TECHNICAL ORDER NO. { 30-100A-1, 30-100B-1, 30-100F-1 }

SPECIAL EDITION

FOR DISTRIBUTION TO ALL PILOTS

15 JANUARY 1944

INSTRUMENT FLYING

Basic and Advanced

RESTRICTED

TECHNICAL ORDER NO. 30-100A-1

INSTRUMENT FLYING

BASIC

WITHOUT RADIO AIDS

SPECIAL EDITION FOR DISTRIBUTION TO ALL PILOTS

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PART I

SECTION I

INTRODUCTION

"Instrument Flying is a pilot's best Life Insurance." It pays off in life instead of death. In modern day flying, the statement may be confidently made that no pilot is worthy of the name "Pilot" if he cannot fly his aircraft proficiently by its flight instruments as well as by visual reference to the ground. The term "contact" flight has been construed to mean flight without reference to the flight instruments. The student must realize that "Contact" is a weather condition and not a distinct method of controlling a modern military aircraft. The pilot who is qualified to control an aircraft solely by reference to his flight and other instruments is obviously also qualified to fly under "contact" conditions. Inasmuch as the "seat-of-the-pants" pilot cannot control the aircraft when "contact" weather conditions do not prevail, flight training must be conducted for the specific purpose of graduating competent "Instrument Pilots."

The student pilot must be taught the use of *all* flight instruments including those commonly used in the now obsolete 1-2-3 method of instrument flying. The 1-2-3 system was devised before the perfection of the artificial horizon, directional gyro, and the "sensitive" type altimeter. This system fostered over-controlling and inaccuracy. It was chiefly used in the "Old Days" as a method to get out of bad weather safely rather than as a method to go places under adverse weather conditions. The chief argument for the continued use of the 1-2-3 system (sometimes referred to as the "Needle, Ball, Airspeed" system) is that it is the only method which permits recovery from a spin. The principal danger for the inexperienced pilot is *not* a *spin*, but a diving spiral. Recovery from such a spiral is quickly accomplished through leveling the wings by the coordinated use of rudder and ailerons. If, however, the student is taught to recognize a spin from obvious indications of the full instrument panel, noticeably the lack of excessive airspeed, he will be able to execute normal spin recovery under any system of instrument flying.

A good instrument pilot can fly any aircraft, with precision, by reference to its instruments under either instrument or contact conditions. Therefore, "Instrument Consciousness," the habit of frequent and subconscious cross checking of instruments, simplifies the transition from one type of aircraft to another.

Night flight can be much more easily and accurately controlled by reference to instruments than by visual reference to the multitude of lights, or absence of lights. Otherwise, the pilot may become confused if he neglects his instruments and attempts to stay "contact."

The combat pilot must be competent in instrument flying and in the use of all radio and navigational aids which are available. Not only his own life but that of his crew will often depend solely upon his competence in this all-important type of flying. Most of the time no visual reference to the natural horizon will be possible during the hours of darkness; hence, all night flights, including take-offs, become, by necessity, instrument flights. Instrument take-offs, therefore, must be stressed in training. War operations cannot be delayed or suspended because of unfavorable weather conditions. Instrument flying weather will be encountered by combat pilots frequently, and to evade enemy interception the pilot may find it necessary to fly within the overcast for extended periods of time. Landings after operational flights often must be made under conditions of extremely reduced ceilings and visibility. Instrument approaches will be necessary and even instrument landings may be required.

The modern system of teaching instrument flying is known as the "full panel" system. Previous skill gained by the student under contact conditions is utilized.

In contact flight, the pilot flies by watching the position of the aircraft relative to the natural horizon. He controls the aircraft by the coordinated use of all controls to change the attitude, or to hold it constant. Thus, every pilot has learned that the performance of an aircraft at any given power setting is determined by its attitude.

"Attitude instrument flight" is the controlling of an aircraft on instruments by reference to its attitude, although the natural horizon cannot be seen. The pilot looks at his instruments to see whether the aircraft is doing what he wants it to do and then, just as in contact flight, he changes the attitude of the aircraft if necessary—always thinking of changing the attitude—until he attains the desired performance.

The main criticism of this modern system of flying has been that it must of necessity depend too much on the artificial horizon, which might become inoperative. The answer to this is that full panel instrument flight is in no way dependent on the artificial horizon alone. While it is true that the artificial horizon provides the most realistic indication of the attitude of the aircraft by showing a small replica of the natural horizon, other instruments provide equally useful indications of the aircraft's attitude. With a small amount of experience the student can use the other instruments equally as well as the artificial horizon to control the attitude and performance of the aircraft and will learn to consider the more reliable instruments as the final indication of attitude. For instance, banks are shown and controlled by the turn indicator (and the directional gyro), while pitch is shown and controlled by the altimeter and airspeed indicator; however, since the artificial horizon provides the most realistic indication of the plane's attitude, its importance is *stressed* only at the start of a student's instruction in order to provide a natural, logical, and relatively easy approach to instrument flying.

The full panel system has many advantages. The student's interest is aroused from the start, particularly with adequate ground school instruction as a part of the system, and the transition from contact to instrument flight comes naturally and quickly.

Strain and fatigue in both student and instructor are materially reduced. Instruction is comprehensive and thorough and follows step by step in a sensible order. Learning comes faster and the results are far superior to those obtained under the "1-2-3" system, both in confidence and in accuracy. From the standpoint of the instructor, instrument flying instruction becomes an interesting job rather than a chore.

Any pilot who is able to control an aircraft by visual reference to the natural horizon has taken the first step toward becoming an instrument pilot. Supplementing his experience and knowledge with the information contained in this series of technical orders, he should be able to learn easily and quickly to fly by instruments. The modern method of instrument flying training teaches him to use *all* instruments, both the basic gyro instruments and the rate instruments, and to use them in their proper relationship. The loss of the directional gyro or the artificial horizon through failure or damage affects only the extreme accuracy and ease of the instrument flight. At all times by cross-checking, the pilot knows which instruments are functioning correctly and how to use them.

In order to become a competent instrument pilot, it is necessary that the student be given the proper training in the full panel system by competent instructors both on the ground and in the air.

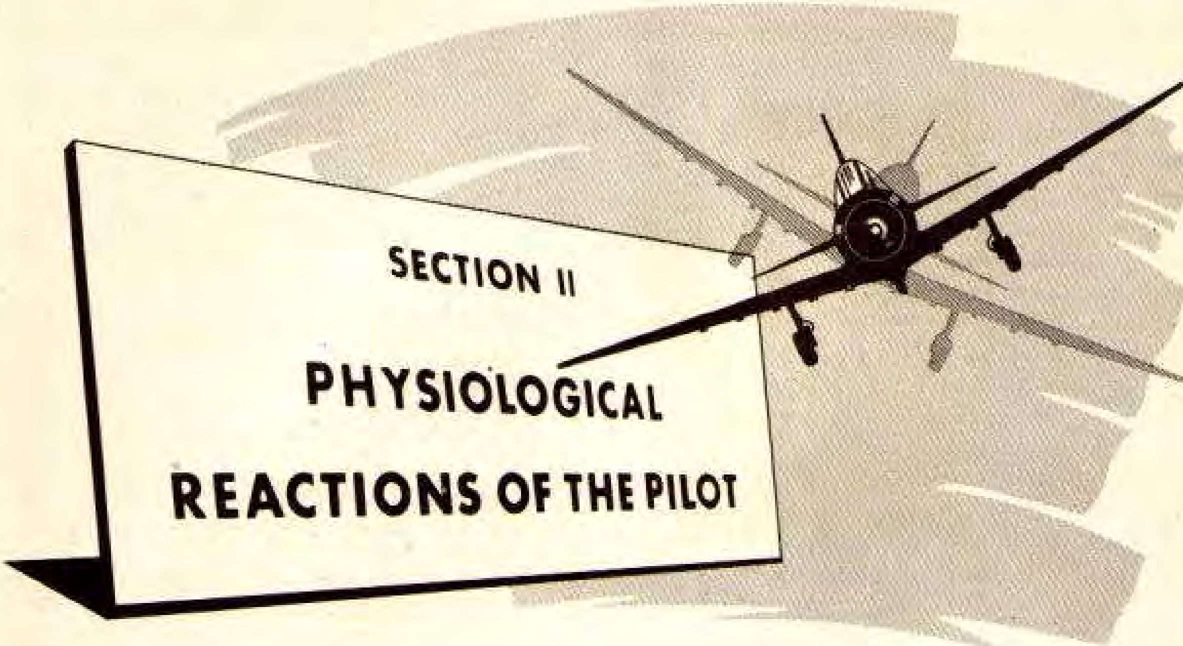
Instrument flying is the first step toward weather flying. The efficient instrument pilot with proper equipment need have no fear of reasonably bad weather. The question of what types of weather can be flown safely is purely a matter of the pilot's knowing his own abilities and the limitations of his equipment. A knowledge of these limitations can be obtained only through experience. The considerations affecting weather flying will be covered in T. O. No. 30-100D-1, Instrument Flying, Technique in Weather.

Flying on instruments for any length of time will be considerably more tiring than flying contact, and the rate of fatigue depends upon the amount of concentration necessary. In turn, the amount of concentration necessary depends upon the stability of the aircraft, the smoothness of the air, and the accuracy necessary for the particular type of flying done. Cross-country flights at fairly high altitude are an example of one extreme. In order to keep from becoming tense and tired the pilot should not concentrate too intensely. After practice, and with a reasonably stable aircraft, a pilot will be able to fly a fairly straight course by glancing at the instruments every ten or fifteen seconds. The less concentration necessary the longer the pilot can fly on instruments without becoming too tired. At the other extreme, instrument landings require the most concentration, then thunderstorm flying and low approaches, and in that order.

As most pilots know, there is a great deal of difference between instrument flying under the hood and under actual instrument conditions. In the first case, with a safety pilot, the mental hazard is practically nonexistent. Under actual conditions the mental hazard is always present and will vary in intensity with the prevailing conditions. It will vary with the pilot, depending upon his experience, temperament, and his physical and mental state at that particular time. It will vary with the mechanical condition of the aircraft, radio equipment, weather encountered, fuel supply, etc. It is very desirable for the inexperienced instrument pilot to practice as much as possible under actual conditions. When on cross country these pilots should fly in an overcast whenever possible.

At night turn the lights up, but not so bright that the safety pilot cannot see approaching aircraft, and fly on instruments. The more this is done, the easier it becomes, and with a constantly decreasing strain on the pilot. Remember to practice with the turn and bank until its use becomes easy, as there are times when that instrument may be the only reliable gyroscopic instrument.

In summation, the following thoughts should be constantly borne in mind. Competency at any art or technique can be acquired only by constant practice and sincere application. It is your duty to your crew, yourself, and your country to become highly proficient in the art of instrument flying, so that all communiques will read: "From this operation all our aircraft returned safely."



SECTION II
PHYSIOLOGICAL REACTIONS OF THE PILOT

1. SENSATIONS AND THE PILOT.

a. In contact flight the pilot flies his aircraft by watching its attitude relative to the terrain. The impressions he receives from his eyes are so strong that all other impressions are suppressed, and he is only vaguely conscious of them.

b. In instrument flight the pilot really starts to notice his other sensations for the first time; however, he should *never* interpret the attitude of the aircraft from any of these sensations. He must not get tense or try to fight against his sensations, but by a thorough understanding of his sensations he should learn to disregard them and to visualize the attitude of the aircraft as indicated by the instruments.

c. The sensations experienced in either instrument or contact flight arise principally from the inner ear, deep muscles (deep sensibility), and the eyes. To a lesser extent, hearing and the internal organs help in creating the sensations felt in flight.

d. It must be remembered from the start that the sensations are created by the combinations of all these senses. Each of these senses will be discussed separately in order that its individual functions can be understood. However, these senses always work in coordination and never alone.

2. THE INNER EAR.

a. Inside the ear is a small bony structure known as the "Inner Ear," and it is responsible for most of man's non-visual sensations of balance. The inner ear has two separate parts. One part, the semi-circular canals, give the individual a sensation of rotating or turning. The other part, the static organ, gives the individual a sense of the direction from which any force, such as gravity or centrifugal force, is acting on his body.

b. A person can turn in any direction so slowly that his semi-circular canals will not create the sensation that he is turning at all. In fact, a pilot may be continuously accelerated in a turn, and if the acceleration is less than at a rate of 2° per second, he will not be conscious of turning at any time. The pilot, as a result, can sense rapid changes in attitude of the aircraft, but will not sense slow changes.

c. The static organ merely registers the total forces acting on the pilot's head. In a perfect turn the ball would be centered, and the static organ would record only that a force is acting directly downward on the pilot. Since the resultant of centrifugal force and gravity act directly downward on the pilot, the static organ would not record the fact that the aircraft is banked. In a slip or a skid the ball is displaced from the center, and the static organ, acted upon by the same forces, would create the same sensations as if the pilot's head were being tipped or tilted on the ground. Thus, in any slip or skid, whether in level flight or in a turn, the pilot will receive the sensation that the aircraft is tilted without any relation to its true attitude. Fig. 1.

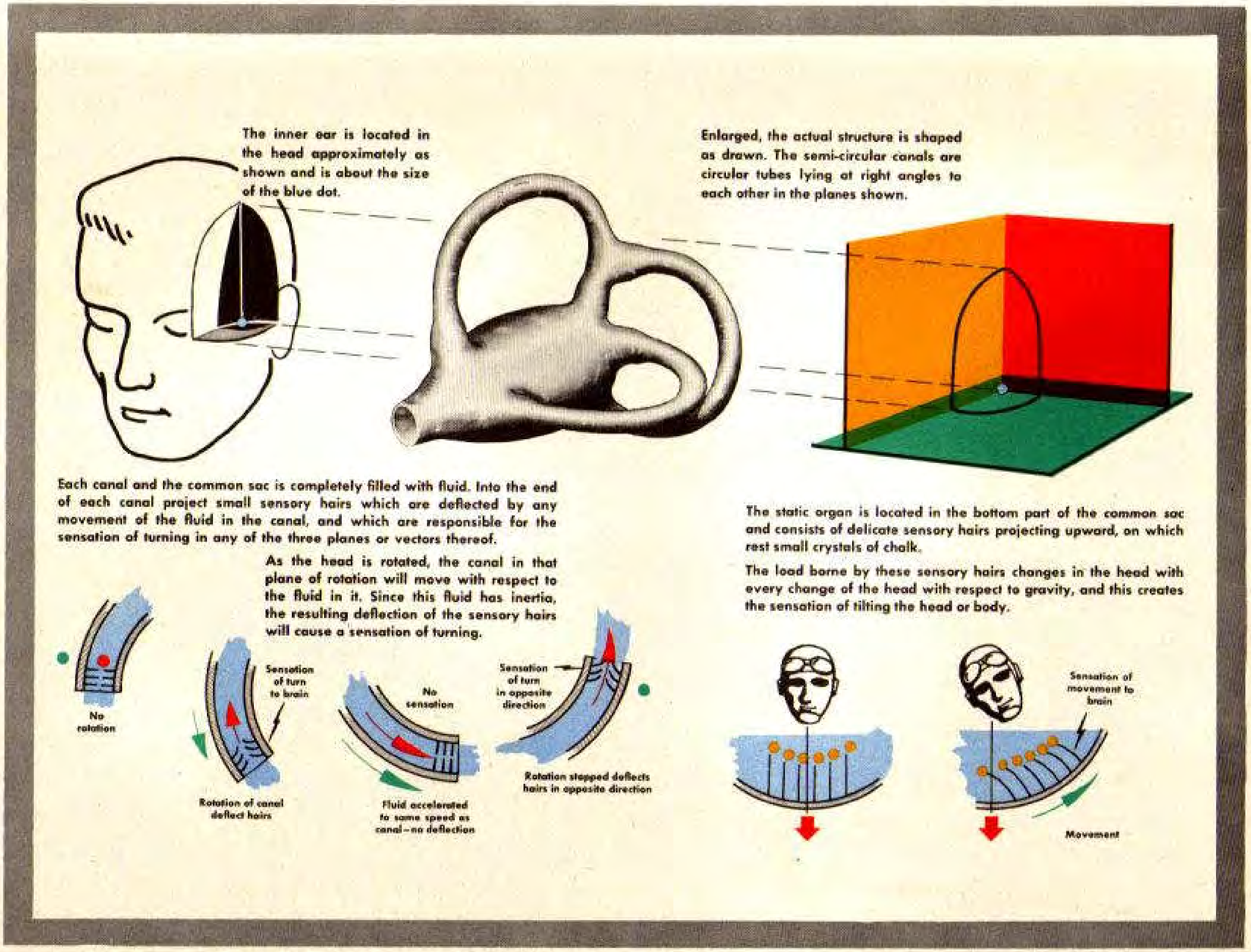


Figure 1—The Inner Ear

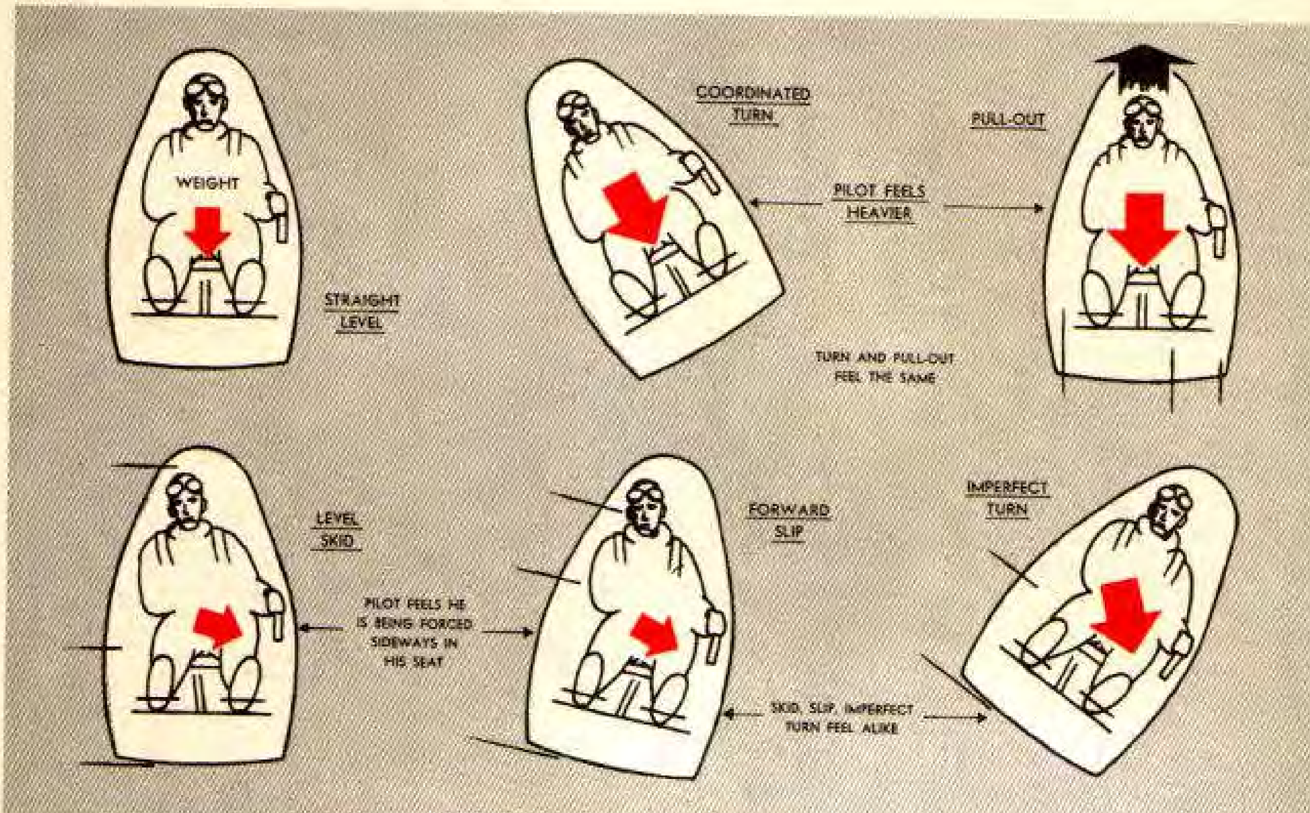


Figure 2—Deep Sensibility

3. DEEP SENSIBILITY.

A combination of sensations of pressure and tension of the skin, muscles, joints, tendons, and viscera of the person is known as deep sensibility. These effects are best felt on the seat, because gravity and centrifugal force act mostly on that part of the pilot. Changes in attitude of the aircraft will cause a pilot to feel heavier or lighter, or to have a feeling of being forced sideways in his seat. For example, in starting a climb, or pulling out of a dive, the pilot will feel heavier, as if he were being forced down in the seat. In instrument flight, deep sensibility becomes completely unreliable. When the pilot is forced up or down in his seat, either as a result of vertical movements of the aircraft due to rough air, sharply leveling off, or of centrifugal force in a turn, his "deep sensibility" will give him the false impression of going into a climb or dive. In a slip or skid, in any attitude, the pilot will be forced sideways in his seat, and will get the impression that the aircraft is tilted in the direction of the slip or skid.

4. VISION.

a. In contact flight, vision is the all-important sense the pilot uses to fly his aircraft properly. Vision of the natural horizon is a means of orientation so strong that all other senses are suppressed. Obviously in instrument flight the pilot is suddenly deprived of his fundamental sense in relation to the earth's horizon. Because of the complete unreliability of his other senses, he must rely solely on what he sees within the limits of the cockpit.

b. In night flying, outside vision, like the other senses discussed, becomes unreliable to a certain extent, due to the confusion of lights and the absence or partial absence of the natural horizon, and the pilot must learn to disregard this outside vision and his other sensations and rely on the readings of his instruments.

5. HEARING.

Hearing is a great aid in determining certain things concerning the flight path of the aircraft. The sound of the motor in climbs and dives and the noises created by the slipstream furnish the pilot with information concerning the attitude of the aircraft. In instrument flight, however, this information can only serve as an indication and not as a reliable interpretation of the actual attitude of the aircraft.

6. SENSORY ILLUSION.

The sensations experienced by the pilot are responsible for many illusions in instrument flight. These illusions may be roughly divided into two groups: *Those experienced while maintaining straight flight. Those experienced while turning.*

7. SENSORY ILLUSIONS IN STRAIGHT FLIGHT.

a. An aircraft may be tipped or tilted in rough air quite rapidly, and the pilot may receive the correct impression of the attitude of the aircraft. He then recovers so slowly that the angular motion in the recovery is not perceptible and his senses retain the feeling that the aircraft is still tipped or tilted. This impression may be so strong that the pilot will lean over to one side in an attempt to assume what he supposes to be the vertical. This is known as "the leans" and is one of the strongest and most commonly felt sensations in instrument flight. The same impression though opposite in reaction may occur when a rapid recovery is made from an attitude which has been slowly and imperceptibly assumed by the aircraft.

b. An aircraft may turn slowly away from the desired heading without the pilot sensing the turn. This turn, if gradually accelerated, may be of such nature that resumption of straight flight gives the sensation of continued turning, or the start of a turn in the opposite direction. The mental impression of turning, then, may persist long after the actual turn has been made. The same false impression may persist in varying degrees with the rotation of the aircraft about any of its axes.

c. Deep sensibility may cause the pilot to have the sensation of climbing in straight flight when the aircraft enters an updraft, because of the fact that he is forced down in his seat and feels heavier than usual. He may likewise have a sensation of diving when the aircraft enters a downdraft, because he feels lighter than ordinarily.

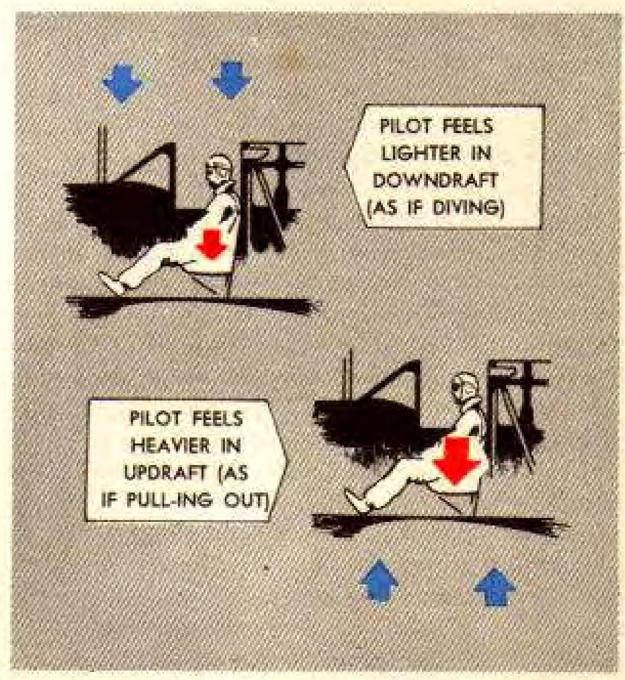


Figure 3—Up and Down Drafts

8. SENSORY ILLUSIONS IN TURNS.

a. The usual turn is entered so slowly and is at such a slow rate of turn that there is no sensation of turning whatsoever. The "standard rate turn" commonly used in instrument flight is at the rate of three degrees per second. At this rate of turn, the illusions of the pilot may be similar to those encountered in straight flight; that is, the pilot may feel from time to time that he is turning in the wrong direction or is banking either too much or too little, or that the aircraft is climbing, diving, or rolling.

b. With steeper turns and especially steep turns executed at high airspeed, the deep sensibility and the static organ give the illusion that the aircraft is executing a loop. This is caused by the fact that in a steeply banked turn the pilot is forced directly down in his seat. The pilot has no sensation that the vertical axis of the aircraft is inclined, and his mind normally connects such downward forces with the force of gravity. Consequently, he has no sensation that the aircraft is banked; in fact he normally has a distinct impression that the aircraft is not banked. Since the pilot has no sensation of turning, or of banking, he mentally connects the forces acting on him with those sensed when pulling up into a loop. The sensation of doing a loop varies in intensity with the degree of bank of the aircraft and is continuous throughout a steep turn.

c. As recovery is made from a steep turn to level flight, the lessened force acting downward on the pilot's body creates the illusion of extreme lightness, and the pilot feels that he is pushing over into a steep dive. This in turn may cause the pilot to try to counteract the sensation by pulling up into a dangerously steep climb.

d. Illusions as to the angle or direction of bank also come from the deep sensibility and the static organ as a result of the aircraft slipping or skidding during a turn. Such slipping or skidding will cause the pilot's body to be forced to one side or the other, causing an illusion that the aircraft is banked or is tipped in that direction.

e. If the pilot holds his head steady in a turn, he will have little sensation of turning. However, if he changes the position of his head for any reason, such as to look down in the cockpit, he will have the sensation of doing a rapid roll or of snapping around in the turn. This occurs because the movement of the pilot's head into a different plane in space will place a new semi-circular canal in the plane of rotation of the aircraft. This canal will rapidly accelerate in angular motion, while the canal originally in the plane of rotation of the aircraft will have an angular deceleration.

9. SENSATIONS DURING RECOVERY FROM A SPIN.

a. During a spin the pilot is subjected to high rotational speeds. If the spin is continued for more than an extremely short period of time, the fluid in the semi-circular canals will become so accelerated that upon recovery to straight flight the pilot will have a very marked sensation of falling off into a turn in the opposite direction, and consequently he will tend to return to a spin or a spiral in the same direction as before. This strong sensation and the fact that dizziness makes close observation of the instruments difficult, make spin recovery an extremely difficult maneuver, requiring the utmost in pilot self-control. For this reason the inexperienced pilot should not engage in maneuvers under instrument conditions which could result in the aircraft's falling into a spin.

10. HYPNOSIS.

Hypnosis may be defined as a condition of super attention. The conditions in flight very often are excellent for the development of hypnosis. Fatigue frequently makes a pilot sleepy, and when other factors in the aircraft are present, hypnosis may occur. The roar of the motor, the sound of the slipstream, focusing attention on a few instruments, and very often the steady signals from the "beam" become so monotonous that they produce a condition of super attention. This phenomenon occurs in all degrees. Very often pilots have crossed the beam and suddenly awakened on the other side unaware of how they got there. Conditions sometimes become so severe that the pilot is unaware of the attitude of his airplane. When the pilot does become aware of what is happening, he will probably act too quickly and become very badly confused, unless he puts absolute trust in the instrument indications.

11. ILLUSIONS IN NIGHT FLYING.

a. Night flying can be much more confusing than simple instrument flight through clouds, and probably many of the accidents and fatalities in night flying result from the fact that pilots rely too much upon their vision and other senses, rather than upon their instruments. At night the inexperienced pilot is continually looking around to find some light on the ground by which he can orient himself. Unless he is flying near a large city where there are enough lights to make a good pattern, this habit of trying to orient himself with relation to the ground is extremely hazardous. Any experienced pilot can tell how he has mistaken a star for a light beneath him and how he thought lights were moving past him, when actually he was turning about the lights. A pilot can easily get so confused that he does not know which way is up actually, or whether the aircraft is turning, diving, rolling, or climbing. *Most confusing and dangerous of all is the situation in which the pilot attempts to look backwards to see the only lights available, such as after a takeoff over unlighted territory.*

b. The reason for the particular confusion in night flying is that a pilot's eyes deceive him as well as his other sense organs. He does not have any definite horizon to use as a plane of orientation; he has only isolated points of light. His sensations may tell him that these are in a certain position with relation to the aircraft when in fact they are in a completely different relation, and, as a result, when the aircraft does not act as he expects it to, he gets completely confused. In addition, the inexperienced pilot at night usually forgets about his instruments and is so busy looking around that he glances at the instrument panel only after he has become confused, or after he has unknowingly entered a tight diving spiral.

c. The one solution for this is for the pilot to watch the instrument panel, with only occasional glances out at the lights. If he gets the habit of using the *instruments as his major reference* and of using the *lights only as a secondary reference,* he will not get into trouble.

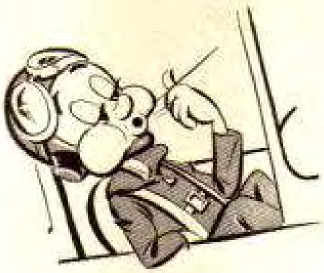
12. CONFLICT OF INSTRUMENTS WITH SENSES.

a. The learned reactions of contact flying are usually well established by the time the student pilot begins instrument flying; therefore, he has a certain base line of experience which sometimes helps him in instrument flying, and sometimes hinders him. A human being has depended on his own senses for years and he cannot be expected to immediately accept instruments as a substitute for his senses. Even after a pilot has learned to fly on instruments, he will still instinctively depend on what he feels.

b. Until the student pilot becomes proficient in instrument flying, he will make errors in correction which are attributable to the fact that even though he is looking at the instruments, he is still instinctively depending on his senses. Mistakes of this type are natural because of the dependence on the senses in contact flying.

c. It must be remembered that when a pilot is flying on instruments his emotions may cause him trouble, if he gets into unusual circumstances. The inexperienced instrument student becomes slightly tense and apprehensive when he is in doubt as to this position. This occurs normally with most pilots when they begin instrument training; however, it is usually mild and disappears with training and practice. Unfortunately certain individuals when placed in difficult situations will have a reaction which can only be described as panic; some do foolish things which are contrary to all their training and some are frozen with fear. *Such cases are, however, exceptional.* The limitations which are placed on the pilot by his senses and learning are not insurmountable. They can generally be overcome with intelligent application in training and in practice.

13. WHAT TO DO ABOUT THESE SENSATIONS.



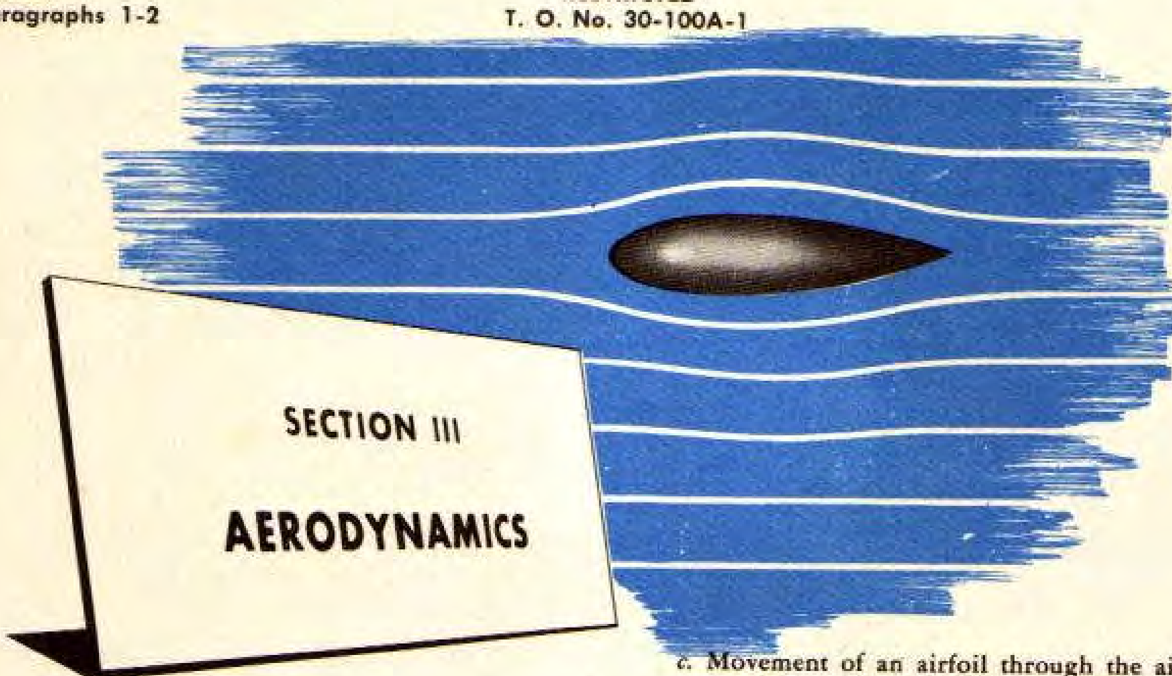
Once the pilot knows that these sensations experienced in instrument flight are perfectly normal and that he may feel them at any time, he has taken the most important step towards disregarding them in his instrument flying. There are certain additional tricks of the trade, however, which may aid the pilot in eliminating these sensations:

(1) Relax completely both mentally and physically. As an aid to this say to yourself—"there I go again," and if possible laugh at yourself.

(2) Watch your instruments and make yourself believe they are telling the truth.

(3) Shake your head and move your body around. This will help you relax as well as help you eliminate the unpleasant sensations.

(4) If you feel that the aircraft is banked in one direction, although it actually is level, try banking in the opposite direction. Then return to level flight. When the aircraft is again level, you probably will have lost the false sensation.



SECTION III

AERODYNAMICS

1. GENERAL.

Before learning to fly instruments by the full panel system, the pilot must understand how and why the aircraft flies as it does. He must be able to interpret the indications of the full instrument panel in terms of the attitude of the aircraft. A knowledge of that portion of aerodynamics related to the various flight attitudes will greatly simplify the explanation and learning of instrument flying. Therefore, this is not a complete discussion of aerodynamics, but only a short treatise of the points of interest to the student instrument pilot. Additional information may be found in appropriate texts, such as T.M. 1-400.

2. WHAT IS AERODYNAMICS?

a. It is that branch of science dealing with the motion of air, or other gaseous fluids, and the forces acting on solids in motion relative to the air, or other gaseous fluids.

b. The study of aerodynamics started with man's first attempts to fly. In the beginning he tried to imitate the birds by building machines with flapping wings. Copying from the birds, he evolved the "airfoil" which then closely approximated the shape of the bird's wings. As design progressed, he kept the wings stationary relative to the whole machine, and the "airfoil" evolved into the "wing" as we know it today.

c. Movement of an airfoil through the air creates certain reactions: If a flat plate is moved through the air, the molecules of air will strike it and be deflected downward (as shown). This deflection will exert a force upward on the plate, like one billiard ball hitting another. This same reaction will occur upon an airfoil moved through the air.

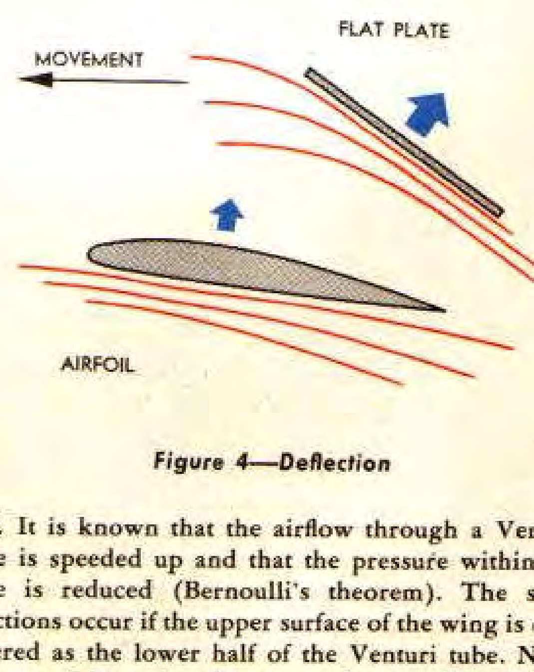


Figure 4—Deflection

d. It is known that the airflow through a Venturi tube is speeded up and that the pressure within the tube is reduced (Bernoulli's theorem). The same reactions occur if the upper surface of the wing is considered as the lower half of the Venturi tube. Now, because of this reduced pressure above and the deflecting force exerted on the underside of the airfoil by its motion through the air, the *reaction called resultant lift will be created.*

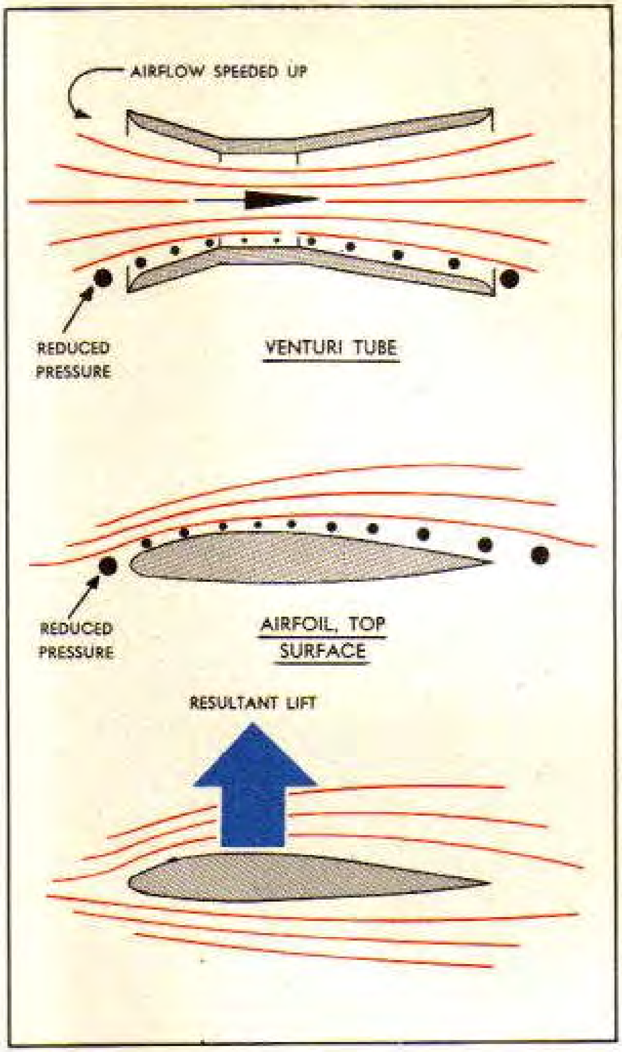


Figure 5—Resultant Lift

3. FORCES ON AN AIRCRAFT IN FLIGHT.

a. Lift. "Resultant Lift" is divided into two distinct parts, the component of lift and the component of drag, the latter being caused by the motion of the airfoil through the air. The amount of lift and drag created by the airfoil at a definite airspeed is directly dependent upon the angle at which the airfoil is placed relative to the airstream. This angle is known as the "angle of attack" and is measured between the chord line of the airfoil and the relative wind, which may be considered the flight path of the aircraft. The lift and drag will increase as the angle of attack is increased. The limit is the "burble point," beyond which lift no longer increases though drag does, and the airfoil can no longer support the aircraft.

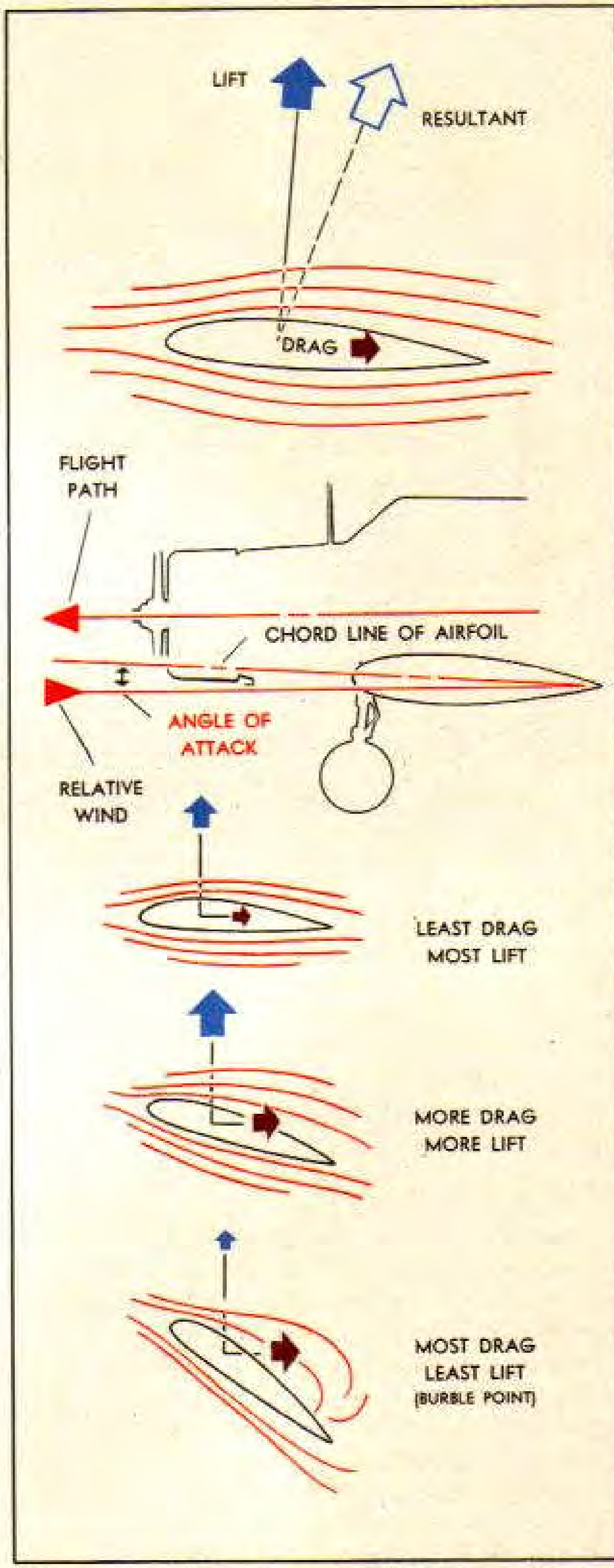
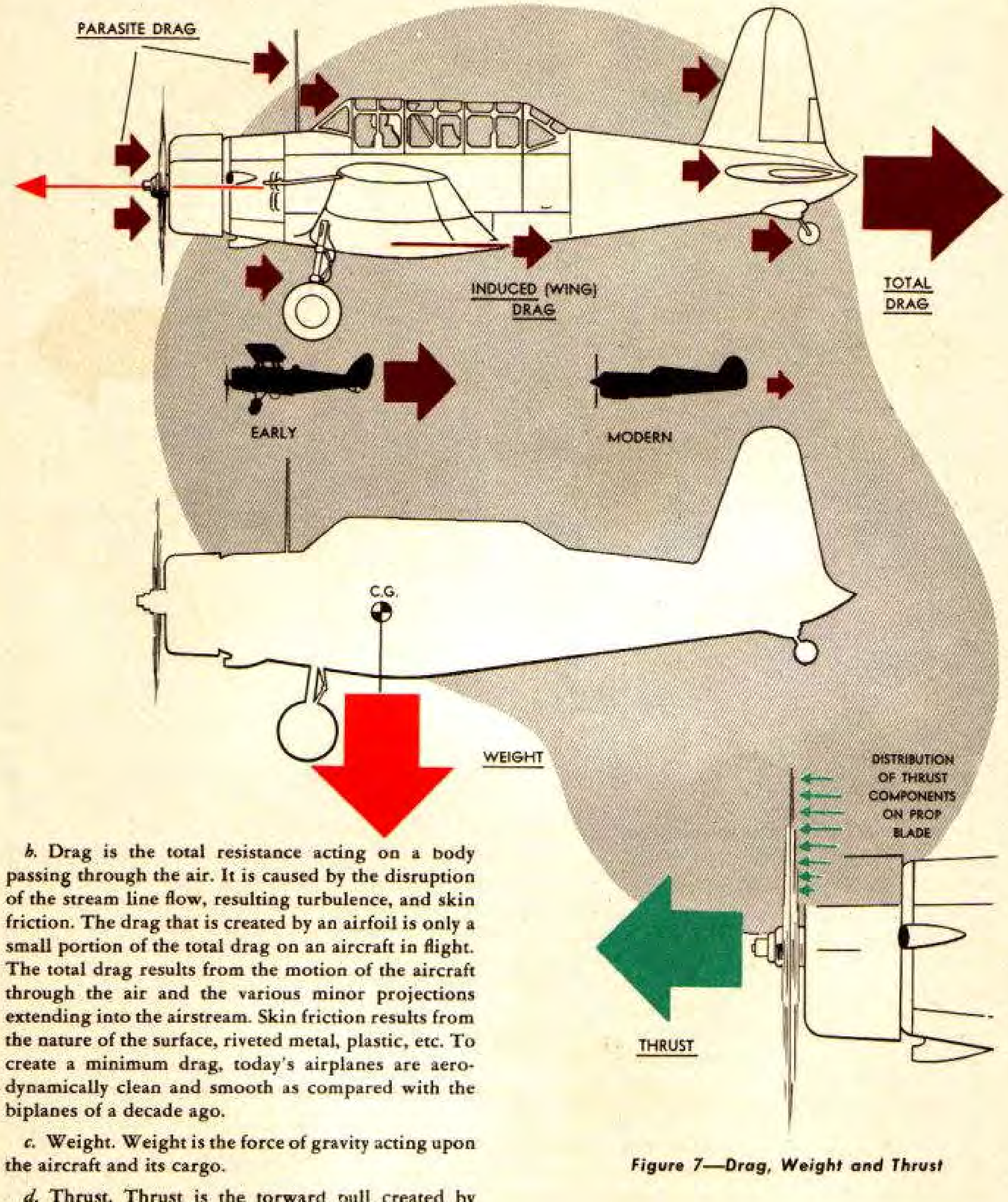


Figure 6—Lift and Drag



b. Drag is the total resistance acting on a body passing through the air. It is caused by the disruption of the stream line flow, resulting turbulence, and skin friction. The drag that is created by an airfoil is only a small portion of the total drag on an aircraft in flight. The total drag results from the motion of the aircraft through the air and the various minor projections extending into the airstream. Skin friction results from the nature of the surface, riveted metal, plastic, etc. To create a minimum drag, today's airplanes are aerodynamically clean and smooth as compared with the biplanes of a decade ago.

c. Weight. Weight is the force of gravity acting upon the aircraft and its cargo.

d. Thrust. Thrust is the forward pull created by the propeller and its resulting slipstream.

Figure 7—Drag, Weight and Thrust

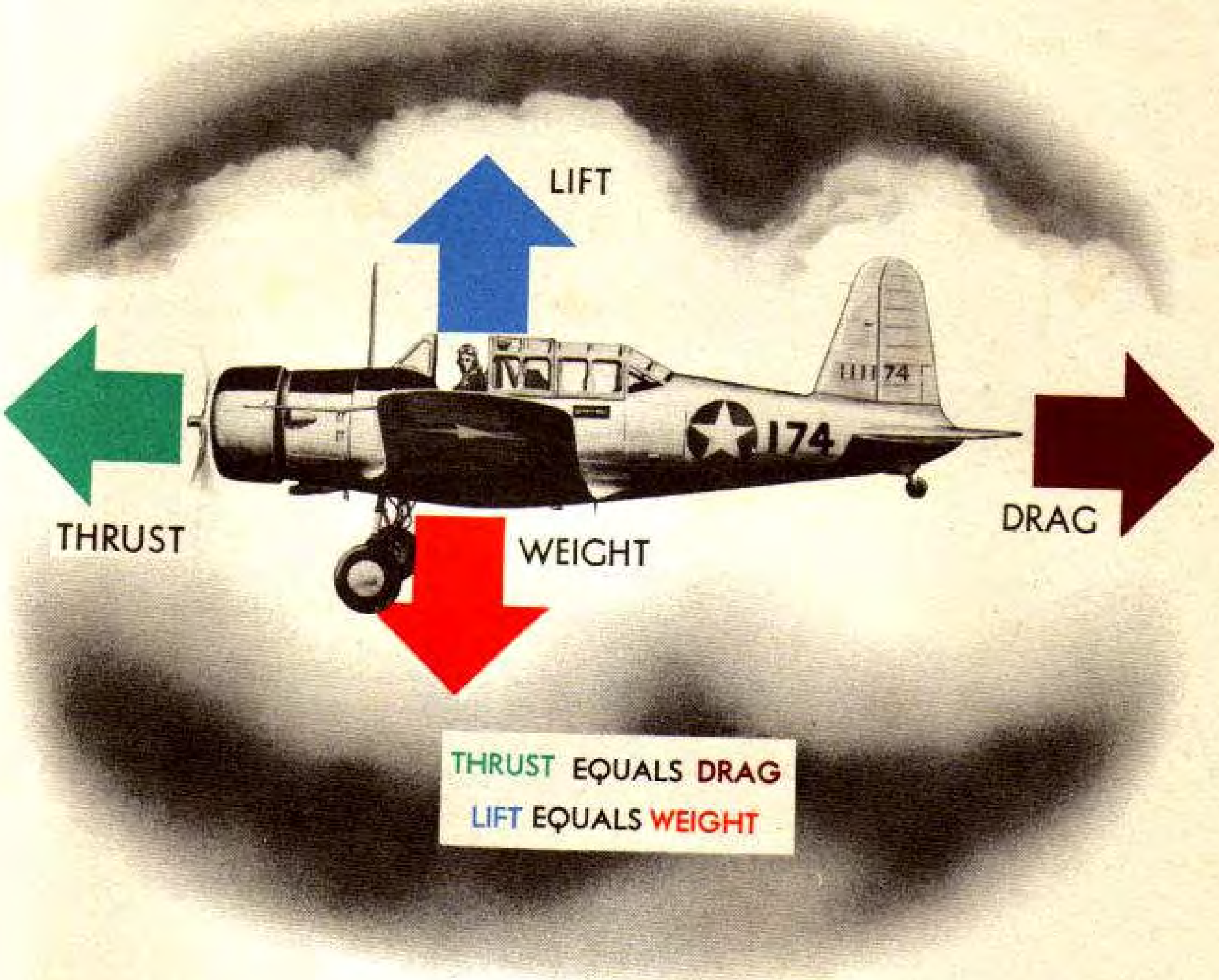


Figure 8—Forces on an Aircraft, Straight and Level

e. Summary. Here then are all of the forces acting on an aircraft in straight and level, unaccelerated flight. The direction and magnitude of some of these forces varies, but for practical purposes the following may be considered to hold true for normal flight attitudes.

Lift always acts perpendicular to relative wind (flight path).

Drag always acts parallel to relative wind (rearward).

Weight always acts vertically downward (toward the center of the earth).

Thrust always acts parallel to longitudinal axis (forward).

4. ATTITUDE.

Attitude is always the relationship of the longitudinal axis and of the lateral axis of the aircraft to the horizontal reference plane. It should not be confused with either flight path or angle of attack. The flight path is determined by the attitude, while the angle of attack, (which is related only to the wing), is determined by attitude and flight path.

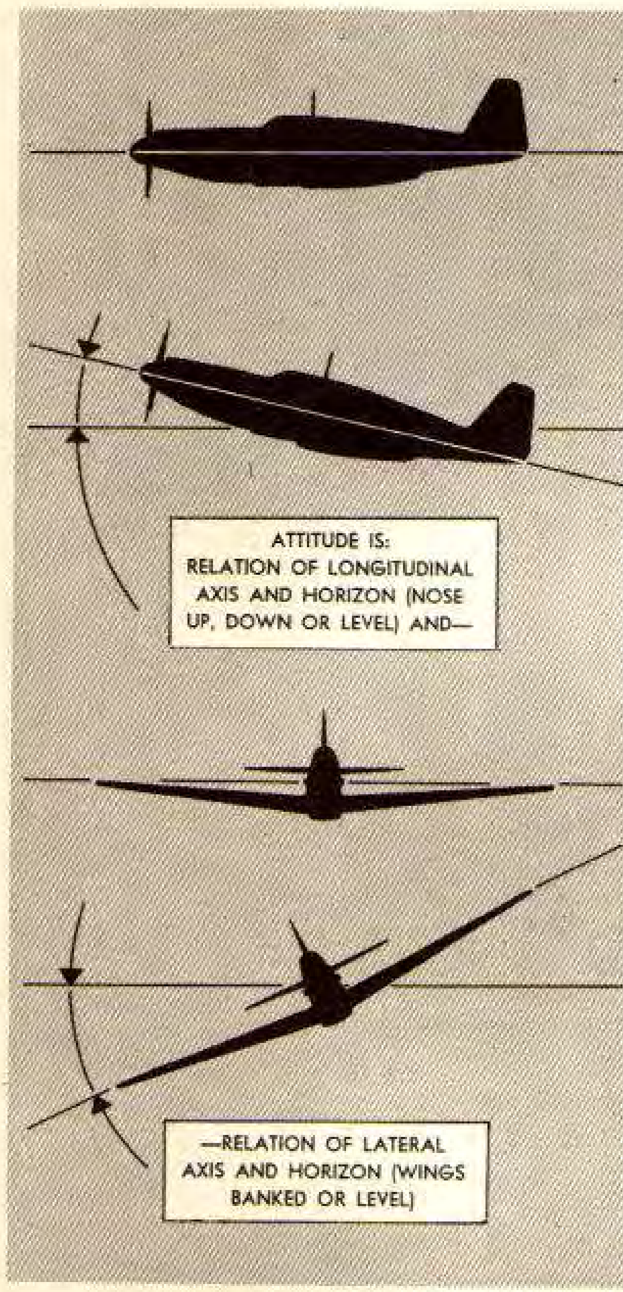


Figure 9—Attitude

5. FACTORS AFFECTING ATTITUDE.

a. In maintaining straight and level flight, three factors affect attitude; airspeed, air density, load.

b. Airspeed. At slow airspeeds the angle of attack of an airfoil must be relatively large to produce the constant lift necessary to maintain level flight. As a result the aircraft must be flown in a nose-high attitude. As power is increased and the aircraft is accelerated, the nose must be lowered, because the angle of attack necessary to produce sufficient lift to maintain level flight will become smaller.

Remember! Any change in airspeed requires a change in attitude to maintain straight and level flight.

c. Air Density. The density of air decreases with increasing altitude or with higher air temperatures. In maintaining a level flight path at high altitude or in very warm air the relatively nose-high attitude of the aircraft will be more noticeable, because to produce the same amount of lift the angle of attack of an airfoil must be increased as the density of the air decreases. The reverse of this is also true; at lower altitudes and in low temperatures the aircraft will *not* have to be flown in a nose-high attitude.

Remember! Decreased air density means increased nose-high attitude to maintain straight and level flight.

d. Load. The normal weight of an aircraft requires a definite angle of attack for its airfoil to maintain straight and level flight. However, to sustain a heavier load at the same airspeed, the angle of attack of an airfoil must be greater to provide the increased lift necessary. Also more power must be added to overcome the increased drag due to increased angle of attack if the same airspeed is to be maintained. For example, at the start of a bombing mission an aircraft must be flown in a slightly nose-high attitude to maintain level flight. As the bomb and fuel load are expended, the nose of the aircraft must be lowered to maintain level flight.

e. Since airspeed, air density and load vary, and because combinations of them cause even more variation, the pilot will have to learn from experience with any given type of aircraft approximately the correct attitude required under different conditions.

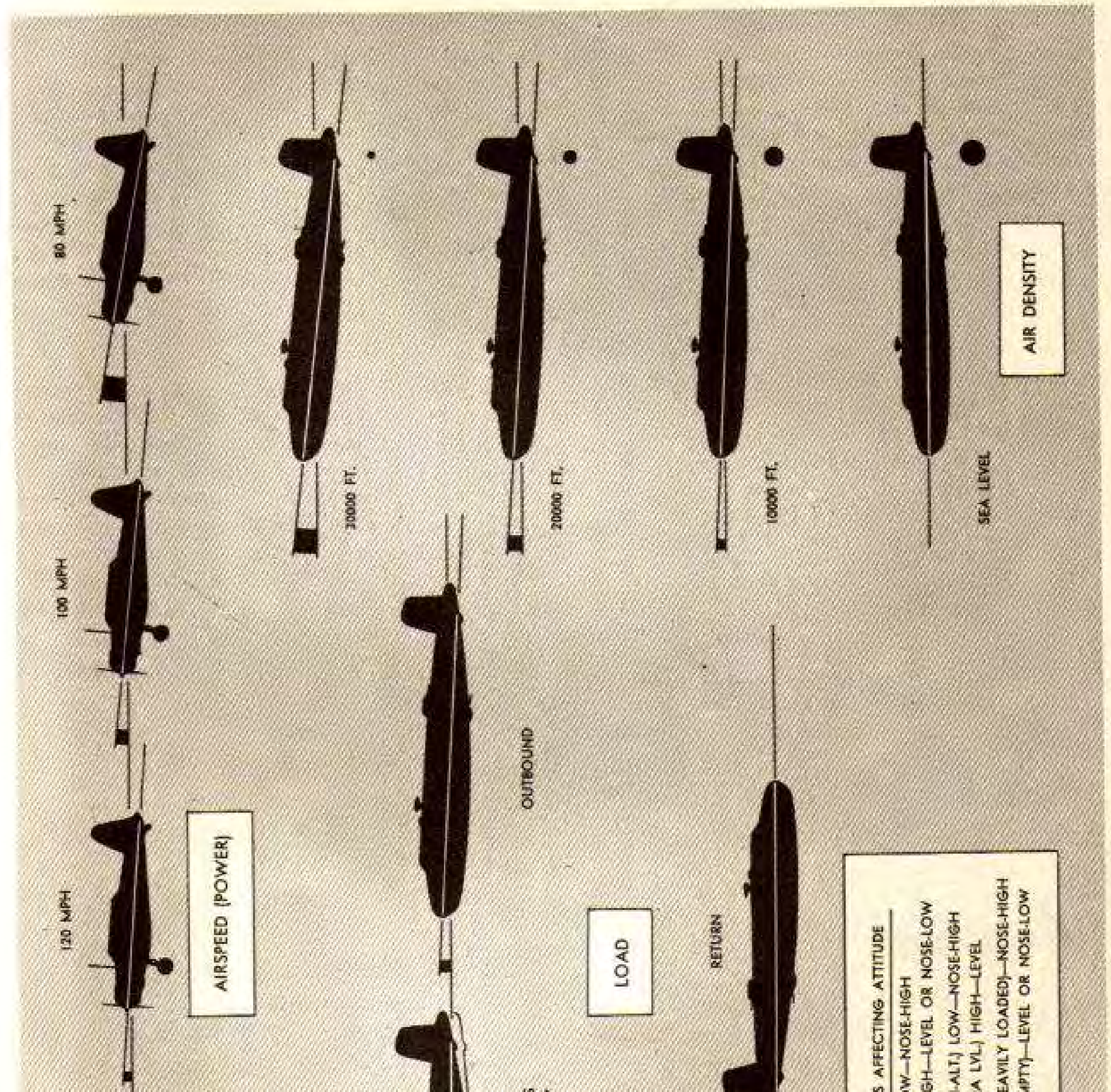


Figure 10—Factors Affecting Attitude

6. CLIMB.

a. For all practical purposes the lift in normal climb or descent is the same as in level flight, because the angle of attack of the airfoil with respect to the flight path of the aircraft will be constant regardless of any variation of the flight path from the horizontal.

b. The forces acting on an aircraft go through definite changes when a change in attitude is effected. For example, consider the changes occurring while going from straight and level into a climb with power remaining constant.

c. The first change occurring when back pressure is applied to the stick is that of lift. This results from the change in attitude with its corresponding increase in the angle of attack. Momentarily the lift becomes greater than the weight of the aircraft and will force it upward. The flight path is then inclined upward and as a result the angle of attack will be reduced to normal and the corresponding lift will also return to normal.

d. As the climb is started, the airspeed will gradually diminish. This change in airspeed is gradual rather than immediate because of the momentum of the aircraft. The thrust required to maintain straight and level flight is not sufficient to maintain the same airspeed in a climb, because of the added work needed to raise the aircraft to a higher level. The reduced airspeed will cause a reduction in drag, and when the lower values of thrust and drag again become equal, the plane will climb at a constant airspeed, slower than cruising.

e. To go from level flight into a climb and have the airspeed remain constant, the pilot must increase the power output of the engine. This is necessary because the added work needed to raise the aircraft to a higher level requires an increase in thrust over that needed to maintain straight and level flight.

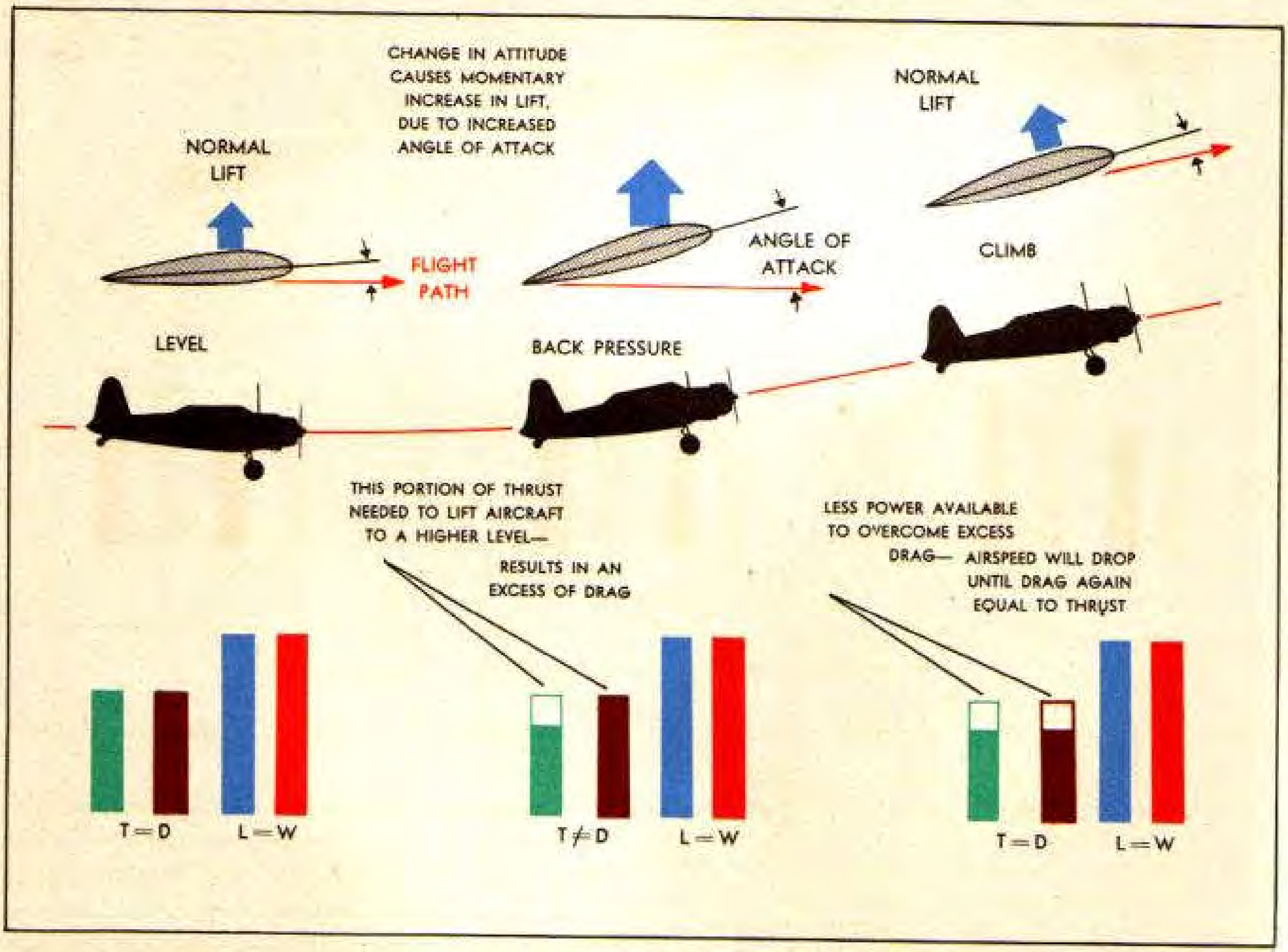


Figure 11—Climb, Power Constant

7. DESCENT.

a. Consider the changes in the forces acting on an aircraft when going from straight and level flight in a descent, with power remaining constant. When forward pressure is applied to the stick, the first change occurs in lift. This results from a change in attitude with a corresponding decrease in the angle of attack. Momentarily the lift becomes less than the weight of the aircraft and will cause it to start upon a descending flight path. As a result, the angle of attack of the airfoil will again approach normal and the lift will again equal the weight, just as in level flight.

b. As the descent is started, the airspeed will gradually increase. Since the aircraft is now going "down hill," the engine is doing less work than in climbing, or in level flight. This decrease is, in effect, added power and causes the airspeed to increase. It is evident, then, that to go from level flight into a descent and maintain a constant airspeed, the pilot must reduce the power.

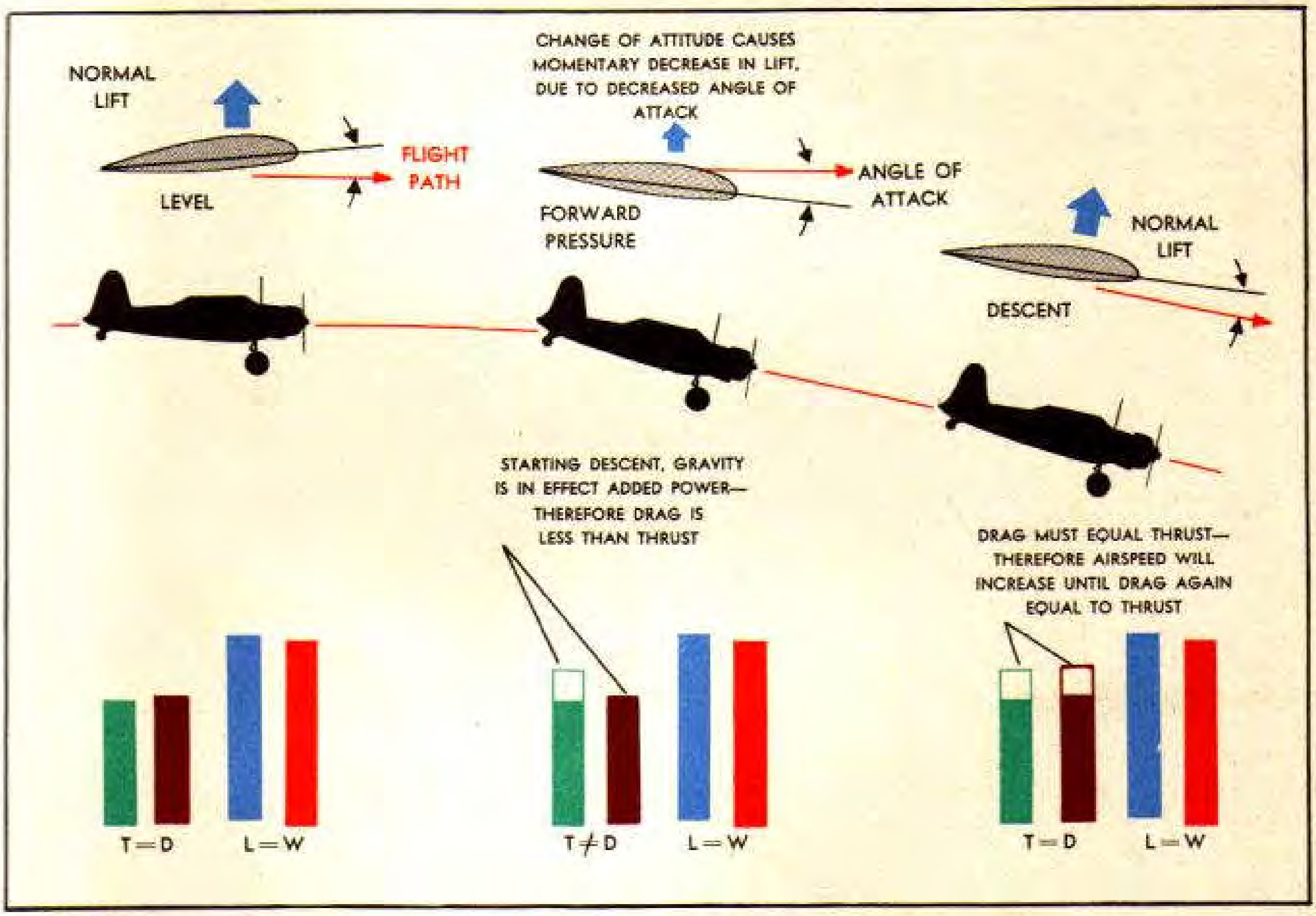


Figure 12—Descent, Power Constant

8. EFFECT OF AIRSPEED ON VERTICAL SPEED.

a. For the same change in attitude, the vertical speed of a fast aircraft will be much greater than the vertical speed of a slower aircraft. This increase in vertical speed with change of attitude is particularly noticeable in the vertical speed indicator in fast aircraft. A small change in attitude will result in great changes in vertical speed. For any given change in attitude under normal conditions, the vertical speed will be directly proportionate to the airspeeds of the respective aircrafts.

b. An analogy of this occurs when two automobiles travel 60 and 30 m.p.h., respectively, and climb a hill which rises 500 feet in each mile. The one going 60 m.p.h. will climb 500 feet each minute, but the other going 30 m.p.h. will only climb 250 feet each minute.

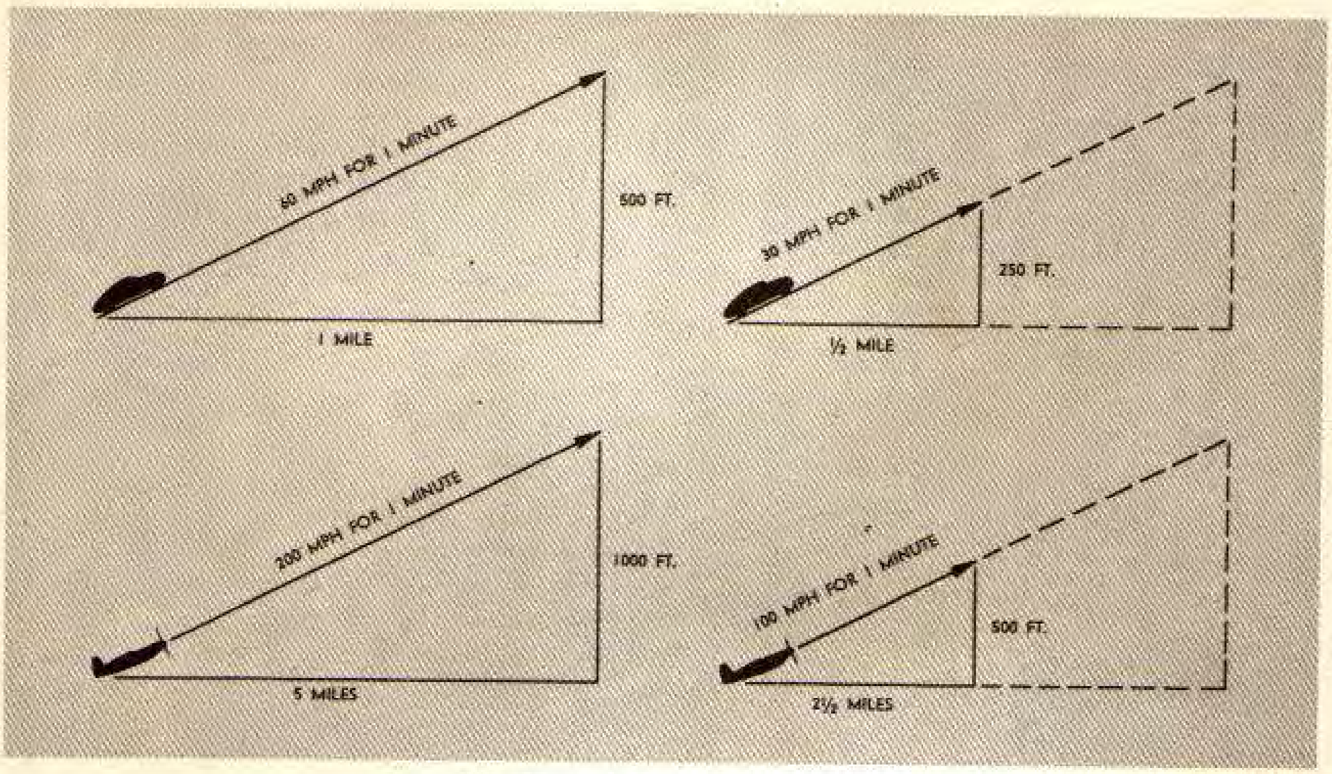


Figure 13—Effect of Airspeed on Vertical Speed

9. ELEVATOR ACTION WITH CHANGING POWER AND SPEED.

a. The pitching attitude of the aircraft is controlled by the elevators. The use of the elevators will differ, however, with any change in power and airspeed. The slipstream striking the elevators in a downward direction, in effect, creates a negative angle of attack for the elevator. A negative lift, therefore, is exerted by the elevators.

b. Changing power and airspeed will change the amount of downwash and the resulting amount of negative lift exerted by the elevator. As power and airspeed increase, down-wash and slipstream velocity will increase. The negative lift on the elevator and the lift of the wing will increase. The aircraft will have a definite tendency toward assuming a nose-high attitude.

c. If the pilot desires to maintain a straight and level flight path, he must use forward pressure on the stick, or the trim tab, as he increases his power. Any decrease in power or airspeed will have an opposite effect; negative lift of elevators and lift of the wing will decrease. The result will be a definite tendency of the aircraft to assume a nose-low attitude. Back pressure on stick or trim tab must then be applied as power or airspeed is reduced.

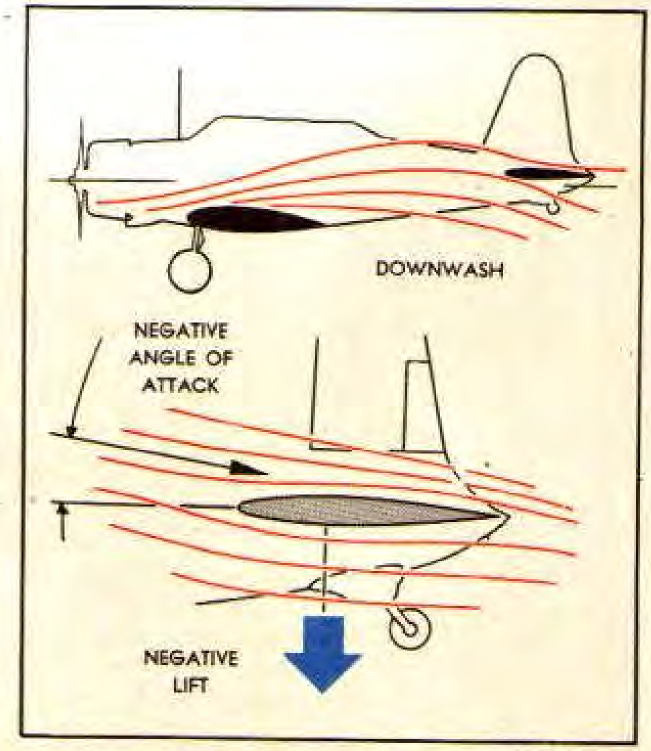


Figure 14—Downwash Effect

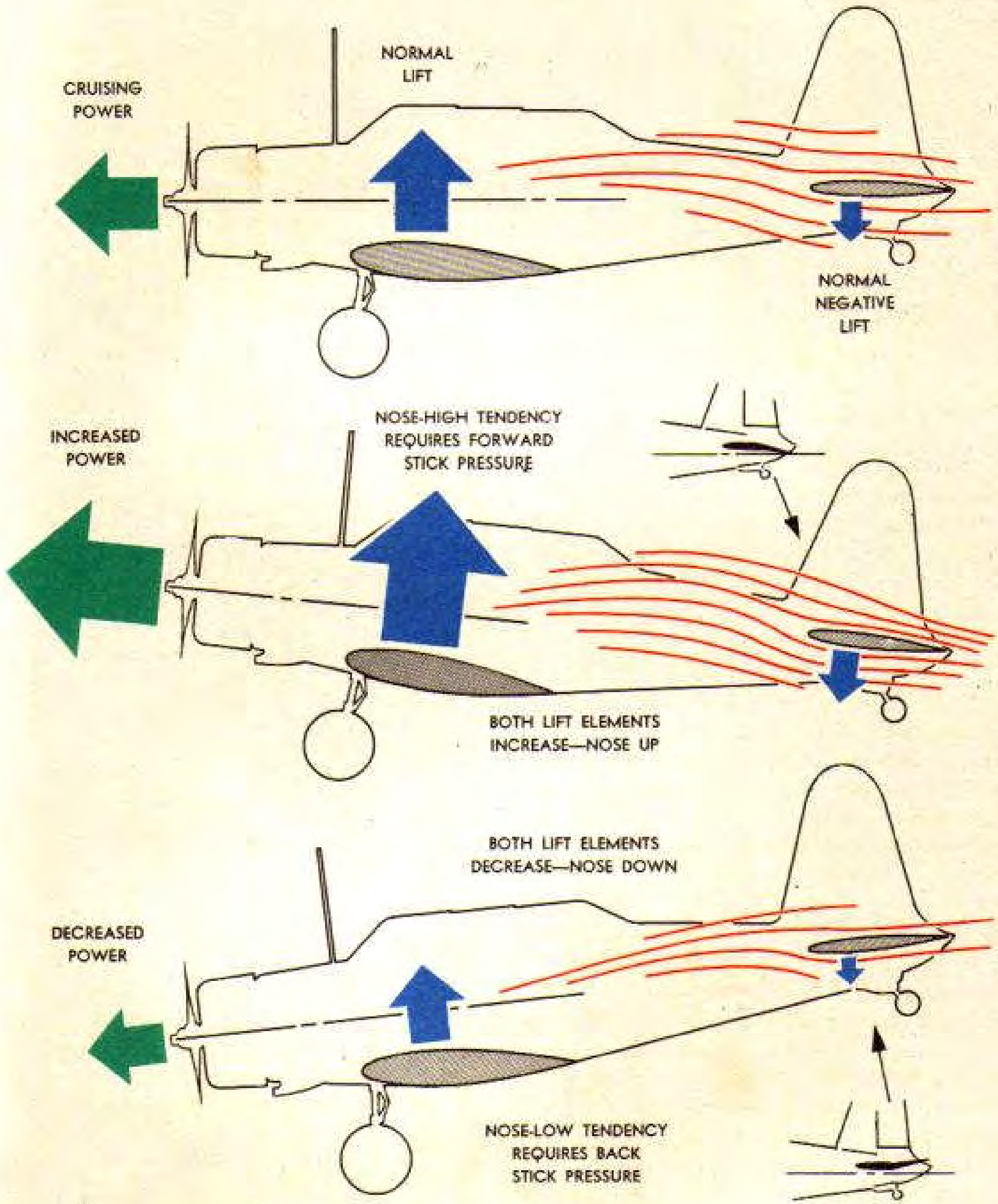


Figure 15—Downwash, Changing Power and Airspeed

10. TURNS.

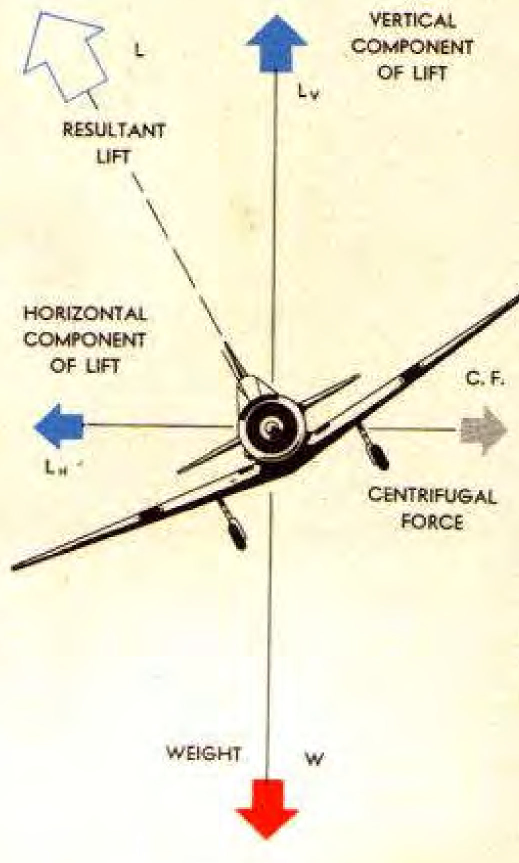
A pilot who understands the forces acting on an aircraft in a turn and how he brings those forces to bear upon the aircraft should have no difficulty with directional control The misconceptions in the minds of many pilots as to the manner in which an aircraft is turned have been partially responsible for the faulty manner in which instrument flying has been taught, learned, and practiced.

11. FORCES ACTING ON AIRCRAFT IN A NORMAL TURN.

a. An aircraft, like any moving object, requires a sideward force to make it turn. In a normal turn this force is supplied by banking the wings of the aircraft so that the lift, which always acts perpendicular to the span line of the wings, is exerted inward as well as upward.

b. The force of lift in a turn is separated into two components at right angles to each other. One component can be drawn vertically and opposite to the force of gravity and the other horizontally in the direction of the turn. The horizontal component of the force of lift represents the force which is pulling the aircraft out of a straight flight path. In a correctly executed turn, this force always acts in the direction of the center of a circle around which the aircraft is turning.

c. In a correctly executed turn, the force to turn the aircraft is *not* supplied by the rudder. An aircraft is not steered like a boat nor like a car; it must be banked. If the aircraft is not banked, there is no force available to pull it out of a straight flight path, provided it is not skidding. Conversely, whenever an aircraft is banked, it will turn, provided it is not slipping.



$L_V = W$
$L_H = C.F.$
$L = \sqrt{W^2 + C.F.^2}$

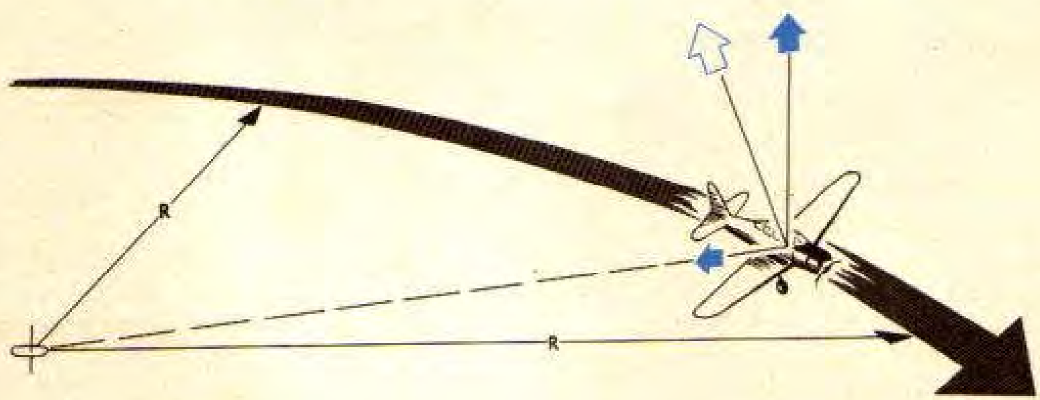


Figure 16—Forces on an Aircraft, Normal Turn

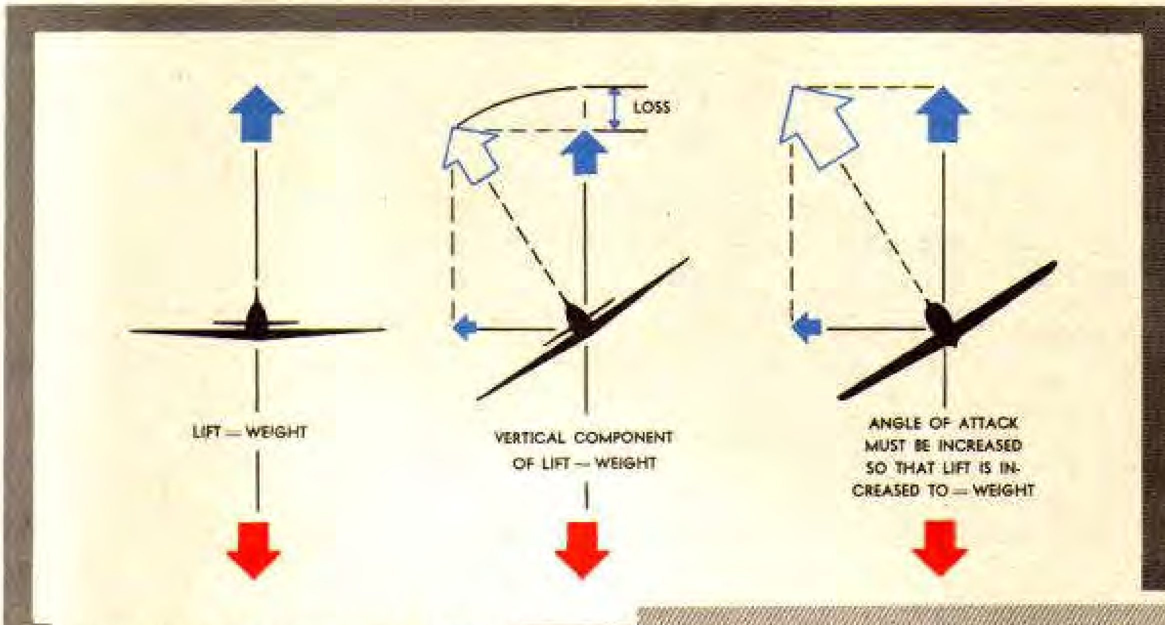


Figure 17—Changes in Lift in a Turn

12. CHANGES IN LIFT IN A TURN.

a. Banking the aircraft causes a loss of *vertical* lift. Consequently, the aircraft will start to lose altitude unless the total lift is increased by increasing the angle of attack of the airfoil until the vertical component of lift is equal to the weight of the aircraft, that is, equal to the force of gravity.

b. At a given airspeed, the rate at which an aircraft will turn depends upon the magnitude of the horizontal component of lift. This depends directly upon the angle of bank. The greater the angle of bank, the more the horizontal component of lift and corresponding rate of turn are increased. Also, the greater the angle of bank, the more the *total* lift must be increased to give a vertical component equal to the weight of the aircraft. The following table shows how, in a correctly executed turn at a constant airspeed, the aircraft will turn more rapidly the more steeply it is banked.

13. INCREASE OF DRAG IN A TURN.

The increase of lift required to hold altitude in a turn requires an increase in the angle of attack of the airfoil. The drag of the airfoil is proportional to the angle of attack, and consequently the drag will increase as the lift is increased. This will result in loss of airspeed in a turn, unless the power is increased. This loss of airspeed will be proportional to the rate of turn, because the increase of lift necessary to increase the rate of turn will be accompanied by an increase in drag.

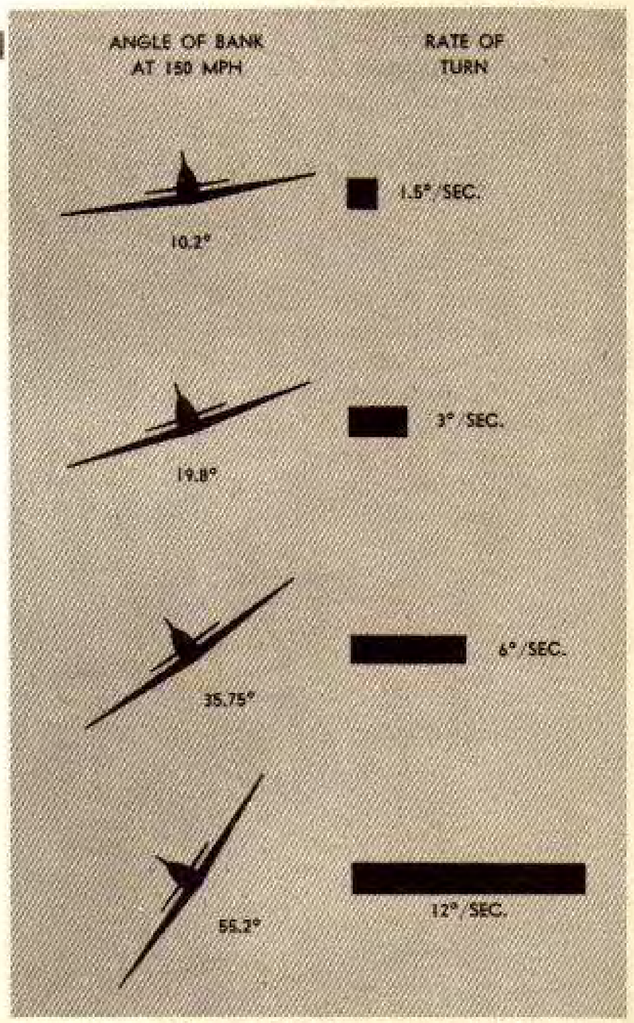
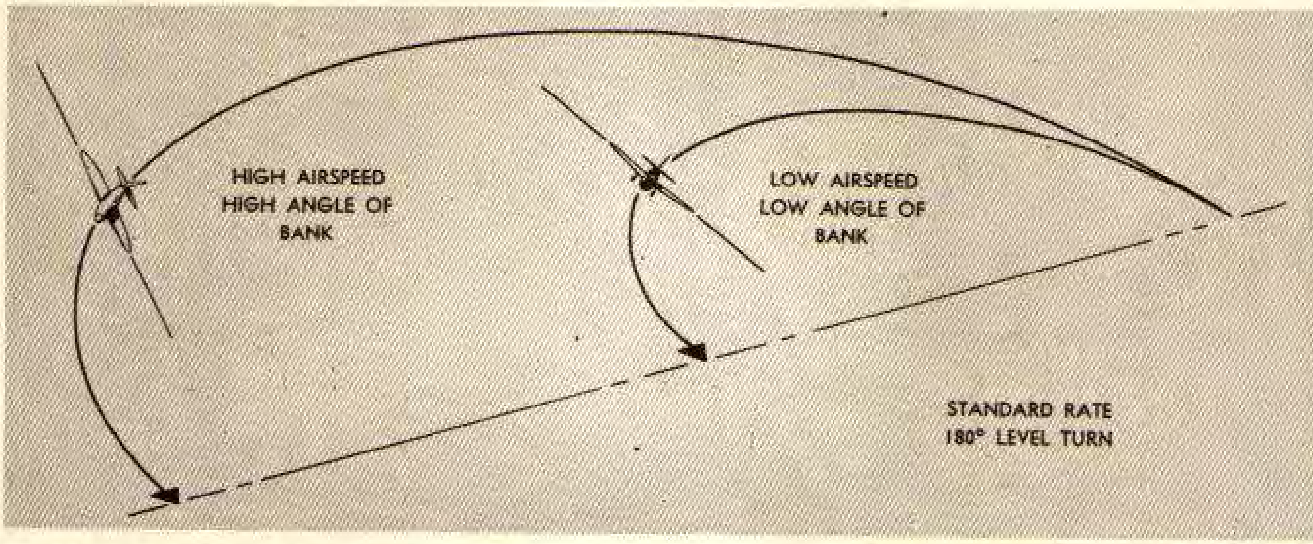


Figure 18—Angle of Bank—Rate of Turn



14. ANGLE OF BANK AND AIRSPEED.

In order to maintain a given rate of turn, the angle of bank must be varied with the airspeed. This becomes particularly important in flying high speed aircraft when relying on the indications of the turn needle. For instance, in flying at 400 miles an hour, it is necessary to bank the aircraft approximately 44° to do a "standard rate turn" (at the rate of 3° per second) on the turn indicator. At this angle of bank, only about 79% of the lift of the aircraft is being exerted in a vertical direction with the result that the aircraft will lose altitude unless the pilot increases the angle of attack sufficiently to compensate for the loss of vertical lift. Angles of bank for turns at the rate of 3° per second and at the rate of 1½° per second for different airspeeds are shown on the following table:

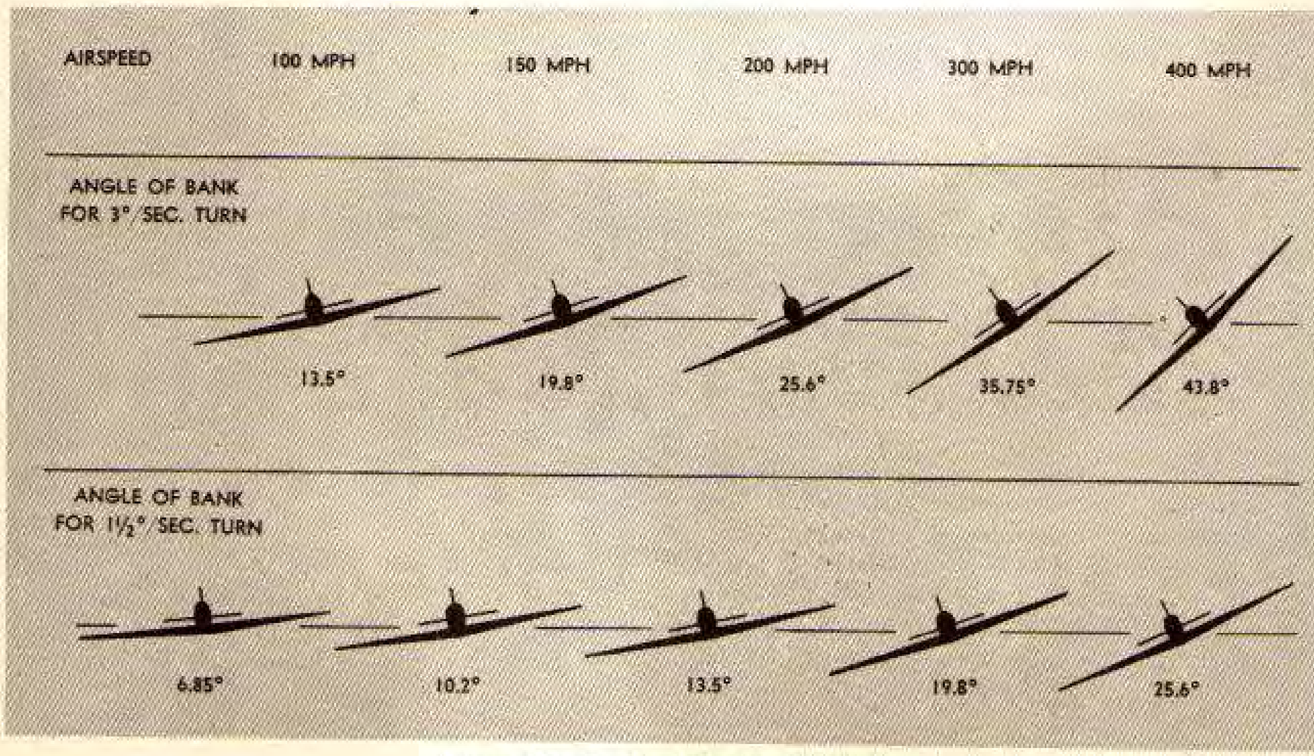


Figure 19—Angle of Bank—Airspeed

15. LOAD FACTOR AND ANGLE OF BANK.

a. Load factor is the ratio between the load acting upon an aircraft in level flight and any other possible load that is exerted upon an aircraft. It depends upon the weight of the aircraft and the maneuver being performed. In straight and level flight the load factor is "1," which means that the wings are supporting only the weight of the aircraft. In a turn at a 60° bank, the load factor is "2," which means that the wings are supporting twice the weight of the aircraft. When the aircraft is correctly banked, the load factor increases as the angle of bank increases. This is shown in Figure 20.

b. In instrument flight it is unwise to make steep turns at low speeds. Consequently, the increase in stalling speed is not of particular importance except under unusual circumstances. For instance, when an aircraft is severely iced up, its stalling speed is higher due to the ice formation. Since the stalling speed of the aircraft increases as the load factor increases, any further increased load factor in a turn might result in a stall. Also, in extremely turbulent air the load factor on the wings may be increased by vertical gusts, and this increase might be sufficient to make an aircraft stall during a turn, whereas it would not stall in a straight and level flight.

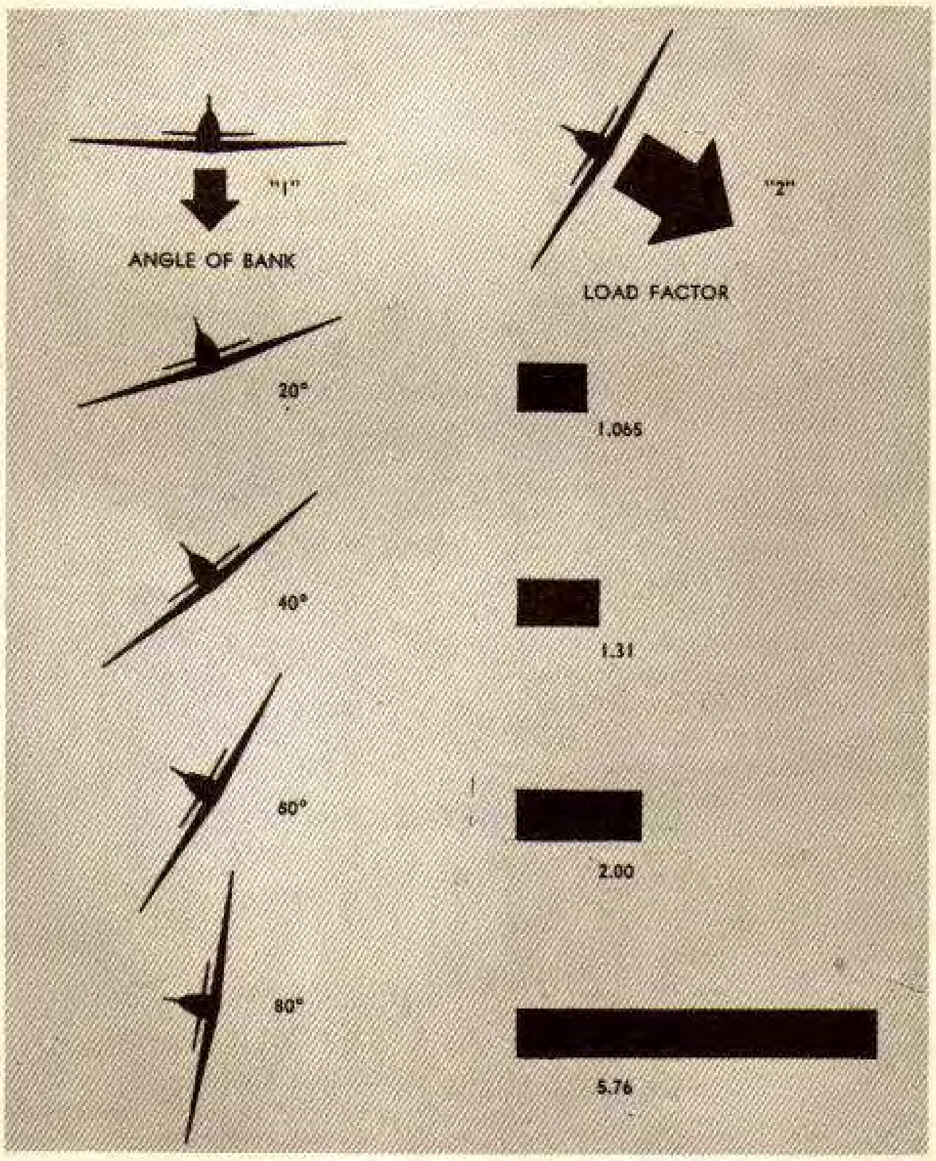


Figure 20—Load Factor and Angle of Bank

16. SLIPS AND SKIDS.

a. Except when it is being slipped or skidded, an aircraft points directly along its flight path. The aircraft may be yawed out of the flight path by the use of rudder or by an incorrect adjustment of the rudder trim tab. The same yawing effect can be caused by the ailerons, for if one aileron is down, it exerts more drag than the other aileron which is up. With a correctly trimmed aircraft, the effect is much like that of a weather vane. When the yawing force is removed, the aircraft will of itself head along its flight path.

b. To maintain straight flight without slipping or skidding, the adjustments of the rudder trim tab must be varied for different power settings since changing torque will vary the airstream over the vertical tail surfaces and will slightly vary the directional control. Single-engine aircraft ordinarily require more right rudder as the power is increased.

17. SLIPPING AN AIRCRAFT WITHOUT CHANGING ITS HEADING.

In a straight slip the aircraft is banked. This bank would normally result in a turn, since there is a force exerted on the aircraft in the direction of the bank. This force would normally pull the aircraft out of its straight flight path, and the aircraft following this tendency to point along the flight path would change its heading so that it would begin to turn. If these forces continue to act, the aircraft would continue to turn. In a straight slip, however, the aircraft is prevented from turning away from its original heading by rudder pressure. Thus, the bank of the aircraft results merely in its being pulled sideward. This is indicated by the fact that there is a sideward pressure of air on the fuselage. Also, the ball bank indicator is displaced in the direction of the bank and the pilot senses that the aircraft is banked in that direction. The latter results from the fact that the aircraft is flying straight in a tilted attitude and that there is no centrifugal force acting on it.

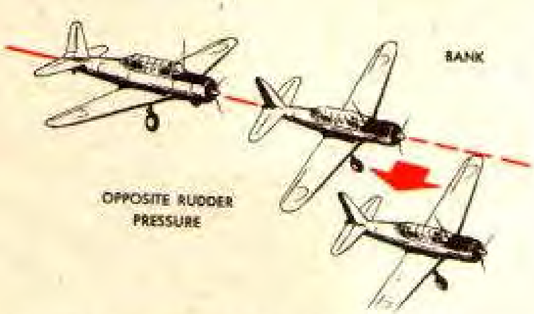


Figure 21—Slip with no Change in Heading

18. SLIPPING AN AIRCRAFT IN A TURN.

A slip in a turn is like a slip in straight flight because the aircraft is not allowed to turn (as fast) as it should for the angle at which it is banked. In other words, the aircraft is not allowed to head directly along its flight path but is yawed slightly to the outside of the path it should follow in the turn. The yaw may be the result of top rudder pressure, or in certain aircraft, the result of the drag of the top aileron on entering the turn. As in straight slips, a slip in a turn is indicated by the pressure of air against the side of the fuselage as a result of the aircraft being pulled sideways in the direction of the turn by the forces of lift. Further indications of the slip are the displacement of the ball bank indicator to the inside of the turn and the pilot's sensing that the aircraft is banked in that direction. These reactions are both caused by the fact that the aircraft is banked too much for the rate of turn, so that the resultant of gravity and centrifugal force acts downward. Another reason for a slip is that the aircraft is turning more slowly than is proper for the angle of bank because of the outward yaw effect of the rudder or ailerons preventing the lift component of the wings from turning the aircraft.

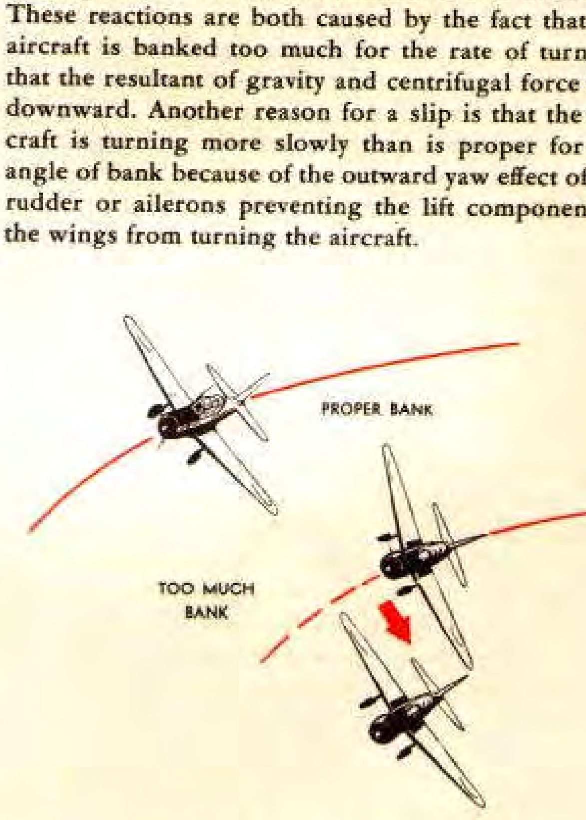


Figure 22—Slip in a Turn

19. SKIDDING THE AIRCRAFT AROUND A TURN WITH THE WINGS LEVEL.

An aircraft may be turned without banking the wings, simply by yawing it with the rudder or the rudder trim tab so that the thrust of the engine will pull the aircraft out of a straight flight path. If this yaw is maintained so that the thrust line is at an angle to the line of flight, the aircraft will be pulled around in a turn. This skid is indicated by the centrifugal force in the turn causing the ball bank indicator to be displaced to the outside of the turn and the pilot sensing a force acting in the direction of the skid. It is also indicated by the pressure of air on the side of the fuselage away from the direction of the turn, because the aircraft is being yawed out of its flight path and is skidding.

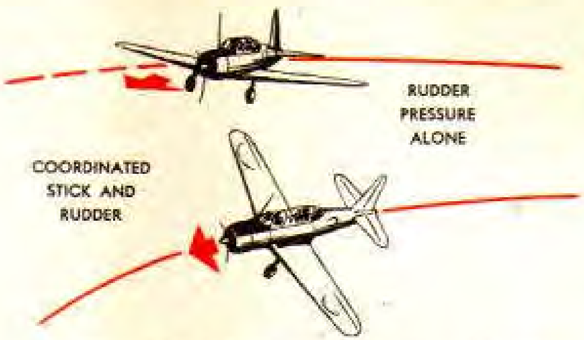


Figure 23—Skidding Turn, Wings Level

20. SKIDDING IN A TURN WITH WINGS BANKED.

Skidding in a turn with the wings banked means that the aircraft is being turned faster than it should for the amount that it is banked. This increase in rate of turn results from the force of thrust from the propeller acting inward from the flight path and the inward force supplied by the horizontal component of lift. The skid will carry the aircraft outward from flight path and away from the direction of turn. The fact that the aircraft is skidding is indicated by the displacement of the ball bank indicator to the outside of the turn and by the pilot sensing a force acting in that direction. These are both the result of centrifugal force caused by the inward turning effect of the propeller thrust. A skid is further indicated by air pressure on the side of the fuselage away from the direction of turning.

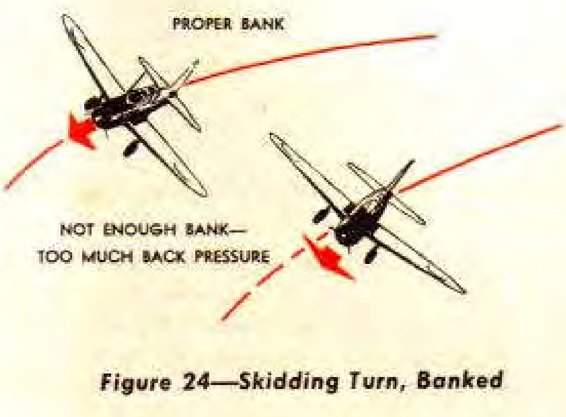


Figure 24—Skidding Turn, Banked

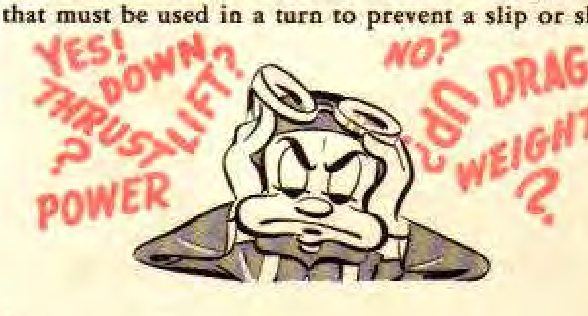
21. COORDINATED USE OF RUDDER AND AILERONS.

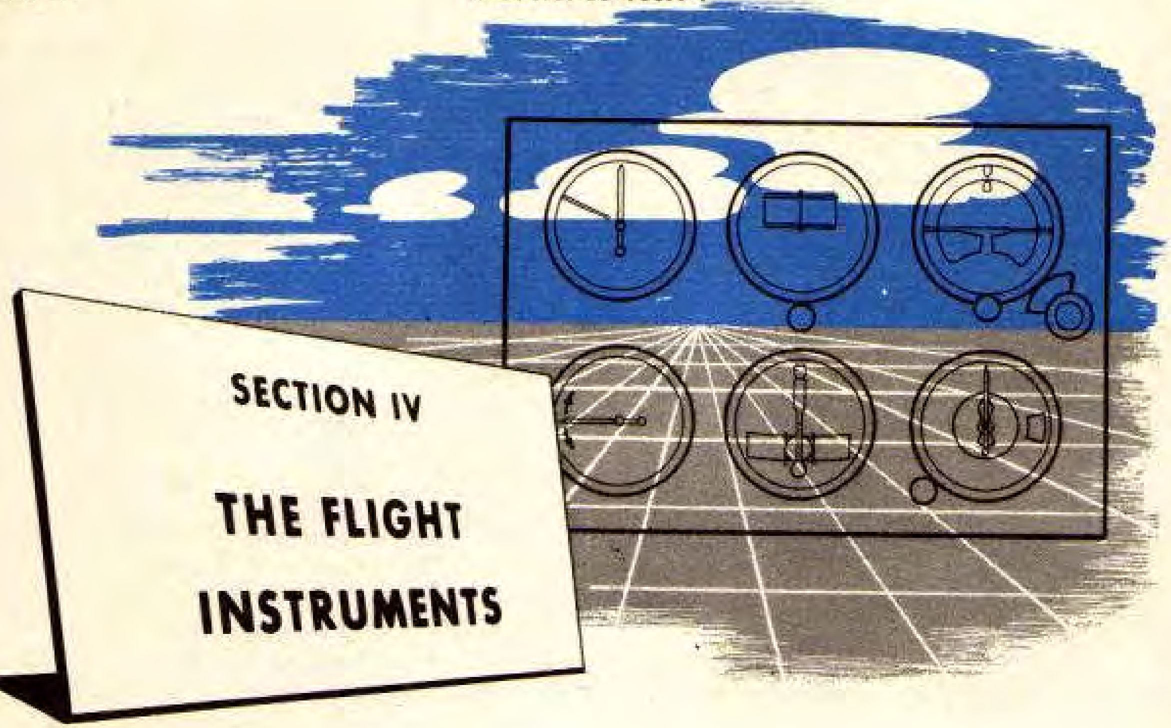
a. Most aircraft may be banked by either ailerons or rudder pressure alone. If the aircraft is banked by the ailerons only, it will tend to slip because the outside aileron will have more resistance than the inside aileron. The amount of slipping will depend on the violence with which the controls are used, since the more the ailerons are moved out of a neutral position the greater will be the yawing effect of the aileron drag. If the ailerons are used slowly and moderately, the slipping will be inconsequential.

b. An aircraft may be banked by the rudder only. This is caused by the aircraft being yawed toward the inside of a turn. The lift of the outside wing will be increased over that of the inside wing, because the speed of the outside wing increases over that of the inside wing. At best, the effect of the rudder is slow. If the rudder is used with any force, considerable skidding will accompany the increase in the angle of bank.

c. It is difficult to bank an aircraft flying at high speeds by the sole use of the rudder. The principal reason for this is that the yawing effect of the rudder does not materially increase the lift of the outside wing. In fast aircraft the radius of the turn is so great that the increase in the speed of the outside wing over that of the inside wing is extremely small and has little effect upon the relative lift of the wings.

d. An aircraft is correctly banked only by the coordinated use of the rudder and the aileron. The relative use of these two controls is determined by the characteristics of the particular aircraft at the speed at which it is being flown. The indications of the ball bank indicator will provide an accurate gauge for determining the relative pressure on the two controls. After the aircraft has been banked for a turn, the angle of bank should be held constant without skidding or slipping. This will require some readjustment of both ailerons and rudder pressure, depending upon the characteristics of the particular aircraft, its speed, and its angle of bank. No general rules can be laid down for determining in advance for any aircraft exactly the relative amount of either rudder or aileron pressure that must be used in a turn to prevent a slip or skid.





1. OPERATING SYSTEMS.

a. The six instruments normally called "flight instruments" are:

Artificial Horizon
Directional Gyro
Turn and Bank Indicator
Airspeed Indicator
Rate of Climb Indicator
Altimeter

In addition to the above instruments the magnetic compass may also be called a flight instrument.

b. The Artificial Horizon, Directional Gyro and Turn and Bank Indicator are gyro instruments, the gyro rotors being operated by vacuum systems drawing air from the cases of the instruments, and allowing air to be sucked in to the resultant vacuum through suitable air jets which drive the gyro rotors. Some of the newer instruments are operated electrically and are so designed that the gyro wheel becomes part of an electric motor. The vacuum is provided by an engine-driven vacuum pump. Alternate sources of vacuum are usually available in multi-engine aircraft by an additional vacuum pump driven by another engine. Single engine aircraft may be equipped with a venturi tube to provide an "alternate vacuum source" for emergency use, should the engine-driven pump fail.

c. The alternate vacuum source must be distinguished from the *alternate source* of *static pressure* used in activating the Airspeed Indicator, Rate of Climb Indicator, and Altimeter; should the static head be blocked by ice. Very often the two systems are confused in the mind of the average pilot. He must know, which system (vacuum or pitot-static) operates which instruments. The compass is, of course, activated only by the magnetic field of force about the earth.

d. In the pitot static system, two tubes are mounted on the aircraft as far away from any disturbed air as possible. One section is the pitot tube, which receives the dynamic or impact pressure of the air created by the forward motion of the aircraft. The other section, consisting of the static tube, has very small perforations which receive only the pressure of still air. The pitot tube is provided with baffles and traps to prevent rain or water from rain or melted ice getting past the head of the tube. Both the pitot and the static heads are provided with a heating element sufficient to keep all but severe ice from blocking the openings. A switch in the cockpit marked "pitot heat" causes current to flow through the element when the switch is turned on.

e. The static pressure line from the static tube of the pitot static head leads to the airspeed, rate of climb and altimeter through a "static pressure selector valve" and thence into the instruments. When this valve is set on "airspeed tube" the static pressure from

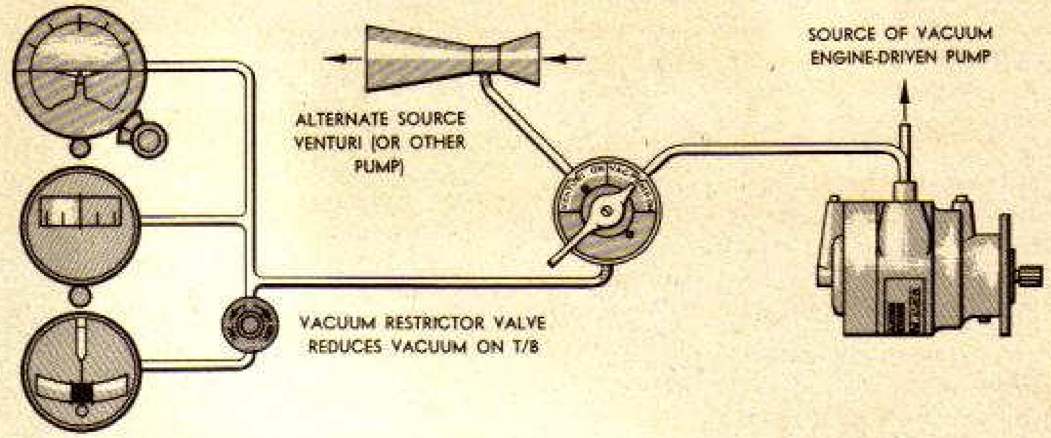


Figure 25—Alternate Source, Vacuum

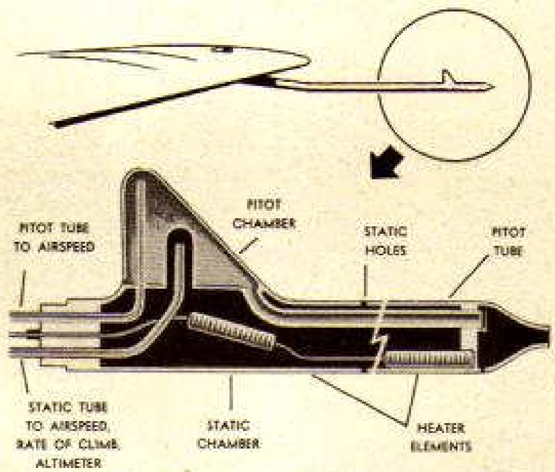


Figure 26—Pitot—Static Tube

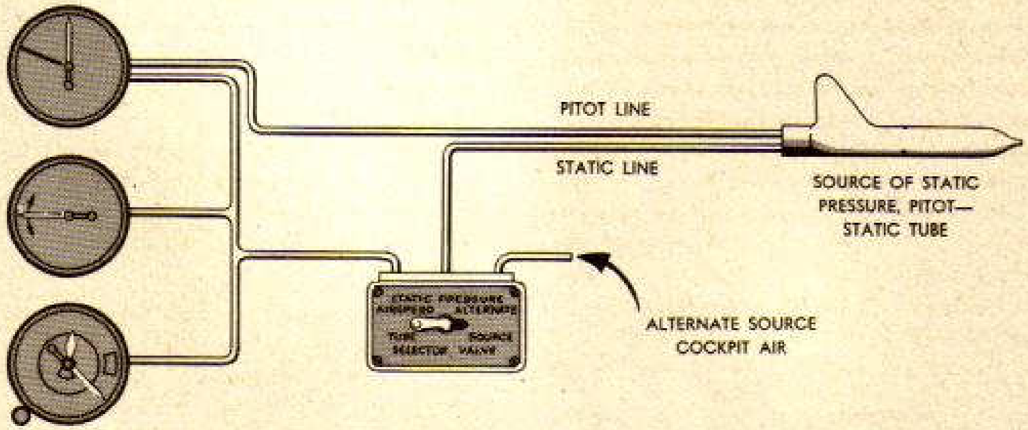


Figure 27—Alternate Source, Static Pressure

the pitot static tube head is used. When the valve is on "alternate source" the static head is cut off and the instruments are vented to the cockpit air. Inasmuch as the static air pressures within the cockpit are usually lower than the outside surrounding air, when this alternate source of static pressure is used, care must be used in flying the aircraft. The airspeed will give a reading *greater* than the proper indicated airspeed, and the altimeter will read *higher* than the proper indicated altitude. Particular care must be used by the pilot in making low approaches, and in landing, due to these false readings of the altimeter and the airspeed.

f. In the event the alternate source is also blocked by oil or dirt—breaking the glass of the instrument will afford another source of static pressure.

g. In shifting to alternate vacuum supply, on the other hand, it is only necessary to shift to the other engine pump, or in single engine aircraft turn the valve to "Venturi."

NOTE

Should the vacuum system operate *only* from a Venturi tube, instrument take-offs must not be attempted, as the speed of the aircraft alone provides this source of power—which speed is not obtained until after take-off.

2. ARTIFICIAL HORIZON.

a. DESCRIPTION.—The artificial horizon is a direct reading indicator of the bank and pitch attitude of the aircraft. The instrument relies for its indications upon the principle of the stability of a freely mounted gyroscope. When the aircraft banks or pitches, the instrument case being fixed to the aircraft, moves with it, but the gyro mounted inside maintains its stable plane of rotation in space. These movements of the instrument case with respect to the gyro are shown on the face of the instrument as movements of the miniature aircraft with respect to the horizon bar. The bank of the aircraft is accurately indicated by the bank of the miniature aircraft relative to the horizon bar. Degree of bank is indicated by the pointer on the scale around the top of the instrument. The pitch of the aircraft is indicated by the vertical position of the miniature aircraft relative to the horizon bar. In a climbing attitude the miniature aircraft will be above the horizon bar. In a descending attitude the miniature aircraft will be below the horizon bar.

b. ADJUSTMENT OF THE MINIATURE AIRCRAFT.—The miniature aircraft can be adjusted vertically by a knob at the bottom of the face of the

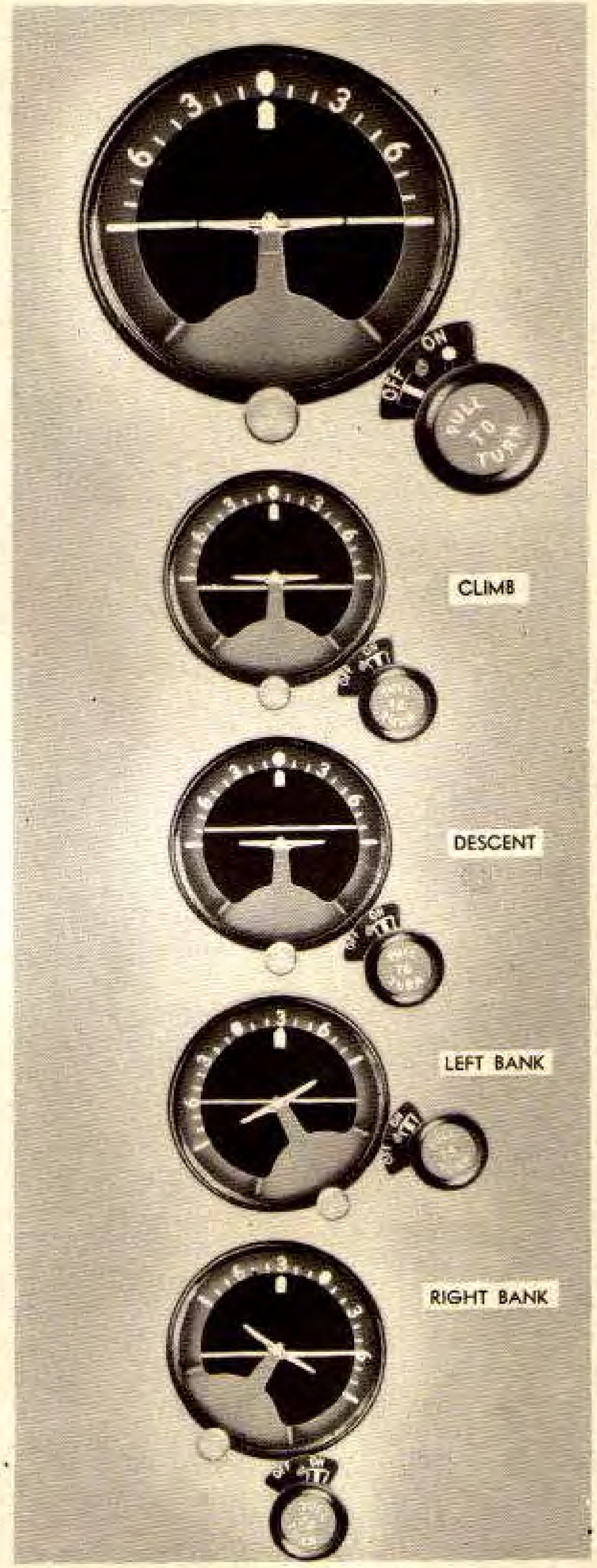


Figure 28—Artificial Horizon and Its Indications

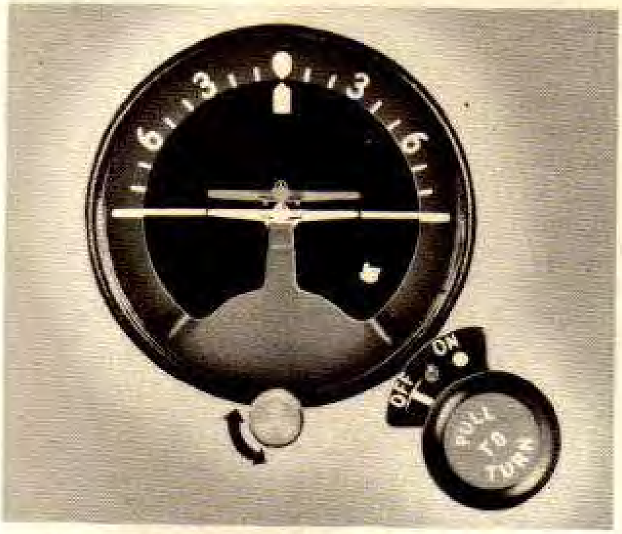


Figure 29—Adjustment of Miniature Aircraft

instrument. In flight this adjustment makes it possible to set the miniature aircraft exactly on the horizon bar at the attitude required to maintain level flight. *Always adjust the miniature aircraft to the proper position when the aircraft is in level flight.* Small changes away from the desired attitude can thus be quickly noticed and the aircraft can easily be returned to its correct attitude.

c. CAGING MECHANISM AND LIMITS OF INSTRUMENT.—The function of the "caging" knob is to lock the gyroscopic element of the instrument to prevent damage during maneuvers which exceed its operating limits. To cage the gyro pull the caging knob (marked "PULL TO TURN") and turn it clockwise *as far as it will go; then push the knob in.*

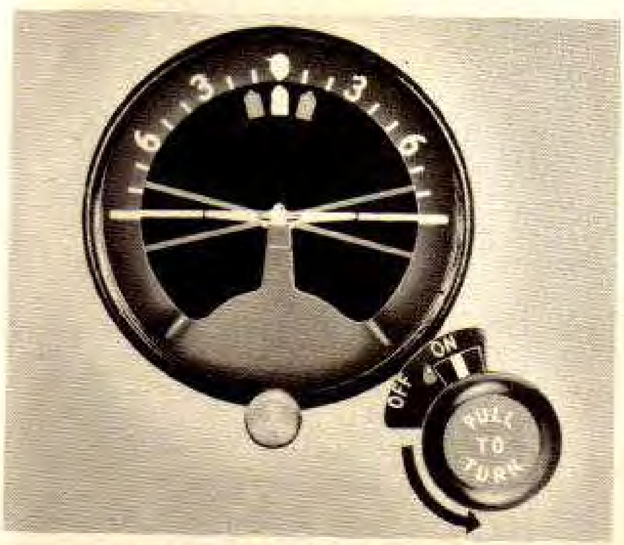


Figure 30—"Caging—Uncaging"

In this position, the reference line points to OFF and the warning dot on the right hand side of the cage dial is exposed to warn the pilot that the gyro is caged and therefore not indicating. To uncage the gyro pull the caging knob and turn it *counterclockwise as far as it will go; then push the knob in.* In this position the reference line points to "ON" and the warning dot is covered showing that the instrument is indicating. Make certain that the warning dot is *completely* covered, otherwise the gyro is not entirely free or uncaged.

If the aircraft banks over 110° or dives or climbs over 70° the gyro will hit stops, upset, and become useless. When this happens the gyro should be immediately caged. It should be uncaged again *only when level flight has been resumed.* If it is uncaged in a bank, or when the nose of the aircraft is not on the horizon, the horizon bar will be released horizontally with respect to the instrument case but not with respect to the true horizon. *During maneuvers which would exceed the operating limits, the gyro should be caged; at all other times the gyro should be uncaged.*

d. BANK AND PITCH ERROR.—The artificial horizon is subject to slight errors in both bank and pitch due to the effect of the erecting mechanism in a turn. These errors are greatest after a turn of 180°. (If the turn is continued through 360° the bank errors should cancel out and the indications of the instrument should again return to normal.) The "bank error" causes the instrument to indicate slightly less than the actual amount of bank during a turn, or a slight bank in the opposite direction after straight flight has been resumed. This error never should be in excess of 6° and consequently is so small that it should not cause any serious error in the control of the aircraft, providing the instrument is checked against the turn indicator to see that no turn is being made. The "pitch error" causes the horizon bar to dip slightly below its correct position for level flight. The error is small—the horizon bar is seldom displaced more than its own width below its normal position. However, if the pilot follows the indications of the gyro horizon in very slow turns without reference to the other instruments, he may enter a gradual descent. This could be dangerous at low altitudes. Consequently the pilot in all turns should carefully and frequently check the attitude by reference to the other instruments, particularly the altimeter. Bank and Pitch error only exists during and immediately after a turn, and is corrected by the instrument itself within two minutes after completion of a turn.

e. OTHER ERRORS.—Errors in the indications of the instrument may be caused by the bearings being worn and dirty or any of the moving parts of the mechanism being out of balance. Such errors are unpredictable and can be corrected only by overhaul. The instrument also will not operate properly if the effective vacuum is insufficient. The instrument will operate at any vacuum between 3.5" Hg. and 5.0" Hg. the desired being 4.0" Hg. Even if the proper vacuum is delivered to the instrument, a clogged or dirty filter may prevent the proper flow of air into the instrument. The result will be the same if the vacuum were insufficient.

NOTE

Caution—Always check the indications of this instrument against the turn indicator.

f. FIELD REPAIRS.—If the instrument is not operating properly, check and clean, if necessary, the filter screen at the back of the instrument, observe whether a vacuum between 3.5" Hg. and 5.0" Hg. is being delivered by the engine-driven pump. Then check the lines to the instrument, with particular attention to flexible coupling. This check should be made by inspection and also by feel to see if the tube is crushed. No other repairs should be attempted by other than an experienced instrument mechanic.

g. COCKPIT CHECK FOR THE ARTIFICIAL HORIZON.—Immediately after starting the engine the pilot should note the horizon bar. It should start to move or wobble the moment the motor is started, indicating that suction is taking the air out of the case and the incoming air is starting to rotate the gyro wheel. The bar should slowly but steadily move to a position indicating a steep climb or three point landing attitude. (Provided the miniature aircraft is set at the proper position, i.e., the silver scribe line set to neutral.) An additional check that should be made after the instrument rotor has attained proper operating speed (5 minutes at 4" Hg.). Make a few taxiing turns and note the horizon bar. It should not tilt or depart from the horizontal.

3. DIRECTIONAL GYRO.

a. DESCRIPTION.—The directional gyro operates on the principle of the stability of a freely mounted gyroscope. Essentially, it consists of gyroscopic wheel which is mounted so that it rotates in a vertical plane. The mounting is free so that the instrument case which is fixed in the aircraft can turn a full 360 degrees about the wheel.

b. A circular card, calibrated like a compass card, is attached horizontally to the vertical frame of the gyro.

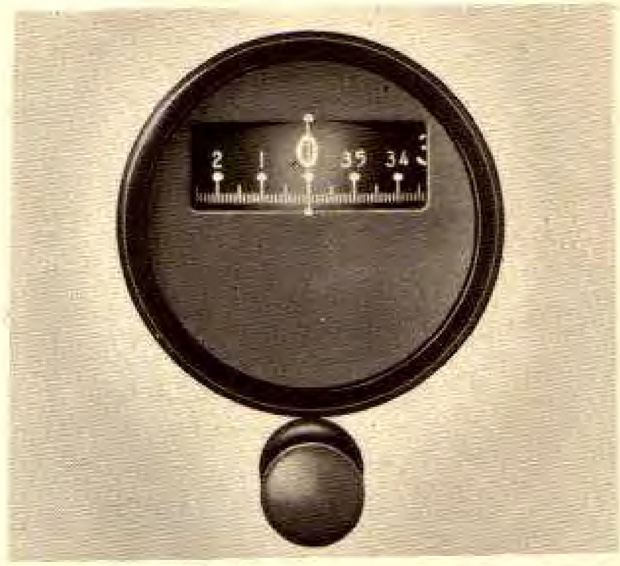


Figure 31—Directional Gyro

The card is visible at the face of the instrument. As the aircraft turns, the gyro wheel will maintain its same plane of rotation in space and consequently the aircraft will move about the circular card. The directional gyro thus provides a stationary reference for determining whether the aircraft is turning or is flying straight. The card should be adjusted so that the heading appearing at the lubber line on the face of the instrument coincides with the magnetic headings of the aircraft (except for an instrument take-off) by means of the caging knob.

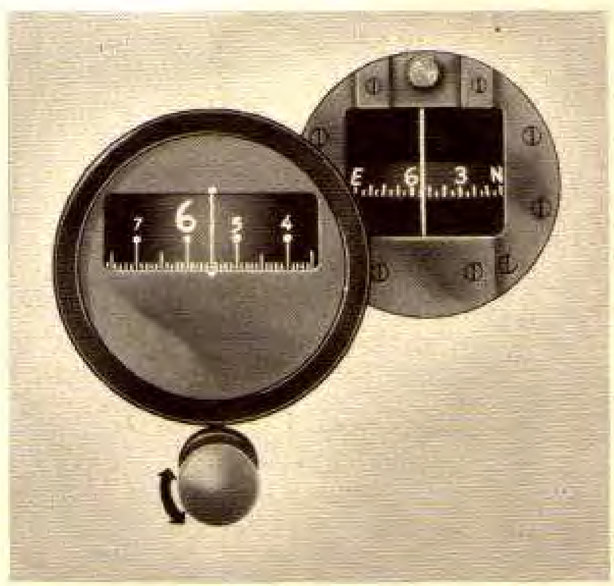


Figure 32—Setting the Directional Gyro

c. CAGING MECHANISM AND LIMITS OF THE INSTRUMENT.—When the knob is pushed in, the gyro is caged and held vertical by two arms. The vertical frame, and the circular card can then be turned to any desired position. Pulling out the knob releases the gyro and disengages the gear at the base of the instrument. The instrument is now free to indicate. If the aircraft is banked, climbed, or dived over 55°, stops will come up against the horizontal frame causing the gyro wheel to upset which, in turn, will cause the card to spin. When the gyro spins, the indications of the instrument are worthless. After it spins, the instrument must always be caged and reset to the magnetic heading. During maneuvers which would exceed the operating limits, the gyro should be caged. *At all other times the gyro should be uncaged.*

d. SETTING THE DIRECTIONAL GYRO.—After setting the gyro, pull the knob full out. This must be done in order to disengage completely the gear at the base of the instrument. *Pull the knob straight out. Do not twist it when pulling it out, except for test outlined under g. below, since this will cause the gyro wheel to precess and tip from its vertical position.*

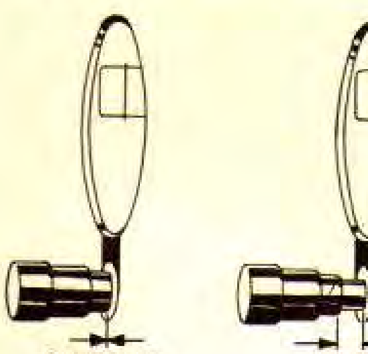


Figure 33—"Caging" Knob

e. ERRORS.—When there is excessive drift, the cause is often excessive friction in the bearings from dirt or wear or stiff lubricants due to cold weather. Such errors can be corrected only by overhaul of the instrument. The instrument will also show excessive drift if the vacuum is insufficient. The exact amount of vacuum is not extremely critical—the instrument will operate between 3.5" Hg. and 5.0" Hg. with the desired vacuum 4.0" Hg. At less vacuum than 3.5" Hg. the gyro wheel will not rotate at a high enough RPM and it will not be sufficiently stable. Even if the proper vacuum is delivered to the instrument a clogged or dirty filter may prevent the proper flow of air into the instrument. The result will be the same if the vacuum were insufficient.

f. FIELD REPAIRS.—If the instrument is not operating properly, check and clean, if necessary, the filter and screen at the base of the instrument, observe whether a vacuum between 3.5" Hg. and 5.0" Hg. is being delivered by the engine pump. Then check the lines to the instrument with particular attention to flexible couplings. This check should be made by inspection and also by feel to see if the tube is crushed. No other repairs should be attempted by other than an experienced instrument mechanic.

g. COCKPIT CHECK FOR THE DIRECTIONAL GYRO.—After the engine is started allow about five minutes at 4" Hg for the instrument rotor to accelerate to its proper speed. Cage the instrument and then twist the caging knob, and *at the same time* pull it out sharply. If the card spins the rotor does not have the proper rigidity and the instrument cannot be depended upon. The heading should remain constant at the heading shown on the instrument when the knob was pulled out. In addition, the directional gyro should be set with the magnetic compass before taxiing out. Then after taxiing out and when in alignment with the take-off runway note the directional gyro reading. It should approximate the compass and the runway heading. Recheck the directional gyro heading with the compass after take-off and reset if necessary.

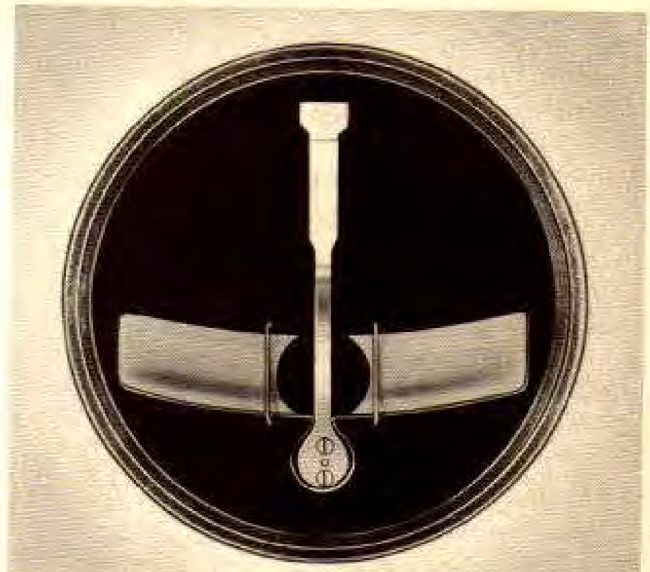


Figure 34—Turn Indicator

4. TURN INDICATOR.

a. DESCRIPTION.—The turn indicator is an instrument which indicates the direction and approximately the rate at which an aircraft is turning. Essentially, it consists of an air driven gyro wheel mounted so that it will precess when the aircraft turns, the amount of its precession being determined by the rate of turning of the aircraft.

b. CALIBRATION.—The indicator should be calibrated so that when the nose of the aircraft moves around in the yawing plane at 3 degrees a second the needle is deflected its own width in the direction of the turn. On some faster types of aircraft the needle is calibrated to move two needle widths in a turn at the above mentioned rate.

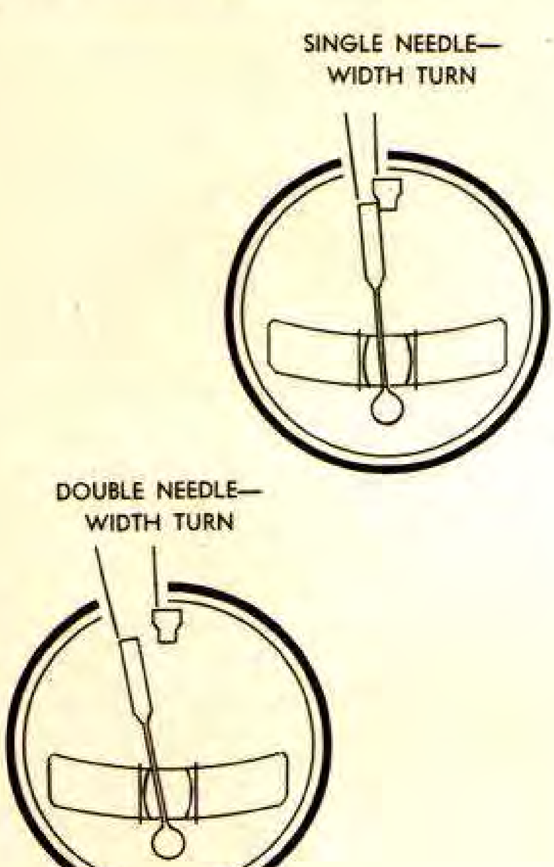


Figure 35—Turn Indicator Indications

c. ERRORS OF THE INSTRUMENT.—The errors of this instrument are such that an *exactly* accurate indication of the *rate* of turn is not provided at all times. Worn or dirty bearings, or stiff lubricants in the bearings supporting the horizontal frame will cause greater resistance to the forces of precession than would normally occur and will cause the instrument to indicate less than it should for a given turn. Less than normal indications will be especially noticeable in cold weather, before the lubricants in the bearing have had time to warm up. Any variation in the speed of the rotor wheel will cause a corresponding variation in the indications of the instrument. The greater the RPM of the wheel, the greater will be the force of precession for a given rate turn, and the greater will be the indication for such a turn. The speed of the gyro wheel is dependent on the velocity of the air through the jet. This velocity will vary with changing vacuum, and consequently the indications of the instrument are extremely critical with respect to the operating vacuum. The limits are fixed at 1.9" Hg. to 2.1" Hg. The passage of air through the jet will be reduced if the filter at the air intake is clogged or dirty. *The filter must always be kept clean.* The pilot should be cautioned to give the gyro sufficient time to attain the specific RPM before attempting to use the instrument. *At least three minutes of suction at 2" Hg. will be required to bring the gyro wheel up to speed. In emergency take-offs made under instrument conditions, before the gyro wheel has reached full speed, straight flight should be maintained as long as practicable and any turns made on the turn indicator should be made at a very low indicated rate of turning.* In rough air the needle will fluctuate from side to side. Under these conditions the average reading must be considered.

d. FIELD REPAIRS.—If the instrument is not working properly, the only repairs that can be made in the field are to check the vacuum and the entire air system, if the instrument is vacuum operated. First check and clean the filter, clean the jet, if necessary, with a pipe cleaner, then check the lines between the vacuum pump and instrument, both by inspection and by feel, with particular attention to the flexible connections. If a suction gauge is in the aircraft, check the suction at the case. Under no conditions will the seal of the instrument ever be broken.

e. COCKPIT CHECK FOR THE TURN INDICATOR.—A few minutes after the engine is started and the aircraft is being taxied to take-off position, do a few turns. The turn needle should indicate the turn properly and should not be sluggish in its indications and should return to neutral immediately the turn is stopped. The same effect can be accomplished by lightly pushing the side of the instrument panel if it is a shock mounted panel. An additional check should made on the turn needle. After take-off if still contact, apply enough bank so that the turn needle moves to the standard rate position. In this manner you can determine if the bank is approximately normal for a standard rate turn.

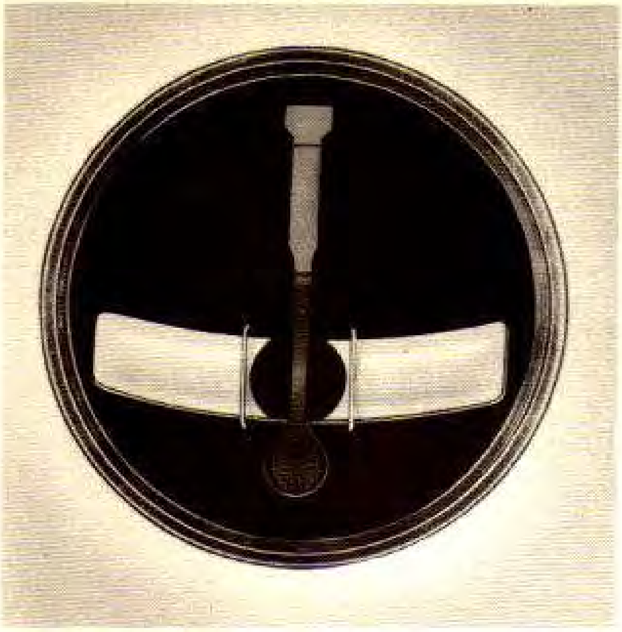


Figure 36—Ball Bank Indicator

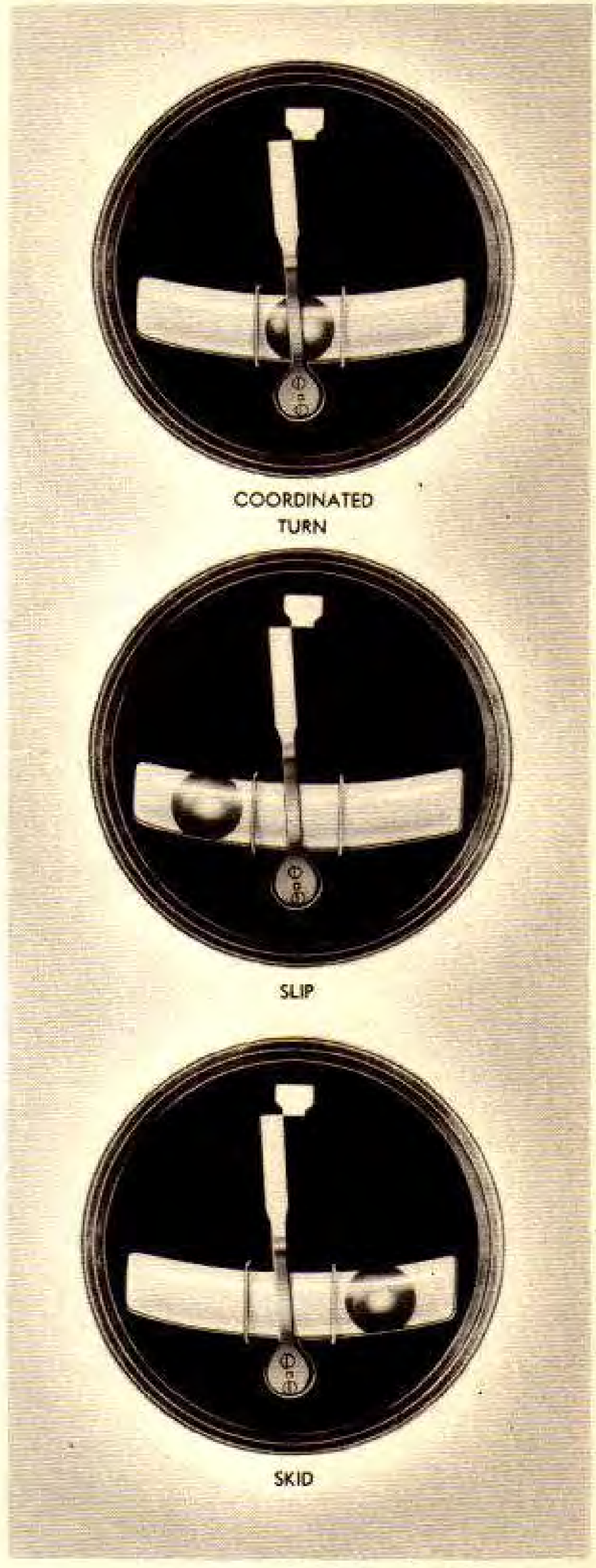


Figure 37—Indications of Turn and Bank Indicator

5. THE BALL BANK INDICATOR

a. DESCRIPTION.—This instrument is a simple pendulous device. It is merely a ball sealed in a curved glass tube. The tube is filled with a clear fluid which supplies sufficient damping to prevent the ball from oscillating excessively in rough air or under varying lateral forces. An expansion chamber is provided at one end of the tube. Safety wire around the tube at two points near the center provides a reference for indicating the center of the tube.

b. USE OF THE INSTRUMENT.—In level flight, the ball by its own weight takes a position at the center of the tube. If a wing drops in straight flight the ball will roll down to the position of the tube that is the lowest. In a turn, the ball will be affected by gravity and centrifugal force. In rough air it will also be affected by lateral accelerations resulting from the pressure of air against the side of the fuselage in a slip or a skid. In a perfectly banked turn, the ball bank indicator will be in the center of the tube. In slipped or skidded turns the ball will be displaced. Since slips or skids are corrected by the proper *relative* use of aileron and rudder, the instrument shows whether these two controls are correctly coordinated. In a slip the turn needle and the ball bank indicator are on the same side. In a skid they are on opposite sides.

Figure 38—Airspeed Indicator

6. THE AIRSPEED INDICATOR.

a. DESCRIPTION.—The airspeed indicator consists of an airtight instrument case which is open only to the static side of the pitot static tube. The case is thus kept at atmospheric pressure at all times. Inside the case is a diaphragm which is connected to the pitot side of the pitot static tube. As the aircraft moves through the air, the pressure in the pitot tube is transmitted to the inside of the diaphragm and the diaphragm expands. With increasing pressure, the expansion of the diaphragm will increase. Changes in the thickness of the diaphragm are multiplied by a system of gears and levers and are indicated on the face of the instrument in knots or miles per hour.

b. ERRORS IN THE INDICATIONS OF THE INSTRUMENT.—"Indicated airspeed" is simply what is shown on the face of the instrument. It is a measurement of the difference between the pressure in the pitot tube and the pressure in the static tube. It is rarely the true airspeed. The pressure of the air striking the pitot tube at any given airspeed will vary with the density of the air. The less dense the air, the less will be the impact pressure. Since the atmospheric pressure decreases with altitude and since the density of the air is also dependent upon temperature, both temperature and altitude must be taken into account in correcting the airspeed indications. To obtain true airspeed under varying conditions, the pilot may use the airspeed correction scale on any standard flight computer. Rough corrections for the altitude error may be applied by adding 2% to the indicated airspeed for every thousand feet above sea level. Corrections to calibrate the instrument are required due to the fact that it is impossible to place the pitot static tube in a completely undisturbed airflow. These corrections are practically the same for every aircraft of the same type and are given on a scale posted in the aircraft or contained in the Pilot's Flight Operating Instructions.

c. The airspeed indicator is particularly important in instrument flight since its indications (a) determine the correct attitude of an aircraft in climbs and descents and (b) shows when the aircraft is in danger of stalling or when dangerously high speeds are being approached. For navigational purposes its indications can be used to determine the true airspeed at which the aircraft is traveling. Under modern long range cruising procedure it can be used to determine the power output of the engines.

NOTE

The indicated airspeed at which an aircraft will stall is the same no matter what the altitude or temperature. The airspeed indicator therefore provides a correct indication at all times of safe flying speed, provided the instrument is functioning correctly.

7. RATE OF CLIMB INDICATOR.

a. DESCRIPTION.—Like the altimeter, the rate of climb indicator is simply a sensitive differential pres-

Figure 39—Airspeed Indicator Indications

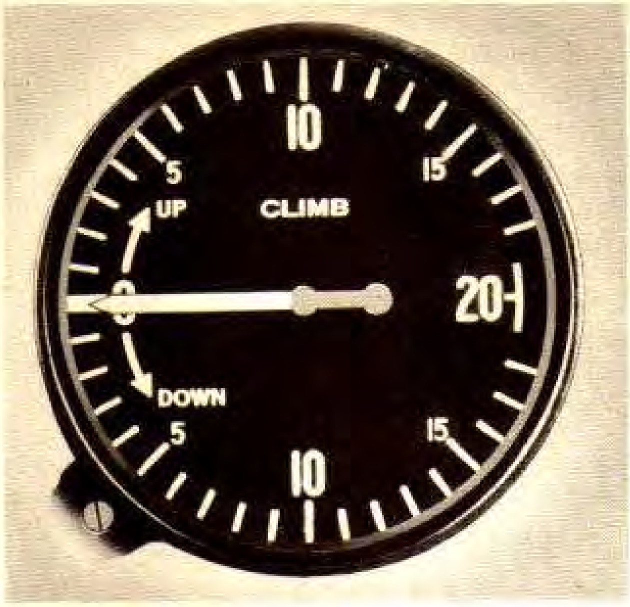


Figure 40—Rate of Climb Indicator

Figure 42—Sensitive Altimeter

sure gauge. The inside of the diaphragm is connected directly to the static line of the pitot tube, while the case is vented to this same line through a small restricted tube. Consequently, whenever the aircraft is changing altitude, pressure within the diaphragm changes prior to the change in pressure within the case, which is vented by a capillary tube.

b. In using the instrument, the pilot must always remember that it indicates rate of change of altitude, and not the attitude of the aircraft. It will be found, however, that changes in altitude can be more readily detected and corrected or controlled by reference to the altimeter, rather than to the rate of climb.

c. The instrument is difficult to use in controlling the attitude of the aircraft due to the large vertical accelerations of modern high speed aircraft, and due to its unstable readings in rough air.

Figure 41—Rate of Climb Indicator Indications

8. THE ALTIMETER.

a. DESCRIPTION.—The altimeter is a device for measuring atmospheric pressure. Since atmospheric pressure decreases with altitude, the instrument is simply an aneroid barometer calibrated to read in feet instead of inches of mercury. The case of the instrument is airtight except for one opening which is connected to the outside air through the static side of the pitot-static tube. The pressure in the static tube and in the case of the instrument which is connected with it is always the atmospheric pressure of the outside air at that point in space. The part of the instrument which is affected by changes of atmospheric pressure is a partially evacuated airtight metal diaphragm mounted in the case. As atmospheric pressure decreases, the diaphragm expands. As atmospheric pressure increases, the diaphragm contracts. Changes in the thickness of the diaphragm are multiplied by a system of levers and gears which actuate three pointers on the face of the instrument. The dial on the face of the instrument is calibrated in feet. Each number indicates one hundred feet for the largest pointer, one thousand feet for the medium pointer and ten thousand feet for the smallest pointer. Also on the face of the instrument is a barometric pressure scale calibrated in inches of mercury and an adjusting knob which can be used to adjust the barometric pressure scale. Some altimeters such as those used by the R.A.F., have their barometric pressure scale calibrated in millibars (1013.5 millibars is equal to 29.22 inches of mercury).

b. USAGE.—In flight the altimeter is one of the most important instruments in the airplane. In addition to affording the pilot a means of clearing obstructions, making low approaches and avoiding other traffic, its indications of pressure when combined with other factors provide a method of determining engine performance and true airspeed. For accomplishing the first three usages the proper method of setting the barometric pressure scale must be known, and in order to use the instrument for the second two usages the pilot must know what is meant by "pressure altitude." "Pressure altitude" is in practical usage, not a pressure, but an altitude. If the barometric pressure scale on the face of the instrument is set to 29.92 the altitude shown on the instrument is the *pressure altitude.* In practice pressure altitude is the altitude of the aircraft over the 29.92 pressure level. Used in conjunction with the temperature at that level, corrections of indicated airspeed to true airspeed; and corrections of indicated altitude to true altitude, can be made on any standard flight computer. When using the altimeter in normal flight or for low approaches or traffic separation, the indicated altitude as shown on the face of the instrument is used. This indicated altitude may be an altitude over sea level, or an altitude above a certain point of terrain, such as an airport. As the pressure of the atmosphere at any point on the earth's surface is constantly changing, the barometric pressure scale must be set so that the instrument will read correctly for the particular pressure obtained at the time and place where the altimeter is to be used.

c. SETTING THE BAROMETRIC SCALE.—In setting the barometric pressure scale, the "Altimeter Setting" system is used almost exclusively. Under this system the scale is set to the corresponding pressure at that particular point *reduced to sea level,* and the altimeter will consequently read the indicated altitude over *sea level.* As a result, upon landing, the altimeter will read the surveyed elevation of the airport over sea level. This setting for the barometric scale is called the "Altimeter Setting." Setting the barometric pressure scale so that the altimeter will read *zero* on landing (except at sea level, of course) is seldom used—but when used, the setting is called "field elevation pressure," which is the pressure obtained at the airport *uncorrected* to sea level. All United States Weather Bureau reports give the "Altimeter Setting" and the pilot need not use nor remember any other system. The pilot should remember, however, that in using "Altimeter Setting," the indicated altitude will be that over *sea level* and not over the terrain, and should therefore allow for proper clearances. He should remember that upon landing, the altimeter will read the *elevation of the field.*

d. ERRORS IN ALTIMETER INDICATIONS.

(1) CHANGES IN PRESSURE.—The altimeter is a pressure instrument. Changes in the altimeter settings along the route to be flown will, if the barometric pressure scale is not reset accordingly, cause the altimeter to read incorrectly. *Lowered* pressures cause the diaphram to expand and result in a reading higher than the correct reading, thus causing the pilot to believe he has *more* altitude than he actually has. Always reset the barometric scale to conform to the changed altimeter settings along the route or at the destination, particularly when going into a region of lowered barometric pressure.

(2) TEMPERATURE.—On the ground, altimeter settings are corrected for temperature, and therefore on low approaches or landings no further corrections by the pilot, for temperature are necessary. However, in flying over mountainous terrain, when the temperatures aloft are abnormally low for the altitude being flown, the altimeter will also give a reading higher than the correct altitude. In such cases ample extra terrain clearance must be allowed for by the pilot—or he may use any standard computer to determine his true altitude. Otherwise he might assume that he has more altitude than he actually has.

(3) SCALE ERROR.—Some altimeters develop a "scale error", which is nothing more than a mechanical error in the instrument indications. This error should be checked on the ground prior to flight by obtaining the latest altimeter setting, and after turning the barometric gradient scale on the face of the instrument to this reading, note if the altimeter reads the correct elevation of the field above sea level. If the error is over 50 feet, the pilot should suspect that he has been given the wrong altimeter setting, or that he has an instrument which is damaged or not functioning properly.

e. THE RADIO ALTIMETER.

(1) The radio altimeter is now in production and may come into increasing use. This instrument indicates the altitude of the aircraft *above the terrain being flown over.* It must *never* be used to control the attitude of the aircraft, as if the pilot attempts to maintain a constant reading on such an instrument, he is attempting to make the aircraft follow the contour of the terrain beneath.

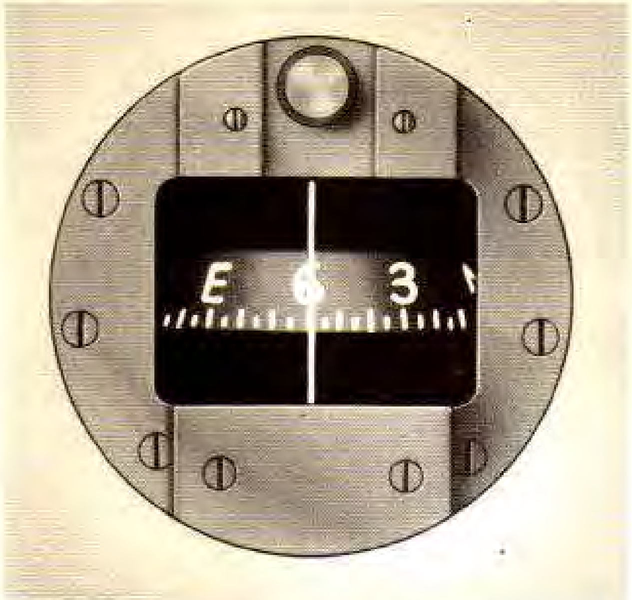


Figure 43—Magnetic Compass

9. THE MAGNETIC COMPASS.

a. DESCRIPTION.—Any magnetized needle, if freely suspended, will tend to line up parallel to the earth's magnetic field. This principle is utilized in the design and construction of the magnetic compass used in aircraft. The "pilot's type" magnetic compass is actuated by bar magnets mounted in a frame. Attached to this frame is the graduated compass card. This assembly is pivoted on a low friction bearing at a point above its center of gravity in such a manner that it will balance horizontally. Thus, the assembly is free to line itself up with the earth's magnetic field. The case of the compass is filled with a liquid, serving to dampen the oscillations of the card assembly in rough air and to reduce the friction at the pivot. Temperature affects the performance of the compass. Very low temperatures, with resulting increased viscosity of the damping fluid will result in sluggish operation. However, very high temperatures seldom decrease the viscosity enough to cause an appreciable difference in the performance of the compass. The indications of the compass card are read against a "lubber line" on the face of the instrument, representing the fore and aft axis of the aircraft. Because the weight of the compass card assembly is great compared to the effect of the earth's magnetic field thereon, the compass will start to change direction slowly, and will "overswing" once it has started to move. Also, movement of the liquid in the case in rough air and in turns will cause the indications to vary temporarily. This is known as "swirl."

b. VARIATION.—The compass can be used in practice as a direction indicator only by knowing the relationship between its indications and true geographic directions. The true and magnetic north do not coincide and the difference between the true north and the direction in which a compass (affected only by the earth's magnetic field) points is termed "variation." When the compass points west of true north, the variation is *West.* When the compass points east of true north, the variation is *East.* Magnetic variation is indicated on any chart used for air navigation. "Variation" at any region may change from year to year in small amounts, but this change is inconsequential as far as air navigation is concerned, except in the case of some of the older charts of the arctic regions, which should be used with care by the pilot. Various schemes have been devised for remembering how to apply the variation, either westerly or easterly, to convert true directions to magnetic directions. The simplest and easiest to remember of these rules is as follows: "East is least and West is best" or "East is minus, West is plus", which means to convert a true course to a magnetic course, *subtract* easterly variation or *add* westerly variation. However, when converting magnetic bearings to true bearings, (as in radio direction finding) *ADD* easterly variation and *SUBTRACT* westerly variation from the magnetic bearing.

c. DEVIATION.—The indications of the compass are also affected by the distortion of the earth's magnetic field induced by the magnetic properties of the iron and wiring contained in the aircraft's structure. This is known as deviation. Consequently, the compass must be corrected by adjusting the "compensating magnets" which are part of the instrument until this error is reduced to a minimum. This correction can be made on the ground and is known as "swinging the compass." Any deviation which cannot be compensated by adjusting these magnets is entered on the "Compass Correction Card" mounted on the aircraft instrument panel near the compass. The pilot must make corrections as indicated on this card. Deviation in any aircraft may change from time to time, and it is necessary to re-compensate the magnetic compass at regular intervals.

d. ERRORS OF THE COMPASS IN FLIGHT.—Whenever the compass card is tilted to the eastward or westward it is acted upon by the vertical component of the earth's magnetic force and is rotated so as to give a false reading. In the magnetic compass the vertical component exerts its greatest downward pull at the north-seeking end of the card in north latitudes and at the south-seeking end in south latitudes. In either case the force causing rotation will be the greatest when the card is tilted about the N-S line; that is, when either the east or west side of the card is depressed. This tilt of the card will occur when an aircraft headed north or south turns toward the east or west (northerly turning error) and when an aircraft headed east or west speeds up or slows down (acceleration error).

(1) NORTHERLY TURNING ERROR.

(*a*) With aircraft on *northerly* heading, and when turning toward east or west—the indications of the compass *will lag* or indicate a turn in opposite direction.

(*b*) With aircraft on a *southerly* heading, and when turning toward east or west—the indications of the compass *lead* the turn and indicate a greater amount of turn.

(*c*) With aircraft on an *east or west* heading, no error is apparent while turning toward north or south.

(2) ACCELERATION ERROR (CLIMB OR DIVE, DECREASE OR INCREASE IN AIRSPEED).

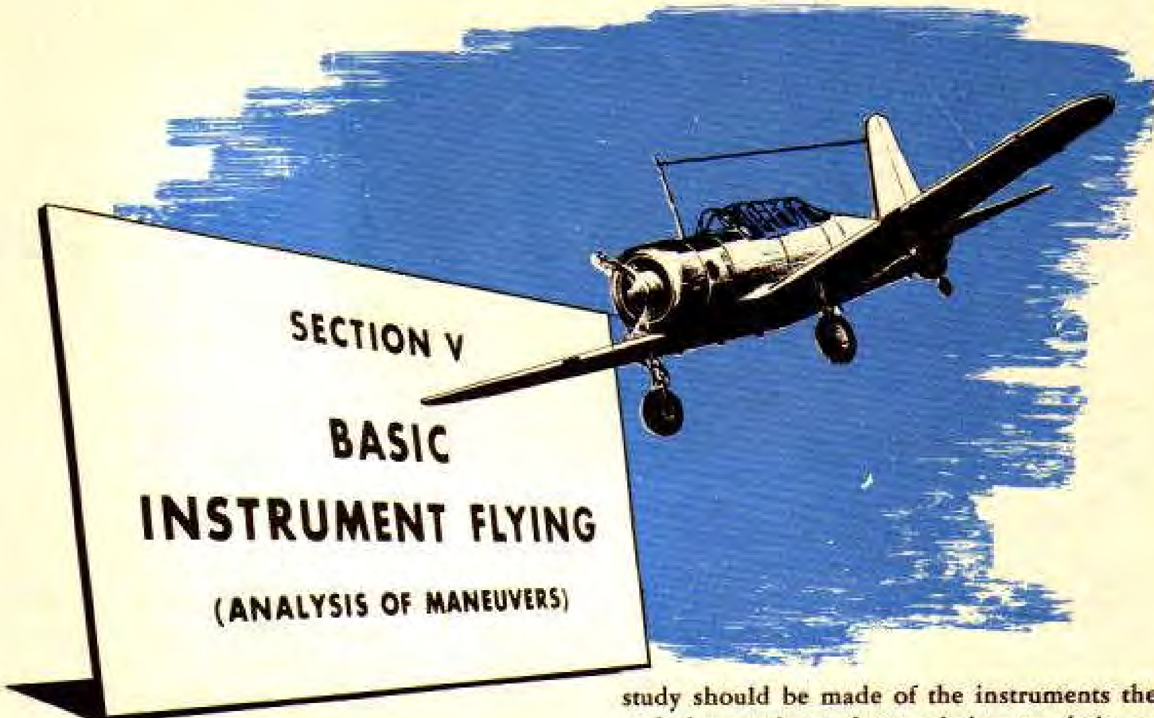
(*a*) With aircraft on *east or west* heading, *a dive* will cause compass to indicate a turn toward *north.*

(*b*) With aircraft on *east or west* heading, *a climb* will cause compass to indicate a turn toward *south.*

(*c*) With aircraft on a *north or south* heading, no error is apparent when climbing or diving.

(3) The above "errors" are true in north latitudes, and are reversed in southern latitudes. At or near the equator these errors disappear.

MINIMIZING ERRORS.—It will be apparent from The above that the compass should be read only when the airplane is flying straight and level at a constant speed. By reading the compass only under these conditions errors can be held to a minimum.



1. GENERAL.

DEFINITION.—By basic instrument flying is meant the actual operation of the aircraft on all the instruments and without reference to radio flying or navigational flying. The material in this chapter is an analysis of the maneuvers involved in basic instrument flying, not a course of instruction. The course of instruction or syllabus is given fully in Part II of this Technical Order.

b. PURPOSE.—The chapter is developed so that each maneuver commonly performed by a pilot learning to fly by instruments is discussed in a separate section. The sections contain a brief summary of the practical aerodynamics relating to the maneuver, the proper manner of execution of the maneuver, and the common faults usually encountered. The analysis will in no way take the place of a flight instructor or of practice in the air. It is aimed at shortening the time of instruction by giving the instructor and student in advance of his flight period the fundamental facts which they must know and use in flight. Prior to undertaking the basic course and during the time allotted for ground school while taking the course, a study should be made of the instruments themselves and the pertinent facts relating to their operation. (See Section IV.)

c. One of the most important things for a pilot flying instruments to do is to make an *adequate* cockpit check of the flight instruments prior to take-off. *A standard check is given in the chapter on preflight familiarization in the Instructors Syllabus comprising Part II of this manual. All pilots should memorize this check and use it in every case where instrument flying is to be done.*

2. STRAIGHT AND LEVEL FLIGHT.

a. FORE AND AFT CONTROL.

(1) When speaking in terms of attitude in relation to fore and aft control we mean the angular difference between the longitudinal axis of the aircraft and the true horizon.

(2) The attitude of an aircraft for level flight will vary with airspeed. There will be several degrees change in the angle of attack necessary to maintain constant lift with changing airspeeds. The aircraft will fly nose-high at low speeds. The attitude of the aircraft for level flight will also change with differences in load, the angle of attack having to be increased with increased load. The attitude for level flight will also change with differences in air density, the angle of attack having to be increased as the air becomes thinner, at high altitudes or at high air temperatures.

(3) The real or artificial horizon merely shows that an approximately correct attitude has been assumed and permits the pilot to hold that attitude constant under changing power or airspeed conditions. The pilot cannot know in advance exactly the correct attitude in which to place the aircraft under any given set of conditions. This must be determined by observing the movement or lack of movement of the altimeter when the approximate attitude has been reached.

(4) Changes in pitch attitude, when the aircraft has been trimmed, may usually be made with very small movements of the elevators, unless extreme turbulence is encountered.

(5) Maintaining a level flight attitude with changing power or airspeed sometimes requires considerable use of the elevators. As an example, with increasing airspeed the aircraft will climb without any movement of the elevators or the elevator trim tab. An increase of either power or airspeed tends to throw the aircraft into a nose-high position. The opposite effect will occur with reduced airspeed or reduced power, and the aircraft will tend to go into a dive. Considerable forward or backward movements of the elevator controls may be required to counteract this tendency of the aircraft to change attitude with changing airspeed or changing power.

(6) A pilot, by watching the trend of the altimeter movements, can judge fairly closely whether or not the correct attitide has been assumed. For every movement of the altimeter corrective action is taken by changing the attitude of the aircraft with the elevators. If altitude is being gained, the nose is too high and should be lowered. If altitude is being lost, the nose is too low and should be raised. If corrective action is taken promptly, small pressures on the controls, causing small changes in altitude, should be sufficient. In changing attitude with reference to the altimeter, be sure to make allowances for the fact that the aircraft may have considerable vertical momentum, which will carry it either up or down for a short time after the attitude has been changed. If the correct attitude for level flight has been assumed, this momentum will fall off gradually to zero. This will not apply, of course, in sustained up or down drafts.

(7) The artificial horizon is of great assistance in assuming and maintaining a level flight attitude. With it the pilot can put the nose of the aircraft on the horizon and hold it there, irrespective of changing pressures on the controls. He can then make small changes in the attitude as indicated by the trend of the altimeter. Once the position of the nose of the aircraft for level flight has been found, the same altitude can be maintained within a few feet in smooth air by *small* changes in the attitude as indicated on the artificial horizon. This will be easier if the miniature aircraft is adjusted so that the top of its wing is level with the top of the horizon bar, or by keeping the dot in the center of the miniature aircraft centered on the horizon bar. In normally smooth air, if altitude is gained when the miniature aircraft indicates level flight, the indication is obviously wrong and should be corrected by raising the miniature aircraft slightly with the setting knob. If the aircraft is losing altitude, the miniature aircraft should be lowered slightly. In each case, the miniature aircraft must be returned to its proper position on the horizon bar by use of the elevators and ailerons after the correct setting has been found.

b. HOLDING A CONSTANT AIRSPEED.—With a given power setting and a constant attitude the aircraft will fly level at only one indicated airspeed in calm air. In rough air, regulate all diving, climbing or level flight altitudes by flying a reasonably constant airspeed. Use the elevator trim tab to take the pressure off the controls so that the aircraft will fly level, hands-off. It will then be easier to make the very slight changes in pressure on the stick required to keep the altitude constant.

***Note on use of rate of climb indicator:* The vertical accelerations for small changes in longitudinal attitude of high speed aircraft are so great, that the apparent lag of the rate of climb indicator makes this instrument practically useless for maintaining level flight. The needle moves up and down to extreme readings with little or no apparent change in attitude.**

c. COMMON FAULTS.

(1) Overcontrolling with the elevators which results from not realizing that small changes in attitude are sufficient to maintain level flight, and not taking into account the fact that the aircraft has vertical momentum which will carry it up or down for a short time after a change in attitude has been made.

(2) Failure to use trim tab to take the pressure off the controls when necessary.

(3) Failure to refer frequently to the altimeter and failure to take immediate corrective action once it has moved, unless in very rough air.

(4) Failure to exert forward pressure on the stick with increasing airspeed or power, or to exert backward pressure on the stick with decreasing airspeed or power, in order to maintain a level flight attitude.

(5) Failure to fly a reasonably constant airspeed in rough air regardless of the altimeter movements.

d. DIRECTIONAL CONTROL: *Reasons why an aircraft turns from straight flight.*

(1) Improper trim of an aircraft will cause it to turn. If a stable aircraft is correctly trimmed, it should fly straight in smooth air. An incorrect setting of either the rudder or aileron trim tab will be reflected in the tendency of one wing to drop, with a result that the aircraft will start to turn (unless the aileron and rudder trim tabs compensate to produce a slip on a constant heading). Incorrect setting of the rudder trim tab will result in a tendency to skid gradually out of a straight flight path. A skid, however, will usually also cause the aircraft to bank due to one wing being speeded up with a resultant increased lift on that wing. With the aircraft banked, part of the lift is toward the center of the turn.

(2) An aircraft may turn as a result of pressures unconsciously applied to the controls by a pilot who is tense. A common example of this occurs when a tense pilot unconsciously exerts unequal pressure on the rudder pedals, causing the aircraft to skid and then bank and turn.

(3) Rough air will cause the aircraft to turn from straight flight as it will often rock the wings of an aircraft out of the horizontal. This may be seen either on the artificial horizon or on the ball bank indicator. The resulting bank may then cause the aircraft to turn. The aircraft may also be yawed as a result of gusts of rough air. The result of the above movements will be a momentary displacement from straight flight, while, if the gust is sufficiently sustained, the aircraft will be banked with the result that it will turn. In normal flight, the yawing effect of rough air will be indicated on the turn indicator by quick movements on either side of neutral. If a bank and turn results, the turn indicator will indicate more movement on one side of neutral than on the other.

(4) The directional gyro and the turn needle both indicate when the aircraft is turning. The artificial horizon and the ball bank indicator show the cause of the turn. When the aircraft is flying straight, its wings are usually approximately level. This is true unless the ball bank indicator is displaced, indicating that the aircraft is slipping or skidding on a constant heading. Any turning of the aircraft as shown on the directional gyro and turn indicator is usually the result of the banking of the aircraft. Whether it is banked or not can be shown definitely by the artificial horizon, if slipped or skidded, by displacement of the ball bank.

(5) By reference to the artificial horizon, keep the wings level by the use of ailerons. When using the ailerons to hold the wings in this position use enough rudder to keep the aircraft from slipping and skidding. Trim the aircraft so that it will fly straight by itself. Use the trim tabs as necessary to take the pressure off the controls, especially the rudder, for changed conditions of flight. In single engine aircraft when the airspeed or power increases, more right rudder is usually required to maintain straight flight, and vice versa. This is due to torque.

(6) If the aircraft starts to turn, it may be assumed that the wing on the inside of the turn is dropping. Even in skidded turns the wing to the inside of the turn will tend to drop because of decreased speed relative to the outside wing, unless this skid is eliminated and the wing is picked up by positive aileron action.

(7) Do not try to stop a turn by use of the rudder alone, except for single-engine recovery on twin-engine aircraft. If this is done, especially after an instrument take-off, the aircraft will go into a slip which, at low altitudes, might be dangerous. Use the controls in exactly the same manner as in contact flight and level the wings by the coordinated use of

ailerons and rudder. When the turn has been stopped, release the pressure on the ailerons and rudder so that the aircraft will resume its normal flight without banking in the opposite direction.

(8) A constant heading is maintained primarily by watching the directional gyro and by keeping the wings level with the artificial horizon. They are particularly useful in maintaining a heading in rough air. If through carelessness, or rough air, the aircraft gets off its heading, take positive action to return it to the desired heading promptly by banking and turning the aircraft as in normal contact flight. For ease of flying at cruising altitudes, very slight deviations of the directional gyro may be corrected by use of rudder or ailerons alone. For instance, only a constant gyro heading and a constant airspeed need be held for "relaxed" flight. The turn indicator must be used if the directional gyro is not operating. Hold a constant course through keeping the turn indicator centered by coordinated use of ailerons and rudder and check the heading on the compass. In rough air, if oscillations are consistently to one side of the neutral, the aircraft is banking, and positive action should be taken to level the wings.

(9) Common Faults.

(*a*) Attempting to recover from a turn by use of rudder without ailerons (except one engine failure on twin-engine aircraft).

(*b*) Failure to check the directional gyro frequently to see whether the aircraft has drifted off course.

(*c*) Failure to take corrective action promptly to return to the desired course.

(*d*) Failure to keep turn and bank indicator as nearly centered as possible in rough air, allowing fluctuation errors to average up.

(*e*) Failure to trim aircraft properly.

(*f*) Tendency of the pilot to exert unbalanced pressures on the controls, particularly the rudder, due to muscular tension.

3. NORMAL LEVEL TURNS.

a. RELATION BETWEEN ANGLE OF BANK AND RATE OF TURN AT ANY GIVEN AIRSPEED.—The angle of bank of an aircraft governs the rate of turn. The greater the angle of bank, the greater the rate of turn. A close relationship between the two will exist, unless the aircraft is being slipped or skidded by heavy application of rudder. Thus, when the ball bank indicator is approximately centered, the turn needle and the artificial horizon both indicate different aspects of the maneuver.

b. THE SLIP AND SKID.—A skid will increase the rate of turn for a given angle of bank. A slip will decrease the rate of turn for the same angle of bank. In a skid the aircraft is being turned both by the bank of the wings and by the propeller thrust acting inward from rudder action, and consequently it turns faster than it would were it acted on by the lift of the wings alone. In a slip, the aircraft is prevented from turning at the rate it should turn for any given angle of bank by the rudder. Thus, the rudder may cause a slight change in the rate of turn at this given angle of bank. Correcting for a slip or skid will thus vary the rate of turn. Be prepared to vary the angle of bank if it is desired to keep the rate of turn constant while correcting for a slip or a skid.

c. To correct for a slip or a skid, use the rudder to bring the ball bank indicator to the center. (The ball bank indicator is the only instrument which shows skidding or slipping.) Use inside rudder to correct for a slip, decreasing the angle of bank if the same rate of turn is to be maintained. Use outside, or less inside, rudder to correct for a skid, increasing the angle of bank if the same rate of turn is to be maintained.

d. USING THE CONTROLS.

(1) To maintain a constant rate of turn with increasing airspeeds, the angle of bank must be increased. This is of particular importance in flying high speed aircraft on the turn indicator needle. IMPORTANT: At speeds in excess of 200 m.p.h., do not exceed one-half standard rate turns. That is, do not turn at a rate greater than 1½° per second. Any very steep bank may be dangerous for the inexperienced pilot when actually flying on instruments.

(2) WHAT IS MEANT BY COORDINATED USE OF AILERONS AND RUDDER.—Frequent mention is made of "coordination" and "coordinated use of ailerons and rudder" in this technical order and elsewhere. This means that pressures are applied to these two controls *simultaneously*. Good coordination requires that pressures be applied to stick and rudder, so that the aircraft neither skids nor slips, that is, the ball bank indicator is not displaced.

(3) Roll in and out of a turn using a positive movement of the aileron control, coordinated with the rudder. If rudder is not used correctly, note that on entry into the turn the aircraft slips and on recovery the aircraft skids. This is due to aileron drag. To demonstrate aileron drag, raise the nose and reduce the airspeed to about 30 m.p.h. above the stalling speed and hold the rudder pedals absolutely stiff. Then apply aileron first right and then left and watch the nose of the aircraft swing in the opposite direction of the applied ailerons. If at all times the aileron control is applied smoothly and easily, the slip and skid caused by aileron drag will be kept at a minimum.

(4) Use of the rudder. In slow aircraft the required rudder pressures are surprisingly small, even at the start of the turn. In fast aircraft a great deal more pressure is required, and turning is effected almost entirely by aileron control.

(5) To start a turn, apply a steady coordinated pressure on the ailerons and rudder in the direction of the desired turn. Watch the change in attitude of the aircraft by watching the increase in bank on the artificial horizon and the increase of rate of turn on the turn indicator. Keep the pressure on the controls until the desired angle of bank or rate of turn is established and then use ailerons and rudder to stop the tendency of the aircraft to continue to increase its bank and rate of turn.

(6) When the desired angle of bank has been attained and the aircraft starts to turn, back pressure must be exerted on the controls to hold a constant altitude. The amount of this pressure will depend on the angle of bank. Beyond a 20° bank, the stick pressures increase rapidly. Accurate control of the fore and aft attitude can be accomplished by reference to the altimeter. Watch the turn needle and altimeter closely and the instant the aircraft starts to lose altitude, lift the nose slightly, controlling the angle of bank and rate of turn by use of the turn needle.

(7) Refer to the altimeter frequently and take immediate corrective action with the elevators if it starts to move. Fore and aft control can be maintained easily with reference to this instrument. Corrective action must be taken promptly, particularly if altitude is being lost.

(8) The Airspeed meter can be used as a secondary reference for fore and aft control provided the level flight airspeed at the same power has been established.

In moderate turns (under 20°) this cruising airspeed will be reduced only slightly if the same altitude is maintained.

(9) During the turn use only such rudder pressure as is necessary to keep the aircraft from slipping or skidding. Frequently check the altimeter to insure that proper fore and aft control has been maintained.

(10) Hold the angle of bank constant by keeping the rate of turn constant. By doing so, the ability to coordinate the controls, to react quickly to changes in the attitude of the aircraft, and to fly accurately and well, is acquired.

(11) Check your gyro headings during the turn. Be ready to come out of the turn before the desired heading has been reached.

(12) To come out on a heading, start taking off bank in advance of reaching the heading. The time required to return to straight flight from a turn depends on the angle of bank, the weight of the aircraft, and the amount of pressure exerted on the controls.

(13) To come out of a turn, apply coordinated aileron and rudder pressure in the opposite direction to the turn and gradually ease off back pressure on the stick. (In rolling out of a steep turn it is necessary to exert definite forward pressure on the stick.) Then watch the change in attitude by noting the decrease of bank on the artificial horizon and the decrease of rate of turn on the turn indicator. For fore and aft control, the center of the miniature aircraft may be kept on the horizon line, but if the altimeter starts to move, make necessary corrections with the elevators immediately.

(14) Timed turns. Timed turns are necessary only if the directional gyro is inoperative. Then the turn needle must be relied on as follows: When flying at any airspeed in making turns where the change of direction is less than 20°, turn at the rate of 1½° per second. This will be either a one-half needle width turn or a one needle width displacement of the turn needle, depending upon the calibration of turn indicator being used. At airspeeds under 200 m.p.h., make all other turns at 3° per second. Time the turn from the *start* of entering the bank to the *start* of the recovery. Make the start and recovery at the same rate. With slow aircraft the rudder may be used to exactly control the rate of turn and to hold the turn needle steady in the position required for a timed turn. The rate of the turn may be increased or decreased by banking action of the ailerons. If the ball bank indicator is not centered, push rudder on the side it is off, to compensate for the skid or slip, being careful not to over bank.

(15) COMMON FAULTS.

(*a*) Too much rudder pressure at start of turn, during the turn or on recovery.

(*b*) Back pressure on stick applied too early with the result that the nose of the aircraft is not on the horizon (as shown by the dot in the center of the miniature aircraft not being exactly centered or slightly above the horizon bar) and by altitude being lost or gained.

(*c*) Too little back pressure on stick during the turn with the result that altitude is lost due to the nose of the aircraft falling below the horizon.

(*d*) Failure to remove back pressure, or exert forward pressure, on the stick during recovery, with the result that the nose comes too far above the horizon, as shown by the miniature aircraft being slightly above the horizon bar and by gaining of altitude.

(*e*) Angle of bank varying, due to inattention to turn and bank indicator. This will result in the altitude control being uncertain due to the fact that with varying bank the fore and aft stick pressures are constantly changing.

(*f*) Failure to check altimeter frequently and to take corrective action immediately.

(*g*) Slipping or skidding through the turn as a result of too much attention to the angle of bank and rate of turn and too little attention to the ball bank indicator.

(*h*) Allowing the aircraft to overbank.

4. STEEPLY BANKED TURNS.

a. GENERAL.

(1) A steeply banked turn is similar, except in degree, to a moderately banked turn. A turn with a bank in excess of 40° is often referred to as a "steeply banked turn." The execution of such a turn, while seldom necessary or advisable in instrument flight, is a good test of the ability of the pilot to control an aircraft smoothly and to react quickly to changes in attitude.

(2) There are many misconceptions about steep turns, such as the one about the alleged "reversed control." It must be emphasized that the action of the aircraft and the use of the controls in steep banks is exactly the same, in principle, as in more moderately banked turns.

b. FORE AND AFT ATTITUDE.

(1) Fore and aft attitude during the turn varies with the angle of bank and airspeed. As the bank of the aircraft is increased, the vertical component of lift on the wings must be increased by increasing the angle of the attack. This is shown by the nose-high altitude of the miniature aircraft on the artificial horizon. As the bank is increased, the drag increases and the airspeed falls off. This necessitates a gradual increase in the nose-high attitude of the aircraft until a stable airspeed has been reached.

(2) The pilot should be prepared to exert considerable back pressure on the stick to maintain a constant altitude in a steep bank. The amount of back pressure depends upon the angle of bank and consequently the rate of turn of the aircraft. Aileron and rudder pressures are constant throughout a steep turn. In entering the turn and in recovering to straight flight, they need be no greater than in starting and recovering from a moderately banked turn, but more time is required for acquiring and taking off bank.

(3) The power available plays an important part in a steep turn. Due to the decreased component of lift and consequently the increased drag encountered in a steep turn, the airspeed will decrease near the danger point, unless enough power is available to overcome the increased drag. An aircraft's reserve power determines how steeply it can turn. If an aircraft is flying level at full power, it cannot execute a steep turn at the same airspeed without losing altitude. In aircraft with a very high wing loading, extremely steep banks, at any airspeed, may cause a very dangerous high speed stall, or a vertical reversement, which may cause the inexperienced pilot serious trouble, even complete loss of control.

c. EXECUTION OF A STEEP TURN.

(1) Enter steep turns exactly as in more moderate turns. Use coordinated aileron and rudder pressure to make the aircraft bank. As the angle of bank increases, apply a steadily increasing back pressure on the stick. When the desired angle of bank has been reached, neutralize the aileron and rudder controls.

(2) Keep the nose slightly high at all times. Control of the bank of the aircraft in a steep turn is relatively easy. However, the beginner will have some difficulty at first with altitude control because he will allow the aircraft to slip by trying to hold the nose up with so-called "top rudder" rather than applying enough back pressure on the stick. He should check the altimeter frequently and correct immediately for any change in altitude. In rolling into the turn, the pilot should watch carefully so that the nose stays right on the horizon. As the aircraft starts to turn, he should be prepared to raise the nose of the aircraft slightly above the horizon. He should pay close attention to the attitude of the miniature aircraft on the artificial horizon and never let the nose fall below the horizon.

(3) If the aircraft starts to lose altitude, a considerable change in pitch angle will be required to regain altitude. In a steep turn the aircraft will descend rapidly with small reductions in the angle of attack. In correcting for this condition, do not jerk back on the stick, to do so may cause the aircraft to stall, even at high airspeeds.

(4) The angle of bank should be held constant during the turn. The pilot should exercise care not to increase the angle of bank when he pulls back on the stick to compensate for a loss of altitude. This is a common error. At its worst, it may result in a dangerous, tight, diving spiral, which is responsible for killing more pilots than all the spins ever done. *If in trouble, take off bank, get the nose down, and get back to a safe airspeed.*

(5) Recover to straight flight exactly as with more moderate turns. Use coordinated aileron and rudder pressure to take off bank and level the wings. As the angle of bank is reduced, the backward pressure on the stick must be reduced. When the wings become level, the backward pressure can be completely relaxed. In some aircraft it is necessary to exert forward pressure on the stick to reduce the angle of attack necessary for level flight immediately after coming out of a turn. Therefore, care must be taken to check the altimeter and make appropriate changes in the attitude if altitude is being gained. The natural tendency is to

keep the nose above the horizon during the recovery with a result that the aircraft gains altitude.

(6) Pay no attention to sensation during steep turns and recoveries. In a steep turn, a pilot normally has a sensation of doing a loop. On recovery, he has a sensation of pushing over into a dive. These sensations may cause faulty control unless they are disregarded by the pilot.

(7) COMMON FAULTS.

(*a*) Not holding altitude as a result of failure to keep the nose of the aircraft on or above the horizon or not increasing power for the turn. Pilots often are too eager to raise the nose of the aircraft on entering into a turn and as a result gain altitude. They should follow the indications of the altimeter closely. When the altimeter *starts* to show a gain or loss of altitude, the nose should be lowered or raised immediately.

(*b*) Failure to hold the angle of bank constant and particularly letting the angle of bank increase when increasing the pitch to correct a nose-down position.

(*c*) Failure to keep a safe airspeed in all turns.

(*d*) Gaining altitude on recovery from the turn as a result of failure to release back pressure on the stick, or in some aircraft, as a result of failing to exert sufficient forward pressure on the stick.

5. CLIMBS.

a. GENERAL.

(1) At a predetermined power setting, there is one attitude of the aircraft which will give the most efficient climbing airspeed under any given set of conditions. If the attitude is held constant, the aircraft will climb at a constant rate once the airspeed has become constant. If the nose of the aircraft is raised above this attitude, the rate of climb will increase up to a point where the aircraft starts to "mush." Then the airspeed will fall off, and the rate of climb indicator and altimeter will start down.

(2) Since the correct attitude depends on several variable conditions, it can only be approximated by the pilot. Only by reference to the airspeed meter can the pilot determine the exact attitude to maintain the desired climbing airspeed. Since climbs are customarily made at constant predetermined airspeed, the attitude of the aircraft may be determined and controlled with reference to the indications of the airspeed meter.

b. ENTERING A CLIMB.

(1) Raise the nose of the aircraft and set power for climb. If the artificial horizon is used, hold the nose of the aircraft at the estimated correct attitude. Hold it constant, irrespective of changing stick pressures. The airspeed will start to fall off immediately, since a part of the thrust is being utilized in climbing the aircraft. As the aircraft's momentum dissipates, the airspeed will gradually approach a steady reading. If the airspeed does not appear to be approaching the correct reading, make such small changes in the attitude as may be required to bring it to the correct reading. When a change in attitude has been made, the pilot should watch the trend of the airspeed.

(2) With practice, the pilot can easily make similar changes in attitude without the use of artificial horizon. In adjusting the attitude with reference to the airspeed indicator, moderate use of the elevators will be sufficient to change from cruising to climbing attitude. A slow rate of change of airspeed will mean that the desired small change in the attitude has taken place. Rapid changes in airspeed normally indicate that too radical a change of attitude has taken place, and may indicate that a dangerously nose-high attitude has been assumed.

(3) Use of the trim tabs varies with different aircraft. Slight change of the elevator trim tab from level flight setting may be sufficient to put the aircraft into a climb at increased power. The increase in power and

the resulting increased down-wash on the tail surfaces will tend to make some aircraft hold a nose-high attitude. With single-engine aircraft right rudder pressure must be increased as power is increased and also when the aircraft's speed falls off. If the climb is to be extended for any length of time, the rudder trim tab should be used to equalize the rudder pressure.

(4) Inasmuch as some changes in attitude will have to be made during the climb to maintain a constant airspeed, they should be made promptly by small corrections with the elevators.

(5) Rate of climb indicator is difficult to use for control due to its apparent lag.

(6) COMMON FAULTS.

(*a*) Placing aircraft in dangerously nose-high attitude, due to failure to allow time for aircraft to lose momentum and for the airspeed to fall off.

(*b*) When flying without the artificial horizon, making radical initial changes in attitude when controls should be used lightly to make the required small changes in attitude—or overcontrolling.

(*c*) Failure to allow for changing stick pressures as airspeed falls off.

(*d*) Failure to take prompt corrective action whenever airspeed departs from desired value.

(*e*) Failure to use a constant airspeed as the deciding factor of the correct attitude.

6. FROM A CLIMB TO LEVEL CRUISING FLIGHT.

a. PROCEDURE.—First, stop upward momentum of the aircraft by reducing angle of attack. Before reaching the desired altitude start lowering the nose of the aircraft to reduce the angle of attack and thus reduce the lift. The vertical distance required to stop the upward momentum will depend largely on the weight and speed of the aircraft. Fly at constant altitude while the climbing power accelerates the aircraft to cruising airspeed. On reaching the desired altitude make such changes in the attitude as are necessary to fly level. It will be found that the nose will be high at first, and as the aircraft gradually accelerates, the nose may be lowered until the aircraft is at cruising airspeed. The nose should then be approximately on the horizon. This will require forward pressure on the stick. Use of the trim tab during this period may not be necessary. When cruising airspeed has been reached, throttle back to cruising power and trim the aircraft. It will be found that much of the forward pressure on the stick will be reduced by reducing the power and that a very small movement of the trim tab may be sufficient.

b. METHOD OF LEVELING OFF WITH LARGE AIRCRAFT.—With large aircraft, the following method of leveling off may prove best. Ascend to 200 or 500 feet above the desired altitude and adjust throttles, propeller pitch, cowl flaps, and mixture controls to cruising positions. Then move stick or control column forward and dive slightly to pick up cruising airspeed by the time the desired altitude is reached. When this altitude is reached, set the elevator, rudder, and aileron trim tabs for level flight. This procedure will usually prevent any tendency of the plane to "drag" its tail in cruising.

c. COMMON FAULTS.

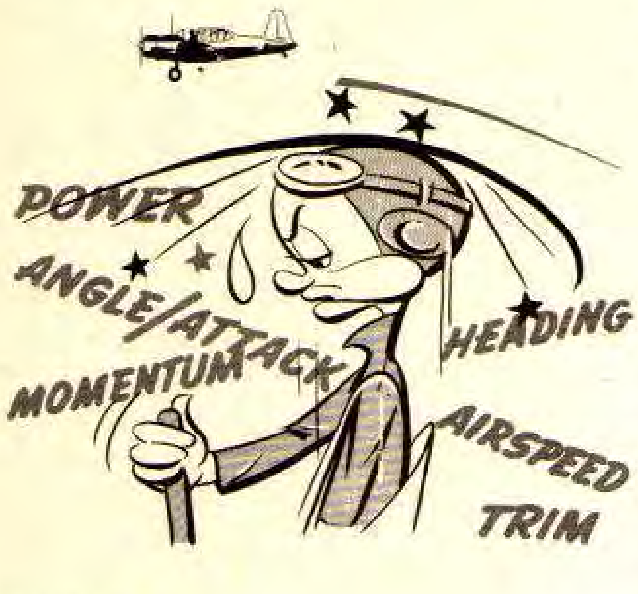
(1) Failure to leave on climbing power until cruising airspeed has been gained.

(2) Failure to exert sufficient forward pressure on the stick as the aircraft is accelerating.

(3) Failure to check upward momentum in advance of arriving at desired altitude.

(4) Failure to control heading by not referring to directional gyro.

(5) Failure to adjust trim tabs promptly and smoothly.



7. DESCENTS.

a. GENERAL.

(1) At a constant airspeed the amount of power used will determine the rate of descent. That is, the less power used, the greater will be the rate of descent. The amount of power used will determine the correct attitude to maintain constant airspeed in the descent. The less power used, the more the nose will have to be lowered below the horizon to maintain a constant airspeed.

(2) If the descending airspeed is less than the cruising airspeed, the attitude of the aircraft may have to be changed only slightly from the cruising attitude.

(3) Descents should always be made at constant airspeed. Under those circumstances, the indications of the airspeed indicator govern the attitude of the aircraft.

b. TO ENTER A DESCENT.

(1) First, throttle back to descending power and hold attitude approximately constant until the altimeter indicates a downward trend; then the nose is raised only slightly to hold altitude constant. This will also help slow up the aircraft due to the increase of the angle of attack. The pilot can maintain approximately the same attitude and altitude easily by referring to the artificial horizon. As the airspeed falls off, the aircraft will have a tendency to fall into a nose-low position due to the decreased down-wash on the tail surfaces. Firm back pressure on the stick or considerable elevator trim tab must be used to check this tendency. If the altitude is held constant, the airspeed will gradually fall off and will gradually approach a steady value as the aircraft's momentum is dissipated.

(2) In controlling the attitude without the use of the artificial horizon, the pilot must be prepared to use steadily increasing back pressure on the stick to obtain the desired steady decrease in airspeed. The pilot must consciously counteract the tendency to relax pressure on the stick, in order to prevent the aircraft from going into a dive.

(3) The pilot should promptly reset the elevator trim tab to reduce the pressure on the stick. A gradual backward movement of the trim tab may accomplish the desired result of steadily reducing the airspeed more smoothly than a backward movement on the stick. On single-engine aircraft rudder trim tab may be necessary to check the tendency of the nose to yaw to the right because of the reduced slipstream effect when the power is reduced. By the time the airspeed has fallen off to the descending value, the aircraft should be correctly trimmed for the descent. Little further adjustment of the trim tabs will be necessary as the descent is continued.

c. PROCEDURE WHILE IN A DESCENT.

(1) When airspeed is at or near descending airspeed, keep it constant with the elevators. The amount of elevator control depends principally on the amount of power used. Small changes in attitude will usually be sufficient, except with a large reduction in power. The aircraft should be retrimmed to fly hands-off at the desired airspeed during the descent.

(2) Hold the airspeed exactly constant during the descent. Small variations in the airspeed may mean greatly varying rates of descent. Above all, do not let the airspeed vary if the problem is to establish a predetermined rate of descent.

(3) The rate of descent should be controlled by changes in power and not by changes in airspeed. However, with slow aircraft in smooth air, the reading of the rate of climb indicator can be used as a close approximation of the true rate of descent. If the rate of descent is too slow, reduce power; if it is too fast, add power. At the same time make such changes in the attitude of the aircraft as are necessary to keep the airspeed constant, lowering the nose as power is reduced and raising it slightly as power is increased. The one exception to the rule occurs when the rate must be increased or decreased for a very short period of time. Then slight changes in the airspeed may be permitted to increase or decrease the rate of descent.

(4) Predetermined power settings make rate descents easy and accurate. A pilot may, by a little experimenting, determine exactly what throttle setting will give the required rate of descent for a given airspeed. Then when the desired let-down airspeed is reached the descent may be easily accomplished by setting the throttle on the predetermined setting.

d. COMMON FAULTS.

(1) Letting nose drop as power is reduced and airspeed falls off. This is a natural fault as considerable back pressure on the stick must be exerted to keep the nose up, until the aircraft has been retrimmed.

(2) Making radical change in attitude. Pilots seldom realize that the usual descending attitude differs little from level cruising attitude.

(3) Failure to use elevator trim tab promptly to reduce stick load.

(4) When flying without the artificial horizon, failure to use the controls so as to obtain a gradual decrease in airspeed as the aircraft slowly loses its momentum.

(5) Failure to take prompt corrective action whenever airspeed departs from the desired value.

(6) Failure to refer frequently to the directional gyro to hold a constant heading.

(7) Failure to keep the airspeed exactly constant.

(8) Failure to hold a constant altitude while reducing cruising airspeed to descending airspeed.

8. FROM A SLOW AIRSPEED DESCENT TO LEVEL CRUISING FLIGHT.

a. PROCEDURE.

(1) In advance of reaching desired altitude, set power to cruising power. Hold descending attitude as airspeed picks up. The force required to accelerate the aircraft from descending to cruising airspeed is supplied by gravity acting in addition to cruising power. As the aircraft accelerates, forward pressure on the stick must be exerted in order to maintain a descending attitude. The trim tab may be used to take some of the pressure off the stick.

(2) When desired attitude is reached, level aircraft to cruising altitude. If the power is added sufficiently in advance of arriving at the desired altitude, the aircraft will be at cruising airspeed slightly before level flight is to be resumed. Gradually level the aircraft and hold the altitude constant. Reset the trim tabs as required to compensate for pressure on the stick and to counteract any tendency of the aircraft to yaw to the left due to torque as power is increased.

(3) At times, such as in a pull up from a low approach, it may be desired to level off or go into a climb from a slow airspeed descent and maintain level flight or climb at the same airspeed at which you were descending. Under these conditions, open the throttle to the approximate manifold pressure necessary to maintain level flight or to climb at that airspeed. It will be necessary to open the throttle before the desired altitude is reached, so that the downward momentum is checked in sufficient time to prevent going below this altitude. The height above the desired altitude at which the throttle is opened depends upon the weight of the aircraft and the rate of descent. For heavy aircraft and any aircraft at high rates of descent the throttle should be added well in advance of the desired altitude where level flight or the climb is to be started.

b. COMMON FAULTS.

(1) Failure to add throttle sufficiently in advance of arriving at desired altitude before the descent has been checked, and allowing the aircraft to descend below the desired altitude.

(2) Adding too much throttle too far in advance of arriving at the desired altitude with the result that the aircraft levels off or even enters a climb before reaching the desired altitude.

(3) Failure to hold a constant airspeed, as power is added to go into level flight, or climb, after a low approach.

9. CLIMBING AND DESCENDING TURNS.

a. PRECAUTIONS.

(1) Climbing and descending turns must be accurately controlled in instrument flight, since casual flying in such turns is more likely to result in dangerous loss of control than in any other maneuver.

(2) In both climbing and descending turns, the drag of the aircraft is greater than in straight climbs or descents. Consequently, to maintain a constant airspeed either power must be added or the nose must be lowered slightly below the straight climbing or descending attitude. The steeper the bank, the more the nose must be lowered, or the more power must be added to maintain a constant airspeed. The rate of climb will be less in a climbing turn than in a straight climb at the same airspeed and power setting. The rate of descent will be greater in a descending turn than in a straight descent at the same airspeed. Power must be increased in a turn if the same rate of climb or descent is to be maintained as in straight climbs and descents.

(3) The position of the nose of the aircraft must be held constant during entry into the turn. Before commencing the turn, first note the position of the miniature aircraft which gives the desired climbing or descending airspeed. Then bank the wings by use of ailerons and rudder to the desired degree. Hold the center of the miniature aircraft at the same position while the aircraft is being banked, irrespective of changing control pressures.

(4) During the turn, make such changes in attitude as are necessary to keep the airspeed constant. Use sufficient stick pressure to maintain the desired attitude at all times.

(5) *Avoid steeply banked climbing or descending turns while on instruments.*

10. RECOVERIES.

a. UNUSUAL POSITIONS.

(1) An aircraft may be placed in an unusual position under instrument conditions as a result of the confusion, or carelessness of the pilot, or action of excessively turbulent air. In any of these cases, the aircraft will usually do one of two things: it will either fall into a spin or go into a diving spiral, usually a spiral. Recovery from a spin is relatively easy under most conditions. At slow airspeeds the controls are "soft," and the controls can be easily moved. Recovery from a steep diving spiral is usually difficult, due mainly to the confusion and tenseness of the pilot, the extreme control pressures, and the danger of putting excessive stress on the pilot and the aircraft.

(2) Experience has shown that almost every accident that can be attributed to loss of control of an

aircraft on instruments has been caused, not by a spin, but by the aircraft getting into a high speed diving spiral. Every pilot should therefore master the technique of recovering from such a position.

(3) Recoveries are usually made difficult by the extreme tenseness of the pilot. Often a pilot will think that he is using all his strength to move the controls when in effect he is merely working against himself. This is particularly true in the use of the rudder, where a pilot's leg muscles may be so contracted as to make it impossible for him to exert enough pressure on one pedal to overcome the pressure on the other pedal.

(4) The aim of all recoveries must be to resume straight flight at a safe airspeed with the least possible loss of altitude. In all recoveries it must be assumed that neither the artificial horizon nor the directional gyro will be operative and consequently the pilot should be accustomed to recovering from any unusual position by the use of the turn and bank indicator and the airspeed meter.

b. RULES FOR RECOVERY.

(1) Straighten out the aircraft if it is turning. Use firm coordinated aileron and rudder pressure to stop any turning motion, *unless* the turn needle and the ball bank indicator are displaced to the opposite sides and the airspeed is relatively low (probably indicating a spin). The rate of turn of the aircraft will immediately decrease, although the aircraft may be turning so rapidly that the decrease will not be immediately indicated by the turn needle moving from its maximum indication. (The turn needle will show a maximum rate turn for anything over one 360° turn every twenty seconds.) If the spiral is a tight one, you are no doubt turning faster than this, and when recovery action is applied, the turn needle will not indicate such until you slow down the turn below this rate. As the rate of turn becomes less, the airplane will quickly straighten out and the pilot must use care not to overcontrol. He is usually tense, and therefore his tendency is to over-correct and to throw the aircraft into a bank in the opposite direction. Disregard the indications of the ball bank indicator until the turn has been stopped. It may then be centered in the usual manner.

(2) Throttle back immediately if the airspeed is building up; the pilot can avoid the danger of high G pull-outs, blacking out, excessive loss of altitude and general overstress on himself and the aircraft by taking off power when the airspeed is excessive. By throttling bank the picking up of excessive speeds, especially in recovering from positions in which the aircraft is on its back or partially inverted, is avoided.

(3) Do not use the elevators to check excessive speed until the turn has been stopped. Then use them moderately and beware of putting the aircraft into a dangerous nose-high attitude. Any use of the elevators in a turn may tend to increase the rate of turn and to make recovery more difficult. Beware of jerking back on the stick. That may cause the aircraft to stall and snap-roll over upon its back even at high indicated airspeeds. Moderate use of the elevators will usually be sufficient, since a stable aircraft will have a tendency to go from a dive at high airspeed into a dangerously nose-high attitude. Check this tendency by coming forward gradually on the stick to keep the attitude constant the instant the airspeed starts to decrease, indicating that the aircraft is approaching a level flight attitude. This attitude should be held using such forward pressure on the stick as is necessary to check any tendency to climb until the aircraft has lost its momentum and the airspeed has returned to normal cruising. The throttle may then be opened.

(4) If the airspeed is falling off rapidly, the best rule is to push forward on the stick.

(5) SPIN RECOVERY.

(*a*) A spin will usually be indicated by the ball bank indicator being displaced to the outside and the needle to the inside but will mainly be indicated by comparatively low airspeed. This will instantly indicate to the pilot that he should execute a normal spin recovery, using rudder to stop the rotation, and forward pressure on the stick to regain airspeed and finally such back pressure on the stick as is necessary to recover from the dive.

(*b*) Occasionally in a very steep spin the turn indicator and ball bank indicator are displaced to the same side. In this event, the pilot can only assume that he is in a spiral, and he should use both aileron and rudder to recover. This may result in recovery or it may result in the spin slightly flattening out. In the latter case the ball bank indicator will be displaced to the outside of the spin, and the pilot should immediately execute a normal spin recovery as above. In any event the airspeed will drop to a comparatively low airspeed affording a reliable indication to the pilot that he is in a spin, not a spiral.

(*c*) In a spin, since the position of the ball is not a positive indication of a spin or a spiral, it may be well to notice the displacement of rudder pedals. In a spiral the rudder pedals are usually stiff, and are practically aligned with one another. However, in a spin the rudder will usually be full on in the direction of the spin with a softer "feel."

(6) Be sure to disregard your sensations in spin or spiral recoveries. If you do not, you may fall into a steep spiral in the same direction as the spiral from which you recovered. Remember that in almost all cases, a spiral and not a spin results from loss of control on instruments. *Check your airspeed indicator immediately*, and if it is excessive, cut off power and use aileron and rudder until the spiral is straightened out.

11. INSTRUMENT TAKE-OFF.

a. GENERAL.

(1) Instrument take-off technique will vary slightly with different types of aircraft. The following method is deemed best for single-engine aircraft of medium power and stable aerodynamic qualities. In general, the same principle will apply to all aircraft.

(2) The instrument take-off outlined below is purposely performed in approximately a three-point attitude. This will result in a short take-off run and a high initial rate of climb, which will insure certain clearance of obstructions. Instrument take-offs for twin-engine aircraft or when on long, large fields, where the aircraft may be held on the ground longer during the take-off run, will be discussed later in this chapter.

Complete cockpit check *will* be made before the plane is taxied out.

b. PRIOR TO TAKE-OFF.—Make sure that the artificial horizon is uncaged. Then, by means of the adjusting knob on the artificial horizon, set the miniature aircraft so that its wing tips are lined up with the 90 degree markers on the sides of the dial. This will show approximate attitude of the aircraft before take-off.

Be sure that the horizon bar is horizontal before take-off.

Set the rudder trim tab to correct take-off position. Set the elevator trim tab to a slightly tail heavy position. Line the aircraft up in the proper direction for take-off, pull the aircraft straight forward to make certain that the tail wheel is in its proper alignment and locked, if so equipped. Warm up and check engine carefully. Check the operation of all flight instruments, and just prior to opening the throttle, set the directional gyro on zero. Hold the brakes and open the engine to a little more than idling power to prevent possible "loading up" and to insure even, positive acceleration upon take-off. Release the brakes and as the plane starts to roll, open the throttle evenly to maximum take-off power. During the take-off, directional control must be maintained with the rudder and steerable tail wheel, within a maximum of two degrees of the original heading, as indicated on the directional gyro. The important instruments to watch now are the directional gyro and the artificial horizon. As the plane gathers speed down the runway, allow the plane to fly off the ground in a tail low attitude. As the aircraft leaves the ground, allow the airspeed to pick up slowly. Take a little more time than usual to allow the airspeed to build up to its normal climbing speed, making certain that the plane is in a climb all the time. This is important for the "rate of climb" indicator and the altimeter are not accurate enough, at this point, to give a useful reading. In allowing airspeed to increase, never depress the nose of the aircraft enough to cause the rate of climb to assume a negative value.

c. Once the aircraft is airborne, lateral and directional control are maintained by keeping the wings level by the artificial horizon with a cross-check on the turn needle. The wings will stay level until the wheels leave the ground; therefore, the stick should merely be centered until the aircraft becomes airborne. The instant the wheels leave the ground, the pilot should immediately use the "Full Panel" and insure constant and proper climbing attitudes and indications. Any wing-down tendency must be corrected immediately in order to keep accurate directional control.

d. Longitudinal control consists in keeping the take-off attitude constant until one or two hundred feet has been gained, and then very gradually reducing nose-high attitude until airspeed picks up to normal climbing. When normal climbing airspeed has been attained, gradually reduce power to normal climbing values and assume normal climbing attitude. Care must be taken not to lower the nose too quickly at the reduced take-off airspeed, for this may result in serious loss of altitude. The airspeed must have a tendency to increase after take-off but only *very* slowly until all obstructions are well cleared.

e. MULTI-ENGINE INSTRUMENT TAKE-OFFS.—Where more than one engine is involved, it should be remembered that all engines must be checked carefully before take-off. The friction lock on the throttles must be tightened to avoid slipping back of either of them, which would cause uneven power distribution and subsequent "yaw." As most, or all, multi-engine aircraft and tactical single-engine aircraft are equipped with retractable landing gear, it is imperative that the pilot wait until his aircraft is definitely airborne and is constantly indicating a climb before the gear is retracted, else through error, he may lose enough altitude to fly back into the ground or runway. After the gear is retracted, the aircraft must be retrimmed for climb, due to the reduced resistance and shifting of landing gear position, else the angle of attack may increase too sharply. On the other hand, the pilot should not wait too long to retract his gear or too long to gain his single-engine speed.

NOTE

In the case of aircraft equipped with a nosewheel the foregoing procedures are correct except that on take-off the tail of the aircraft usually must be lowered slightly during the take-off run rather than the nose, in order to obtain a positive angle of attack.

f. COMMON FAULTS.

(1) Failure to make an adequate cockpit check of all instruments before take-off.

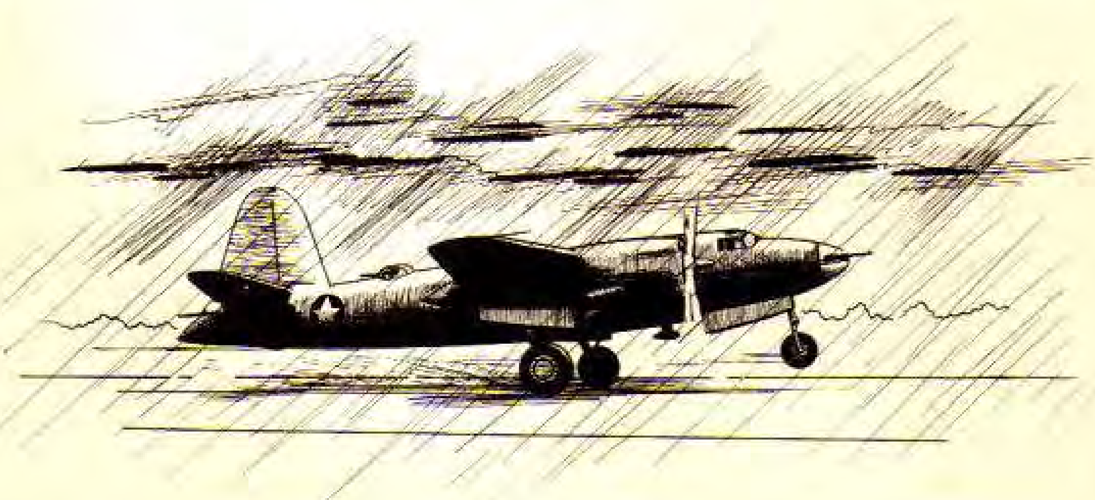
(2) Swerving and failure to maintain accurate directional control on the ground. Remedy is to make small movements of the rudder pedals the instant the directional gyro shows a changed heading and neutralize the rudder after the correction has been made.

(3) Assuming an extreme nose-high attitude immediately following take-off, that is, not maintaining the take-off attitude, thereby inviting a stall.

(4) Tendency to nose-down following take-off so that there is a serious loss of altitude which may result in flying back into the ground. This is one of the most common faults.

(5) Failure to hold the wings level following take-offs as a result of not watching the artificial horizon. This is usually caused by tenseness, which causes the pilot to pull the stick or wheel to one side or the other, or to exert too much pressure on the rudder, which would cause a skid, and consequently a loss in airspeed.

(6) Failure to cross-check on the turn needle and airspeed after the airplane has left the ground.



RESTRICTED

TECHNICAL ORDER NO. 30-100B-1

INSTRUMENT FLYING

ADVANCED

WITH RADIO AIDS

SPECIAL EDITION

FOR DISTRIBUTION TO ALL PILOTS

NOTE: This Technical Order replaces T. O. No. 30-100B-1 dated 1 October 1943.

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15 JANUARY 1944

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PART I

PARTS II and III, Instructor's Syllabi, are not included in this special edition.

PART I

FOREWORD

In the few brief years that comprise the history of aviation many developments have occurred which make the flying of aircraft easier and safer. With each passing day new aids to the pilot are being developed.

Advanced instrument flying consists almost entirely of navigation under instrument conditions, using all types of radio aids available, combined with as much dead reckoning as is necessary to provide for the lack of such aids in combat areas. Successful dead reckoning and the use of radio aids are largely a matter of common sense and good judgment.

A prerequisite of advanced instrument flying is that the pilot already be thoroughly versed in basic instrument flying. That is, he must be able to fly the aircraft satisfactorily by the "full panel" system before he attempts to learn the advanced phases of instrument navigation. For complete information concerning basic instrument flying consult T.O. 30-100 A-1, "Instrument Flying, Basic, Theory and Practice."

SECTION I

ALTIMETER USAGE

1. THE ALTIMETER AND PRESSURE CHANGES.

a. Aeronautical records show any number of aircraft accidents which can only be attributed to the pilot having failed to properly set his altimeter. In the interest of safety, it is absolutely essential that every pilot become familiar with the proper use of this instrument.

b. The altimeter is nothing more than an aneroid barometer with the indicator dial graduated in feet instead of in inches of mercury. Being a barometer, the altimeter gives an indication of altitude corresponding to the existing pressure of the atmosphere surrounding the aircraft. A decrease in pressure of the surrounding air will allow the aneroid cell to expand, and this expansion rotates the pointers on the face of the instrument to indicate a higher altitude. Conversely an increase in pressure surrounding the aircraft compresses the aneroid cell, causing the pointers to indicate a lower altitude. From this a most important rule is derived:

RULE

In flying from an area of relatively high pressure into an area of lowered pressure, the altimeter will indicate an altitude higher than the actual altitude. To correct, reset the altimeter according to the latest "Altimeter Setting" received in flight.

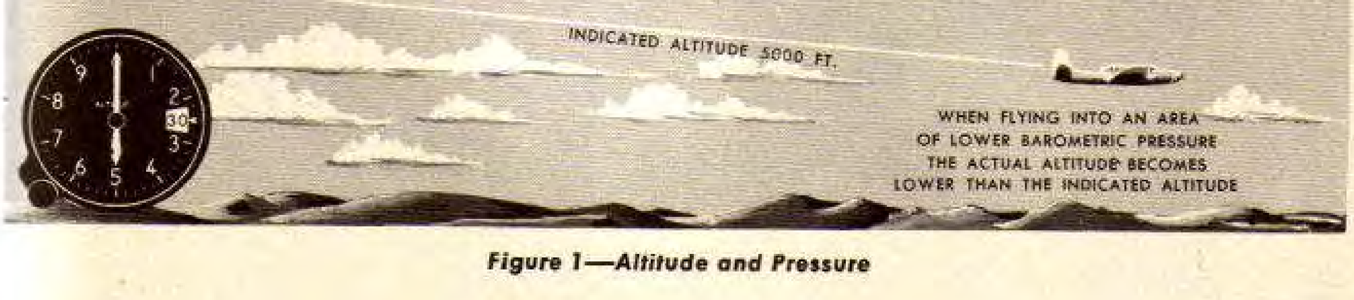


Figure 1—Altitude and Pressure

2. THE ALTIMETER AND TEMPERATURE CHANGES.

The calibration of the altimeter is based on the International Standard Atmosphere which assumes a sea-level pressure of 29.92 inches of mercury at a temperature of 15°C., and a *temperature change with altitude* of approximately 2°C per thousand feet. Since temperature affects air density, this 2°C decrease per thousand foot increase in altitude results in a uniform decrease in pressure with increase in altitude. The altimeter is calibrated on this basis. This "standard atmosphere" seldom exists in nature, but is a close *approximation* of *average* conditions. It follows that any variation from this *average* will cause an incorrect altitude to be indicated although the altimeter has been corrected in accordance with the prevailing altimeter setting. This temperature error is not serious except when low temperatures are encountered over mountainous terrain. Under these conditions the indicated altitude will be considerably higher than the true altitude at which the aircraft is actually flying.

RULE

When flying through air colder than standard, the altimeter will indicate an altitude higher than the actual altitude. Correction for air temperature can be determined by use of a computer or temperature correction chart.

Figure 2—Altitude and Temperature

3. ALTIMETER SETTING.

a. On the face of the instrument will be found a small window with a scale graduated in inches of mercury. These graduations correspond to various barometric pressures. This scale may be rotated by the adjusting knob on the rim of the instrument, so that any normal barometric pressure may be set in the face of the window. This scale is adjusted so that the altimeter will indicate correctly the altitude for different barometric pressures which may be furnished the pilot by the weather station or by radio. In the past few years, a standard method of "setting" the altimeter has been evolved, and should be used at all times. This method is called "Altimeter Setting." It is found on all weather sequences, and is usually furnished the pilot prior to take-off, in flight, and prior to landing.

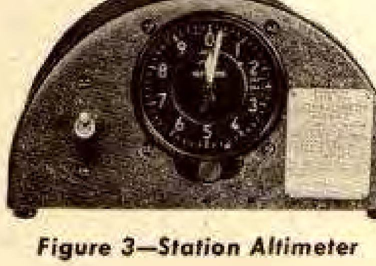


Figure 3—Station Altimeter

b. In practice the "Altimeter Setting" system is simply a coordination of settings between an altimeter on the ground and the altimeter in an aircraft (in flight). At least two "Station Altimeters" are kept in the Control Tower of an airport. They are sensitive altimeters usually of the same standardized type used in A.A.F. aircraft. These altimeters are set at the exact tower elevation (above sea level), and cross-checked against each other. Since the barometric pressure of the air is changing more or less constantly, it is obvious that changes in the barometric scale indications of these instruments will occur, if the correct elevation is to be maintained. However, with the station altimeter kept at the proper elevation, a pilot desiring an Altimeter Setting will be given the barometric scale reading at that moment. He can then set the aircraft altimeter to this reading and know that it will indicate the altitude (above sea level) within the operating limits of the instrument. An additional check on the accuracy of the "Station Altimeter" is provided by the weather station at the airport. The "Station Barometer" is read at intervals. The barometric pressure reading is then corrected to the corresponding pressure at sea level. This station pressure reduced to sea level is also the Altimeter Setting and is checked with the Station Altimeter reading. Under combat conditions where

"Station Altimeters" or weather bureau information may not be available, the altimeter of an aircraft on the ground is set to the field elevation, and the barometric scale reading transmitted to pilots (in flight) desiring an "Altimeter Setting."

c. This altimeter setting gives an indicated altitude over sea level to the pilot in that vicinity, and is used practically exclusively on both local and cross country flights. The pilot must remember that being at an altitude over sea level, he must allow for ample clearance of terrain and obstructions which may be higher, and that his altimeter in no way indicates his altitude over the terrain, but only over sea level. This setting, being a pressure setting, is uncorrected for abnormal temperatures found aloft, and therefore the pilot must take into consideration any abnormally low temperatures he may encounter in flight, as well as any changes in altimeter setting required enroute.

4. A PRACTICAL ILLUSTRATION OF ALTIMETER SETTING.

a. In Fig. 4 the pilot of a B-17, bound for Denver, has taken off from Corpus Christi and gained an altitude of 6,000′, having set his altimeter at 30.52 to correspond to the existing barometric pressure at Corpus Christi. At 6,000′ the indicated altitude and the actual altitude are essentially the same since the altimeter has been set for the existing pressure at sea level, (though uncorrected for temperatures at cruising altitude). As shown in the diagram along the route the aircraft has entered a region of lowering pressure and the altimeter setting at Big Springs is now 29.52. However, being concerned with the weather ahead the pilot has failed to call in for the altimeter setting, and, although his altimeter still indicates an altitude 6,000′ above sea level, the actual altitude above sea level is only 5,000′, the pressure having fallen 1″ Hg. Soon after passing over Big Springs the pilot encounters an overcast and is now entirely dependent upon his instruments. The pressure has dropped still further in the Denver area and the altimeter setting there is 28.52; however, the altimeter in the aircraft still indicates 6,000′ above sea level as it was last set for the region of higher pressure over Corpus Christi. Nearing Denver, the pilot calls Denver Radio asking for altimeter setting and receives "Altimeter Setting is Two Eight Five Two," which he immediately sets off on the barometric scale in the face of the altimeter by turning the adjustment knob of the instrument.

b. The indicated altitude is now 4,000′ which is also very near the true altitude above sea level as the altimeter has been adjusted for the change in pressure (though not for temperature at cruising altitude). The aircraft is climbed up to 6,000′ above sea level and the flight continued on into Denver. Had the pilot failed to adjust his altimeter for the correct altimeter setting he would have crashed into the ground before reaching Denver (Alt. 5300′) for although he was flying at an indicated altitude of 6,000′ above sea level, the actual altitude was only 4,000′ above sea level, because of the region of low pressure into which he had flown.

Figure 4—Altimeter Setting, Cross-Country

FIG. 5

USE OF "ALTIMETER SETTING" FOR LANDING

1. Call in to the tower and request altimeter setting.
2. Tower replies and gives altimeter setting.
3. Set the barometric scale to correspond to the altimeter setting. The altimeter will indicate the altitude over sea level.
4. Plan your approach procedure on the basis of the new altimeter indications.
5. Upon landing the aircraft your altimeter will read the surveyed elevation of the field.

NOTE: *Due to various factors in the mechanism the altimeter may not be depended upon for an exact reading and consequently it is not recommended to depend upon the instrument for an indication accuracy closer than 75 feet.*

5. THE "ZERO SETTING" SYSTEM.

The pilot will find that the "Altimeter Setting" system is universally used and very rarely will it ever be necessary to use the altimeter in any other manner. However, should the pilot desire to land with the pointers reading zero rather than the surveyed elevation of the airport, he may do so by requesting by radio the "field elevation pressure." He will then receive a barometric setting *uncorrected* to sea level, and the instrument should read zero altitude upon landing.

NOTE

This method can only be used if the altitude of the airport is near enough to sea level that the field elevation pressure will be within the limits of the barometric scale on the instrument.

6. PRESSURE ALTITUDE AND THE ALTIMETER.

In some of the older altimeters no barometric scale was provided and it was necessary to rotate the small pointers found on the rim of the instrument to correspond to pressure altitude variations. Inasmuch as this system is obsolete, and would require lengthy explanation it is omitted in this manual. In practice *pressure altitude* is an *elevation above* a pressure level, and is not a barometric pressure to be set off in the barometric window of the altimeter. Pressure altitude is nothing more than the *elevation* over the standard pressure level of 29.92, and is easily found in flight by setting the barometric scale of the modern altimeter at 29.92. The pressure altitude is then read directly on the altimeter. *Density altitude,* as used in engine performance data, is a correction of pressure altitude for temperature. On these subjects the pilot who is interested may refer to appropriate texts, but he should know what pressure altitude is and how to determine it in flight in order to make necessary temperature corrections for both true altitude and true airspeed.

7. CHECKING THE ALTIMETER.

a. Prior to using the altimeter on any flight, it is essential that the pilot make certain ground checks. The pilot should obtain from the Weather Office the altimeter setting for the point of departure, his point of destination, and his alternate field, and see that these settings are *written down* where he may refer to them in the cockpit. A good way to do this is to have them written on the clearance sheet itself. He should also note mentally the *trend* (whether rising or falling) of the altimeter setting at each point. These notations are important for the following reasons:

(1) It enables him to determine the scale error, and therefore the approximate accuracy of the instrument.

(2) In the event of radio failure along the route, he can closely approximate the altimeter setting at all points to which he may fly, and make a reasonably low approach if necessary without obtaining further information as to the proper altimeter setting.

(3) Cases have happened in the past where the pilot has been given the incorrect altimeter setting by the control tower at his point of destination. By knowing what the approximate altimeter setting should be, the pilot is in a position to challenge such misinformation.

(4) It enables the pilot to successfully clear all obstacles, including mountains that might be along the route, by the use of simple computations or allowances.

b. Upon getting in the cockpit, the pilot should immediately set the barometric scale on the altimeter to the altimeter setting given him by the Weather Office for his point of departure, and note whether the altimeter reads the correct field elevation above sea level. Any discrepancy will be the scale error in the Instrument which must be taken into consideration throughout his flight. If the error is excessive (over 75 feet), he should immediately suspect that he has been given an incorrect setting, or that he has a damaged or malfunctioning instrument. He should recheck the altimeter setting, and, if found correct, he would then know that the instrument could not be relied upon. Tap the face of the instrument lightly when making this check, and note any excessive "jumping" of the hands of the instrument which might indicate that the hands are sticking.

c. As the pilot approaches different points along the route, where he may obtain his new altimeter setting, he should reset the instrument accordingly. Particularly is this true when flying into regions of lower barometric pressures, which, if the setting is unchanged, will cause the pilot to assume that he has more altitude than he actually has.

d. When flying over exceptionally high terrain with abnormally low temperatures aloft, the pilot must be very careful to use a computer to correct the indicated altitude for the abnormally low temperature, *or* he must allow amply for additional clearance over the highest terrain to compensate for the errors in the altimeter. The errors caused by abnormally low temperatures aloft are of the same effect as errors caused by low barometric pressures, and, therefore, the instrument indicates to the pilot that he has more altitude than he actually has. Proper correction for temperature is explained in Section IV. Use of the Computer.

8. SUMMARY.

The "Altimeter Setting" system is standard, easy to understand and use. Always use this system (unless unusual circumstances dictate otherwise,) and remember four simple rules:

1. "Altimeter Setting" always gives a reading above *sea level,* and on the ground the altimeter will therefore read the *elevation* of that field above sea level.

2. Areas of *lowered* barometric pressure will, if the altimeter setting is not changed accordingly, cause the altimeter to indicate to the pilot that he has more clearance over the ground than he actually has.

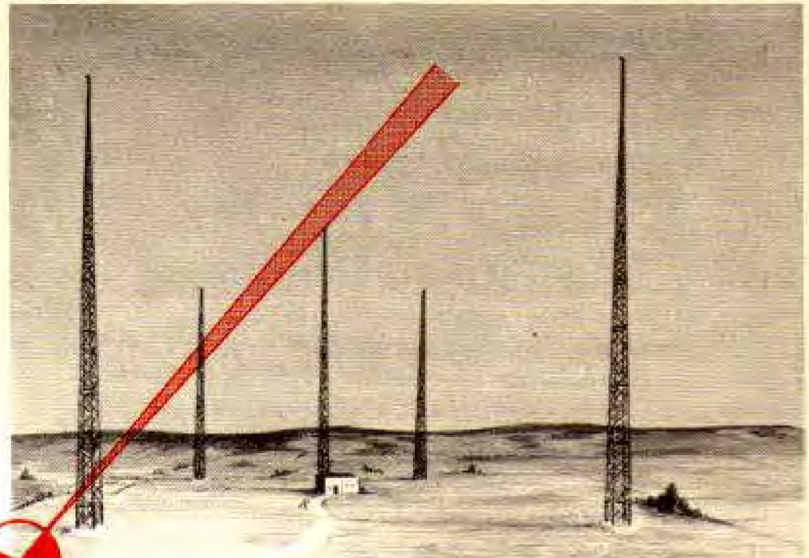
3. Areas of abnormally low temperature aloft, will *also* cause the altimeter to indicate to the pilot that he has more clearance over the ground than he actually has.

4. Always check the altimeter for scale error *on the ground* before take-off, and carry with you in writing the forecast of the altimeter settings for your point of destination and alternate field.

NOTE:

Radio altimeters are being installed in certain types of Army Air Forces aircraft. These instruments measure the actual height of the aircraft over the terrain. The radio altimeter cannot be used to maintain a level flight path since its indications vary with the terrain. It is not an attitude instrument.

SECTION II
RADIO AIDS TO NAVIGATION



1. GENERAL.

The pilot who has mastered basic instrument flying is able to control the attitude of an aircraft by reference to instruments alone. He is able to fly his aircraft into conditions of reduced visibility and continue his flight by reliance upon methods of dead reckoning. He will be able to maintain a reasonably accurate course, provided he knows the direction of the wind at his flight level. Indeed, under many conditions, he may have to carry on without the help of radio navigational aids. If the pilot proceeding on an instrument flight arrives in contact weather conditions with sufficient remaining fuel supply, he can then continue to his destination by methods of pilotage. However, the above is an emergency procedure and today's extensive military and civil flying would be very difficult if carried out only by such methods. A comprehensive system of radio aids to navigation comprising the civil airways system of the United States and of the Dominion of Canada has been installed to provide navigation facilities available under instrument flight conditions. The principal component of the system is the radio range station, a radio station emitting aural signals by means of which directions may be established.

2. RADIO RANGE OPERATING PRINCIPLES.

a. A radio range, which controls the intensity of its signals in certain directions, may be compared with a conventional broadcast station, which normally radiates its energy with substantially the same intensity in every direction. Figure 6 illustrates the circular shape of the pattern covering the area over which a broadcast station would be heard with an ordinary receiver. Signals are strong near the transmitter and grow weaker gradually as they spread out in all directions until they fade out entirely. The radius of this circular area could be considered greater or less as the receiver volume is advanced or retarded, or the transmitter power is increased or decreased.

b. The shape of the pattern in which signals are audible can be controlled to some extent by use of specially designed transmitting antennas. The pattern

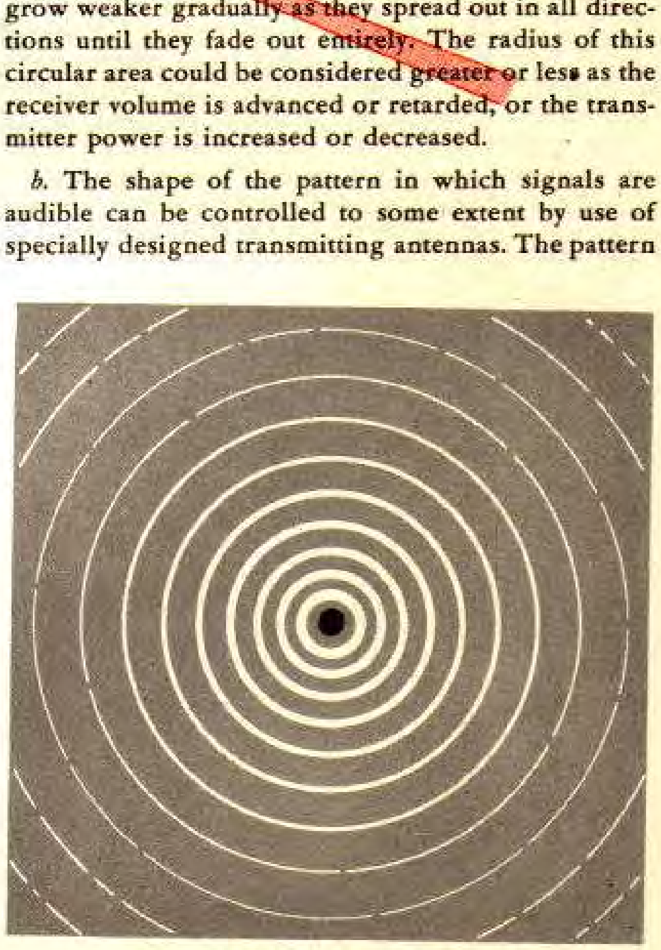


Figure 6—Single Antenna Pattern

of a directional antenna system, (Fig. 7) may be compared with the pattern of the broadcast antenna. It will be seen that radiation of energy is suppressed in both directions at right angles to the antenna system, and maximum radiation is obtained in the direction in line with it. For identification purposes the signals radiated by the antennas are broken into a succession of dots and dashes corresponding to the letter "N" (— ·). Figure 8 represents the area which would be covered by an identical antenna system at the same location but at right angles, and transmitting a succession of "A's" (· —). Two such antenna systems radiating alternately would cover the area shown in Fig. 9. It is obvious that only in the zone in which adjacent signals overlap would both the A and N signals be audible. The energy of the radio range transmitter is fed alternately into the two antenna systems by an automatic switching arrangement. Transmitted first is the DAH of the "N" (by one antenna system) followed by the DIT of the "A" (from the other antennas); Then the DIT of the "N" (first antennas) followed by the DAH of the "A" (second antenna). (See Fig. 10.) The cycle repeats itself, except when interrupted by the station identification signals. Since there is no pause between the alternate signals, a steady tone will be heard wherever the energy from the two antenna systems is received with equal intensity. This wedge shaped zone is the "ON-COURSE" signal, (or beam) and is 3° wide. The four range courses are printed as beams of this width on aeronautical charts, and the magnetic bearings of the courses are included thereon.

Figure 7 — Directional Antenna Pattern

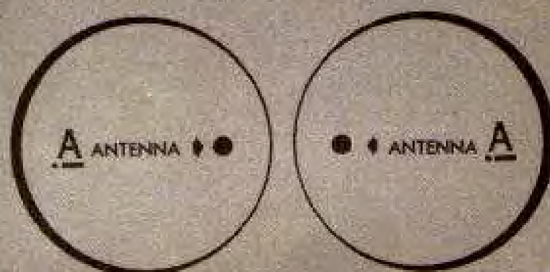


Figure 8 — Directional Antenna Pattern, at Right Angles

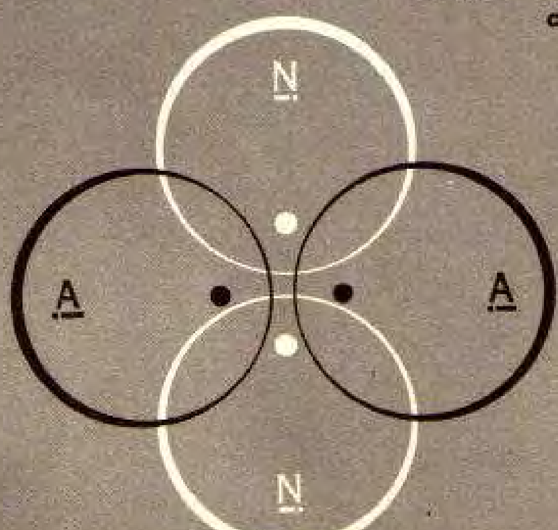


Figure 9 — Radio Range Pattern

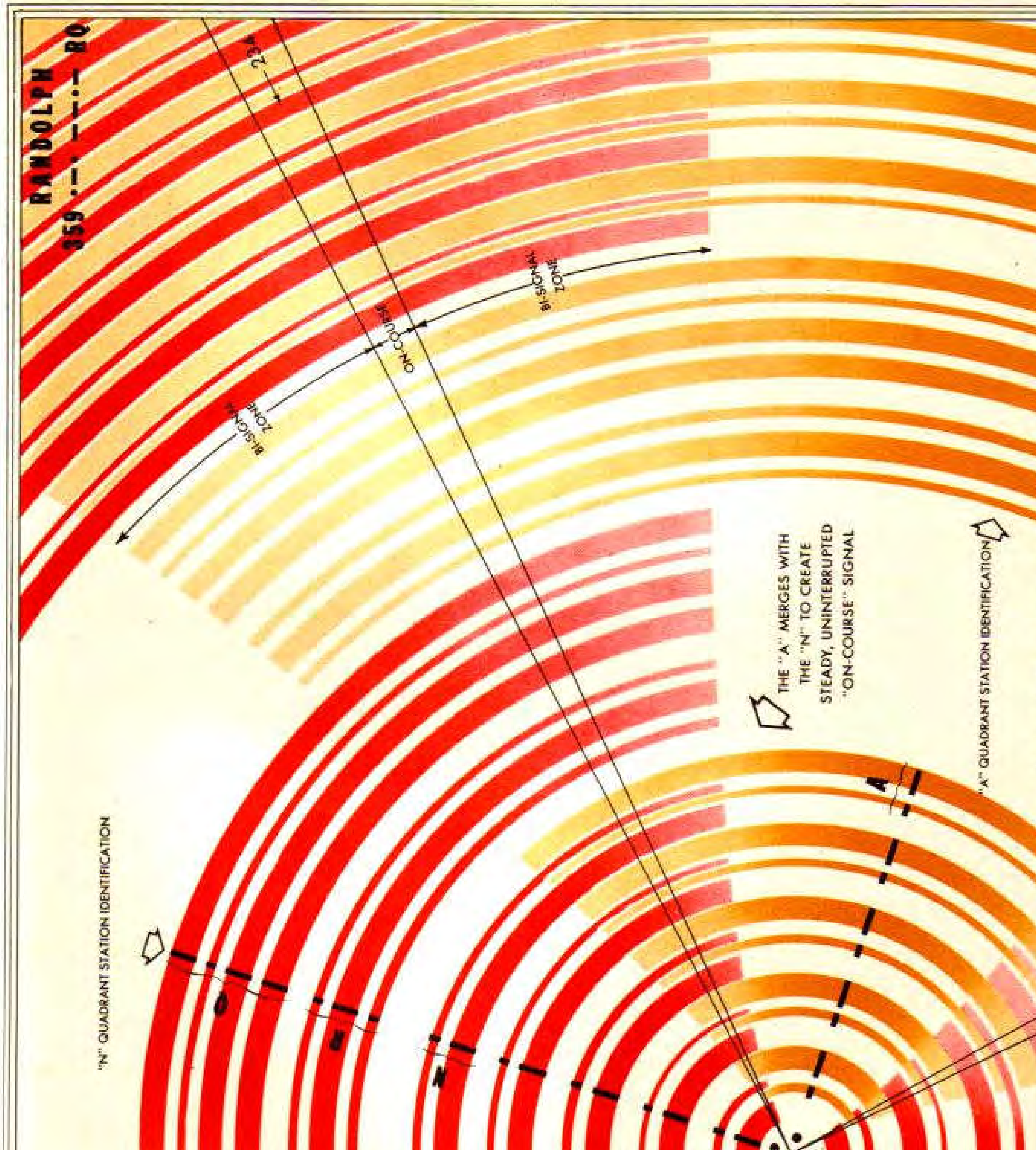


Figure 10—Signal Pattern, Radio Range

c. The "on-course" is, therefore, an equal signal strength zone. However, since the A or N signals *gradually* merge to form this "equal signal" zone, it follows that when slightly off-course, the signal of the opposite quadrant will still be heard as a monotone background. For example, a pilot flying slightly off-course in an "N" quadrant will distinguish the N signals. A background will also be heard, which will be of lessening intensity as the distance from the "on-course" increases. This "background" as stated above, is the "A" signal of the opposite quadrant interlocked into the now predominant "N" signal. This area within which the "background" is heard, is termed the BI-SIGNAL ZONE. (See Fig. 10.) Although the term "twi-light" zone is also used to describe this area, BI-SIGNAL ZONE will be used throughout these texts. The bi-signal zone is bounded on one side by the on-course signal, and fades on the other side toward the center of the quadrant into the pure A or N signal.

d. Like the entertainment band, the aeronautical frequency spectrum (200 to 400 kcs.) must accommodate a great number of stations, and some interference is unavoidable. To eliminate all danger of mistaken identity, each station is assigned an individual two or three letter identification. For instance, the station identification for the range in figure 10 is *RQ* (· — · — — · —). If a pilot tunes the receiver of his aircraft to the transmitting frequency (359 kcs.) and · — · — — · — is heard, he will have definitely established the fact that he is listening to the Randolph Field radio range. As mentioned before, the transmission of the A and N signals is interrupted every half minute by the sending of the identification signals. The station identification is also alternately transmitted over both antenna systems. FIRST over the N ANTENNAS, and THEN over the A ANTENNAS. While on-course the pilot will hear two sets of identification signals, but in the bi-signal zones, one or the other of the sets of identification signals will predominate. In the part of the quadrant where only the clear N is heard, one set of identification signals *followed by a pause* will be noted. In the A quadrant the transmission of the identification will be *preceded* by a pause. (See Fig. 11.) (When the pilot is flying in the bi-signal zone the relative loudness of the two sets of identification signals will help him to anticipate the nearness of the on-course.)

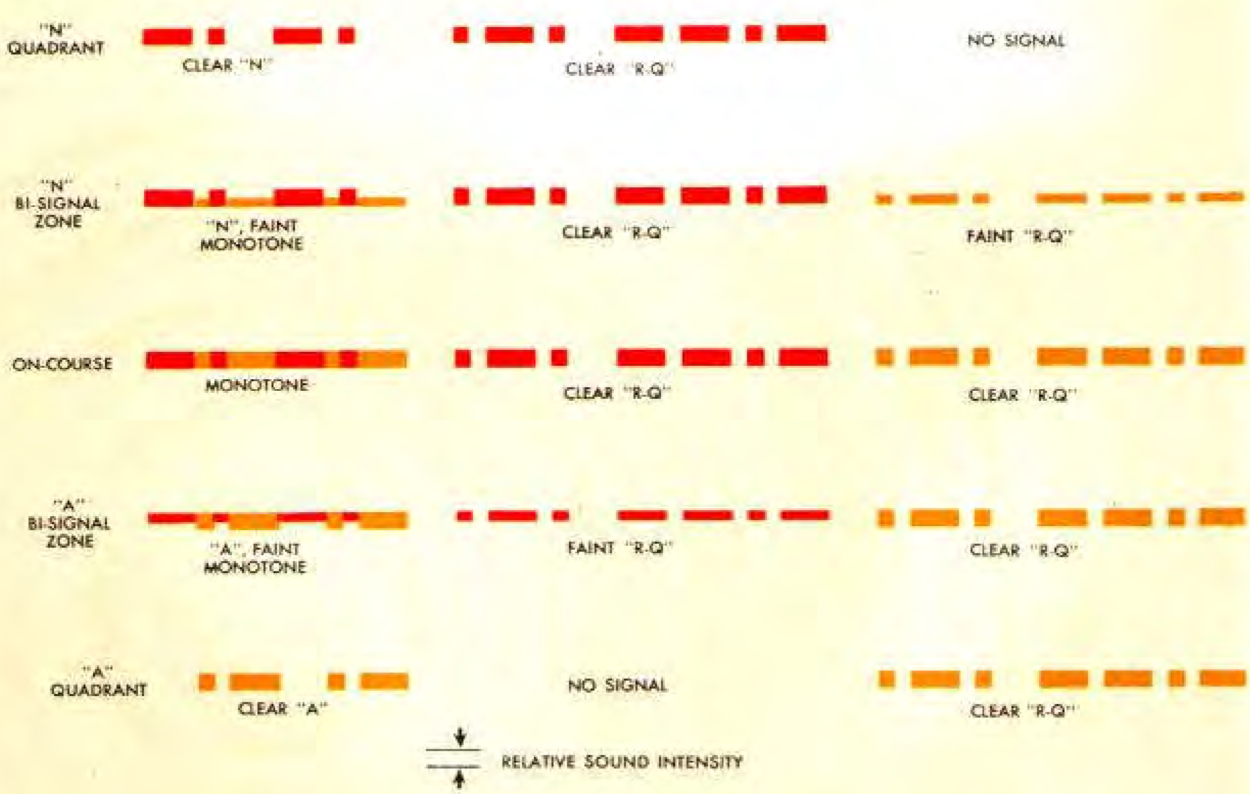


Figure 11—Interlocking of Signals

e. Immediately above the range station is an inverted cone shaped area where the antenna signals cancel each other and no signal is radiated. This is known as the *cone of silence.* When a pilot is flying toward the range station along the "on-course," the strength of the signals gradually becomes greater (builds) until relatively close to the station where they rapidly increase in volume. As the aircraft passes over the station, the signals fade completely as the cone of silence is crossed and a build will be noted at the other side. (See Fig. 12.) Unless the receiver volume is turned to near minimum, and the aircraft is exactly on-course when crossing the station, the signal will not fade out completely.

f. The pilot of an aircraft flying away from the range station and following the on-course will start with the receiver volume near minimum. The signal strength would drop off rapidly at first, making it necessary to advance the *manual* volume control at frequent intervals. (Automatic volume control is unsuitable for radio range flying.) As the signal becomes progressively weaker with distance, the volume control will have to be advanced less frequently. Eventually the limit of receiver sensitivity will be reached, or atmospheric noises and interfering stations will become louder than the desired signal. This occurs under ordinary conditions and with full powered stations at distances of 100 to 200 miles. At this distance, it is possible to fly for several miles before a noticeable change in signal strength is apparent to the ear. It is likewise possible to deviate a considerable distance to either side before the ear can detect a change in relative signal strength of the A or N.

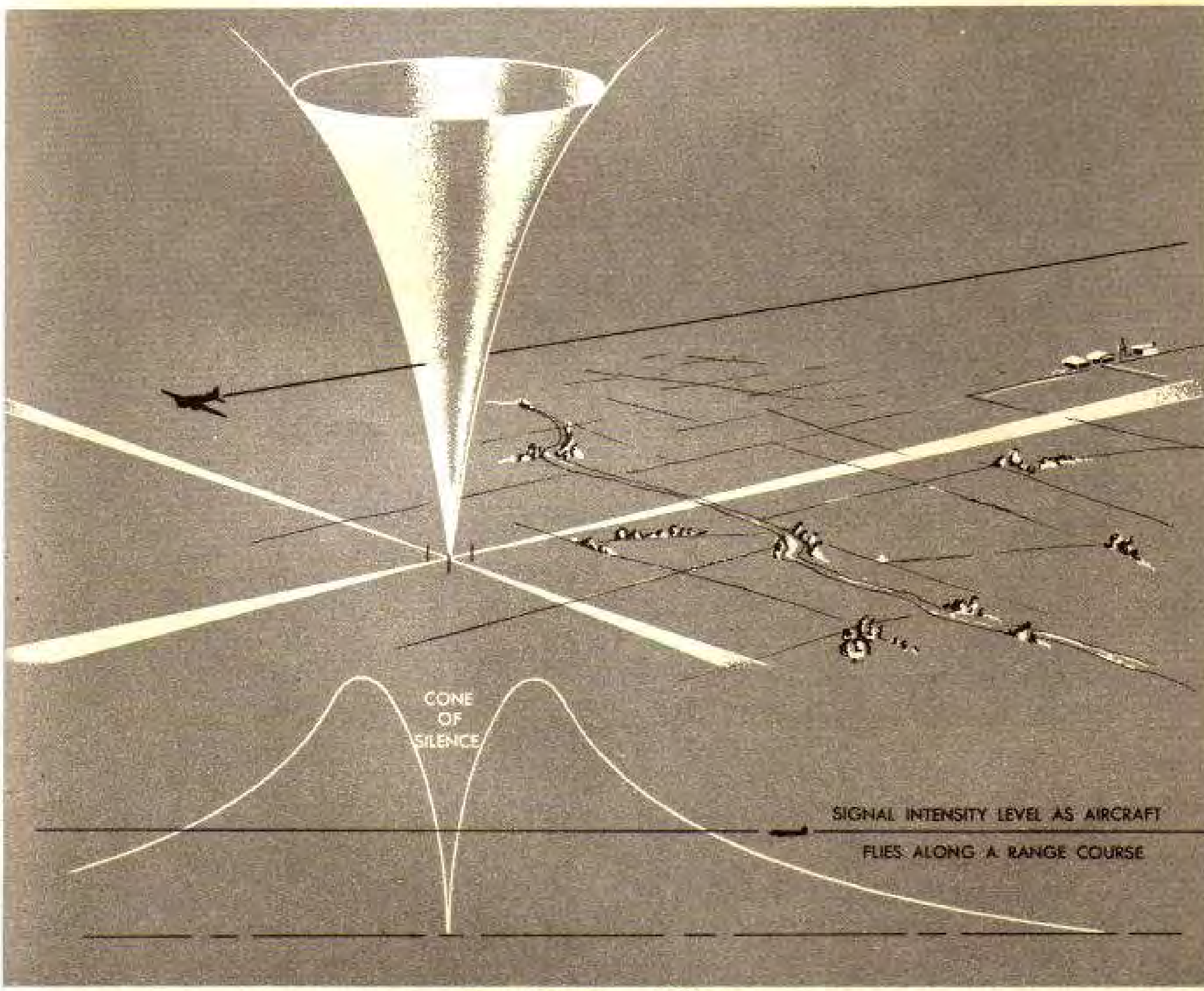


Figure 12—Cone of Silence

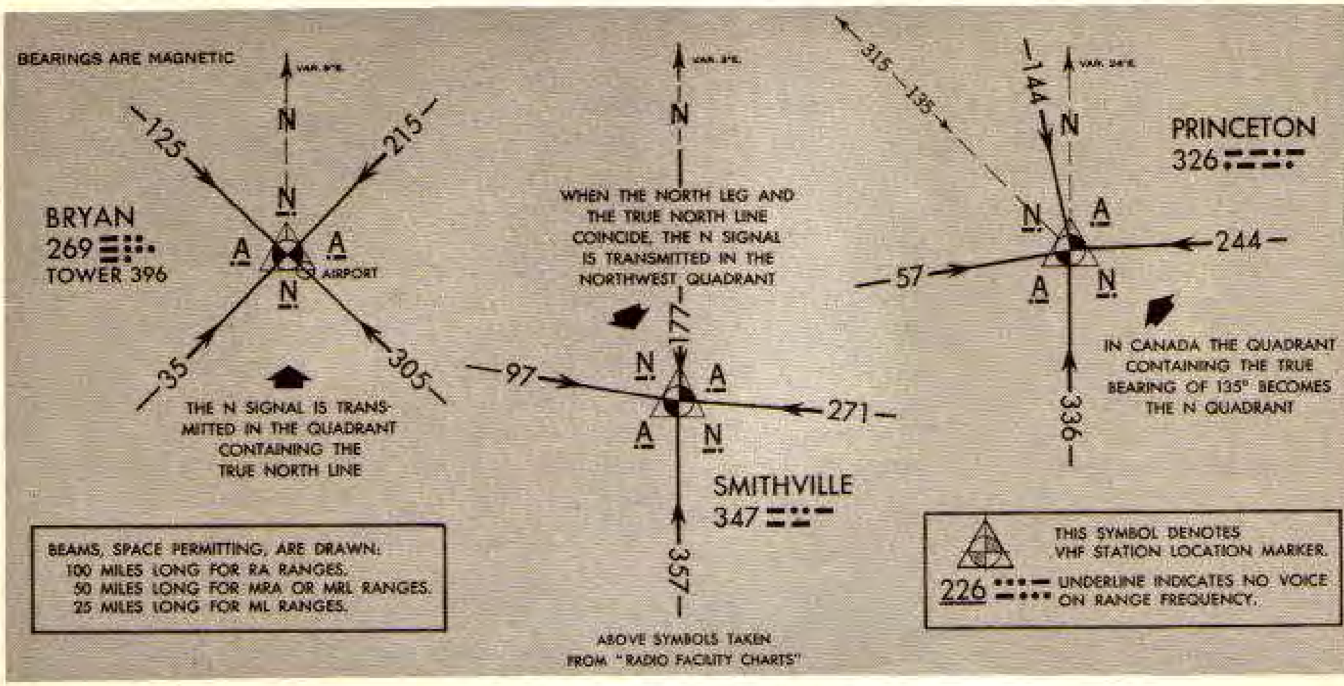


Figure 13—"A" and "N" Quadrants

3. A AND N QUADRANTS.

All radio ranges operated by agencies of the United States have the off-course signals arranged according to the following rules: a true north line through the station passes through the N quadrant. If the north on-course coincides with the true north, the N quadrant is the northwest quadrant. Canadian radio ranges transmit N in the northwest quadrant, the northwest quadrant being defined as the quadrant containing the true bearing of 315° from the station. The A quadrants are identified in the A.A.F. Radio Facility Charts, carried in all military aircraft, by the black sectors of the circle drawn around each radio range station. In addition, in the case of Canadian stations included in these charts, the letter N with the code signal — · is shown in the NW quadrant near the station.

4. POWER OF RADIO RANGES.

The power used for radio range transmission varies with the different stations. A full-powered station uses more than 150 watts, a medium powered station 50 to 150 watts, and a low powered station less than 50 watts. Except for signal strength, little difference will be noted in these stations when flying the ranges aurally. In the A.A.F. Radio Facility Charts, the full-powered stations are shown with their on-course signals 100 miles in length, while medium-powered and low-powered stations are shown as 50 and 25 miles, respectively.

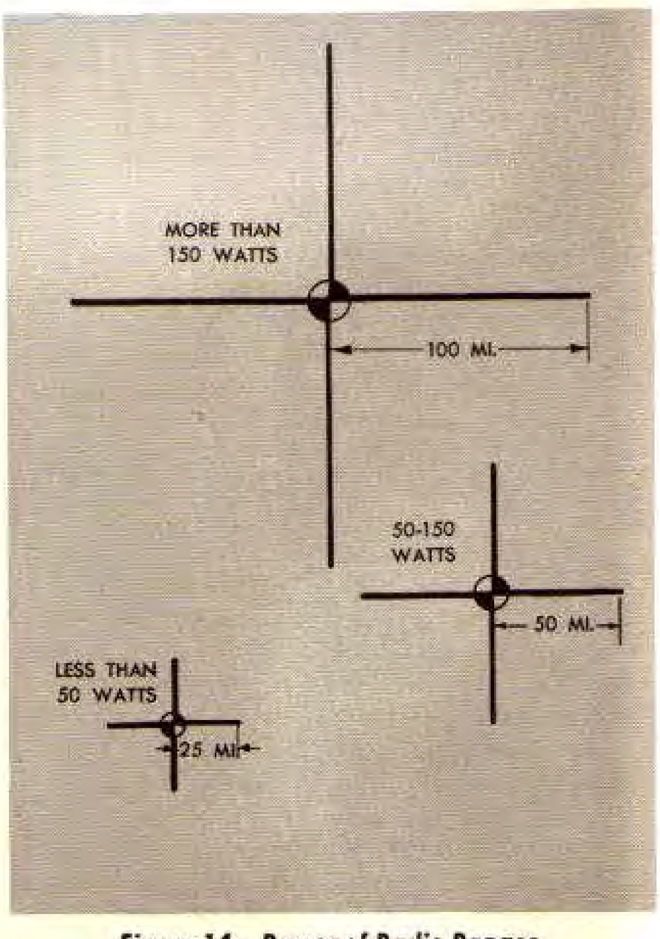


Figure 14—Power of Radio Ranges

Figure 15—Loop Type, Radio Range

Figure 16—Tower Type, Radio Range

5. TYPES OF RADIO RANGE INSTALLATIONS.

a. LOOP TYPES. The earliest practical development of radio range equipment was based on the same principles, except that loop antennas were used for the transmission of the range signals and voice broadcast. Loop type radio ranges are still in operation at many localities and this type of installation will probably be continued in use because of the simple antenna installations. The antenna system consists of two crossed wire loops suspended between four corner posts. See figure 15. They are easily constructed and within their inherent limitations can be satisfactorily used particularly as "marker radio ranges" to serve a particular airport. There are two disadvantages to this type of installation:

(1) The transmission of radio range signals must be suspended while a voice broadcast is being made.

(2) The signals received by the pilot at distances beyond 30 miles are not always reliable. They are subject to night effect, swinging, multiple courses, etc.

b. TOWER (SIMULTANEOUS) TYPES. The improved antenna systems of the newer radio range station consist of five vertical steel towers. The radio range signals are transmitted over the four corner towers, while voice broadcasts are made over the center tower. The carrier of the corner towers is transmitted only at the instants when the DAH's or DIT'S of the A and N signals or the station identification are being sent. The carrier wave of the center tower is on at all times, and this continuous carrier is of material assistance in radio compass operation. This installation is known as the simultaneous radio range because voice broadcasts are made while the regular radio range signals are being transmitted. The N and A signals are modulated at a 1,020 cycle audible tone. Most of the audible portions of the male voice are in the lower end of the frequency band of 200 to 3,000 cycles, with some overtones, harmonics, etc., going considerably higher and some tones lower than this range. There is comparatively little of the human voice right at the 1,020 cycle frequency, so that the elimination of voice frequencies within a narrow range centered at 1,020 cycles has little appreciable effect on speech intelligibility.

c. To use this system effectively, the aircraft receiver circuit must contain a small filter unit. One band of this filter cuts out all voice signals, leaving the range signals undisturbed. The other band cuts out most of the range signals, permitting voice signals to come through to the headset without interference from the range signals. These filters have a three-position switch, permitting either voice signals alone to pass, range signals alone, or both.

d. In operation, the pilot flies with the filter switch set on BOTH. He hears the range signals, and if a voice broadcast comes on he can usually hear either the voice or the range signals without difficulty—just as you can listen to the music or the voice as you desire when someone is speaking on a commercial broadcast with a background of music. If static or some other factor causes the voice and range signals to interfere, the pilot can, by moving the filter selectors, switch to VOICE or to RANGE, receive whichever signal he elects, alone and without interference from the other. With the filter switch on RANGE much of the static, as well as the voice interference is eliminated.

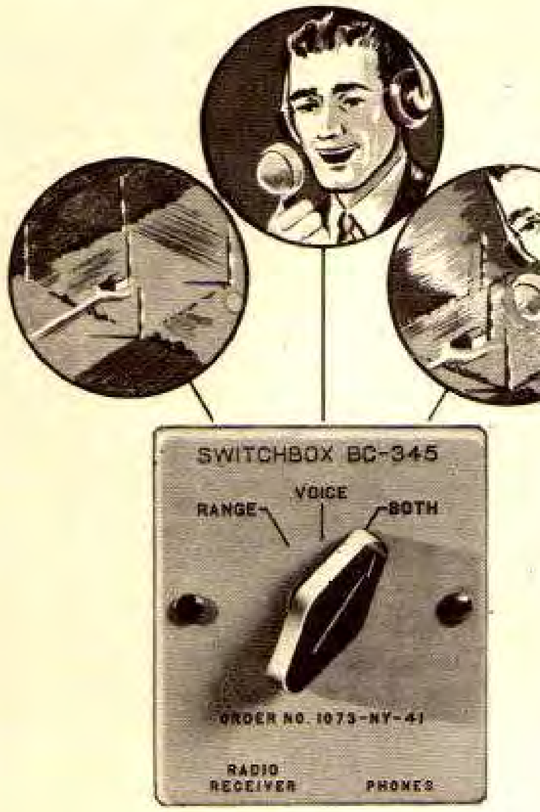


Figure 17—Filter Box

6. IRREGULARITIES.

a. The pilot should have a complete understanding of the inherent limitations of each radio range he intends to fly before attempting to fly them during inclement weather. Range courses which theoretically should be perfectly straight may be found to have kinks or bends. This is most likely to occur where the courses pass close to or over hilly or mountainous terrain, or over mineral deposits. Under such conditions a course is sometimes broken up into several parallel courses, usually referred to as "multiple courses." Multiple courses are extremely difficult to follow, due to their being very narrow and usually very erratic. They are very confusing to the average pilot who has had limited experience with them. A multiple course may have the same signals on both sides or may have the normal signals on either side or may have the signals reversed. Bent courses, sometimes called dog-leg courses, usually are of little consequence, since the bend generally is small and away from and around the obstruction that caused it. However, in mountainous country bends have frequently been found that necessitated a change of compass heading of 45° for a short distance in order to stay on course. Several such bends may occur on a range in a short distance. Obviously such a range would be hazardous to a pilot who was not familiar with that particular range and its peculiarities. These conditions may be found anywhere but generally are confined to hilly or mountainous terrain. A bent course creates the impression that the course is swinging if the aircraft proceeds on a straight line.

b. Other peculiarities may be observed, such as a "leaning" cone of silence or inability to hear a range as far as expected. This may occur where courses are not 90° apart. Investigation usually reveals that one or more of the four courses were intentionally shifted from the normal 90° alignment when the station was originally tuned. Such changes are necessary to make certain courses coincide with the civil airways or line up in some other desired direction. These changes could be accomplished by rotating the loop transmitting antenna or relocating the tower radiators, as the case may be, but in actual practice the same result is more conveniently achieved electrically by merely readjusting the transmitting apparatus.

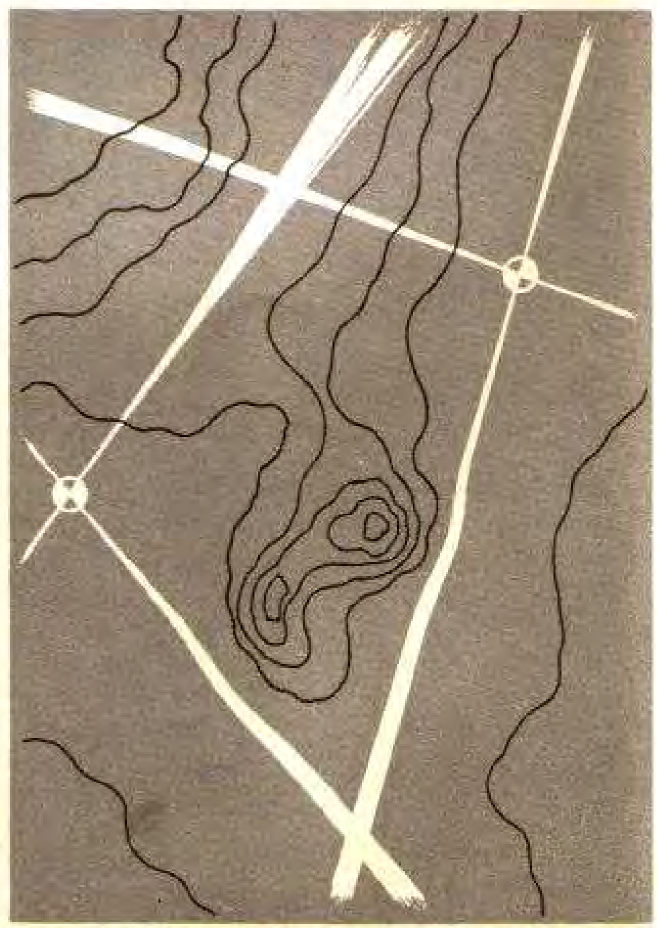


Figure 18—Multiple Courses, Bent Beams

c. Night Effect Swinging Beams.—Theoretically, the only time that courses actually do swing from their fixed position is usually for a short period at sunrise and sunset. During this period the electrically ionized region in the stratosphere, known as the "Kennelly Heaviside Layer," is presumed to be changing its position. This causes the sky wave from the loop antenna to be reflected back to earth and interfere with the ground wave upon which the desired operation of the range depends. As a result the overlap areas shift positions and the beam swings. This effect has been almost entirely overcome by substituting for the loop antenna the newer steel tower range stations. The pilot when flying on a course of the loop type range station should try to fly the center line of the swings. Within approximately 30 miles of the station this night effect disappears.

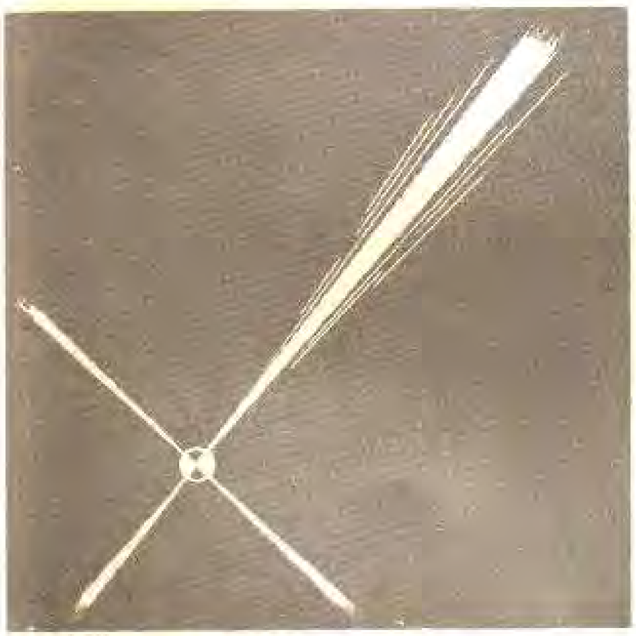


Figure 19—Night Effect

d. Electrical or mechanical breakdown of the transmitting equipment could cause complete failure, or, more serious yet, a condition which might for the moment be mistaken for an on-course signal where none should exist. Every conceivable precaution is taken to prevent failure of radio ranges by frequent regular inspection, cleaning, and overhaul. In addition, a monitoring system is maintained. Not one, but several, receiving stations are charged with the responsibility of listening to each range for evidence of course deviation or other fault. Any departure from normal is investigated immediately and teletype warnings are sent out to all concerned.

7. NON-DIRECTIONAL RADIO BEACONS.

Recently a number of the radio range stations have been converted to non-directional facilities. These stations transmit a continuous carrier wave interrupted by the regular station identification. They can only be used with the radio compass as a homing aid and for direction finding.

8. MARKER INSTALLATIONS.

a. GENERAL.—Because definite fixes are not provided by the radio range station, excepting when passing directly over the cone of silence or intersections, fan markers have been included in the Federal airways system.

b. FAN MARKERS.—The fan markers are high frequency radio transmitters installed at some distance from the radio range across one or more of its on-course signals. These fan markers operate on a frequency of 75 megacycles, emitting a signal which may be received aurally or visually depending on the receiver installation in the aircraft. Army Air Forces marker beacon receivers currently in use utilize the visual signal only. The signals are keyed to conform with the number of the on-course signal across which they are located. The first on-course signal in a clockwise direction from true north is No. 1, and the fan marker, if any, on this on-course will be keyed with one dash; the markers on the remaining legs are keyed to correspond. The signals emitted by the fan markers, their names, and the distance from the marker to the radio range station are shown on the radio facility charts. Passing over a fan marker definitely establishes the position of the aircraft, and position reports, for airway traffic control purposes, are made by reporting time and altitude over the marker. It must be noted that no voice facilities are operated in connection with the fan marker and that position reports must be made to the associated radio range station.

c. LOW POWERED FAN MARKERS.—Fan markers are being installed at distances of from 2 to 4 miles from the airport on the leg of the beam passing over the airport. These markers are keyed in the standard manner. If a low powered marker is installed, the keying of the regular marker on the same beam is changed by the addition of two dots preceding the regular identification, i.e., (· · — — —).

d. STATION LOCATION MARKERS.—Station location markers are installed at most radio range stations. These markers also operate on a frequency of 75 megacycles but are not keyed, and emit a steady signal vertically into the cone of silence, thus definitely establishing the position of the aircraft over the station. This signal may be either visual or aural or both, depending on the receiver installation. Visual reception only is provided by the radio receivers in use by the A.A.F. It should be noted that the station location marker transmitters operate on a power of 5 watts and that the markers are received only up to limited altitudes over the station. In rare instances, at low altitudes, the visual marker beacon receivers may be actuated by false sources of power such as high tension lines, but reception of the station location marker signal and the fade and surge of the cone of silence positively locate the radio range station.

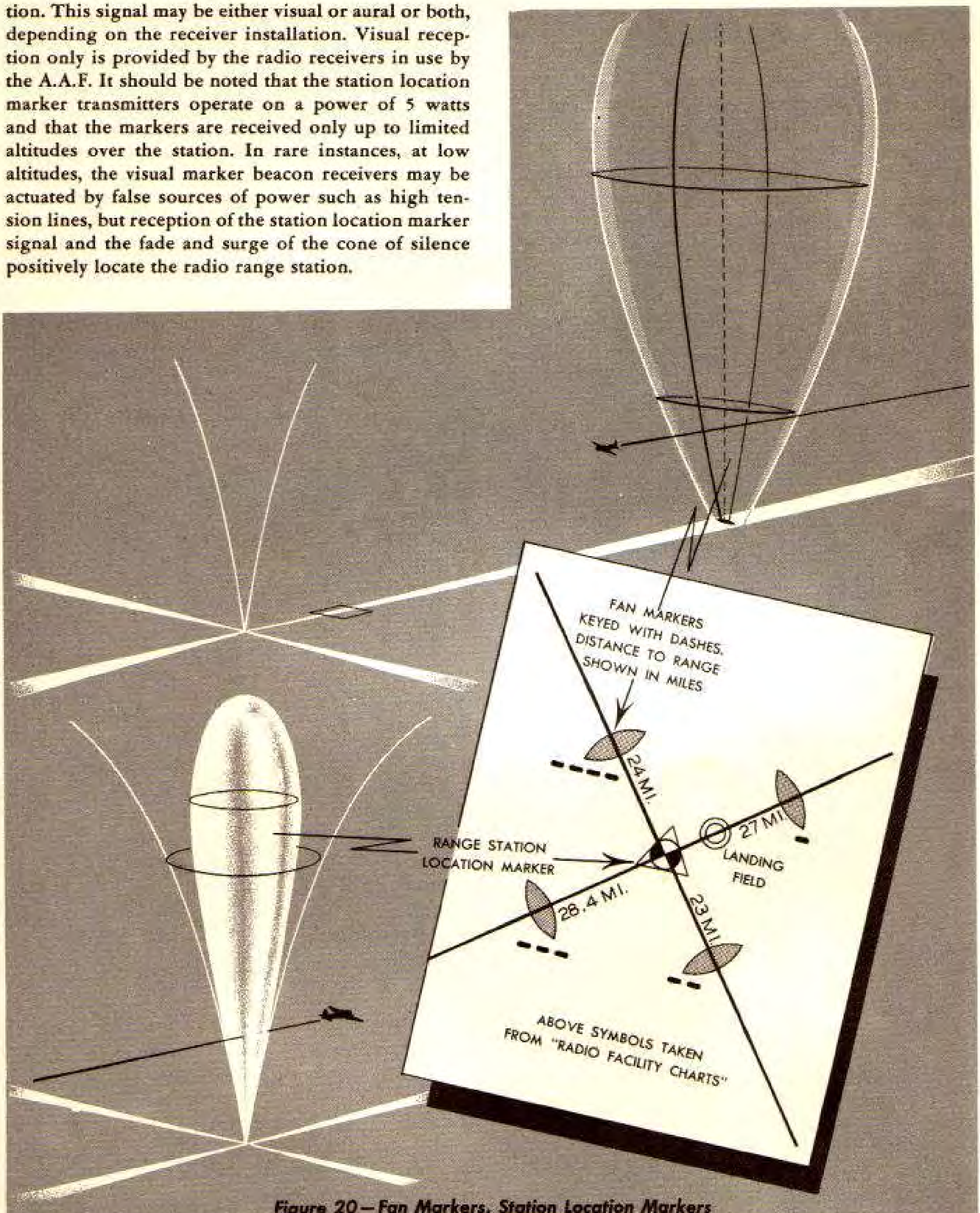


Figure 20—Fan Markers, Station Location Markers

9. WEATHER BROADCASTING STATIONS.

Radio range stations, with very few exceptions, are equipped for voice communication with aircraft. Continuous listening watches are maintained on the itinerant aircraft frequencies, Army aircraft frequency, and on an airline aircraft calling frequency. Weather reports for the route being flown may be requested from all radio range stations equipped with voice facilities. Weather reports, winds aloft reports, and terminal forecasts are also available at all Army Airways Communication Stations and will be broadcast by these stations upon request in accordance with current instructions in the use of weather codes.

10. AIRPORT TRAFFIC CONTROL TOWERS.

Airport traffic control towers are installed at many commercial, municipal, and Army airports throughout the country. The tower operators exercise control under contact flight conditions over air traffic only within a short distance from the airport for the purpose of directing take-offs, landings, taxiing, and related maneuvers. They have no jurisdiction over traffic on the airways. Because in most instances radio ranges with their associated voice stations are located at airports having airport control towers, it is necessary that pilots direct their calls to either of these two stations. Use the expression "Tower" when calling airport control towers and the expression "Radio" when calling a radio range station. Similarly the expression "Army Airways" is used when calling an Army airways communication station. At certain major airports the C.A.A. operated control towers are equipped to broadcast instructions to aircraft in flight directly on the radio range frequency. In these cases the airport control tower will operate both on the regular tower frequency, and on the radio range frequency. For example at St. Louis, Missouri the tower frequencies are 209 and 278 kcs. The use of 278 kcs. is confined to take-offs and taxiing instructions, while 209 kcs. will be used for "Approach Control" of incoming aircraft. Both frequencies will be found in the Radio Facility Charts. (Note: As of date of publication "Approach Control" has been suspended.)

11. RADIO RANGE PROCEDURES.

a. BEAM BRACKETING.

The primary purpose of beam bracketing is to establish the heading which will carry an aircraft along a known path (the beam) to a reference point (the cone of silence). From this point a pilot is able to work a let-down along this known path with a reasonable degree of safety. Since the heading of the beam will be known to the pilot in most cases, bracketing then resolves itself into a method of determining wind drift and making the necessary drift correction to stay on the beam. The bracketing of an "unknown beam" will be discussed later.

(1) *KNOWN BEAM, PRIMARY METHOD.*

It is assumed that the pilot has planned his flight to intercept the west leg of a radio range at some distance from the station. The published bearing of the beam being 110°, he will fly to intercept the beam at a right angle. If he is coming in from the south, this heading will be 20°. When the flight reaches the Bi-signal zone, the pilot will note the time which elapses until he reaches the monotone of the beam. This will provide a rough idea of the distance to the station. Unlike the edge of the on-course monotone, the edge of the Bi-signal zone next to the quadrant signal is an ever widening parabola as it extends from the station outward.

As the pilot reaches the monotone of the "on course", he will turn to cross the beam at an angle of 30°. In this case the heading will be 80°. Holding this course through the beam, and until the first opposite "off course" signal is heard, the pilot will turn right to a heading of 140° (a course 30° off the beam bearing). He has now checked the width of the beam. The two headings 80° and 140° are the limits of the bracket between which lies the heading which will hold the 110° beam. Upon encountering the right hand edge, the pilot turns to the left to a heading of not more than 90°. As soon as the "on-course" is reached, he turns right again to a heading of not more than 130°, that is, the limiting headings will be 90° and 130°. Thereafter, reducing the brackets by 10°, the headings will be 120° and 100°. The next reduction is five degrees to 105° and 115° respectively.

The method is purely mechanical up to this point. However, as the pilot becomes familiar with the changing signals, he will stop his turns immediately when he detects a change of signals. The ability to bracket the beam by sound rather than by computation of headings will be very quickly developed. Thus, the mechanical limits of this type of bracketing will be considered as limits *beyond* which turns should not be continued.

The effect of wind on this system will be to reduce the size of the brackets. If the wind is from the right, the limit will be the beam heading *plus* 30°. If the wind is from the left, the limit will be the beam heading *minus* 30°. The reasons for this can be explained as follows: A wind velocity one half the indicated airspeed of the aircraft at right angles to the course will produce a drift angle of approximately 27°. Therefore, the heading to hold a given track will not be more than 30° from the magnetic course. If the correction of 30° is too great, the aircraft will be drifted back onto its course if the uncorrected heading is flown. Hence, the correct heading to maintain a given track lies somewhere between the magnetic bearing of the track and a 30° correction toward the direction from which the wind is blowing. The direction of a strong cross wind can be deduced by the length of time required to cross the beam when making the initial turn.

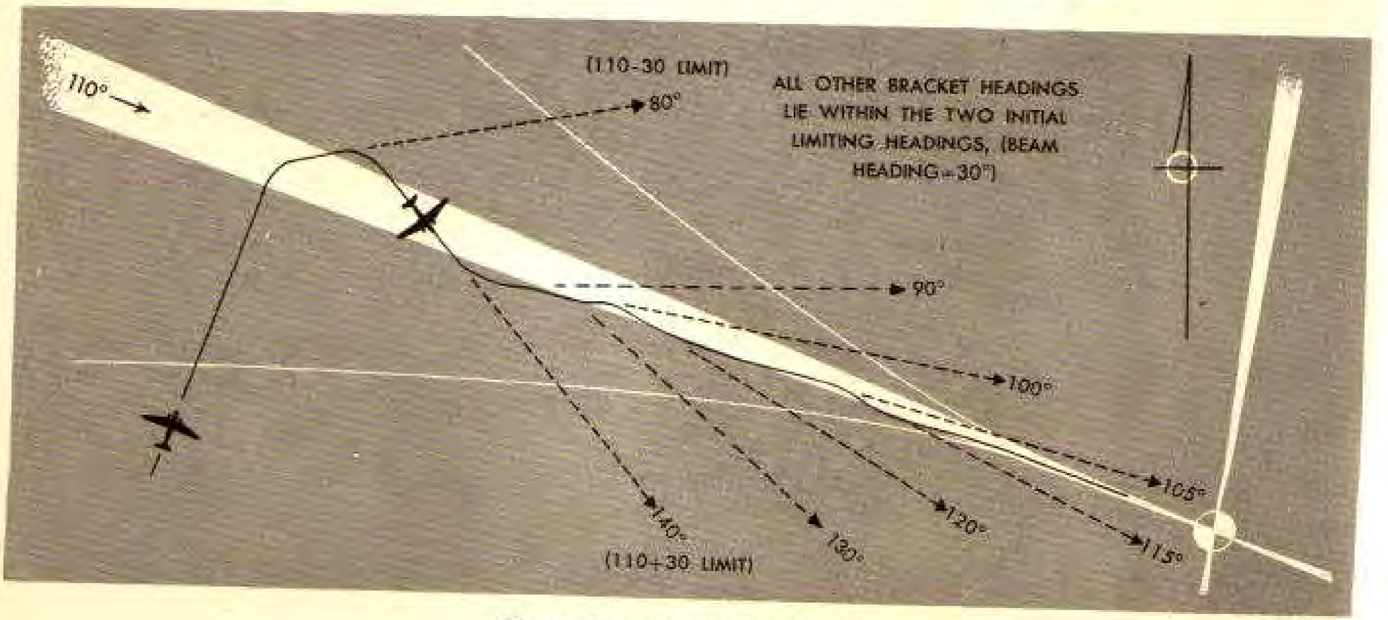


Figure 21—Primary Bracketing

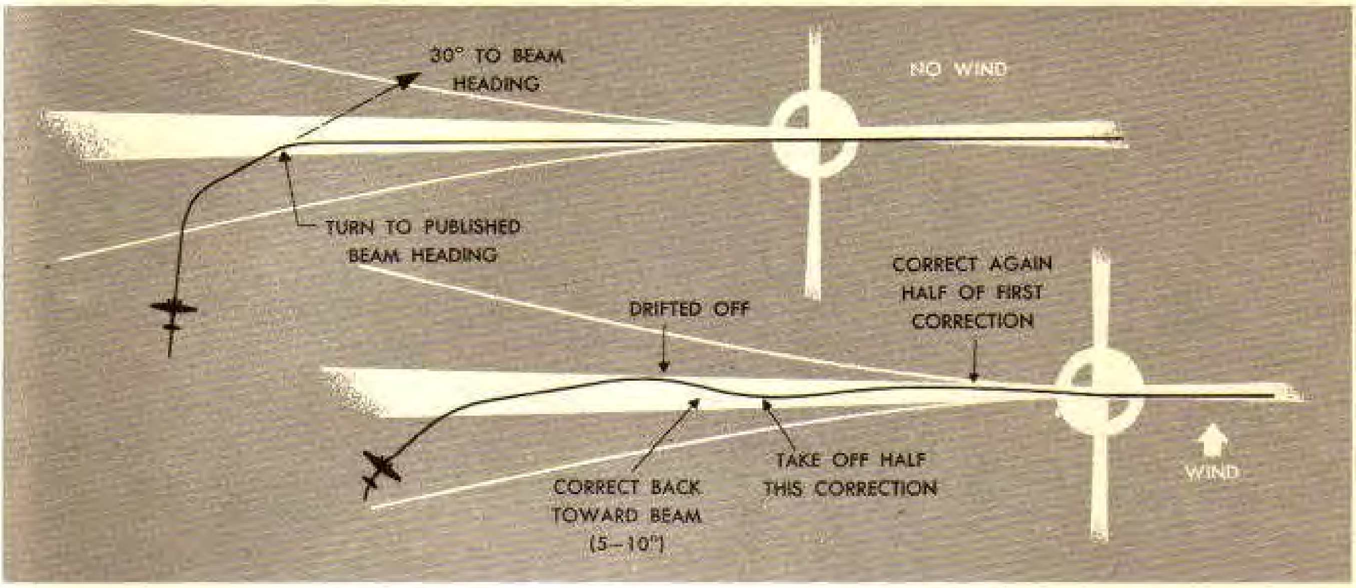


Figure 22—Close-in Bracketing

(2) *KNOWN BEAM, CLOSE-IN METHOD.*

In many cases it is desirable to establish the heading which will keep the aircraft on the beam, without making numerous bracketing turns. This is especially true when close-in, as on the final approach to the station, for a let-down over an airport. In such cases it is important not to "lose" the beam because it would be hard to get back on before reaching the station.

Approach the beam at approximately a right angle. When well into the bi-signal zone turn to a course 30 degrees to published beam heading. Upon entering "on course" turn immediately to published heading. Hold this heading until the aircraft drifts off the on-course. In a perfect "no wind" condition the published heading would carry the aircraft through the cone of silence. However, there will almost always be sufficient wind to drift the aircraft to one side or the other. The speed with which the aircraft drifts off the "on-course" gives a good indication of the velocity of the wind.

As soon as the first "off-course" signal is received, correct back toward the beam. If the aircraft drifts off, a 5 or 10-degree correction should be sufficient. Upon reentering "on-course" take off half of this correction. Hold this heading until drifted off again, in which case correct back about half the original correction. See figure 22.

NOTE

In all methods of beam bracketing it is desirable to "ride" the on-course when close to the station.

This method may also be used beginning at a considerable distance from the station. However, in this case corrections may be made to bring the aircraft to the right hand edge of the beam due to the increased width. Otherwise, it might take considerable time for the aircraft to drift from one side to the other and much time would be spent in beginning to bracket.

(3) *UNKNOWN BEAM.*

NOTE

The method of bracketing described below is not advocated for general practice; however, the pilot should be familiar with this system in order to bracket a beam of an unknown heading if he is confronted with this problem.

Upon encountering the beam, continue straight through it, noting the heading. When the first opposite "off-course" signal is received, start a standard rate turn to the left. Continue this turn until back to the edge of the beam, provided, however, that this turn must not exceed 180 degrees. Upon reencountering the beam edge, note the heading and immediately start a standard rate turn to the right. This noted heading will be the first bracket. (See figure 23.) Continue this turn until the first off-course signal on the right of the beam is again picked up. This heading will be the second or opposite bracket. (The heading which, after the first turn, took the aircraft into the beam and the heading noted immediately thereafter when leaving the beam, are the original brackets. Somewhere between the two is the

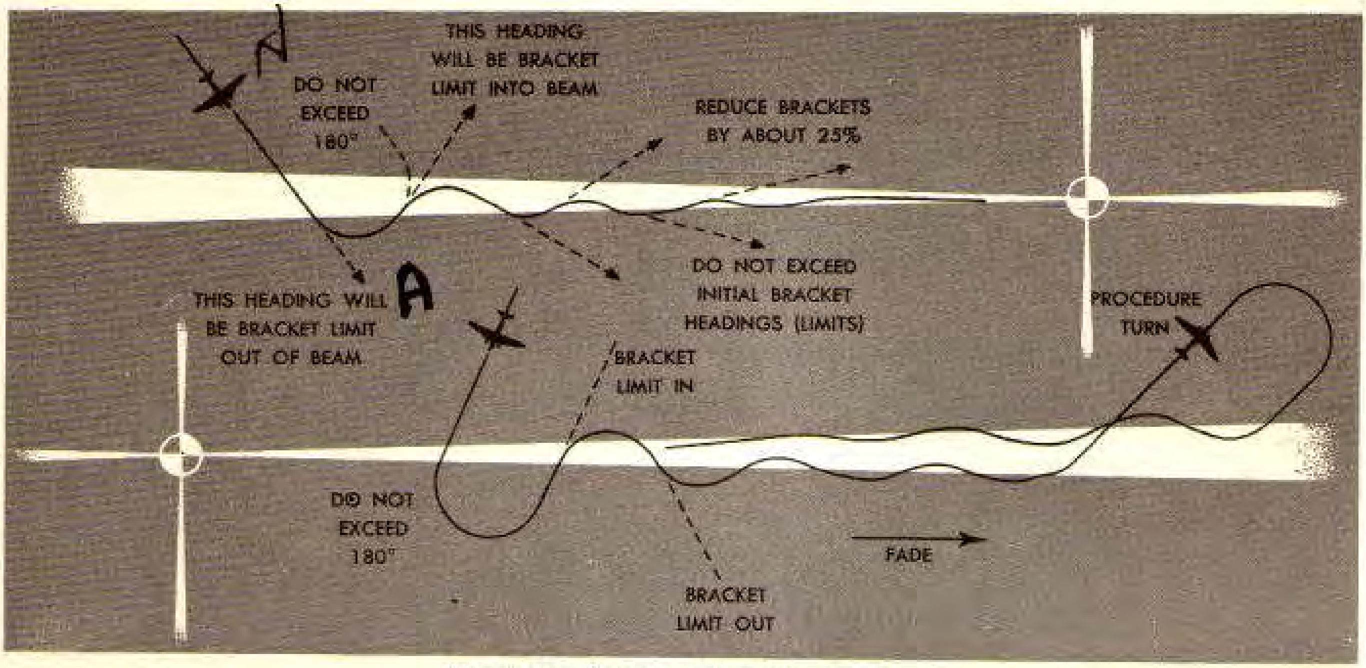


Figure 23—Unknown Beam Bracketing

heading of the beam.) Upon hearing the first off-course signal, again start a turn to the left, reducing the first or left hand bracket by about 25 per cent; then hold this heading until the beam is reencountered. Upon reaching the beam edge, promptly start a turn to the right to a new heading which will reduce the right-hand side of the bracket by about 25 per cent. Continue this process, reducing the bracket by about 25 per cent with each turn. It will be noted that each pair of turns cuts the size of the bracket in half. The process should be continued until the brackets are reduced to from 3 to 5 degrees.

(4) *APPROACHING THE STATION.*

Even the experienced pilot finds it difficult to hold the aircraft precisely on-course when very close to the station. It is very easy to lose the on-course signal, with resulting confusion, if bracketing is continued when close in. The signals received close in may give the impression of being much farther away from the beam than is actually true, because the bi-signal, next to the on-course, disappears very quickly. *The pilot should realize the importance of closely holding the aircraft on the heading found when bracketing the on-course.* Even if he misses the cone it is easy to determine when the station is passed *if he holds this heading.* After all the objective is not merely to hit the cone but to pass the station flying the heading which keeps him on course, and to know when the station is passed. It makes little difference if the aircraft passes one or two hundred feet to one side of the cone as long as the pilot knows that he is flying along the desired path.

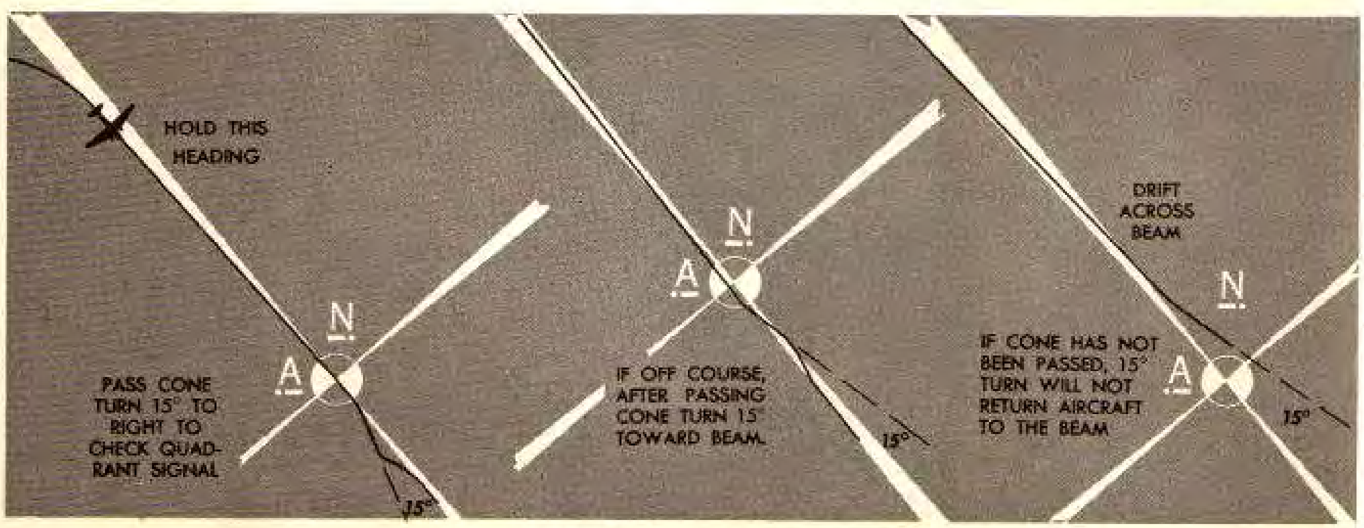


Figure 24—Approaching the Station

In this instance, it is as easy to determine exactly when the aircraft has arrived at the range station as it is to actually hit the cone. The aircraft will quickly pass into an "on-course" with an immediate change of signals. If the approximate heading determined through bracketing has been held, this can only be the range station. After passing the station, if off-course, make a correction back toward the beam (approximately 15°) as a final check; if on-course, turn 15° off to check the quadrant. Frequently when passing to one side of the station, as described above, it is possible to detect the surge and fade of volume common to the cone of silence. This, of course, to a lesser degree than when passing over the cone itself.

The volume should be kept at a comfortable level at all times. This necessitates frequent adjustments as the station is approached, being careful not to adjust the volume as the station is being passed.

The most common fault in bracketing a beam is over correction. It is difficult to visualize the extreme narrowness of the "on-course" and the exceedingly rapid narrowing of the bi-signal zone near the cone of silence. Consequently, the average pilot will usually make entirely too large course corrections when approaching the radio range station.

b. PROCEDURE TURNS AND HOLDING.

(1) *PROCEDURE TURNS.*

This term is used to describe the standardized maneuver performed to reverse the direction of an aircraft when flying on a beam. It is used in holding procedures and let-downs.

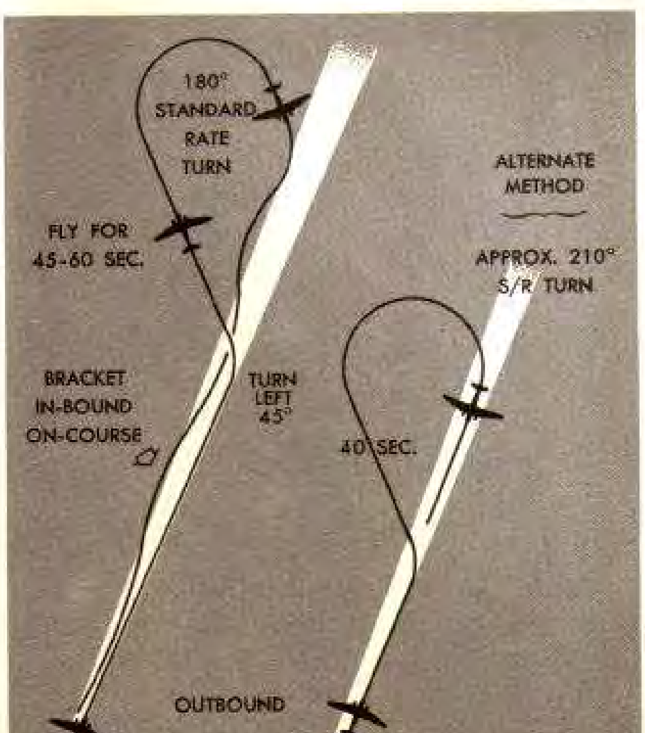


Figure 25—Procedure Return

The aircraft is flown to the left, off-course, for 45 to 60 seconds at an angle of approximately 45 degrees. (Do not start timing until the left hand bi-signal zone has been reached.) There a standard rate 180 degree turn away from the range station is started and the resulting heading maintained back to the beam. Then the inbound beam heading is bracketed and maintained in the usual manner.

(2) *CLOSE-IN PROCEDURE.*

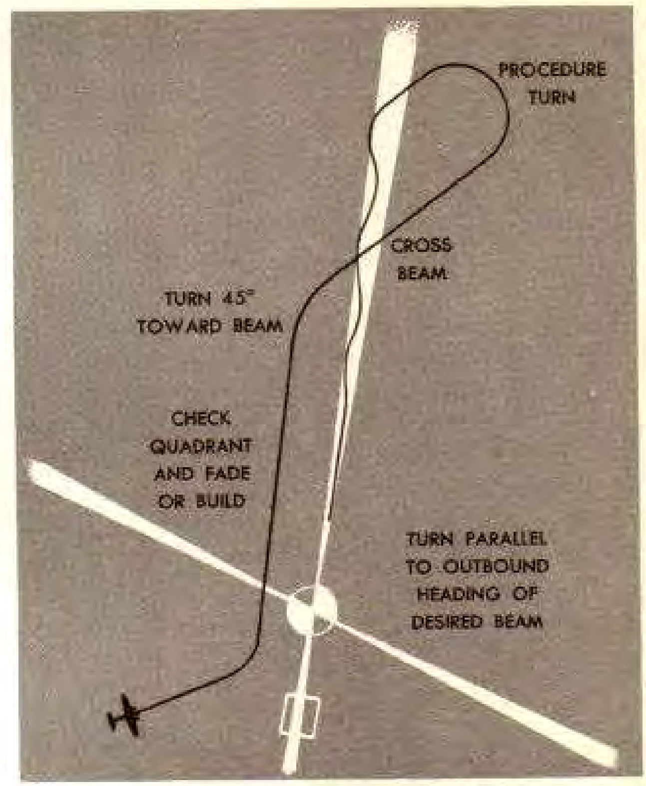


Figure 26—Close-in Procedure

When the rapid change of signal strength indicates that the pilot is close to the station he should follow a simple plan to prevent his becoming confused as he proceeds from one off-course signal or quadrant to another. When the pilot realizes he is close to the station, he need not work an orientation problem, since he knows his approximate location. He must only intercept the leg which he desires to use for his approach procedure. The most satisfactory method of achieving this result is described below.

The aircraft is turned to a heading paralleling the outbound heading of the beam on which it is desired to make the initial approach on the station. This heading is held and the changing signals ignored until a fade is obtained. The signal received will indicate on which side of the beam the aircraft is flying. A turn of 45 degrees toward the desired beam is then started. This heading is held until the beam is crossed and the aircraft is 45 seconds beyond the beam. A 180 degree turn away from the station is now made to get back to the beam and the on-course is bracketed toward the radio range station in the usual manner.

(3) *HOLDING.*

Airways traffic control frequently finds it necessary to hold aircraft over given points and at given altitudes, particularly when a number of aircraft approach the same airport for a landing under instrument flight conditions. Holding procedures will be conducted under airway traffic control (ATC) instructions. The point on which to hold will be specified by ATC and may be a radio range station or the intersection of two radio ranges. For instance, the instructions may be "hold 4 minutes east of blank radio fix at an assigned altitude such as 5000 feet." When the aircraft arrives over the airport for a landing under instrument flight conditions, an altitude will be assigned to the pilot. He will not change this altitude except when directed to do so by ATC. When instructed to hold, the pilot will receive directions such as " . . . maintain 4000 feet, hold on west leg of range between the station and a point 4 minutes west. Expect approach clearance at 2025." As soon as the preceding aircraft lands he will be instructed to descend to 3000. Then he becomes number two to land. When the next preceding aircraft has landed, he will be number one to land, and the pilot will be given his approach clearance and cleared to the tower.

NOTE

When holding it is desirable to reduce power and airspeed to save fuel and avoid flying too far from the station.

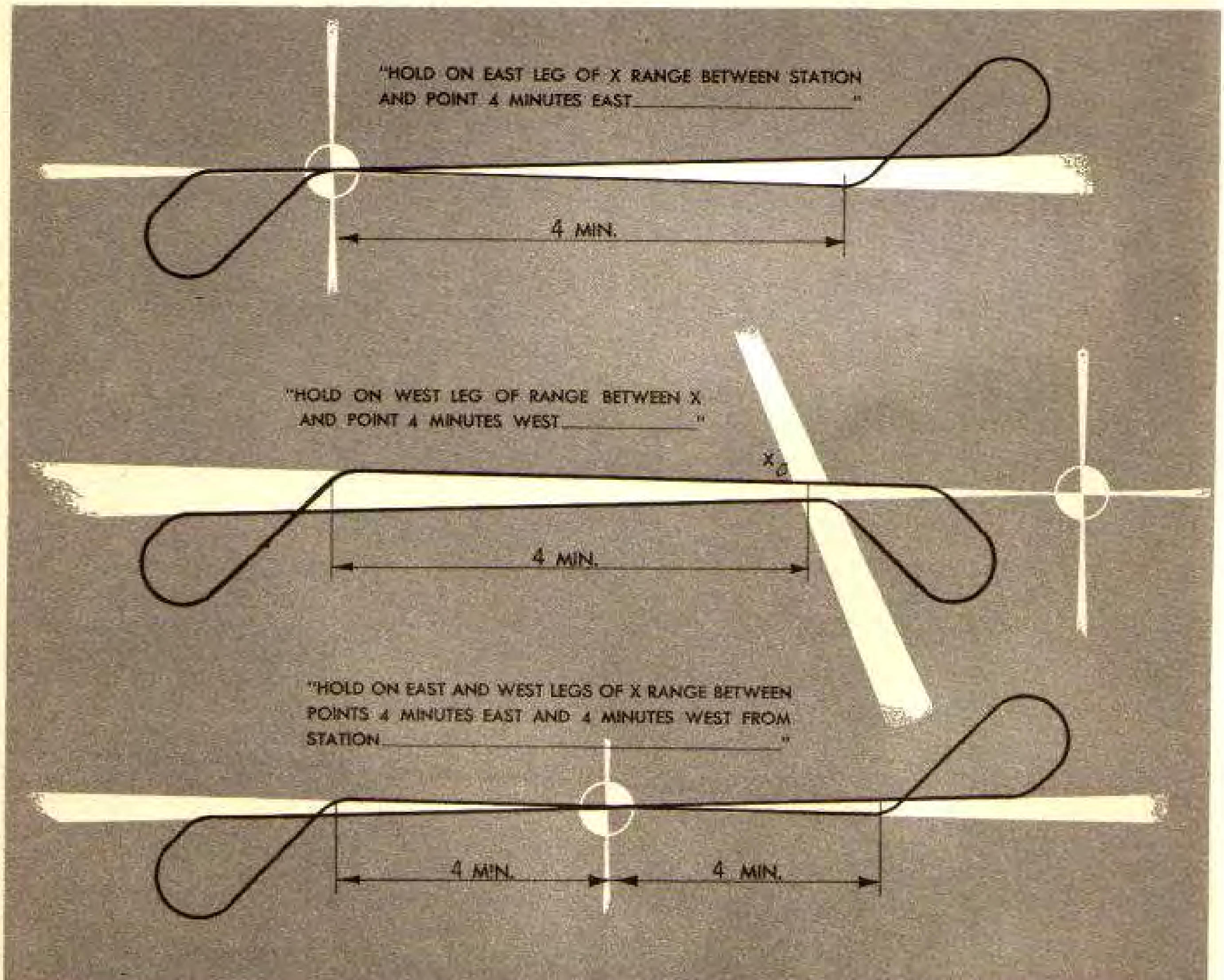


Figure 27—Holding

c. RADIO RANGE ORIENTATION.

Much has been written about orientation on the radio range, and numerous systems have been devised. All of these methods have their advantages and disadvantages. The pilot must know one satisfactory method of solving an orientation problem for use if ever he should become lost.

After the pilot has tuned in the radio range station on which the problem will be flown, he will turn parallel to either of the approximate bisector headings of the quadrant in which he is flying. The volume should first be turned up high. The pilot must listen carefully and note if background, or the station identification of the opposite quadrant, can be heard. If the other station identification is audible, the pilot should decrease the volume until the second identification is just audible. Then, if this background fades in a short time, the aircraft must be on a heading which is taking it away from one of the on-course signals and a 180° turn should be made. Second, if no background is heard while the pilot has turned up the volume, he will decrease the volume to as low a level as is consistent with clear reception. He will hold the bisector heading and if a definite fade in signal strength is noted he will turn 180° and hold this heading until a beam is intercepted. If the signal strength is increasing on the original heading, he will readjust the volume control and continue flying the bisector heading until a beam is intersected. Upon reaching a beam, the pilot will fly through it and on the opposite side turn left not to exceed 180° and bracket the beam.

After the brackets have been narrowed down to only a few degrees, he decreases the volume and checks for a fade or build just as was done in identifying the station. If the volume increases, the aircraft is on the leg headed toward the station. If the volume fades, the leg is identified as the one going away from the station. In the latter case, the pilot must do a procedure turn-around and follow the beam to the station. If the compass heading and the published bearings of a beam happen to agree approximately, the beam is not definitely identified. Fade or build must be checked while flying on-course.

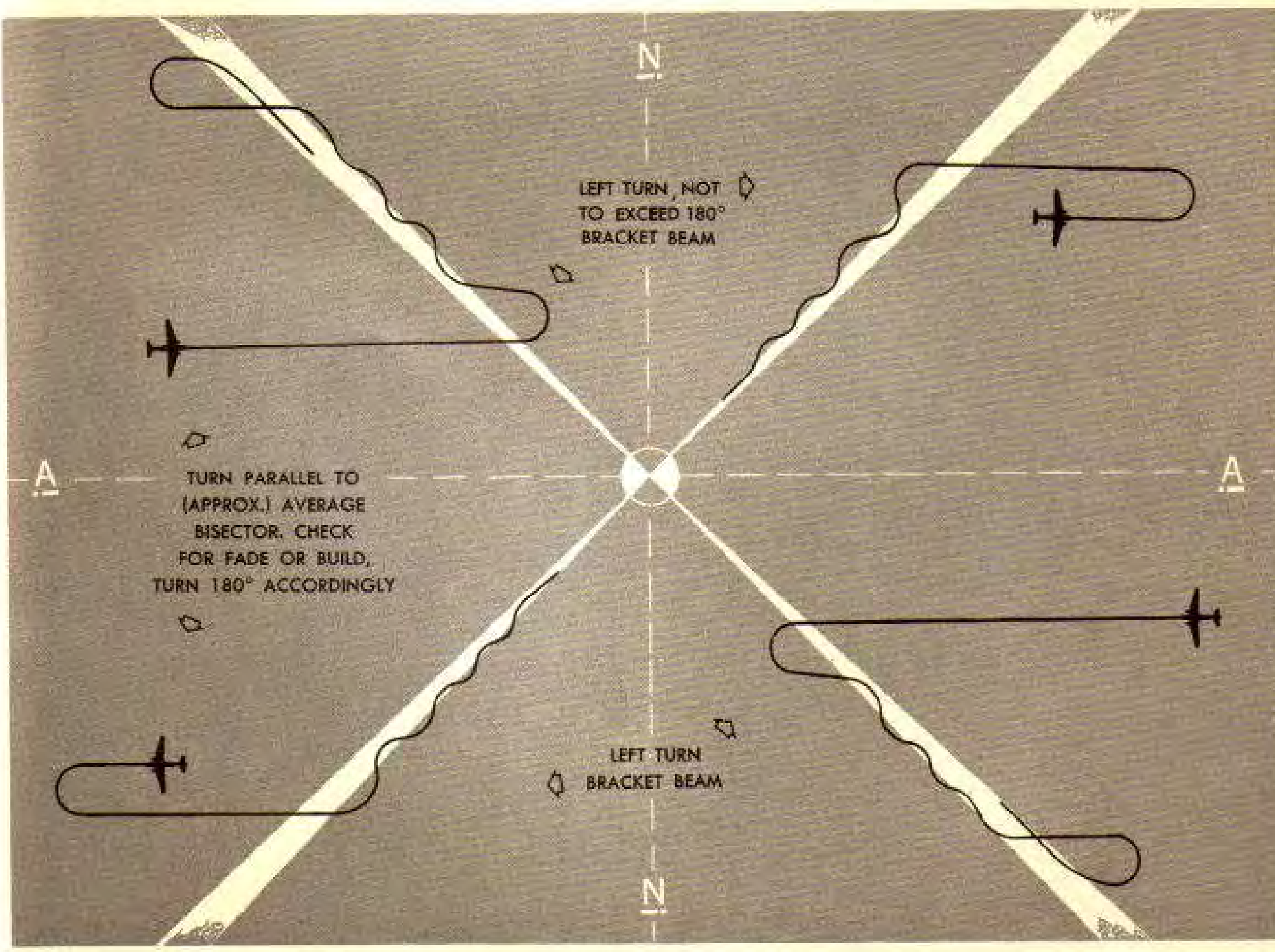


Figure 28—Radio Range Orientation

d. LETDOWNS, PULL UP AND LOW VISIBILITY APPROACH.

(1) *INSTRUMENT LETDOWN.*

When the ceiling and visibility are low at the destination an instrument letdown is necessary. The standard instrument letdowns for many airports will be found in chart form in the Army Air Forces, Instrument Letdown Procedures, Technical Order No. 08-15-3. However, certain general rules apply in all cases:

The pilot must make the initial approach and intercept the cone of silence before starting any letdown. Descent is usually made while flying outbound and returning inbound on the leg which is most nearly opposite to the leg aligned over the airport. The letdown is made at reduced airspeed, proceeding out for approximately 3 minutes from the cone of silence before making a procedure turn around. During this time the wheels are usually lowered and the landing cockpit check is performed. Landing flaps should be used if the aircraft normally requires part flaps for safety at slow airspeeds. After the procedure turn around, the aircraft is flown inbound "on-course," letting down so as to cross the cone of silence at the final approach altitude. When the cone has been crossed, the exact time is noted and the final descent made to the minimum altitude over the airport.

If the distance between the radio station and the airport permits, the pilot should plan his final descent to reach the minimum altitude $\frac{1}{4}$ to $\frac{1}{2}$ mile short of the airport. If the aircraft is then in position to land straight in, the pilot should be prepared to lower the flaps as soon as the airport is sighted.

As soon as the aircraft is within radio communicating distance of the destination, and before descending from the flight altitude level assigned by ATC, the pilot must call the TOWER or RADIO and obtain: (1) approval for instrument letdown; (2) ceiling; (3) visibility; (4) surface wind; and (5) altimeter setting.

While making an actual instrument let-down, the pilot should always have in mind a predetermined minimum altitude below which he will not descend. This minimum altitude will depend on the pilot's knowledge of his own limitations and the terrain features at that particular airport. If he has not broken through at this altitude, he should pull up; however, if there are no obstructions close to the field, either on the approach or beyond the field, the pilot may choose to fly at this altitude for 15 to 30 seconds to see if there is a "hole" in the ceiling up to that altitude. If he still has not "broken out", he will have to pull up.

(2) PULL UP FROM LOW APPROACH.

A pull up from a low approach is simple and there should be no hesitation after the decision has been made. Increase power to at least climbing manifold pressure, start climb and get wheels up. Keep constant airspeed. Be careful to check the vertical momentum in time to avoid getting to a lower altitude than the minimum planned. Be careful of raising flaps too soon! Missed approach procedure, for the particular range being flown, should be used; ordinarily this requires the pilot to climb to the initial approach or other designated safe altitude, calling the range or tower for approval to attempt another approach, or proceed to alternate airport.

(3) LOW VISIBILITY APPROACH.

During periods of extremely poor visibility it is very easy to "lose" the airport at which you intend to land while turning around to approach on the desired runway. This is especially true in large aircraft that require considerable space to turn. For this reason every pilot should have some "system" so that he is sure of getting back into the airport once it has been located.

The following "system" is suggested.

Fly along the desired runway in the opposite direction to which you intend to land, setting the gyro compass on the runway heading. After the edge of the airport has been passed, turn 45 degrees to left (or right if more desirable), fly for forty (40) seconds on this heading, then start a standard rate turn to the right. Turn until the landing runway heading has been reached. This heading should put the aircraft on the landing approach lined up approximately with the runway. Small corrections from this heading will line the aircraft up exactly with the runway once it has come into view. The wind direction and velocity should be taken into consideration in executing this maneuver.

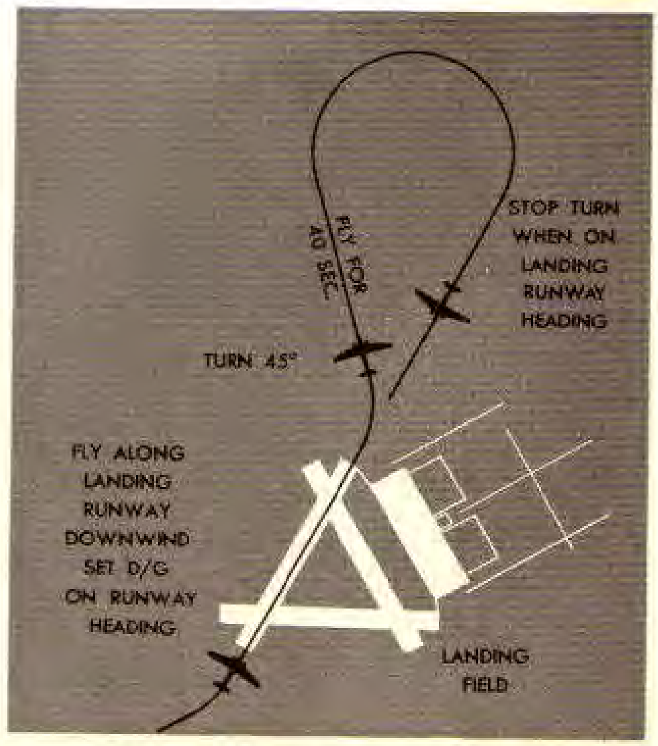
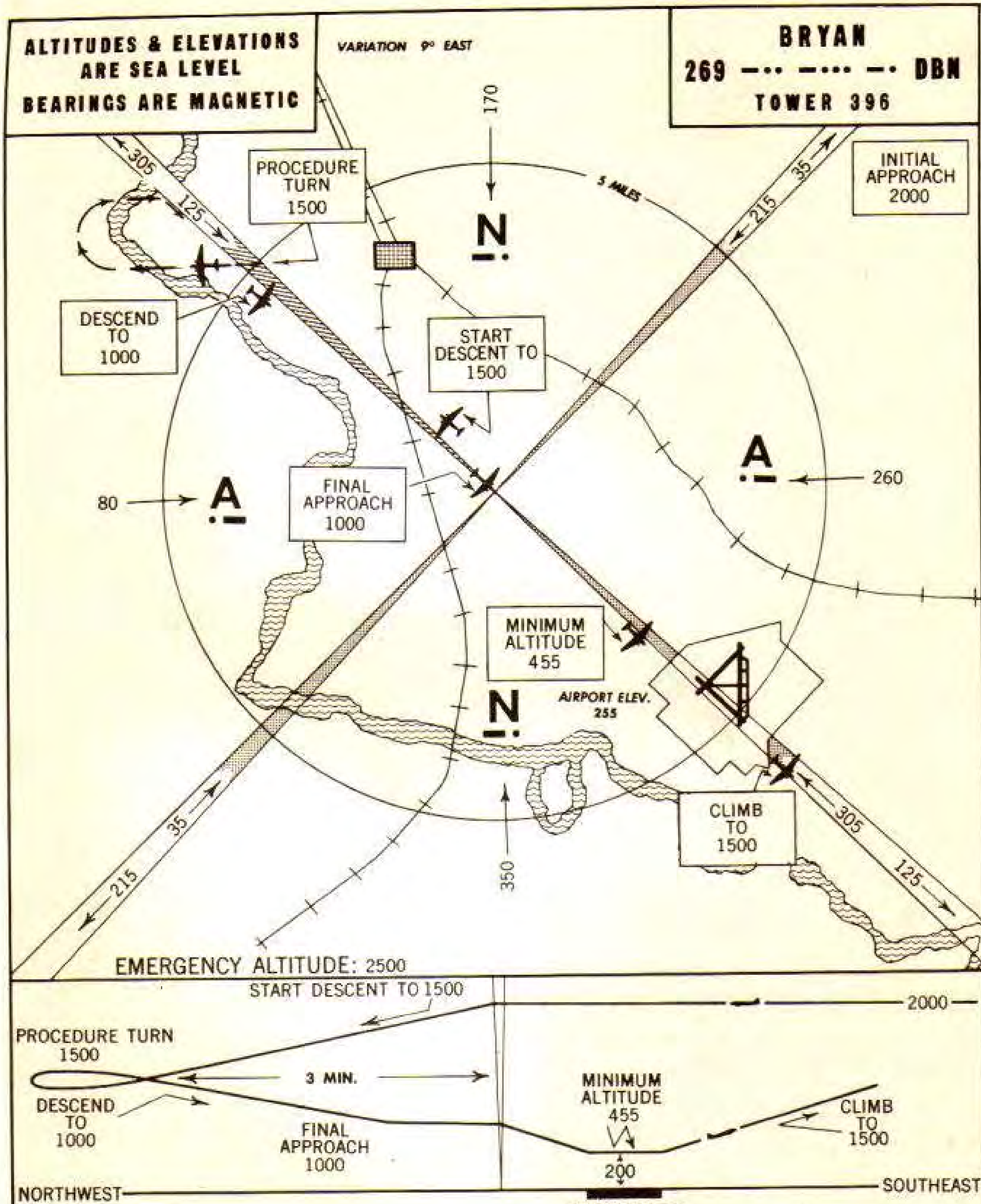


Figure 29—Low Visibility Approach

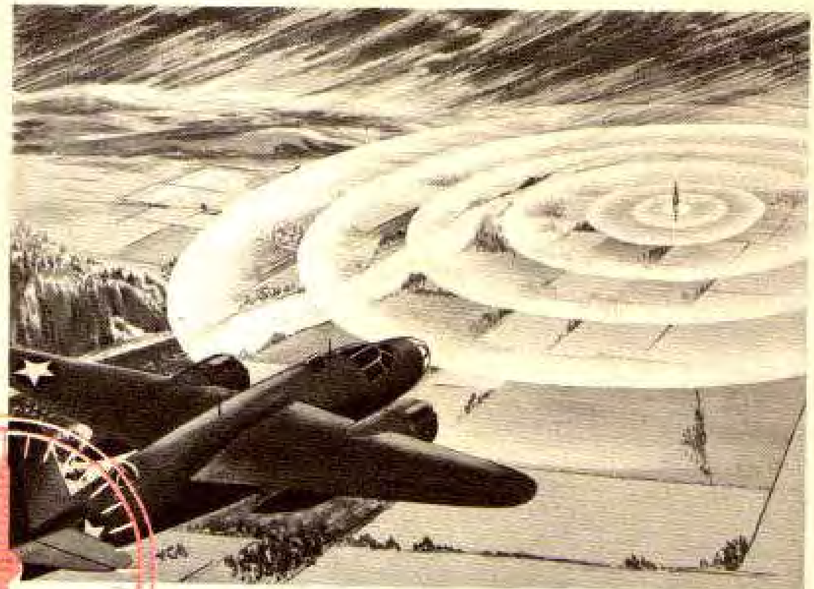


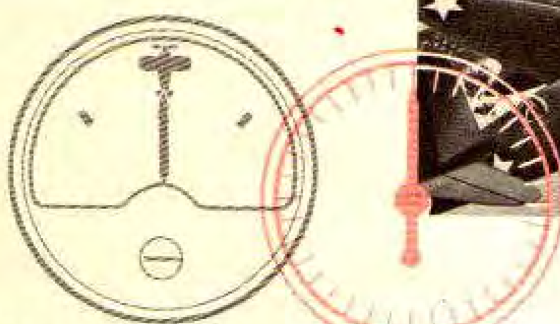
TIME-DISTANCE STATION TO FIELD 4.2 MILES					
110 M.P.H.	120 M.P.H.	130 M.P.H.	140 M.P.H.	150 M.P.H.	160 M.P.H.
2 MIN. 18 SEC.	2 MIN. 6 SEC.	1 MIN. 56 SEC.	1 MIN. 48 SEC.	1 MIN. 41 SEC.	1 MIN. 34 SEC.

BRYAN *Figure 30—Instrument Letdown Procedure* **BRYAN**

SECTION III

THE RADIO COMPASS





1. GENERAL.

a. CHARACTERISTICS OF A LOOP ANTENNA.

Everyone is familiar with the fact that most ordinary "portable" radios will pick up radio broadcasts with a varying degree of volume, depending upon the position in which the set itself is placed. That is, reception will fade or build in volume as the set is turned around. This characteristic is exhibited because most "portable" radios are equipped with a simple loop antenna built directly into the case. Loop antennas, even in this simple form, have definite directional characteristics, as follows:

(1) Plane of loop in line with radio station-maximum volume.

(2) Plane of loop at right angles to a line to the radio station-minimum volume.

(3) These directional characteristics are utilized for navigation and other purposes in the modern, highly efficient loop antenna installed in A.A.F. aircraft. Like the antenna of a "portable" radio, an aircraft loop antenna picks up signals at maximum strength (volume) when the windings of the loop are parallel to a line drawn from the transmitting antenna to the loop (the edge of the loop is pointed toward the station). This is the "maximum" position. It picks up signals at minimum volume when the plane of the loop is at right angles to a line drawn from the radio station to the loop (the "hole" of the loop points toward the station). This is the minimum or "null" position. The radio compass is designed to make use of the "null" position because when the loop is in the minimum signal position a small change of loop or aircraft direction will give a sharp change of volume, that is, the null or minimum signal position is very narrow, provided the volume control (AUDIO) is used properly. When the loop is in the maximum position a large change in the position of the loop or in the heading of the aircraft can be made and little, if any, change in the volume of the signal received in the headset will be noticeable.

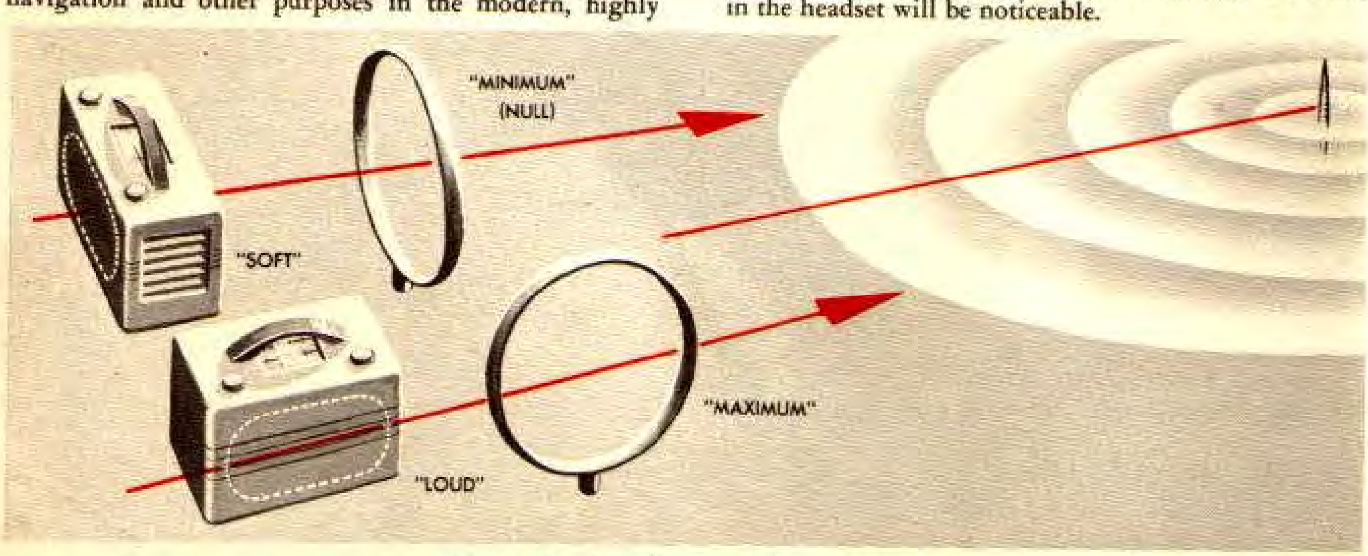


Figure 31—Loop Position Characteristics

b. TYPES OF RADIO COMPASSES.

When installed in an aircraft together with a suitable radio receiver, fixed antenna, control box, etc., the directional qualities of this loop can be used for radio direction finding. This loop antenna-radio receiver combination is called the "Radio Compass" although the term "Radio Direction Finder" is also used. There are three types of radio compass equipment installed in army aircraft at present.

1. *FIXED LOOP* with left/right indicator. The indicator employed with this equipment is centered when the loop is in the "null" position. Fixed loop radio compasses are still in service in a small number of aircraft and, because their use is essentially similar to the use of the newer types of equipment, they will be further described in the last part of this section.

2. *ROTATABLE LOOP* with left/right indicator. This later development in airborne radio direction finding equipment employs a manually rotated loop antenna. An azimuth scale, located near the loop rotating crank shows the position of the loop relative to the longitudinal axis of the aircraft. The indications of the left/right indicator are identical to those for the fixed loop type compass. When the left/right indicator needle is centered, the loop is in the null position, and the needle of the azimuth indicator points to the relative bearing of the radio station from the aircraft.

3. *AUTOMATIC RADIO COMPASS.* This type of radio direction finding equipment is the latest development, and is the present Army Air Force standard. When this set is used on COMP position, the loop is automatically rotated to line up with the radio station in the "null" position. A pointer turning upon an azimuth scale is synchronized electrically with the loop and indicates the position of the loop, with respect to the aircraft; and thus the relative bearing to the radio station to which the radio compass is tuned.

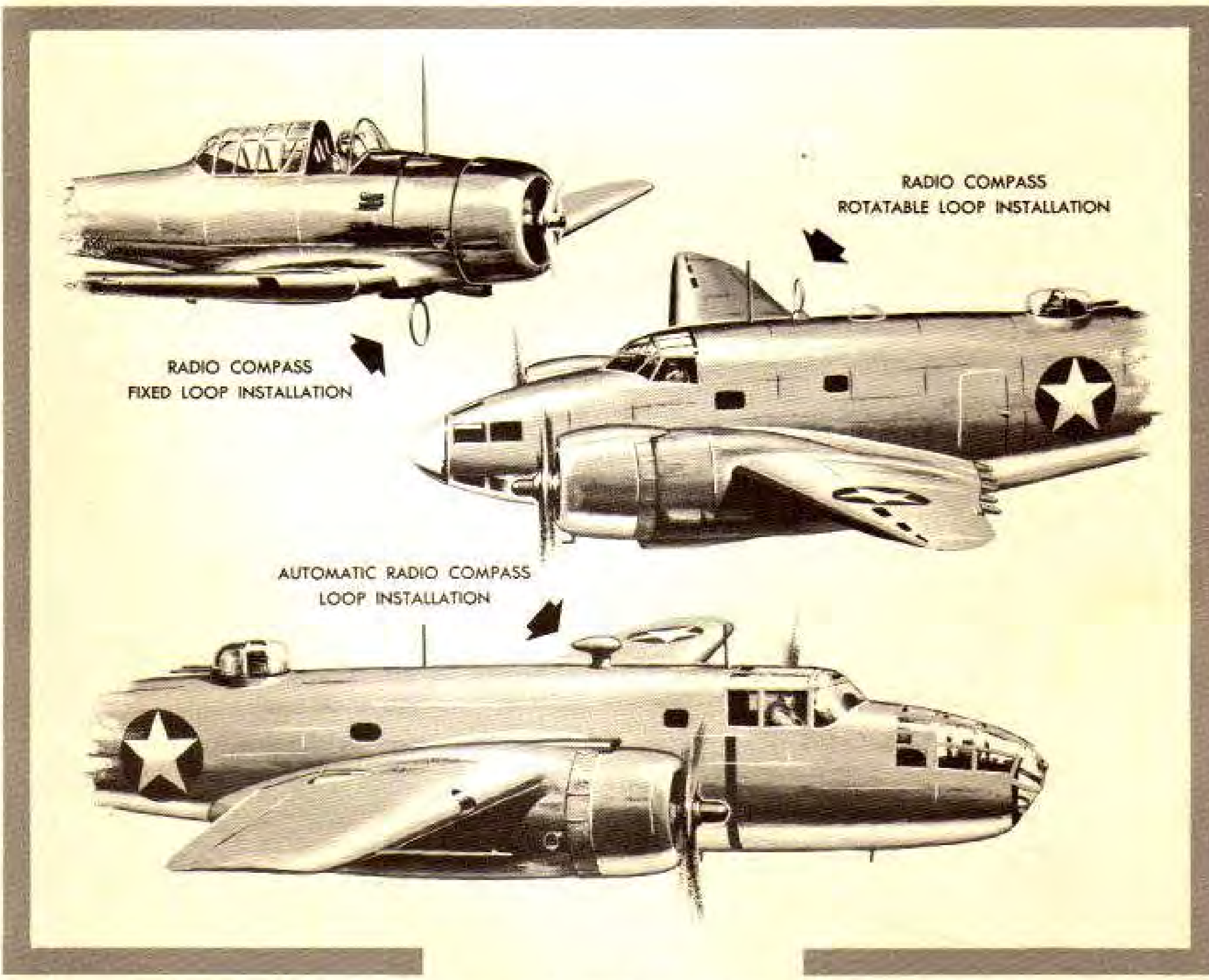


Figure 32—Radio Compass Types

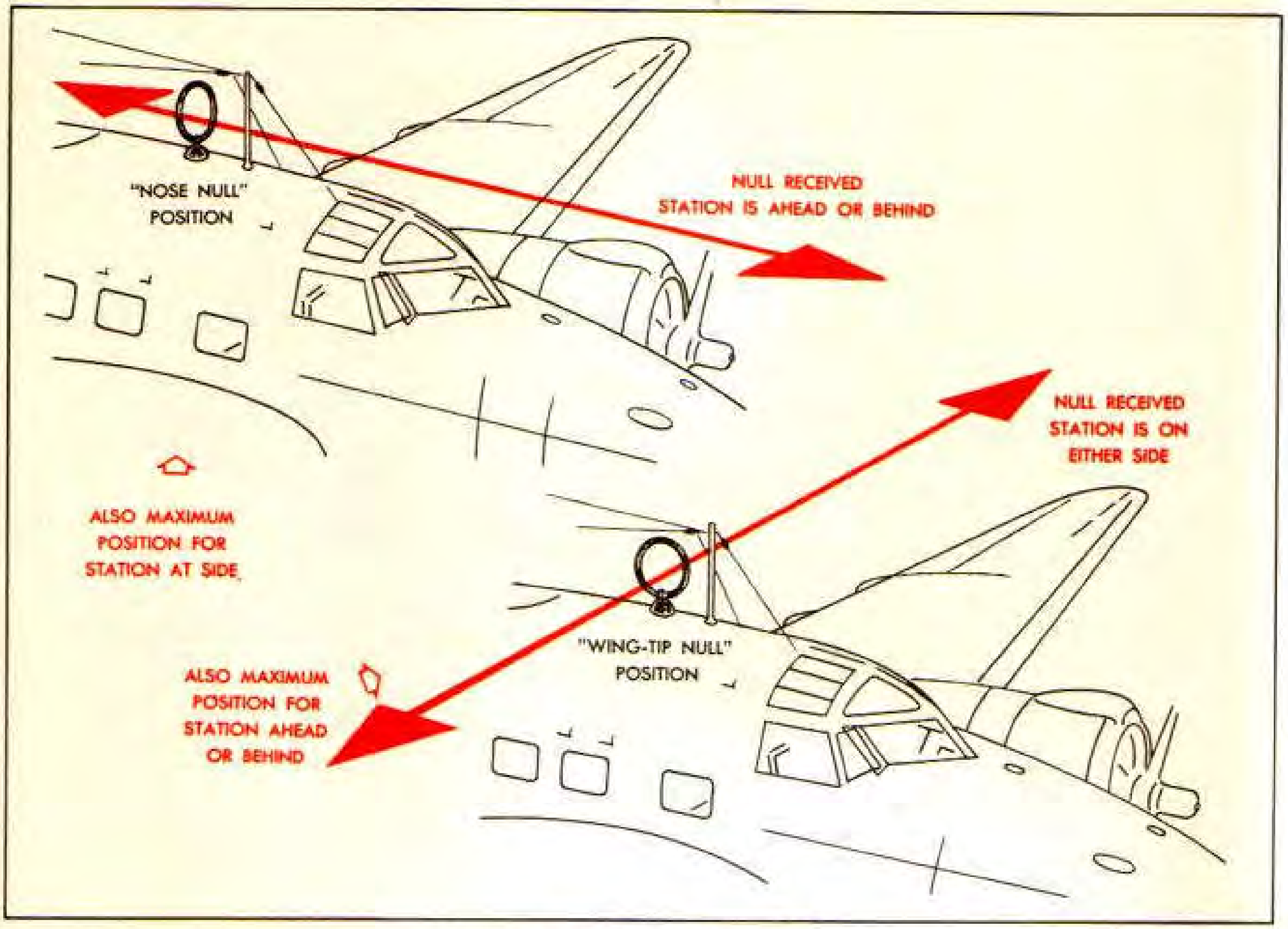


Figure 33—Wing Tip—Nose Null

c. THE AURAL NULL.

As stated in the foregoing, the "null" position of the loop antenna is indicated by the "Radio Bearing Indicator" of the Automatic Radio Compass; or by noting the reading on the azimuth scale when the L/R needle is centered in the case of the older equipment. However, under some conditions it is necessary to determine the "null" position without using the visual indicators. The "null" position of the loop can be determined aurally by noting the minimum strength of the signals received in the headset while the position of the loop is changed relative to the radio station. This minimum signal is termed the "Aural Null." The terms "nose null" and "wing tip null" are defined as:

(1) *NOSE NULL.*—The "hole" in the loop antenna points toward the nose of the aircraft, and an "aural null" will be received if the radio station is directly ahead or to the rear.

(2) *WING TIP NULL.*—The "hole" in the loop antenna points toward the wings of the aircraft, and a "null" will be received when the radio station is 90° to the right or left of the aircraft.

(3) *MAXIMUM SIGNAL POSITION.*—The modern loop antennas are well shielded and can be used to receive radio range signals and voice broadcasts at times when normal reception is impossible due to precipitation static. Only a loop antenna which can be rotated can be used for this purpose, because the loop must be turned 90° from the "null" position. A small, or even a relatively large, change in the position of the loop or in the heading of the aircraft will produce little apparent change in signal strength when the loop is used in "maximum" position. It is to be noted then, for best definition of radio range signals or voice on LOOP, the loop must be maintained on the 90° or 270° position (in relation to the aircraft headed toward or away from the radio station—if the aircraft or the loop is turned 90°, the signal strength will become weaker).

(4) *180° AMBIGUITY.*—It can be seen from figure 33 that an aural null will result whenever the plane of the loop is perpendicular to the radio waves from the station, regardless of which side of the loop the station is located. There is no direct way of knowing which of the two possibilities is correct. This uncertainty of position is known as the "180° ambiguity" of the aural null. This ambiguity can be easily solved in flight as explained later in the text.

Figure 34—Automatic Radio Compass

2. AUTOMATIC RADIO COMPASS (SCR-269 SERIES).

a. DESCRIPTION.

(1) Most standard installations can be controlled from either of two locations in the aircraft. One set of controls is mounted in the pilot's compartment (see Figure 34) and the other in the navigator's or radio operator's compartment. At each position there is a control box and an azimuth indicator dial, graduated from 0° through 360°, which shows the position of the loop with respect to the longitudinal axis of the aircraft. The indicator needle of the azimuth dial is electrically connected with the loop itself and moves with it. When using the automatic radio compass in the COMP position, the loop is automatically controlled and the pilot's indicator needle points to the station to which the equipment is tuned. *TWO* antennas are involved in this automatic action. In addition to the loop there is a non-directional antenna (either whip or wire type). The signals heard, while the equipment is operating on COMP position, are received over this antenna and are of constant intensity regardless of the direction of the loop antenna. The signals picked up by these two antennas energize a phasing system which operates the motor on the loop drive and keeps the loop in the null position relative to the radio station.

(2) Since the automatic action of the radio compass depends upon these *two* antennas, it must be remembered that the loss of either antenna will render the automatic system inoperative. It is unlikely that the loop will become lost, except by enemy action; however, the phasing (non-directional) antenna may be lost due to icing conditions. Loss of the phasing antenna will become immediately apparent by the disappearance of the audible signals and by the rotation of the indicator needle. The equipment can no longer be used for automatic direction finding. Since the loop antenna is still available, the receiver must then be used on LOOP position and the location of the radio station determined by the AURAL NULL procedure. In aural null direction finding, the function switch is turned to the LOOP position, and the loop is rotated by the LOOP L/R switch until the signal completely disappears. Aural null methods will be explained in detail later in this text.

b. TUNING.

1. Set the Interphone Jack-box selector switch to COMP and adjust output (volume) control to maximum.

2. Turn the Range-Voice-Both switch to BOTH.

3. Set the radio compass control box to ANT position.

NOTE

When first tuning for a station always use the ANT position because when the equipment is on COMP position the automatic volume control is in the circuit and it is difficult to tune accurately for maximum signal intensity by sound or by use of the tuning meter.

If the function switch is on LOOP, the loop may be in the null position with reference to the desired station and the station may not be heard at all.

4. Push the CONTROL switch to operate the green light on the control box. The green light indicates when the control box has control.

NOTE

At times the control button will not take control away from the other remote control box if the switch of that box is OFF. This is caused by low voltage in the electrical system. The control button should be held down firmly for a few seconds, or the function switch of the other box should be turned to any ON position, i.e. COMP, ANT, or LOOP.

5. Move the band selector control to the desired frequency band.

6. Turn TUNING crank to the desired station frequency and rotate back and forth for maximum right deflection of the tuning meter and preferably for maximum signal strength to make sure that the desired station is properly tuned in. If the tuning meter fluctuates (as on loop type radio range stations), disregard it, and tune for maximum signal strength. When the station is being received as clearly as possible, listen for the station identification before taking a bearing. This is extremely important.

7. Turn the Function switch to COMP if the equipment is used for automatic direction finding or homing.

NOTE

Occasionally the azimuth needle of the SCR-269 series Automatic Radio Compass will spin violently when the function switch is turned to COMP. When this occurs, immediately switch to any other position and wait for the needle to stop. Then turn back to COMP. Repeat if necessary. Tuning to another station will have no effect since this rapid spinning is caused within the set itself. Loss of the phasing antenna will cause a relatively slow rotation of the needle; when this occurs, aural null procedures must be used.

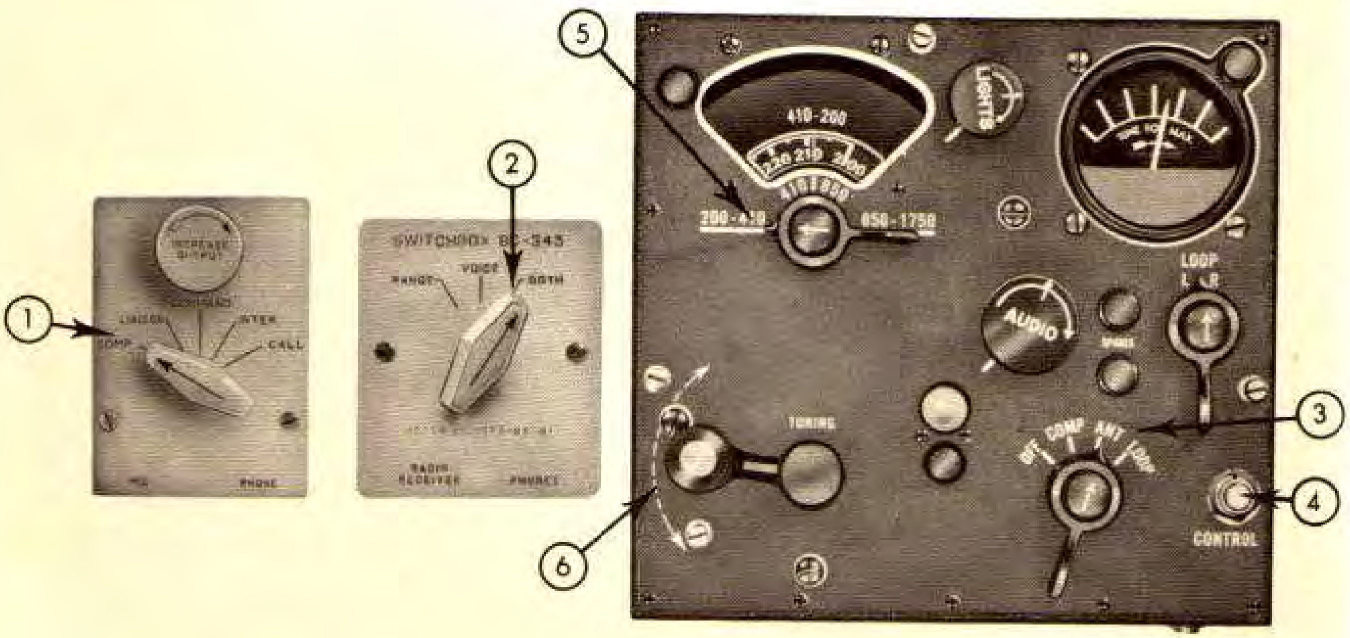


Figure 35—Tuning the Automatic Radio Compass

c. TO REDUCE PRECIPITATION STATIC.

The radio compass may be used as an auxiliary receiver. However, when it is used to fly the radio ranges, certain precautions must be taken. For the most reliable aural reception of radio range signals, use the ANT position. If precipitation static causes poor reception, turn the switch to LOOP and rotate the loop to maximum signal position by the use of the LOOP L/R switch. Push in the switch to rotate the loop rapidly. See Figure 36. However, do not rely on the signals received on LOOP when near the station, because the "A" and "N" are often reversed, and the cone of silence may be difficult to detect. Do not use COMP position as the automatic volume control is then in the circuit and will cause a broad "on-course." Fades and builds of signal strength will be very difficult to detect on this position.

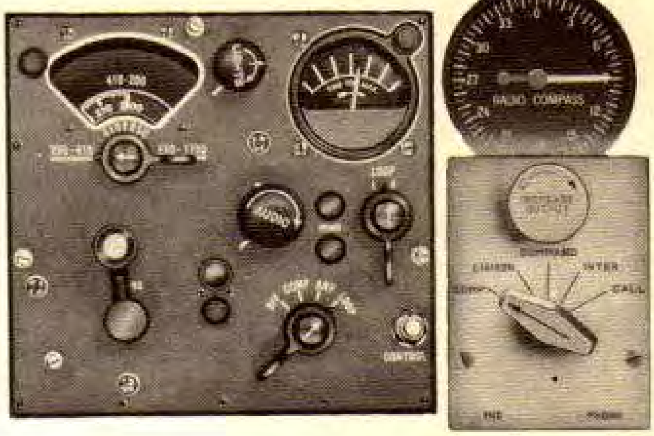


Figure 36—Anti-Static Reception

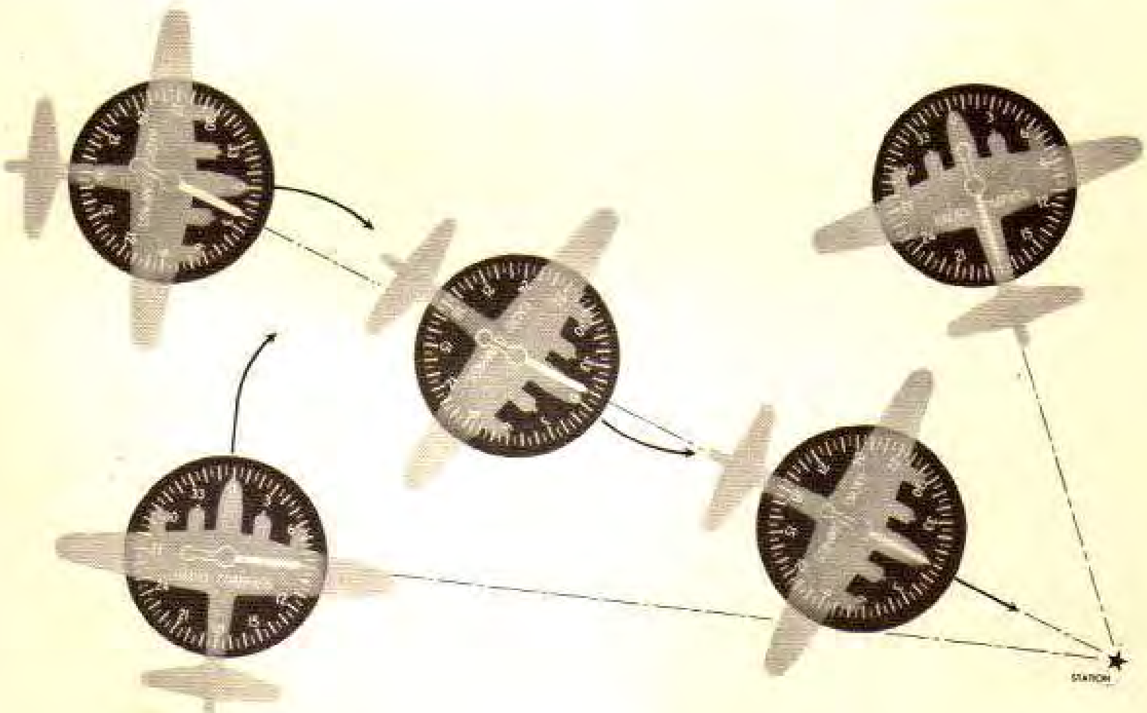


Figure 37—Indications of the Pilot's Bearing Indicator

d. HOMING.

1. Tune station as described, under *(b)* above, then switch to COMP. Adjust "AUDIO" control for satisfactory volume.

2. Turn in the direction shown by the pilot's bearing indicator. If the pointer is to the right of zero, the radio station is to the right of the heading of the aircraft. A gentle turn to the right is started and when the pointer is at zero, the aircraft is headed toward the radio station. See Figure 37.

NOTE

When on COMP this equipment includes automatic volume control, and builds or fades cannot be received satisfactorily.

e. DRIFT CORRECTION AND HOMING ON A KNOWN BEARING—TRACKING.

(1) When the pilot's bearing indicator needle of the automatic radio compass is at 0°, the aircraft is headed toward the radio station to which the receiver is tuned. The gyro heading of the aircraft will be the bearing toward the station. If this gyro heading is held constant, the effect of a cross wind will be to drift the aircraft to one side or the other of this bearing toward the station. Drift will become apparent by noting the movement of the indicator needle away from 0° while a constant gyro heading is being flown. When a distinct change in radio compass bearing is observed, turn the aircraft 20° into the wind (in the direction in which the needle is deflected). Hold this correction until the automatic radio compass indicator needle reads 20° or 340° (20° downwind from 0°) when the bearing toward the radio station will again be intercepted. Then turn back 10° toward the original gyro heading. If the radio compass bearing now remains constant, in this case at 10° or 350°, the correction for wind drift has been made. If the radio compass bearing changes from this reading, it will move in the direction in which another correction must be made. See Figure 38. Repeat the process until the correct heading has been found. The initial correction of 20° used in this example is satisfactory for most conditions. However, if the rate of change of the radio compass bearing is very rapid when the aircraft is first headed toward the station, a larger correction will be necessary. In this case, if the position of the aircraft is known to be a considerable distance from the station, a strong cross wind exists, or, if the aircraft is close in, even a moderate wind will cause a large apparent drift from the desired bearing.

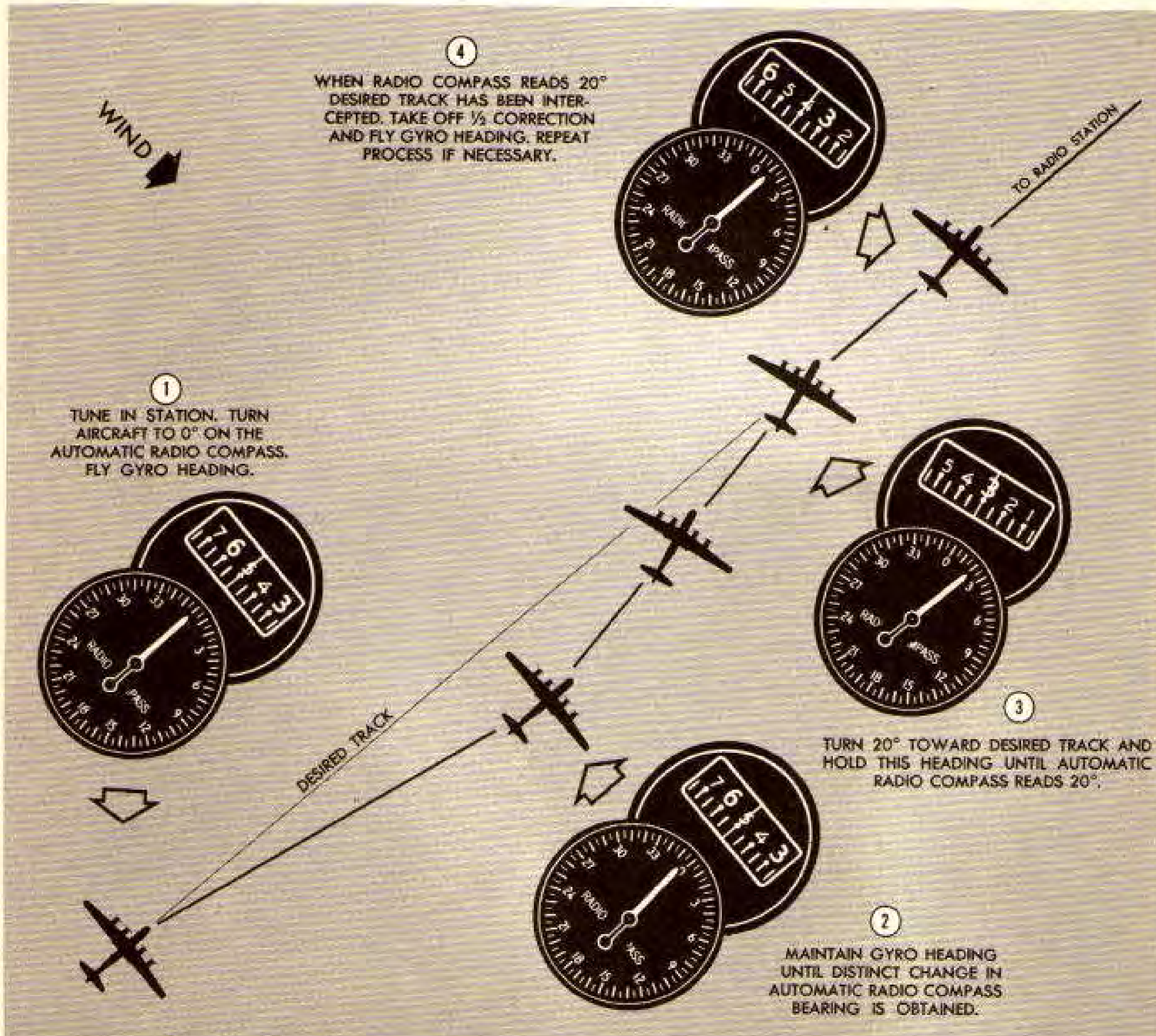


Figure 38—Drift Correction

(2) When the distance to the radio station is known, the necessary drift correction can be quickly determined in the following manner:

(a) Fly the gyro heading toward the station and note the changing radio compass bearing after flying a reasonable length of time. See Figure 39.

(b) Divide the total time to the station by the time flown, and multiply the result by the number of degrees of change of radio compass bearing. The answer will be the drift correction in the direction indicated by the radio compass needle.

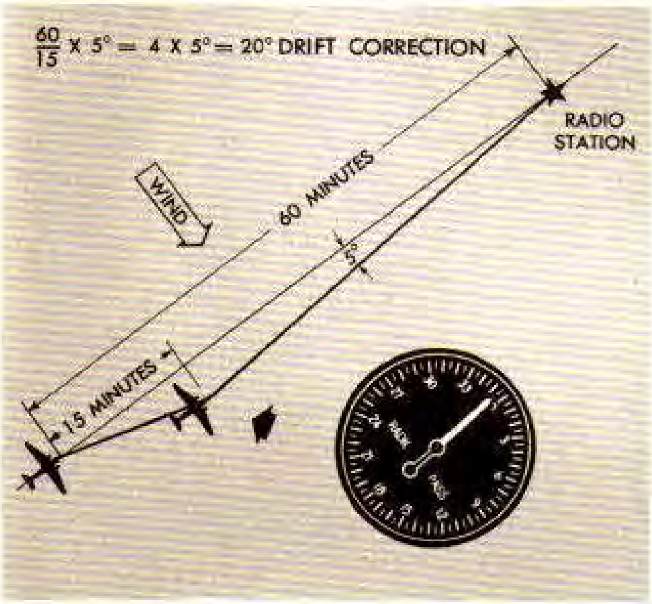


Figure 39—Drift Calculation

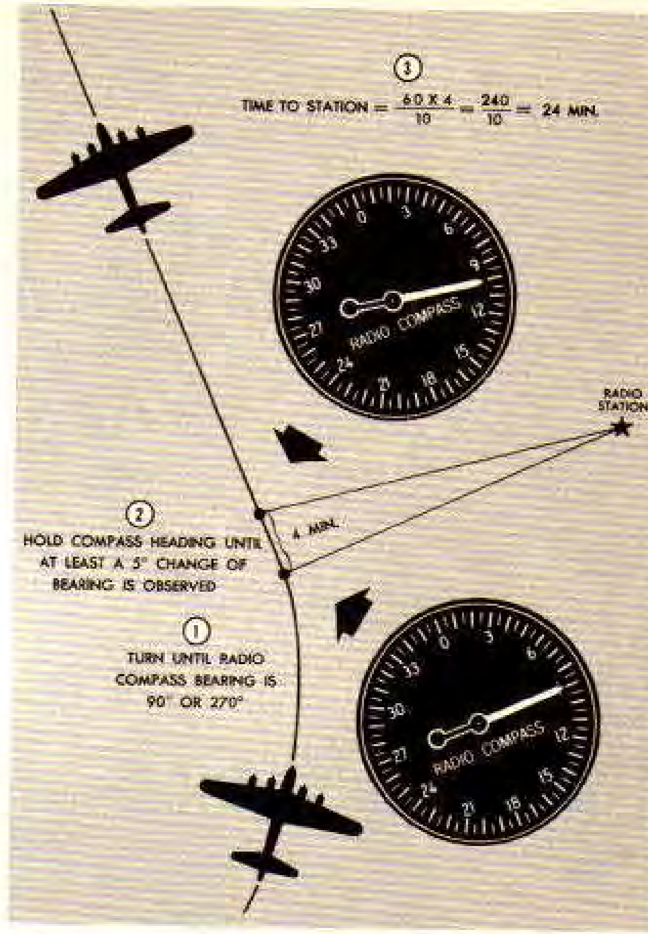


Figure 40—Distance Calculation

f. RECOGNIZING THE STATION.

(1) In the case of a radio range station, a rapid rise in volume, in spite of the automatic volume control, will be the first indication of the closeness of the station. When very close to the station, even a slight lateral departure from the desired track will cause a large deviation of the indicator needle. It is therefore desirable to make a correction of heading immediately when the compass needle deviates slightly from zero. Do not overcorrect. In the immediate vicinity of the station, the needle action will become erratic and the gyro heading previously established must be flown and no attempt should be made to chase the needle. As the aircraft passes over, or slightly to either side of the station, the needle will swing back and forth and will settle in the 180° position when the station has been definitely passed. For timing purposes, the time when the needle passes 270° or 90° may be taken as the instant of passing the station.

(2) Do not expect a surge in volume as a high powered broadcast station is approached. The volume will often remain unchanged within a large radius of the station.

g. DISTANCE CALCULATION.

(1) With the automatic radio compass, the direction of the station is immediately known when the station is tuned in and the function switch is turned to COMP position. However, the distance to the radio station must be determined by calculation. As the pilot usually measures distance by time, especially on instrument flights, the following method can be used to determine the length of time required for the aircraft to travel to the station from its position at the *end* of the distance check. The method is reasonably accurate in a condition of calm air, or even moderate winds, unless the airspeed is changed. Allowance should be made for the effect of strong wind.

(2) The method is as follows: Turn the aircraft until the azimuth needle is on 90° or 270°. Note the time and hold a constant heading until a change in relative bearing of at least 5° is noted. This will occur rapidly when close to the station, and for better accuracy in this case, the heading should be held for at least one minute. In any case, a 20° change of bearing should not be exceeded, as the result becomes inaccurate at greater angles. When the time and change of bearing have been determined, the following formula is used:

$$\text{Minutes to the Station} = \frac{60 \times \text{Minutes flown between bearings}}{\text{Degrees of Bearing Change}}$$

$$\text{Distance to the Station} = \frac{\text{True Airspeed} \times \text{Minutes Flown}}{\text{Degrees of Bearing Change}}$$

b. INTERCEPTING AND TRACKING ON PREDETERMINED BEARINGS.

(1) There will be cases when it is necessary to home on a station on a given track, due to terrain features, danger areas, or for other reasons. If the desired track is known, intercepting and following it to the station with the radio compass is a relatively simple problem.

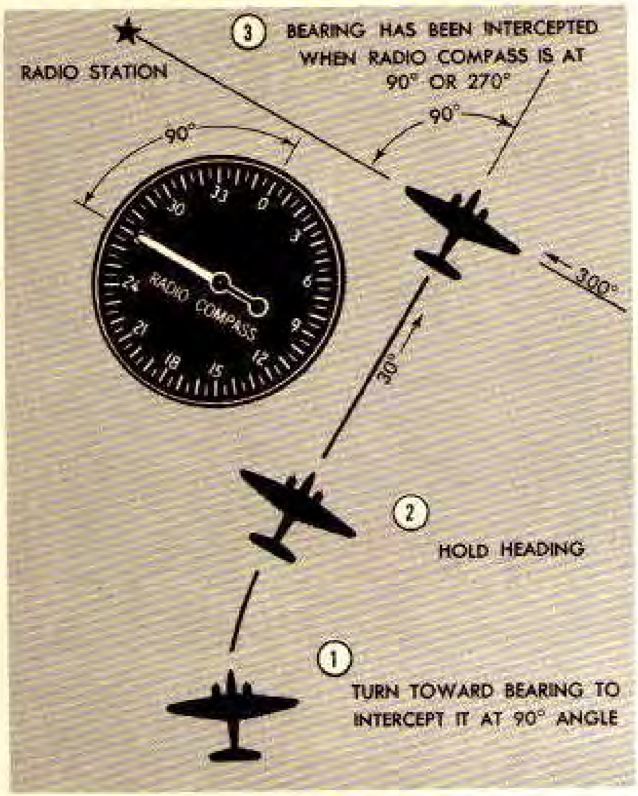


Figure 41—Intercepting Bearing at 90°

(2) For example, while flying on a magnetic heading of north and homing on a station, your chart shows an intervening danger area ahead. You determine by reference to the chart that a bearing of 300° magnetic toward the radio station will clear this area.

(3) Turn to a gyro heading to intercept this desired bearing at a 90° angle. In this case the compass heading will be 30°. Holding this course, you observe the radio compass bearing indicator until it reads 270° (0° minus 90° on the indicator). At this instant the aircraft will be on the bearing of 300° toward the radio station. See Figure 41. A standard rate turn, in the direction shown by the radio compass needle, will bring the aircraft onto the desired track. Home on the radio station and apply the necessary drift corrections.

(4) Similarly, any desired bearing can be intercepted at any angle. It is only necessary to fly a heading to intercept the bearing at the specified angle. When the radio compass bearing is plus or minus the value of the angle of interception from 0°, the bearing will have been intercepted.

(5) When within 10 minutes of the station, it is necessary to anticipate turn to avoid overshooting the desired bearing. When at greater distances, the radius of turn will introduce no appreciable error.

NOTE

Effect of Inaccurate Magnetic Headings.

A radio compass bearing, unlike a radio range beam, is computed by considering the heading of the aircraft and the relative bearing indicated on the azimuth dial. On a radio range leg, the bearing of the station is definitely determined by identifying the position of the aircraft on that particular leg regardless of the heading of the aircraft at that time. However, since a bearing taken with the radio compass depends on both the relative bearing (reading of the pointer on the azimuth dial) and the heading of the aircraft, it is essential to obtain accurate bearings that the correct heading of the aircraft be known. Therefore, the pilot must frequently check the directional gyro (if used) with the magnetic compass; and must apply the magnetic compass deviation correction when determining the magnetic heading of the aircraft. At great distances from the station, a few degrees error in computing a bearing will amount to a considerable distance error in the position of the aircraft.

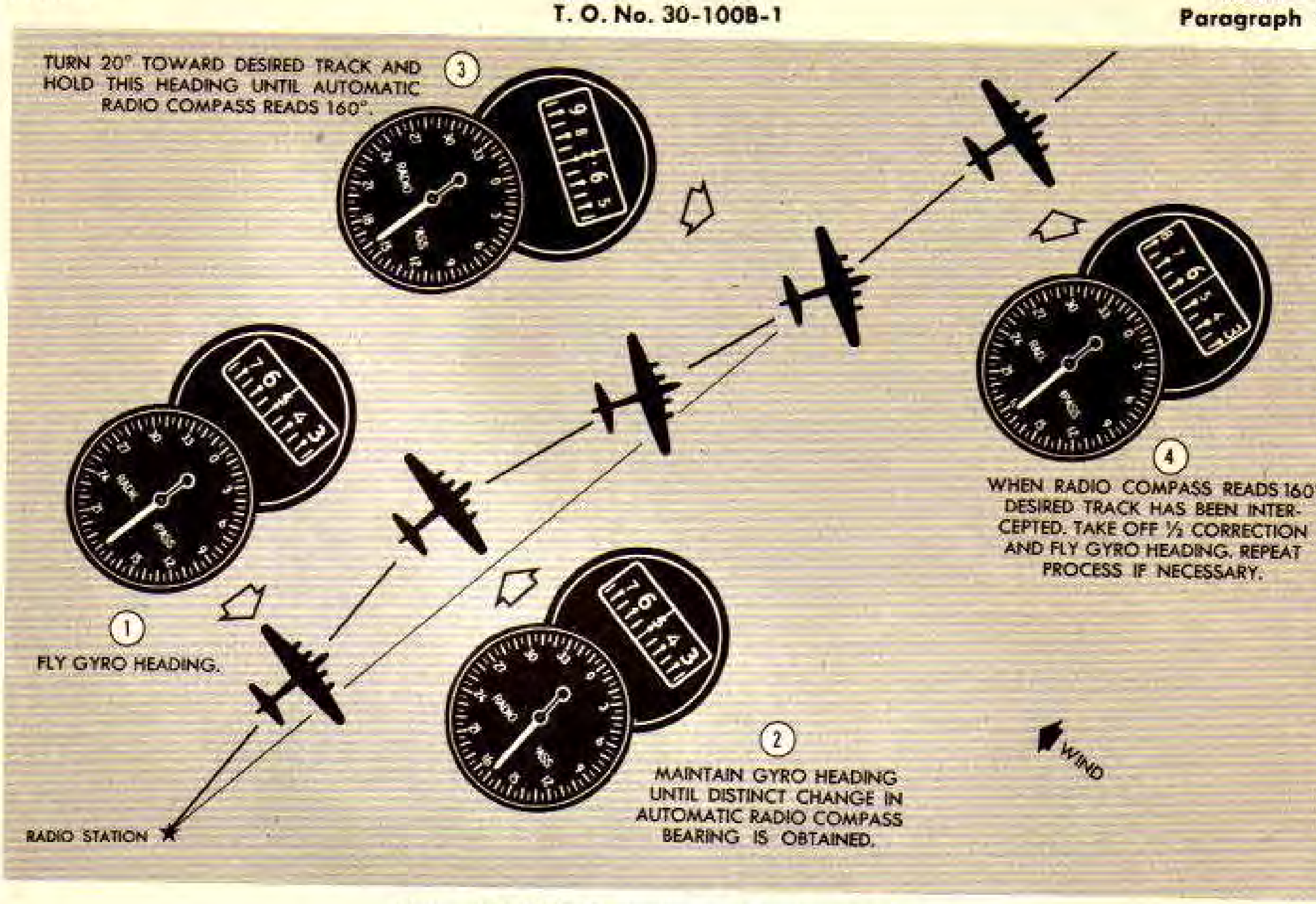


Figure 42—Drift Correction on Outbound Track

i. MAKING GOOD A TRACK AWAY FROM STATION.

(1) After the radio station has been passed, it may be desirable to make good a definite track away from the station. The technique used is essentially similar to that practiced when homing to the station and making drift corrections.

(2) After passing the station, the known gyro heading toward the desired objective is flown. The radio compass bearing is observed while holding this heading. It will be in the vicinity of 180° since the radio station is to the rear of the aircraft. If the needle moves toward 170°, the wind is from the right and the aircraft is drifting toward the left of the desired track. When a definite change of radio compass bearing has been noted, a 20° correction of heading, into the wind, is made. This correction is held until the radio compass bearing is 20° off 180°. If the correction was to the right, the aircraft will be again on the desired track when the radio compass bearing becomes 160°, that is, 180° minus 20°.

(3) If the aircraft is now returned to the original heading, it will again drift off the desired track. Therefore, a 5° to 10° correction into the wind is made, and the radio compass bearing observed as before. If the correction has been accurately determined, the radio compass bearing will remain constant as the gyro heading is flown. Figure 42.

NOTE

Never fly from a radio station by keeping the radio bearing constant at 180°. Fly the gyro heading and observe the radio compass for deviation from the desired track.

j. FLYING THE RADIO RANGES.

(1) When an orientation problem must be flown, it is not necessary to prove the position of the aircraft by the true fade-out or any other method of range orientation. It is only necessary to tune in and identify the station on ANT, and to turn the function switch to COMP. The bearing indicator will immediately point to the relative bearing to the radio range station.

(2) The pilot can now either turn to intercept the nearest on-course signal of the radio range station, and then bracket the beam toward the range station as in normal radio range flying; or he can turn the aircraft in the direction indicated by the radio compass and home directly on the station. As the aircraft passes over the station, the needle will turn 180°. If an instrument letdown is necessary, the pilot can now fly out on the final approach leg and execute the standard letdown procedure for that station.

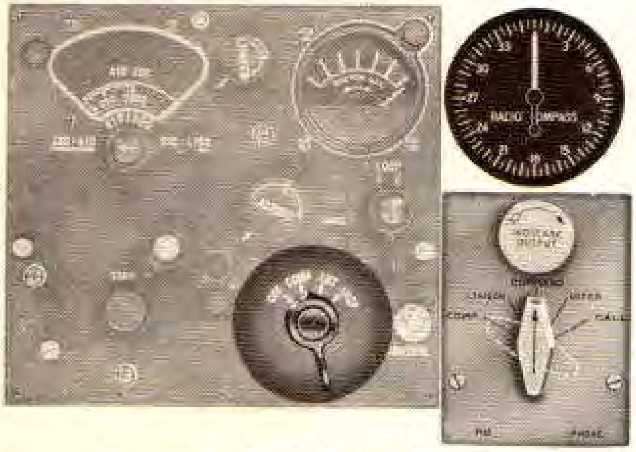


Figure 43—Radio Range Reception

(3) It is desirable to listen to the radio range signals while flying the airways. Since the radio compass, operating on COMP position will tend to produce broadened on-course signals, it is best to listen to the signals on the additional radio receiver installed in the aircraft. This can be done by tuning in the automatic radio compass with the interphone control box switch on COMP position. When the radio station has been identified on the automatic radio compass and the indicator is operating, switch the interphone control box switch to the command receiver. Using this receiver, the aural signals of the radio range can be used for additional check. Figure 43.

(4) Similarly, the radio range can be flown aurally with the command receiver while the radio compass is used to provide fixes on another radio station located to either side of the on-course signal. If a suitable station can be utilized, the exact position of the aircraft will be known at all times by observing the changing radio compass bearing to that station.

(5) For example, assuming an aircraft is flying the south leg of the Chanute, Kansas radio range. The pilot is listening to the on-course over his command receiver. The heading of the aircraft is 176°, indicating the absence of any drift. While referring to his chart, the pilot notes the Coffeyville homing facility is ahead and off to the right of his course. He decides to take a running fix on that station as he passes by. First, since he is listening on the command receiver, he will turn the interphone jack box switch on COMP. He then tunes in Coffeyville on the radio compass, identifies the station, and switches the radio compass function switch to COMP. The radio compass bearing indicator shows a bearing of 10° and the pilot knows that the homing facility is well ahead and to the right of his course. Leaving the radio compass tuned in, the pilot now switches the interphone jack box back to COMMAND and flies the Chanute on-course aurally. The radio compass bearing will change until the needle of the indicator reaches 90°, as Coffeyville is directly to the right of the aircraft. An exact position fix has been obtained. See Figure 44.

(6) In this example, the on-course of the Chanute, Kansas radio range serves as one line of position, while the radio compass bearing on Coffeyville provides the other. A fix can be determined at times when the relative bearing to the second radio station is other than 90° or 270° by using the radio position finding procedure covered in paragraph *k* (Position Finding).

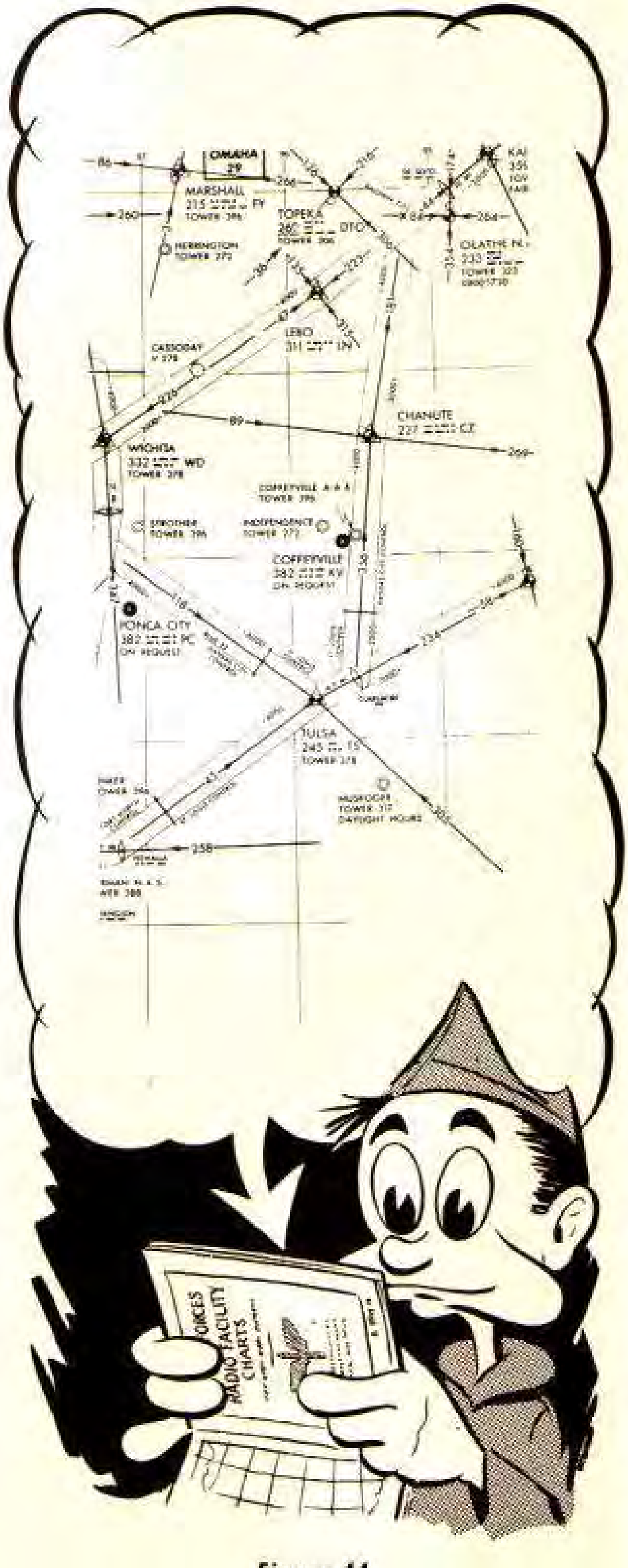


Figure 44

(7) A fix can also be obtained at times when the aircraft is not being flown on any radio range course. The radio compass is tuned to a radio station to either side of the intended flight path and the relative bearing of the radio compass is noted. The aircraft need not be turned off the intended track to obtain this running fix. When the relative radio compass bearing is 10 degrees ahead of the wing tip position (90° or 270°) hold the heading constant and note the time when the bearing is exactly 80° or 280°. Continue flight on this constant heading until the bearing is 90° or 270°. Use the following formula to find the approximate distance in miles from the radio station.

$$\frac{\text{True airspeed x minutes flown}}{\text{Change of bearing}} = \text{Distance to station}$$

(Ground speed, instead of true airspeed, should be used in this formula if this information is available. Since ground speed will often be unknown when flying under instrument conditions the true airspeed is used and the result will be approximate). See Figure 45.

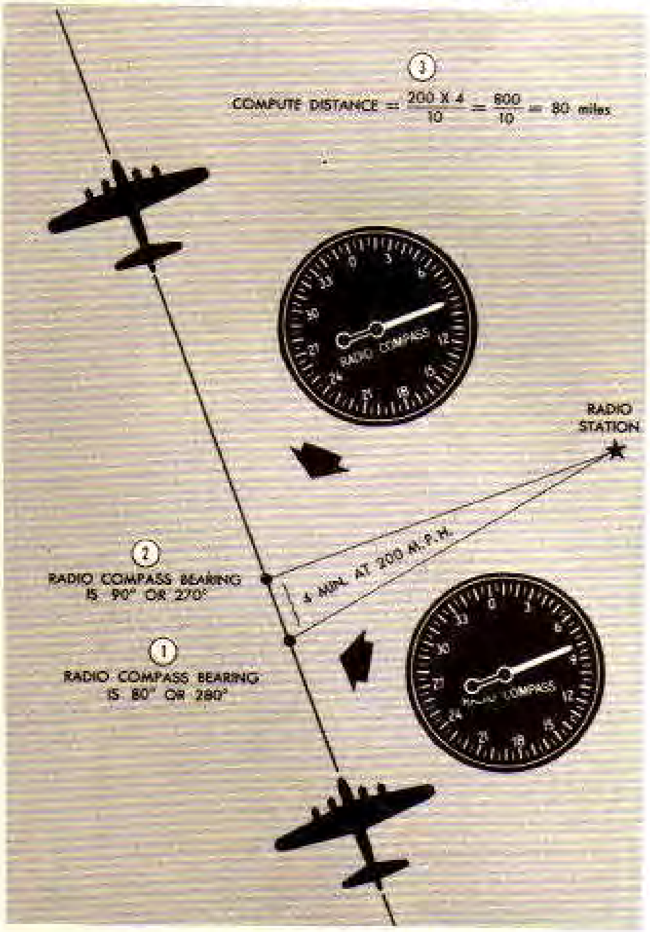


Figure 45—Distance Calculation

k. POSITION FINDING, VISUAL METHOD.

(1) Prior to making fix determinations, locate the stations to be used on a chart, tune in and identify them, logging the exact dial reading for each station. In this way the radio compass may be rapidly turned from one station to the other(s) and delay and errors are minimized.

(2) Maintain a constant heading, and for best accuracy take a series of bearings in rapid succession. Do not compute magnetic or true bearings until all compass indicator readings have been taken and recorded. Delay between bearing observations will cause large errors.

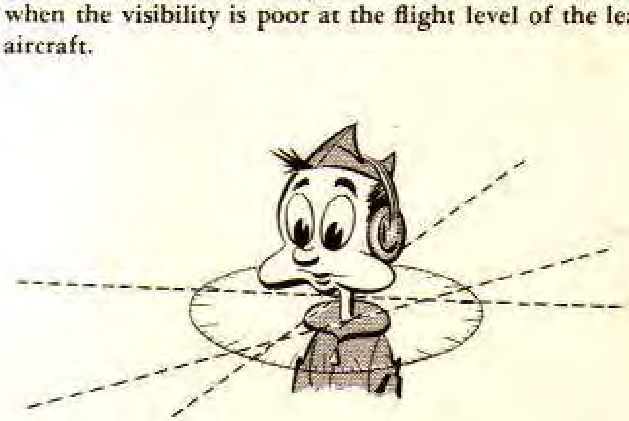
(3) Record the relative bearing. Apply correction for the compass heading to the bearing thus obtained and the result will be the magnetic bearing from the aircraft to the radio station.

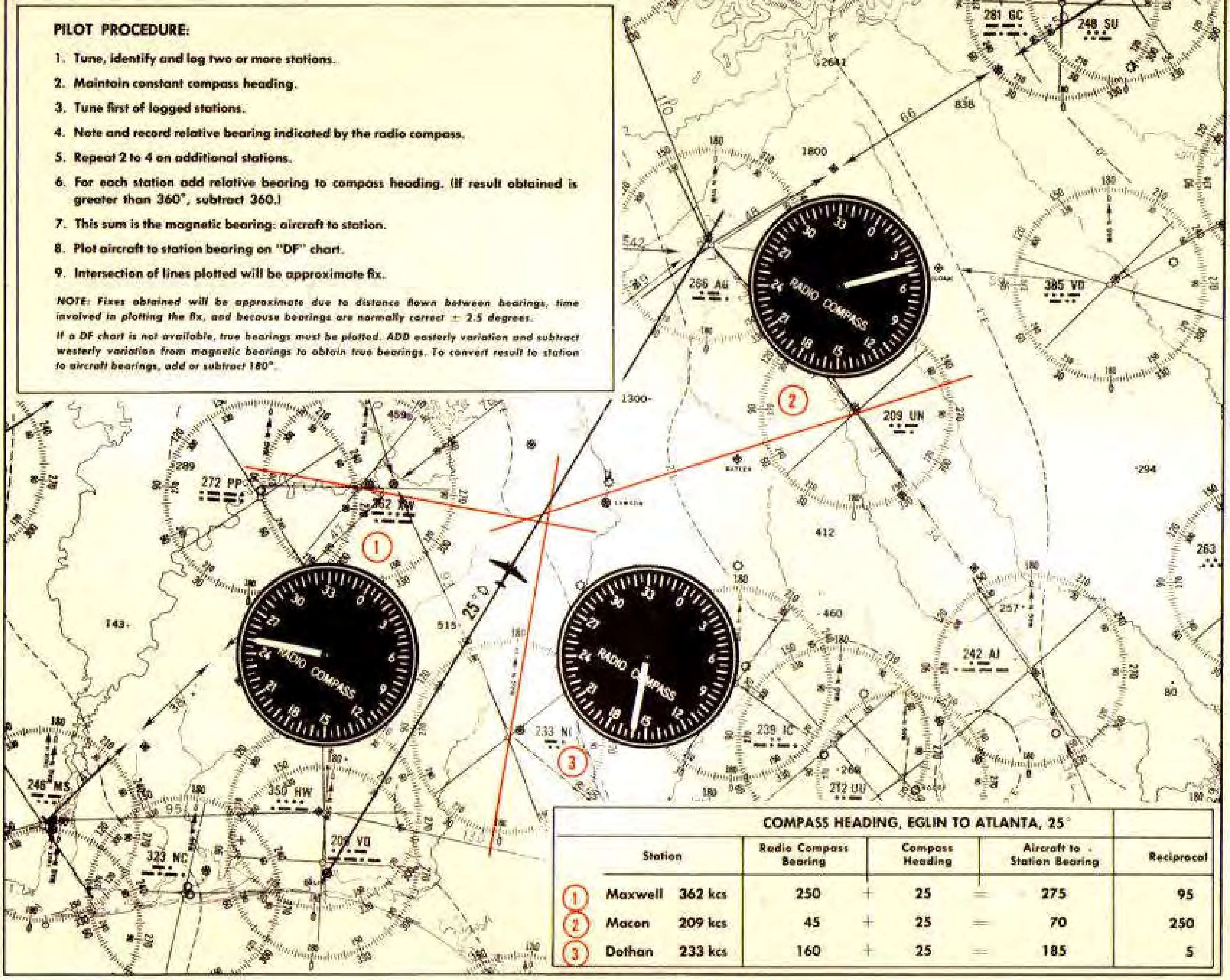
(4) If the chart being used for plotting is a Direction Finding Chart, the magnetic bearing can be laid off of the Compass roses printed around the radio station shown on these charts. See Figure 46, page 38. If any other type of chart is used, the bearing must be further corrected for the magnetic variation of the location of the radio station, and the reciprocal bearings must be calculated and used.

(5) Bearings on three or more stations, 30° or more apart, should be used. The intersection of the lines plotted from these stations will be the location of the aircraft. The fix thus plotted will be a triangle rather than a point, due to the travel of the aircraft while the bearings are taken. To convert magnetic bearings to true bearings, necessary if a DF chart is not available, add easterly variation and subtract westerly variation.

l. HOMING ON ANOTHER AIRCRAFT IN FLIGHT.

A formation which has become dispersed while passing through an overcast or other area of low visibility may be reassembled in flight by homing on a signal emitted by the liaison transmitter of the lead aircraft. The radio operator of the lead aircraft will tune the transmitter to a prearranged frequency and transmit a homing signal which should be frequently interrupted by a code identification letter. CW, MCW or voice can be used as desired. The elements of the formation can then be homed on the leader by tuning the automatic radio compass to the homing frequency. If CW transmission is utilized, the CW switch of the Radio Compass must be on CW for aural identification of the signal. After tuning, the elements of the flight need only fly the automatic radio compass indicator on 0° until the flight leader is sighted. Caution should be used when the visibility is poor at the flight level of the lead aircraft.





PILOT PROCEDURE:

1. Tune, identify and log two or more stations.
2. Maintain constant compass heading.
3. Tune first of logged stations.
4. Note and record relative bearing indicated by the radio compass.
5. Repeat 2 to 4 on additional stations.
6. For each station add relative bearing to compass heading. (If result obtained is greater than 360°, subtract 360.)
7. This sum is the magnetic bearing: aircraft to station.
8. Plot aircraft to station bearing on "DF" chart.
9. Intersection of lines plotted will be approximate fix.

NOTE: Fixes obtained will be approximate due to distance flown between bearings, time involved in plotting the fix, and because bearings are normally correct ± 2.5 degrees.

If a DF chart is not available, true bearings must be plotted. ADD easterly variation and subtract westerly variation from magnetic bearings to obtain true bearings. To convert result to station to aircraft bearings, add or subtract 180°.

COMPASS HEADING, EGLIN TO ATLANTA, 25°

	Station		Radio Compass Bearing		Compass Heading		Aircraft to Station Bearing	Reciprocal
1	Maxwell	362 kcs	250	+	25	=	275	95
2	Macon	209 kcs	45	+	25	=	70	250
3	Dothan	233 kcs	160	+	25	=	185	5

Figure 46—Position Finding

m. RADIO COMPASS LET-DOWN.

(1) If a suitable radio station is available and if the terrain does not make the let-down too hazardous, an instrument let-down can be easily made by using the automatic radio compass. If no radio station is available, an aircraft can be taxied out beyond the end of the runway, and its liaison transmitter used to send out a homing signal.

(2) Make the initial approach from any suitable direction, homing on the radio station. The altitude of the initial approach should be high enough to allow ample clearance of all surrounding terrain. A high initial approach, on the other hand, may require an excessive rate of descent, and therefore, should be avoided where possible. While on the initial approach, call the tower for the magnetic bearing from the radio transmitter to the airport; the altimeter setting, surface wind, ceiling, visibility, etc.

(3) On passing over the radio station, note the time and turn to the heading which is the reciprocal of the radio station-to-airport bearing. Reduce airspeed, and begin a normal descent, lower the landing gear, and complete the landing cockpit check.

(4) The outbound gyro heading is maintained for three minutes. It is not necessary to correct for drift or to make good any particular track. At the end of three minutes, turn 45° to the right and hold this heading until the radio compass bearing is 145°; then make a left-hand standard rate turn to a heading perpendicular to the station-to-airport bearing. Hold this heading until the radio compass bearing is 275°, and then again turn left to the station-to-airport bearing. See Figure 47.

(5) Home on the radio station while letting down to the final approach altitude. On passing the station, fly the station-to-airport bearing on the directional gyro until the aircraft is over the field, descending to the minimum altitude.

(6) If the transmitter is located at a distance from the airport, it may be necessary to offset the effect of a cross wind. This can be done by making good an outbound track from the radio station to the field. (See Par. 2.*i.*)

(7) If contact conditions are not reached over the airport, immediately climb to the initial approach altitude and call the tower for further instructions.

(8) Errors due to drift are automatically minimized in this type of radio compass let-down. The aircraft is placed exactly on the transmitter-to-airport bearing at the completion of the procedure turn. This is accomplished by completing the turn when a radio compass bearing of 275° is reached. Because the aircraft is homed on the station from a position on a known bearing and for a short distance, the effect of any side wind is minimized. However, the approximate drift angle should be determined and, if necessary, the gyro heading flown from the station to the field should be corrected into the wind.

(9) If a cross wind exists, it is preferable to make this procedure turn downwind from the station-to-airport bearing. When the procedure turn is to the left, the radio compass bearing will be 215° and 85° respectively.

(10) In cases where the homing station is on, or very close to, the airport (i.e. when the control tower or an aircraft on the ground is used) let-down to the minimum altitude must be started after the procedure turn is completed.

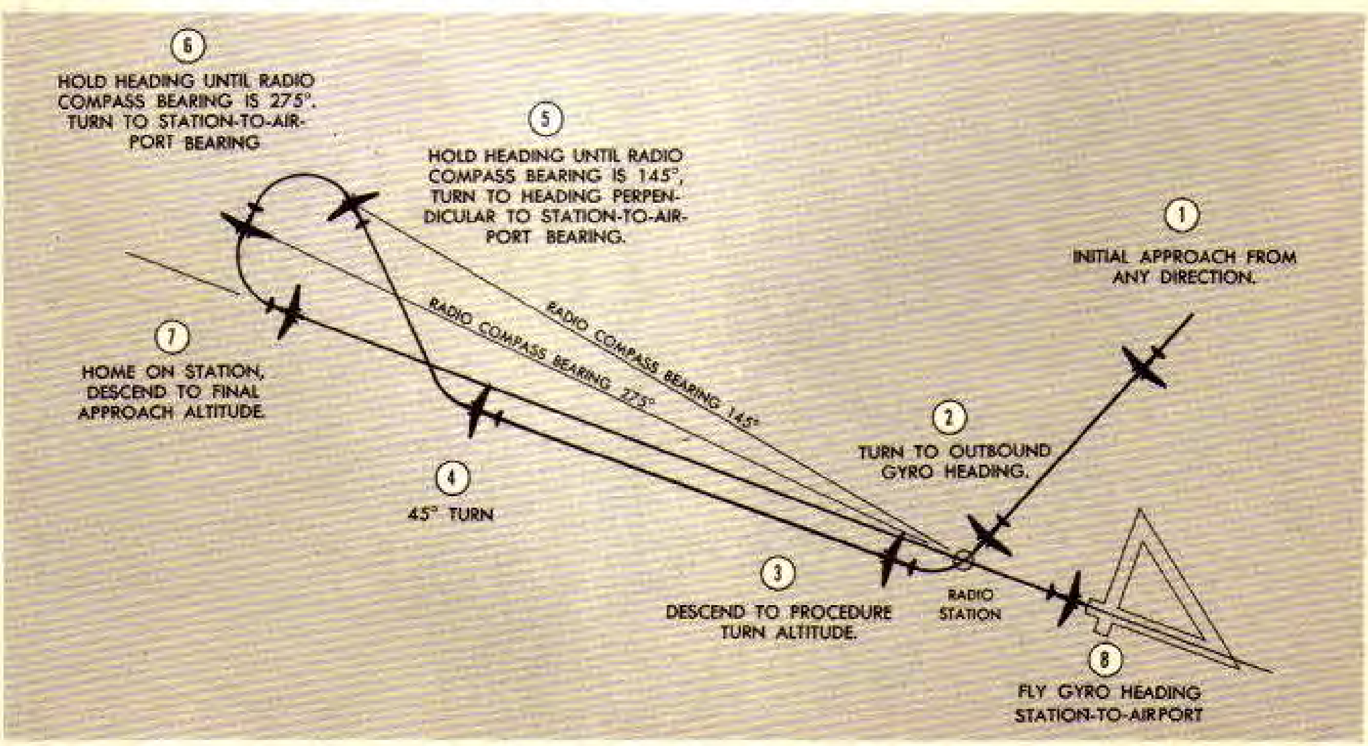


Figure 47—Instrument Let-Down

n. ADDITIONAL NOTES.

(1) The Automatic Radio Compass may be used as a directional instrument in an emergency during instrument flight when all other directional and turning indicating instruments are inoperative. (Example: Complete failure of suction system and loss of magnetic compass.) In such an emergency, tune to the nearest radio station and switch to "Comp" position. Note the position of bearing indicator needle, and turn until the needle is on the 0° or 180° position (whichever can be reached by the shortest amount of turn), and hold that position and keep the ball-bank indicator centered.

(2) All turns of large amount should be made very cautiously. A good method is to turn about 30° at a time momentarily rolling out ot the turn, and then turning 30° farther, etc.

(3) Caution should be used in approaching very close to a station, since the bearing indicator changes very rapidly close in, and turning the aircraft enough to center the needle on 0° may result in dangerous spiral. Contact or on top flight should be achieved as soon as possible. A let-down should never be made unless the ceiling is sufficiently high to permit safe clearance of all terrain and other obstructions for many miles surrounding the station.

3. AURAL NULL PROCEDURES.

a. GENERAL.

(1) The automatic operation of the radio compass depends on the combination of signals from both the loop antenna and the vertical or phasing antenna. Because of icing conditions, an accident in the air, or malfunction of some sort, the phasing antenna may be lost or become inoperative. Under these conditions, the pilot must rely entirely on aural null indications for direction finding, homing, and let-downs. It is obviously important, therefore, that the pilot be thoroughly familiar with aural null procedures.

(2) A failure of the phasing antenna will be indicated by satisfactory reception with the function switch on LOOP, but no reception on ANT or COMP. To tune in a station in this case, it is necessary to rotate the loop with the L/R switch to an estimated maximum position in relation to the desired radio station. This will avoid tuning in the station with the loop in a null position and the resulting lack of signal.

(3) It must be realized that a high signal heard in the headset provides a sharp null, while a low signal results in a wide null. If the null is several degrees wide, turn the AUDIO volume knob up. When the volume level is high, a smaller movement of the loop is necessary to change the strength of the signals being received and the "null" will be narrow. When the null has been narrowed by the use of the volume control as much as possible, the bearing can be closely determined by splitting the null width on the azimuth dial. At times, due to great distance from the radio station, it may be impossible to narrow the null to more than 15 - 20°. In such cases, "splitting the null" will still provide a reasonably accurate bearing.

(4) Caution must be used in taking aural null bearings on radio range stations when flying off-course, the silence during the station identification may be momentarily mistaken for the null. The same mistake may occur when using a commercial broadcasting station during changes of program or similar pauses in transmission. However, use of the CW switch, located on the radio compass receiver itself, will cause a continuous tone to be received which is not affected by these factors. The CW switch will not work on loop type radio ranges because of the absence of a continuous carrier wave. When the recep-

tion of radio signals is poor, and it is difficult to get a reliable null aurally, the tuning meter will give a visual indication of the null. Watch the tuning meter as the loop is rotated, and when the null position is reached, tuning-meter will deflect toward the minimum (or counter-clockwise) side. It must be remembered that bearings taken by the aural null method are subject to 180° ambiguity if the location of the station is not known. This ambiguity can be solved as outlined below.

b. TO SOLVE THE 180° AMBIGUITY.

1. To solve the 180° ambiguity, turn the loop to the wing tip null position with the L/R switch.

2. Then turn the aircraft until an aural null is received. Note the compass heading.

3. Fly this heading, feeling for the change in position of the null by rotating the loop, until a desired angle of change is obtained (5° - 10°).

4. When a distinct change in bearing is obtained, note the position of the bearing indicator.

5. If the bearing has decreased the station is to the left; if the bearing has increased, the station is to the right. The distance to the station can then be computed by noting the length of time flown, and the number of degrees of bearing change. See Figure 48.

6. If the aural null is to be used for homing, turn the aircraft toward the station and fly toward the station with the null at 0° on the bearing indicator but check periodically for movement of the null. It is easier to rotate the loop than to turn the aircraft.

NOTE

While flying this problem an exact heading must be maintained. If the nose of the aircraft is off the heading a few degrees, there will be an equal error in the angular change of the null.

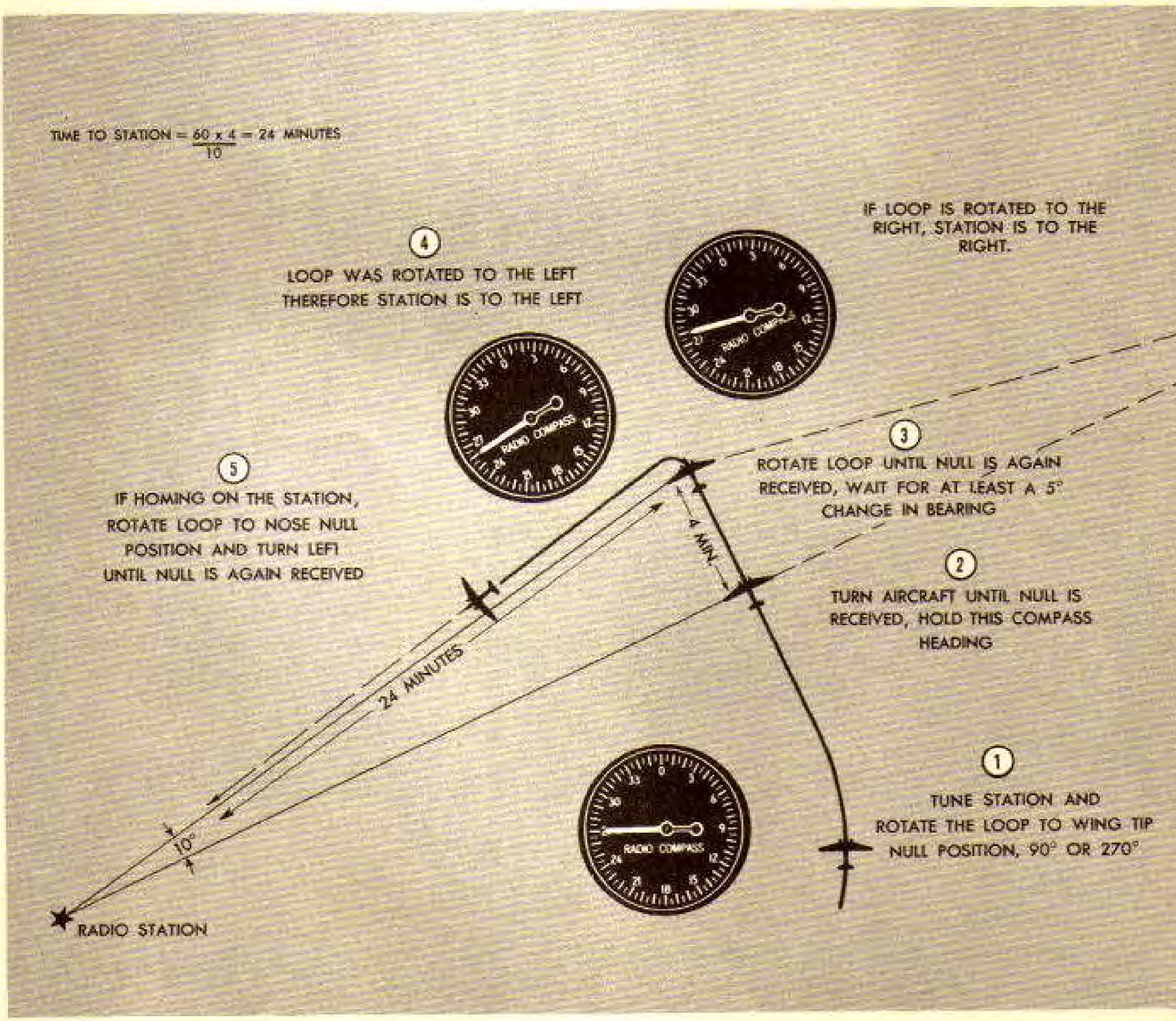


Figure 48—Aural Null Orientation

c. TRACKING.

After obtaining the nose null, observe the compass heading and fly that heading as accurately as possible until the aircraft drifts off the bearing (until a signal is heard). Rotate the loop slowly to the right or left of the nose null position until the null is found. If it is necessary to rotate the loop to the right to obtain the null, the aircraft has obviously drifted to the left of the bearing and a cross-wind from the right is being encountered. In any case turn the aircraft, right or left as necessary, 20° toward the bearing and offset the loop 20° in the opposite direction so that the null will occur again when the aircraft returns to the original bearing. If a 20° correction does not bring the aircraft back to the original bearing promptly, make additional corrections. When the null occurs, turn the aircraft back 10° and reduce the loop offset to 10°. In this manner a bracket is formed. If a signal is heard after flying on the heading, return to one of the original headings to get on the desired bearing (offsetting loop again so null will be heard when bearing is reached). Then turn to some intermediate heading so as to cut down the bracket. This process is repeated until a heading is established which will keep the aircraft on the desired bearing. See Figure 49.

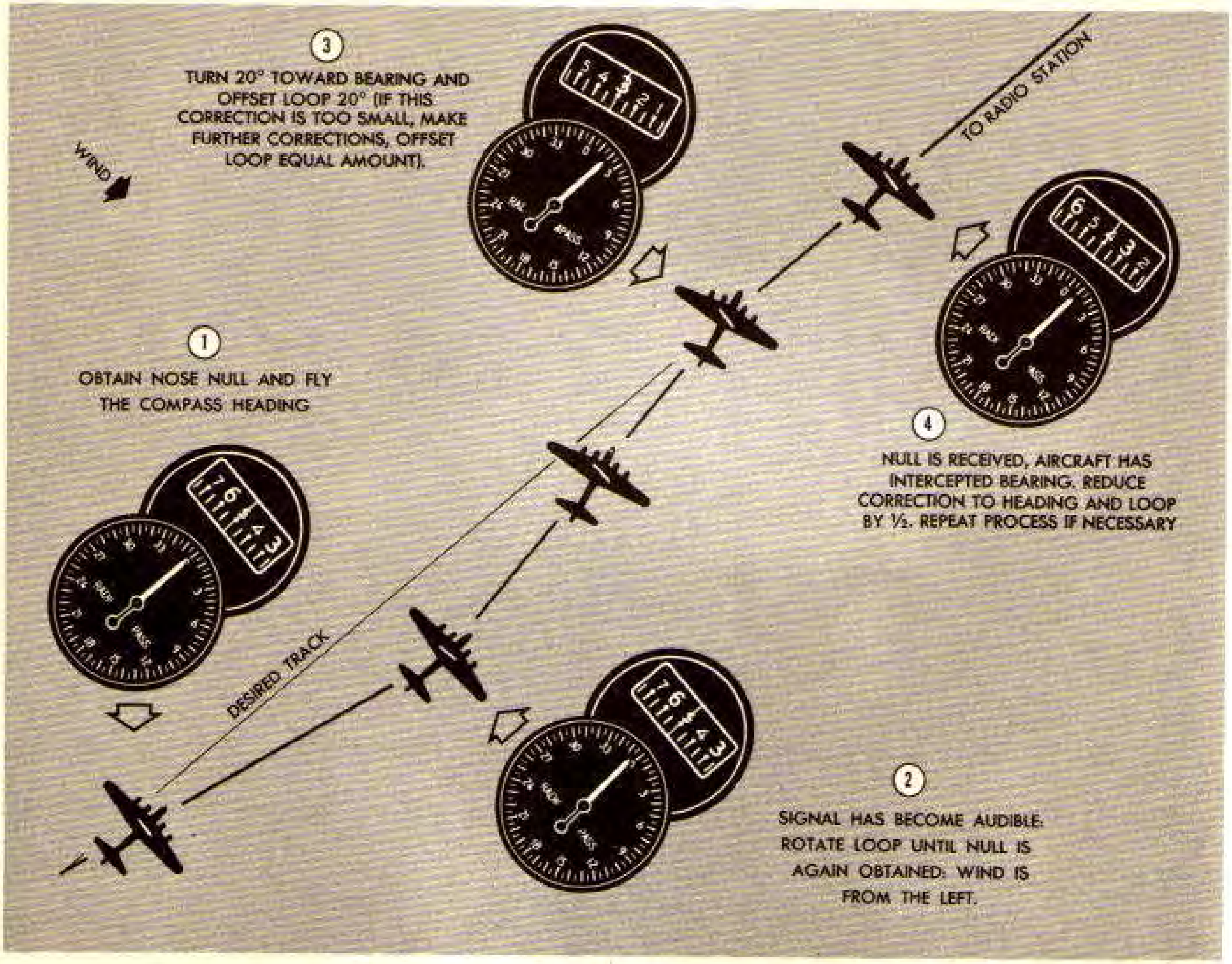


Figure 49—Drift Correction—Aural Null

d. PASSING THE STATION.

(1) In homing by use of the aural null method, it is usually difficult to determine the exact time of passing over the radio station. As the station is approached, the volume steadily grows louder and, in the case of a radio range station, may surge rapidly when extremely close in. Even with careful reduction of the AUDIO control in attempting to keep the null at a usable width, it may become impossible to get a completely silent null. Instead, the null may be replaced by a wide zone of minimum signal; that is, the loop can be rotated a large amount to either side of the null position without changing the volume of the signal being received. This

condition will continue after the station has been passed, the distance depending on the AUDIO setting and the strength of the radio station. If the AUDIO setting has been kept low, the volume will begin to fade, and it will again become possible to locate the null definitely; thus signifying that the station has been passed.

(2) This method of recognizing the passing of the station is rarely exact enough to use in making a low approach. However, it usually will determine a radio fix within two or three minutes, and can be used in navigation (from station to station) or as an initial approach preparatory to beginning a box low approach.

NOTE

When homing on a very powerful non-directional radio station the volume may appear to remain constant for several miles before the station is reached and after it is passed, thus increasing considerably the time required to determine that the station has been passed.

(3) If a more exact time of passing the station is required, the aircraft may be deliberately flown to one side of the homing bearing before the station is reached following the null while doing so. When the null reaches the wing tip position the aircraft is directly opposite the station. It should be remembered that the aircraft must be flown far enough to the side of the station to get a definite null.

(4) It is good practice to follow the null when maneuvering in close vicinity of the station. Bearings, when close in, will change rapidly and the null may be easily lost.

e. INTERCEPTING A DESIRED BEARING.

(1) This problem can be solved with the aural null as easily as with the equipment on COMP. To intercept a bearing at, for example, 90°, the loop is set to the wing tip null position (90° or 270°) and a perpendicular heading toward the beam is flown. The perpendicular heading is held until the wing tip null occurs, and the desired bearing is intercepted. When within 10 minutes of the station, it is necessary to anticipate the turn to avoid overshooting the desired bearing. For standard rate turns the amount of lead will vary from 13½° when 1 minute out, to 3½° when 5 minutes out, and 2° when 10 minutes from the station (see Par. *j.*).

(2) Angles other than 90° can be used. The aircraft is flown to intercept the desired bearing at the specified angle and the loop is offset toward the station, from the nose null position (0°) to the amount of the angle of interception. If the loop is offset to the left, the amount of the angle must be subtracted from 360°.

f. MAKING GOOD AN OUTBOUND TRACK.

(1) Upon passing the station or intercepting the outbound bearing, turn to the desired bearing. At the same time, rotate the loop to the tail null position (180° on the azimuth needle). Drift correction while flying away from the station is done in the same manner as when homing. However, the position of the station must be considered in its relation to the tail of the aircraft instead of the nose, and the heading will be the reciprocal of the bearing (with drift correction applied). If the bearing reciprocal heading will not hold the aircraft on the desired bearing, "search" for the station by rotating the loop azimuth needle to either side of the tail null (180°) position. If the null is regained by moving the azimuth needle to the right of 180°, then the station is to the right of the tail, and it will be necessary to correct to the right to get back on the bearing. This will be done as follows:

(2) Turn 20° toward the bearing. At the same time, move the azimuth needle to the right of the tail 20°, or to the 160° position. When the null is again received, the aircraft has intercepted the desired bearing. Then turn back to the left to a heading with an arbitrary amount of drift correction to the right (about 5° to 10°). At the same time, set the azimuth needle to

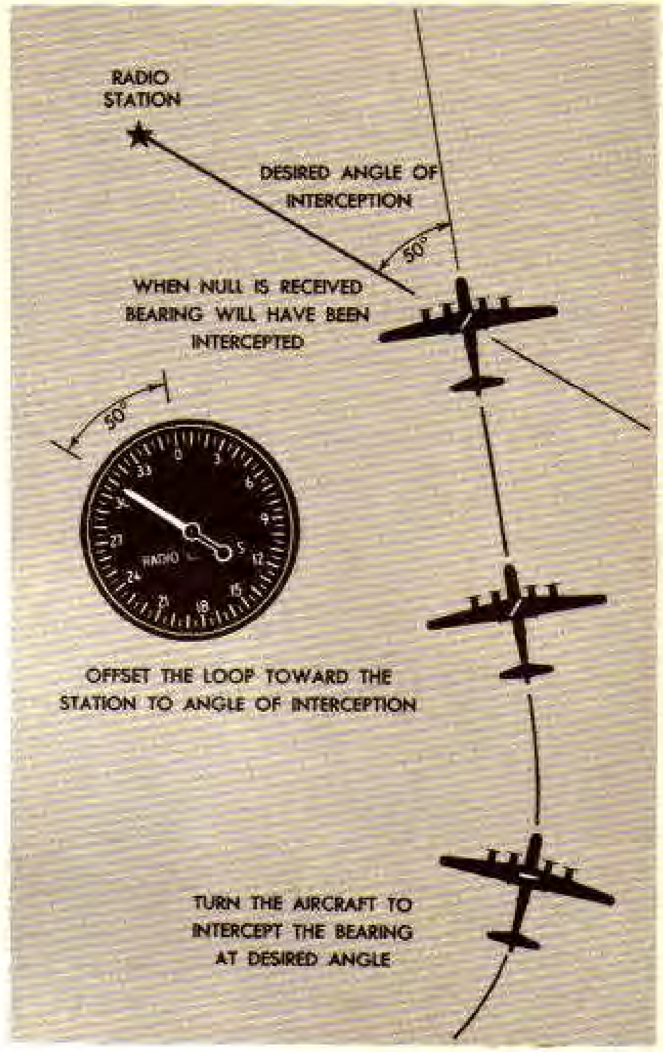


Figure 50—Intercepting Bearing at 50°

the right of the 180° position the same amount as the drift correction.

(3) If the corrected heading still does not keep the aircraft on the bearing, repeat the process until the proper drift correction is found.

g. POSITION FINDING, AURAL METHOD.

(1) Holding a constant heading and, with the function switch on ANT, tune in the station on which the first bearing is to be taken. Make station identification positive by waiting for the identification. (If no signal can be heard on ANT, switch to LOOP and rotate the loop for maximum volume position. Tune and identify the station.)

NOTE

Stations to be used should first be located on a chart. To avoid delay between bearings, the stations should be tuned in, identified, and their respective dial settings recorded.

(2) Switch to loop and obtain a null as sharp as possible. Observe and record the relative bearing of the null and the time it was taken. (Note: The first bearing should be taken on the station which is most nearly ahead of or behind the aircraft, as this bearing will have a minimun amount of change during the fix).

(3) The remaining stations should be quickly tuned in and the bearings noted.

NOTE

All bearings should be taken as rapidly as possible. Do not convert to magnetic or true bearings until all relative bearings have been recorded.

(4) The pilot must remember that the bearings recorded are relative bearings. In order to convert these bearings into geographical or magnetic bearings, the relative bearing must be added to the observed compass heading of the aircraft. If this result is over 360°, subtract 360° for the magnetic bearing of the station.

(5) It must also be remembered that the bearings taken were from the aircraft to the station. In order to plot the fix more easily, it will be necessary to convert the bearings into station-to-aircraft bearings. This is done by simply adding or subtracting 180°.

h. LET-DOWN, AURAL METHOD.

(1) A method of making an instrument let-down on a non-directional radio station, using the automatic radio compass is shown in paragraph 2.*m.* of this section. This method is satisfactory when the automatic feature of the radio compass is in operation, but cannot be used when aural null indications are the only means of orientation. Because a definite fix can be obtained only to one side or the other of the radio station, and not directly over it, another method must be found A let-down procedure known as "Boxing the Station" was devised and this procedure can be employed whenever it is necessary to let down using aural null indications only.

(2) "Boxing the Station," as the name implies, consists simply of flying a square course around the station. The purpose of boxing is to place the aircraft in position to begin a let-down on the station-to-field bearing. The box may be started either before or after passing over the station. In either case the first turn from the homing bearing will be to a heading either parallel or perpendicular to the station-to-field bearing, whichever is closer.

NOTE

Wind direction and terrain should be taken into consideration in deciding whether the box shall be started to the right or to the left. All things being equal, the box should be started in the direction which will permit the least number of legs before a let-down is started.

In the first case the turn away from the homing bearing is started about three minutes out from the radio transmitter. In the second case, the turn is started as soon as you are sure the station has been passed. It is important to remember that, when using the second method, the first turn must always be greater than 90° to avoid flying away from the station. Follow the null with the L/R switch as the turn is being made. After the turn is completed, maintain an accurate heading and continue to follow the null until it progresses to the wing-tip position.

NOTE

If the box is started before the station is reached the ETA may frequently be quite inaccurate. A simple orientation can be worked at the time of the first wing-tip null which will definitely prove the position of the aircraft. 20° before reaching the first wing tip null note the time, and again note the time when the wing tip null position is reached. The time from the station can be rapidly calculated by multiplying the time for the 20° change of null by 3. For instance, if a 20° change of null required ½ minute, the aircraft would have been ½ x 3 = 1½ minutes from the station when the wing tip null was received. This process may be repeated at each wing tip null position, if desired.

After the wing tip null has been noted, fly the same heading for two minutes. Turn 90° in the direction of the station and fly this heading. Again follow the null until the wing tip position is reached. When the first null was noted, the airplane was known to be on a line of position from the station, but its exact position was not known unless the procedure outlined in the above NOTE was followed. After the second wing tip null has been received, the position of the aircraft is definitely fixed. Thus a let-down may be safely commenced only after the second wing tip null has been noted. Two minutes after the second wing tip null, another 90° turn is made and the new heading again held until the wing tip null is obtained. This boxing process is continued until sufficient altitude has been lost and/or until the aircraft is headed outbound parallel to the final approach. On this outbound heading, timing is again started as the aircraft passes the station. Time should be predetermined to allow for 1½ to 2 minutes for the final descent after the turn onto the final approach into the field. Another 90° turn toward the station is made and this heading held until the null is slightly ahead of the wing tip position. A turn onto the final approach leg is then made. Turn the loop to the nose null position and home. Let-down to the minimum altitude over the field is made on this leg. See Figure 51 for additional details.

(3) Due to the changing distances between the aircraft and the radio station during the boxing procedure the strength of the signal received changes rapidly and thus changes the apparent width of the null. Again it is necessary to stress that the width of the null must be kept at a proper size by judicious use of the AUDIO volume control.

(4) When the radio station is on, or close to the airport the pattern is always flown to make the final letdown to the minimum altitude toward the station. As in Figure 51, the aircraft arrives over the field, headed toward the radio station. With reference to this illustration, it can also be seen that the direction of the wind will become approximately known after the second turn has been made. In still air the aircraft should arrive at the third wing tip null 2 minutes after the 90° turn was completed. A greater or shorter time would indicate a head or tail wind for this leg of the box. A similar estimate can be made on the last leg of the box; at this time a cross-wind will be very apparent because of the additional time flown parallel to the field-to-station bearing. Allowance must be made for the fact that the turn is commenced before the wing tip null is actually received.

(5) It has been assumed in this example, Figure 51, that the radio station is located on or very near the field. If the station is more than 2 minutes away from the air-

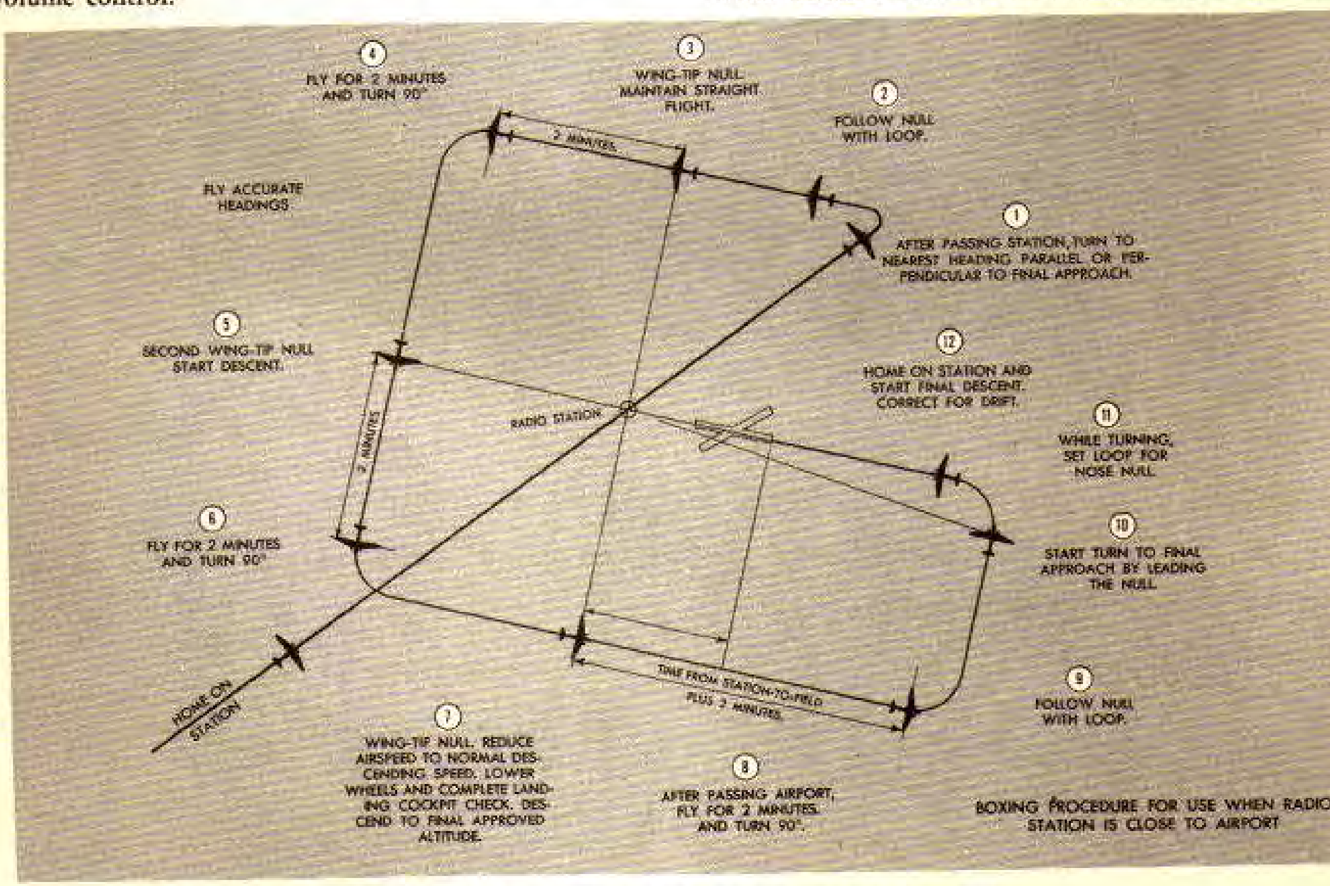


Figure 51—Aural Null Let-down (Boxing the Station)

NOTE

The tuning needle may help in determining accurately the width of the null, and will be particularly helpful in cases where the broadcast sound is not continuous. Turn the CW switch to the ON position for aural recognition of the null in the latter case.

port at the airspeed flown, this procedure must be slightly modified. An example of this type of procedure, including an aural null orientation problem, follows:

(a) To illustrate aural null orientation and boxing procedures further, the detailed example in Figure 52 is presented. In this example the pilot has found that

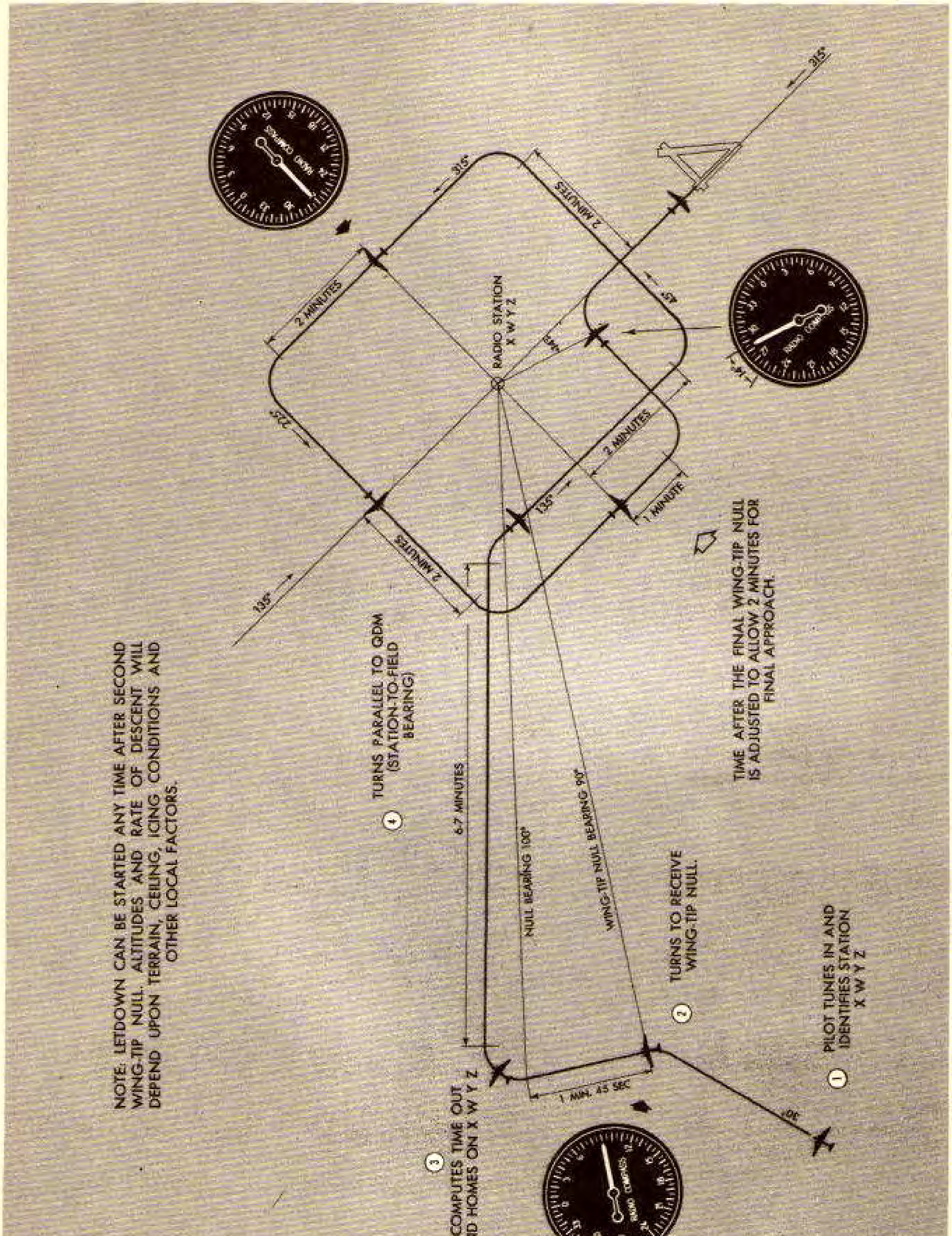


Figure 52—Orientation and Boxing Procedure

the Automatic Radio Compass is inoperative on all except the LOOP position. At his destination there is a radio station "XWYZ," 8 miles from the landing field. The station-to-field bearing is 135°. Dead reckoning has brought him to position (1), and he is flying on a heading of 30°. Rotating the loop to maximum position the pilot is able to tune in and identify radio station XWYZ.

(b) He now rotates the loop to the wing tip position and turns the aircraft until a wing tip null is received. The direction in which the turn is made is immaterial, however, in this example the turn is made to the left. The pilot notes the heading of the aircraft, 350°, at the time of receiving the null. He holds this heading accurately and follows the null until at least a 5° change in null bearings is obtained. The null has changed from 90° to 100°, and the position of the radio station is proven to be to the right of the heading of the aircraft. With the Loop L/R switch the pilot rotates the loop to the nose null position, and turns the aircraft to the right until the nose null is received. By using the formula: 60 x time flown ÷ bearing change = time to the station; the pilot has concluded that he is 10 minutes out. He therefore holds the nose null for approximately 7 minutes, until 3 minutes out, and then turns parallel to the station-to-field bearing, to a heading of 135°. He is now in the position where the "Boxing" procedure is started. The pilot rotates the loop back to the wing tip null position and holds the heading of 135° until the wing tip null occurs. At that time the station will be directly to the left of the aircraft. Flying for 2 minutes after the null, he starts a standard rate turn in the direction of the station, to a heading perpendicular to the station-to-field bearing, in this case a heading of 45°. He holds the heading until a wing tip null is again received. Flying another 2 minutes, he again commences a 90° turn to the left to the outbound station-to-field bearing, holding this heading until the null is received. If the time between this turn and this null is longer or shorter than 2 minutes, the pilot knows that a head or tail wind is being experienced while flying on the heading of 315°. After the null, the aircraft continues on this heading for 2 minutes and another turn to the left is made. Time between this turn and the next wing tip null will indicate the existence of a head or tail wind on this heading (225°) and an estimate of a drift correction for use on the final leg can be made.

(c) The fourth side of the box will be completed 2 minutes after the wing tip null on this leg. The pilot is now ready to head for the field for the final approach. A 90° turn to parallel the 135° station-to-field bearing is made. After the wing tip null 1 minute again elapses, after which the 90° turn to a heading to intercept the final approach track is made. It is now necessary to anticipate the turn onto this bearing. The aircraft will be 1 minute out when the turn is made and the angle of lead at this time interval is approximately 14°. Hence, he will rotate the loop 14° ahead of the wing tip null position, in this case to 284° and start the right turn when the null is received. He rotates the loop to the tail null position and makes his final let-down when the tail null is received. The heading of the aircraft should be 135° when the aircraft is on the final approach. Approximate correction for drift can be made as when flying an outbound track. The pilot already has some idea of the direction of the wind from the timing of the legs of the box. (Airspeed of 120 m.p.h. is used in this example.)

(d) The following points must be borne in mind.

1. Establish position by an aural null position check.

2. Commence the box when approximately three minutes from the radio station. Be sure of terrain clearance. That is, start the box at an altitude at least 1,000 feet above all obstacles within 25 miles of the radio station

3 Establish the headings of the box while homing. They will be: *a.* The station-to-field bearing. *b.* The reciprocal of this bearing. *c.* Perpendicular to the station-to-field bearing and *d.* The reciprocal of this bearing. The initial leg of the box can be either parallel to or perpendicular to the station-to-field bearing.

4. Fly the same time interval after each wing tip null. Two minutes were used in the example; however, 1 minute legs will work in calm air. If the time between the turn and the null is greater than the time interval flown on the reciprocal heading, a headwind is being encountered on that heading. It must be remembered, however, that wind direction and velocity frequently changes with altitude.

5. Position is known after the second wing tip null, and altitude can be lost on the succeeding legs of the box.

6. The entire procedure must be flown to accurate magnetic compass headings. Boxing the station is a precision maneuver.

7. The pilot who becomes competent in this procedure will have no difficulty with any other radio navigational problem.

i. HOMING WHEN LOOP CANNOT BE ROTATED.

(1) It is possible that a case may occur when the loop cannot be rotated due to extreme cold or loop motor failure. The position of the loop will be shown by the needle of the bearing indicator and homing on a radio station aurally will be a simple problem.

(2) As always, tune and identify the desired radio station on ANT if possible. Should no signal be obtainable on ANT, switch to LOOP. The loop antenna may be in the null position relative to the radio station. In this case turn the aircraft until a strong signal is heard.

(3) After the station has been identified, make a gentle turn until a null is obtained. Note the gyro heading at that instant. Fly this heading until the signal becomes audible; then turn the airplane slightly to find the null again. If a turn to the left found the null, the station is to the left; if a turn to the right, the station is

to the right. Now turn in the direction of the station the number of degrees the indicator needle is from 0° and the aircraft will be headed directly toward the station. (See Figure 53.)

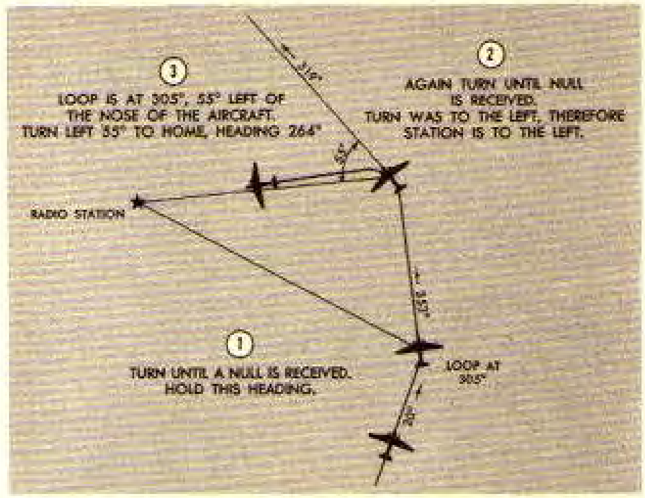


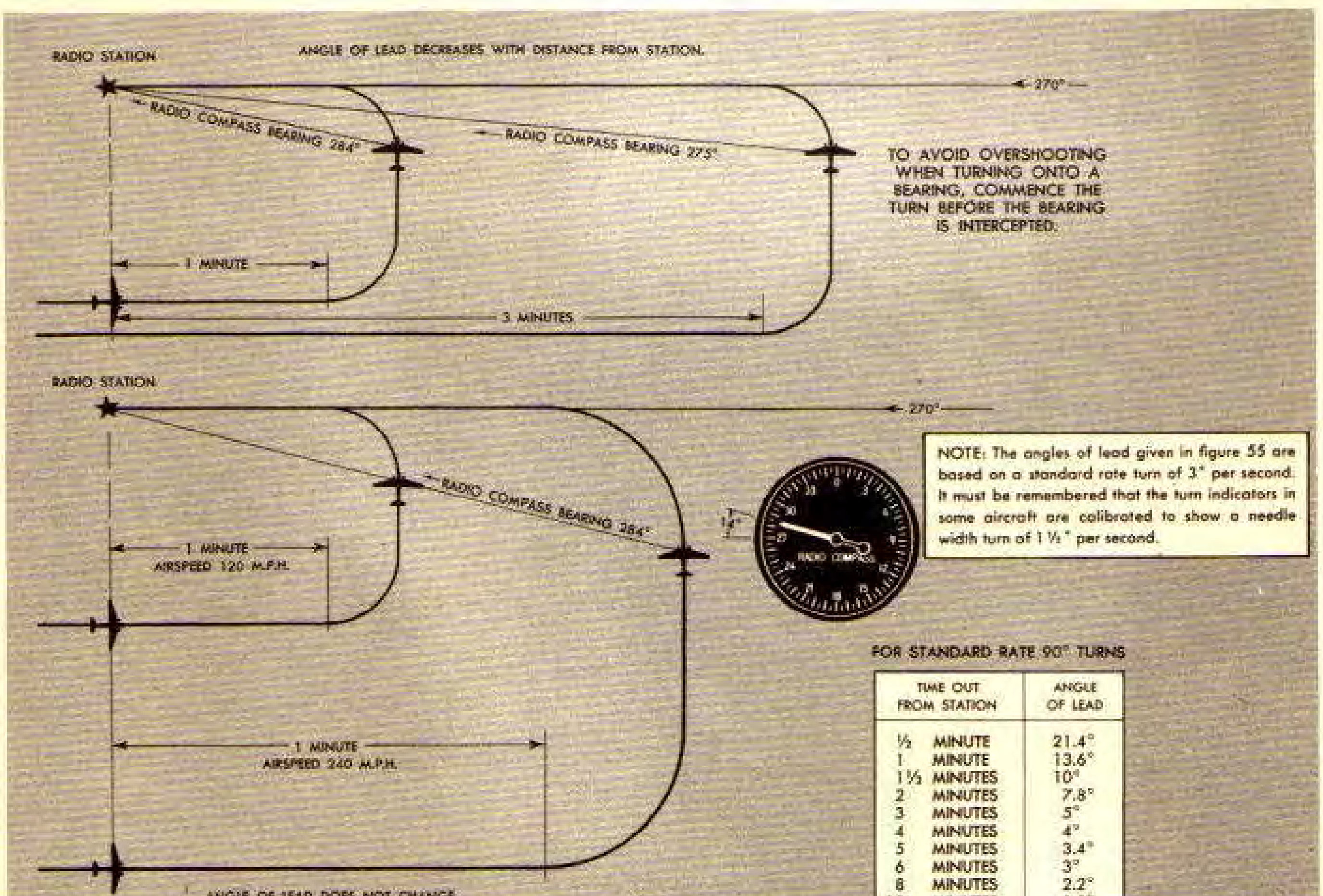
Figure 53—Homing When Loop Cannot Be Rotated

NOTE

In turning the aircraft to find the null, the pilot will immediately know if the turn is being made in the wrong direction; this error in choice of direction will be indicated by an increase of volume in the headset, in which case the pilot must turn in the opposite direction.

j. ANGLE OF LEAD IN TURNS.

When intercepting a bearing more than 10 minutes out from the radio station no appreciable error will be introduced if the turn onto the bearing is started when the radio compass bearing is the same as the angle of interception. However, close to the station the radius of the standard rate turn should be taken into consideration. This factor must also be allowed for in a boxing procedure when turning onto the final approach. Figure 54 illustrates standard rate turns, and it will be noted that the angle of lead does not change with airspeed but does change with distance from the station. The angle of lead for 90° standard rate turns and for distances up to 10 minutes from the radio station is included in the table in the illustration.



TIME OUT FROM STATION	ANGLE OF LEAD
½ MINUTE	21.4°
1 MINUTE	13.6°
1½ MINUTES	10°
2 MINUTES	7.8°
3 MINUTES	5°
4 MINUTES	4°
5 MINUTES	3.4°
6 MINUTES	3°
8 MINUTES	2.2°
10 MINUTES	1.8°

Figure 54—Angle of Lead, 90° Turns

4. THE MANUALLY ROTATED LOOP RADIO COMPASS

(1) This equipment is essentially similar to the Automatic Radio Compass, except that the loop antenna is rotated manually. The position of the loop is shown by a needle turning upon a 360° azimuth scale. The equipment includes a L/R indicator, and when this indicator needle is centered the loop is in the null position relative to the radio station.

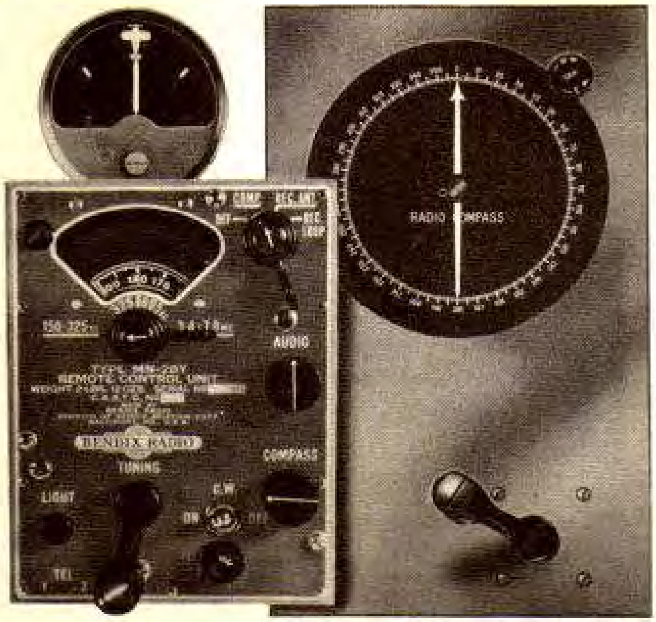


Figure 55—Rotatable Loop Radio Compass

(2) In homing, for example, when the L/R indicator needle is centered and the aircraft is turned, the needle will deviate from center. If the radio station is ahead, the needle will point right when a left turn is made; a correction to the right will be necessary to bring the aircraft back "on-course". The needle will deviate to the left when a right turn is made; a correction to the left will bring the aircraft back "on-course". The student may visualize that the needle points toward the station, that is, the direction toward which the aircraft should be turned to regain a heading toward the station. If the radio station is behind the position of the aircraft, a reverse needle action will be observed. A turn to the right will cause the needle to deflect toward the right and vice versa. In this case the turn should be continued until a 180° turn has been completed, and the needle is again centered. The aircraft will then be headed directly toward the station. If the loop, instead of the aircraft, is turned the behavior of the needle will be the same.

(3) *The needle does not measure the course deviation in degrees.* Its sensitivity can be adjusted by the indicator response control (COMPASS).

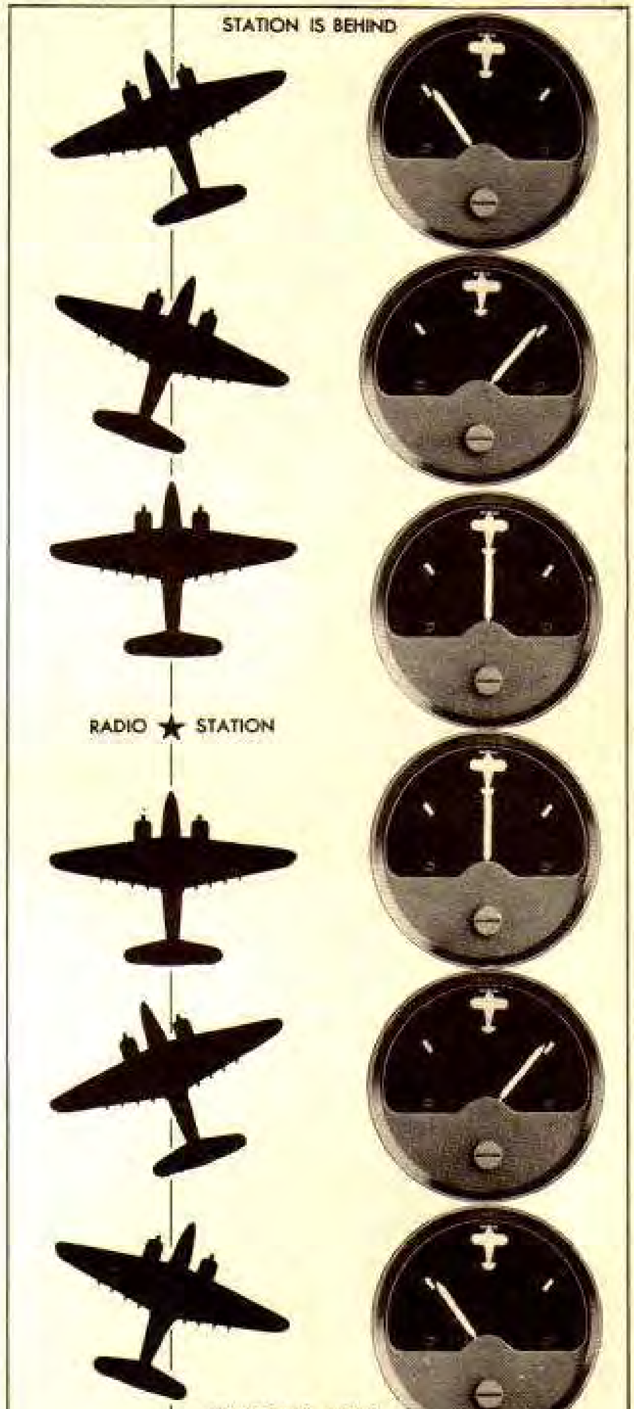


Figure 56—Left/Right Indicator

(4) The manually rotated radio compass may be used for direction finding by the visual method or the aural null method; for homing by the aural null method; as a radio receiver on ANT position; and as a radio receiver on LOOP position to reduce precipitation static.

a. OPERATION.

(1) *DIRECTION FINDING—VISUAL METHOD.* —Tune in and identify the station, function on ANT then switch to COMP. The needle of the L/R indicator is now observed. If the needle deflects toward the right, rotate the loop with the hand crank for an increasing loop azimuth dial reading; or, if the needle deflects toward the left, rotate the loop for a decreasing azimuth dial reading. Rotation must be continued until the L/R indicator needle is centered. The reading of the azimuth dial will then show the bearing of the radio station relative to the longitudinal axis of the aircraft. To plot a "fix", at least two and preferably three bearings should be taken on different radio stations. See Figure 57.

(2) *DIRECTION FINDING—AURAL NULL METHOD.*—Tune in and identify the station, function on ANT then switch to LOOP. It may be necessary to rotate the loop to maximum position to identify the station, and to obtain a good signal. Rotate the loop until a sharp decrease is noted in the headset volume. Observe the reading of the loop position on the azimuth dial. This reading will be the bearing of the radio station relative to the longitudinal axis of the aircraft, *or its reciprocal.*

(3) *AURAL NULL HOMING.*—"Nose Null". Proceed as above and rotate the loop to zero indicated on the azimuth dial. Turn the aircraft until a sharp decrease in volume is noted in the headset. The radio station will be either ahead or directly behind. This "180° ambiguity" must be solved by the procedures covered in paragraph 3 of this section.

Figure 58—Anti-Static, Secondary Receiver Operation

RECEIVER OPERATION.—When it is desired to use the radio compass as a radio receiver, turn the function switch to ANT and tune in to the desired radio station. Receiver action will be identical with that of any radio receiving equipment.

If the function switch is turned to LOOP the equipment may be used under conditions of severe precipitation static when ordinary radio receiving equipment would not produce intelligible signals. The loop should be rotated to maximum signal strength position.

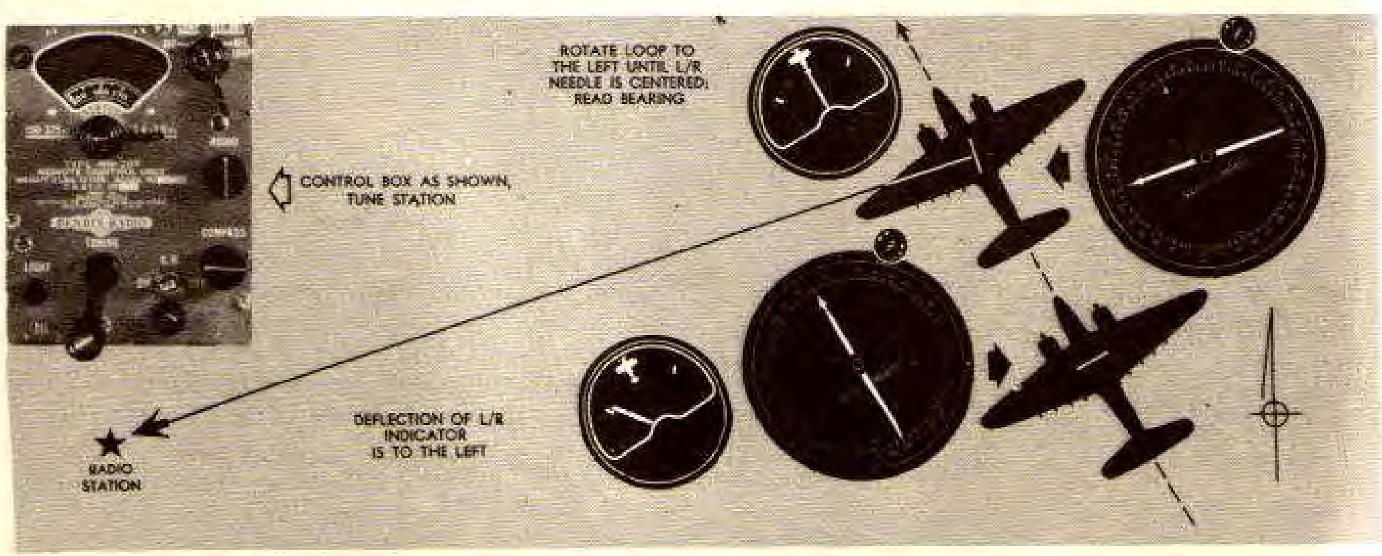


Figure 57—Direction Finding

b. HOMING-DRIFT.

The loop must be rotated to the homing position (nose Null, "0" on the loop azimuth dial). Then the L/R indicator needle is centered by turning the aircraft in the direction indicated by the needle. The compass heading is noted while the L/R indicator needle is centered. This heading is held until the wind drifts the aircraft to one side or the other and the L/R indicator needle shows a distinct deflection. Now, the aircraft is turned in the direction indicated by the needle until the needle is again centered. Note the number of degrees turned. Assume, for example, that it was necessary to turn 5° to the left to center the L/R indicator needle. This will indicate wind from the left. Therefore, an additional turn of 5° to the left is made (or a total correction of 10° from the original heading). The loop is now off-set 5° to the right, so that the needle will be centered after the aircraft has been turned. This first drift correction is approximate and the process must be repeated until an adequate correction for drift is determined. (See Figure 59.) When passing over the radio station, the needle will flick from one side to the other and stay there momentarily. After passing the station, the indications of the needle will be reversed.

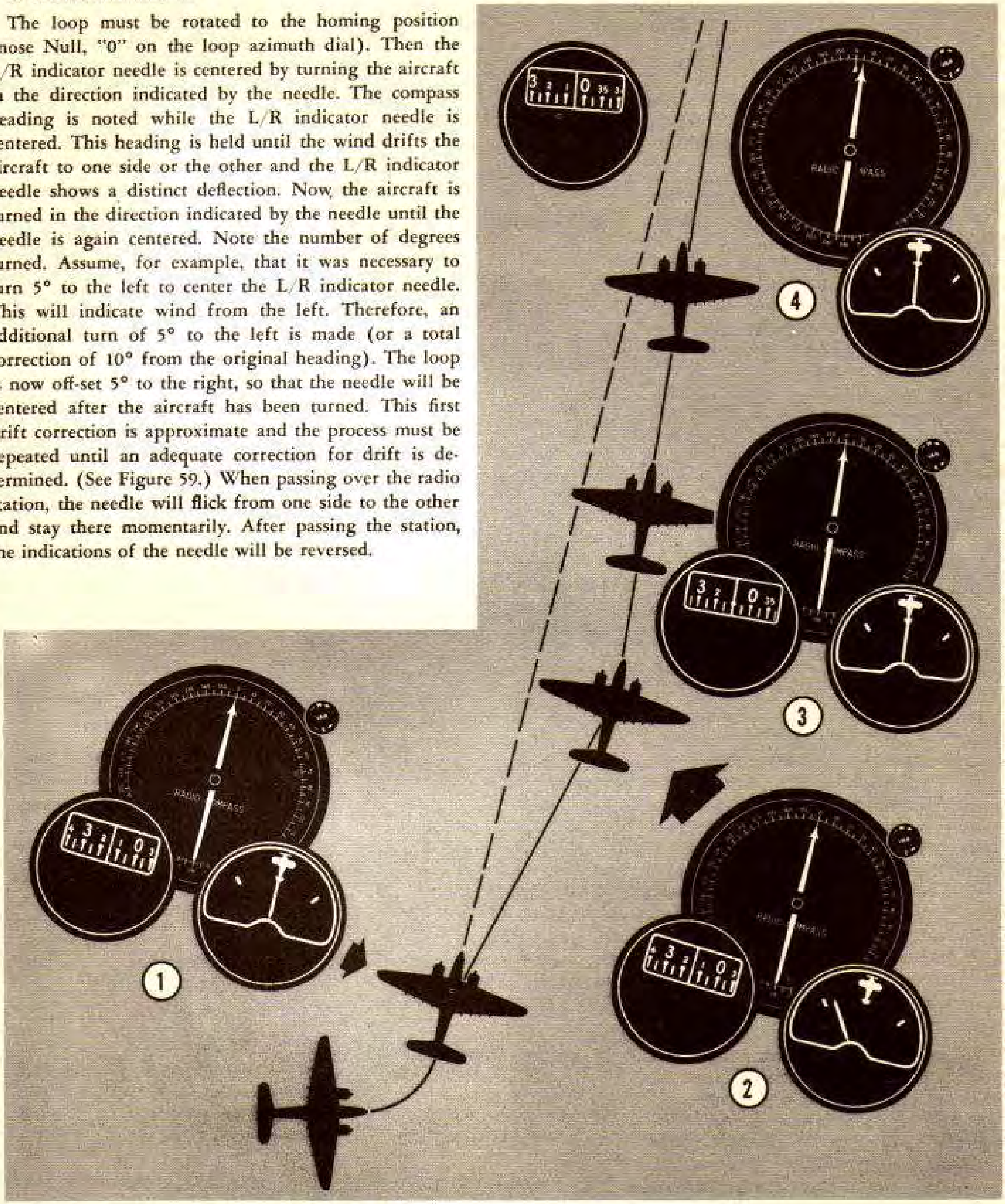


Figure 59—Homing, Drift Correction

5. THE FIXED LOOP RADIO COMPASS.

a. The fixed loop types of radio compasses are essentially identical to the manually rotated loop types. The loop is mounted in the "Nose Null" position on the aircraft, and therefore no loop rotating crank or azimuth scale is included in the installation. The uses of the equipment are as follows:

Homing with the left/right indicator.

Reception of radio range signals or voice broadcasts.

Reception of signals when static is prevalent.

Direction finding.

Figure 60—Fixed Loop Radio Compass

b. OPERATION.

(1) HOMING.

1. Switch to COMP.
2. Tune for greatest deflection of tuning meter.
3. Adjust AUDIO control for volume.
4. Identify the station.
5. Turn COMPASS control to adjust the deflection of the left/right indicator needle.
6. Turn the aircraft in the direction indicated by the needle and *continue turning* until the needle is centered. The aircraft will be headed toward the station. (This may require a turn up to 180°). Refer to Figure 56, page 49.

If the L/R needle was centered when the station was first identified, advance the COMPASS control to increase L/R indicator sensitivity and turn the aircraft until a marked deflection is obtained. Observe the deflection and then turn in the direction indicated by the L/R needle until it is again centered.

While the equipment is being used on COMP to home on the radio ranges, the pilot can hear the range signals and voice broadcasts which may be made on the range frequency. The aural reception of the A and N signals cannot be relied upon for on-course or cone of silence indications. The Automatic Volume Control will broaden the apparent course width.

(2) TO USE AS A RADIO RECEIVER.

1. Switch to ANT.
2. Tune for greatest deflection of tuning meter.
3. Adjust AUDIO for volume.

Aural radio signals will be received and the L/R indicator will be inoperative.

(3) TO REDUCE STATIC.

(Only practical when the desired radio station is to either side of the course of the aircraft.)

1. Switch to LOOP.
2. Tune in desired station, maximum deflection of tuning meter.
3. Adjust AUDIO control.

(4) DIRECTION FINDING—VISUAL METHOD.

1. Proceed as for homing.
2. Turn the aircraft until the L/R indicator needle is centered.
3. Note the heading of the aircraft.
4. Repeat the process for one or more additional stations at 30° from the first station.
5. Correct the headings noted for magnetic variation and plot on aeronautical chart.

The fix obtained will be approximate only.

c. DRIFT.

(1) With the fixed loop, when the aircraft is flown so that the L/R indicator needle is constantly centered, the nose of the aircraft will always be pointing directly at or away from the radio station. If no correction is made for drift, the heading of the aircraft will be changing constantly, and the aircraft will follow a curved course to the station. Insofar as time required to complete a flight is concerned, it makes little practical difference whether the drift be corrected or not. With a wind velocity of 1/3 the airspeed of the aircraft and coming from the most effective angle, the time difference between flying a straight course with drift correction and flying the curved course without correction for drift is only 6% or 3½ minutes per hour. For winds of less strength or at less effective angles the time differential is even less.

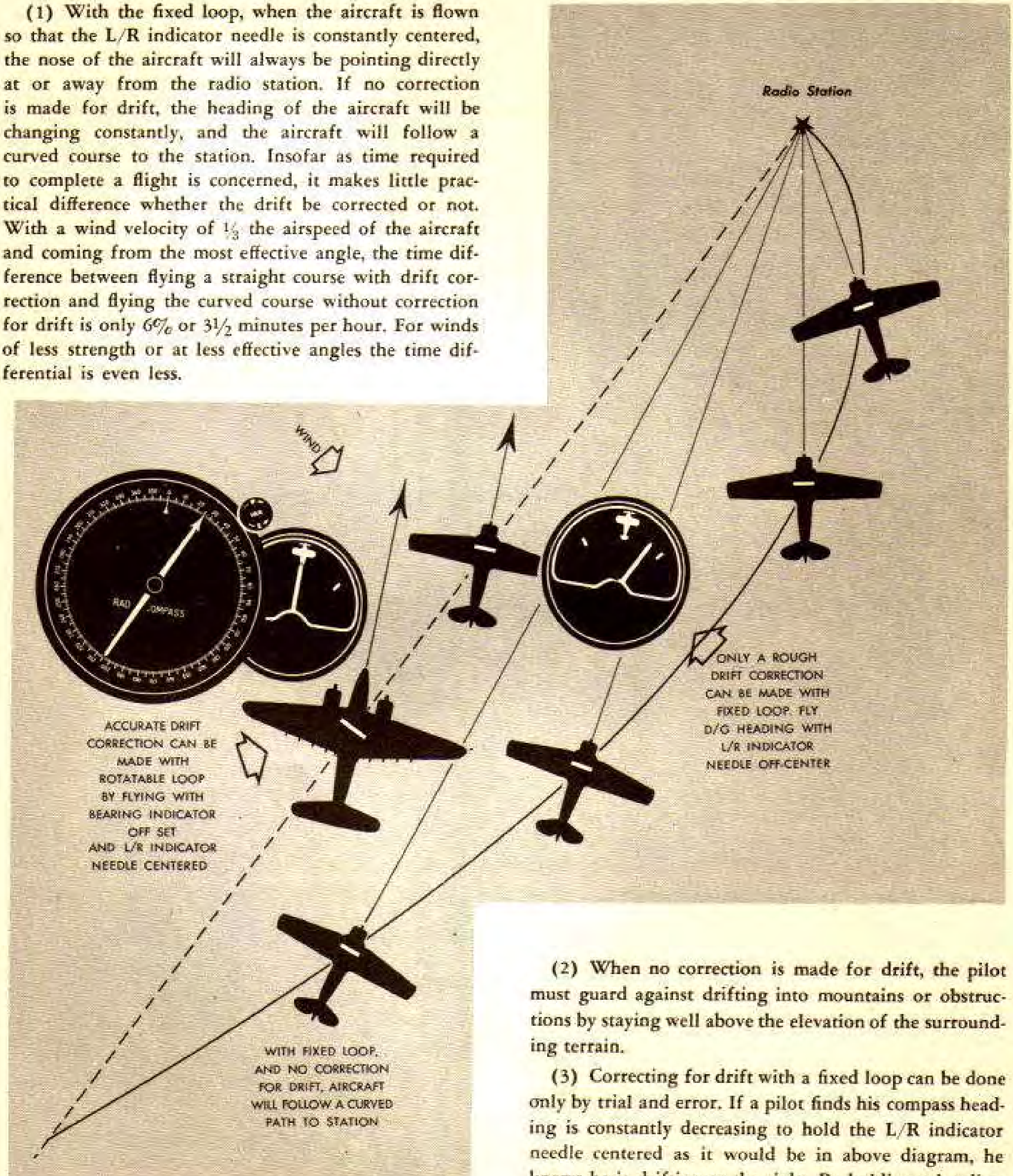


Figure 61—Drift

(2) When no correction is made for drift, the pilot must guard against drifting into mountains or obstructions by staying well above the elevation of the surrounding terrain.

(3) Correcting for drift with a fixed loop can be done only by trial and error. If a pilot finds his compass heading is constantly decreasing to hold the L/R indicator needle centered as it would be in above diagram, he knows he is drifting to the right. By holding a heading to the left, he can approximately counteract for drift.

d. AURAL NULL ORIENTATION.

With any type of radio compass it may be necessary, due to partial failure of the equipment, to resort to aural null methods. By this method, homing or position finding can be accomplished. With the fixed loop types, the loop is mounted in the "nose null" position. The pilot will tune in and identify the station on ANT. After the station has been identified, the pilot will turn the function switch to LOOP. The directional gyro is set with the magnetic compass, and a slow turn is started. When the "null" is received the gyro heading is noted. The "null" must be bracketed by increasing the volume and by making small corrections in heading by reference to the directional gyro. The aircraft is now on a line through the station, but the station may be either in front or behind the aircraft. The method for solving this "180° ambiguity" with the fixed loop installation is as follows:

1. The aircraft being on a line through the radio station:

2. Turn 90° to the right and fly for 3 or 4 minutes.

3. Then, turn left until the null is again obtained.

4. Read gyro heading when the new null is received. If gyro heading has decreased, station is ahead; if gyro heading has increased, station is behind.

5. If the difference in these two gyro headings is too small (less than 10°), the aircraft should again be turned 90° to the right for 3 minutes more and the null heading again established.

6. To approximate the distance to the radio station a simple formula may be used: Time in minutes flown between the nulls, multiplied by the airspeed, and divided by the difference in headings of the nulls will give the approximate distance to the station in miles.

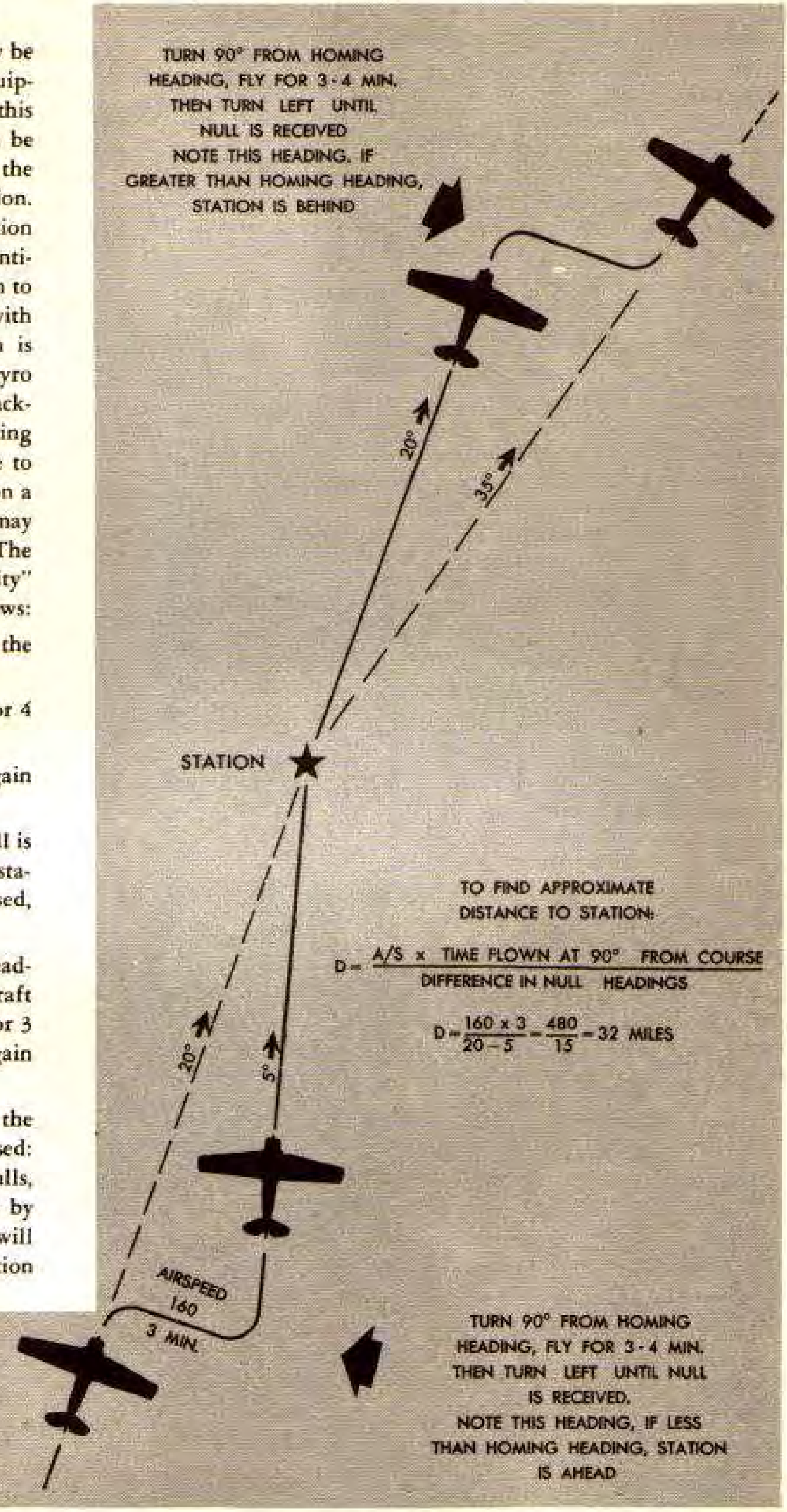


Figure 62
Solving 180° Ambiguity

6. RADIO STATIONS.

a. PRECAUTIONS IN SELECTION OF STATION.

(1) Commercial radio broadcast stations usually can be received from greater distances than radio range stations. This is true because of the greater power of the transmitters of commercial stations. However, the radio waves radiated by the lower frequency stations (such as the radio ranges) are generally less distorted and give more accurate bearings if the reception is reasonably strong and clear. It is usually found that regardless of frequency, the station which can be received with the most clarity and strength will give the most accurate and reliable bearing.

(2) If an interfering signal is heard in the headset, it is probably causing an error in bearing. To check, tune a few kilocycles either side of maximum signal strength. A change of bearing with tuning indicates an interfering signal. In this case, select another station, or proceed by dead reckoning until closer to the desired station. Exercise care when taking bearings on commercial broadcast stations carrying the same program, as they may be mistaken for each other. Avoid taking bearings on synchronized stations except when close to the desired station. If that type of station stops transmitting or fades, bearings might be taken on other stations having the same frequency. Avoid using a station which cannot be identified. A listing of commercial radio stations will be found in T. O. No. 08-15-2, which is carried in all aircraft.

(3) Note that the marker beacon receiver in use at present is in operation whenever the Radio Compass is turned on. The indicator lamp will light when the aircraft passes over a 75 mc Fan Marker, Cone of Silence Marker or Instrument Landing Marker. The identification signal of keyed markers will be shown by the flashes of the indicator lamp. The receiver, when flying at low altitudes over a fan marker, may not follow the keying while in the strongest part of the field. In this case the light will remain on until the strong field has been passed.

b. TERRAIN AND ATMOSPHERIC EFFECT.

Various factors distort the travel of radio waves. This causes fluctuating or erroneous bearings. The most common causes are:

(1) *NIGHT EFFECT.*—This is an irregular reflection of radio waves from the sky (or the heavyside layer). It is generally present, during the hours of darkness, but is most prevalent during periods just before and after sunset and sunrise. The maximum night effect will be noted in the commercial broadcasting stations in the frequencies range above 1000 kcs; however, under some conditions, night effect will be noted in the radio ranges. In general it can be said that the greater distance from the station the more pronounced the irregularities will be. Adcock radio ranges stations seem to be least affected by this phenomena, as they radiate very few "sky" waves. Night effect may be recognized by fluctuating bearings, and there seems to be little or no remedy for it. The error can be minimized by using an average value of the fluctuations. When close to the radio station these errors will be at a minimum.

(2) *ELECTRICAL DISTURBANCE EFFECT.* — Radio waves usually are distorted somewhat in the vicinity of frontal activity involving extensive electrical disturbance, such as thunderstorm. It may be recognized by fluctuating bearings on "COMP" position. During the occurrence of lightning, the bearing will appear to be in the direction of thunderstorm. See Figure 63. The proper technique is to disregard the wild fluctuations, and rely on dead reckoning and/or aural null procedures.

Figure 63—Electrical Disturbance Effect

(3) *MOUNTAIN EFFECT.*—The reflection of radio waves from mountains, known as mountain effect, causes erroneous or fluctuating bearings at times. For this reason, bearings taken in the vicinity of mountainous terrain should be used with caution.

(4) *SHORE LINE EFFECT.*—Radio waves are distorted at the shore line when they travel over a large body of water. The effect is similar to the deflection of light rays at the surface as they enter a body of water. The deflection is greater when the bearing crosses the shore line as a small angle, than when it crosses at a large (or more nearly perpendicular) angle. For this

reason, bearings taken on land stations from aircraft over water are to be used with caution when the bearings cross the shore line at less than a 30° angle. Shore line effect also introduces an error in the bearings taken by land Radio Direction Finding Stations. This error is, however, in the opposite direction from the error affecting the bearings taken by an aircraft. See Figure 64.

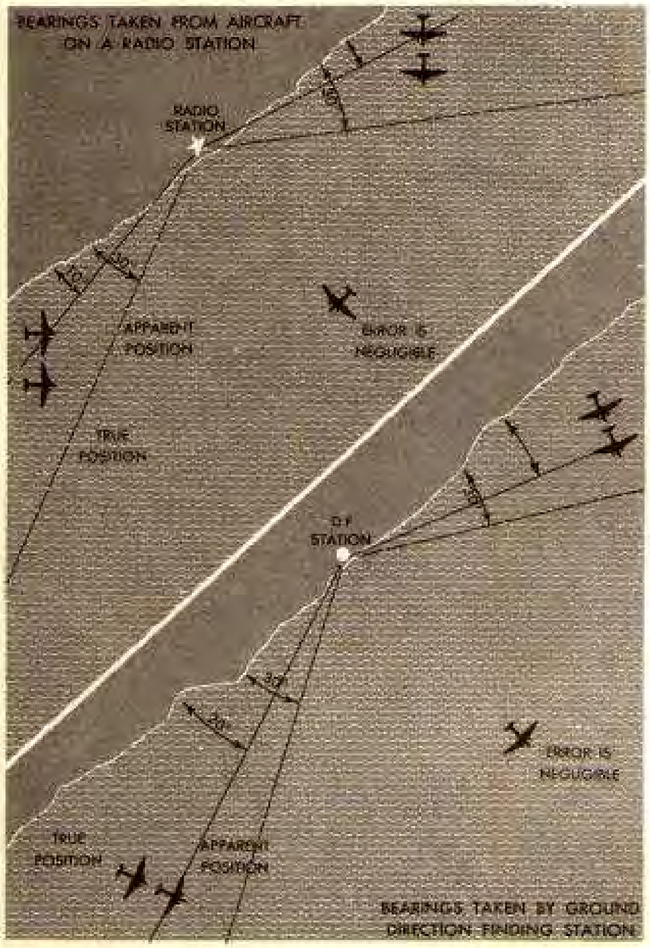


Figure 64—Shoreline Effect

7. OPERATING PRECAUTIONS.

a. QUADRANTAL ERROR.

This error is sometimes called "loop deviation." It is caused by the radio signals being deflected around the metal structure of the aircraft, thereby making the bearings inaccurate. The error is usually least at 0°, 90°, 180°, and 270° positions of the loop. Since the Automatic Radio Compass (SCR-269 series) is compensated for quadrantal error, the pilot need not consider it.

b. EFFECT ON THE MAGNETIC COMPASS.

On some installations, the magnetic compass may deviate excessively while the Radio Compass is turned on. This may be true particularly in installations made in small training type aircraft. Unless the magnetic compass has been swung with the radio compass "ON", the pilot should determine the effect of the radio compass, because serious navigational error will result. If this deviation is not recorded, the radio compass should be turned off when an accurate reading of the magnetic compass is desired.

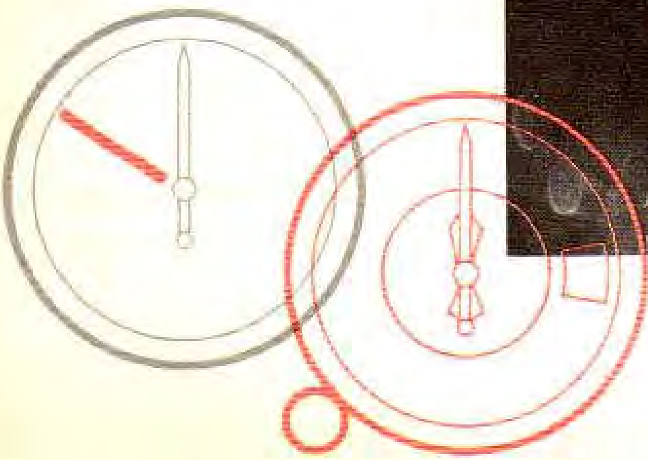
c. EFFECT OF LOW VOLTAGE.

The SCR-269 series Automatic Radio Compass operates at its best efficiency when supplied with the proper amount of electrical current. When the set is installed in an aircraft it is adjusted to operate on the voltage normally supplied by the electrical system of that aircraft. If the voltage falls below the normal value, it may cause poor performance in the radio compass, such as:

(1) Weak reception.
(2) Broad aural nulls.
(3) Weak tone on CW.
(4) Poor sensitivity on COMP.
(5) Sluggish control change.

Therefore, for good performance of the radio compass the pilot should check that the generator voltage regulators are kept in proper adjustment.

SECTION IV
USE OF THE COMPUTER



1. GENERAL.

The computations necessary in dead reckoning may be made on any standard computer. Navigation "on instruments" must be quick and accurate and a computer should always be used, to check distance and ground speed between radio fixes and other such calculations necessary to good navigation. On extended flights, varying barometric pressures and temperatures make it necessary to correct altimeter and airspeed indications. The use of circular slide rule face of the E-6-B for computations of speed—time—distances, airspeed and altimeter corrections is explained herein. A complete discussion may be found in T.O. No. 05-35-9.

2. DISTANCE CONVERSION (Figure 65).

Equivalent distances, statute miles to nautical miles or to kilometers can be quickly determined as in the following example.

EXAMPLE.

GIVEN: Distance .... 200 Nautical Miles

FIND: Equivalent distance in statute miles and kilometers.

SOLUTION: Set 200 (20) miles on rotating disk opposite index marked "NAUT". Opposite indices marked "STAT" and "K_m" read statute miles and kilometers, respectively.

ANSWER: 230 Statute Miles, 369 Kilometers.

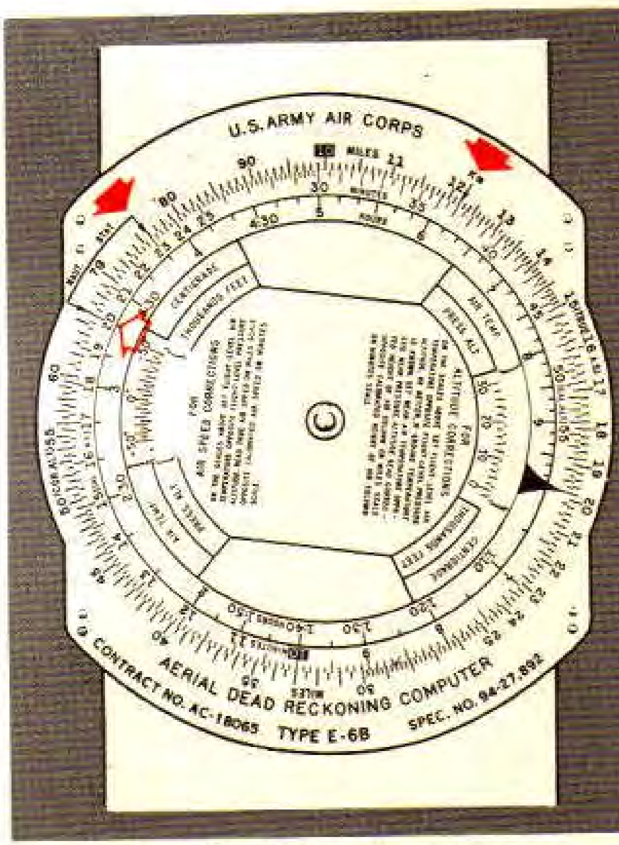


Figure 65 —Distance Conversion

3. SPEED—TIME—DISTANCE (Figure 66).

The following are examples of the various speed—time—distance computations that can be solved with the Type E-6B computer.

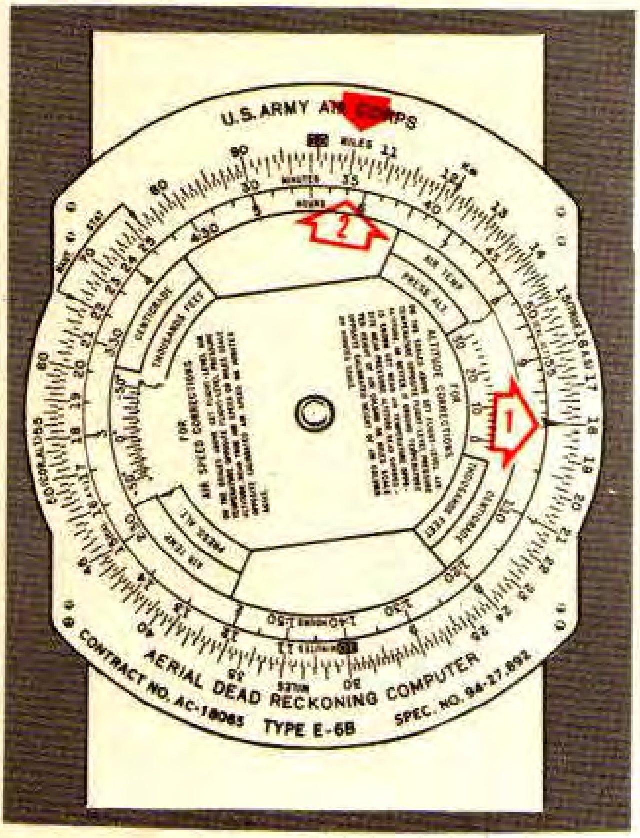


Figure 66—Speed—Time—Distance

EXAMPLE 1.

GIVEN: Groundspeed .... 180 MPH
Time of Flight .... 35 Min.

FIND: Distance Travelled.

SOLUTION: Set the speed index (heavy arrowhead-shaped mark on rotating plate) opposite 180 MPH (18) on the outer "miles" scale. Opposite 35 on the "minutes" scale read the distance travelled on "miles" scale.

ANSWER: 105 miles.

EXAMPLE 2.

GIVEN: Groundspeed .... 180 MPH
Distance to travel .... 210 Miles

FIND: Time required to fly distance.

SOLUTION: Set speed index to 180 MPH (18) on "miles" scale. Opposite 210 on "miles" scale read 70 (7) on "minutes" scale or 1 hour 10 minutes (1:10) on "hours" scale (innermost continuous scale).

ANSWER: 1 Hour 10 Minutes.

EXAMPLE 3.

GIVEN: Distance Travelled .... 240 Miles
Elapsed Time .... 1 Hr. 20 Min.

FIND: Groundspeed.

SOLUTION: Set 1 hour 20 minutes (1:20) on "hours" scale opposite 240 (24) miles on "miles" scale. Opposite speed index read groundspeed on "miles" scale.

ANSWER: 180 MPH.

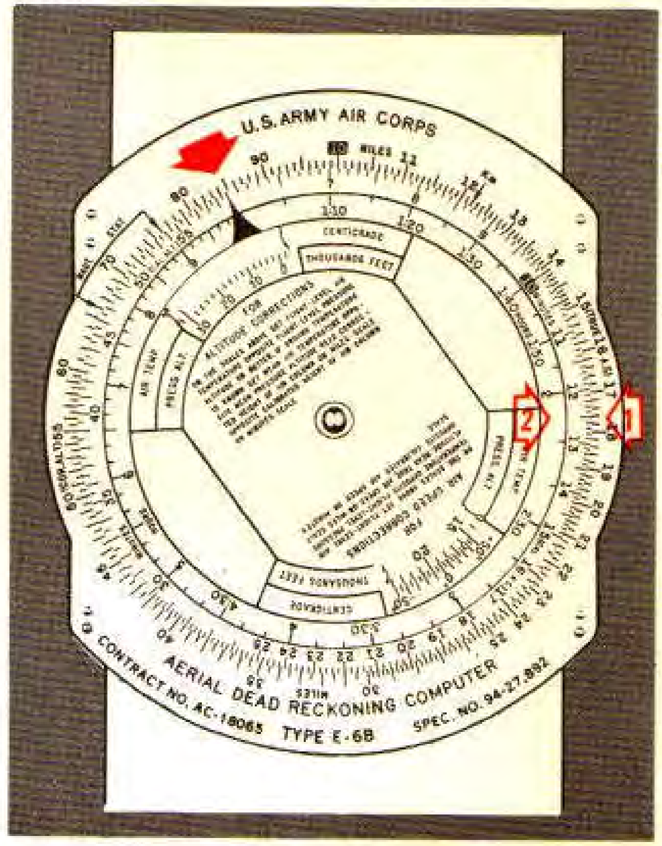


Figure 67—Fuel Consumption

4. FUEL CONSUMPTION

EXAMPLE 1.

GIVEN: Fuel Consumed .... 175 Gal.
Elapsed Time .... 2 Hrs. 04 Min.

FIND: Rate of consumption.

SOLUTION: Opposite 175 on the "miles" scale set 2 hr. 04 min. on the "hours" scale. Opposite the speed index (heavy arrowhead-shaped mark) read the rate of fuel consumption on the "miles" scale.

ANSWER: 84.6 Gal. per Hr.

NOTE: In the above and other cases in which the setting of time in excess of one hour is involved the use of the divisions on both the "hours" and "minutes" scales facilitates the more accurate setting of the rotating disk.

EXAMPLE 2.

GIVEN: Fuel Remaining .... 220 Gal.
Rate of Consumption .... 84.6 Gal. per Hr.

FIND: Remaining flight time.

SOLUTION: Set speed index to rate of consumption, 84.6 Gal. per hr. on "miles" scale. Opposite fuel remaining on "miles" scale read remaining time of flight on "hours" scale.

ANSWER: 2 Hours 36 Minutes.

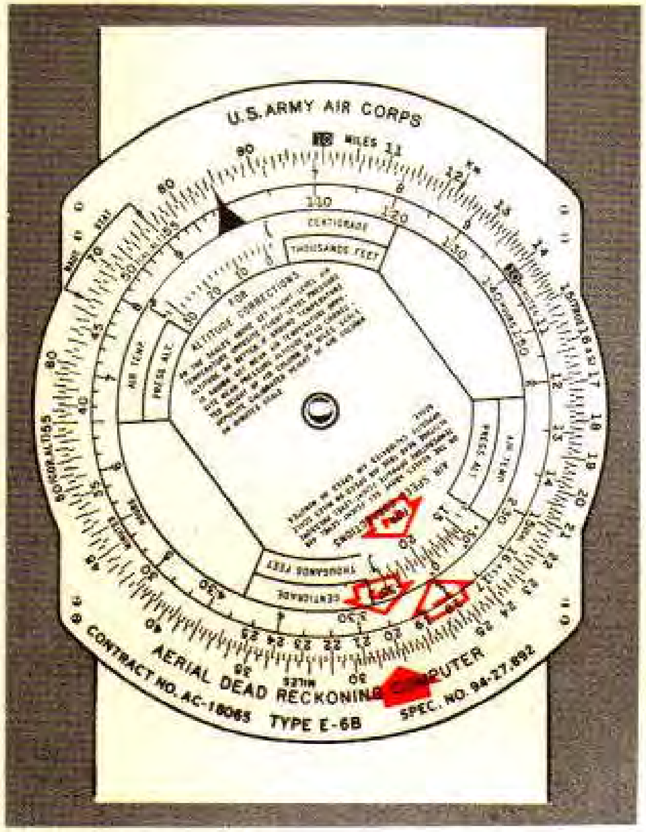


Figure 68 —Airspeed Correction

5. AIRSPEED CORRECTION

NOTE: In computing the true airspeed, it is necessary to use the "calibrated" airspeed (the indicated airspeed corrected for installation errors), the pressure altitude (the altimeter reading when the indices of the instrument are set to standard sea level conditions) and the air temperature aloft in degrees centigrade.

EXAMPLE.

GIVEN: Calibrated Airspeed.........................200 MPH
Pressure Altitude...........................20,000 Ft.
Air Temperature aloft.........................—10° C.

FIND: True Airspeed.

SOLUTION: Adjust the rotating disk to bring the temperature, —10° C., opposite the figure 20 (20,000 ft.) which appears in the "Pressure Altitude" cutout. Opposite 200 MPH (20) on the "minutes" scale read the true airspeed on the "miles" scale.

ANSWER: 282 MPH.

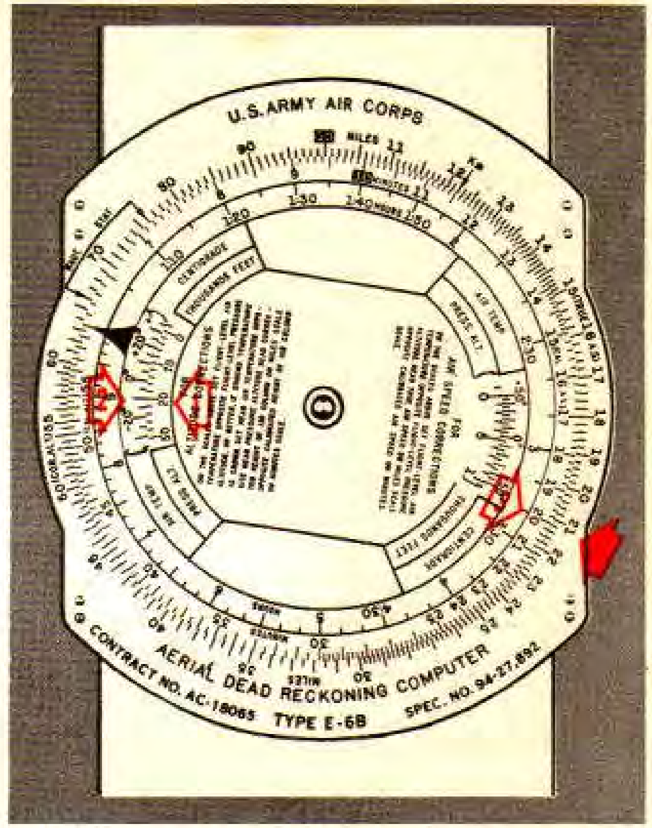


Figure 69—Altimeter Correction

6. ALTIMETER CORRECTION

EXAMPLE.

GIVEN: Air temperature aloft —10° C. Pressure altitude 20,000 (Reading of instrument with indices set to standard sea level conditions, 29.92).

FIND: Correct Altitude.

SOLUTION: Set pressure altitude 20,000 ft. (20) opposite temperature aloft, —10° C., which appears in "Air Temperature" cutout. Opposite pressure altitude (altimeter reading) on "minutes" scale read corrected altitude on "miles" scale.

ANSWER: 21,200 Feet.

NOTE: If the data is available the pressure altitude used in altitude corrections should be corrected for instrument and installation errors before use.

If a ground level pressure altitude and temperature are also known a more accurate method of correction is to set the mean pressure altitude opposite the mean temperature.

Wind problems, interception triangles and similar graphical vector problems encountered in aerial dead reckoning can be solved on the reverse side of the computer. A complete discussion will be found in T. O. No. 05-35-9.

SECTION V

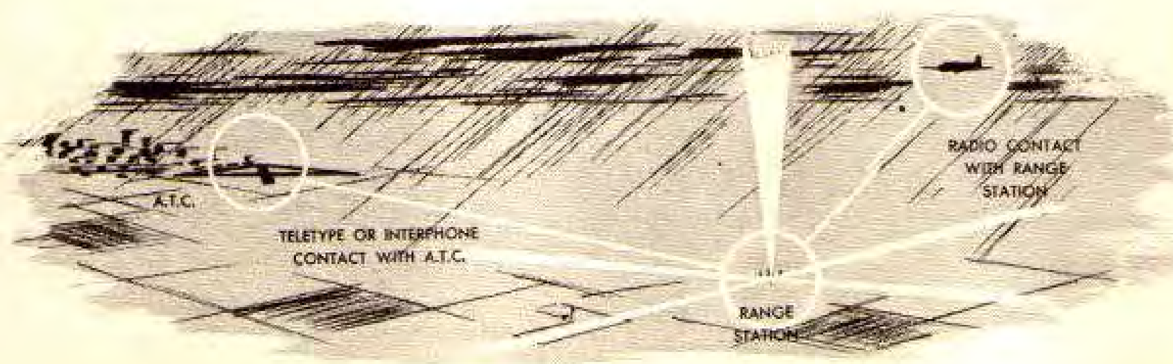
FLIGHT PLANS

1. GENERAL.

a. Military pilots are required to submit a flight plan on Army Air Force Form No. 23 "Clearance" before commencing any, except a local flight. If the flight is not "on instruments" the flight plan will be transmitted to the destination, and the arrival of the aircraft will be reported to the point of departure. In the case of an instrument flight, the flight plan is transmitted to Airway Traffic Control where it is approved with respect to known air traffic conditions. When approved by ATC the flight plan must be adhered to in all respects, except in an emergency, and if any changes are considered necessary by the pilot enroute, he should submit a request for an approval of such a change to the proper ATC. Because ATC cannot be contacted directly by the pilot in flight, all calls are relayed through radio range stations, A.A.C.S. stations or control towers. If a change of altitude or of the flight itself becomes necessary due to unforeseen weather changes or due to other emergency conditions, before ATC approval for a change in flight plan can be obtained, the pilot will report the new altitude or flight plan to ATC as soon as communication can be established.

b. Enroute the pilot must report the progress of the flight to ATC whenever he passes over a radio fix, such as a radio range station, the intersection of two radio range legs, or a fan marker. Time of passing and altitude should be included in these "over" reports. Changes in airspeed must also be reported.

c. This information is used by ATC to separate the various flights proceeding along the airways on instruments, both by altitude level and by time separation.



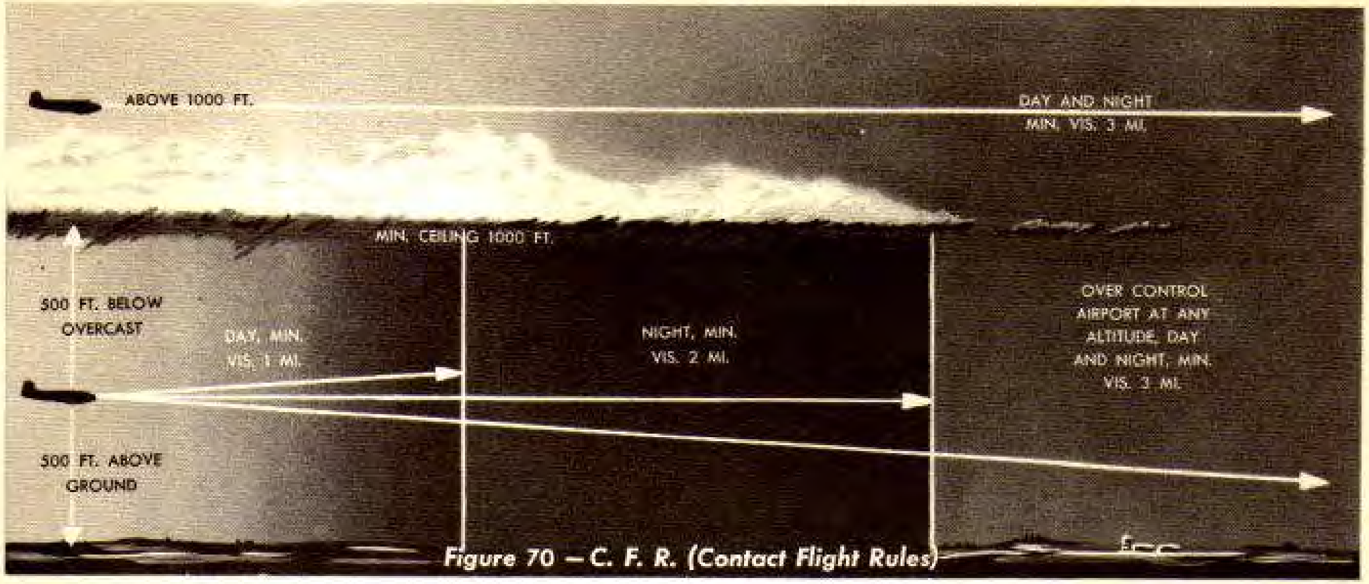


Figure 70 — C. F. R. (Contact Flight Rules)

2. TYPES OF FLIGHT PLANS — CONTACT FLIGHT RULES.

a. CFR. ATC flight plan approval not required. The pilot flying under CFR rules must remain at least 500 feet below the overcast at all times. He must not fly less than 500 feet above the ground unless otherwise directed by competent military orders. Flight may be over broken clouds, provided visual reference to the ground is available and the aircraft is flown at least 500 feet above the clouds and not closer than 2000 feet to any cloud in a horizontal direction.

When flying under contact flight rules along or across a civil airway during daylight hours the specified airway flight altitude levels must be maintained. In addition, when flying at night, or for formation flights day or night, a flight plan specifying the altitudes to be flown on civil airways must be filed with ATC.

b. 70/CFR. (Altitude/Contact Flight Rules) ATC flight plan approval not required. The altitude (in this case 7000 feet) followed by CFR indicates the pilot intends to fly at 7000 feet under contact flight rules as above. If cloud formations do not permit continued flight at this specified altitude the pilot must descend to a level where contact flight rule conditions are available. If CFR flight becomes impracticable the pilot must either land where CFR conditions prevail, or he may request and obtain ATC approval to continue the flight under an instrument flight plan.

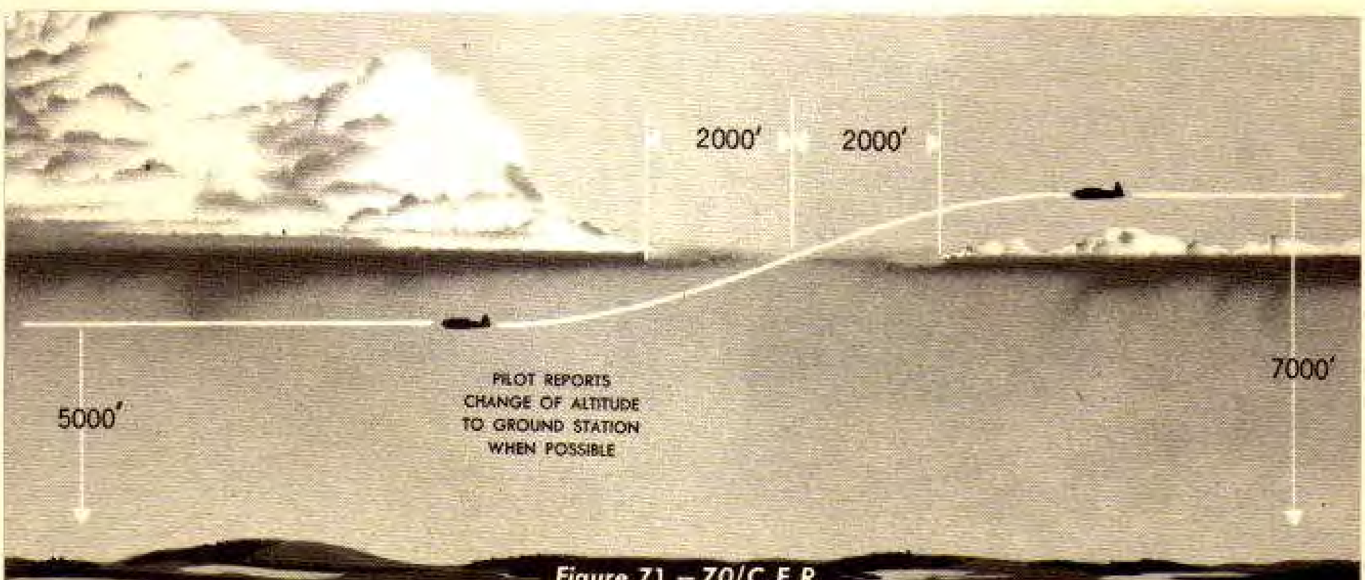


Figure 71 — 70/C. F. R.

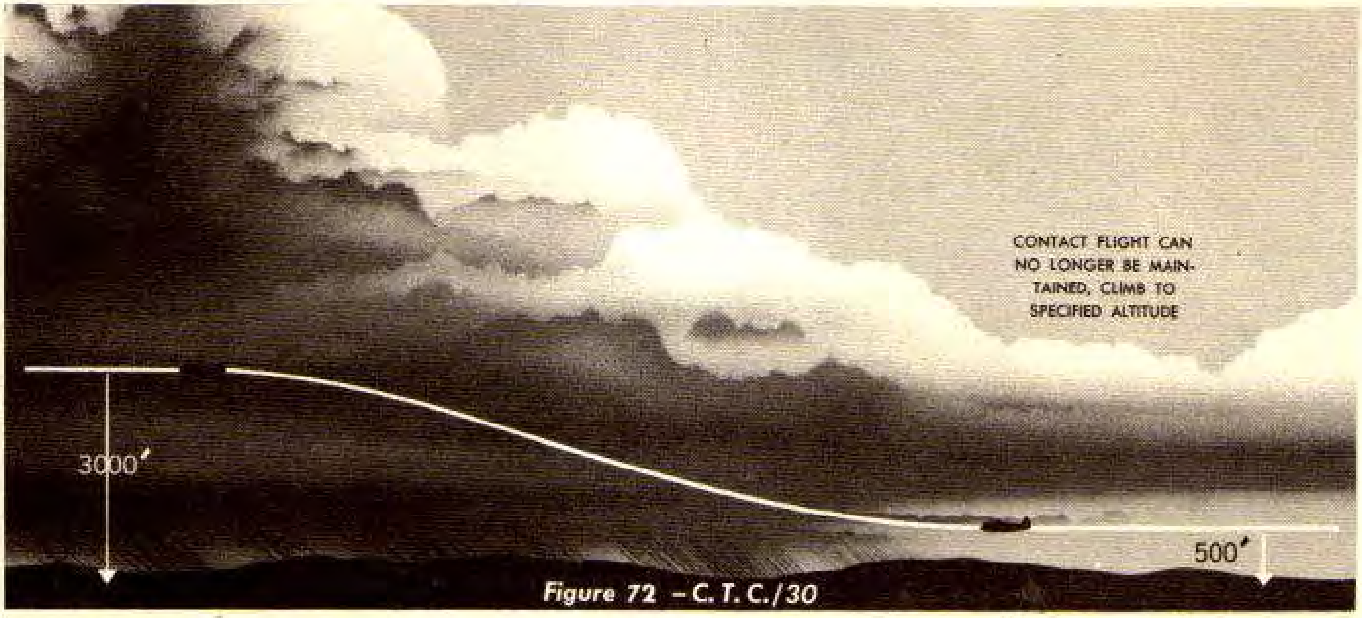


Figure 72 – C. T. C./30

3. TYPES OF FLIGHT PLANS — INSTRUMENT FLIGHT RULES.

Pilot must possess a valid instrument card. All instrument flight plans must be approved by Airway Traffic Control, if the flight will be conducted along or across the Civil Airways.

a. CTC/30. (Contact/altitude.) Under this type of instrument flight plan the pilot will fly contact, that is by visual reference to the terrain, as long as possible. If it is necessary to continue the flight "on instruments" the pilot must fly at the specified altitude, in this case 3000 feet. ATC will hold this altitude open for the flight, that is, no other aircraft will be authorized to fly at this altitude considering the time separation factor. The altitude specified must always be the minimum safe altitude for the route.

b. STRAIGHT ALTITUDE. The pilot specifies an altitude level at which he proposes to fly to his destination.

c. 500 FEET ON TOP. This type of flight plan can be approved only during daylight hours. The flight may be conducted at any altitude above the overcast at the pilot's choice, except that the aircraft must not be flown closer than 500 feet to the top of the clouds. Clearance must be obtained before climbing or descending through the overcast.

Figure 73 — Specified Altitude, "Instrument"

SECTION VI
PLANNING THE INSTRUMENT FLIGHT

1. GENERAL.

a. The most essential part of any instrument flight is intelligent planning *prior* to take-off. Such planning not only tells the pilot whether to go or not to go but it also tells him what to expect enroute and what to do about it when the expected (or the unexpected) happens. Lack of intelligent planning for instrument flight is inexcusable. In any accident resulting from faulty instrument flying, the primary cause can usually be traced to one of two things: Either the pilot was technically incompetent, or lack of intelligent planning is evident. For instance, the pilot who departs on an instrument cross-country having consulted *only* the teletype sequence reports knows nothing except that the weather at his destination will *not* be what the sequence reports indicate at the time of take-off. Invariably some change will have occurred in the weather at his destination during the flight.

b. In planning the instrument flight, the pilot should assure himself of many things. If he is not technically competent, there is no need for him to plan further, for he should not even leave the ground. He must know his equipment and just what it will do. His aircraft instruments and radio must be adequate for the flight. He must also consider his terrain, his course and his ground aids, such as radio facilities. Lastly, he must spend considerable time in studying the weather and its *trends* to see if it tallies with his own limitations and the limitations of his equipment.

c. In all of the above considerations, there must be no doubts, no confusion and no acting from emotions instead of judgment. The surest way to get into trouble in weather flying is to strap your aircraft on and take-off just because of false pride, or with the feeling "don't know, but guess I can make it". It is obvious that weather does not improve or remain the same due to wishful thinking. It is never smart to battle unknown elements.

d. Having decided that "intelligent humility" is the answer, the pilot will go thoroughly into all phases of his proposed flight. He will assure himself that the instruments, radio and all other equipment of his aircraft is functioning, and will consider if they are suitable and adequate for the flight. He will calculate the fuel range of the aircraft, particularly with reference to head winds at the flight altitudes, approach and landing delays; the effects of the use of carburetor heat, ice accumulation, excessive loads, etc. The fuel of the aircraft must be adequate to permit a change of flight plan to the "alternate airport." Fully familiar with his equipment, the competent pilot will anticipate the failures which may occur in flight and he will know what course of action to take in the event of such a failure.

2. WEATHER.

a. The most important part of careful pre-flight planning, the intelligent pilot realizes, is knowing the weather. He will never just "check" the weather; he will "study" it closely. To discover the expected intensity and *trend* of the weather is the most essential part of this "study". Weather seldom remains the same; it is always in a process of constant change. As an example, severe thunderstorms may dissipate completely at night, or the reverse may occur as a cold front approaches a mountain barrier. Thunderstorms of severe intensity may develop very quickly in advance of such a front.

b. The average pilot is not a meteorologist, but by discussion with a qualified forecaster he can obtain a very complete picture of conditions to be encountered along the route of the flight he is planning. The intelligent pilot can often judge the forecaster's ability and knowledge of the particular weather situation under discussion through his statements. The "study" should not be terminated until the pilot has gained a clear and thorough understanding of: 1, the actual conditions enroute; 2, the probable severity thereof; and 3, the trend of the conditions if unfavorable weather is indicated. If the pilot does not have a clear picture of the situation, he should either seek further enlightenment or he should abandon the flight.

c. Valuable aids to the pilot's study of the weather are the Department of Commerce route and terminal forecasts transmitted every six hours over the C.A.A. teletype circuits. These forecast sequences present an evaluation of sky conditions, ceilings and visibilities expected in the next few hours over the airways and at terminal airports. Last of all, the pilot should examine the hourly sequence weather for reporting stations on or near his proposed route. If the direction of general movement of weather is known, examination of sequence report in that direction from the proposed flight route will assist in estimating approaching weather conditions. Passing of fronts may be indicated by reported windshifts. Dew points and temperature reports included in the weather sequences will be important to the pilot. Weather trends can also be noted by comparing barometric pressure reports with previous readings at the same station.

d. The point of all weather "study" by the intelligent pilot may be summarized: He correctly evaluates all reports and forecasts available to him into a coherent whole which gives him a picture as accurate as possible

of the prevailing weather conditions, and of the conditions *to be* expected along the route over which the flight is to be made. With this evaluation the pilot can then, ***and only then,*** arrive at a decision. He can, depending upon the conclusions formed, either delay the flight, or he can make it with the peace of mind necessary for its successful conclusion.

3. TRANSITION.

a. The greatest transition for the inexperienced pilot comes when he first meets weather conditions making actual instrument flight necessary. The student has by long hours of simulated instrument flight under the hood mastered the necessary technique, but, the emotional and physical sensations he will experience when actually dependent solely upon himself and his instruments, may cause him to fail if he is at all uncertain of his ability. Unstable reactions are brought on by the onset of fear, fear felt largely because the pilot does not know what to expect. The pilot must recognize this "fear of the unknown" and must overcome it by foresight and intelligent planning. The pilot who cannot understand this should not fly on instruments.

b. The causes of this fear must be removed, not by fighting it, but by careful pre-flight planning. By thorough planning the pilot will know at all times just what to expect. The student who uses this approach to the transition from simulated to actual instrument flight will find that this fear will disappear after the first few instrument flights.

c. It is very important to overcome this mental hazard and eliminate avoidable errors by intelligent planning. Therefore, the student should make his transition to actual instrument flight in the overcast with ample ceiling and visibility underneath. Navigation flights on instruments should only be made with the knowledge of definite areas of clear weather to which the pilot may proceed by dead reckoning, should landing at an alternate airport become necessary. By choosing these conditions, the student will always know that he has a safe alternate plan in case of difficulty. The pilot should be in good physical condition and free from worry. Worry, apprehension and poor physical condition from loss of sleep or other causes, should keep the pilot on the ground.

d. After a few such flights the mental hazard will disappear and transition will have been successfully accomplished. The student should not be permitted to become "cocky" however; he should take it easy and progress normally to more difficult flight procedures, such as instrument approaches.

e. The pilot should take advantage of all opportunities to practice instrument flight which may present themselves. The gyro instruments should be caged during some of the flights so that skill on the rate instrument may also be acquired.

f. Flying on instruments for any length of time will be considerably more tiring than flying contact, and the rate of tiring depends upon the stability of the aircraft, the smoothness of the air and the exactness necessary for the particular type of flying to be done. Cross-country at fairly high altitudes is an example of relatively simple instrument flights. A high degree of concentration should *not* be used in order to keep from becoming tense and tired. After practice and with a reasonably stable aircraft, a pilot should be able to fly a fairly straight course by glancing at the instruments every ten or fifteen seconds. The less concentration necessary, the longer the pilot can fly on instruments without becoming too tired. At the other extreme, instrument landings require the most concentration followed in order by thunderstorm flying and low approaches.

g. All of the above must be taken into consideration in planning the instrument flight. If the pilot has intelligently considered these factors and then proceeds to carry out the flight, understanding what he will encounter and with knowledge of what he will do en route, he can quickly learn to become a competent instrument pilot. For further information on weather planning consult T.O. 30-100D-1 "Instrument Flying, Technique in Weather", and the next Section.

SECTION VII
WEATHER FLYING

1. GENERAL.

a. The type of weather, its severity and extent, which a pilot may fly safely is largely dependent upon the individual limitations of the pilot, after taking into full consideration the equipment he has to fly, the terrain, the ground aids available, and any other factors involved in the existing situation. Therefore, it is manifestly impossible to lay down definite rules and regulations; it is only possible to make certain *suggestions* which may aid the pilot in determining his own limitations, or serve as guidance to what he may expect.

b. Certain it is, however, that pilots should not attempt any weather flying until they have become competent in both basic and advanced instrument flying. The practice of allowing pilots who are not competent in the technique of instrument flying to barge out into bad weather is, to say the least, a great injustice to the pilot himself.

c. On the other hand, pilots who have proved themselves competent in basic and advanced instrument flying should be *encouraged* to fly weather, although they should do so in progressive steps and of their own volition. Competent pilots should have a desire to put into practice their knowledge. The pilot should gradually undertake more difficult flights, as his experience, confidence and judgment improve. After all, the goal of all instrument flying training is to equip the pilot so that he will be able to fly safely in adverse weather.

d. Assuming that the pilot is competent in all phases of technique, the types and amounts of weather which the pilot may fly depend on his own limitations, and his limitations in turn depend wholly on his personal judgment. Judgment is usually a combination of intelligence and experience, and only the pilot can judge where he stands in these matters.

e. The information in this chapter is the result of experience and is for the purpose of assisting the pilot in using his intelligence, not to tell him what or when to fly.

2. SUGGESTIONS FOR THE PILOT.

When a pilot looks only at the weather sequences without reference to the weather map, the only thing he can be sure of is that the weather at his destination will not be exactly the same as that given in the sequence report prior to his departure. The type and trend of the weather must be ascertained from the last few weather maps, and a discussion must be had with a competent meteorologist prior to obtaining any information from the weather sequence reports. He must be certain that he knows what he will encounter and what he is to do about it before departing in any type of bad weather. Further, he must be reasonably confident that he can negotiate the trip successfully. Particular information should be secured on the following factors:

1. Low ceiling or visibilities at the destination (ground fog or low stratus).

2. Relation and trend of dew point and temperature.

3. Winds aloft (directions and velocities).

4. Icing conditions (type, duration and severity).

5. Rough air (including thunderstorm activity and severity of fronts).

6. Trend and movement of the prevailing weather system.

7. Limitations of the pilot and his equipment.

3. RAIN.

A heavy rain will sometimes cover the windshield to such an extent that it will be easier to fly by instruments than visually. Sometimes a drop in air speed will be recorded, due to water blocking the Pitot tube. If a reduction is noticed, turning on the Pitot heaters will usually bring the airspeed indicator back to normal. About the only time that obstruction of vision due to rain on the windshield becomes a hazard is when landing. When this is necessary, the mental hazard is greater than the actual hazard, as enough of the airport (or its lights, if at night) can be seen when within 100 feet of the ground to make a satisfactory landing. In very heavy rain, it may be desirable to make an instrument approach, just as if in an overcast, in order to line up properly with the runway. Never "turn loose" of the instruments until you are *definitely* contact.

4. THUNDERSTORMS.

a. In flying through thunderstorms, the equipment must be adequate and structurally strong, and the pilot thoroughly competent. Thunderstorm conditions must be flown primarily with the airspeed and the gyro instruments. The barometric instruments can, and do, give false readings, due to rapid changes of pressure encountered in the thunderstorm.

b. The rate of climb is of practically no value, due to normal lag in the instrument and large vertical accelerations. It can be considered as giving a reasonably correct reading only during periods of calm.

c. The altimeter is subject to the same vertical accelerations, as the rate of climb, but not to any appreciable lag. The reading may be taken as correct during periods of comparative calm, except for change of pressure from original setting.

d. THE DIRECTIONAL GYRO is of great value for direction and should be set before entering a turbulent area. During periods of comparative calm, it should be checked with the compass. Be certain, however, that the compass has completely settled down before re-setting the gyro, as it is better to have the gyro precess 10° or 15° than to be wasting time trying to keep it exactly with the compass.

e. THE COMPASS is of little value except in periods of calm, due to excessive swinging. It should be checked in periods of calm for general direction.

f. THE TURN AND BANK INDICATOR is very important. It will stay in operation regardless of the attitude of the aircraft. In severe turbulence the needle will fluctuate rapidly, and the ball may travel from one side to the other, *but as long as neither one stays on one side or the other,* there is no cause for worry. By keeping them as nearly centered as possible, the fluctuation errors will average up.

g. THE AIR SPEED INDICATOR, if the Pitot tube is free from ice or water, will operate fairly accurately. Ice will, of course, slowly put the airspeed out. Heavy rain will slow it down sometimes because of partial blocking of the air entrance. It is not unusual to lose 20 to 40 m.p.h. indicated air speed. There have been rare cases where the instrument went out completely. Most of the time Pitot heat will keep the tube free enough of both water and ice to give an accurate reading, if turned on before the rain or ice is encountered, or before they have become too heavy.

h. THE ARTIFICIAL HORIZON should be used, but it should be checked constantly with the turn and bank indicator. If they do not agree, consider the turn and bank indicator as being correct. Cage and then uncage the artificial horizon (while flying level) if it has tumbled. It is usually possible to go through violent thunderstorms and have the artificial horizon continue to function. However, do not trust it entirely, as it is more subject to failure normally than the turn indicator.

i. The following technique in handling the aircraft in extreme turbulence is generally accepted as being the best:

(1) Have the altitude about four or five thousand feet above obstructions, or just above cloud roll preceding storm, if it is not less than four thousand feet.

(2) With an aircraft of fairly low wing loading, slow down to approximately 40-50 m.p.h. above stalling speed. This will allow sufficient extra speed above stalling to take care of gusts.

With an aircraft of high wing loading (40 to 60 lbs. per sq. foot), care must be taken NOT to reduce in speed too much, due to the possibility of a high speed stall in extreme turbulence. On aircraft where part flaps will materially reduce stalling speed and make the aircraft more stable, it may be advisable to use 10 to 15 degrees of flaps. These are things which the pilot must judge for himself after a thorough study of the type of aircraft he is flying.

(3) Increase power to about 200-300 R.P.M. faster than cruising in order to have flexibility and power available when needed.

(4) Set directional gyro with compass before entering turbulence.

(5) Check artificial horizon with turn and bank indicator.

(6) Do not try to fly UNDER a thunderstorm or front, and definitely do not try to stay contact. You may be able to do so for a while, only to have the ground and clouds come together. Also, the greatest turbulence will be found under, around the edges, and near the top of a thunderstorm. When hail is present, it is usually found on the outside edges. If a thunderstorm is entered in the center and at normal altitudes, the tendency is to gain more altitude than is lost. In extreme cases, the up currents will carry the aircraft up to ten or fifteen thousand feet before the other side is reached. Don't worry, remember that it is abrupt contact with the ground which causes fatal accidents, and the more altitude the farther you are away from that contact.

NOTE

It is not desirable to drop the landing gear. However if it is necessary to increase the power without increasing speed in order to keep the head temperatures up to safe operating limits, lowering the landing gear will usually create sufficient drag to necessitate the additional power needed.

j. TO SUM UP.

(1) Keep the attitude of the aircraft as level as possible, keeping a reasonably constant airspeed, but do not worry about the altitude. Always correct for attitude, but never try to lose altitude gained by up currents, or gain altitude lost by down currents (unless it is absolutely necessary to clear obstructions on the course). Altitude is the best protection, but by trying to compensate for the loss or gain of it, there is a possibility of stalling or diving when that particular current has passed and the opposite one takes effect. Spins or spirals have resulted from too little speed with the nose high. Structural failures from too much

speed. Keep the plane level at a reasonable speed, and there is little danger of either with a structurally sound aircraft and adequate instruments.

(2) Keep the airspeed within limits, but do not try to keep an exact airspeed, as it would mean constant jockeying of the throttles. This is not only a lot of work, but a tail gust may catch you with the throttles back, or vice versa. Use the throttles when the low or high limits are exceeded, but be careful not to over-use them.

(3) Lightning has been found to be harmless, even with a direct hit. Probably the most damage found from a direct hit was a small scorched hole where the mast antenna came through the skin on the top of the fuselage. The only precautions which may be necessary when very severe lightning is present are to take off the earphones to avoid possibility of being momentarily stunned by acoustic shock and, if at night, turn up the cockpit lights to keep from being momentarily blinded. "St. Elmo's fire" will be present in most electrical disturbances. It will take the form of a bluish ring on the circle of the propeller tips, the static charges building up and discharging repeatedly until the heavily charged air has been passed. Charges from lightning flashes or static will usually pass off into the atmosphere by way of the wing tips, or tail surfaces.

(4) Stay relaxed, maintain positive control, let the airplane "wallow" through.

5. ICE.

a. There are three types of "wing" or surface ice, rime, clear (or glaze), and frost. Frost seldom forms on aircraft in the middle latitudes, particularly in flight. It can be dangerous on take-off however. Never take off unless all frost has been removed from the wings and tail surfaces. Clear or rime ice may not be disregarded in the air, but it has been found that a majority of icing conditions may be flown successfully if the aircraft is equipped with proper de-icing equipment, and an intelligent approach to the situation is used.

b. Wing ice has been encountered in a temperature range of -10 to $+37$ degrees F, which would correspond to centigrade temperatures of about -23 to $+3$ degrees, with the most accumulations between $+20$ and $+30$ degrees fahrenheit or -6 to -1 centigrade, approximately. Naturally, a temperature above freezing will melt ice quickly. As soon as the surface temperature of the aircraft rises above freezing, any accumulated ice will melt off.

c. It is also true that ice will evaporate at subfreezing temperature in clear, dry air. If ice is accumulating and it is possible to get on top of the overcast, or between overcasts, ice will gradually evaporate. The length of time necessary to lose it completely will depend on the amount of ice and the dryness of the air.

d. It has been found that an hour is usually sufficient for an average deposit to evaporate and about thirty minutes for a lighter deposit. There are times, of course, when time or weather will not permit finding clear air, and it will be necessary to clear a spot on the windshield, or break a hole in it. The best way to clear a spot is with a paint scraper, wide putty knife, or some similar device. This may have to be done again just before landing to remove any light coating that may have accumulated after the first scraping. If it is necessary to break a hole in the windshield, move to one side to avoid being cut, and break the hole in the left side so that the pilot will be able to see through the hole without getting a direct blast of air. It is almost impossible to hold the eyes open with a direct blast of rain, sleet or snow against them. Snow is not as stabbing as rain or sleet, but will obstruct vision by building up on the eyelids and lashes. On aircraft that are equipped with a small window on the pilot's side of the windshield, it is advisable to open it before the ice gets too heavy, thereby making it difficult or impossible to open.

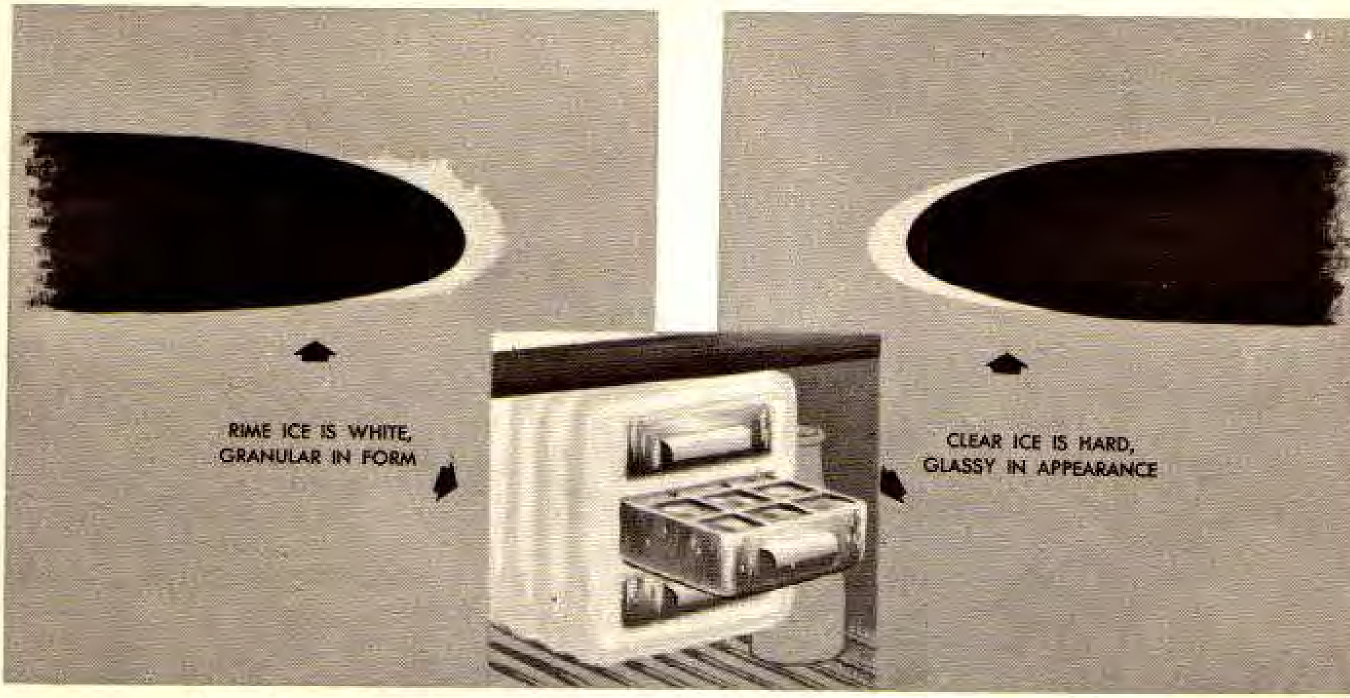


Figure 74 —Rime Ice

Figure 75 —Clear Ice

6. RIME ICE.

This type of ice is formed by the rapid freezing of small cloud particles. They become ice upon contact with the aircraft. Rime ice is hard but porous, similar to the so-called frost that builds up on the freezing compartment of an electric refrigerator. Rime ice does not tend to follow the contour of the wing or other surface of the aircraft, but will build out in front of any surface such as the leading edges of wings, stabilizers, windshields, rivet heads, etc. If it accumulates, a loss of speed will occur, due to the increased parasitic resistance (usually about 20 to 40 m.p.h. indicated), but flying characteristics will not be appreciably changed as long as there is no abrupt change of attitude. However, with an abrupt change of attitude, the airflow will be very erratic until the new attitude has been held constant for a brief period. The loss of lift from the erratic flow will naturally increase stalling speeds and the time and altitude necessary to recover from a stall or spin. There have been some accidents attributed to this; if there is wing ice, keep plenty of flying and gliding speed and do not level off for landing until the wheels are practically on the ground, and then only slightly and gradually. Land on the wheels with the tail high. Wing stalling speed will be higher, and one wing may stall before the other. It is also possible for the stabilizer to stall before the wings, allowing the nose to become heavy abruptly and leaving no control with the elevators.

7. CLEAR ICE.

Clear ice is produced by the relatively slow freezing of water deposited by numerous *large* cloud particles. It is relatively rare to have an absolutely clear ice condition; generally it will be mixed with rime. Clear ice will be smooth to rippled, or rough, depending on how much snow, sleet or rime is mixed with it. It can be distinguished from rime by its hard and glassy appearance. It can usually be avoided by a change of altitude. If in the tops of cumulus, come down; if in freezing rain, go up. While rime usually forms in stable clouds (such as stratus), clear ice is found in unstable clouds (such as cumulus).

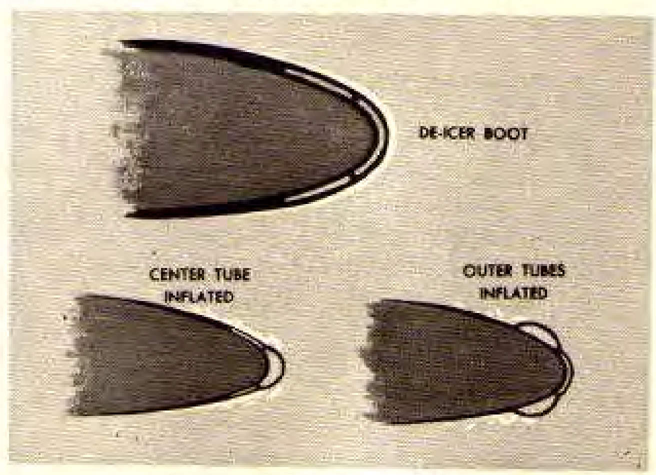


Figure 76 –De-Icers (Wing)

8. USE OF DE-ICERS.

The use of the "rubber boot" type of de-icer is simple. Let about ⅛" of ice accumulate on the wings before turning on the de-icer. When that coating is cracked off, turn off de-icers until ⅛" is again accumulated, and repeat as necessary. The reason for this procedure is that ⅛" of ice will usually crack off cleanly in fairly large pieces, but less than that will tend to just crack, leaving rough surfaces upon which more ice will adhere more quickly and unevenly. However, in case of very rapidly adhering clear ice, or icing conditions at night when the amount of ice cannot be accurately determined, it may be better to leave the de-icers on constantly to avoid the possibility of building up more ice that the de-icers can handle.

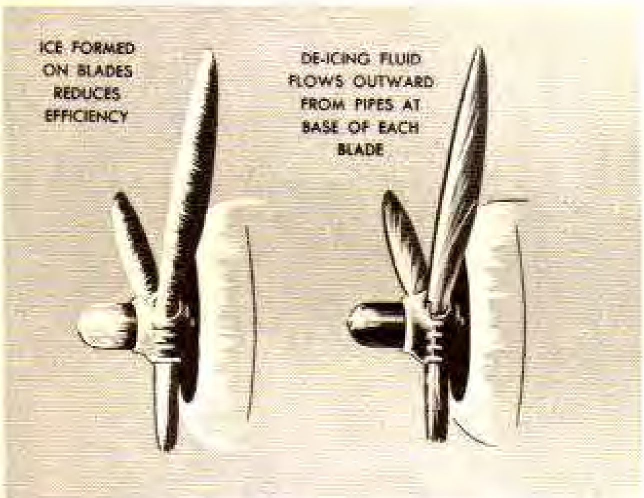


Figure 77—Anti-Icers (Prop.)

9. PROPELLER ICE.

Ice will build up on the leading edge of the propellers if the propeller de-icing fluid is not started flowing soon enough, or if it does not distribute properly. It is best to keep ice off if possible, but if this cannot be done, the result will be disconcerting though usually not serious. As long as the ice forms evenly, there will be little or no noticeable effect. With tapered propellers, it will usually build up to a certain thickness, a piece of it about a foot long will come off the end, and the resulting unbalanced condition will cause enough vibration to shake off the rest. The engine will again be smooth until such time as the process is repeated. Usually, the club type propellers throw the ice off without any noticeable vibration. Some of it will come off against the fuselage, causing a noise similar to banging on a dishpan.

10. AIR INTAKES.

Any air opening or air duct can get filled and closed, or partially closed with ice, heavy snow, or even water. It will form more quickly of course, if that opening is screened. Check the particular aircraft that you are flying for vulnerability to this type of ice, and what the results would be if it formed.

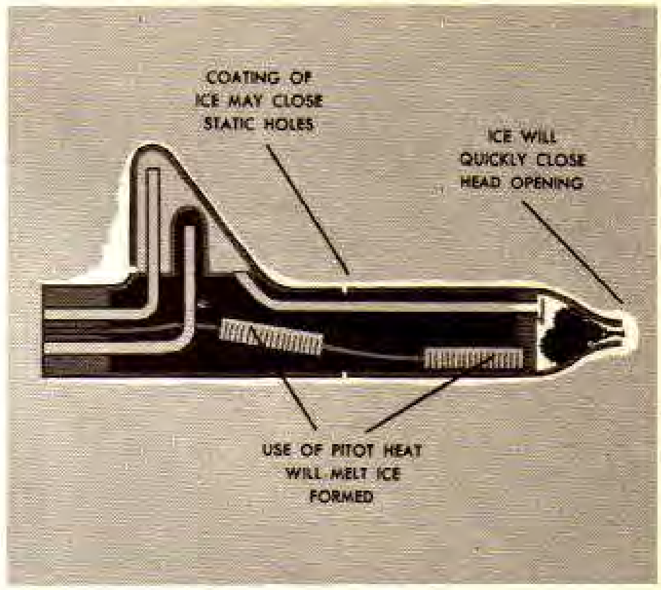


Figure 78 —Pitot Ice

11. PITOT ICE.

Air speed Pitot tubes have been taken care of with reference to ice, by electrical heaters, but icing on the Pitot mast may cause a reduction in velocity past the Pitot tube openings, with a resultant drop in indicated speed. There are also certain formations of ice around the mast and Pitot head that can cause the airspeed to read slightly higher than normal.

12. CARBURETOR ICE.

a. Contrary to original reports, the "pressure type" carburetor *will* ice up, and in some circumstances very badly. Ice is caused by a drop in temperature due to the expansion of gases in the mixing chamber. This drop in temperature (about 50 degrees F.) takes heat from the walls of the carburetor and adapter, thereby presenting below-freezing surfaces to any moisture in the mixture. Ice will build up on the surfaces directly in the path of the mixture. In most installations this would be on the butterfly valve and on the angle of the adapter. The results of tests also show that considerable ice will form on the fuel nozzle itself, but it is doubtful if enough could form to affect the fuel flow from the nozzle holes.

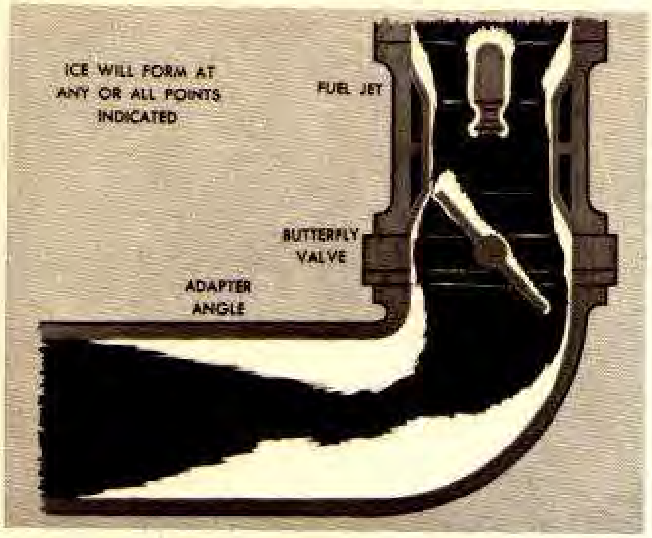


Figure 79 —Carburetor Ice

b. It can readily be seen that with a 50-degree drop in temperature, carburetor ice can form with an outside, or free air, temperature as high as 70 or 75 degrees F. (23 C.), if the moisture content is such that the dew point and temperature are within about 12 degrees of each other. The higher the moisture content and the lower the temperature, the more probability of ice forming. In the pressure type carburetor, ice formations will not change the fuel air ratio, and therefore will not cause engine roughness. It will partially close the opening, causing a loss of suction and a loss of power. During a test, under the most perfect icing conditions that could be simulated in a testing chamber, enough ice formed to completely block the passageway, causing the engine to stop entirely.

c. Due to loss of power during cruising, where the throttle setting is constant, carburetor ice will cause a drop in manifold pressure. However, while taxiing, idling the engines, taking off, or landing, it is difficult to detect this, due to manual changes of throttle and manifold pressure. While taxiing, carburetors have been known to ice up badly enough to cause loss of power sufficient to prevent taking off. In this condition of low throttle setting the butterfly valve partially blocks the passageway and limits the power to the size of the opening that is left, regardless of how far the throttle is advanced. With proper equipment, the elimination or prevention of carburetor ice is quite simple, requiring either a method of heating the intake air, alcohol injected into mixture, or both. When heat is used, the method is to utilize exhaust heat to warm the carburetor intake air sufficiently to have it still above freezing after expansion and cooling of the mixture. To do this requires sufficient heat to raise the temperature of the intake air 100 degrees fahrenheit. The amount of this heat used, of course, will depend upon the outside temperature. More heat than necessary should not be used, as the loss of power due to the heated air amounts to about 1% for every 10 degrees of additional heat, or about 10% for full heat.

d. On some types of aircraft, a thermometer is installed in the carburetor mixing chamber or the air intake near the carburetor, so that the pilot may know exactly how much heat to use for prevention of ice, and to avoid using superfluous heat. On an engine equipped with turbo-supercharger, it is not necessary to have special equipment for heating the air, as the compressing of the air by the supercharger produces sufficient heat. Under conditions of reduced throttle setting, however, the turbo probably would not be turning fast enough to produce sufficient compression to heat the air to the desired temperature. Therefore, when a slower speed is desired and carburetor icing conditions are present, create drag by lowering the gear and part flaps, so that as much power as possible may be used for the lower airspeed.

e. In laboratory tests made with alcohol, a flow at the rate of 20 lbs. per hour (about three gallons) was sufficient to *prevent* carburetor ice formations under the worst possible conditions, and a flow of 80 pounds per hour was sufficient to remove the worst possible ice formation in 30 seconds. Thirty seconds did not seem long enough to melt the ice, and it was assumed that the alcohol loosened the ice from the walls, the impellor chewed it up, and it then passed thru the engine in liquid or gaseous form. Alcohol would not be practical as the only method of removing or preventing carburetor ice formations; due to the additional bulk and weight for sufficient quantity necessary for long flights, but all aircraft except those in combat should be equipped with enough for emergency use, with a flow meter to measure accurately the amount being used in order to prevent waste. Combat aircraft cannot carry alcohol, as an incendiary bullet would explode a partially filled tank. At reduced power, ice forms more rapidly, and enough exhaust heat may not be available. If a flow of alcohol is started before beginning the low approach, the carburetor will be kept clear, and full power will be available if it should be necessary to go around again. It would also leave the pilot, or pilots, completely free to concentrate upon the approach and landing without worrying about the possibility of loss of power from carburetor ice, as alcohol does not produce any noticeable loss of power.

13. INSTRUMENT LET-DOWNS.

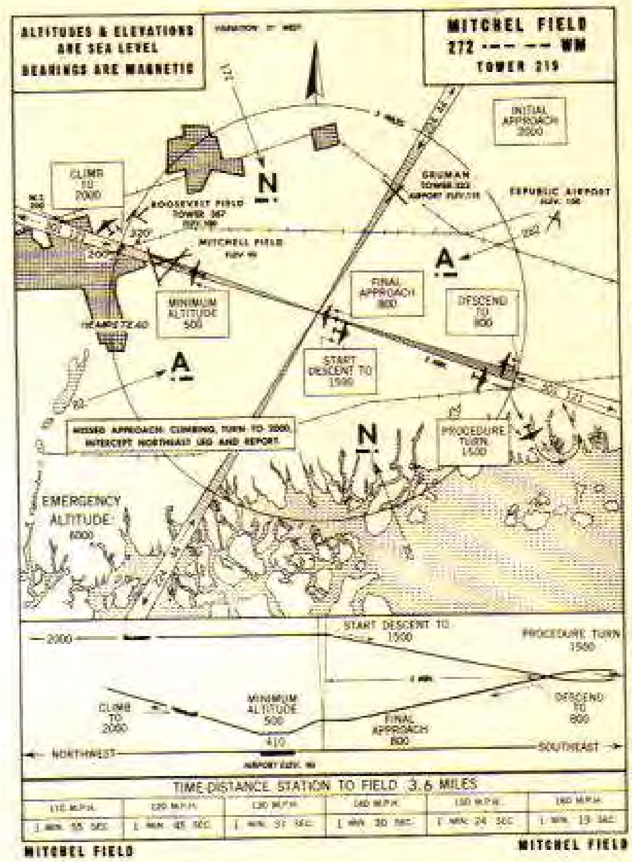
a. An instrument let-down, preparatory to getting under a low ceiling, is just precision instrument flying close to the ground. There are a few tips, however, that may be of value to the pilot. There is a mental hazard present under actual low ceiling conditions that is not present when under the hood. Practice flights under actual instrument conditions will eliminate this mental hazard and it will practically disappear after several low approaches are negotiated successfully.

b. Regardless of the type radio homing device used, the first requirement is to determine definitely the fact that you are over the *right* range station or marker, at sufficient altitude to clear all obstructions. Never try to find the ground just because you are getting near the station, even if the clouds are broken. If instruments have to be used at all, use them exclusively until such time as contact flying may be used exclusively. This is important at all times, but when close to the ground it should be strictly followed. The reason for this is that it is difficult to go from contact flying to instrument flying without a certain lag before becoming entirely oriented on the instruments. With the pilot who has not reached a state of complete confidence in the instruments, there is an additional lag while he is persuading himself that the instruments are to be trusted over his senses.

c. When the position over the station has been verified conclusively, follow the procedure chart in the Army Air Forces Instrument Let-down Procedures book which is carried in your aircraft. If no procedure is available for the particular station, call the tower and obtain this information by radio. The initial approach will be at an altitude high enough to clear all obstacles safely. Over flat country, the difference in altitude between the initial approach and the final approach over the radio range station will be, in most instances, not over 2,000 feet. Where the airport is located in mountainous terrain, the initial approach will necessarily be high enough to clear obstructions within a 25-mile radius by at least 1,000 feet. The difference in altitude between the initial and final approach will, in many cases, be considerable. In some instances, a rate of descent of 1,000 f.p.m. must be used, while at other times a shuttle must be flown to lose sufficient altitude.

d. If visual contact is not reached at the minimum altitude, an immediate climb to the "climb to" altitude must be started.

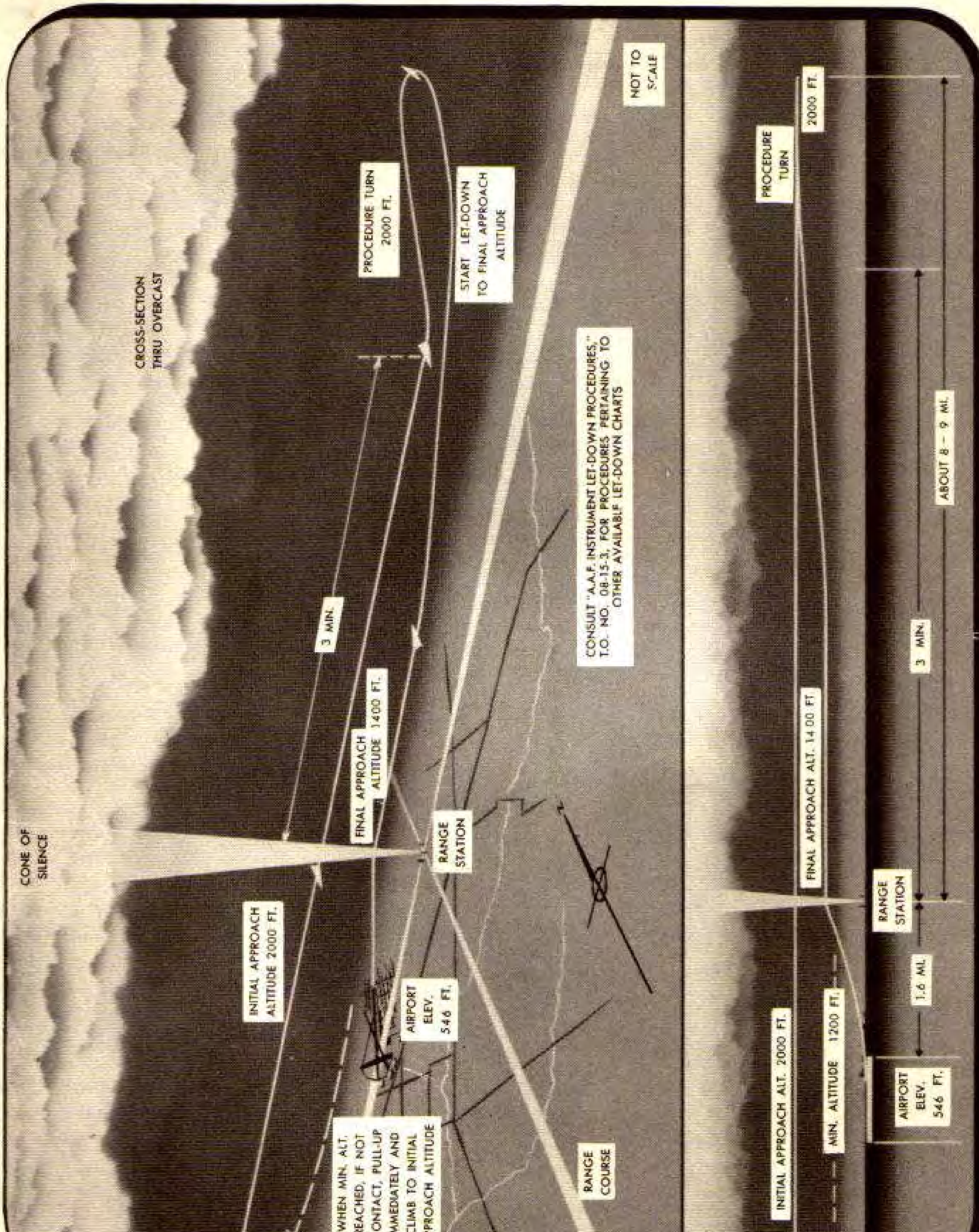
e. When approaching the station, the usual fault is over correcting directionally. Remember that very close to the station it is almost impossible to stay on the "on-course", due to the narrowness of the "on-course" signal. If a correction must be made, under-correct rather than over-correct. It is far better to miss the station 50 to 200 feet to one side than to be heading the wrong direction in when visual contact is made and the field reached.



f. Upon reaching the station, reduce throttle sufficiently to assume a rate of descent desired for that particular approach. Put the flaps down when contact flight is reached, if flap action is fairly fast. The reason for not putting flaps down sooner is twofold. Flaps will reduce speed to near-landing speed, and if ceiling is lower than anticipated and contact is not reached, there will be less resistance, and altitude can be gained more quickly if the flaps are still up. There will be some variations to this. Some aircraft may have more stability with flaps down, in which case it may be desirable to put down about half flaps before or as the station is reached, but save most of them to kill the excess speed after breaking contact. This has prevented many an accident due to running out of runway.

14. GROUND FOG—LANDING.

a. Landing in ground fog is possible, provided the pilot is able to locate the exact edge of the field and


CROSS-SECTION THRU OVERCAST
PROCEDURE TURN 2000 FT.
START LET-DOWN TO FINAL APPROACH ALTITUDE
NOT TO SCALE
CONSULT "A.A.F. INSTRUMENT LET-DOWN PROCEDURES," T.O. NO. 08-15-3, FOR PROCEDURES PERTAINING TO OTHER AVAILABLE LET-DOWN CHARTS
3 MIN.
FINAL APPROACH ALTITUDE 1400 FT.
CONE OF SILENCE
RANGE STATION
INITIAL APPROACH ALTITUDE 2000 FT.
AIRPORT ELEV. 546 FT.
WHEN MIN. ALT. REACHED, IF NOT CONTACT, PULL-UP IMMEDIATELY AND CLIMB TO INITIAL APPROACH ALTITUDE
RANGE COURSE
2000 FT.
PROCEDURE TURN
ABOUT 8 - 9 MI.
3 MIN.
FINAL APPROACH ALT. 1400 FT.
RANGE STATION
1.6 MI.
INITIAL APPROACH ALT. 2000 FT.
MIN. ALTITUDE 1200 FT.
AIRPORT ELEV. 546 FT.

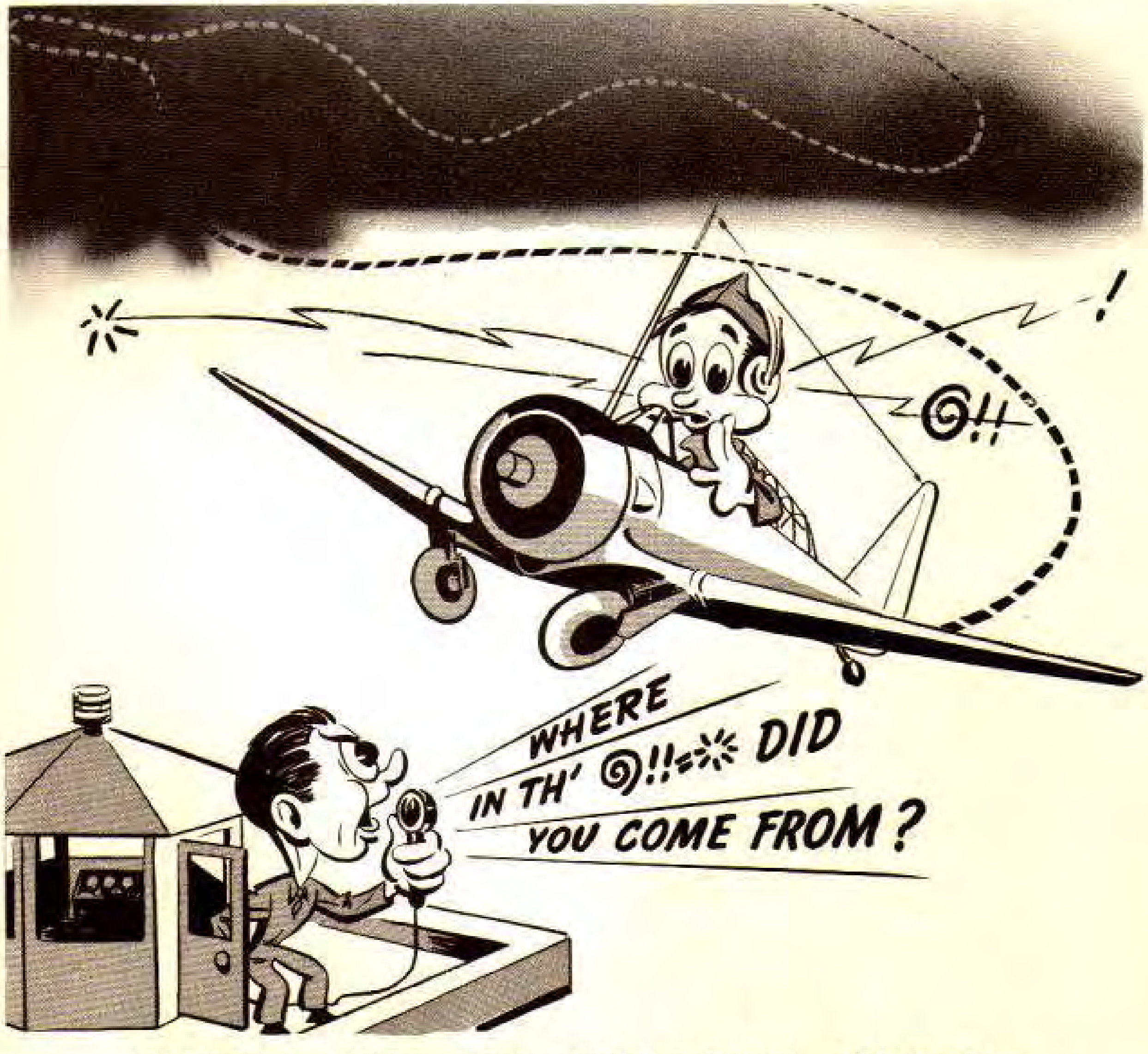
the landing area is large enough and not confined to a runway. Considerably more distance will be required than for a normal landing due to the necessity of keeping a little more speed, altitude, and power for the instrument landing.

b. To make an instrument landing through ground fog, establish a power glide, faster than stalling, and a rate of descent of *400* feet a minute. Hold that glide and altitude until *actual contact* with the ground is made. When contact is made, cut off the power completely, but do not pull the tail down. If anything is done, push the wheel forward slightly. The cushion will take up part of the high rate of descent, and a few bounces will take up the rest. If the tail is kept high, the bounces will be forward, and the nose will not go up in the air. The negative angle of attack will keep the aircraft from trying to fly again.

c. Extreme care must be used in attempting a landing in thick ground fog. Any mistake occurring near the ground will be very difficult to rectify. It is not recommended, unless the pilot knows exactly what he is doing through long experience.

15. IMPORTANCE OF PRACTICE.

Remember that the more practice in actual weather and instrument flying is obtained, the easier it becomes. Every pilot should take every possible opportunity to get practice "under actual conditions", as it is only by such flying that the mental hazard of flying in adverse weather becomes a thing of the past.



ALWAYS CALL FOR ALTIMETER SETTING AND APPROACH CLEARANCE

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TECHNICAL ORDER NO. 30-100F-1

INSTRUMENT FLYING

ARMY AIR FORCES

INSTRUMENT APPROACH SYSTEM

PUBLISHED BY AUTHORITY OF THE COMMANDING GENERAL, ARMY AIR FORCES

NOVEMBER 10, 1943

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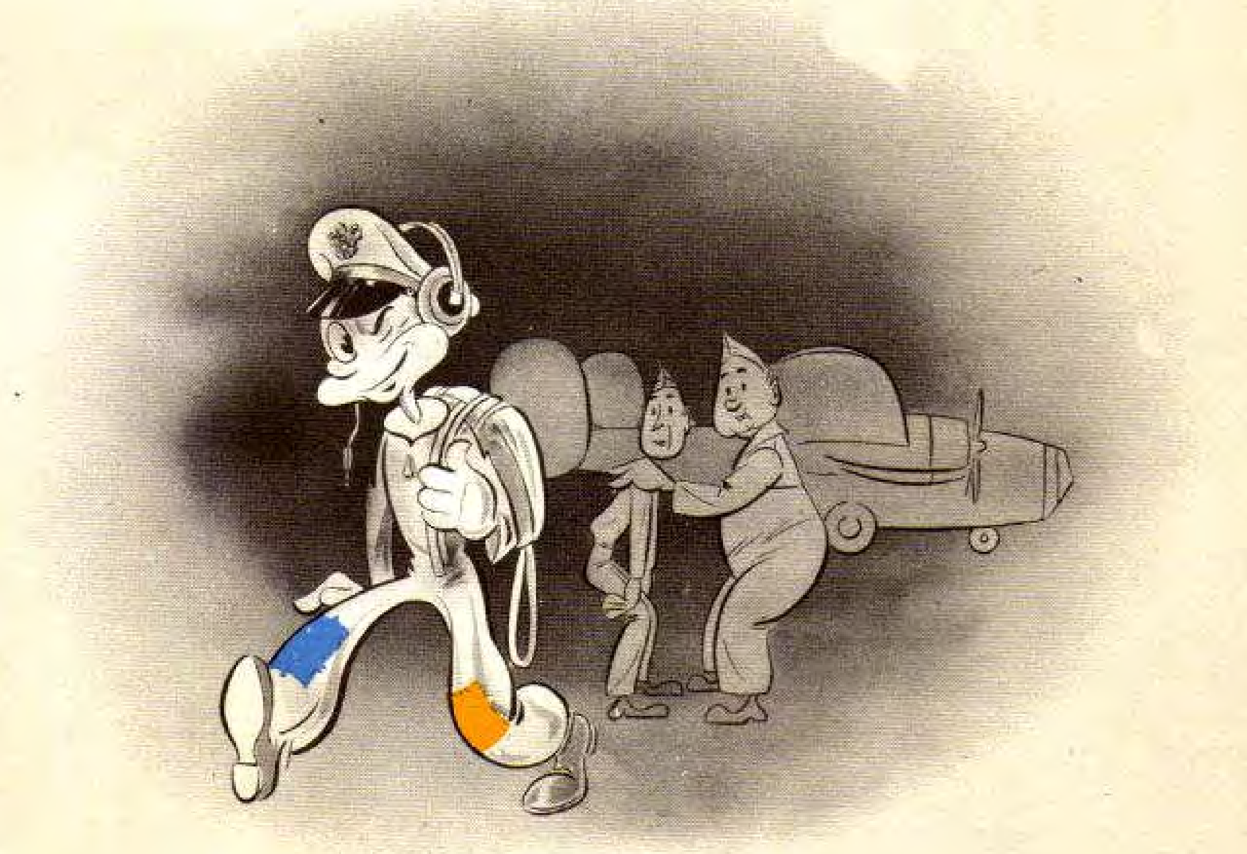
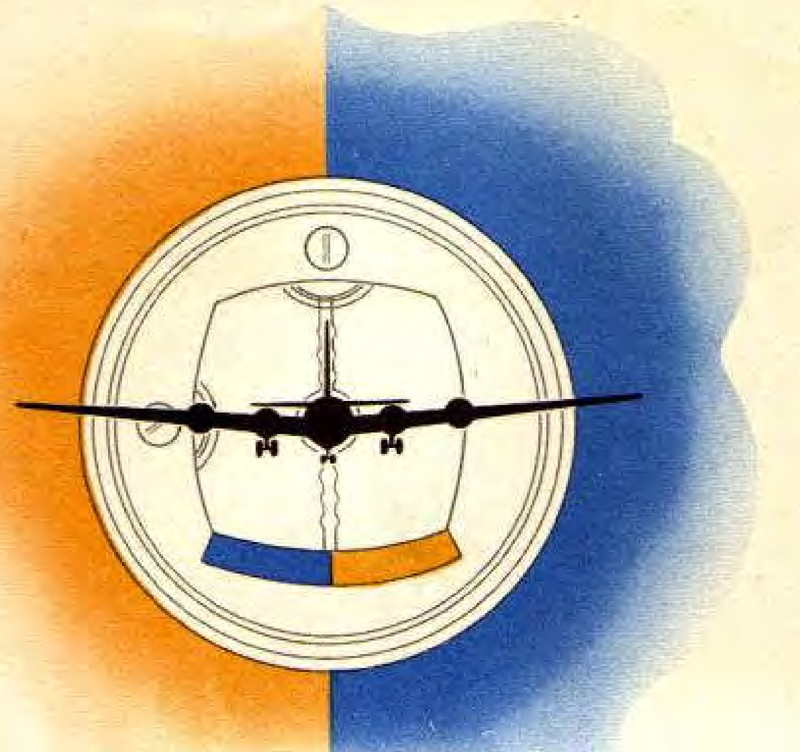




FOREWORD

Instrument approach procedures on the radio ranges are limited to let downs through the overcast, provided ceiling and visibility are above a relatively high minimum. The aircraft must proceed to an alternate airport whenever the ceiling and/or visibility is lower than the approved minimum for this type of operation.

Special installations are required to provide the pilot, in flight, with accurate directional guidance along the landing flight path when landing under lower minimums becomes necessary. These radio landing aids must guide the pilot through the overcast on a line of flight which will bring the aircraft to a landing on the near end of the runway under conditions of zero/zero visibility and ceiling.

The original Army Landing System, employing two portable radio transmitters emitting a signal on 201 kilocycles and 219 kilocycles respectively, now known as the Modified A-1 System, can be successfully used to guide the pilot below a 250-foot overcast into a position whence a contact landing straight ahead is practical. The one great advantage of this system is that no equipment need be installed in the aircraft in addition to the Left-Right Radio Compass or the Automatic Radio Compass already available. It is not a true landing system because the flight path of the aircraft cannot be controlled accurately enough to bring the aircraft onto a runway.

The foregoing installations are being currently superseded by the complete "Localizer-Glidepath" installations, which are described in detail under Section III. The earlier equipments are also covered herein, because the Modified A-1 system is still in operation and use, and because the Runway Localizer installation is a component part of the complete system. The Localizer-Glidepath employs the ultra high frequency fan markers, the runway localizer and the glidepath transmitters. The position of the aircraft is shown with respect to the runway approach line by the Blue/Yellow indications of the pilot's localizer indicator (I-101-C) and with respect to the glide path approach by the horizontal needle of the same indicator. This glidepath is projected, from a point a short distance from the approach end of the runway to be used, at an angle 2° to 2.5° above the horizontal.

The British Standard Beam Approach System, also known as the Lorenz, renders let downs to minimum ceilings of 100-foot practical. A detailed discussion of the flight procedures in use with the British Standard Beam Approach System has been published for the information of the Service in T.O. No. 30-100E-1.

SECTION I
THE MODIFIED A-1 SYSTEM

1. GENERAL DESCRIPTION.

a. The Modified A-1 System is essentially the old Air Corps system of instrument landing, modified with respect to the distance from the landing field at which the component parts of the ground equipment are operated. Two definite check points are provided on the prolongation of the runway to be used for landing. Descending on this line to predetermined altitudes over each check point, the aircraft is lined up to permit a straight-in contact landing. The indications of the sensitive altimeter are used to control the altitude at which the check points are passed. Because the flight path of the aircraft cannot be flown precisely, the aircraft must not descend below 200 feet above the level of the airport on instruments.

b. The ground installations for this system consist of a pair of compass locator transmitters, each equipped with a VHF marker beacon transmitter mounted on trucks to provide mobility. Power for operation of the units is provided by generators mounted in the trucks, thus each station is a completely self contained unit. The stations differ only in frequency and tone modulation of the signals emitted by the compass locator transmitters, and in the keying of the marker beacons signals. Thus no doubt of the identity of the station, tuned in and received, can exist.

2. MIDDLE MARKER STATION.

This unit is placed 4500 feet from the down-wind end and on the prolongation of the runway to be used for landing. The compass locator transmitter emits a signal, tone modulated at 700 cycles, on 201 kilocycles. The VHF marker beacon signal on 75 megacycles is keyed to transmit six dashes per second in a vertical fan-shaped pattern.

NOTE

In previous publications this station was designated as the "Inner Station." To avoid confusion with the boundary marker of the localizer system, and to standardize, it is now designated the "Middle Marker."

3. OUTER MARKER STATION.

This unit is placed 3.5 miles from the Middle Marker Station in a straight line with the runway, and Middle Marker Station. The compass locator transmitter emits its signal, tone modulated at 1100 cycles, on 219 kilocycles. The VHF marker beacon signal on 75 megacycles is keyed to transmit two dashes per second in a vertical fan-shaped pattern.

4. AIRCRAFT EQUIPMENT.

This aircraft must be equipped with the Automatic Radio Compass (although the older types of Left-Right indicating radio compasses can also be used for training purposes) and the associated marker beacon receiver. No additional radio equipment is required in the aircraft. It should be noted that the earlier models of marker beacon receivers obtain their power supply from the radio compass, thus, whenever the radio compass is operating the marker beacon receiver is also functioning. Later models of marker beacon receivers obtain their power directly from the aircraft power supply and operate independent of the radio compass. Present type marker beacon receivers provide *only visual* indications. The reception of the keying of the 75 megacycle signals depends upon the type of marker beacon transmitter over which the aircraft is flying. When flying over radio transmitter BC-302, the transmitter used originally with the A-1 system, the light on the instrument panel remains continuously on while the aircraft is in the field of the transmitter. However, when flying over marker beacon transmitters emitting keyed signals, the light flashes in unison with the keying of the signal.

5. AUTOMATIC RADIO COMPASS OPERATION.

a. Radio control box switch to "COMP." (See Figure 1.)

b. Push "Control" switch to operate green light.

c. "Band Switch" to 200-410.

d. Turn "Tuning" crank to 201 or 219 kilocycles and listen for 700 or 1100 cycle tone as the case may be. Rotate crank back and forth for maximum deflection of tuning meter for exact dial setting.

e. Adjust "Audio" for satisfactory head-set level.

NOTE

If desired the radio compass can be operated independently from the other radio equipment and the interphone circuits, by plugging the pilot's head set directly into the jack on the radio control box.

f. The Pilot's Indicator, of the Automatic Radio Compass, (see Figure 2) will indicate "ZERO" whenever the aircraft is headed directly toward the radio transmitting station. If the station is to one side or the

Figure 1—Automatic Radio Compass Control Box.

other the pointer will indicate the number of degrees in relation to the heading of the aircraft. A reading of 33 (330 degrees) indicates the station is 30 degrees to the left of the heading of the aircraft. A correction to the left is necessary (provided drift due to wind is not considered).

Figure 2—Pilot's Bearing Indicator.

6. THE COMPLETE FLIGHT PROCEDURE.

a. (See Figure 3.) The pilot, maintaining flight altitude of the aircraft, will tune the Automatic Radio Compass to 201 kilocycles and listen for the 700 cycle tone of the Middle Marker Station. Before the Middle Marker Station is reached he will call for the altimeter setting and for an approach clearance. After setting the sensitive altimeter, which will then read the surveyed elevation of the airport (plus or minus instrument errors) upon landing, and after he has been cleared for approach, he will pass over the Middle Marker Station. The marker beacon light will flash and the pointer of the Automatic Radio Compass will swing 180 degrees as the aircraft crosses the station.

b. The pilot must immediately tune the radio compass to 219 kilocycles and turn the aircraft until the pointer of the Pilot's Indicator again reads "ZERO". The aircraft will not be homing on the Outer Marker Station. The accuracy at which the remainder of the problem is flown will largely depend upon the rapid tuning to the Outer Marker Station. The pilot must beware of turn tightening which may result if he tries to regain time lost in tuning to the Outer Marker Station.

c. While homing on the Outer Station the directional gyro may now be set on 180 degrees, and a descent to an altitude of 1200 feet above the level of the airport is made.

d. When the Outer Marker Station is crossed as indicated by the 180 degree swing of the Automatic Radio Compass indicator pointer, and by the flashing of the marker beacon light, the gyro heading of the aircraft is maintained for 30 seconds. Then a procedure turn is made by a 45-degree change of heading, either to the right or left depending upon the terrain, held for 40 to 45 seconds followed by a standard rate turn to regain the inbound heading. At the completion of this turn the aircraft will be flying toward the station on the inbound heading. The directional gyro and the pointer of the Automatic Radio Compass indicator should both read "ZERO". If this is not the case, the pointer of the Automatic Radio Compass must be flown toward the Outer Marker Station.

e. After the procedure turn has been completed the landing gear is lowered, flaps are extended if required for the type of aircraft being flown, and power is adjusted for let down as indicated in the applicable operating instructions. A descent is made to 800-900 feet and the Outer Marker Station crossed at that altitude.

f. Immediately upon crossing the Outer Marker Station, the radio compass is again tuned to 201 kilocycles (the Middle Marker Station) and altitude is lost at a constant rate of 400 to 500 feet per minute, holding the air speed well above stalling. The directional gyro is readjusted to zero if necessary. The Middle Marker Station must be crossed at an altitude of between 200 and 250 feet above the level of the airport.

g. After the Middle Marker Station is passed the gyro heading of zero degrees and the rate of descent is held until 200 feet is reached. The airport should now be visible, and the aircraft should be in position to land contact straight ahead. The Gyro Heading, not the indications of the Automatic Radio Compass, must be flown after the Middle Marker Station is passed. If the Middle Marker Station is reached at too high an alti-

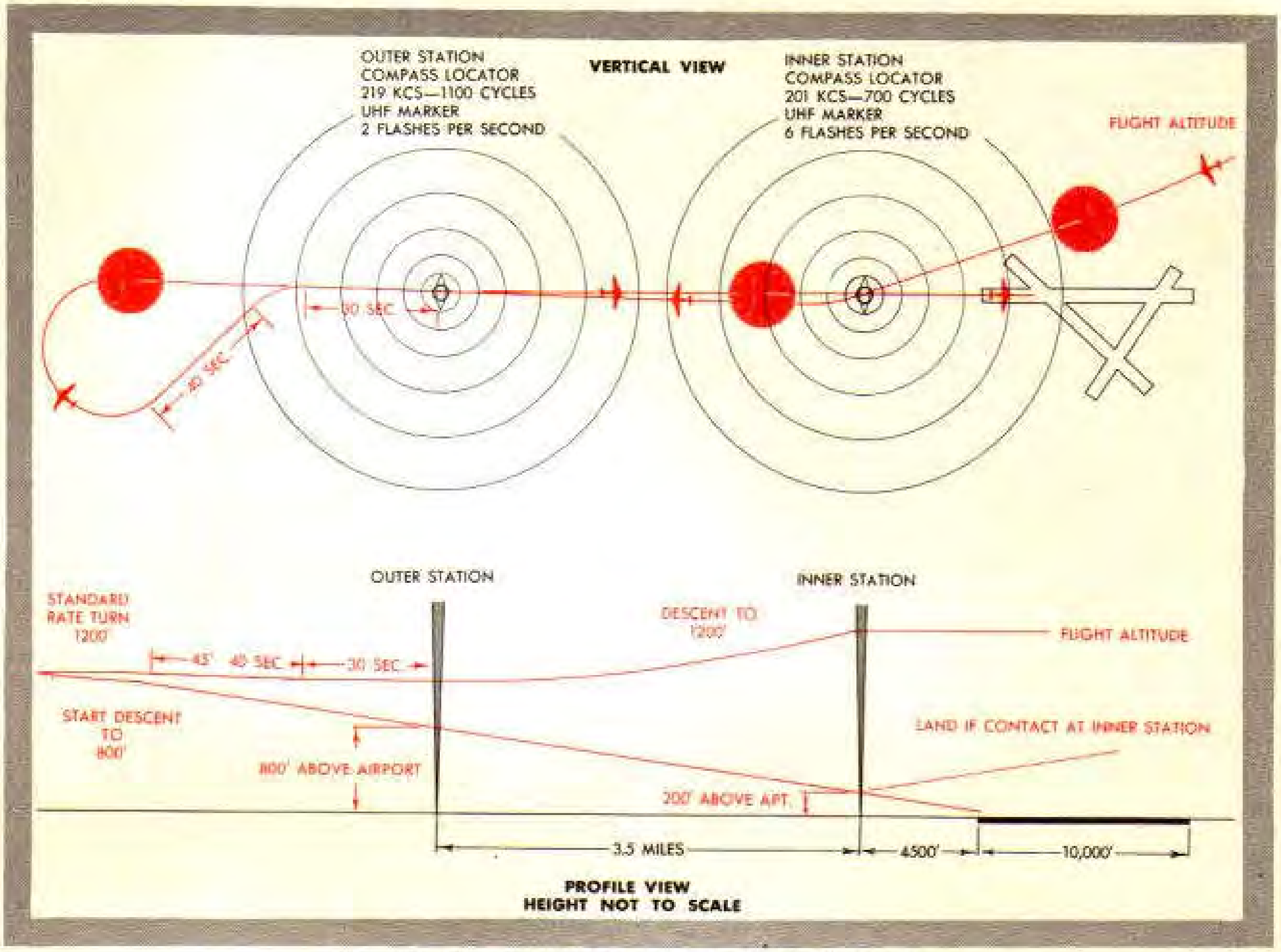


Figure 3—Complete Flight Procedure—Modified A-1 System.

tude, an immediate climb must be made and the entire procedure repeated. A new landing clearance must be obtained from the control tower in this case.

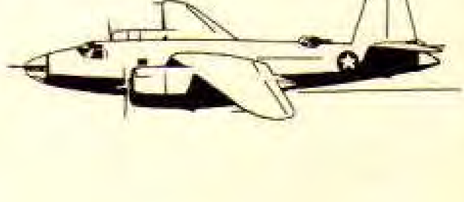
7. ADDITIONAL NOTES.

a. No effort can be made in this Technical Order to specify precise operating instructions for the types of aircraft which may be flown on the Modified A-1 or Localizer Landing Systems. The specific conditions of flaps, propeller pitch, manifold pressure, etc., necessarily differ with the various types of aircraft. It is important that the attitude of the aircraft and the rate of descent be constant throughout the final let down. This condition should be established before the Outer Marker is crossed.

b. With some aircraft it may be desirable to make the turns at one-half standard rate. In this case the off-course heading of the procedure turn must be held for double the normal length of time before the one-half standard rate is started.

c. If, on the initial approach, the Middle Marker Station is reached at a heading close to that to be flown toward the Outer Marker Station, the problem becomes much simpler because no excessive turning will be necessary when tuned to the Outer Marker Station. The initial approach can, with the Automatic Radio Compass, be planned so as to reach the Middle Marker Station on an "easy approach heading."

d. The automatic feature of the radio compass becomes inoperative if the phasing antenna is lost due to icing or other causes. This may be checked by switching to "ANT" and checking the aural signal. If no signal is heard, the loss of the phasing antenna is indicated.



SECTION II
THE RUNWAY LOCALIZER SYSTEM

1. GENERAL DESCRIPTION.

In this system the compass locator stations of the Modified A-1 system are replaced by the Runway Localizer transmitter. The pilot is provided with an accurate indication of the alignment of the flight path of the aircraft with the runway to be used for landing. An additional VHF marker beacon transmitter is installed at the down-wind end of the runway to provide a final "stand by for landing" indication. The installation, see figure 8, then consists of the Localizer, the Boundary Marker, the Middle Marker, (1 mile from the end of the runway) and the Outer Marker (3½ miles from the inner marker). The Middle and the Outer Markers are keyed as in the Modified A-1 System with 6 and 2 flashes per second respectively, while the final clearance marker is unkeyed. The Radio Compass Locator stations, while available in a few of the early installations are not used in the system. However, the Radio Compass Receiving equipment must *not* be switched off, because this action will render the marker beacon receiver inoperative. This is true except in the case of aircraft equipped with the independently operated marker beacon receiver.

2. LOCALIZER.

a. The transmitting equipment is a mobile, self-contained unit mounted in a truck. Approximately ½ hour is required to place the transmitter in operation, if the equipment is not in place. The equipment is operated at a position approximately 1000 feet from the upwind end of the runway

b. The transmitter is crystal controlled to one of six available frequencies between 108.3 and 110.3 megacycles. The signal is modulated at 90 and at 150 cycles; the two fields being considered as blue and yellow colored sectors as a matter of convenience. The pattern produced is similar to a two on-course radio range, and is flown as such by visual indication. The blue sector is transmitted to the right of the beam, right with respect to the inbound aircraft. The yellow sector then is to the left of the inbound aircraft. The normal range of the beam is in excess of 25 miles at an altitude of 2500 feet; this range increases with altitude.

3. AIRCRAFT RECEIVER.

a. The receiver installed in the aircraft for use with the Runway Localizer Transmitter is remotely controlled by a small control box installed near the pilot's seat. (See Figure 4.) The six available frequencies, at one of which the Localizer will be operating, are indicated by the letters U, V, W, X, Y, Z inscribed on the control box. To operate the equipment the main

Figure 4—Runway Localizer Control Box.

switch is turned "ON" and the selector switch turned to the desired frequency. The set is now operative and the Pilot's Localizer Indicator (Figure 5) installed on the instrument panel, will indicate the color area of the transmitter in which the aircraft is then flying by the deflection of the indicator needle. That is, if the aircraft is flying well off-course in the blue area of the transmitter, the needle will indicate a full scale deflection in the blue area of the indicator. The direction toward the beam will not be indicated by this needle deflection. The following should be noted with reference to the needle action.

Figure 5—Pilot's Localizer Indicator.

b. When the aircraft is flying on the front beam of the Localizer, headed toward the runway, the action of the needle is directional, that is, when the needle points right, the aircraft must be turned right to regain the center of the Localizer beam. This needle action also applies when flying on the back beam and the aircraft is headed away from the station transmitter.

c. When the aircraft is flying on the Localizer in the reciprocal direction, that is, headed away from the runway when on the front beam, the sensing of the needle will appear reversed. A turn in the direction indicated by the needle will take the aircraft further away from the beam in this case.

d. In either case the needle will correctly be deflected in the color area of the Localizer installation.

e. The blue area is on the right of the aircraft when the aircraft is headed *toward the runway on the front beam.* (See Figure 6.) Since the aircraft flying off-course in the blue area will be to the right of the beam a correction of heading toward the left is necessary to regain the on-course. The indicator shows this correction, and the needle can be followed.

f. The blue area is on the left of the aircraft when the aircraft is headed *away from the runway on the front beam.* Since the aircraft flying off-course in the blue area will now be to the left of the beam, a correction of heading toward the right is necessary to regain the on-course. But the indicator now shows blue and the needle will be pointing toward the left, away from the beam. The relative location of the aircraft to the beam will be correctly indicated, but the sensing will be reversed.

g. The needle is very sensitive and will give a full scale deflection when the aircraft is 3.5 degrees to either side of the on-course. This high degree of sensitivity permits the use of the indicator for accurate runway localization. If the pointer is no farther off-center than one-quarter scale, the aircraft will land on the runway. Five thousand feet from the localizer transmitter a one-third scale deflection indicates a distance of 75 feet from the center of the on-course. It should be noted that for zero/zero landings at least 7000 feet of runway must be available.

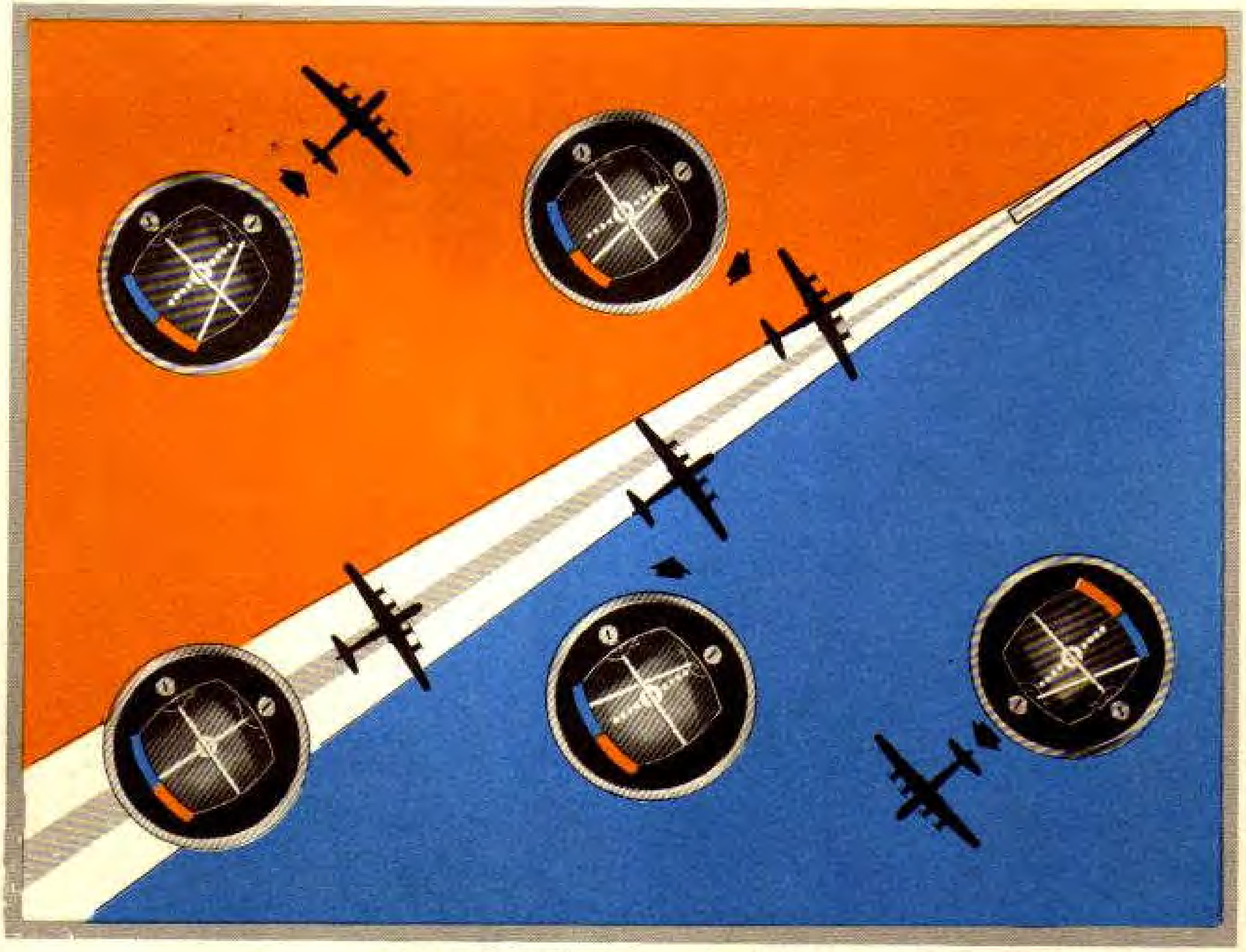


Figure 6—Localizer Indicator Needle Action.

4. THE RUNWAY LOCALIZER PROCEDURE.

a. (See Figure 8.) Permanent installations will be at airports also equipped with radio range stations. In these cases, the aircraft will be flown to the radio range station as in standard airways flying, and the pilot will call for the altimeter setting and his approach clearance. He will switch "ON" the localizer receiver. After having set the altimeter, and being cleared to land, the pilot will set course from the cone of the radio range to the point of intersection of the known radio range leg with the beam of the runway localizer.

b. Thereafter, the system varies from the Modified A-1 system only in that no further reference to the Automatic Radio Compass is made, the Localizer furnishing on-course indications. Flying the leg of the radio range, the pilot will observe the needle of the Localizer indicator. The needle will move from its original full scale deflection toward center as the aircraft approaches the Localizer beam. The pilot now turns the aircraft to intercept the Localizer beam, assuming the outbound heading toward the procedure turn. On the outbound heading the needle will point to the correct color areas, but sensing will appear to be reversed as previously explained. Following the pointer will not return the aircraft to the on-course. Corrections may be made by reference to the directional gyro until the aircraft is on-course and flying in line with and away from the runway. This heading will bring the aircraft over the "Outer Marker." The pilot will be able to check the operation of the "Middle" and "Outer" Marker as well as the operation of the marker beacon receiver as the aircraft passes over these stations. It is to be noted that the signal of the boundary marker may or may not cause the marker beacon indicator light to flash. This marker operates on limited power and consequently will not be received at the initial approach altitude in most cases. If the "Middle" marker is not received the pilot should check the main switch of the Radio Compass. If the marker beacon receiver is operating and either the "Middle" or "Outer" markers are not received the pilot should not continue the procedure until the tower has been requested to check the operation of the equipment.

c. The heading at which the localizer indicator needle remains within one-quarter scale of center should be established. Descent to 1200 feet above the level of the airport is made between the Middle Marker Station and the "Outer Marker," if this altitude was not reached between the radio range and the Middle Marker Station. When the Outer Marker Station Marker Beacon indication is received, course is maintained for 60 seconds. Then the procedure turn is made.

d. After the procedure turn has been completed the landing gear is lowered, flaps are extended if required for the type of aircraft being flown, and power is adjusted for let down as indicated in the applicable operating instructions. A descent is made to 800 feet and the Outer Marker Station crossed at that altitude.

e. When the procedure turn is completed, the needle indications of the localizer indicator become directional. The on-course can now be precisely flown by following the localizer needle. It will be necessary to exercise caution not to overcorrect when the course becomes more difficult to follow as the Middle Marker Station and the runway are approached. All major corrections to course *must* be made before the "Middle Marker" is reached.

f. The altitudes over the "Outer" and "Middle" marker must be 800 to 900 feet and 200 to 250 respectively. The Boundary or Final Clearance Marker, which will cause the Marker Beacon Lamp to light, indicating the safe landing area is just ahead is crossed at 50 feet. If an actual blind landing is necessary, a normal descent is continued all the way to ground contact.

g. It will be found that after a few practice flights drift can be easily established by flying the needle within the center circle of the indicator and that small brackets will be adequate to hold the aircraft on the beam.

Figure 7—Aircraft Installation.

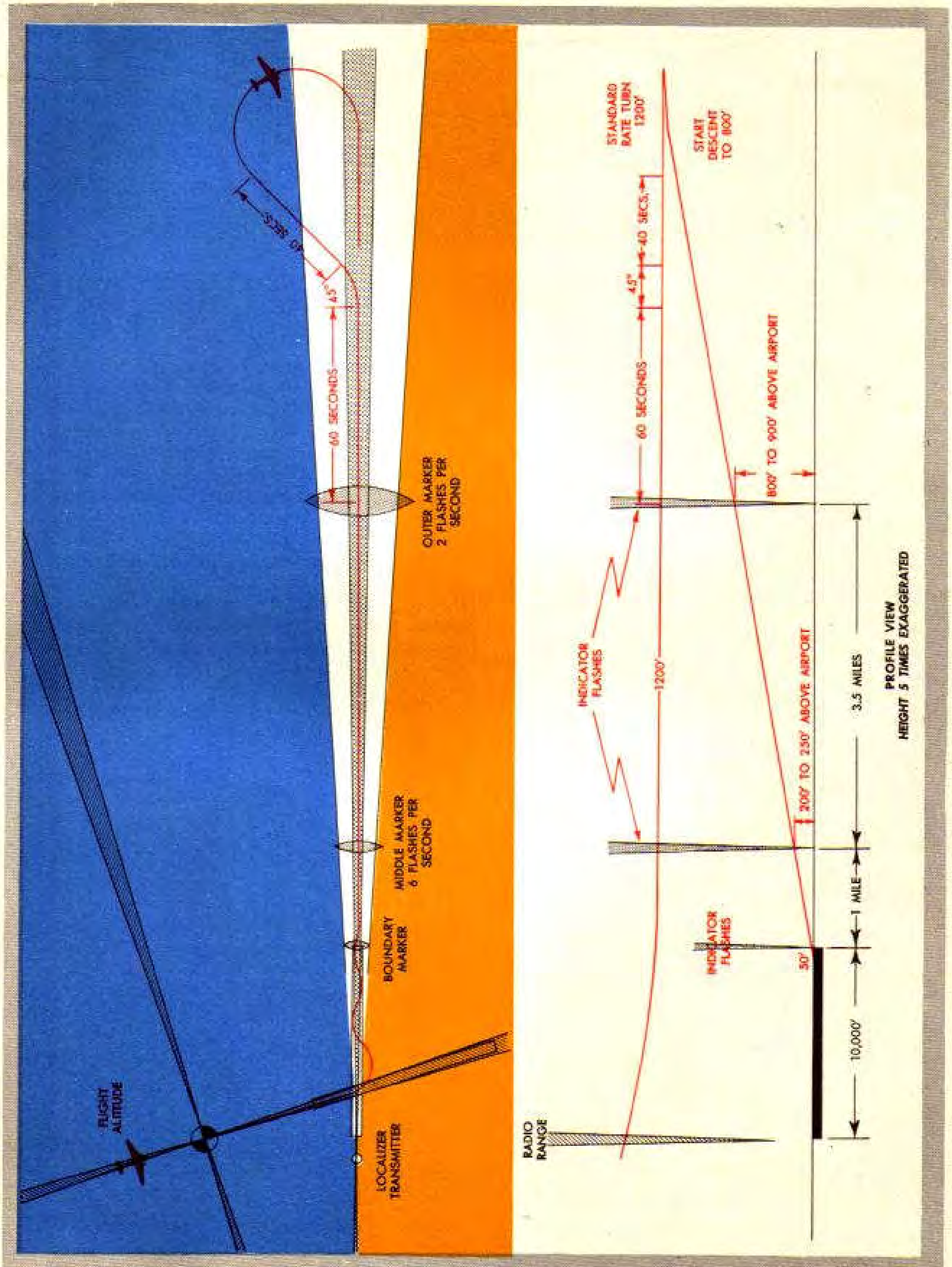


Figure 8—Complete Flight Procedure; Runway Localizer System

SECTION III
ARMY AIR FORCES INSTRUMENT APPROACH SYSTEM

1. GENERAL DESCRIPTION.

a. The present standard equipment (SCS-51) is being installed at Army Air Forces Fields and Bases. This equipment is self contained and is mounted in a truck and a trailer. Air transportable equipment is also being designed and fixed installations are being made by the C.A.A. at various airports throughout the United States. The complete installation consists of:

(1) The Runway Localizer Transmitter.

(2) The Glide Path Transmitter.

(3) The Outer Marker Station Transmitter.

(4) The Middle Marker Station Transmitter.

(5) The Boundary Marker Transmitter.

b. The Army Air Forces Instrument Approach System provides the pilot with a straight line glide path, flown by noting the horizontal needle of the runway localizer indicator. It also provides a visual indication of the lateral alignment of the flight path of the aircraft with the runway. The three markers, when used in connection with the sensitive altimeter, provide a further check. After homing to the airbase by any navigation aid available (that is radio compass or radio range) the aircraft will be flown to intersect the runway localizer path. After reaching the localizer path the flight is conducted by reference to the localizer indications. The A.A.F. Marker Beacon Indicator flashes when the aircraft passes over any of one of the three marker beacons, and on the final approach when the Outer, Middle and Boundary Markers are passed. The Automatic Radio Compass must therefore not be switched off, because this action would render the Marker Beacon Receiver inoperative, unless the aircraft is equipped with the independently operated Marker Beacon Receiver. On the final approach the aircraft being at the desired altitude is flown on the Localizer until the glide path is intersected. The pilot then establishes a uniform rate of descent by reference to the combined indication of the localizer and the glide path.

2. LOCALIZER.

a. The transmitting equipment is a mobile, self contained unit mounted in a truck. Approximately ½ hour is required to place the transmitter in operation, if the equipment is not in place. The equipment is operated at a position approximately 1000 feet from the upwind end of the runway.

b. The transmitter is crystal controlled to one of six available frequencies between 108.3 and 110.3 megacycles. The signal is modulated at 90 and at 150 cycles; the two fields being considered as blue and yellow colored sectors as a matter of convenience. The pattern produced is similar to a two on-course radio range, and is flown as such by visual indication. The blue sector is transmitted to the right of the beam, right with respect to the inbound aircraft. The yellow sector then is to the left of the inbound aircraft. The normal range of the beam is in excess of 25 miles at an altitude of 2500 feet; this range increases with altitude.

3. THE GLIDE PATH.

a. The transmitting equipment is a self-contained unit mounted on a small trailer of a size which makes it possible to load it into large cargo type aircraft such as a C-47. Approximately ½ hour is required to place the transmitter in operation, if the equipment is not in place. The equipment is operated at a position approximately 1000 feet down-wind from the approach end of the runway and 500 feet to one side. Simple adjustments make the equipment operative at either side of the runway. (See Figure 9.)

b. The transmitter is crystal controlled to a frequency of approximately 335 mc. The pattern produced

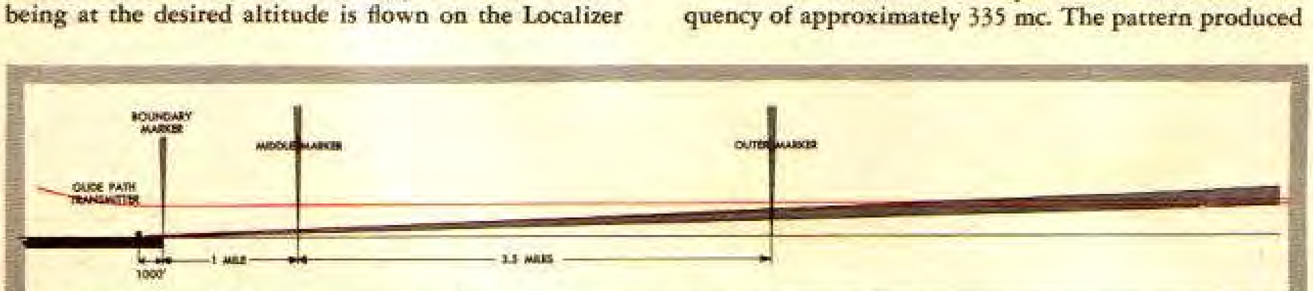


Figure 9—Scale Profile of Glide Path Installation.

is similar to the localizer except the "on-course" lies in a nearly horizontal plane. The glide path makes an angle of approximately 2½ degrees with the horizontal, however, this angle is adjustable over a small range, for use with various types of aircraft.

c. At a vertical angle of 17½ degrees a false course exists but is of reversed sensing and at 22½ degrees a false course of true sensing occurs. It will be realized, however, that the false courses will be unflyable in normal operation because of the high angle, since they would give a rate of descent of 5000 feet per minute or greater.

4. THE MARKER STATIONS.

a. The Outer Marker.—This unit is placed 3.5 miles from the Middle Marker Station. It consists of an ultra high frequency transmitter emitting two dashes per second in a vertical fan shaped pattern.

b. The Middle Marker.—This station is placed 1 mile from the end of the runway, and transmits a signal keyed to six dots per second in an identical pattern.

c. The Boundary Marker.—This station also operates on 75 megacycles but at a lower power output. The signal emitted is unkeyed and, it should be noted, the signal may or may not be received when passing over this station at the initial approach altitude.

5. AIRCRAFT RECEIVER.

a. The receiver installed in the aircraft for use with the glide path transmitter is remotely controlled, either by the localizer control box or by a separate control box installed near the localizer control box in the pilot's compartment. To operate the equipment the main switch is turned "ON". Since the receiver is fixed tuned, no tuning adjustments are necessary. The pilot's combined localizer—glide path indicator will indicate the position of the aircraft with respect to the glide path by the deflection of the horizontal needle.

b. When the aircraft is above the desired glide path the indicator needle is deflected downward and if the aircraft is below the desired path the needle is deflected upward. That is, the needle points in the direction the aircraft must be flown to approach the glide path. *This is true regardless of the heading of the aircraft.* (See Figure 10.)

c. The needle is very sensitive and will give a full scale deflection when the aircraft is 0.3 degrees above the glide path or 0.5 degrees below the glide path. This requires that the aircraft be aligned quite accurately on the glide path at some distance from the field. Only very minor corrections are allowable near the field.

d. The horizontal needle will be normally set to give a fly up indication when no signal is being received. This is done to reassure the pilot; thus he receives an "on-course" indication only when the equipment is working properly and the aircraft is on the desired glide path.

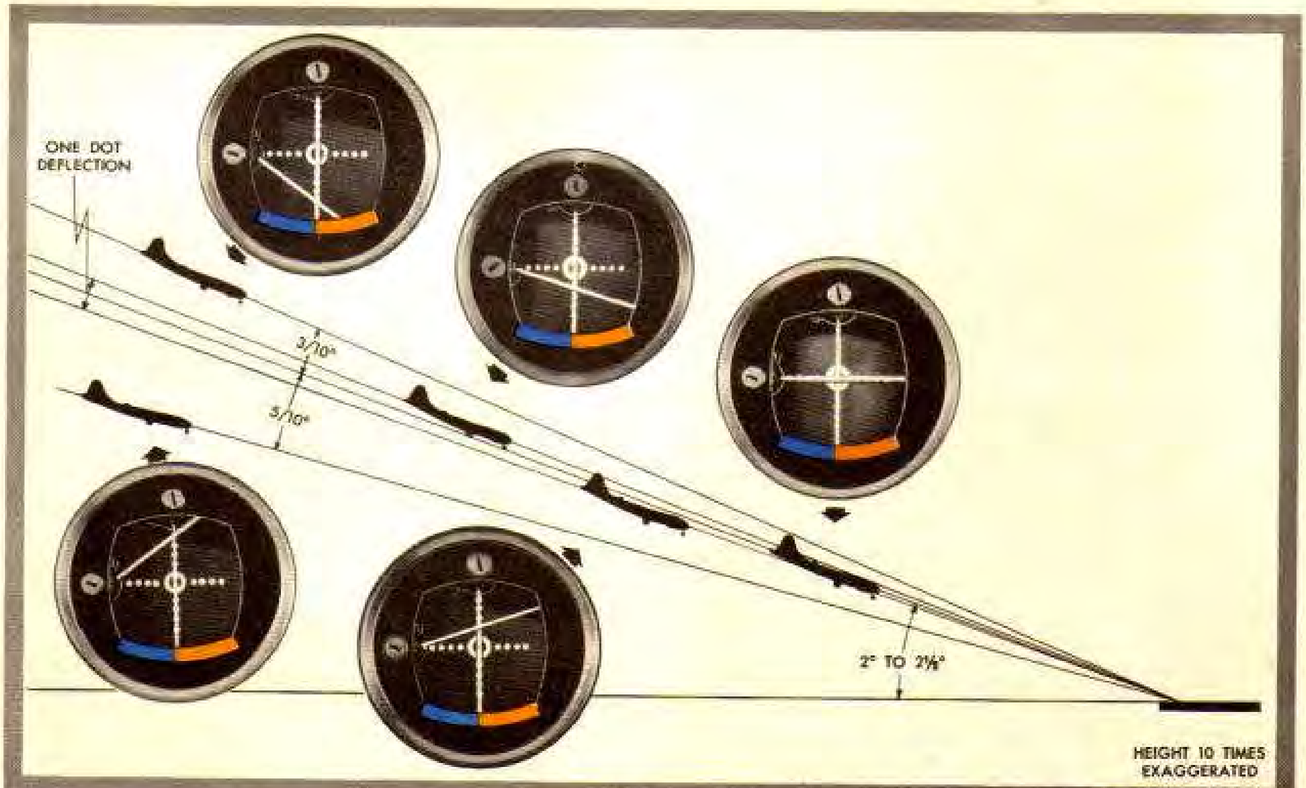


Figure 10—Glide Path Indicator Needle Action.

6. THE RUNWAY LOCALIZER AND GLIDE PATH PROCEDURE.

a. All permanent installations in the United States of the combined localizer and glide path systems will be at airfields also equipped with a radio range station. In these cases, the aircraft will be flown to the radio range station as in standard airways flying, and the pilot, while maintaining flight altitude, will contact the control tower for the altimeter setting and his approach clearance. (Before the range station is reached, the localizer and glide path units in the airplane will be turned *ON* by the single switch located on the localizer control box.) When the units are warmed up the desired localizer frequency is selected by placing the selector switch opposite the frequency number of the airport in question. (See Figure 4.)

b. Descend to 1200 feet over the range station and follow the particular beam leg which intersects the localizer path. (See Figure 11.) Bracket the localizer beam on the outbound heading. If the localizer beam is quickly bracketed the middle and outer markers will be passed on the outbound heading.

c. After the outer marker has been received the course is maintained for a maximum of 60 seconds, then a procedure turn is made either to the left or right depending upon the terrain.

d. After the procedure turn has been completed the landing gear is lowered, flaps are extended if required for the type of aircraft being flown, and power is adjusted for let down as indicated in the applicable operating instructions. As the procedure turn is being completed inbound indications on the glide path may be noted. A descent is made to 800-900 feet along the glide path and the Outer Marker is crossed at that altitude.

e. When the procedure turn has been completed, the needle indications of the localizer and glide path become directional and elevational respectively. The on-course can now be precisely flown by following the localizer in conjunction with the glide path. It will be necessary to exercise caution not to overcorrect when the course becomes narrower as the aircraft approaches the field.

f. The altitudes over the "Outer" and "Middle" Markers must be 800-900 and 200-250. This will be relatively simple if the glide path is followed. If the aircraft is below the glide path at any point *fly straight* until such time as the on-course indication is again received. *Do not attempt an abrupt climb to intersect the beam again.* The Boundary Marker will cause the Marker Beacon Lamp to light indicating the safe landing area just ahead, and a normal descent continued all the way to ground contact.

g. In the event that a *blind landing* is to be made after passing the boundary marker at approximately 50 feet reduce power and continue until ground contact is made and immediately close the throttles.

(1) For nose wheel type aircraft, hold nose wheel off the runway until after initial shock. After the nose wheel is lowered, brake to a normal stop, holding a constant gyro setting and using the localizer as a reference. The localizer is so sensitive on the runway that a needle deflection will be noted if the aircraft is but a few feet off the center of the landing runway.

(2) If a conventionally geared aircraft, upon contact with the runway, the power should be cut and the control column pushed forward enough to prevent the aircraft leaving the runway. As the tail wheel is lowered, the plane must be kept aligned with the runway by brake, rudder, or throttles. The localizer needle is a definite location checker.

7. ITEMS TO KEEP IN MIND WHILE FLYING THE INSTRUMENT APPROACH SYSTEM.

a. Maintain flight altitude until in contact with the tower.

b. Know your landing base either by careful reference to an Army Air Forces Instrument Approach Procedures book or by personal acquaintance with same.

(1) Check heading of the landing runway.

(2) Obstructions to landing.

(3) Altitude of landing runway.

(4) Relation of the radio range legs to the localizer beam.

(5) Turn on your approach equipment well before reaching the radio range.

c. Outbound pattern.

(1) Determine your drift.

(2) Remember that flying the *outbound* heading, *fly away from the needle.*

(3) Cross the outer marker and fly from 45 seconds to one minute before beginning your procedure turn.

d. Inbound pattern.

(1) If the procedure turn is completed before any localizer needle indication is noticed fly as to intersect the localizer beam at 30°.

(2) As the procedure turn is completed, lower gear, and flaps if desired, adjust power setting for a uniform approach.

(3) *On the inbound heading fly into the needles.*

(4) *Large corrections are unnecessary.* Once on the beam, taking the drift into consideration, any turn over 10° either way from the landing heading will usually result in an unsuccessful approach.

(5) *Do not overcorrect, give the plane time to react to a correction.*

(6) Do not make large corrections near the ground even though the *needle shows a major deflection. From the middle marker on down the localizer needle can be deflected as far off as one dot to the left or right and the aircraft will land on the runway.*

(7) *VERY IMPORTANT!!!* WATCH YOUR *AIRSPEED!!!*

(8) *Do not be too proud to go around.*

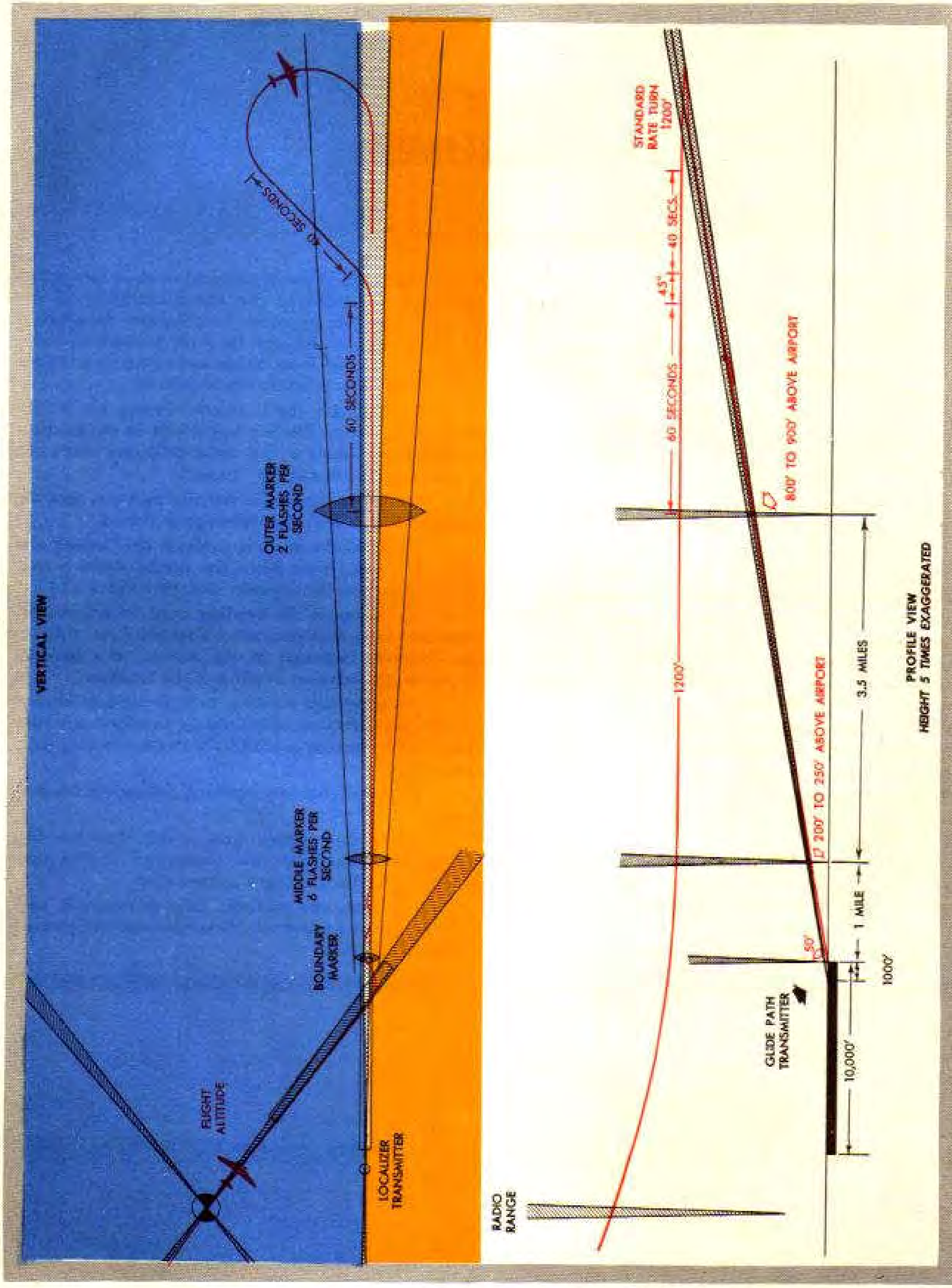


Figure 11—Complete Flight Procedure; A.A.F. Instrument Approach System

SECTION IV
PROCEDURES

1. ORIENTATION.

a. Normally the pilot will home on a radio range or a radio homing station. He will fly to intercept the localizer—glide path course from this known position. It will not be necessary to work an orientation problem on the localizer.

b. Circumstances may arise when the homing station cannot be utilized because it is inoperative or due to mechanical failure of some of the airborne radio equipment. If the localizer-glide path receiver is still operative an orientation problem can be flown and a let-down completed on this installation.

c. The frequency channel on which the localizer is operating will be known to the pilot. He will also know the position of the equipment relative to the runway, and the inbound magnetic bearings of the front and back beams. When the equipment is switched "ON" the indicator needle will be deflected to either side thus showing the position of the aircraft to be in the blue or in the yellow sector.

d. The aircraft must then be flown on a heading which will intercept the localizer beam. This heading will be the inbound bearing of the front beam, plus 90° if the aircraft is in the *yellow* sector; or, the inbound bearing minus 90° if the aircraft is in the *blue* sector. (See Figure 12.)

e. Proceeding on the heading thus determined the beam of the localizer is intercepted. The pilot must now establish which of the beams, either front or back beam, he has intercepted.

f. The front or back beams can be identified by timing the width of the intercepted beam at two points sufficiently separated so that the convergence of the beams will become apparent. To eliminate the effect of the wind, the crossing must be made at the same heading each time, thus insuring the same ground speed for each timing. The procedure is as follows:

(1) Maintain the intercept heading (± 90° to the beam bearing). The vertical needle of the localizer indicator will show a full scale deflection until the aircraft begins to cross the "beam".

(2) When the needle starts to indicate, note the time at which a four dot deflection is shown.

(3) Hold the heading through the "beam" and note the elapsed time when the needle shows a four dot deflection on the opposite side. (See figure 12.)

(4) Maintain the heading until 30 seconds beyond the beam, then commence a standard rate turn, in the direction indicated by the needle, to a heading ± 30° of the inbound heading of the localizer.

(5) Hold this heading until 30 seconds beyond a full scale deflection, then make a standard rate turn back to the heading at which the beam was originally crossed.

(6) Hold this new heading, timing the beam as before.

(7) If this elapsed time is less than the first timing, the front beam was intercepted. If this time is longer, the back beam was intercepted.

(8) From the position thus determined, turn to fly on-course toward the marker stations and proceed with the let-down.

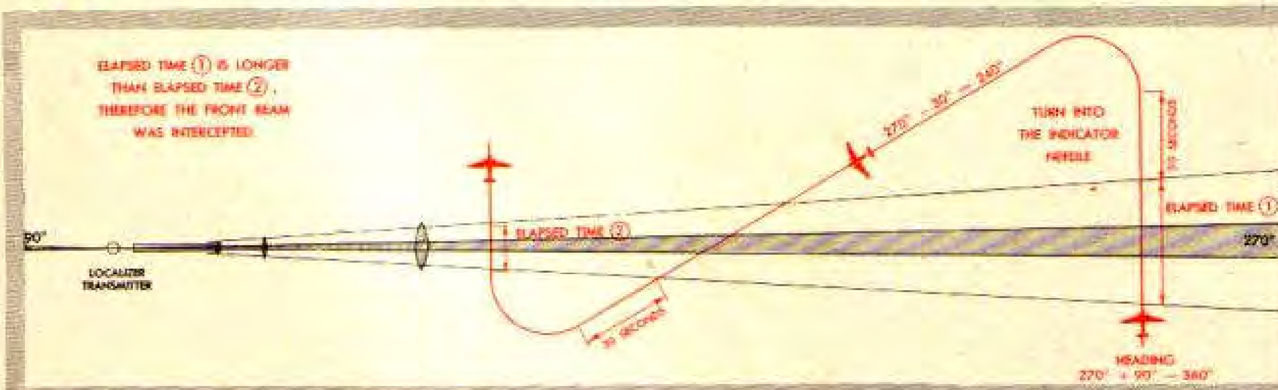


Figure 12—Timing the Beam.