withstand vibration, and immune to puncture by the high ignition voltage. A minimum clearance of ¾-inch should be provided between any portion of the shield and exposed metal conductors or terminals carrying high voltage. Also, the shield design must be such as not to interfere with normal heating and cooling of spark plugs and must permit normal servicing of spark plugs without special tools.

The presence of shields tends to increase somewhat corona discharge from high-voltage circuits. It is therefore customary, wherever possible, to group the high-voltage cables inside a single shield.

Lacquered copper shielding braid used on small wires should be inspected frequently for deterioration. Small wires of the braid sometimes break and the broken ends become corona discharge points. Also, abrasion may injure the lacquer finish necessary to protect the rubber covering of the cable from deterioration caused by moisture, oil, and ozone produced by corona discharges.



Courtesy American Airlines

The radio rack used in American Airlines DC-6.

Shielding the Magnetos. The distributor, distributing blocks, and breaker mechanisms of magnetos are enclosed in a metal case that is ventilated—generally at the bottom—to prevent moisture condensation inside the shield. The ignition distributing wires and switch and booster leads are brought out through water-tight outlets in the magneto shield. The shields are designed so that they may be removed without disconnecting leads or disturbing other parts of the assembly. The terminal block of the booster magneto is shielded with a moisture-proof metal cover provided with a single water-proof outlet for the booster and ground leads.

Switch Lead Shielding. Metallic copper shielding braid is much used for shielding the magneto switch leads, although it is being replaced by flexible or solid conduit (which is used to shield the entire electrical system) in recent aircraft. If braided shielding is used, care must be taken that the braid does not contact the exposed switch terminals—this difficulty is encountered particularly on multi-engined planes in which two or more ignition switches are grouped. It is best, in these cases, to terminate the braid and bond it to the ignition switch cover. It is then not necessary to shield the wires inside the switch cover.

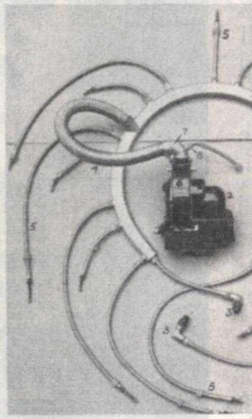


FIG. 18. Typical ignition shielding system.

Manifold-Type Ignition Shielding Harness. The manifold-type harness consists of a metal manifold ring containing unshielded high-voltage ignition leads. Ignition leads from the manifold to the spark plugs are enclosed in flexible tubing equipped with a threaded fitting at one end for connection to the manifold and a cap fitting at the other end for connection to the shielded spark plug. The groups of leads from the manifold to the magneto distributors are similarly enclosed in flexible tubing, which is connected to the manifold through a suitable union box and to the shielded magneto with an elbow fitting. The flexible tubing is usually enclosed in copper braid to insure effective shielding. This type of assembly is mechanically and electrically sound and is comparatively easy to install and service.

TYPICAL SYSTEMS

A typical ignition shielding system used on commercial aircraft engines is shown in Fig. 18. The main harness consists of an aluminum manifold (1) containing high-voltage cables from the magneto distributor heads (2). The groups of leads from the magneto outlets to the manifold are enclosed in moisture-proof flexible aluminum tubing covered with copper braid (4). The individual leads from the manifold to the spark plugs (3) are enclosed in flexible tubing of smaller diameter (5). Each lead is equipped with a moisture-proof connector at either end, for connecting the lead to the spark plug and manifold. The magneto covers (6) completely enclose the distributor blocks, and the large flexible tubing leading to the manifolds connects to the magneto through an elbow fitting (7). The elbow fitting differs somewhat for various types of engines. Outlets (8) are provided in the elbow fittings for the booster and ground leads. Spark plugs are enclosed either in metal cases (not shown) or in shields that are integral parts of the plug (3). An auxiliary harness shown in Fig. 19 provides a shielding for the booster and ignition switch leads. The ignition switch and the booster magnets (not shown) are also completely shielded.

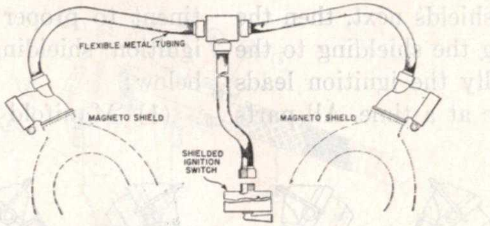


FIG. 19. An auxiliary harness used to shield booster and ignition switch leads.

The Rome System. The harness of the Rome-type ignition shielding system consists of a set of spark plug ignition cables laid together and covered with rubber. This bundle of cables is then vulcanized to a semi-flexible state and covered with cotton braid and tightly-woven phosphor-bronze wire braid. The entire harness consists of four such built-up cables. The magneto shields have two outlets for ignition wires and one outlet for the booster magneto and ground cables. The spark plug shields are constructed of two halves machined to make a water-tight joint and held together with a clamp. The shields hold the ignition wire terminals in contact with the spark plug. The entire assembly is easily dismantled by removing the retaining clamps. Booster magneto and ground leads are enclosed in braided metallic shields.

The Breeze System. The Breeze ignition shielding system is designed to eliminate ignition radio interference and to protect the ignition system in every possible way. The entire ignition system is covered, thereby protecting all cables from deterioration caused by weathering, oil, and moisture. Fig. 20 shows the harness details. The manifold ring is constructed of seamless brass tubing; and moisture-proof, flexible aluminum tubing covered with double braid houses each ignition lead. Both ends of each lead are equipped with rubber washers that act as packing clamps and prevent moisture from seeping into the shielding tubing.

The spark plug shield body is constructed of special metal designed to resist work-hardening and crystallization due to vibration. The shield cap is made of insulating material having high dielectric strength covered with a metal cap to shield the spark plug. The entire cap is easily removed by releasing its clamp. Fig. 21 shows the constructional details of the Breeze spark plug shield.

IGNITION SHIELDING MAINTENANCE

If the ignition shielding system is dismantled for inspection or to permit engine overhaul, the magneto shield is removed first, the distributor block and spark plug shields next, then the brackets securing the shielding to the engine, and finally the ignition leads are removed, one at a time. All parts should be inspected for mechanical soundness and cleaned before being replaced. After the shielding system is reassembled, it may be further waterproofed by applying a melted mixture of beeswax and rosin to all joints in shields and around connectors in the shielding. A radio mechanic may service the ignition shielding system if so directed; however, a licensed mechanic is always in charge of the engine and its fittings.

Several other important points pertinent to proper maintenance of the ignition shielding system are listed below:

(1) Manifold tubing and ignition

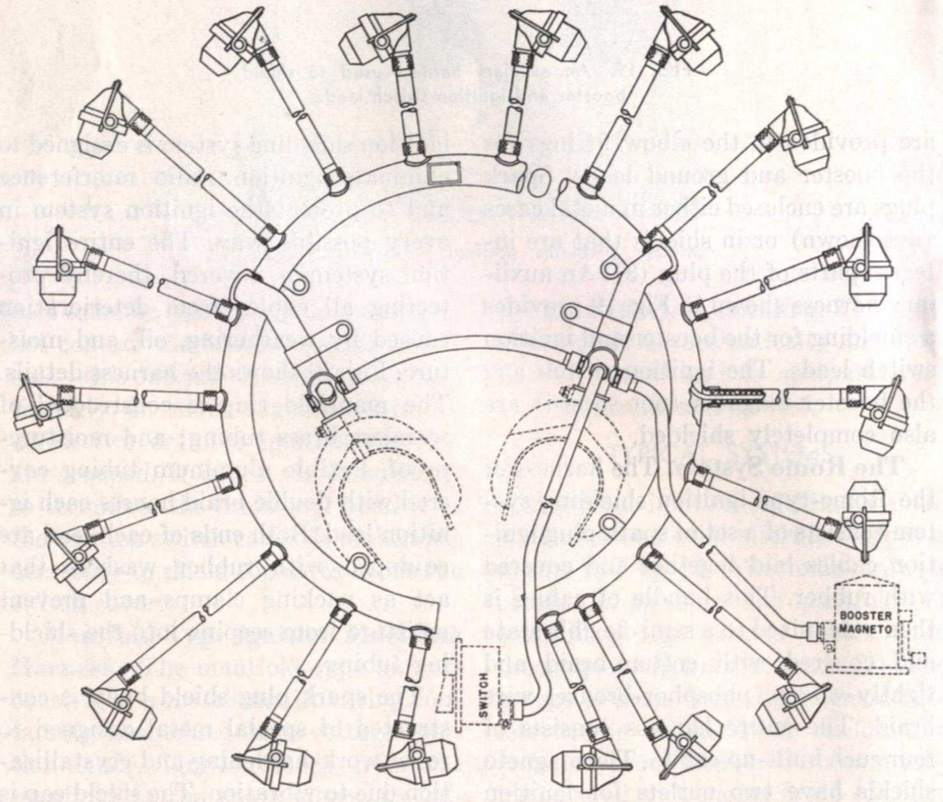


FIG. 20. General arrangement of the Breeze ignition shielding system harness.

leads should be carefully and frequently bonded to the aircraft structure (engine). Failure to bond a single lead to a spark plug may cause noticeable interference.

(2) The ignition shielding must be complete. Even one inch of exposed high-voltage cable may cause radio interference.

(3) A soldered connection should never be made to shielding containing high-voltage cable. The amount of heat required to make a good soldering joint may be sufficient to damage the rubber cable insulation, causing gradual insulation breakdown.

(4) Before the cables are installed, ignition manifolds should be inspected for rough spots or sharp corners which might damage the cable insulation. Any rough spots should be smoothed and any sharp corners chamfered.

(5) Sharp bends in shielded high-voltage cable should be avoided.

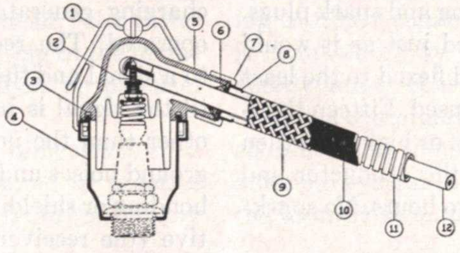


FIG. 21. Details of the spark plug shield used in the Breeze shielding system are: 1, cap clamp; 2, retaining screw; 3, gasket; 4, shield body; 5, shield cap; 6, rubber packing gasket; 7, coupling nut; 8, conduit ferrule; 9, armoring; 10, braid; 11, flexible conduit; 12, high tension ignition cable.

TESTING THE SHIELDING SYSTEM

Various tests are made on a shielding system. Before shielded cable is installed, it is tested to make sure that sparkover between the ignition wires and ground will not occur, that its insulation resistance is sufficiently high, and that there will be no corona discharge from the ignition wires to the shield. After installation, the effectiveness of the system in operation is tested. Let's see how these tests are made.

Ignition Shielding Sparkover Test. The sparkover test is made before installing the ignition shielding assembly on an engine. The ignition system is assembled, connected, and grounded just as it would be on the engine, except that the magnetos are not used and mica insulators are placed between the spark plug points to prevent them from sparking. A voltage of 15,000 volts (effective) at 60 cycles is then applied between the ignition wires (in parallel) and ground, and maintained for five minutes. No sparking should occur. Sparking can be observed audibly or, more exactly, by a sudden increase in deflection of an indicating instrument connected in series with the circuit.

Insulation Resistance Test. The same setup is used for this test as for the sparkover test except that the mica insulators are removed from the spark plugs and the spark plug interiors are protected from moisture. The complete assembly is then sprayed with water for three hours and the insulation resistance of individual leads to ground is measured at one-hour intervals. The insulation resistance of any lead must not be less than one megohm.

Corona Test. This test is made on a section of high voltage ignition cable of the same length as the leads between the manifold or casing and spark plugs. The cable is shielded just as it would be on the engine and flexed to the least radius of curvature used. Fifteen thousand volts (60 cycles or higher) is then impressed between the conductor and shield for at least two hours. No sparking should occur.

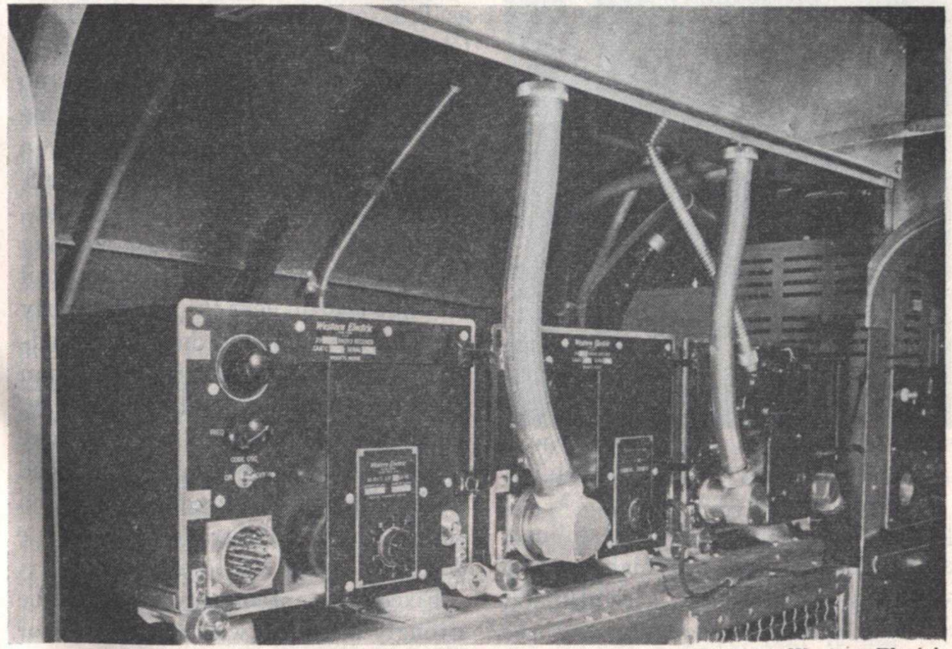
Operating Test. The only positive test of the shielding system is to check its operating performance. Its effectiveness can be gauged by listening to an aircraft radio receiver with the plane first on the ground and then in flight. Any noises other than the normal receiver background noise are probably caused by defective shielding (or bonding). Noises present in flight but not on the ground are due to loose or bad connections, etc., that become troublesome only under flight vibration conditions.

While the ground test is being made, the engines are run at normal cruising speed, both ignition switches and the main line switch or circuit breaker are turned on, the transmitter and all receivers are turned on, and all auxiliary electrical equipment, including the charging generator, is connected and operated. The receiver is then tuned to a signal and the volume reduced until the signal is just audible. If noises other than the normal receiver background noises and static are heard, the bonding or shielding is probably defective (the receiver, of course, must be properly installed and adjusted, should have a voltage amplification of one to three million, and should be used with an antenna extending at least six feet above the fuselage). No ignition noises should be heard at any engine speed at any setting in the entire tuning range of the receiver.

Aircraft Antennas

Because of the variety of special-purpose transmitters and receivers carried by modern aircraft, a number of antenna designs have been evolved. A single aircraft may carry several types, each serving a particular radio set or function. Aircraft antennas may be classified into three general types—"fixed," "trailing wire," and "shunt-fed wing" types. The fixed type may be further subdivided into "mast," "fin," "loop," "belly," "overhead," etc. varieties, designated according to the method of support, location, or physical configuration.

Since the physical dimensions of a fixed antenna are limited in practice by the dimensions of the aircraft, many of these antennas are compromises with the ideal. For example, a desirable half-wave antenna for transmission of certain low frequencies used in aviation radio would be a vertical radiator two thousand feet long, obviously not a practicable length, whereas an ideal half-wave antenna for the planes ultra-high-frequency radio altimeter would be only fourteen inches long. Therefore, the problem of choosing a proper combination of antennas is complicated by both electrical and aerodynamic considerations, and is usually a compromise between antenna efficiency and the permissible drag the antenna system necessarily adds to the aircraft structure. Antenna masts,



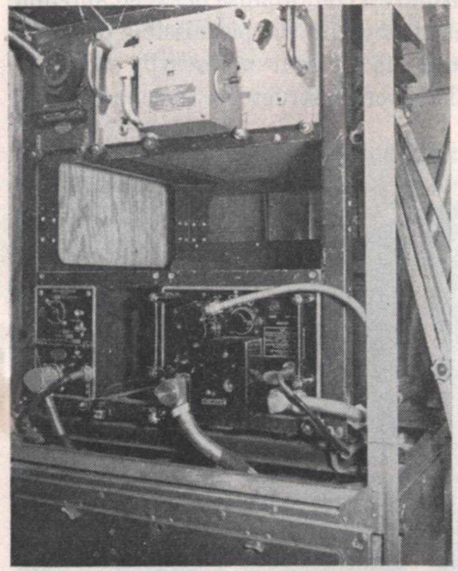
Courtesy Western Electric

This picture shows two multi-frequency Western Electric receivers and a transmitter installed in an American Airlines plane. The receiver in the foreground is a spare. Notice the mounting system used to protect the equipment against shock.

supports and fitting, loop housings, etc. are streamlined; the streamlining decreases their air resistance, inhibits the formation of static-causing corona discharges, and decreases the probability of heavy icing on these surfaces. Loop housings, in addition to being streamlined, are frequently made retractable. The antenna supports and masts must be mounted and located so that no undue stress is developed either in the supports or in the plane's structure.

PRACTICAL ANTENNA TYPES

Vertical-Mast Antennas. This type of antenna may be a vertical wood or



Courtesy T.W.A.

Radio rack used in TWA DC-3 aircraft.

plastic mast (tapered and streamlined, and perhaps 3 to 5 feet high) with a wire through its center, a rigid metal mast, or a whip-mast similar to those used on automobiles. The whip type offers less wind resistance than the rigid mast, decreases vibration dangers, and does not accumulate ice readily. Vertical-mast antennas are desirable for the reception of radio range signals, and are much used on small aircraft for this purpose.

V.H.F. receiving antennas may also be of the vertical-mast type, although other types, such as the horizontal "belly" dipole for receiving marker beacon signals, are also used. The usual v.h.f. receiving antenna is a quarter-wave vertical mast grounded to the aircraft, which then forms part of the antenna system. The lead-in is connected to the point on the vertical mast that gives the correct impedance match with the transmission line to the receiver.

Overhead and Belly Antennas. These antennas may be designated according to their physical configuration as T, L, or V types. The overhead antenna is supported between the vertical stabilizer (or stabilizers) and stub masts forward on the fuselage or wing tips. The belly antenna is usually a single-wire fore-and-aft antenna supported between stub masts on the underside of the fuselage. An antenna supported between wing tips and tail with the lead-in near the tail is a fairly efficient antenna, but has the disadvantage of having greater drag than the single-wire fore-and-aft antenna. To reduce the ice pickup of fixed-wire antennas, they are usually arranged so that the angle between the antenna and the direction of travel of the plane does not exceed 15 to 20 degrees.

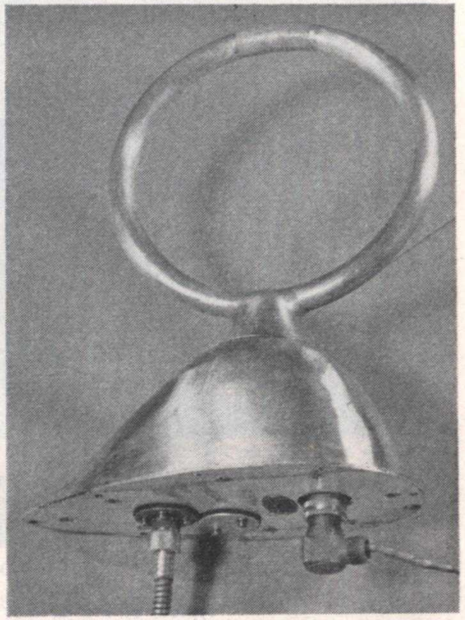
Fixed-wire antenna systems must be strongly installed, with due regard for the extra load imposed by flight stresses and ice accumulation. Antenna wire, for example, should be replaced if

frayed or nicked. Even a small nick may cause the wire to break under flight stresses. Insulators should be kept clean and replaced if cracked or chipped.

Shunt-Fed Wing Antennas. The shunt-fed wing antenna uses the wing of the aircraft as the radiator. The wing is excited by a feeder wire brought through the fuselage and connected some distance out on the wing (the distance is governed by impedance-matching considerations). The other side of the transmitter output is connected to the airplane's body. This arrangement compares favorably with fixed-wire antennas if the plane's wing spread is 40 per cent or more of the working wavelength.

Loop Antenna. The radio-compass loop antenna, Fig. 22, is usually mounted in a streamlined housing on the belly of the aircraft, and on high-speed aircraft is usually arranged so that it may be retracted into the fuselage when not in use. The belly location is preferable since the directional properties of a loop mounted on top of the fuselage are impaired when an aircraft is close to the transmitting station because of the field distortion caused by the airplane's body. In addition to its direction-finding uses, the loop is also used as an anti-static antenna. The loop is electrostatically shielded, and since some static disturbances are predominantly electro-static in nature, the loop shielding tends to reduce noise pickup. However, noise-free reception is not possible even with the anti-static loop under all conditions, notably in areas of heavy precipitation static.

Trailing-Wire Antenna. The trailing-wire antenna usually consists of a wire reeled out through a fairlead in the plane's tail or belly and terminated with a weight or other drag device. Occasionally, however, the wire is of fixed length, not retractable, and allowed to trail during both landing and take-off. Some small aircraft are equipped with a trailing-wire antenna that runs



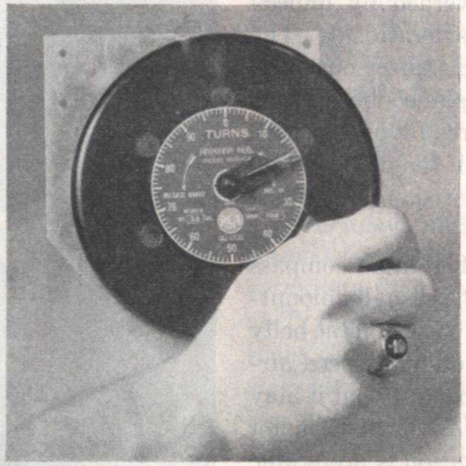
Courtesy T.W.A.

FIG. 22. Shielded-loop antenna used for an aircraft radio-compass.

through fairleads in the fuselage near the cockpit and on top of the vertical stabilizer; the wire terminates in a rubber cone that acts as an air drag. This antenna is also used as a fixed antenna when completely reeled in. In general, the trailing-wire antenna is relatively efficient. Its radiation resistance is quite high since it is well removed from the aircraft's body, and it has the added advantage of being adjustable for operation at any desired frequency by varying the length of wire reeled out, thus eliminating much loading and tuning apparatus.

Trailing-wire antenna reels carrying 150 to 500 feet of wire are available. The reel may be operated manually, or electrically by remote control; in either case an indicator is provided to show the length of wire reeled out. Fig. 23 shows one type of reel.

The weight on a trailing-wire antenna led through the bottom of the fuselage has some tendency to oscillate as it is reeled up close to the fuselage, particularly if the reeling speed is not carefully controlled. To prevent the possibility of the weight's swinging into a propeller, the antenna fairlead is usually located well back on the aircraft. The antenna may be led back to a desirable position through fairleads either outside or inside the aircraft; outside fairleads are preferable from the electrical standpoint but aerodynamically undesirable. An efficient way to install a remotely operated reel is to run a lead-in outside the airplane as directly as possible, and carry it back to the automatic reel fairlead, which can be located at any desirable location in the aircraft. The reel fairlead should project at least one foot beyond surrounding portions of the aircraft to prevent a swinging weight from damaging the aircraft.



Courtesy R.C.A.

FIG. 23. The RCA AVA41A antenna reel, typical of the devices used to pay out or reel in a trailing-wire antenna.

Transmitting Antennas. The transmitting range of a transmitter is dependent upon the radiating efficiency of the antenna. Fixed antennas radiate most efficiently only when operated at their fundamental and harmonic frequencies. Therefore, since fixed antennas are ordinarily used on several frequencies, some means of antenna tuning must be provided. Antenna tuning is usually incorporated in the transmitter, but for low frequencies requiring a long antenna a separate tuning unit is usually provided. These devices, in effect, compensate electrically for the too-short antenna, making it possible to load the antenna properly. In general, fixed antennas used for transmission should be as long as the size of the aircraft permits and should be kept as far away from the aircraft structure as possible.

Since high voltages exist at the antenna lead-in, particularly at low frequencies, the lead-in must be well insulated at its point of entry into the aircraft.

Receiving Antennas. Although antenna length is not as critical for receiving as for transmitting, a well-designed receiving antenna will greatly improve receiver performance. Receivers should be located as close as possible to the antenna to avoid long interior lead-ins, which attenuate the signal (particularly at high frequencies), pick up noise voltages, and may introduce undesirable directional effects if the antenna is used with the beacon receiver. Also, excessive capacity between the lead-in and ground may prevent proper tuning of the antenna circuit and thereby reduce the gain normally provided by this circuit. To reduce noise pickup, the lead-ins are usually shielded and the shield is bonded to the aircraft structure. Sometimes, to insure a low-impedance internal connection to the receiver, a matching transformer is installed close

Courtesy Pan American

The flight compartment of a Pan American clipper. Since these aircraft make long overwater flights, they carry a navigator (left foreground) in addition to the pilot and co-pilot.

to the point at which the antenna enters the fuselage. The internal lead-in should have no sharp bends and should not be installed close or parallel to other wiring in the aircraft.

In general, a fixed transmitting antenna is also an efficient receiving antenna. However, only the "T" configuration—consisting of an essentially flat top with a central lead-in—should be used for reception of beacon signals, since the "L" configuration has undesirable directional characteristics.

Antenna Wire. The chief requirement of antenna wire is that it must be mechanically strong. Either solid or stranded wire may be used. Airlines usually use 6×7×0.008-inch stranded silicon bronze wire having a breaking strength of approximately 200 pounds. All joints and splices made in antenna wire must be mechanically strong.

Lesson Questions

Be sure to number your Answer Sheet 56RC.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. What are the five basic flight instruments of an aircraft?
2. Why is aircraft radio equipment shock-mounted?
3. What are the three chief sources of radio interference in an aircraft?
4. Is corona discharge more likely to occur from a sharp point or a rounded surface?
5. What is meant by the statement that the metal portions of an aircraft should be electrically bonded?
6. Is extensive shielding of the ignition system necessary in aircraft?
7. What is the best test of a shielding system?
8. What are the three main types of aircraft antennas?
9. What kind of antenna is used for a radio compass?
10. What are the two chief advantages of a trailing-wire antenna?

SELF-EDUCATION

"The best culture is not obtained from teachers when at school or college—but by our own diligent *self-education* when we have become men."

This quotation has been proved true many, many times. Let's take a few outstanding examples. President Ulysses Grant was often called "Useless" by his mother because he showed so little promise as a young man. General Stonewall Jackson was noted for his slowness while a pupil at West Point. Watt—who invented the steam engine—was notoriously dull in school. Sir Walter Scott was outstanding in school *only* for his readiness to pick a fight—and was not known as an author until he was over forty.

To again quote, Gibbon said, "Every person has two educations. One which he receives from others—and one, more important, which he gives to himself."

You are now busy *giving yourself* an education which can and should be the most important education of your entire career.

J. E. SMITH