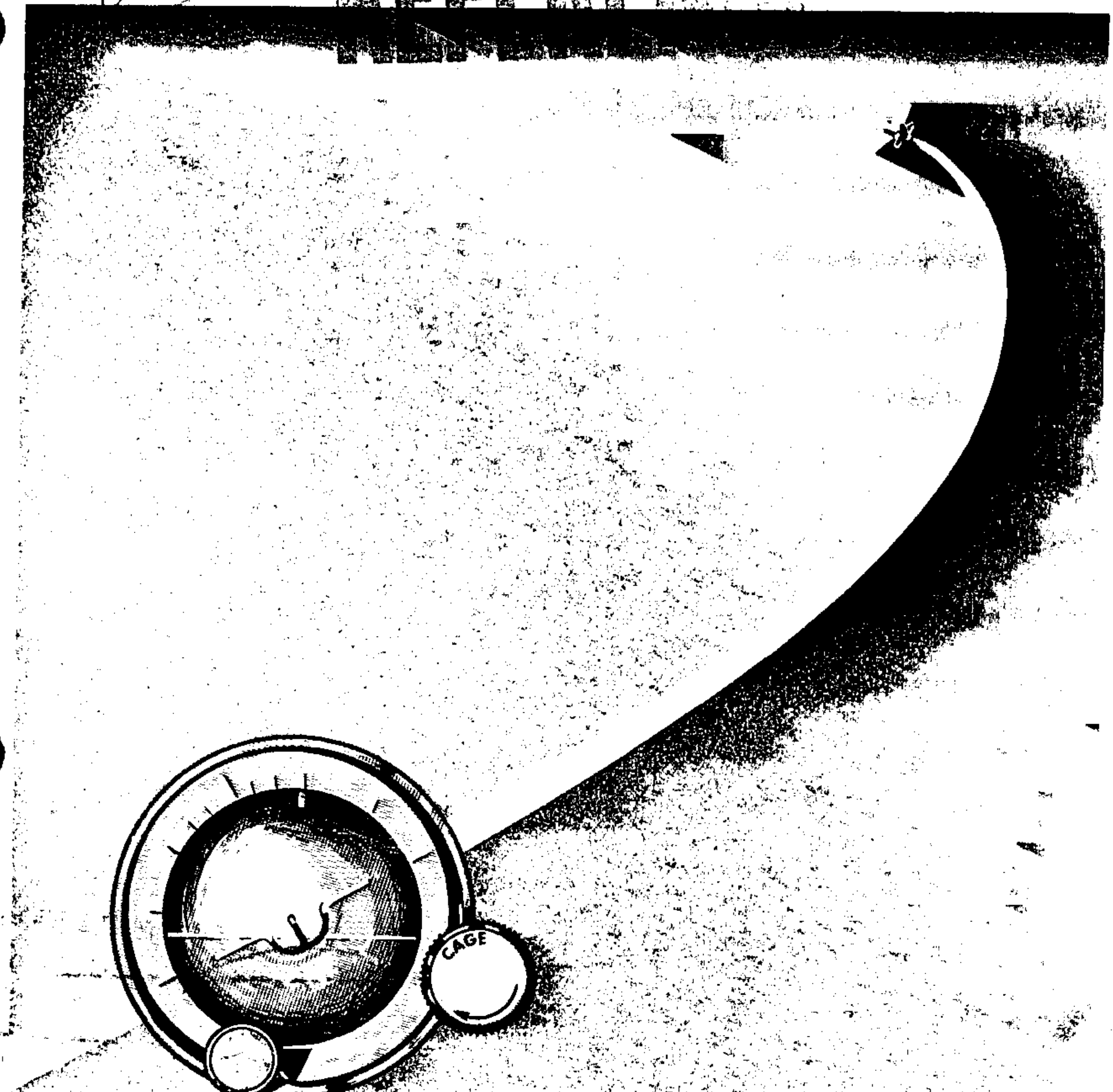
AC 61-27B



INSTRUMENT FLYING HANDBOOK

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

REFERENCE

INSTRUMENT FLYING HANDBOOK

Revised 1971

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

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FOREWORD

General Aviation in the United States has grown tremendously during the past decade. The aircraft industry has designed aircraft to satisfy the requirements of business firms, professional men, sportsmen, crop dusters, flight training schools, and others. Our aviation community is thus expanding to include an ever-broadening spectrum of the American public.

The Federal Aviation Administration is vitally concerned that this huge air travel potential be exploited in a safe and orderly manner. To this end, development of sound training programs and materials receive high priority among the many activities of the FAA. Since a wide variety of general aviation aircraft possess instrument flight capability—a key factor in achieving greater aircraft utilization—more and more pilots are therefore preparing themselves to "fly the weather."

The *Instrument Flying Handbook* has been developed in response to this increased flight activity and to the continuing requests from individuals and training organizations for an FAA handbook which is oriented to civilian instrument flying. Together with other flight training materials, the handbook emphasizes the concept that an informed pilot is a safe pilot. In this respect, the handbook supports the primary objective of the Federal Aviation Administration—safety in flight.

This handbook, together with *Aviation Weather,* (AC 00–6) (or an equivalent textbook on meteorology), will provide the flight student with the basic information needed to acquire an FAA instrument rating. Like any basic text, this one should be supplemented by technical periodicals, textbooks, and training aids, depending upon individual training needs, interests, and objectives. The book is designed for the reader who holds at least a private pilot's certificate and who is knowledgeable in all of the areas discussed in the *Pilot's Handbook of Aeronautical Knowledge* (AC 61–23A).

The reader must be aware that regulations, air traffic control procedures, charts, and certain other materials referred to in this handbook are subject to change and amendment. Any question regarding currency of these items should be resolved by checking pertinent source materials or the appropriate FAA office.

The *Instrument Flying Handbook,* issued as Advisory Circular 61–27B, was prepared in the Flight Standards Service of the Federal Aviation Administration. Many valuable contributions were provided by other organizations in FAA. Acknowledgement is made to the numerous firms whose equipment or products are illustrated in this publication.

Comments regarding this publication should be directed to the Department of Transportation, Federal Aviation Administration, Flight Standards Technical Division, P.O. Box 25082, Oklahoma City, Okla. 73125.

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I. TRAINING CONSIDERATIONS

Why Get an Instrument Rating?

Not so long ago, flying by instruments was commonly thought of as a special-purpose skill of little value to the nonprofessional pilot. The private pilot flew for pleasure, usually within a few miles of the local airport. Cross-country flights were short by today's standards, and the pilot flew to his destination airport by visual reference to prominent landmarks. He had to rely on visual contact with the ground because no other means were available for getting him safely from one airport to another. This was "contact" flying; "blind" flying was to come.

With the evolution of blind flying instruments, the distinction between contact and instrument flying was sharply defined in the flight training curriculum. During contact flying the student pilot learned to control the airplane by responding to changes in what he saw, heard, and felt. It was common practice for the flight instructor to cover the instruments in the student's cockpit, thus forcing the beginner to get his "head out of the cockpit" and look for changes in aircraft attitude by references *outside* the cockpit.

Flying by reference to instruments in the early era was considered a "common student error." The pilot controlled airspeed and aircraft attitude by reference to the horizon, by listening for changes in engine RPM, by sensing the sound of the wind through the rigging. He identified a slip or a skid by change in wind impact on his face in open-cockpit trainers. He executed a steep turn by aligning reference points on the aircraft with the horizon and reacting to changes in seat pressure. Even in aircraft equipped with instruments necessary to execute these maneuvers without outside visual reference, the pilot was trained to use the flight instruments as secondary references, if at all. As a student of contact flying, he was taught *not* to use the flight instruments.

He learned to use flight instruments as the primary means of aircraft control *only* when, and if, he progressed to more advanced training. Ironically, in instrument training the student discovered that much of this training apparently contradicted what he had learned as a "contact" pilot. The "swivel neck" habits, necessary during visual flight to insure separation from other aircraft, became pointless under the hood during simulated instrument flight. Instead of reminders from the instructor to "Look around!" and "Clear the area!" he heard "Check your airspeed!" and "What does your altimeter tell you?" The seat-of-the-pants sensations, the "sight, sound, and feel" that were so essential to contact flying, had to be ignored by the instrument pilot as he learned to trust his visual sense alone, regardless of other conflicting sensations. Small wonder that "contact" and "instrument" flying were considered as separate and distinct skills.

To the average nonprofessional pilot, flying meant controlling an aircraft by visual reference to the ground. Blind flying? This was something else—meant for professional airline pilots, military pilots, pioneers, and a few unfortunates who tangled with the weather through carelessness or ignorance. The nonprofessional civilian pilot had neither the equipment to fly safely on instruments nor the need or interest to do so. With the advent of faster and safer aircraft, more reliable flight instruments and radio equipment, and more effective radio aids and ground services, the traditional distinction between visual and instrument flying has undergone corresponding changes.

In sharp contrast to earlier training concepts are the following two quotations from a current military pilot training manual:

> The art of instrument flying, long regarded as a skill apart from contact flying, is now considered the prime method of aircraft control, regardless of weather conditions.
>
> Any instrument flight, regardless of the aircraft used or route flown, is made up of basic maneuvers; the pilot executes these maneuvers by learning to control his flight path by reference to instruments.

High-speed military aircraft cannot be flown safely and effectively without instruments, and mission accomplishment demands all-weather pilot capability. Although this philosophy, basic to military aviation, is neither literally applicable nor desirable in all phases of civil aviation, it reflects important changes affecting civil instrument flight training.

Contact flying and flight by reference to instruments are not taught as distinct and separate skills in unrelated phases of training. Instrument flying is essentially *precision flying*, entirely apart from whether or not the pilot is flying under the hood, in the clouds, or in VFR conditions. As a student pilot, you are flying by reference to instruments when you maintain traffic altitude by reference to the altimeter, when you check the ball of your turn-and-slip indicator to confirm a slip or skid, or when you maintain a predetermined climbing speed by reference to the outside horizon and airspeed indicator.

In terms of precision flying, instrument training begins shortly after your first introduction to the cockpit as a student pilot and continues as long as you maintain an interest in improving your skill. As your proficiency in the interpretation and use of the instruments progresses, you fly visually, "on the gauges," or by a combination of visual, instrument, and "seat-of-the-pants" references, depending upon which source of information best suits your purpose.

From the standpoint of training, instrument flying is a logical extension of visual flying. You learn to use the instruments and navigation equipment, not necessarily to become a weather pilot, but to develop the precision impossible to achieve by visual and other sensory references alone. You learn to fully utilize the potential of your airplane.

Many modern, single-engine airplanes have the capability to go farther, faster, and higher than the airliners of a few years ago. Surveys indicate that the majority of new aircraft sold are equipped for instrument training and for at least limited weather flying. Studies also show that many pilots are operating aircraft loaded with expensive flight and navigation instruments, radio equipment, auto-pilots, and other accessories that for lack of training, they fail to use fully.

Preparation for the instrument rating will better enable you to use the equipment to go when and where you want. Instrument proficiency will aid you in getting in and out of places that are inaccessible to pilots flying by visual flight rules (VFR) and using limited equipment. With or without the rating, as a precision pilot you will fly by reference to instruments. However, without an instrument rating you cannot fly under instrument conditions, as defined by regulations, except in violation of the limitations of your pilot certificate. If you intend to become a career pilot, you cannot advance far professionally without it, except in certain highly specialized commercial operations.

Perhaps you want an instrument rating for the same basic reason you learned to fly in the first place—because you like flying. An education in instrument flying "separates the men from the boys." Maintaining and extending your proficiency, once you have the rating, means less reliance on chance, more on skill and knowledge. Earn the rating, not because you might need it sometime, but because it represents achievement and provides training you will use continually and build upon as long as you fly. But most important, it means greater safety in flying.

Requirements for the Instrument Rating

How much flight time do you need before beginning instrument training? How much total time is required, in flight and on the ground? How much of this time requires direct supervision by a licensed instructor? What assurance do you have that you are getting competent instruction? How do you go about getting training to fly on instruments? Is attendance at an instrument school necessary? What are the advantages of attending an approved school? Can you spread the necessary training over an extended period to fit your spare time from business or other occupations? These are important considerations that should be faced before you begin an extensive and expensive training program. The answers may seem confusing and be misleading unless you take a thorough look at the problems ahead of you.

First, what are the requirements for the issuance of the FAA instrument rating? You will need to carefully review the aeronautical knowledge and experience requirements for the instrument rating as outlined in FAR 61. After completing the instrument rating written test, you are eligible to take the flight test when all experience requirements have been satisfied. It is important to note that the regulations specify *minimum* total and pilot-in-command time requirements. This minimum applies to all applicants, regardless of ability or previous aviation experience. No regulation can be written to specify experience requirements for a particular individual.

The amount of instructional time *needed* is determined not by regulation, but by the individual's ability to achieve a satisfactory level of proficiency. A professional pilot with diversified flying experience may easily attain a satisfactory level of proficiency in the minimum time required by regulation for the issuance of an additional type rating. Your own time requirements will depend upon a variety of factors, including previous flight experience, rate of learning, basic ability, frequency of flight training, type of aircraft flown, quality of ground school training, and quality of flight instruction, to name a few. The total instructional time that *you* will need, and in general the scheduling of such time, is up to the individual most qualified to judge your proficiency, the instructor who supervises your progress and endorses your record of flight training.

Before you decide to acquire instrument flight training, you should ponder the following comments by the chief instructor of an accredited and successful school of aviation:

> Any instrument training program should allow sufficient calendar time for the student to assimilate the material involved in preparing for the instrument rating. . . . Emphasis should be placed on acquiring the education rather than acquiring the rating. . . . It is possible to obtain an instrument rating without acquiring an instrument education. A student who acquires the education need have no fear of failing to obtain the rating, however.

These sentiments are shared by many reputable aviation schools offering instrument training, whatever their differences in other respects. You can memorize a prodigious amount of information in a short time, but you will store away very little of it for future use unless you allow time enough to understand it, relate it to what you already know, and apply it with sufficient repetition.

As your flying experience progresses, you will learn increasingly through your own initiative, with or without the benefit of formal training. It is essential, however, that you lay the right foundation. You can do this by attending an instrument training school selected after careful investigation of its curriculum and reputation, or by joining a flying club which has invested in the necessary equipment and utilizes a competent instructor.

You can accelerate and enrich much of your training by informal study. An increasing number of visual aids and programmed instrument courses are available to the applicant who cannot attend a formal instrument training course. The best course is obviously one that includes a well-integrated flight and ground school curriculum. The importance of close coordination between these two aspects of your education should be apparent from your previous flight experience. The sequential nature of flying requires that each element of knowledge and skill be learned and applied in the right manner at the right time. You can learn volumes of isolated information about flight procedures, basic instrument maneuvers, radio navigation, communications, and Federal Aviation Regulations, yet still have difficulty keeping an airplane right side up.

Until you can plan an orderly instrument flight and have had sufficient dual practice, you can be very easily overwhelmed, not only by the routine revisions of your planning, but by unexpected interruptions that require quick judgment and action. You can learn much of this information while making good use of your VFR time. As a VFR pilot making full use of your equipment and the facilities afforded all flights in controlled airspace, you can polish up communication and navigation techniques so essential to competent instrument flying.

By filing VFR Flight Plans, you can acquire increasing competence in careful flight planning, making enroute estimates, revisions, and position reports in coordination with flight control personnel. You can visit FAA Control Towers, Flight Service Stations, and Air Traffic Control Centers to gain a clearer picture of the problems and processes involved in controlling traffic safely under Instrument Flight Rules. Finally, you should clarify some possible misconceptions about what an instrument rating involves.

Holding the instrument rating doesn't necessarily make you a competent weather pilot. The rating certifies only that you have complied with the minimum experience requirements, that you can plan and execute a flight under Instrument Flight Rules via Federal Airways, that you can execute basic instrument maneuvers, and that you have shown acceptable skill and judgment in performing these activities. Your instrument rating permits you to fly into instrument weather conditions with no previous instrument weather experience.

Your instrument rating is issued on the assumption that you have the good judgment to avoid situations beyond your capabilities. The instrument training program that you undertake should help you not only to develop essential flying skills, but also help you develop the judgment necessary to use the skills within your limitations. An instrument course can provide you with experienced instruction and up-to-date information. However, the program that offers tempting shortcuts may help you get the rating, but may leave important gaps in your flight education that could result in serious problems later on.

A clearer picture of your instrument training requirements can be gained by a study of the training curricula of some reputable aviation schools where successful professionals have made it their business to train pilots to a competent level with minimum expenditure of time and money. A representative ground and flight training curriculum is given later in this chapter.

Training for the Instrument Rating

The lack of informity existing among the instrument courses available to the prospective student complicates the problem of selecting a training program. For ground school training, you can choose anything from an intensive rote-memory course taking 2 to 5 days (with a "guarantee" to pass the required examinations) to a college-level course scheduling nearly 100 classroom hours over a 32-week period.

Flight training courses likewise vary, ranging from the minimum hours of dual required by regulation to the course offering more than the required hours of flight instruction supplemented by varying amounts of time in procedure trainers. Other courses offer proficiency programs tailored to the pilot's needs, guaranteeing nothing but experienced and reputable instruction—as much or as little as is necessary to achieve and maintain instrument proficiency. If all of these courses prepare the pilot for an instrument rating, why spend 8 months to acquire what allegedly can be accomplished in less than a week? Obviously, there must be some serious basic differences of opinion as to how much you should learn and how long it will take you to learn it.

At one extreme is the argument expressed more or less like this: If holding an instrument rating requires only that you demonstrate proficiency under simulated instrument conditions, you still have weather flying to learn after you have the certificate. Accordingly, why not get the certificate in the cheapest and quickest way possible, with a minimum of ground school and simulated time? Then go out and learn where it really counts—under actual weather conditions.

Many pilots acquire weather proficiency as coplilots serving with experienced captains. However, an increasing number of nonprofessional pilots become instrument rated without the opportunity for transitioning to weather flying under experienced guidance. If you are one of this group, learning by experience (by yourself) is going to present many difficulties that you can avoid by adequate training.

In contrast to the course offering only the minimum training necessary for the instrument rating is the formal training provided by most flying schools and universities. Such schools base their curricula on a realistic appraisal of the instrument flying environment and its demands on pilot proficiency. More pilots are becoming instrument rated to fly light aircraft in increasingly congested airspace. This is not a "practice" environment, under instrument weather conditions. Air traffic controllers make no distinction between the novice instrument pilot and the veteran, as far as proficiency is concerned.

Unlike the solo VFR pilot who may learn from a constant succession of errors without necessarily jeopardizing his safety, the instrument pilot (beginner and veteran alike) becomes a serious traffic hazard if he accumulates uncorrected errors. The most competent pilot, thoroughly proficient in the best equipment available, can find himself in situations where everything gets complicated at once. At such a time, he will call on all the training he has had. For example, he may fly a light twin equipped with an ADF receiver for hundreds of hours without an engine malfunction and without ever making an ADF approach. In terms of his actual use of single-engine procedures and training on ADF approaches, his time and money have been wasted —except as insurance.

If your own chances of engine and Omni receiver malfunction seem remote, review the experiences related in aviation periodicals under such headings as "I Learned From This." It takes only one harrowing experience to clarify the distinction between minimum practical knowledge and eventual useful information. When an emergency happens, it is too late to wonder why somebody forgot to instruct you as to what to do about it; and it's no consolation whatever that you didn't expect it to happen to you. Your instrument training is never complete; it is adequate when you have absorbed every foreseeable possible detail of knowledge and skill to insure a solution if and when you need it.

The following outline of ground school, procedures trainer, and flight training subjects represents an average of the instrument courses offered by several excellent aviation schools, amplified to include subject material of increasing importance to the instrument pilot. Syllabus organization and points of emphasis differ among schools for various reasons. However, the graduating student should have a sound understanding of the subjects listed, effectively integrated to present a clear operational picture of the following 10 basic components involved in instrument flight under Air Traffic Control:

Aircraft	Weather Information
Pilot	Rules and Procedures
Airport	Communications
Navigation	Ground Control
Aeronautical Information	Air Traffic Control

Instrument Curriculum

Ground Training

Phase I. The Airplane and Pilot Under Instrument Flight Conditions.

1. Physiological Factors Related to Instrument Flying.
   a. Adjustment to the flight environment.
      (1) Ground habits vs. flight habits.
      (2) Individual differences.
      (3) Importance of physiological factors to the instrument pilot.
   b. Reactions of the body to pressure changes.
      (1) Aerotitis.
      (2) Aerosinusitis.
   c. Reaction of the body to changes in oxygen partial pressure.
      (1) Hypoxia.
      (2) Carbon monoxide.
      (3) Alcohol.
      (4) Hyperventilation.
      (5) Drugs.
   d. Sensations of Instrument Flying.
      (1) Body senses.
      (2) Spatial disorientation.
      (3) Illusions.
2. Aerodynamic Factors Related to Instrument Flight.
   a. Fundamental aerodynamics.
      (1) Airfoils and relative wind.
      (2) Angle of attack.
      (3) Lift/weight, thrust/drag.
      (4) Stalls.
   b. Application of fundamentals to basic maneuvers.
      (1) Straight-and-level flight.
         (a) Airspeed.
         (b) Air density.
         (c) Aircraft weight.
      (2) Climbs/descents.
      (3) Power, airspeed, and vertical speed.
      (4) Power, airspeed, and elevator control.
      (5) Turns.
      (6) Trim.
         (a) Skids/slips.
         (b) Coordination.
3. Flight Instruments.
   a. Source of power.
   b. Function.
   c. Construction.
   d. Operation.
   e. Limitations.
4. Aircraft Control.
   a. Attitude instrument flying.
      (1) Cross-checking (scanning).
      (2) Interpretation.
      (3) Control.
   b. Analysis of basic maneuvers.
      (1) Straight and level.
      (2) Climbs and descents.
      (3) Turns.
      (4) Climbing and descending turns.
5. Basic Radio.
   a. Radio waves, frequency assignment, and characteristics.
   b. Ground facilities and radio class designations.
      (1) VORTAC.
      (2) Marker beacons (Location markers).
      (3) Homing beacons.
      (4) DF facilities.
      (5) ILS.
      (6) Radar.
   c. Airborne equipment.
      (1) Antennas and sources of power.
      (2) Navigation receivers.

(a) ADF.
(b) VOR/ILS.
(c) Other (DME/TACAN).
(3) Communications receivers.
(a) Tuning.
(b) Use.

Phase II. Regulations, Procedures, and Operational Aspects of Instrument Flying.

1. Applicable Regulations and Manuals (FAR and AIM).
2. Aircraft.
   a. Certificates and documents.
   b. Equipment.
      (1) VOR checks—VOT, etc.
      (2) ADF checks.
      (3) Communication checks.
3. Airman.
   a. Pilot certificates and ratings (FAR 61).
   b. Recency of experience.
   c. Instrument rating knowledge, experience and skill requirements.
      (1) Logging instrument time.
      (2) Simulator time.
      (3) Flight instruction.
4. General Operating and Flight Rules.
   a. FAR 91.
   b. Publications—AIM—chart reading.
5. Air Traffic Control Procedures.
   a. Visual flight on VFR and IFR Flight Plans.
   b. Instrument flight.
      (1) Airport traffic control.
      (2) Terminal air traffic control.
      (3) Enroute air traffic control.
      (4) Clearances.
      (5) Communications—frequency use.
      (6) IFR reports.
      (7) Special restrictions on air traffic.
         (a) ADIZ.
         (b) Prohibited, restricted, and warning areas.
6. Weather—Basic Weather Knowledge.
   (a) Winds and general circulation.
   (b) Air masses.
   (c) Characteristics of fronts.
   (d) Icing.
   (e) Turbulence.
   (f) Thunderstorms.
7. Navigation.
   a. Dead reckoning—computer.
   b. Radio Navigation—ADF, VOR, Radar.
      (1) Orientation.
      (2) Bearings.
      (3) Time/distance from station.
      (4) Course interception.
      (5) Tracking/homing.
      (6) Establishing fixes.
      (7) Station passage.
      (8) Instrument approaches—VOR, ADF, ILS, Radar.
8. Flight Planning and In-flight Procedures.
   a. Departure, destination, and alternate airport data and requirements.
      (1) Landing aids.
      (2) Communications facilities.
      (3) Weather services.
      (4) Airport data.
   b. Charts, route, and altitudes.
      (1) Understanding and use of Enroute Low Altitude Charts.
         (a) Routes.
         (b) Intersections.
         (c) Facilities.
      (2) Minimum IFR altitudes.
   c. Application of weather information to flight planning.
      (1) Sources of weather information—forecaster, FSS, telephone, radio.
      (2) Operational weather data.
         (a) *Weather maps:* surface, constant pressure, surface weather depiction, radar summaries.
         (b) *Weather forecasts:* Area, Terminal, winds aloft.
         (c) *Weather reports:* hourly sequence and specials, PIREPS, winds aloft, radar.
      (3) Choice of alternate.
   d. Enroute radio aids.
      (1) Navigation aids.
         (a) Range: VOR (accuracy of VOR radials).
         (b) Location markers.
         (c) Homing facilities.
         (d) D/F facilities (AIM).
         (e) Standard Broadcasting Stations (AIM).
         (f) Radar (vectors). Primary and Secondary.
         (g) DME, TACAN.
      (2) Communications.
         (a) Facilities.
         (b) Frequencies.
   e. Flight log entries and flight plan.
      (1) Reporting points, compulsory and noncompulsory.
      (2) Mileages.
      (3) Time estimates; ETAs between checkpoints, to destination, and alternate airport.
      (4) Groundspeed estimates.
      (5) Winds aloft data.
      (6) Navigation and communications frequencies.
      (7) Magnetic courses.
      (8) Fuel estimates.
      (9) Emergency reference data.

(10) Methods of filing.

f. Departure, holding, and arrival procedures.

(1) AL charts, low altitude area charts, preferred routes, SIDs, STARs.

(2) Radar—terminal and enroute.

g. Weather in flight.

(1) VFR/IFR.

(2) Weather services — FSS (scheduled and special broadcasts), AB Broadcasts, PIREPS.

(3) Effects of changing pressure and/or temperature on flight instruments.

(4) Effects of weather on aircraft performance.

(5) Procedures to be followed as a result of weather changes.

h. Changes in flight.

(1) Deviations from flight plan.

(a) Time/airspeed tolerances (AIM).

(b) Initiation or cancellation of IFR flight plan (AIM).

(c) "VFR on top" operation.

(d) Change in alternate.

(e) Change in altitude.

(f) Change in route.

(2) Emergency procedures.

(a) Equipment failure.

1. Instrument-radar service.

2. Radio — navigation and/or communications.

3. Airframe or powerplant.

(b) Lost procedures.

1. Emergency pattern for radar identification.

2. Communications procedure.

3. VHF/DF.

i. Transitions and Instrument Approaches.

(1) ADF.

(2) VOR.

(3) ILS front and back course.

(4) Missed approaches.

(5) Radar.

Procedures Trainer

Phase I. Basic Instruments.

1. Use of instruments to control attitude, altitude, speed, and direction.
2. Straight-and-level flight.
   a. Pitch control.
   b. Bank control.
   c. Power control.
   d. Trim control.
   e. Change of airspeed and configuration.
3. Turns.
   a. Turns to predetermined headings.
   b. Change of airspeed and configuration.
4. Climbs and descents.
   a. Constant airspeed.
   b. Constant rate.
5. Magnetic compass.
6. Timed turns.
7. Steep turns.

Phase II. Radio Navigation.

1. VOR and ADF.
   a. Orientation.
   b. Time/distance checks.
   c. Interception of predetermined radial or bearing.
   d. Course (radial/bearing) following.
   e. Identification of position.
      (1) Intersections.
      (2) Off-course, including off-course corrections.
      (3) Arrival over station.
   f. Holding and transitions.
2. Instrument approach procedures.
   a. VOR.
   b. ADF.
   c. ILS.
   d. Radar approaches.
3. Departures, routings, and arrivals.
4. ATC procedures.
   a. Clearances.
   b. Position reporting.
   c. Emergencies.

Flight Training

Phase I. Basic Instruments.

1. Preflight procedures.
2. Takeoff procedures.
3. Techniques, procedures, and operating limitations in the use of basic flight instruments.
   a. Altimeter.
   b. Airspeed indicator.
   c. Vertical-speed indicator.
   d. Attitude indicator (gyro horizon).
   e. Turn and slip indicator.
   f. Heading indicator (directional gyro or slaved gyro).
   g. Magnetic compass.
4. Airwork.
   a. Straight-and-level flight—pitch, bank, and power control.*
   b. Turns and turns to predetermined headings, including timed turns.*
   c. Climbs and descents (Constant rate).*
   d. Climbs and descents (Constant airspeed).*
   e. Stalls and maneuvering at approach speeds.
   f. Steep turns.
   g. Recovery from unusual attitudes.*

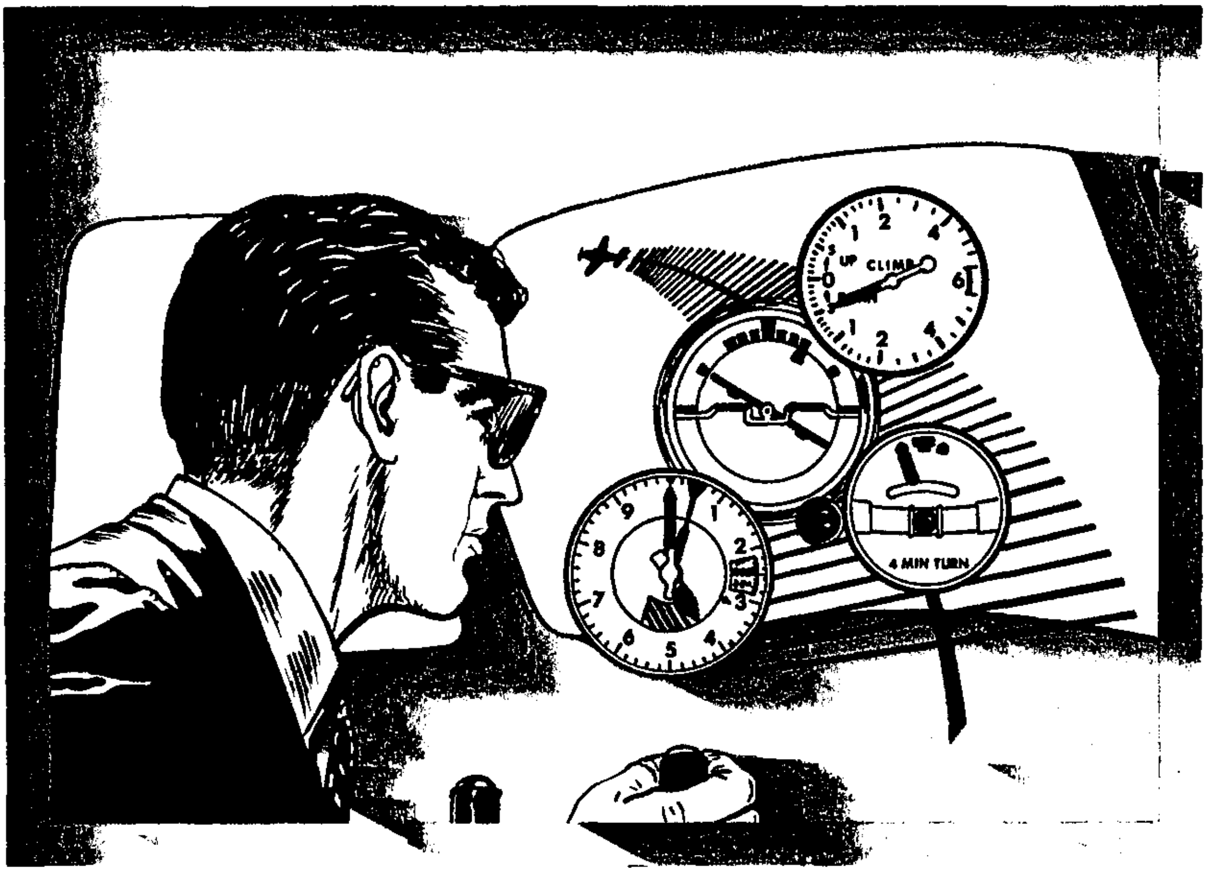
Phase II. Communications, Departures, Enroute Navigation, and Arrivals Under Instrument Flight Rules.

1. Preparation of flight plan, including use of charts, aircraft performance data, weather

services and *Airman's Information Manual.*

2. Arrival estimates—for flight planning and enroute revisions.
3. Tuning radio equipment.
   a. Selection of frequencies.
   b. Use of equipment in flight.
4. Orientation by radio (ADF and VOR).
   a. Identification of position.
   b. Time/distance from station.
5. Course following.
6. Identification of position.
   a. Intersections.
   b. Off course, including off-course corrections.
7. Holding.
8. Instrument approach procedures.
   a. Use of Area Charts and Instrument Approach Charts.
   b. ADF, VOR, and ILS approaches—radar approaches.
   c. Missed approaches.
9. Air Traffic Control Procedures.
   b. Flight Plan.
   b. Clearances.
   c. Emergencies

(* FAA flight test requires competency on these maneuvers using needle, ball, and airspeed only—partial panel.)



II. PHYSIOLOGICAL FACTORS RELATED TO INSTRUMENT FLYING

Your body is not designed for flight. You are equipped to operate as a ground animal, living within narrow limits of atmospheric pressure and adapted to movement on the ground through sensory systems that you react to from habit. At progressively higher altitudes, your system becomes less and less capable of working properly without devices provided to surround your body with sea-level conditions.

As a VFR pilot, you are already familiar with some of the effects on your body due to changes in atmospheric pressure. Your ears "pop" as you climb, and you yawn or chew gum during descent to equalize the pressure inside and outside your eardrums. If you have flown with a head cold, sore throat or upset stomach, you may have already learned that unrelieved pressures against your body cavities can cause excruciating pain during rapid changes in altitude. You have found out, too, that your senses can fool you, if while you are preoccupied with a chart or computer you look up to find your aircraft in a turn.

On a dark, moonless night, lights on the ground can be confused with stars, or a sloping cloud bank can be mistaken for the horizon. Perhaps you have felt annoyance at the flicker of your rotating beacon. Under certain conditions in susceptible persons (perhaps two percent of all persons are susceptible to varying degrees), this irritating reflection of the beacon on an instrument panel or from cloud banks can produce severe nausea, "hypnosis," or loss of consciousness. This "flicker vertigo" can also result from sunlight flickering through a single-engine aircraft propeller such as might occur during a landing approach into the sun with decreased r.p.m. In fact, during World War II, a plan was devised to disrupt night bomber invasions by blinking anti-aircraft lights and beacons at a frequency thought to induce pilot disorientation and dizziness. The war ended before this defense could be tested. Since that time, pilots have become increasingly concerned with human reactions to the flight environment.

As a student of instrument flying, you may not be interested in military flight, pressurized cabins, oxygen masks, and other problems related to high-altitude, high-speed flight. The average civilian light-plane pilot readily adjusts to the effects of the atmosphere and aircraft movement on the body during low-altitude VFR conditions. As an instrument pilot, however, regardless of your altitude and speed, you must understand the reactions of your body to the atmosphere and to the forces related to aircraft control. The WHY, HOW, and WHEN of your body reactions are important for several reasons:

a. You cannot change your habits of adapting to movement on the ground to the habits required for instrument flight without recognizing and ignoring the old habits and developing new ones. Further, once you learn the techniques, you retain them only with practice.

b. Adjustment to instrument flying depends a great deal on individual differences in sensory sensitivity and physiological tolerances. Knowledge of your own particular body limitations is essential to the most effective control of your aircraft.

c. Flight under instrument conditions demands far more concentration and a greater range of attention than is required for visual flight. Physiological factors are directly related to the correct perceptions, decisions, and reactions necessary for aircraft control. As you learn to adjust to these factors, you will become less fatigued by the demands on your capacity for concentration and division of attention.

d. With the production of higher performance civil aircraft, the most efficient operational altitudes are continually being raised. More and more instrument-rated pilots are using their ratings at altitudes where knowledge of physiological reactions is of critical importance.

Pressure Altitude, Partial Pressure, and Physiological Altitude

Pressure altitude is the total pressure of the atmosphere at any given level, based upon standard sea-level conditions. It can be simulated in a pressure chamber for various flight levels by regulating the pressure inside the chamber. As Figure 1 shows, the atmospheric pressure decreases from approximately 760 mm. (29.92 inches) of mercury at sea level to 187 mm. at 34,000 feet.

From sea level to 70,000 feet, regardless of pressure changes, the atmosphere is made up of a nearly constant proportion of mixed gases, mainly nitrogen (78%), oxygen (21%), and carbon dioxide (0.03%). The total pressure at any altitude is made up of the sum of partial pressures of the individual gases in the atmospheric

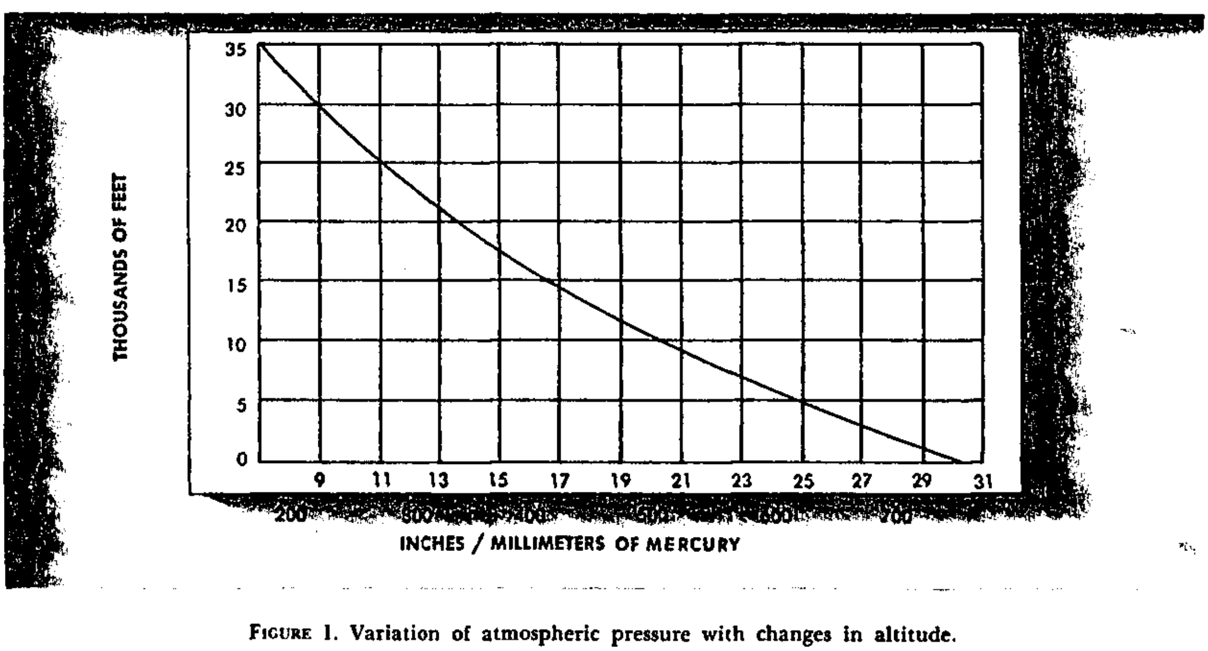


FIGURE 1. Variation of atmospheric pressure with changes in altitude.

mixture at that altitude. At 18,000 feet, for example, the total outside pressure is about 380 mm., roughly half of that at sea level. Thus, 21 percent (80 mm.) of this total pressure is the oxygen partial pressure at this altitude. Your body is affected both by the total pressure at a given altitude (as it effects your body cavities) and by the changing amounts of oxygen in your blood, regardless of whether the oxygen content is determined by altitude or other factors.

The important question is not how much oxygen there is available at any altitude, but how much of it reaches your tissues, and what happens when you absorb too little of it.

The significance of partial pressure and the meaning of the term "physiological altitude" are related to the process by which oxygen gets into the blood. Oxygen is transported from the lungs to the tissues by combining with the hemoglobin in the blood. The amount of oxygen that will combine with the hemoglobin depends upon the oxygen partial pressure in the air cells of the lung, which in turn depend upon atmospheric pressure. At sea level, the oxygen partial pressure is sufficient nearly to saturate the hemoglobin; the higher the pressure altitude, the lower the partial pressure on the lungs, and the less oxygen there is available to combine with the hemoglobin. For example, at a pressure altitude of 34,000 feet, the total pressure on your lungs is 187 mm. and the oxygen partial pressure 38 mm. —about one-fourth of sea-level pressure. Thus, to function properly as a sea-level animal at 34,000 feet, you breathe 100 percent oxygen to provide the oxygen partial pressure (159 mm.) that your lungs are used to at sea-level. Under these circumstances, your physiological altitude is sea level, which is another way of saying that you are providing your central nervous system artificially with the oxygen it needs to function normally at sea level.

Another example: Assume that at sea level a toxic substance gets into your blood stream and reduces the amount of oxygen carried by the hemoglobin to a level equivalent to what the outside atmosphere would provide at 10,000 feet. Under this condition, your brain and body will function at a physiological altitude of 10,000 feet.

Effects of Reduced Total Pressure

The reaction of the body to repeated stresses of atmospheric pressure results in disorders centered in various areas of the body. A description of the most common of such conditions will help the student understand the important relationship of physical fitness to safety in flying.

Aerotitis is a condition of traumatic inflammation of the middle ear caused by pressure differences between the middle ear cavity and the surrounding atmosphere. It produces pain in the ears and temporary deafness during changes in barometric pressure. To prevent this condition the expanding and contracting air within the ear must be adjusted to outside air pressure. Figure 2 shows the eustachian tube and the parts of the ear involved.

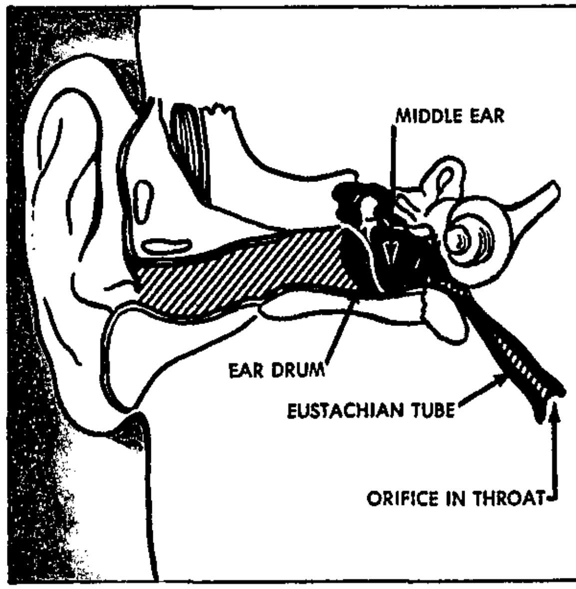


FIGURE 2. Ear structure and eustachian tube.

The outer ear includes the external ear and the auditory canal extending inward to the eardrum, a thin membrane separating the outer ear from the middle ear. The middle ear is a small cavity, surrounded by bones in the skull and filled with air. If this air is trapped during atmospheric pressure changes, the eardrum stretches to absorb the higher pressure. Pressure is normally adjusted through the eustachian tube, the duct leading from the middle ear into the back of the throat. This arrangement works automatically on the ground, where pressure changes are gradual and relatively slight. The tube remains collapsed unless inside ear pressure pops the excess air through the tube orifice or unless the tube is opened by muscular action during swallowing or yawning.

During climbs, this pressure relief valve pops at frequent intervals as the outside pressure decreases. During rapid descents, however, the eustachian tube may not open readily, so that frequent deliberate swallowing or yawning is necessary to stimulate the muscular action. Sometimes it helps to close your mouth, hold your nose, and blow gently to force the tube open. At a critical point in pressure differential, none of these methods will open the tube, and the eardrum can rupture, though this rarely occurs. It is important, then, that you adjust the pressure frequently during descent, especially from high altitudes at high rates of descent. Difficulty in equalizing the pressure can be relieved by leveling off or climbing to lower pressure before continuing the descent at a lower rate.

Aerosinusitis, like aerotitis, results from unrelieved expansion or contraction of air in the head sinuses. The sinus cavities, surrounded by bones in the face and skull, are grouped around the nasal passages. Two of the many pairs of sinuses are shown in Figure 3. Each of the sinuses is connected to the nasal cavity by a narrow opening in the bone structure, lined with mucous membrane. You have no voluntary control over these openings as you have over the eustachian tube and any inflammation of the membranes prevents adjustment of pressure and severe pain can result around the affected sinus. Obstruction to pressure adjustment is more likely to occur during a rapid descent. The only remedy if the condition is severe is to level off or climb until pressure equalizes, then to descend at a reduced rate.

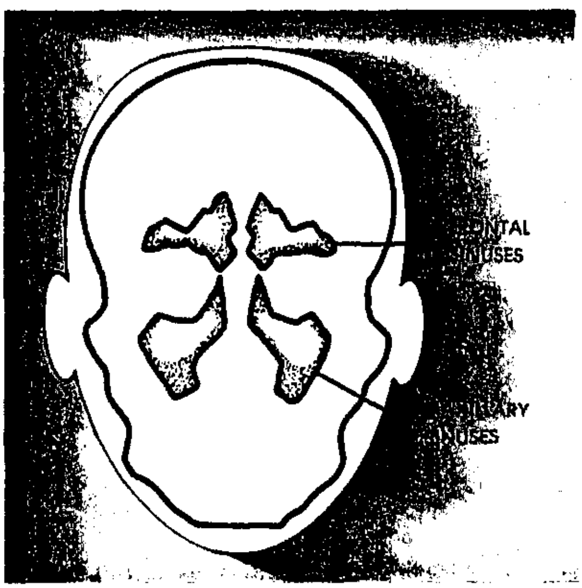


FIGURE 3. Sinuses.

The detrimental implications of these two conditions for the instrument pilot should be evident. If you have a severe cold, you are not likely to fly. However, with a minor cold, respiratory inflammation, or nasal allergy, you may think of flying after the usual dosage of medication, especially if an important business appointment hinges on your flight. The possible effect of a head cold on your control of the aircraft under instrument flight conditions should be understood. The effect of the drugs used in medication will be considered later.

Hypoxia is a condition resulting from an insufficient oxygen supply to the tissues. As a pilot, you are primarily concerned with two of the several types of hypoxia. The first is the result of reduced atmospheric pressure; the other

1 Misread Computer

2 Used Wrong Computer Scales

3 Error in Addition

4 Number Omitted

5 Loss of Consciousness

	GROUND SPEED	DISTANCE N.M.	TIME		
			LEG	TOTAL	
	153	28	11	11	
	180	63	21	32	
	174	110	38	70	
	180	36	12	82	
1	174	43	15	107	3
2	212	76	28	35	4
5	\	80	29		

26,000 Feet — Chamber Test

INSTRUCTIONS:

Log Distances and Leg Times were given and Pilot was asked to Compute Ground Speeds and Total Times.

Oxygen Mask Removed after 4th Entry. Note the errors and Deterioration of Legibility.

FIGURE 4. Effect of oxygen starvation on coordination and computational skill.

is caused by toxic substances in the blood. Although individuals vary in their susceptibility to reduced oxygen pressure, 10,000 feet is considered the upper limit for the average pilot to conduct flight operations without oxygen breathing equipment or cabin pressurization. Up to this altitude, mild hypoxic effects due to decreasing pressure are of little importance except at night, when night vision is measurably affected above 5,000 feet.

Reaction to the reduction of oxygen supply is demonstrated vividly during low pressure chamber indoctrination for pilots who operate at altitudes requiring oxygen and/or pressurization equipment. The hypoxic individual feels symptoms in the following order: dizziness, tingling, blurry vision, warm feeling, and euphoria. The effects progress to mental confusion, inability to concentrate, loss of judgment, slowed reflexes, clumsiness, and finally to a loss of consciousness unless oxygen is administered. The sample flight log used in a high-altitude test chamber illustrates the effect of oxygen deprivation on vision and coordination (Fig. 4).

How important is knowledge of hypoxia to you if you stay below 10,000 feet? The effect of that altitude is, by itself, of little cause for concern. Remember, however, that the closer you are to 10,000 feet for prolonged periods, the more susceptible you are to hypoxic effects from other causes that may raise your physiological altitude seriously above a safe operating level. The other causes include your physical condition and some habits generally considered more or less harmless on the ground.

Carbon Monoxide

Research has shown that three cigarettes smoked at sea level can raise your physiological altitude to 8,000 feet. The reason goes back to the characteristics of hemoglobin. As discussed earlier, hemoglobin combines with oxygen in direct proportion to the oxygen partial pressure in the lung cells. Tobacco smoke also exerts a partial pressure along with the other gases inhaled.

It is the minute amount of carbon monoxide in tobacco smoke that can seriously affect your physiological altitude, for two reasons: First, hemoglobin combines with carbon monoxide approximately 200 times as readily as it does with oxygen, and once combined, the resistance to separation is in the same proportion. Secondly, regardless of oxygen partial pressure, combination of hemoglobin with carbon monoxide reduces the amount of hemoglobin available to carry oxygen and carbon dioxide. Thus, the longer the carbon monoxide is available in the lungs, even in minute amounts, the less oxygen is carried in the blood. When the carbon monoxide concentration in the blood reaches approximately 15 percent, hypoxia symptoms develop. Whether the gas is inhaled from cigarette smoke or from exhaust gases through defective cabin heaters or cracked exhaust stacks, its presence is undetected because it is tasteless, colorless, and odorless. Carbon monoxide poisoning produces dizziness, easily confused with fatigue, and a marked susceptibility to vertigo, to be discussed under "disorientation."

Also, unlike hypoxia resulting from altitude changes, carbon monoxide intoxication is not immediately remedied by administration of oxygen or descent to higher pressure levels. If the effects of chain smoking are added to an assigned altitude of 9,000 feet on a night instrument flight, the exact physiological altitude is not so important as the fact that your body may be reacting far below its sea-level capacity—and you are neither aware of it nor too concerned about what you think is fatigue.

Alcohol

Consider another habit not uncommon among automobile drivers and becoming of increasing significance to pilots, and see how it affects your physiological altitude—namely, "one for the road." This is not a question of staggering into your airplane drunk, but as more average people learn to fly, the number will include more pilots who are likely to mix alcohol with flying. Blood toxicology findings on pilots of 158 general aviation fatal accidents showed 35.4 percent were positive for blood or tissue alcohol. This survey adds that flying skills are measurably decreased by one-fourth the amount of alcohol necessary to produce a measurable decrease in automobile driving skills.

What does alcohol in any amount do to your system, and to what extent does it affect your pilot performance? Alcohol is very soluble and is readily absorbed in the tissues directly through the stomach and small intestine without undergoing the usual digestive processes. As a result, the alcohol content in the blood rises rapidly soon after ingestion, reaches a peak in a half to two hours, and declines slowly thereafter.

The effects of alcohol occur not because the alcohol prevents oxygen from reaching the tissues, but because its presence in the blood interferes with the normal use of the oxygen by the tissues. The effects are well-known and very similar to hypoxia. Less understood are the misconceptions, among them the idea that alcohol in small quantities is a stimulant, and that black coffee or hard exercise will help "burn up" the alcohol and minimize its effects. The rate of oxidation remains fairly constant regardless of the amount present in the system.

Another misconception is that the pilot who can "hold his liquor" on the ground can "hold it" in the air without ill effects. The possible effects in flight can be better appreciated when related to physiological altitude.

Studies have shown that 2 ounces of alcohol at a pressure altitude of 10,000 feet is equivalent to double that amount in terms of body response. That "one for the road" which may not appear to affect you on the ground, may seriously interfere with your mental and physical capabilities as you climb.

Hyperventilation

Hyperventilation is an increase in breathing activity that upsets the balance of oxygen and carbon dioxide in your system. On the ground, or in the air when your equipment and body are working properly, this balance is automatically regulated by your oxygen equipment and by the response of your respiratory system to changes in the carbon dioxide content of your blood. Muscular effort when you run, for example, increases the waste-product content (carbon dioxide) in your blood, causing an unconscious increase in rate of breathing. Faster breathing expels the increased carbon dioxide from your lungs and provides the necessary increase in oxygen for muscular work. But when excessive overbreathing expels carbon dioxide faster than muscular effort produces it, the result is a deficiency of carbon dioxide in the blood. This is called *hypocapnia.*

Constriction of the blood vessels, especially in the brain, causes a reduction in blood flow and oxygen supply,, with resulting symptoms typical also of hypoxia. The symptoms include dizziness, tingling sensations in the toes and fingers, and impairment of vision, hearing, speech, and memory. In extreme cases, spasms and muscle cramps develop in the forearms, feet, and fingers, accompanied by a severe reduction in performance capacity and even by loss of consciousness.

Individual susceptibility to hypocapnia varies widely, and tolerance to it can be increased slightly by practicing voluntary hyperventilation. Pearl divers, for example, remain under water for extended periods by overbreathing prior to immersion, an activity which clears the body of a large amount of carbon dioxide. The result is that they increase the time that they can hold their breaths, since they have created an increased "reservoir" into which they can store the developing carbon dioxide while under water. Through practice, they have raised their tolerance to breath holding. Most people, however, can become dizzy and faint after taking a few fast, deep breaths.

The remedy for hyperventilation is to slow down your rate of breathing and intermittently hold your breath to allow the carbon dioxide to build up to its normal level. The difficulty is that the victim of hypocapnia, like the hypoxic pilot, is not likely to be aware of the seriousness of his condition, nor is he necessarily capable of taking action to correct it.

An equally serious problem lies in the similarity of the symptoms of hypoxia and hypocapnia. If you recognize the symptoms, what remedies do you apply? The answer lies in understanding what brings about the two conditions, and in taking precautions to prevent their occurrence.

The essential precaution against hyperventilation is training. Hyperventilation is likely to occur when you are excited, tense, or scared, because a natural urge exists to overbreathe when you face psychological or physical stress. Stress and fatigue are built into flying, especially instrument flying, in inverse proportion to your knowledge, skill, and level of proficiency.

The VFR pilot who runs into murky weather and climbs to top the overcast at 12,000 feet, hoping to find a "sucker" hole at his destination, is asking for stress. He is tired before his letdown, and without instrument proficiency, likely to be tense and scared if an emergency descent is necessary through instrument conditions. Under stress he breathes faster because his body works that way in emergencies, and the faster he breathes, the less his chances of getting down safely. The instrument pilot, also, can get into trouble if he attempts a stress-inducing flight with neither proficiency, equipment, nor adequate planning to prevent fatigue and tension.

Drugs

The FAA guide for medical examiners, *Drug Hazards in Aviation Medicine,* offers the following advice: "Probably the best general recommendation for flying personnel and others directly associated with flight control is abstinence from all drugs." If the advice were generally heeded, nothing would be gained by further mention of drugs. However, many pilots do not abstain from all drugs, any more than they abstain from drugs before driving a car. Tranquilizers, pep pills, sedatives, sleeping pills, weight control pills, etc. are "best-sellers." Over-the-counter drugs are commonly purchased, not by prescription on the advice of a competent doctor, but on the promise of labels guaranteeing fast relief from tension, headaches, anxiety, and numerous other common ailments. Their side effects may be no more than a nuisance on the ground, and we think of them as harmless quick-acting remedies rather than as drugs that under certain conditions can seriously affect our reactions. In flight they can be hazardous in their effect on vision, coordination, respiration, fatigue, and judgment.

The classes of drugs listed below are a few of those that can be purchased "over the counter" under various labels. They are listed to stress the importance of asking your medical examiner's advice if you have any doubt as to your fitness for flying. Abstinence from flying is usually advisable for from 24 hours to a week following normal dosage.

Drug	*Possible effects*
Antihistamines	Drowsiness, dizziness, nausea, headache; especially hazardous because pilot may be unaware of drowsiness after initial alertness. Vision, coordination, and equilibrium can also be affected.
Stimulants	Dilation of pupils and blurred vision, nervousness, impaired judgment.
Muscle relaxants	Sleepiness, weakness, vertigo.
Barbiturates	Initial excitement, then sleepiness and impaired mental and physical activity not appreciated by pilot.
Tranquillizers	Blurred vision, mental depression, sleepiness.
Weight-control agents	Nervousness, errors in judgment, euphoria (feeling of well-being, regardless of condition).
Antismoking agents	Nausea, discomfort, and distraction can result from the use of antismoking drugs.

Sensations of Instrument Flying

During VFR flight, orientation is maintained by the sense of sight in observing the attitude of the aircraft in relation to the earth's surface. While flying by reference to the natural horizon, the attitude of the aircraft can be readily detected at all times. During instrument flying, when the natural horizon is no longer visible, the attitude "picture" of the aircraft is obtained from the attitude indicator or from a combination of other instruments.

The sense of sight is supported by other senses that help maintain orientation. Sometimes during instrument flying these supporting senses conflict with what is seen. When this happens, there is a definite susceptibility to disorientation. The degree of disorientation may vary considerably with individual pilots, their proficiency, and the conditions that induced it. Therefore, it is important that you understand the senses by which orientation is maintained in order to successfully overcome the effects of false sensations.

Your ability to maintain equilibrium and orientation depends on signals from three primary sources: the motion sensing organs of the inner ear; the postural senses which include touch, pressure, and tension; and the sense of sight. If one of these sensory sources is lost, the ability to maintain equilibrium and orientation becomes considerably lessened.

Motion.—The sense of motion which originates in the inner ear is very important to man in his normal environment—on the ground. The inner ear registers both linear and rotational acceleration and deceleration; thus it is able to detect most turns, slips, and skids during flight. Unfortunately, it is not capable of distinguishing between centrifugal force and gravity, nor is it capable of detecting a constant velocity or small changes in velocity. See Figure 5.

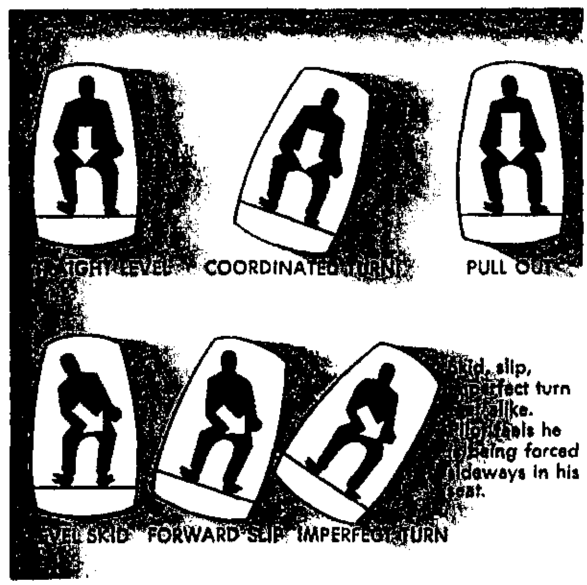


FIGURE 5. Sensations felt from centrifugal force.

False sensations from the inner ear also account for many illusions that are experienced during instrument flight. These illusions are discussed in detail in the portion of this chapter covering spatial disorientation manuevers.

Centrifugal force and gravity are often fused together in flight and the resultant force cannot be interpreted without visual aid. For example: without visual aid, deceleration while turning can cause the inner ear to sense a reverse turn; therefore, the sensations from the inner ear during instrument flying are not reliable and must be disregarded. See Figures 6 and 7.

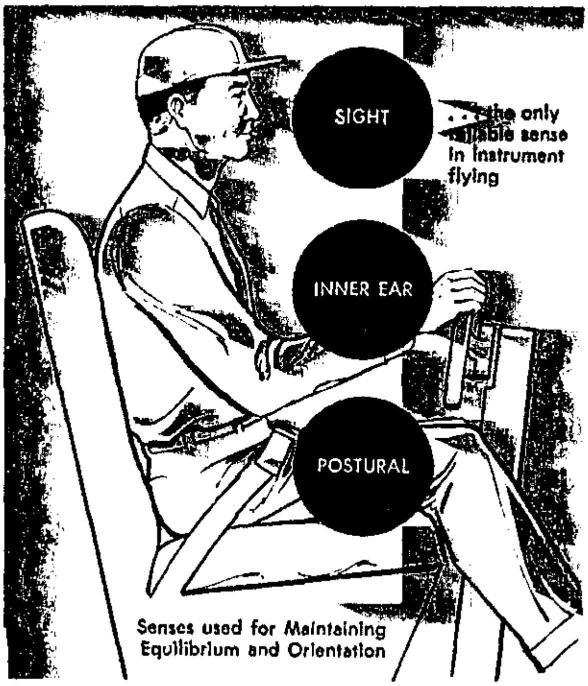


FIGURE 6. Sight—the only reliable sense during instrument flying.

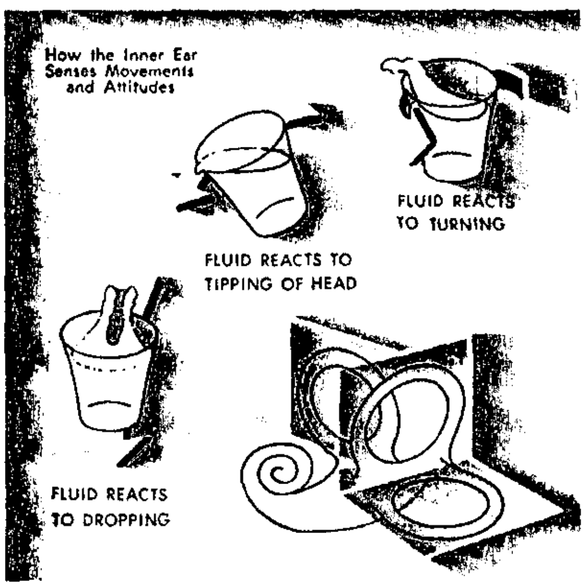


FIGURE 7. The inner ear and motion sense.

Postural Sense.—The postural sense derives its sensations from the expansion and contraction of muscles and tendons, touch and pressure, and the shifting of abdominal muscles. These sensations are more readily experienced in flight than on the ground. Without visual aid, postural sense during flight often interprets centrifugal force as a sensation of rising or falling which may be contrary to fact. Since the postural sense is not capable of detecting continued velocity without acceleration or deceleration, its sensations, like those of the inner ear, are unreliable in flight without visual aid.

Without outside reference or flight instruments, you could interpret a steep bank to be a sharp climb, or a shallow descending turn to be straight-and-level flight. It is also important for you to realize that these false sensations sometimes occur when flying by instruments. You must learn to subordinate these sensations when they conflict with what the flight instruments are showing you.

Sight.—When blindfolded, you find standing somewhat more difficult than usual. To walk in a straight line while blindfolded is almost impossible since normal reference to surrounding objects is lost. When standing on the ground, you are on a stationary platform from which the inner ear and postural senses may realize relatively reliable sensations. A somewhat different problem exists in flight since you are on a movable platform. Without the aid of sight, your other senses are unable to distinguish between the sensations produced by gravity and those produced by centrifugal force; your inner ear, which provides the sense of motion, is unable to detect small forces of acceleration and deceleration without aid from the sense of sight.

Visual illusions sometimes occur as the result of attempting to fly by outside reference when actual flight conditions demand reference to the flight instruments. Some examples of visual illusions follow:

- Flight in and out of clouds can give the impression of rapid changes in speed and attitude.
- Reflected light on the canopy may give a false impression of a steep bank or inverted flight.
- Lights on the horizon at night may appear to be at a much higher elevation.
- The anticollision light can produce a false impression of the aircraft in a turn when flying through clouds at night.

Spatial Disorientation

To the proficient instrument pilot, flying by reference to the flight instruments rarely produces false sensations of any consequence. He has learned to rely entirely upon the instrument indications and to overcome any false sensations. To a pilot with relatively little experience or proficiency in instrument flying, a conflict often occurs between the indications of the flight instruments and what the false sensations are telling him about the attitude of the aircraft. Under these circumstances, disorientation often occurs

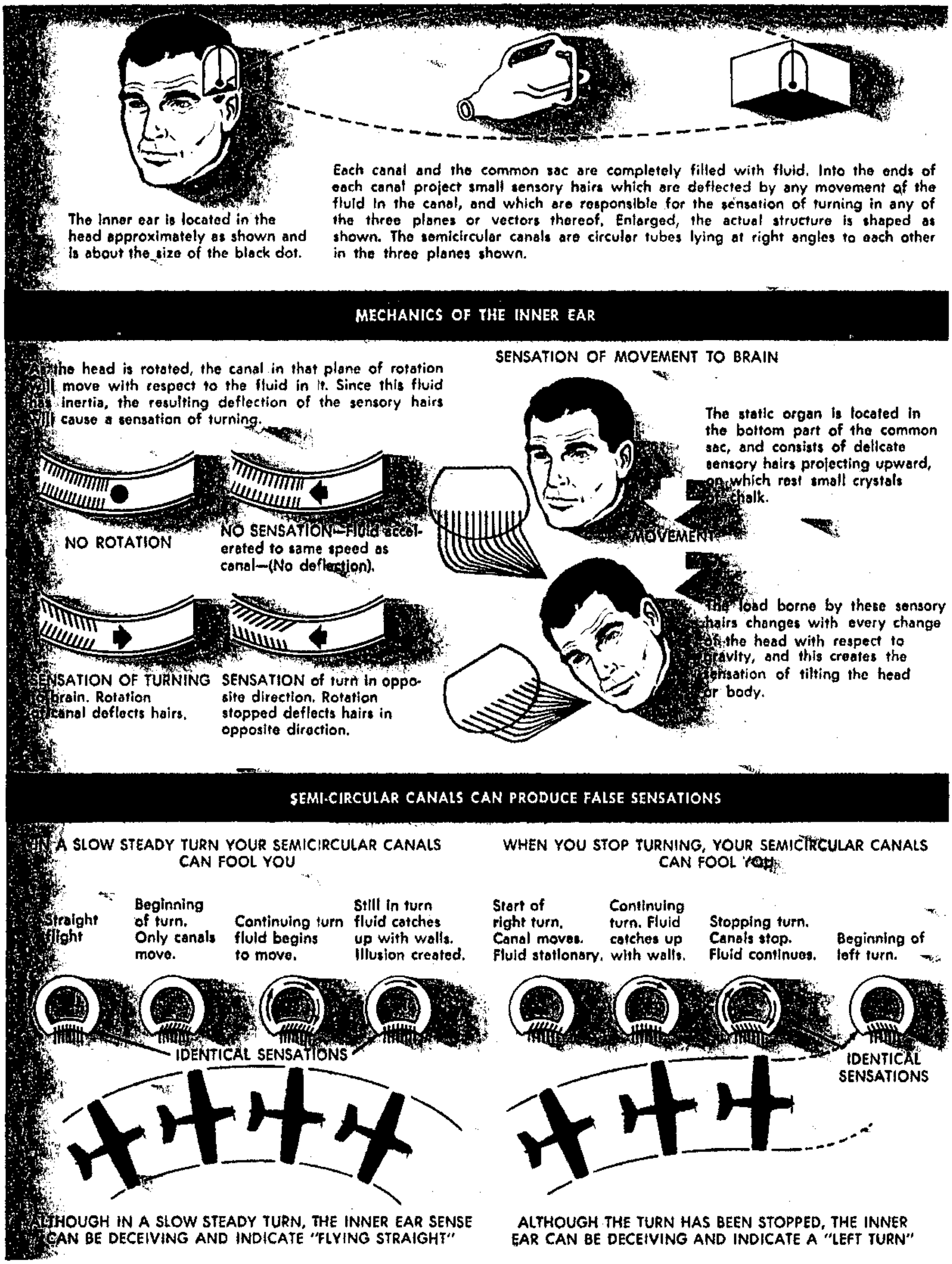


FIGURE 8. False sensations and spatial disorientation.

when there is any degree of belief in the false sensations.

You must choose between the false information often produced by the sense of motion and the postural senses, and the reliable information being presented by the flight instrument indications. It is imperative that you train yourself to rely only upon the instrument indications and to *disregard* the false senses. By learning to disregard these false senses, you will minimize the problem of disorientation.

Spatial Disorientation Maneuvers.—There are a number of controlled maneuvers that can be used to induce spatial disorientation. Each maneuver will normally create a specific reaction; however, any false sensation is an effective demonstration of disorientation.

While performing maneuvers designed to induce spatial disorientation, keep in mind that the objectives are manyfold. These maneuvers indoctrinate pilots in understanding the susceptibility of the human system to disorientation. They demonstrate that aircraft attitudes interpreted from bodily sensations are frequently false and unrealistic. They lessen the occurrence and degree of disorientation through a better understanding of the aircraft motion, head movement, and the resultant disorientation relationship. They instill a greater confidence in relying on flight instrument interpretation for true aircraft attitude.

The maneuvers outlined below are effective in inducing spatial disorientation in that they appear to a pilot to be situations that he could enter inadvertently. Other maneuvers, more violent and prolonged, may have a disorienting effect; however, they would not be the type of maneuvers associated with normal instrument flying.

The following maneuvers should induce a false sensation. However, keep in mind that should there be no sensation during any of these maneuvers, it is still an effective demonstration in that it shows inability to detect turn or roll.

FIGURE 9. Believe your flight instruments.

False Sensation of Climbing While Turning.—This sensation can be induced by closing your eyes while the aircraft is in a straight-and-level attitude. The instructor pilot will then, with a relatively slow entry, execute a well-coordinated turn of about 1½ positive G for 90°. While in the turn and under the effect of the slight positive G, note your version of the maneuver. Without outside visual reference, the normal sensation produced is that of a climb. If you so respond, immediately open your eyes. You can then see that a coordinated turn established slowly produces the same feeling as that of a climb through the actions of the centrifugal force (+G) on the organs of equilibrium in the ears.

Correlation under actual instrument conditions. When the eyes are diverted away from the instruments, should the aircraft enter a slight coordinated turn to either side, the sensation of a nose-up attitude will occur. The aircraft actually does not have to turn; the instantaneous application of similar forces can create the illusion.

The object of this maneuver. When a change of direction in any one of the three planes of motion occurs, if the rate of angular acceleration in the turn is 2°/sec/sec or less, the body cannot detect this motion unless there is some positive visual reference; consequently, the positive G applied during the turn is the only one perceived. Positive G is normally associated with a nose-up attitude or climb. This association is an unconscious habit developed through experience with G forces as well as a direct conscious feeling of climbing due to the effect of gravity on the middle ear mechanism.

False Sensation of Climbing While Accelerating.—While at approach airspeed in a straight-and-level attitude, close your eyes. Accelerate from this low airspeed to climb airspeed maintaining straight-and-level attitude. The normal response, without visual references, will be that the aircraft is climbing. Immediately after this response, open your eyes. This false sensation is readily recognized.

Correlation under actual instrument conditions. While under actual instrument conditions, this sensation can be easily encountered on a missed approach from a low approach, radar approach, or ILS. The sensation of climbing is produced by changing from a slow airspeed for approach to full power for climb airspeed. The change in angle of attack plus aircraft acceleration produces a strong sensation of climbing.

The object of this maneuver. With the body in a normal seated position, when a direct fore-aft motion is applied, the organs of equilibrium are affected by the acceleration in the fore-aft direction. The effect of change of angle of attack compounds the motion. The degree of disorientation and physical response is dependent upon the amount of change in angle of attack and rate of aircraft acceleration.

False Sensation of Diving.—This sensation can be created by repeating the procedure above, with the exception that you keep your eyes closed until the recovery is approximately one-half completed. While the recovery is being executed, with eyes still closed, note your version of the aircraft's attitude. The normal response, without visual references, will be that the aircraft is diving. This false sensation is readily apparent when you open your eyes while still recovering from the turn.

Correlation under actual instrument conditions. While under actual instrument conditions, should the eyes be diverted from the instruments and the aircraft enter a slow coordinated turn as above, and a slow recovery occurs, again the body perceives only the decrease in +G forces. The organs of equilibrium do not perceive the slow recovery from the turn, but do perceive the decrease in +G. This is normally interpreted as entering a dive.

The object of this maneuver. To effect a slow recovery from a coordinated turn at an angular deceleration rate of recovery of 2°/sec/sec or less with a normal decrease in positive G. The mechanism of this illusion is explained above.

False Sensation of Tilting to Right or Left.— This sensation can be induced in the following manner. While in a straight-and-level attitude, with your eyes closed, the instructor will produce a wings level moderate or slight skid to the left. The normal sensation is that of the body being tilted to the right. The false impression may be explained as the effect of side to side accelerative forces on the organs of equilibrium.

Correlation under actual instrument conditions. Should the eyes be momentarily diverted from the instruments and at the same time a skid to one side occurs, a false impression of tilting of the body to the opposite side occurs.

The object of this maneuver. With the body in a normal seated position, when a direct side-to-side motion is applied, the organs of equilibrium are affected by the lateral acceleration in identically the same way they would be if the body were tilted. The effect of tilt will be opposite to the motion.

False Sensation of Reversal of Motion.—This false sensation can be demonstrated in either of the three planes of motion. While straight-and-level, close your eyes. The instructor will smoothly and positively roll the aircraft to one side to approximately the 45° position while keeping the nose level and on a point by blending in aileron and opposite rudder pressure. The roll is abruptly stopped and held. The normal reaction is a strong sense of rotation to the opposite direction. After this sense is noted, observe the attitude of the aircraft in the banked position. The rotary motion, when abruptly stopped while visual references are poor, will produce a strong feeling of opposite rotation.

Correlation under actual instrument conditions. When the eyes are diverted from the instruments, should the aircraft either roll or yaw with an abrupt stop, a sensation of rolling or yawing to the opposite direction is produced. Control response, therefore, based solely on this sensation, would be opposite to the false feeling or a re-entry into the original roll or yaw. This is a common error in recovery from steep turns or unusual attitudes. When abrupt recovery is made, it is often followed by immediate re-entry into the original maneuver.

The object of this maneuver. Because the fluid of the semicircular canals of the middle ear continues in motion through its own inertia after motion is stopped, this continued motion of the fluid produces the same effect as if the body were actually moving in the opposite direction. The normal reaction to this illusion based solely on the sensation perceived is potentially dangerous.

False Sensation of Diving or Rolling Beyond the Vertical Plane.— (Extreme disorientation—with a marked physical response—is very dangerous at low altitudes.) While in straight-and-level flight, sit normally and either close your eyes or lower your gaze to the floor. The instructor will start a positive coordinated roll toward a 30° or 40° angle of bank. As this is definitely in progress, bend your head and trunk down and look to the right or left and immediately assume the normal seated position. The instructor should so time the maneuver that the roll is stopped just as you return to the normal position.

Observe the entry into a steep descending spiral. After the turn is established, lower your gaze to the floor. After approximately 20 seconds, bend your head and trunk down, look left or right, and immediately assume the normal seated position.

In the maneuvers outlined above, an intense disorientation is normally produced which gives the sensation of falling into the direction of roll as well as downward. This sensation is so quick and strong that there is a quick and forcible movement upward and backward to the opposite side. No explanation is needed in that the confusion speaks for itself.

Correlation under actual instrument conditions. When the eyes are diverted from the instruments and the head is moved downward and turned (as when changing frequencies, checking flight log data, or changing floor-mounted fuel selectors), should the aircraft roll or turn at the same time and suddenly the head is returned to the normal position, a true disorientation is normally produced with an almost uncontrollable urge to move physically in the opposite direction. This reflex movement may well be transferred to the controls.

The object of these maneuvers. These maneuvers should induce a combination of two or more of the above false sensations acting at the same time. When the head is moved at right angles to a plane of passive rotation and the rotation stopped abruptly, a sensation of rolling in the opposite direction is produced and a sensation of turning in the opposite direction is also added. The degree of disorientation and physical response is dependent upon many variables, depending on the movement of the aircraft, motion of the head, and the time element.

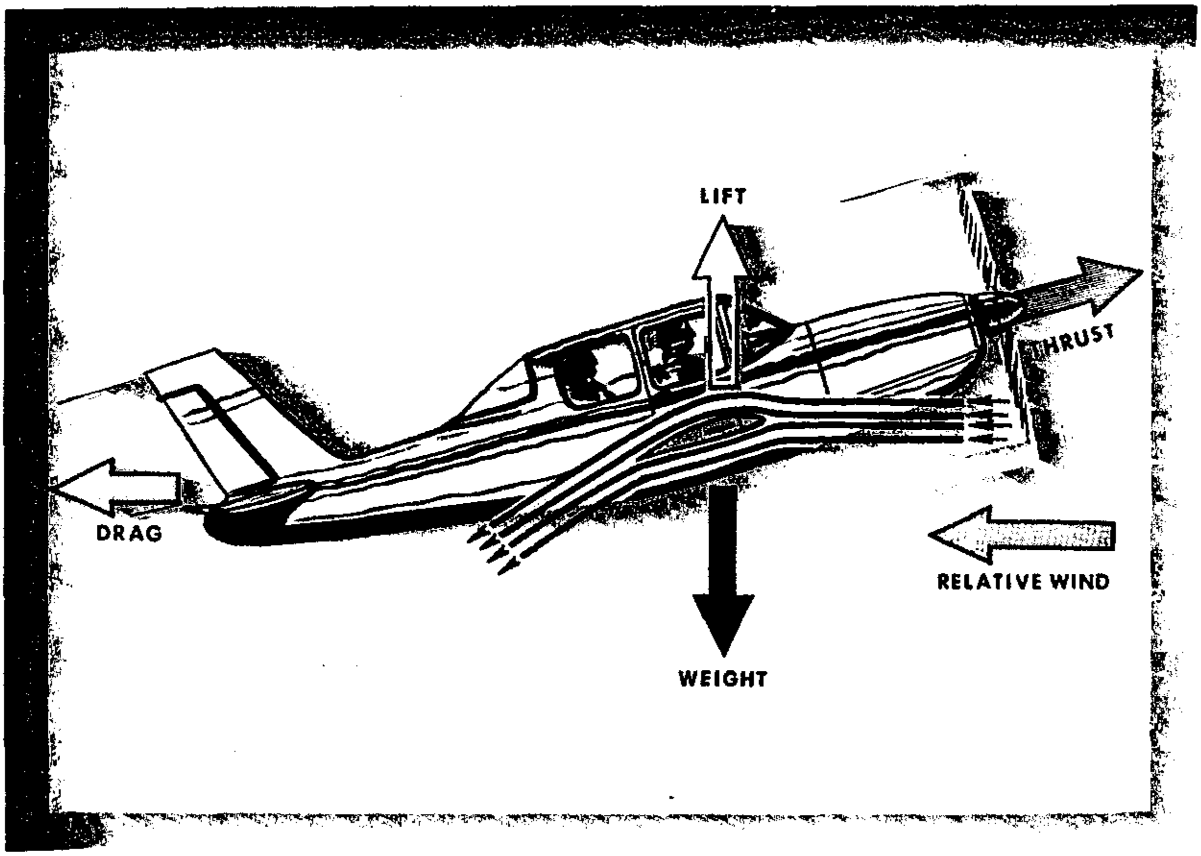
The best preventive measure against this type of disorientation is education against making marked head movements. Extreme caution should be used to limit head movements during descents, turns, and at low altitude with frequent reference made back to the attitude indicator.

Maintaining Spatial Orientation

The sensations of instrument flight are normal perceptions experienced by normal individuals. Unfavorable sensations cannot be completely prevented, but they can and must be ignored or sufficiently suppressed by acquiring absolute reliance upon what the flight instruments are telling you about the attitude of the aircraft.

You must learn to rely entirely upon what you see on the flight instruments regardless of what the false sensations are telling you. This is the key to maintaining orientation.

Practice and experience in instrument flying will also aid in discounting or overcoming the false sensations. As additional proficiency in instrument flying is acquired, you will become less susceptible to these false sensations and their effects.



III. AERODYNAMIC FACTORS RELATED TO INSTRUMENT FLYING

You will be concerned in this section with the forces affecting aircraft performance caused by the interaction of air and the aircraft. With an understanding of these forces, you will have a sound basis for predicting how the aircraft will respond to your control. Important as these forces are to the VFR pilot, they must be even more thoroughly understood by the student of instrument flying. You will find, as you learn the basic instrument flying maneuvers, that your understanding of *why* the aircraft reacts in a particular way to your control is the key to your interpretation of information shown on the instrument panel. The importance of these aerodynamic forces and their direct application to your execution of aircraft maneuvers will be evident. Several basic aerodynamic definitions apply to a discussion of these forces.

If a flat plate is moved through the air (Fig. 10), the airstream which strikes the plate is forced downward on impact against the plate. The reaction to this downward force produces a resultant force upward (lift) and a backward force (drag). A rock or a barn door will fly, given an airstream sufficient to produce lift. More efficient is the airfoil, a surface constructed to produce the maximum lift with the minimum drag. Airfoil shapes vary according to the aircraft performance to which the airfoil is designed. The most efficient shape, for the type of aircraft used for civilian instrument training, has a rounded leading edge, smooth cambered surfaces, and a sharp trailing edge.

As the wing moves through the air, the airstream is divided, part of it flowing over one surface while the remainder flows under the

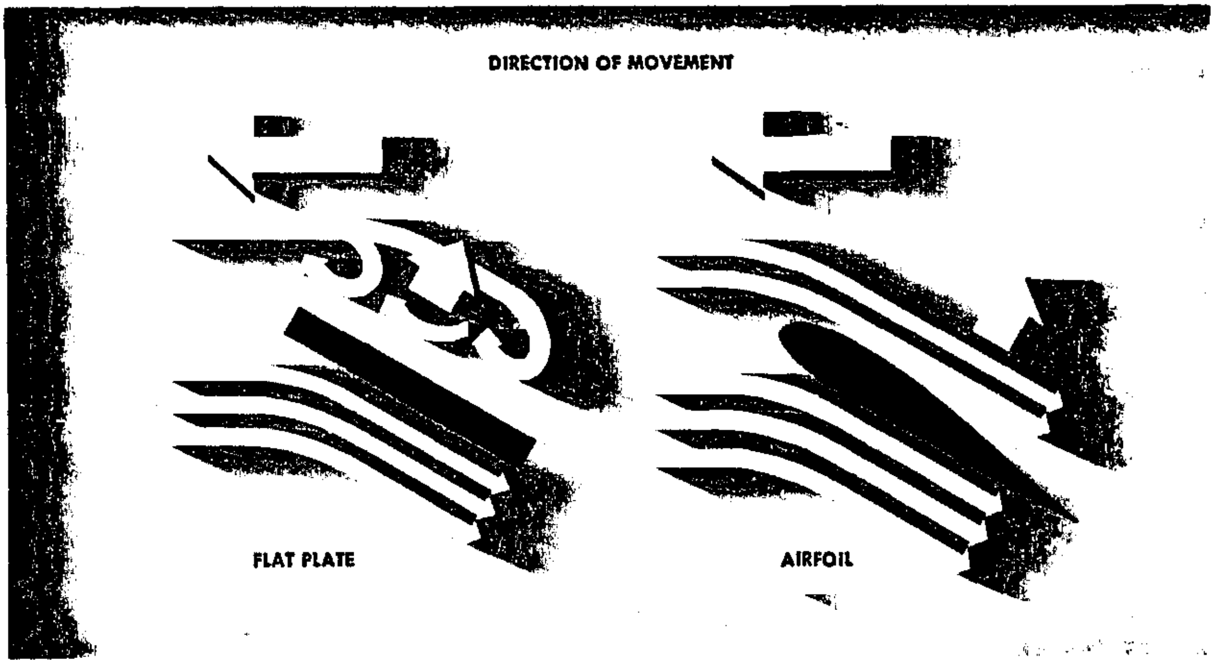


FIGURE 10. The airfoil.

other surface (Fig. 11). The air flowing over the upper cambered surface, as shown in the diagram, has a longer path to travel and has to flow faster than the air over the opposite surface to reach the trailing edge at the same time. Application of Bernoulli's principle to both Venturi tube and airfoil shows that the air flowing faster exerts the lesser pressure. Because of

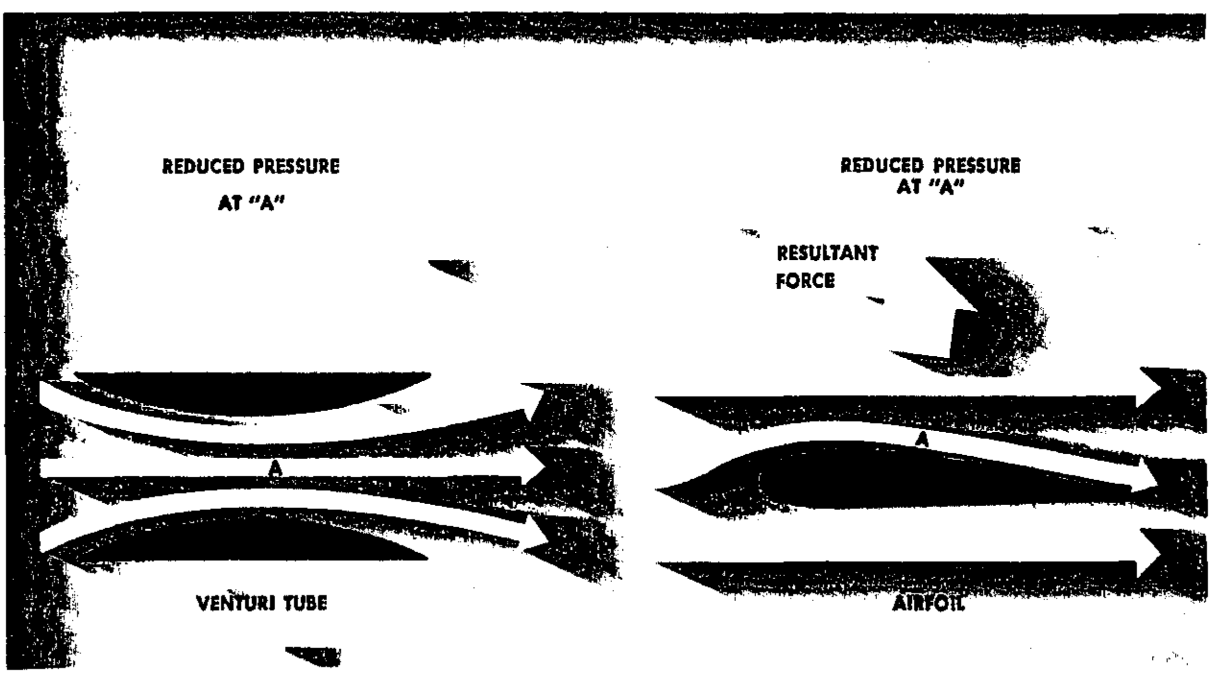


FIGURE 11. Venturi action.

the resulting differential pressure, the wing is supported by the higher pressure below the lower surface.

Lift is also produced at the leading edge when it is so designed that the approaching airstream divides near the lower part of the airfoil. The air is completely stopped here, and a stagnation point or high pressure area is formed. It is important that the high pressure area is produced at the bottom of the leading edge to contribute to lift, instead of at the center of the leading edge to produce drag.

The trailing edge of the wing is also designed for efficient airflow. If the trailing edge were rounded, the lower stream of air would tend to curve around into the area of lower pressure along the upper surface, introducing undesirable forces opposing lift on the after part of the airfoil. A sharp trailing edge permits smooth flow of the upper and lower airstreams past the trailing edge.

The lift/drag characteristics which are determined by airfoil design are affected by other basic factors related to control of aircraft performance.

The relative wind (Fig. 12) is the motion of the air relative to the chord line of the airfoil. The air can be moving past the airfoil or the airfoil can be moving through the air. The relative wind, as applied to airplanes, is parallel and opposite to the flight path of the aircraft.

The angle of attack is the acute angle measured between the chord line of the wing and the relative wind—not between the chord line and the earth's surface. The chord line of an airfoil is merely a conveniently chosen reference line in the wing to measure the real or theoretical width of the wing.

A stall is the result of any condition that disrupts the smooth flow of air over the airfoil to the point where sufficient lift is no longer produced by the differential pressure. The wing can stall in any attitude and at any speed. As the angle of attack of the wing is increased, the air particles are forced to make sharper and sharper changes in direction to follow the contour of the wing. With increasing angles of attack, disruption of smooth airflow occurs initially at the trailing edge and moves forward toward the leading edge at higher angles of attack. The wing stalls when the progressive increase in turbulence on the top cambered surface results in a net loss of lift (Fig. 13).

Aerodynamic Forces

Lift always acts in a direction perpendicular to the relative wind and to the lateral axis of the aircraft. The fact that lift is referenced to the wing, *not* to the earth's surface, is the source of many errors in learning flight control. Lift is not always "up." Its direction relative to the earth's surface changes as you maneuver the aircraft. The magnitude of the force of lift is directly proportional to the density of the air, the area of the wings, and the airspeed. It also depends upon the type of wing and the angle of attack. Lift increases with an increase in angle of attack up to the stalling angle, at which point it decreases with any further increase in

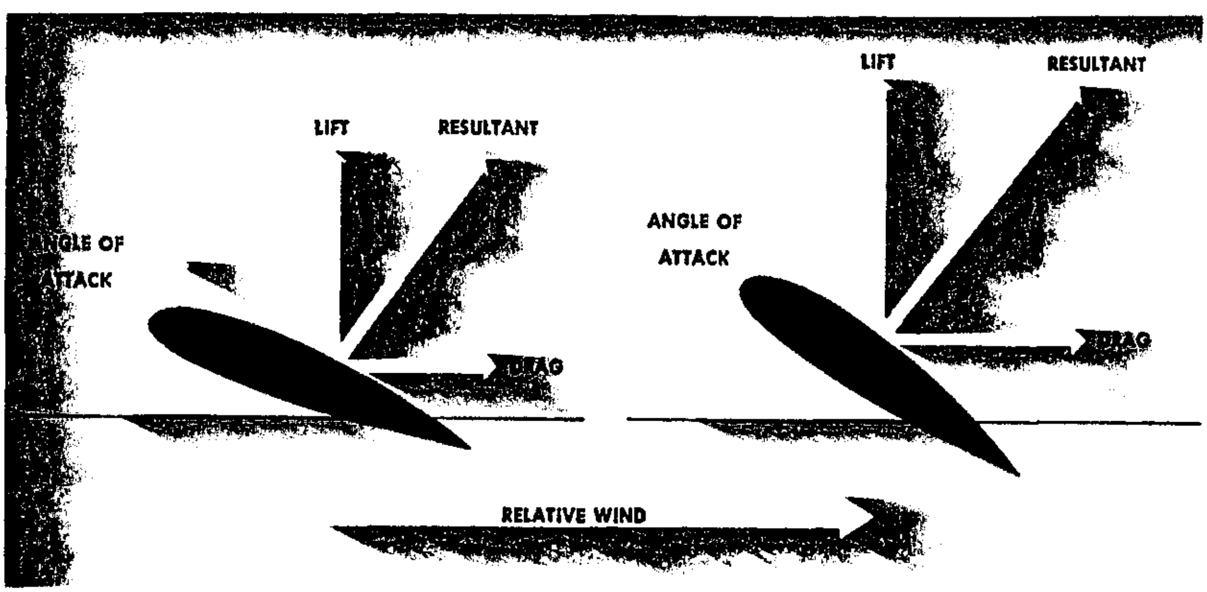


FIGURE 12. Relative wind.

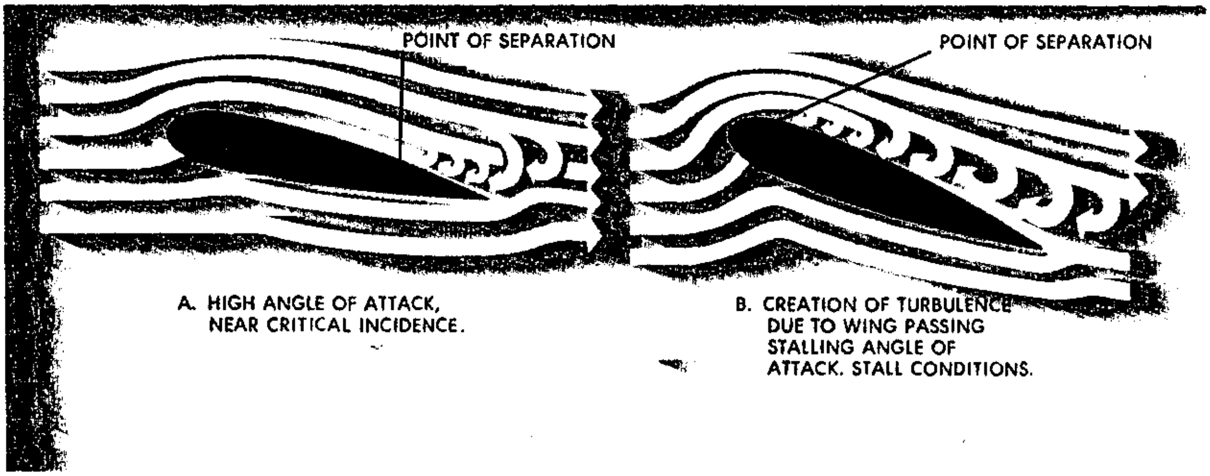


FIGURE 13. Angle of attack and stall.

angle of attack. In conventional aircraft, lift is therefore controlled by varying angle of attack (attitude) and thrust.

Drag is the total resistance of the air to the movement of the aircraft. Drag acts opposite to the direction of flight of the aircraft and is parallel to the relative wind. Induced drag is the result of the same inherent aerodynamic forces that produce lift. Parasite drag is the resistance to airflow caused by inefficient streamlining, skin friction, and projections into the airstream. Total drag is the sum of induced and parasite drag and is affected by airspeed and air density as well as the other factors noted. Changes in drag, whether induced during attitude changes or the result of gear and/or flap extensions, are reflected in performance changes indicated on your flight instruments.

Thrust in conventional propeller-driver aircraft is the force acting forward with respect to the longitudinal axis of the aircraft. The amount of thrust is determined by the power output of the engine, and for all practical purposes acts parallel to the longitudinal axis. Use of power controls thrust, and therefore lift and performance.

Weight is the force of gravity acting on the aircraft and is always downward toward the center of the earth regardless of aircraft attitude and flight path. Both the total weight and its distribution affect aircraft flight characteristics. The relationship of these fundamental factors to aircraft performance in various basic flight attitudes and conditions must be understood if you are to control your aircraft with precision.

Straight-and-Level Flight

Straight-and-level flight is a performance term meaning that an aircraft is maintaining a constant indicated altitude and a constant heading. In coordinated, unaccelerated, straight-and-level flight, weight acts downward toward the center of the earth; lift acts perpendicular to the relative wind and is equal and opposite to weight; drag acts parallel to the relative wind; and thrust acts forward, parallel to the longitudinal axis, and equal and opposite to drag.

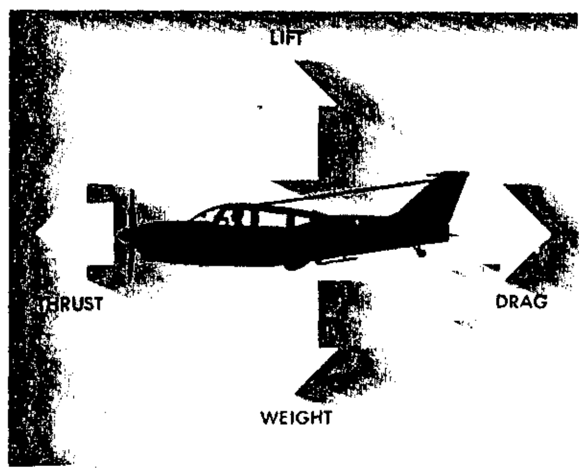


FIGURE 14. Forces in straight-and-level, unaccelerated flight.

In coordinated, straight-and-level, unaccelerated flight, all opposing forces are balanced (Fig. 14), and as long as the specific flight attitude and thrust are maintained, altitude and heading remain constant. Any variation in these forces requires a different attitude (relationship of the aircraft's longitudinal and lateral axes with the earth's surface) if the aircraft is to maintain level flight.

Three factors affect attitude in maintaining level flight—airspeed, air density, and aircraft weight.

(1) *Airspeed.*—At a constant angle of attack, any change in airspeed will vary the lift. At low airspeeds, the angle of attack must be proportionately greater to produce the lift necessary for level flight. The aircraft must therefore be flown in a nose-high attitude to maintain level flight at low speeds. At progressively higher airspeeds, the angle of attack necessary to produce sufficient lift for level flight becomes smaller, and the nose of the aircraft is accordingly lowered. Assuming that weight remains constant, any specific airspeed in unaccelerated level flight is associated with a specific thrust and attitude. In other words, if more power is applied than required for level flight, the aircraft will accelerate if held level, or climb if airspeed is held constant.

(2) *Air Density.*—Lift varies directly with changes in air density, which decreases as either altitude, air temperature, or humidity increases. Thus, to maintain level flight at a given true airspeed, the angle of attack of an airfoil must be greater at higher altitudes and/or outside air temperatures than at lower altitudes and/or temperatures. To maintain level flight at high "density altitudes," the aircraft attitude must be relatively nose-high.

(3) *Aircraft Weight.*—For a given weight and airspeed, a specific angle of attack is required to maintain straight-and-level flight. To support heavier loads at a given airspeed, the angle of attack must be relatively greater to provide the necessary lift. To overcome the induced drag resulting from the increased angle of attack, more thrust is also needed to maintain the given airspeed.

Climbs

For all practical purposes, the lift in normal climbs is the same as in level flight at the same airspeed. Though the flight path has changed, the angle of attack of the wing with respect to the flight path remains the same, as does the lift. There is a momentary change, however, as shown in Figure 15. In going from straight-and-level flight to a climb, a change in lift occurs when back elevator pressure is applied. Raising the nose increases the angle of attack and momentarily increases the lift. Lift, now greater than weight, causes the aircraft to climb. The flight path is inclined upward, and the angle of attack and lift again stabilize.

If the climb is entered without a change in power setting, the airspeed gradually diminishes because the thrust required to maintain a given airspeed in level flight is insufficient to maintain the same airspeed in a climb. Due to momentum, the change in airspeed is gradual, varying considerably with differences in aircraft size, weight, total drag, and other factors. As the angle of attack changes, a component of the weight acts in the same direction, and parallel to, the total drag of the aircraft, thereby increasing the total drag and decreasing the airspeed. The reduction in airspeed results in a corresponding decrease in drag until the total drag (including the component of weight acting in the same direction) equals the thrust.

The forces are again balanced when the airspeed stabilizes at a value lower than in straight-and-level flight at the same power setting. Lift is equal in magnitude to the component of weight that is perpendicular to the flight path. In a climb, this perpendicular weight component is only part of the weight, the other component acting to increase the total drag. Because the latter component must be balanced by thrust,

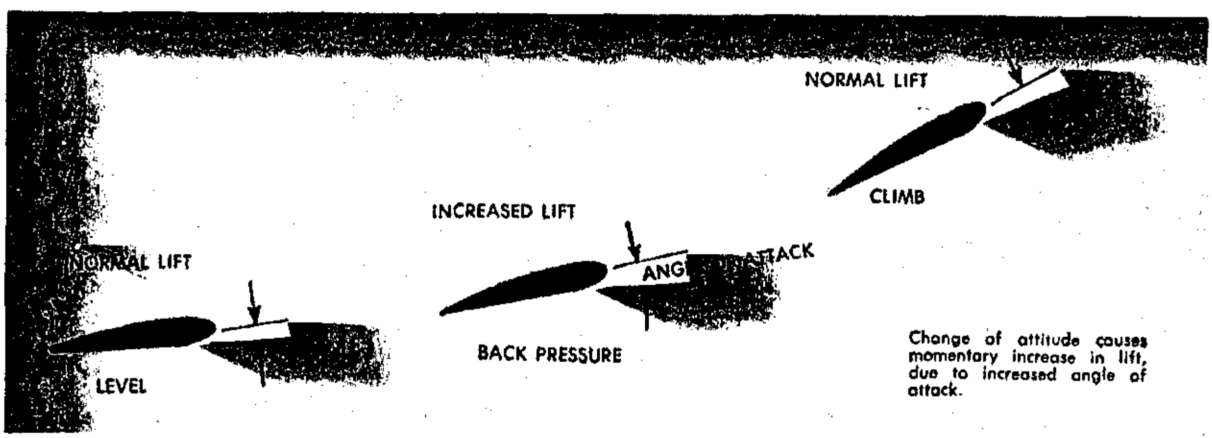


FIGURE 15. Climb entry.

you must increase thrust (power) to maintain constant airspeed on entering a climb from level flight, the amount of power depending on the change in angle of attack.

Descents

On entering a normal descent from straight-and-level flight without a change in power, a disturbance in balanced forces likewise occurs. As a result of forward pressure on the elevator controls, the angle of attack is reduced and the lift proportionately reduced. The weight being greater than the lift, the aircraft follows a descending flight path. A component of the weight now acts forward along the flight path parallel to the thrust, causing a gradual increase in airspeed as well as an increase in drag. When the angle of attack stabilizes and the lift/weight and thrust/drag forces again balance, the aircraft descends at a constant airspeed. Therefore, to enter a descent from level flight, maintaining a constant airspeed, you must decrease power to prevent an increase in thrust resulting from the forward alignment of the weight component.

Power, Airspeed, and Vertical Speed

In a descent, the component of weight acting forward along the flight path increases as the angle of descent increases and decreases as the angle of descent decreases. The power reduction required to maintain a given airspeed in the descent, depends on the rate of descent desired. For example, a high rate of descent at a specific airspeed, requires a greater power reduction than does a lower rate of descent. The proper combination of pitch attitudes, airspeeds, vertical velocities, and power settings for climbs and descents must be learned for each individual aircraft. Having learned the principles and techniques for the execution of these maneuvers for one aircraft, you can readily apply them to other aircraft.

Power, Airspeed, and Elevator Control

Rotating the aircraft about the lateral axis is accomplished by forward or aft movement of the elevator control to displace the elevators. The use of the elevators varies with changes in power and airspeed. The slip stream striking the elevators in a downward direction creates a negative angle of attack for the elevators and causes them to exert a negative lift. Changes in power and airspeed vary the amount of downwash and the resulting negative lift exerted by the elevators. As power and airspeed increase, slipstream velocity and downwash lift on the elevators increases. At the same time, lift on the wing increases and the aircraft has a nose-high tendency. Therefore, if the aircraft is trimmed for level flight, an increase in power and airspeed must be accompanied by forward pressure on the controls if you are to remain in level flight.

A decrease in power and/or airspeed has the opposite effect. The negative lift on the elevators and the lift on the wing decrease, resulting in a nose-low tendency. As you reduce power and/or airspeed, you must hold back pressure on the controls to maintain level flight.

Trim

In the simplest terms, trim may be thought of as balance, which is affected by design, loading, atmospheric conditions, and the aerodynamic factors already considered. Aircraft are designed so that weight always acts through a point called the center of gravity, located along the longitudinal axis at some point within specified limits behind the leading edge of the wing. Likewise, lift acts through a point called the center of pressure, located aft of the center of gravity. Since these two points do not coincide, lift and weight exert a twisting force resulting in a normal nose-heaviness. The twisting force is balanced by the negative lift produced by the horizontal stabilizer and elevators. However, as shown earlier, elevator control and the negative lift of the elevators vary with power/airspeed changes, requiring control application as the balanced forces are disturbed. Aircraft balance is affected not only by design and performance factors, but also by the shifting of the center of gravity and the center of pressure in flight, by the rigging of the aircraft, and by the action of torque and P-factor effects in propeller-driven aircraft.

With the application of power in propeller-driven aircraft, torque yaws the nose of the aircraft to the left. This yaw is controlled by the rudder, and the effectiveness of the rudder depends upon the amount of rudder displacement and the airflow. The airflow depends upon the airspeed and slip-stream velocity. Consequently, the nose will also tend to yaw to the left if airspeed is reduced while the power remains constant. Torque control thus depends upon airspeed, technique in the application or reduction of power, and the amount of torque inducing the yaw.

All of the above factors affecting changes in aircraft balance can be counteracted in light aircraft without the use of trim controls. In fact, many pilots commonly neglect proper trim technique and maintain continual control pressures to hold the aircraft in the desired stabilized attitude. This is not only fatiguing, but undesirable for additional reasons to be considered later. Trim devices vary in different aircraft.

In the simplest light aircraft, only an elevator trim control is provided. If such aircraft are used for instrument training, yawing or rolling tendencies must be counteracted by holding aileron and/or rudder pressures to maintain the desired aircraft attitude. With increased aircraft performance, rudder and elevator trim controls are essential, and in high performance or transport-type aircraft, aileron trim control is also necessary. In many light aircraft having no aileron trim control, the left/right fuel selector has a trim function. Wing heaviness on either side, requiring aileron control to maintain attitude, can be corrected by fuel consumption from the heavy side.

Turns

Many of the common misconceptions associated with aircraft performance and pilot control techniques are traceable to ignorance of aerodynamic forces and their varying effects as the aircraft is maneuvered. Our thinking and terminology are oriented to the ground rather than to the air, and these contribute to misunderstandings. For example, we think of "up" and "down" as referenced vertically to the earth's surface, and the elevators (also a ground-referenced term) as the means of up/down control. Back elevator control pressure should mean "up," and forward elevator, "down." This is true to varying degrees and under certain flight conditions. Under other conditions, back elevator control pressure will fail to produce any "up" result. A related misconception is that because weight always acts downward, lift always acts upward and opposite to weight. This is not always so.

Another mistaken notion is that an aircraft is turned by the rudder (s). This is understandable since the term "rudder" implies a turning function. Further, since the rudder controls rotation about the vertical axis, does it not follow that the aircraft is turned by rudder action? True, you *can* turn an aircraft by moving the rudder. You can also bank the aircraft, or move the nose up, by rudder control, just as you can raise or lower the nose by power changes. Because of these *effects* of control application, misconceptions understandably arise as to the proper *function* of the controls. The fact that the rudder is normally used in turning a conventional aircraft, or that the throttle is used in the execution of climbs and descents simply means that yaw must be controlled in a properly executed turn, and that thrust must be controlled to climb or descend under specified conditions. The interrelated functions of the controls will be clearer as you study the aerodynamics of a turn.

Forces Acting on an Aircraft in Turns

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 aircraft so that lift is exerted inward as well as upward. The force of lift is thus separated into two components at right angles to each other (Fig. 16). The lift acting upward and opposing weight is called the *vertical lift component.* The lift acting horizontally and opposing centrifugal force is called the *horizontal lift component.* The *horizontal lift component* is the sideward force that causes an aircraft to turn. The equal and opposite reaction to this sideward force is

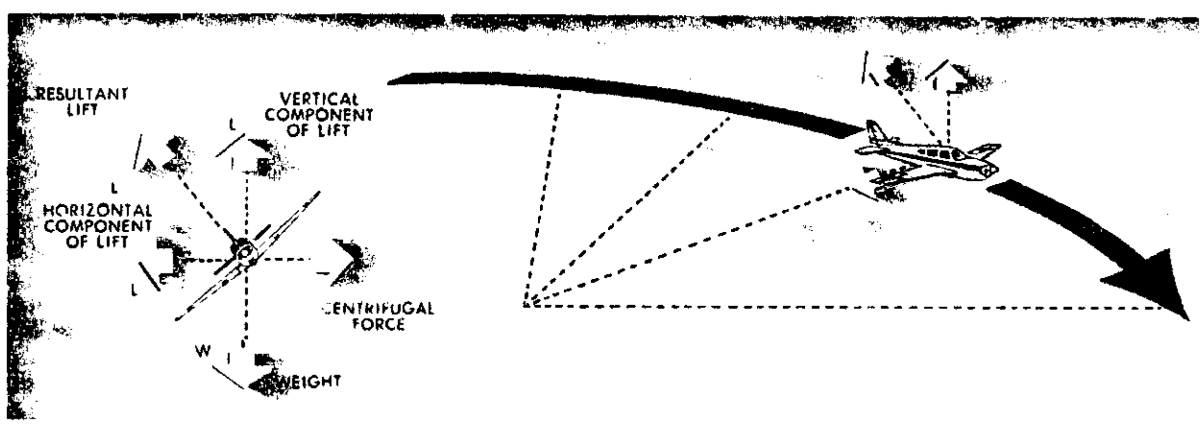


FIGURE 16. Lift components.

centrifugal force. If an aircraft is not banked, no force is provided to make it turn unless the turn is skidded by rudder application. Likewise, if an aircraft is banked, it will turn unless held on a constant heading in a slip. Proper instrument interpretation and aircraft control technique assumes that an aircraft is turned by banking, and that in a banking attitude it should be turning.

Changes in Lift in a Turn

Banking an aircraft in a level turn does not by itself produce a change in the *amount* of lift. However, the division of lift into horizontal and vertical components reduces the amount of lift supporting the weight of the aircraft. Consequently, the reduced vertical component results in the loss of altitude unless the total lift is increased by (1) increasing the angle of attack of the wing, (2) increasing the airspeed, or (3) increasing the angle of attack and airspeed in combination. Assuming a level turn with no change in thrust, you increase the angle of attack by raising the nose until the vertical component of lift is equal to the weight. The greater the angle of bank, the weaker is the vertical lift component, and the greater is the angle of attack for the lift/weight balance necessary to maintain a level turn.

Angle of Bank and Rate of Turn

The rate of turn at any given airspeed depends on the amount of sideward force causing the turn; that is, the horizontal lift component. The horizontal lift component varies directly in proportion to bank in a correctly executed turn. Thus, the rate of turn at a given airspeed increases as the angle of bank increases (Fig. 17). As the illustration shows, at 130 knots and approximately 10° of bank, an aircraft completes a 360° turn in 4 minutes. At the same airspeed and approximately 55° of bank, the rate of turn is eight times as great.

Drag Factors in Turns

Drag is induced both by changes in angle of attack and by displacement of the ailerons as the aircraft rolls into, or out of, a turn. As you raise the nose of the aircraft to increase the lift in a level turn, the drag increases directly in proportion to the increase in angle of attack. The resulting decrease in airspeed is, therefore, proportional to the angle of bank. If you wish to maintain constant airspeed in a level turn, you must add power in proportion to the angle of bank used.

If the ailerons alone are used to roll into a turn, the aircraft will tend to yaw in the direction opposite to the direction of turn, the amount of yaw depending upon the amount of aileron displacement and smoothness or abruptness of control technique. Deflection of ailerons increases the lift on the outside wing and decreases the lift on the inside wing. The drag is proportionately increased on the outside wing, resulting in the yawing effect known as "aileron drag" or "adverse yaw." The function of the rudder in a correctly executed entry and recovery from a turn is to counteract this aileron drag. Once the desired bank angle is established and the ailerons are streamlined, no aileron drag exists and the need for rudder control ceases.

Constant Rate Turns

If the airspeed is increased in a turn, the angle of attack must be decreased and/or the angle of bank increased in order to maintain level flight.

As airspeed is increased in a constant-rate level turn, both the radius of turn and centrifugal force increase. This increase in centrifugal force must be balanced by an increase in the horizontal lift component, which can be accom-

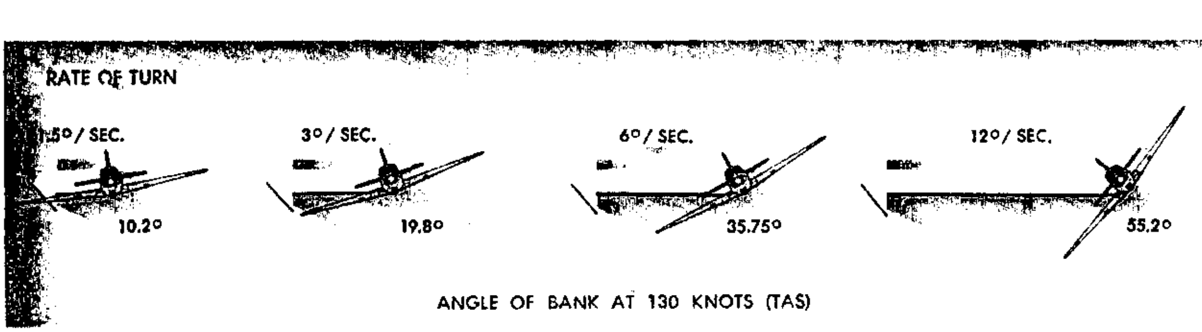


FIGURE 17. Relationship between bank and rate of turn.

plished only by increasing the angle of bank. Thus, to maintain a turn at a constant rate, the angle of bank must be varied with changes in airspeed (Fig. 18).

Load Factors and Angle of Bank

A load factor is the ratio of a specified load to the total weight of the airplane. The specified load may be expected in terms of aerodynamic forces, as in turns. In level flight in undisturbed air, the load factor is 1; the wings are supporting only the weight of the airplane. In a coordinated level turn, the wings are supporting not only the weight of the aircraft, but centrifugal force as well. As the bank steepens, the horizontal lift component increases, centrifugal force increases, and the load factor increases (Fig. 19). In a coordinated level turn with a 60° bank, the wings support a load equal to twice the weight of the aircraft. To provide the lift to balance this load, the angle of attack must be increased. However, if the load factor becomes so great that an increase in angle of attack cannot provide enough lift to support the load, the wing stalls. Since the stalling speed increases directly with the square root of the load factor, you should be aware of the flight conditions during which the load factor can become critical. Steep turns at low airspeed, structural ice accumulation, and vertical gusts in turbulent air can increase the load factor to a critical level.

Slips and Skids

In straight-and-level, unaccelerated flight, an aircraft points directly along its flight path, except when it is slipping or skidding (Fig. 20).

The aircraft may be yawed toward either side of the flight path by rudder action or by incorrect adjustment of the rudder trim tab. The same yawing effect can be caused by inaccurate aileron rigging. If one aileron is deflected slightly downward and the other is aligned properly, the aircraft will tend to yaw in the direction of the down aileron. If the aircraft is in proper trim, with the forces in equilibrium around its pitch, roll, and yaw axes, stabilizing forces will act to maintain this equilibrium. Following a slip or skid, if the aircraft is trimmed for straight-and-level flight and no control forces are held against this stabilizing tendency, the impact of the relative wind against the

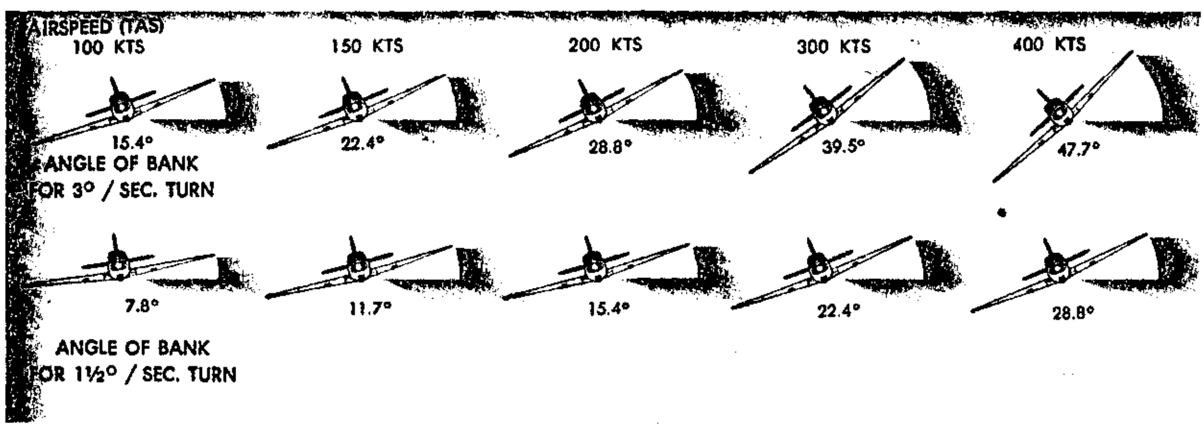


FIGURE 18. Angle of bank, airspeed, and constant rate turns.

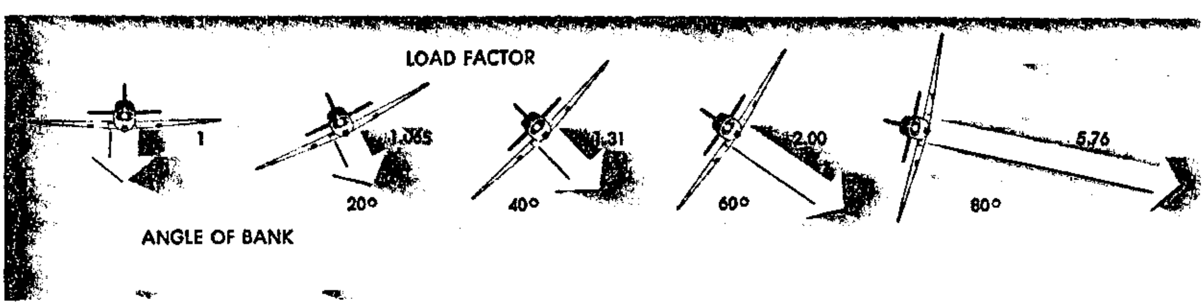
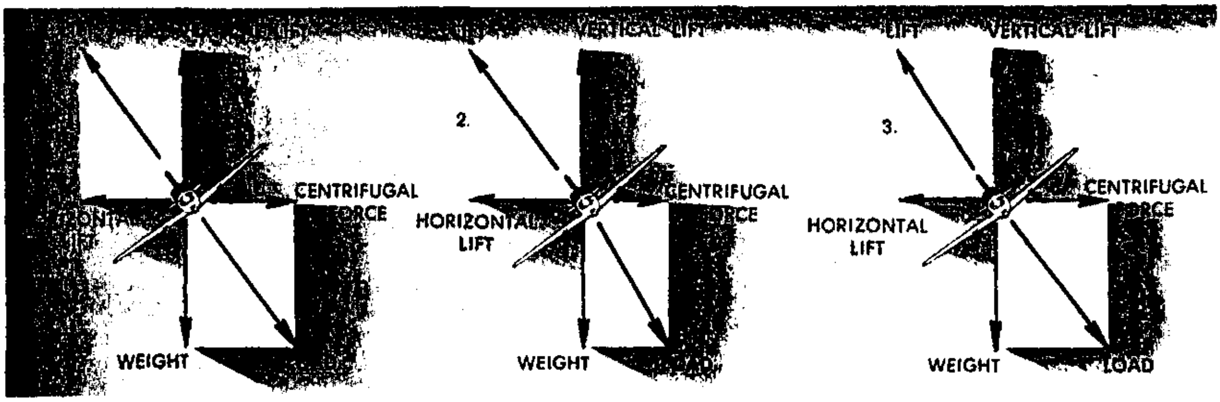


FIGURE 19. Relation of load factor to bank.



1. Normal turn. Centrifugal force equals horizontal lift.

2. Slipping turn. Centrifugal force less than horizontal lift.

3. Skidding turn. Centrifugal force greater than horizontal lift.

FIGURE 20. Forces during normal, slipping, and skidding turns.

vertical surfaces will restore the aircraft to proper alignment with the flight path.

To maintain straight flight in propeller-driven aircraft without slipping or skidding, rudder trim must be adjusted following changes in power settings and/or airspeed because the changes in torque effect and the airstream over the vertical tail surfaces varies the directional control. In aircraft having no controllable rudder trim, rudder pressure must be held to maintain directional trim during changes of power and/or airspeed.

Slips.—During a controlled slip, the aircraft is banked, and as noted earlier, the banking normally results in a turn. By application of rudder control opposite the direction of bank, the aircraft is prevented from turning. The banking results in sideways movement of the aircraft with respect to the direction maintained by rudder control.

In a slipping turn—level, climbing, or descending—the aircraft is not turning at the rate appropriate to the bank being used, and the aircraft is yawed toward the outside of the turning flight path. The aircraft is banked too much for the rate of turn, so the horizontal lift component is greater than the centrifugal force. Thus, the ball of the turn-and-slip indicator is displaced in the direction of bank, toward the inside of the turn. Equilibrium between the horizontal lift component and centrifugal force is reestablished either by decreasing the bank, increasing the rate of turn, or a combination of the two changes.

Skids.—A skid occurs in straight-and-level flight when the aircraft yaws either to the right or left, out of alignment with the desired flight path. A skidding turn results from excess of centrifugal force over the horizontal lift component, pulling the aircraft toward the outside of the turn. The rate of turn is too great for the angle of bank, and the ball in the turn-and-slip indicator is displaced toward the outside of the turn. Correction of a skidding turn thus involves a reduction in the rate of turn, an increase in bank, or a combination of the two changes.

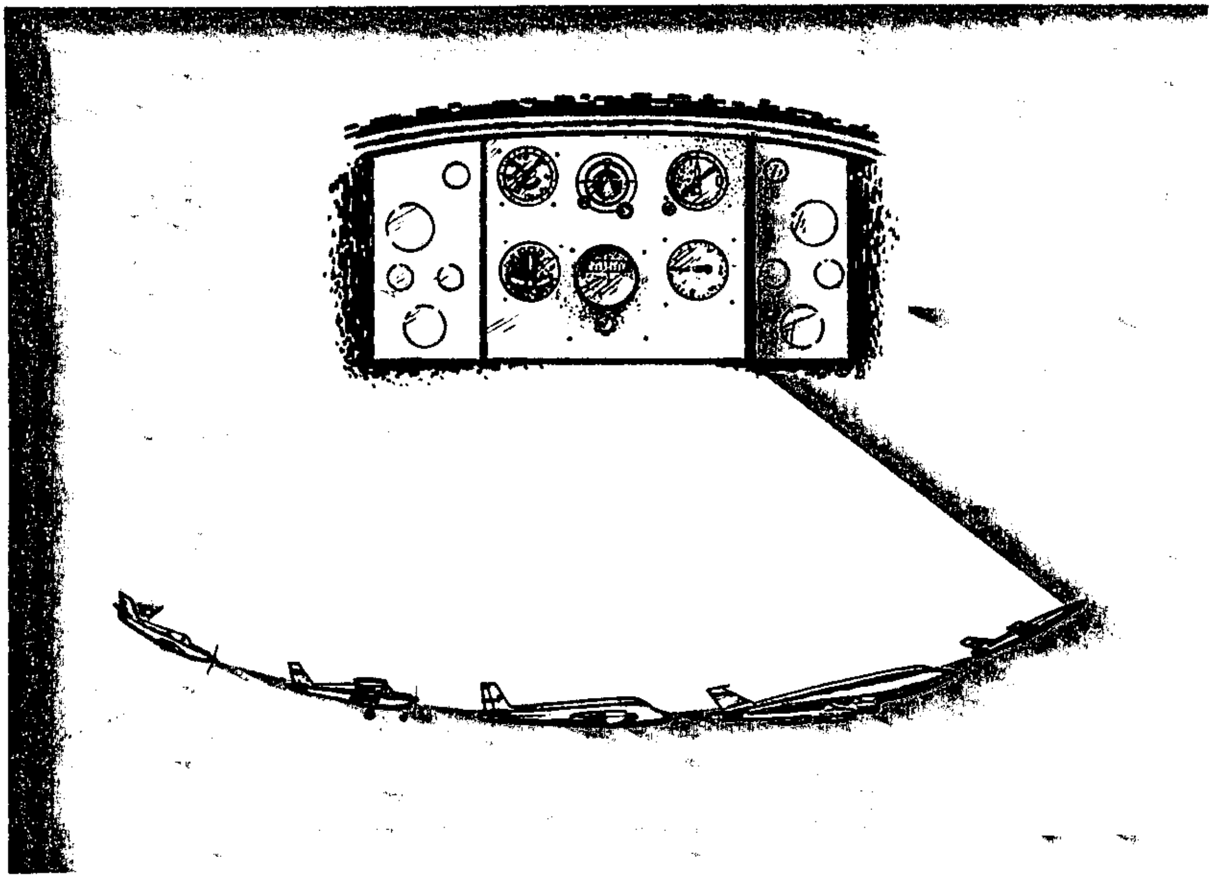
Coordination of Rudder and Aileron Controls

Coordination has a very specific meaning as applied to instrument flight techniques. It means using the controls to maintain or establish various conditions of flight with (1) a minimum disturbance of the forces maintaining equilibrium, or (2) the control action necessary to effect the smoothest changes in equilibrium. A controlled slip or skid, for example, requires considerable muscular coordination; the resulting slip or skid, however, is not a coordinated maneuver in the aerodynamic sense.

Coordination of controls during flight by reference to instruments requires that the ball of the turn-and-slip indicator be kept centered, and that available trim control devices be used whenever a change in flight condition disturbs the existing trim. Development of coordinated control technique depends not only on your understanding of the foregoing aerodynamic considerations, but on your attention to the characteristics of the particular type of aircraft in which you train.

Control sensitivities vary considerably in different aircraft and in a given aircraft at various speeds. From experience, you learn that one aircraft is extremely sensitive on rudder control and perhaps noticeably resistant to movement of elevator control; another aircraft has less than normal lateral stability and tends to overbank; another responds to thrust and drag changes unlike other aircraft. Your application of control pressures must be adapted to each airplane you fly.

Knowing why the aircraft will respond to your control will accelerate your progress in acquiring competent instrument flying techniques.



IV. BASIC FLIGHT INSTRUMENTS

If you are among the large group of pilots for whom training cost is a critical consideration, you will be concerned with minimum equipment requirements. The expected cost deters many pilots who have access to aircraft that may be inadequate for weather flying, yet suitable for initial instrument training. An 85-hp light plane will not perform like the latest super-custom light twin, nor will it necessarily take you on instruments where and when you want to go. However, you can acquire substantial basic instrument flying proficiency in any aircraft having the instruments necessary for control of attitude, altitude, speed, and direction. With an altimeter, airspeed indicator, and turn-and-slip indicator (needle/ball), you have the minimum necessary primary group of instruments. This group is also called the "partial panel" or "emergency panel."

Note that all of the instrument panels shown in Figure 21 include the same basic group. Regardless of how elaborately equipped an airplane is, the instrument pilot must know how to use these minimum instruments necessary for aircraft control. Most of the aircraft currently manufactured for civilian training provide the instruments and equipment required by Federal Aviation Regulation Part 91 for IFR flight. FAR Part 91 also specifies the instruments and equipment needed for daytime Visual Flight Rules and, when applicable, for nighttime Visual Flight Rules.

Gyroscopic Instruments

Of the six basic flight instruments, three (attitude indicator, heading indicator, and turn indicator) are controlled by gyroscopes. Understanding the use of these instruments requires a knowledge of gyroscopic principles, instrument

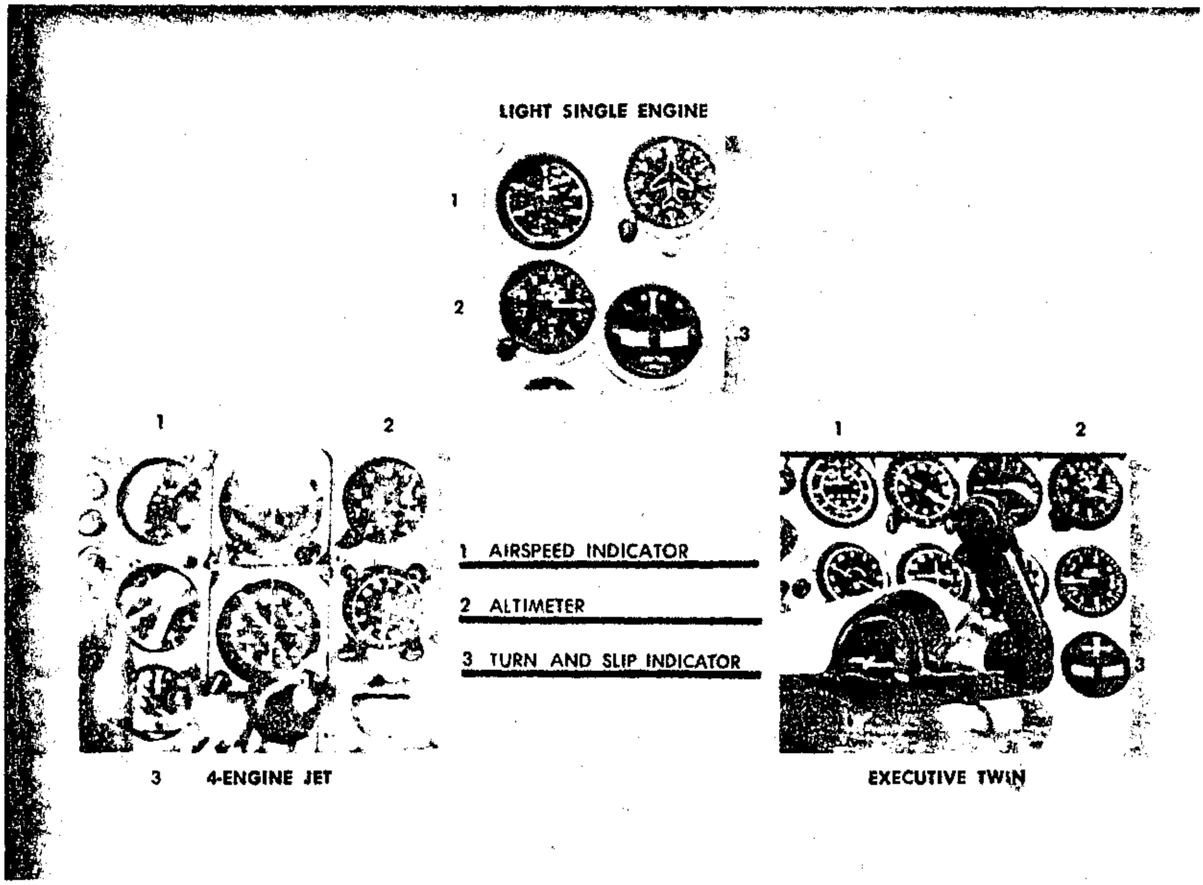


FIGURE 21. Partial panel (light single-engine, executive twin, 4-engine jet).

power systems, and the construction and operating details of each instrument. Without the gyroscope and its practical adaptation to flight and navigational instruments, precision all-weather flying would be impossible.

Gyroscopes.—Any rotating body exhibits gyroscopic properties according to Newton's laws of motion. The first law states: A body at rest will remain at rest; or if in motion in a straight line, it will continue in motion in a straight line unless acted upon by an outside force. The second law states: The deflection of a moving body is proportional to the deflective force applied and is inversely proportional to its weight and speed. A gyroscope, or gyro, is a wheel or disc designed to utilize these principles.

Gyroscopic inertia depends upon several design factors:

1. *Weight.*—For a given size, a heavier mass is more resistant to disturbing forces than a lighter mass.

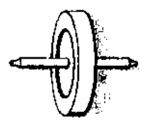
2. *Angular Velocity.*—The higher the rotational speed, the greater the rigidity, or resistance to deflection.

PRINCIPLES OF THE GYROSCOPE

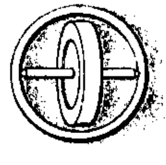
A gyroscope is a spinning mass or wheel, universally mounted, so that only one point — its center of gravity — is in a fixed position, the wheel being free to turn in any direction around this point.

To simplify this explanation we will illustrate the construction of a demonstrating model step by step.

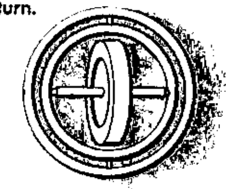
1.
Picture a rotor and axle, with the rim of the rotor more or less facing you.



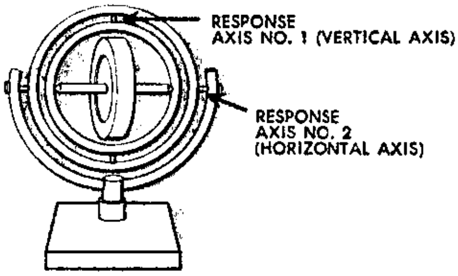
2.
Give it a supporting ring, with bearings on which the rotor and its axle can revolve.



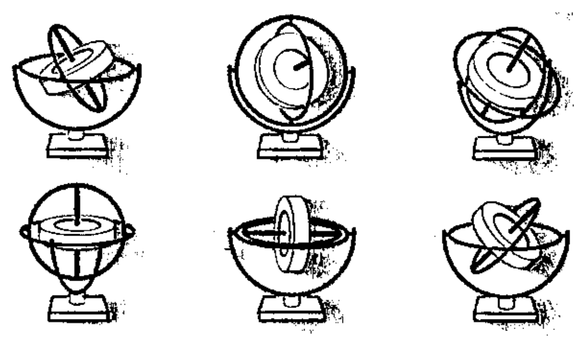
3.
Now add an outer ring with bearings at 90° to the rotor bearings, about which the inner ring with its rotor and axle can turn.



4.
Draw a frame which will support the rotor and its rings on horizontal bearings; this will complete your demonstrating model gyroscope. Disregarding the spin axis, the gyroscope has two degrees of freedom; the assembly can turn about a vertical axis (response axis No. 1) and also about a horizontal axis (response axis No. 2).



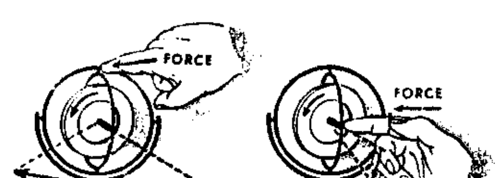
5.
When at rest there's nothing unusual about a gyroscope. It's simply a wheel universally mounted. You can point its axle in any direction without altering the geometrical center of the assembly.



6.
But when you spin the rotor the gyroscope exhibits the first of its two characteristics. It acquires a high degree of rigidity and its axle keeps pointing in the same direction no matter how much you turn the base about. This is **gyroscopic inertia**.

7.
The second characteristic, **precession**, may be illustrated by applying a force or pressure to the gyro about the horizontal axis as shown below (1). It will be found that the applied pressure meets with resistance and that the gyro, instead of turning about its horizontal axis, turns or "precesses" about its vertical axis in the direction indicated by the arrow P. Similarly, if we apply a pressure about the vertical axis, the gyro will precess about its horizontal axis as shown by the arrow P at right, below (2).

GYROSCOPIC INERTIA



PRECESSION

Figure 22. Principles of the gyroscope.

3. *Radius at Which the Weight Is Concentrated.*—Maximum effect is obtained from a mass when its principal weight is concentrated near the rim rotating at high speed.

4. *Bearing Friction.*—Any friction applies a deflecting force to a gyro. Minimum bearing friction keeps deflecting forces at a minimum.

Two types of mounting are used, depending upon how the gyroscopic properties are to be used in the operation of the instrument. A freely of universally mounted gyro is set on three gimbals, with the gyro free to rotate in any plane. Regardless of the position of the gyro base, the gyro tends to remain rigid in space. In the attitude indicator, the horizon bar is gyro-controlled to remain parallel to the natural horizon, and changes in position of the aircraft are shown pictorially (Fig. 23).

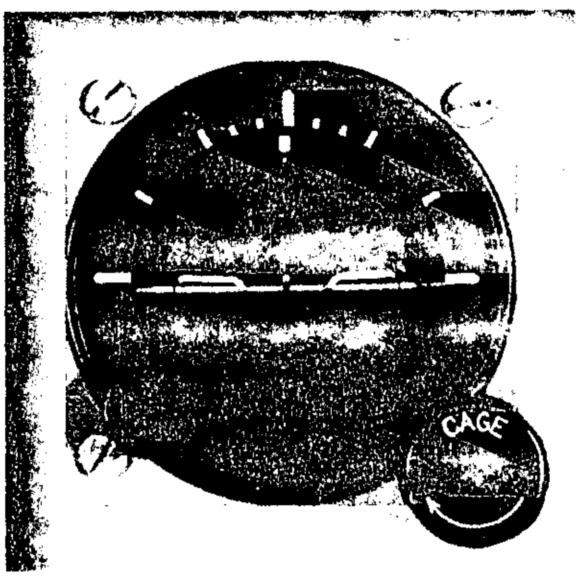


FIGURE 23. Attitude indicator or gyro-horizon.

The semirigid, or restricted, mounting employs two gimbals, limiting the rotor to two planes of rotation. In the turn indicator, the semirigid mounting is used to provide controlled precession of the rotor, and the precessing force exerted on the gyro by the turning aircraft causes the needle to indicate a turn (Fig. 24).

Sources of Power For Gyro Operation

The gyroscopic instruments can be operated either by the vacuum system or the electrical system. In some aircraft, all the gyros are either electrically or vacuum motivated; in others, vacuum systems provide the power for the attitude and heading indicators, while the electrical system drives the gyro for operation of the turn needle. Both systems have advantages and disadvantages.

Vacuum (Suction) System.—The vacuum system spins the gyro by sucking a stream of air against the rotor vanes to turn the rotor at high speed, essentially as a water wheel or turbine operates. Air at atmospheric pressure drawn into the instrument through a filter or filters, drives the rotor vanes and is sucked from the instrument case through a line to the vacuum source, and vented into the atmosphere. Either a venturi or a vacuum pump can be used to provide the suction required to spin the rotors of the gyro instruments.

Vacuum values vary with differences in gyro design for optimum rotor speed, ranging approximately from 8,000 to 18,000 rpm in different instruments. The suction for the three indicators is given in inches of mercury (Hg) as follows:

	Minimum	*Desired*	*Maximum*
	(inches of mercury)		
Turn Indicator	1.8	1.9	2.1
Attitude Indicator	3.5	4.0	5.0
Heading Indicator	3.5	4.0	5.0

Venturi Tube.—The advantages of the venturi are its relatively low cost, and simplicity of installation and operation. A light single-engine airplane suitable for limited instrument training can be equipped with a 2″ venturi (2″ Hg vacuum capacity) to operate the turn needle. With an additional 8″ venturi, power is available for the attitude and heading indicators. A venturi tube and vacuum system are shown in Figure 25. The line from the gyro is connected

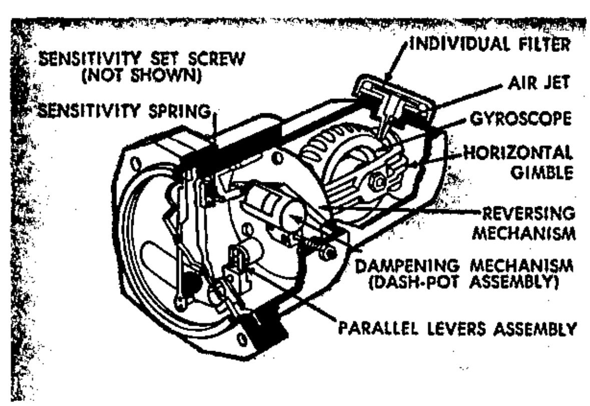


FIGURE 24. Turn indicator.

to the throat of the venturi, mounted on the side of the fuselage. Throughout the normal operating airspeed range, the velocity of the air

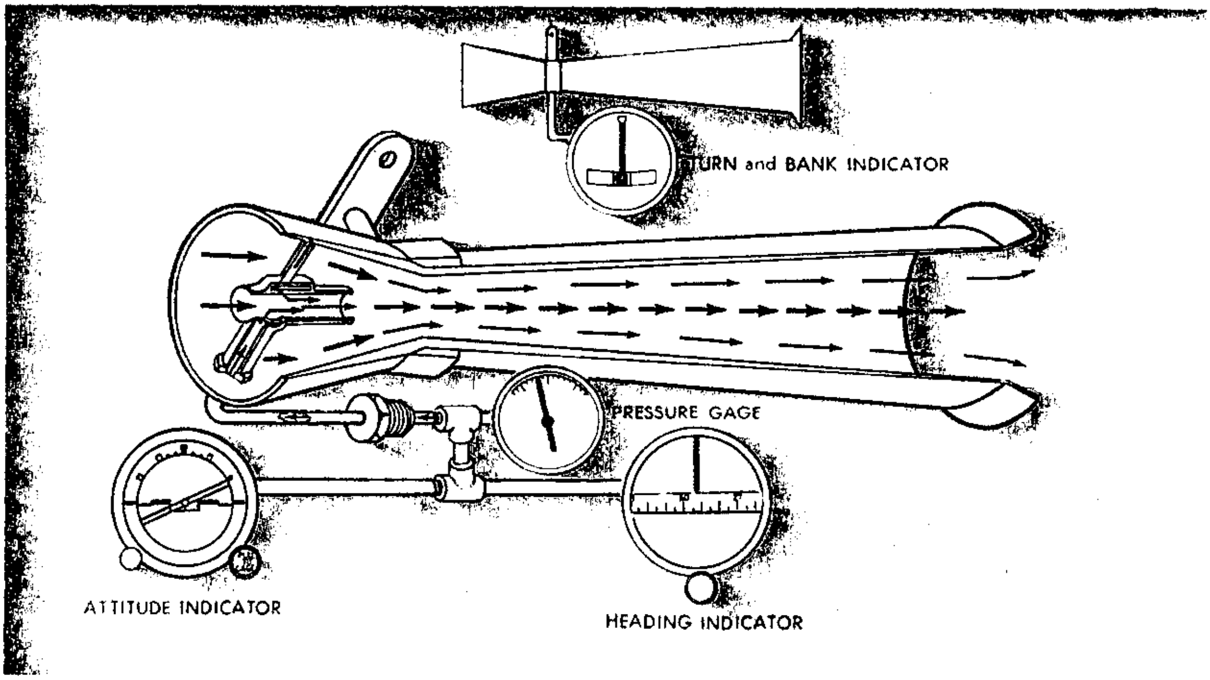


FIGURE 25. Venturi tube and vacuum system

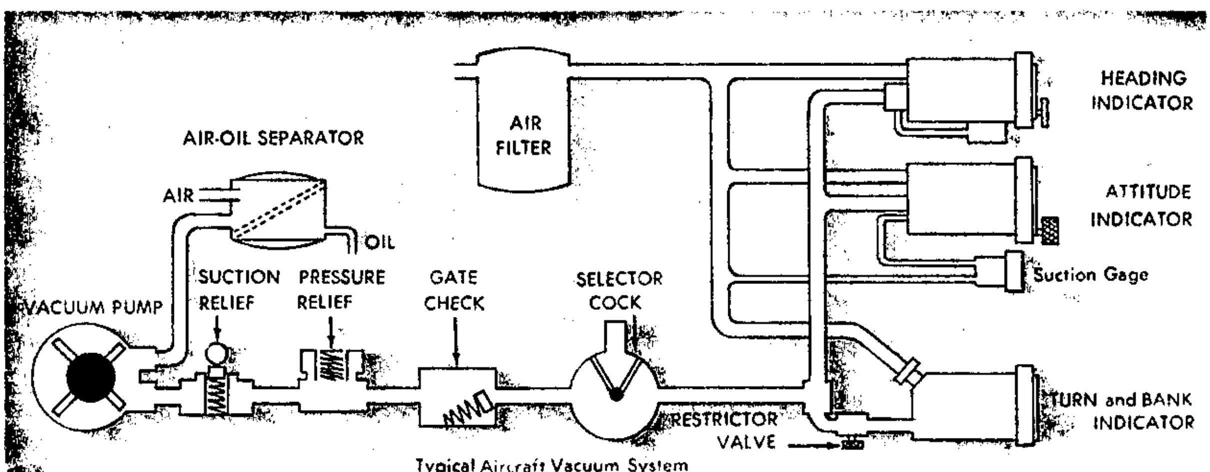


FIGURE 26. Pump-driven vacuum system.

through the venturi creates sufficient suction to spin the gyro.

The limitations of the venturi system should be evident from the illustration in Figure 25. The venturi is designed to produce the desired vacuum at approximately 100 mph under standard sea-level conditions. Wide variations in airspeed or air density, or restriction to airflow by ice accretion, will affect the pressure at the venturi throat and thus the vacuum driving the gyro rotor. Further, since the rotor does not reach normal operating speed until after takeoff, pre-flight operational checks of venturi-powered gyro instruments cannot be made. For this reason, the system is adequate only for light plane instrument training and limited flying under instrument weather conditions. Aircraft flown throughout a wider range of speed, altitude, and weather conditions require a more effective source of power independent of airspeed and less susceptible to adverse atmospheric conditions.

Engine-Driven Vacuum Pumps.—The vane-type engine-driven pump is the most common source of vacuum for gyros installed in general aviation light aircraft. One type of engine-driven pump is mounted on the accessory drive shaft of the engine, and is connected to the engine lubrication system to seal, cool, and lubricate the pump. The diagram in Figure 26 shows the components of a vacuum system with a pump capacity of approximately 10" Hg at engine speeds above 1000 rpm. Pump capacity and pump size vary in different aircraft, depending on the number of gyros to be operated.

Air-Oil Separator.—Oil and air in the vacuum pump is exhausted through the separator, which separates the oil from the air, vents the air outboard, and returns the oil to the engine sump.

Suction Relief Valve.—Since the system capacity is more than is needed for operation of the instruments, the adjustable suction relief valve is set for the vacuum desired for the instruments. Excess suction in the instrument lines is reduced when the spring-loaded valve opens to atmospheric pressure.

Pressure Relief Valve.—Since a reverse flow of air from the pump would close both the gate check valve and the suction relief valve, the resulting pressure could rupture the lines. The pressure relief valve vents positive pressure into the atmosphere.

Gate Check Valve.—The gate check valve prevents possible damage to the instruments by engine back-fire, which would reverse the flow of air and oil from the pump.

Selector Cock.—In twin-engine aircraft having vacuum pumps driven by both engines, the alternate pump can be selected to provide vacuum in the event of either engine or pump failure, with a check valve incorporated to seal off the failed pump.

Restrictor Valve.—Since the turn needle operates on less vacuum than that required for other gyro instruments, the vacuum in the main line must be reduced. This valve is either a needle valve adjusted to reduce the vacuum from the main line by approximately one-half, or a spring-loaded regulating valve that maintains a constant vacuum for the turn indicator, unless the main line vacuum falls below a minimum value.

Air Filter.—The master air filter screens foreign matter from the air flowing through all the gyro instruments, which are also provided with individual filters. Clogging of the master filter will reduce airflow and cause a lower reading on the suction gage. In aircraft having no master filter installed, each instrument has its own filter. With an individual filter system, clogging of a filter will not necessarily show on the suction gauge.

Suction gauge.—The suction gauge is a pressure gauge, indicating the difference, in inches of mercury, between the pressure inside the system and atmospheric or cockpit pressure. The desired vacuum, and the minimum and maximum limits, vary with gyro design. If the desired vacuum for the attitude and heading indicators is 5" and the minimum is 4.6", a reading below the latter value indicates that the airflow is not spinning the gyros fast enough for reliable operation. In many aircraft, the system provides a suction gauge selector valve, permitting the pilot to check the vacuum at several points in the system.

Another commonly used source of vacuum is the dry vacuum pump, also engine-driven. The pump operates without lubrication, and the installation requires no lines to the engine oil supply, and no air-oil separator or gate check valve. In other respects, the dry pump system and oil lubricated system are the same.

The principal disadvantage of the pump-driven vacuum system relates to erratic operation in high-altitude flying. Apart from routine maintenance of the filters and plumbing, which are absent in the electric gyro, the engine-driven pump is as effective a source of power for light aircraft as the electrical system.

Electrical System.—The electrically driven gyro was designed for military aircraft instruments after tests showed erratic operation of vacuum-driven gyros at high altitude. At 18,000 feet, in atmospheric pressure approximately half of that at sea level, the vacuum pump is about half as efficient as at sea level. At progressively higher altitudes or extremely low temperatures affecting oil viscosity, the vacuum system will not create enough suction to operate the gyros at desired speed.

The principal value of the electric gyro in light aircraft is its safety factor. In single-engine aircraft equipped with vacuum-driven attitude and heading indicators, the turn needle is commonly operated by an electric gyro. In the event of vacuum system failure and loss of two gyro instruments, the pilot still has a reliable standby instrument for emergency operation. Operated on current directly from the battery, the electric turn indicator is reliable as long as current is available, regardless of generator or vacuum system malfunction. In the electric instrument, the gyro is a small electric motor and flywheel. Otherwise, both electric and vacuum-driven turn-needles are designed to use the same gyroscopic principle of precession. Figure 27 shows a typical 12-volt, direct-current light plane electrical system.

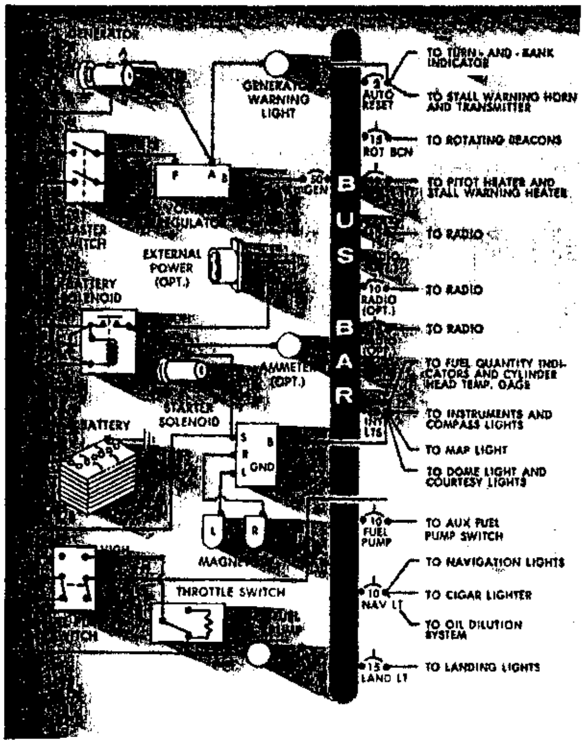


FIGURE 27. Electrical system.

Attitude Indicators

The attitude indicator—also referred to as the gyro-horizon, attitude gyro, and artificial horizon—is constructed to show the attitude of your aircraft in relation to the natural horizon when for any reason you must, or choose to, control your aircraft by visual reference inside, rather than outside, the cockpit. Irrespective of variations in instrument design, all attitude indicators relate a gyro-controlled artificial horizon line to some form of pitch and bank reference.

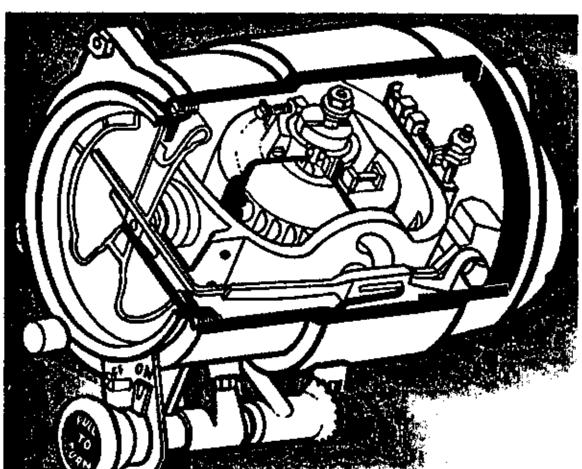


FIGURE 28. Attitude indicator components (vacuum-driven).

Vacuum-Driven Attitude Indicators.—The cutaway diagram in Figure 28 shows the basic components of a typical attitude indicator. The rotor, mounted within a sealed housing, spins in a horizontal plane about the vertical axis. The housing pivots about the lateral axis on a gimbal, which in turn is free to pivot around the longitudinal axis. The instrument case is the third gimbal necessary for universal mounting.

The horizon bar is linked to the gyro by a lever, attached to a pivot on the rear of the gimbal frame and connected to the gyro housing by a guide pin. While the gyro rotates in a fixed plane, the miniature aircraft is superimposed on the horizon line in straight-and-level flight. As the aircraft climbs, dives, or banks, the instrument case rotates on the gimbals while the bank index and horizon bar remain rigid. Thus, the instrument reflects any movement of the aircraft around the pitch and roll axes.

Air is sucked through the filter, then through passages in the rear pivot and inner gimbal ring, then into the housing, where it is directed against the rotor vanes through two openings on opposite sides of the rotor. The air then passes through four equally spaced ports in the lower part of the rotor housing and is sucked out into the vacuum pump or venturi tube.

The chamber containing the ports is the erecting device that returns the spin axis to its vertical alignment whenever a precessing force, such as bearing friction, displaces the rotor from its horizontal plane. The four exhaust ports are each half-covered by a pendulous vane, which allows discharge of equal volumes of air through each port when the rotor is properly erected. Any tilting of the rotor disturbs the total balance of the pendulous vanes, tending to close one vane of an opposite pair while the opposite vane opens a corresponding amount. The increase in air volume through the opening port exerts a precessing force on the rotor housing to erect the gyro, and the pendulous vanes return to a balanced condition. See Figures 29 and 30.

Limits.—The limits of the instrument refer to the maximum rotation of the gimbals beyond which the gyro will tumble. The older type vacuum-driven attitude indicators have bank limits of approximately 100° to 110°, and pitch limits of 60° to 70°. If, for example, the pitch limits are 60° with the gyro normally erected, the rotor will tumble when the aircraft climb or dive angle exceeds 60°. As the rotor gimbal hits the stops, the rotor precesses abruptly, causing excessive friction and wear on the gimbals. The

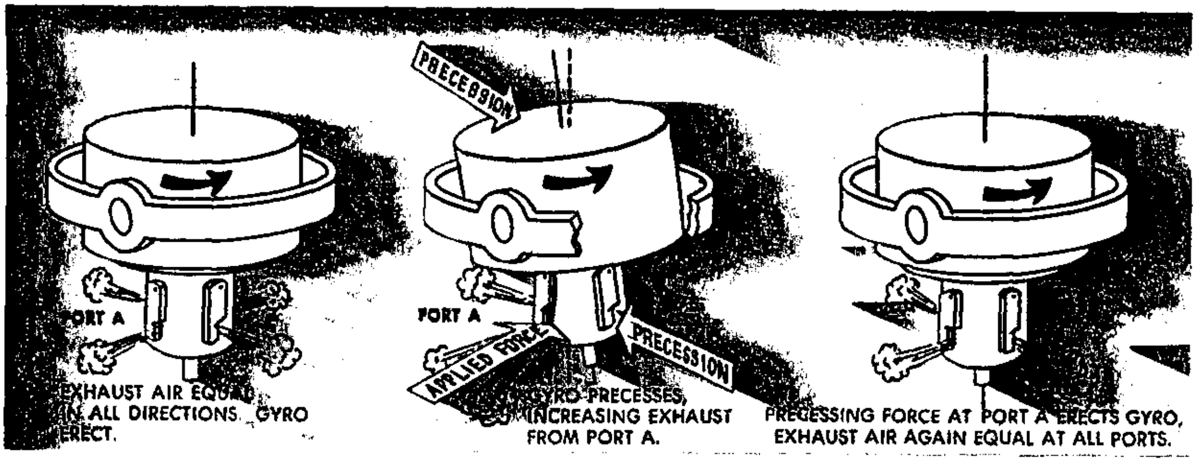


FIGURE 29. Erecting mechanism, vacuum-driven attitude indicator.

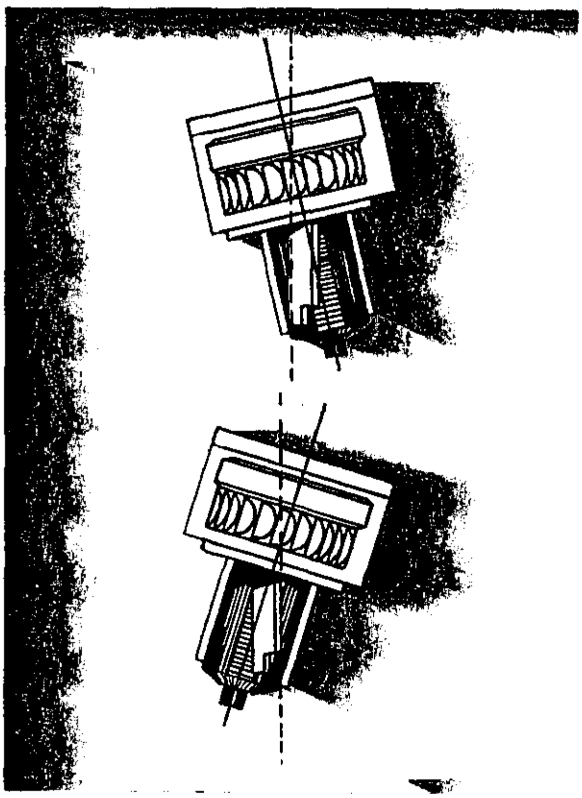


FIGURE 30. Action of pendulous vanes.

rotor will normally precess back to the horizontal plane at a rate of approximately 8° per minute. The limits of more recently developed vacuum-driven attitude indicators exceed those given above.

Caging.—Many gyros include a manual caging device, used to erect the rotor to its normal operating position prior to flight or after tumbling, and a flag to indicate that the gyro must be uncaged before use. Turning the caging knob prevents rotation of the gimbals and locks the rotor spin axis in its vertical position. Because the rotor is spinning as long as vacuum power is supplied, normal maneuvering with the gyro caged wears the bearings unnecessarily. Therefore, the instrument should be left uncaged in flight unless the limits are to be exceeded.

In the caged position, the gyro is locked with the miniature aircraft showing level flight, regardless of aircraft attitude. When uncaged in flight, in any attitude other than level flight, the gyro will tend to remain in an unlevel plane of rotation with the erecting mechanism attempting to restore the rotor to a horizontal plane. Therefore, should it be necessary to uncage the gyro in flight, the actual aircraft attitude must be identical to the caged attitude (that is, straight and level), otherwise, the instrument will show false indications when first uncaged.

Errors.—Errors in the indications presented on the attitude indicator will result from any factor that prevents the vacuum system from operating within the design suction limits, or from any force that disturbs the free rotation of the gyro at design speed. Some errors are attributable to manufacturing and maintenance. These include poorly balanced components, clogged filters, improperly adjusted valves, and pump malfunction. Such errors can be minimized by proper installation and inspection.

Other errors, inherent in the construction of the instrument, are caused by friction and worn parts. These errors, resulting in erratic precession and failure of the instrument to maintain accurate indications, increase with the life of the instrument.

Another group of errors, associated with the design and operating principles of the attitude indicator, are induced during normal operation of the instrument. A skidding turn moves the pendulous vanes from their vertical position, precessing the gyro toward the inside of the turn. After return of the aircraft to straight-and-level, coordinated flight, the miniature aircraft shows a turn in the direction opposite the skid. During a normal turn, movement of the vanes by centrifugal force causes precession of the gyro toward the inside of the turn.

Errors in both pitch and bank indications are usually at a maximum at 180° of turn. As the aircraft rolls out of a 180° turn to straight-and-level flight, as shown on the attitude indicator, the aircraft will be in a slight turn to the right, climbing slightly. This precession error, normally 3° to 5°, is quickly corrected by the erecting mechanism. At the end of a 360° turn, the precession induced during the first 180° is canceled out by precession in the opposite direction during the second 180° of turn. The slight precession errors induced during the roll-out are corrected immediately by pendulous vane action.

Acceleration and deceleration also induce precession errors, depending upon the amount and extent of the force applied. During acceleration the horizon bar moves down, indicating a climb. Control applied to correct this indication will result in a pitch attitude lower than the instrument shows. The opposite error results from deceleration. Other errors, such as "transport precession" and "apparent precession," relate to rotation of the earth and are of importance to pilots and navigators concerned with high-speed and long-range flight.

The application of the foregoing errors as they affect instrument interpretation will be treated later in Chapter V, "Attitude Instrument Flying."

Electric Attitude Indicators.—In the past, suction-driven gyros have been favored over the electric type for light aircraft because of their comparative simplicity and lower cost. However, the increasing importance of the attitude indicator has stimulated development of improved electric-driven gyros suited to light plane installation. Improvements relating to basic gyro design factors, easier readability, erection characteristics, reduction of induced errors, and instrument limitations are reflected in several available types. Depending upon the particular design improvements, the details among different instruments will vary as to the instrument display and cockpit controls. All of them present, to a varying degree, the essential pitch and bank information for attitude reference.

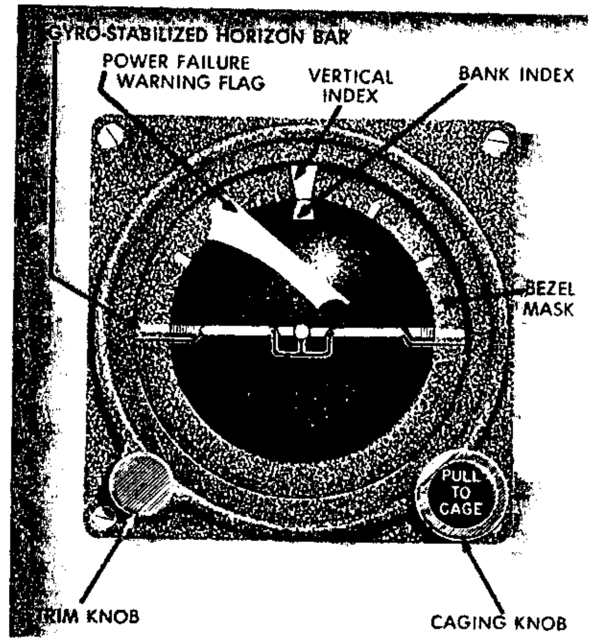


FIGURE 31. H-6B gyro horizon.

Electric gyros may be remotely located, with the gyro assembly mounted at some convenient location other than behind the instrument panel, and with the indicator assembly on the instrument panel driven through a servo motor. Another type is a simpler unit incorporating the gyroscope motor in the instrument case integral with the indicator assembly. The H–6B attitude indicator and J–8 gyro-horizon are representative of this type (Figs. 31 and 32).

J–8 Attitude Indicator.—The J–8 has a vertical seeking gyro, the axis of rotation tending to point toward the center of the earth (Fig. 32). The gyro is linked with a horizon bar and stabilizes a kidney-shaped sphere with pitch attitude markings. The sphere, horizon bar, and bank index pointer move with changes of aircraft attitude. Combined readings of these presentations give a continuous pictorial presentation of the aircraft attitude in pitch and roll with respect to the earth's surface.

The gyroscope motor is driven by 115-volt, 400-cycle alternating current. The gyro, turning at 21,000 rpm, is supported by the yoke and pivot assembly (gimbals). Attached to the yoke and pivot assembly is the horizon bar, which moves up and down through an arc of approximately 27°. The kidney-shaped sphere provides a background for the horizon bar and has the words CLIMB and DIVE and a bullseye painted on it. CLIMB and DIVE represent about 60°

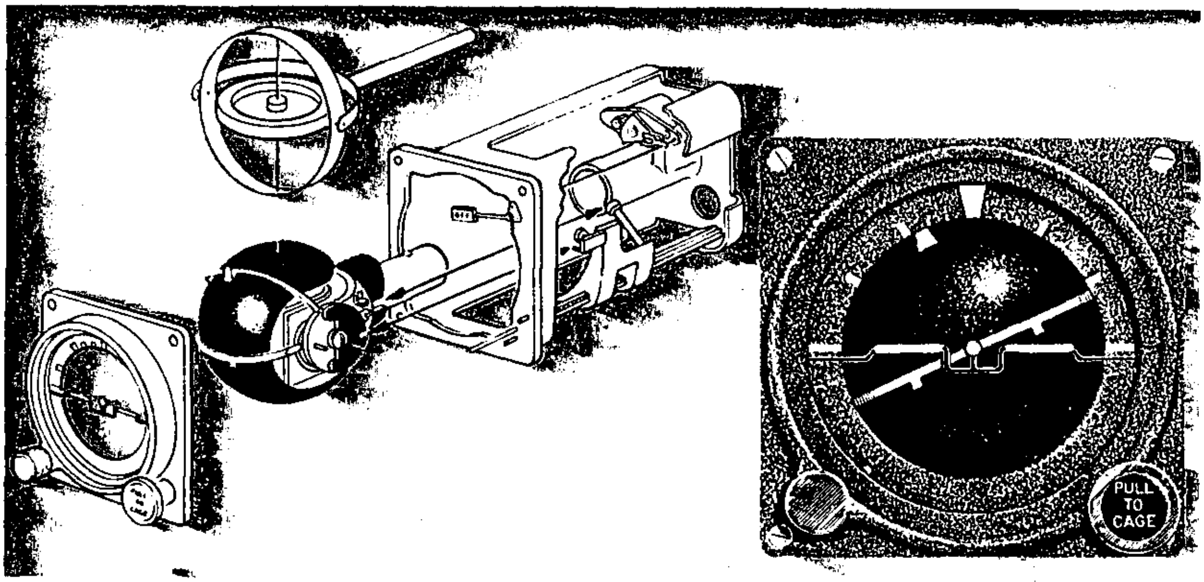


FIGURE 32. Attitude indicator components (electrically driven).

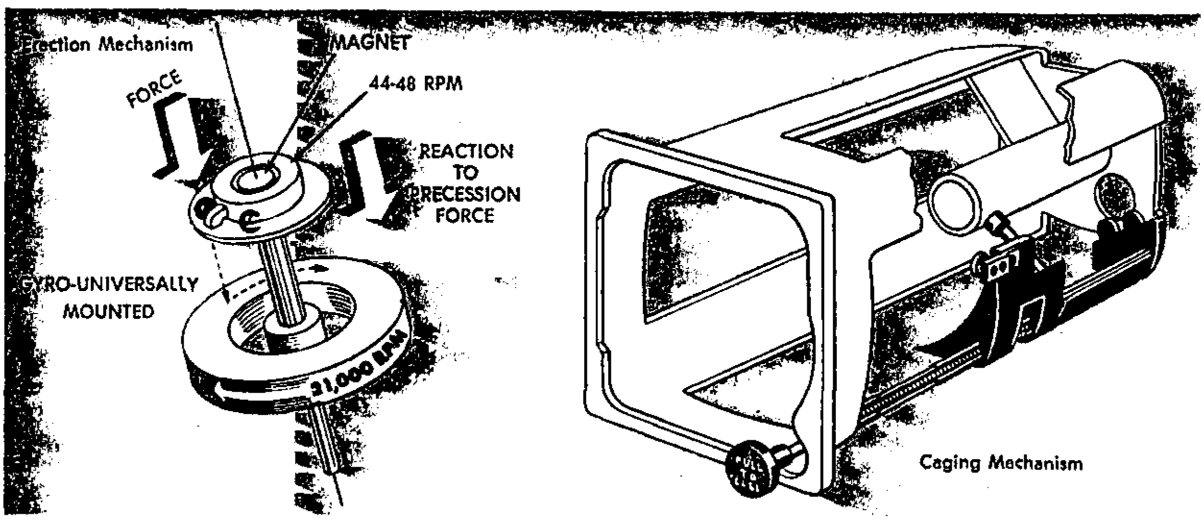


FIGURE 33. Erecting and caging mechanisms of an electric attitude indicator.

of pitch. Attached to the yoke and pivot assembly is the bank index pointer which is free to rotate 360°. The dial face of the attitude indicator is marked with 0°, 10°, 20°, 30°, 60°, and 90° of bank, and is used with the bank index pointer to indicate the degree of bank left or right.

Erection and Caging Mechanisms.—The function of the erection mechanism is to keep the gyro axis vertical to the surface of the earth. A magnet attached to the top of the gyro shaft spins at 21,000 rpm. Around this magnet, but not attached, is a sleeve that is rotated by magnetic attraction at approximately 44 to 48 rpm. As illustrated in Figure 33, the steel balls revolve. If the pull of gravity is not aligned with the axis of the gyro, the balls will fall to the low side. The resulting precession realigns the axis of rotation vertically.

The gyro can be caged manually by a lever and cam mechanism to provide rapid erection. When the instrument is not getting sufficient power for normal operation, an "OFF" flag appears in the upper right face of the instrument.

The instrument permits 360° of rotation about the pitch and bank axes without tumbling the gyro. The expanded motion of the horizon bar provides sensitive pitch indications near the level flight position.

When the aircraft exceeds the maximum of 27° in pitch up or down, the horizon bar is held in extreme position and the sphere becomes the new reference. A continued increase of climb or dive angle approaching the vertical attitude is indicated by graduations on the sphere. When the aircraft nears vertical, the sphere begins to rotate 180°. As soon as the aircraft departs from the vertical, the instrument again indicates the attitude of the aircraft. This momentary rotation of the sphere is known as controlled precession and should not be confused with gyro tumbling. The attitude of the aircraft about the roll axis is shown by the angle between the horizon bar and the miniature aircraft, and also by the bank index relative to the degree marking on the bezel mask (face plate).

Errors.—Following recovery from unusual attitudes, displacement of the horizon bar in excess of 5° in pitch and/or bank may result. Once the instrument senses gravitational forces, the erection mechanism will immediately begin to correct the precession errors at a rate of 3° to 6° per second. In a normal turn, centrifugal force acting on the erection mechanism will produce normal precession errors in pitch and/or bank up to 5° on return to straight-and-level flight. Acceleration or deceleration will also result in precession errors in proportion to the duration and magnitude of the speed change. Following acceleration, the aircraft pitch attitude will be lower than the instrument indication; following deceleration, the aircraft attitude will be higher than the pitch indication until the erection mechanism realigns the gyro.

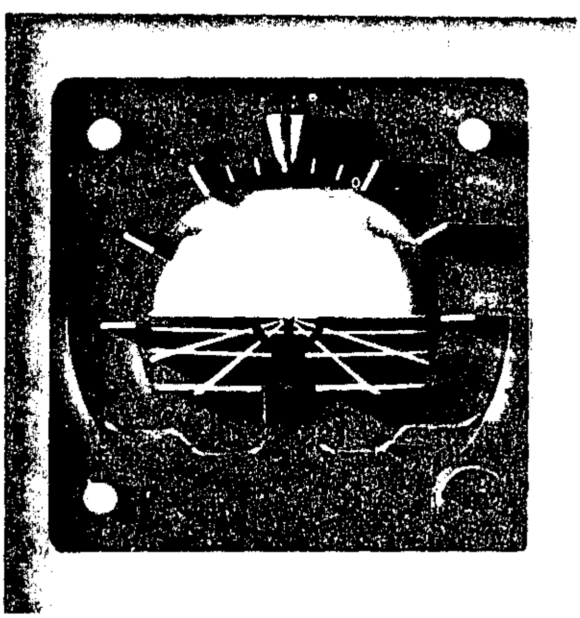


FIGURE 34. Simplified attitude indicator design.

Trends in Attitude Indicator Design

The value of the attitude indicator is directly related to the readability of the instrument; that is, to the speed and ease with which you can get information from it to determine exact aircraft attitude.

Although the older type attitude indicators are not difficult to interpret in normal flight attitudes, reference to other instruments to confirm the indications observed on the attitude indicator is recommended and particularly when abnormal flight attitudes are experienced. The greater the divergence of the miniature aircraft from the horizon line, the more difficult exact interpretation becomes, yet the extreme attitude is the condition requiring immediate and accurate visual information.

The operation of the bank index can also be confusing. When the aircraft is banked to the right, the index moves left (counterclockwise) and vice versa. Students commonly misinterpret this motion of the bank index and apply aileron control in the wrong direction. Requirements of high performance aircraft have accelerated research to improve readability and reliability of the attitude gyro.

One improved attitude indicator design is shown in Figure 34. In this design, the "SLOTTED" bank index has been moved to the upper periphery of the case to improve readability of the angle of bank as read on the graduated scale which is attached to the case. Further bank references are to be seen in the form of converging lines to a point on the horizon. Pitch references are the horizon line and the ground lines parallel to the horizon line.

Integrated Flight System (Flight Director System)

Further advances in attitude instrumentation combine the gyro horizon with other instruments, thereby reducing the number of separate instruments to which the pilot must devote his attention. An integrated flight system consists of electronic components which compute and indicate the aircraft attitude required to attain and maintain a pre-selected flight condition. "Command" indicators tell the pilot in what direction and how much to change aircraft attitude to achieve the desired result. The computed com-

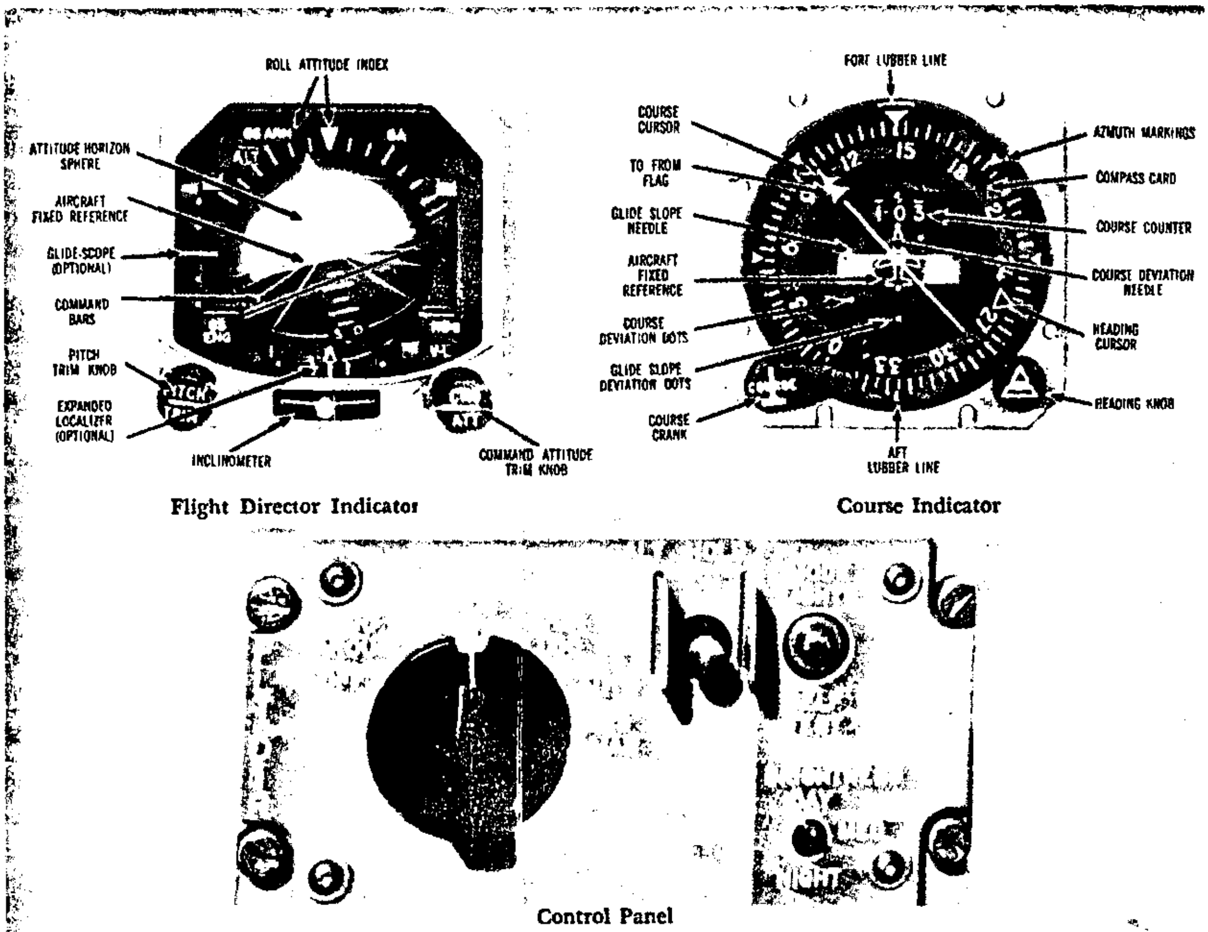


FIGURE 35. Integrated flight system.

mand indications relieve the pilot of many of the mental calculations required for instrument flight.

A typical integrated flight system includes a control panel, a flight director indicator, a course indicator, a steering computer, and an instrument amplifier. The first three of these components are illustrated in Figure 35. The control panel contains the controls by which the pilot selects the desired mode of operation. When a mode is selected, the corresponding annunciator is illuminated on the periphery of the flight director indicator. The modes available in the installation depicted are:

OFF—the command bars move out of sight and the flight director indicator functions as an attitude indicator.

GO-AROUND—a fixed nose-up and wings-level attitude is provided based on such factors as airspeed, angle of attack, and throttle setting.

HEADING—a computed roll command is generated which is proportional to (but limited to a maximum value) the difference between the actual aircraft heading and the heading selected on the course selector.

VOR/LOC—provides for variable angle of capture of a selected VOR radial or localizer, and after capture provides for drift correction.

GS AUTO—provides for automatic capture of the glide slope when approaching it from below.

GS MAN—provides a backup for GS AUTO and provides for manual capture of the glide slope from either above or below.

ALT HOLD—references pitch commands to barometric altitude. Computed commands pictorially command a climb or descent to maintain the altitude the aircraft was flying at the time the ALT HOLD switch was engaged.

The *flight director indicator* incorporates basic attitude information and pitch and roll commands in one instrument. The command bars, positioned by signals from a steering computer, display the integrated pitch and roll commands of the mode selected. A pitch trim knob, located on the lower left corner of the instrument case, changes the position of the attitude-horizon sphere about the pitch axis. A command attitude trim knob, located on the lower right corner of the case changes the position of the command bars about the pitch axis. An inclinometer (ball) indicates coordination. Illuminated annunciators indicate the mode in use. Malfunction of an input reference system is indicated by a warning flag. The course indicator gives the pilot a pictorial presentation of aircraft position relative to VOR radials, a localizer, and a glide slope beam. It also gives heading reference relative to magnetic north. The various features and components of the instrument are labeled in Figure 35. Malfunctions are indicated by appropriate warning flags.

Since compact, low cost integrated flight systems are presently being developed, the future pilot of sophisticated private, business, and executive aircraft as well as the airline and military pilot will be using one of these systems as standard equipment. A flight control guidance system which consists of either an automatic pilot with an approach coupler or a flight director system is required for Category II operations.

Turn and Slip Indicator

The turn and slip indicator, also referred to as the "needle and ball" and "turn and bank" indicator, was the only available reference for bank attitude before the development of the attitude indicator. Its principal uses in modern aircraft are to indicate trim and to serve as an emergency source of bank information in case the attitude gyro fails.

The turn and slip indicator is actually a combination of two instruments: The needle is gyro-operated to show rate of turn and the ball reacts to gravity and/or centrifugal force to indicate the need for directional trim.

Turn Needle Operation.—The turn needle is operated by a gyro, driven either by vacuum or electricity. Semirigid mounting of the gyro permits it to rotate freely about the lateral and longitudinal axes while restricting its rotation about the vertical axis. The gyro axis is horizontally mounted so that the gyro rotates up and away from the pilot. The gimbal around the gyro is pivoted fore and aft.

Gyroscopic precession causes the rotor to tilt when the aircraft is turned. Due to the direction of rotation, the gyro assembly tilts in the opposite direction from which the aircraft is turning; this prevents the rotor axis from becoming vertical to the earth's surface. The linkage between the gyro assembly and the turn needle, called the reversing mechanism, causes the needle to indicate the proper direction of turn.

A spring is attached between the instrument case and the gyro assembly to hold the gyro upright when no precession force is applied. Tension on the spring may be adjusted to calibrate the instrument for a given rate of turn. The spring restricts the amount of gyro tilt. Stops prevent the gyro assembly from tilting more than 45° to either side of the upright position. In addition, a damping mechanism prevents excessive oscillation of the turn needle.

Power for the electric gyro may be supplied from either an AC or DC source. When current is supplied directly from the battery, the needle

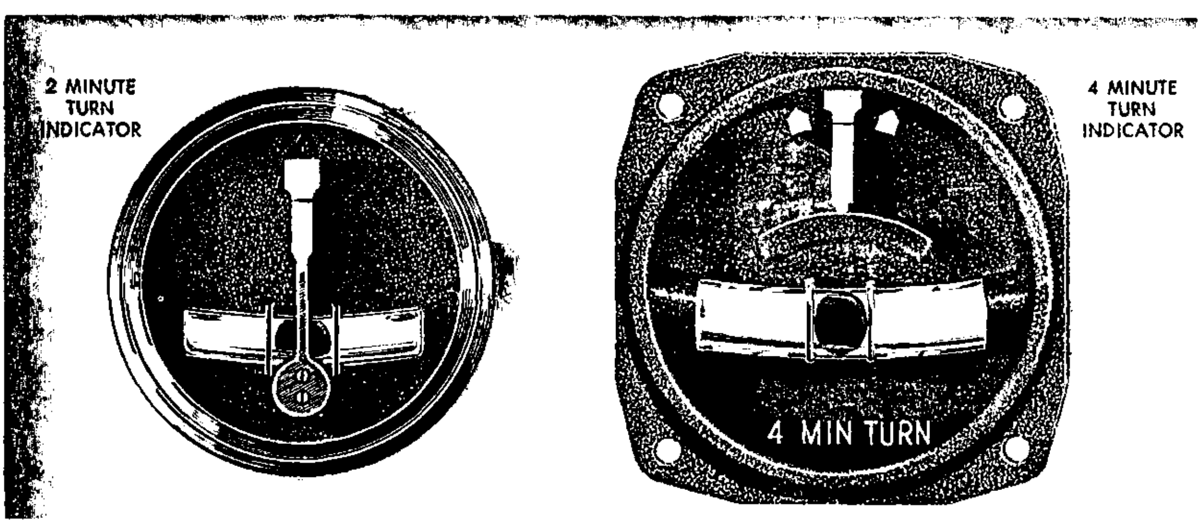
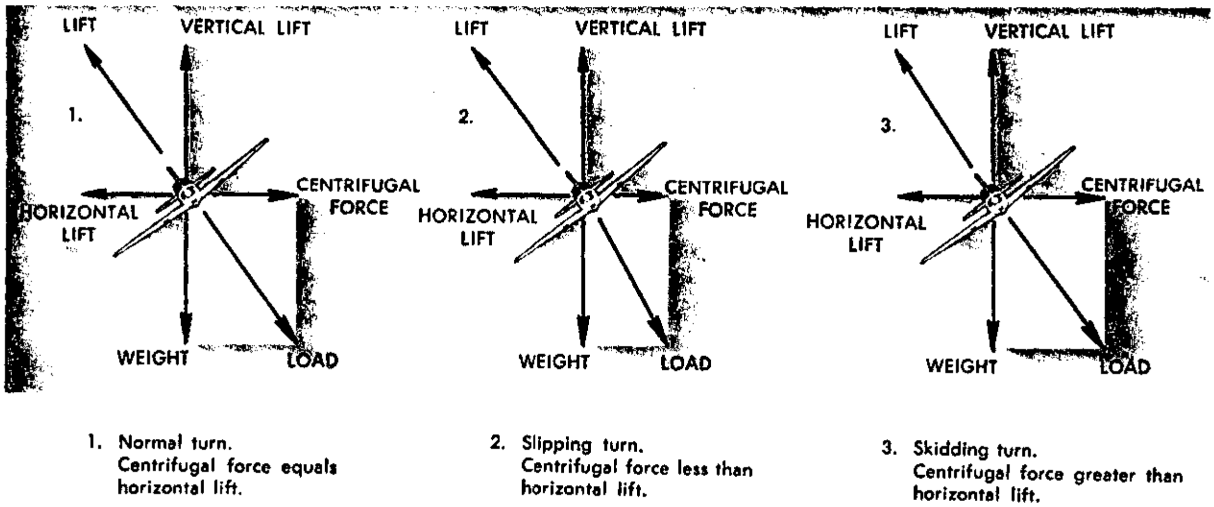


FIGURE 36. Turn indicators (2- and 4-minute).



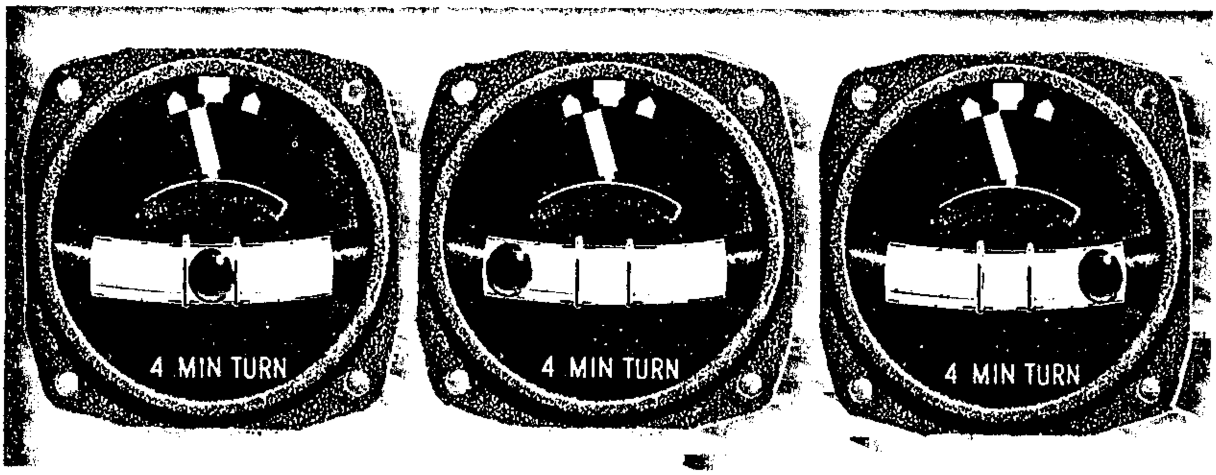


FIGURE 37. Coordinated, slipping, and skidding turn indications.

gives reliable indications regardless of malfunction or failure of other components of the electrical system.

Power for the suction-driven turn needle is regulated by a restrictor valve installed between the main suction line and the instrument to produce a desired suction and rotor speed. Since the needle measures the force of precession, excessively high or low vacuum results in unreliable turn needle operation. For a specific rate of turn, low vacuum produces less than normal rotor speed and, therefore, less precession force. Needle deflection is, therefore, less for this specific rate of turn. The reverse is true for the condition of high vacuum.

The turn needle indicates the rate at which the aircraft is turning about the vertical axis in number of degrees per second. Properly understood, the instrument provides bank as well as rate-of-turn information but it tells you nothing about bank attitude unless you understand the relationship between airspeed, angle of bank, and rate of turn discussed in Chapter III, "Aerodynamic Factors Related to Instrument Flying."

Of the two types of turn needle shown in Figure 36, the 2-minute turn indicator is the older. If the instrument is accurately calibrated, a single needle-width deflection on the 2-minute indicator means that the aircraft is turning at 3° per second, or standard rate (2 minutes for a 360° turn). On the 4-minute indicator, a single needle-width deflection shows when the aircraft is turning at 1½° per second, or half standard rate (4 minutes for a 360° turn). From a comparison of the indexes on the two instruments, you can see why the 4-minute instrument was developed: The half standard-rate (one-needle width deflection) turn used by high-speed aircraft is more easily read on the 4-minute indicator.

Slip Indicator (Ball) Operation.—This part of the instrument is a simple inclinometer consisting of a sealed, curved glass tube containing kerosene and a black agate or common steel ball bearing which is free to move inside the tube. The fluid provides a dampening action, insuring smooth and easy movement of the ball. The tube is curved so that in a horizontal position the ball tends to seek the lowest point. A small projection on the left end of the tube contains a bubble of air which compensates for expansion of the fluid during changes in temperature. Two strands of wire wound around the glass tube fasten the tube to the instrument case and also serve as reference markers to indicate the correct position of the ball in the tube. During coordinated straight-and-level flight, the force of gravity causes the ball to rest in the lowest part of the tube, centered between the reference wires.

Figure 37 shows the forces acting on the ball during turns. During a coordinated turn these forces are in balance, allowing the ball to remain in the center of the tube. When the forces acting on the ball become unbalanced, the ball moves away from the center of the tube.

In a skid, the rate of turn is too great for the angle of bank, and excessive centrifugal force causes the ball to move to the outside of the turn. To correct to coordinated flight calls for increasing the bank or decreasing the rate of turn or a combination of both.

In a slip, the rate of turn is too slow for the angle of bank, and the lack of centrifugal force causes the ball to move to the inside of the turn. To return to coordinated flight requires decreasing the bank or increasing the rate of turn, or a combination of both. The ball is thus used to check for coordinated flight. It is actually a "balance" indicator since it shows the relationship between the angle of bank and the rate of turn. Note that in each instance shown in Figure 37, the aircraft is turning at half standard rate, regardless of the position of the ball.

Errors.—Errors in turn needle indications are due to (1) insufficient or excessive rotor speed; or (2) inaccurate adjustment of the calibrating spring. Checking the instrument for these errors is discussed in Chapter V, "Attitude Instrument Flying."

Turn Coordinator

Recent years have seen the development of a new type of turn indicator, referred to as a "Turn Coordinator" or "Pictorial Turn Indicator." In place of the conventional turn needle indication of rate-of-turn, both instruments pictured in Figure 38, display a movement of the aircraft on the roll axis that is proportional to the roll rate. When the roll rate is reduced to zero, the instrument provides an indication of the rate-of-turn. This new design features a realignment of the gyro in such a manner that it senses aircraft movement about the yaw and roll axes and pictorially displays the resultant motion as described above. Both instruments also possess a dampening feature that provides a more stable

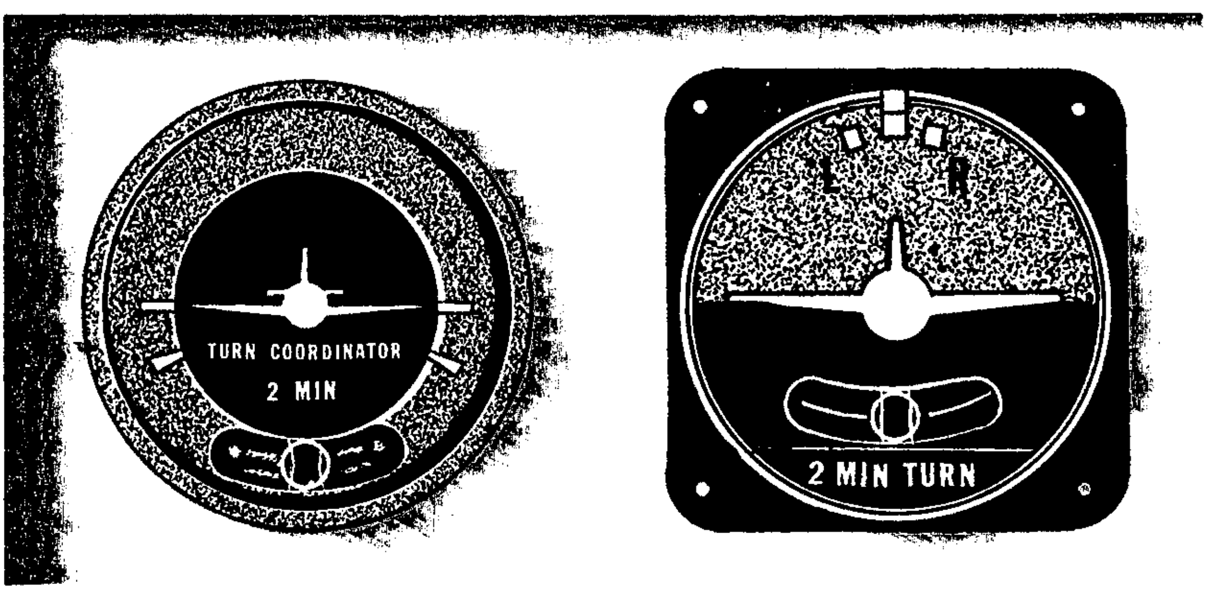


FIGURE 38. Pictorial turn indicators.

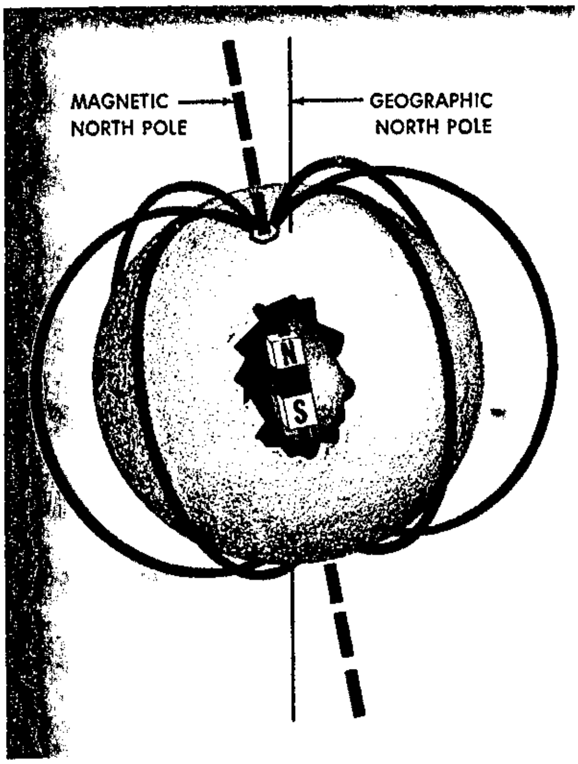


FIGURE 39. Magnetic and geographic poles.

indication than the conventional turn and slip indicator. The conventional inclinometer (ball) is also common to both instruments.

Heading Indicators

Many types of heading or directional indicators are used in modern aircraft. Most of them are complex gyro-controlled systems designed to compensate automatically for errors inherent in older north-seeking instruments.

The heading indicator commonly used in light aircraft is the relatively simple directional gyro, which has no direction-seeking properties and must be set to headings shown on the magnetic compass. Knowledge of the magnetic compass is thus essential to proper use of the directional gyro. The magnetic compass is also important as a standby, or emergency, directional indicator since it requires no aircraft source of power for operation. In order to use the magnetic compass effectively, you must understand some basic properties of magnetism and their effect on the instrument.

Magnetic Attraction.—A magnet is a piece of metal that has the property of attracting another metal. The force of attraction is greatest at the poles or points near each end of the magnet; and the least attraction is in the area halfway between the two poles. Lines of force flow from each of

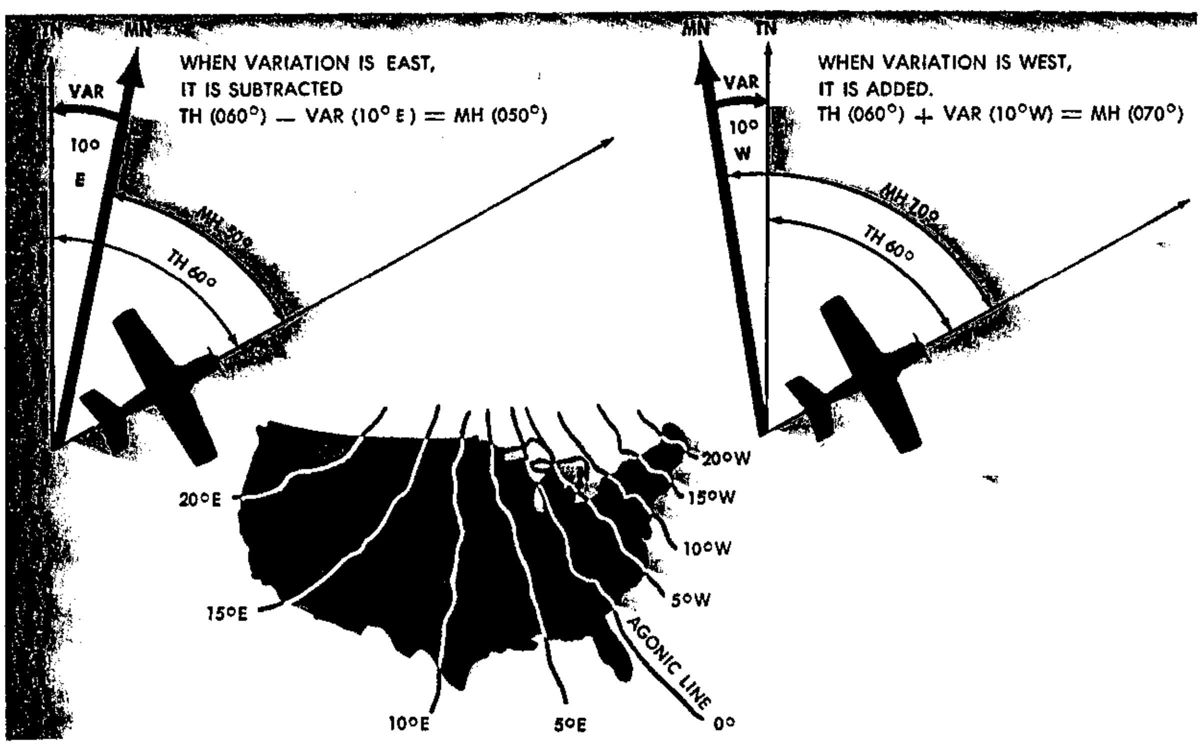


FIGURE 40. Lines of equal variation in the United States.

these poles in all directions, bending around and flowing toward the other poles to form a magnetic field. Such a magnetic field surrounds the earth, with the lines of force oriented approximately to the north and south magnetic poles (Fig. 39).

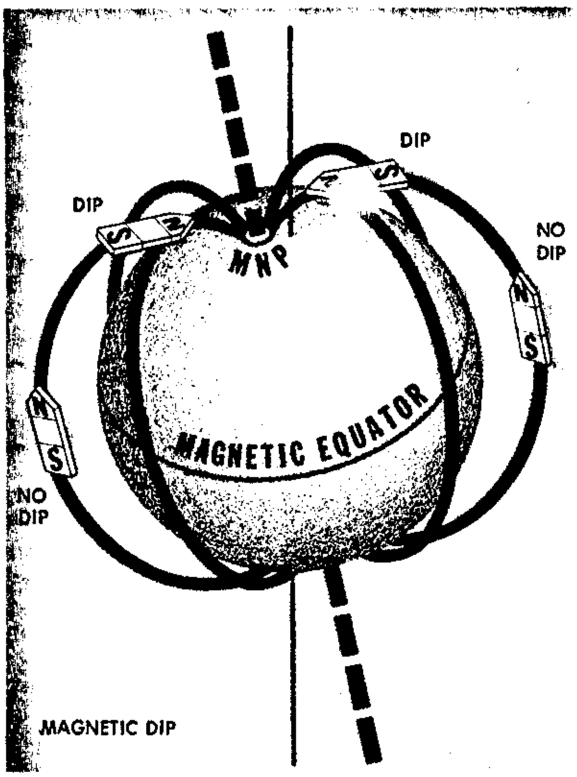
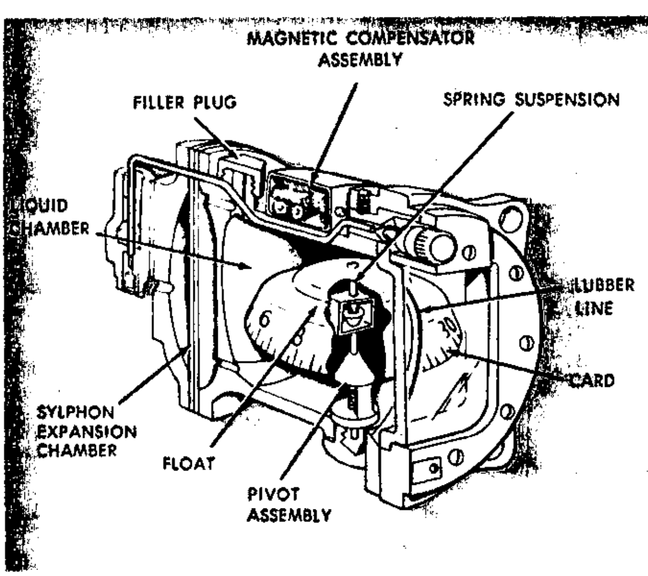


FIGURE 41. Magnetic dip.

In flight, allowance must be made for the difference in locations of the geographic and magnetic poles if your course reference is the geographic (true) pole, because the aircraft compass is oriented to the magnetic pole. Lines of equal magnetic declination or "variation" are called isogonic lines, and are plotted in degrees of east and west variation on aeronautical charts. A line connecting points of zero degrees variation is called the agonic line. These lines are replotted periodically on aeronautical charts to correct any change which may have occurred as a result of the shifting of the poles, or any changes caused by local magnetic disturbances. Figure 40 shows the irregular pattern of the lines of equal variation in the United States.

Magnetic Dip.—A number of compass errors are caused by deflection of the aircraft compass needles as they seek alignment with the earth's magnetic lines of force. Note in Figure 41 how lines of force in the earth's magnetic field are parallel to the earth's surface at the magnetic equator, and curve increasingly downward closer to the magnetic poles. A magnetic needle will tend to assume the same direction and position as the line of force. Thus, the needle will be parallel with the earth's surface at the magnetic equator, but will point increasingly downward as it is moved closer to the magnetic pole. This characteristic is known as magnetic dip. You should understand the relationship between latitude and magnetic dip to be able to effectively



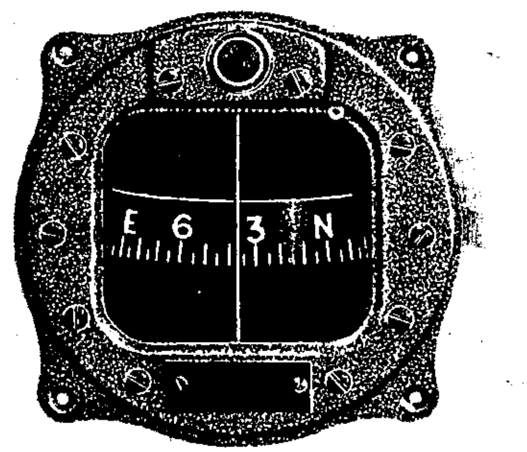


FIGURE 42. Magnetic compass.

use the standby compass either for normal or emergency operations.

Compass Construction.—The magnetic compass is a simple self-contained instrument (Fig. 42). Two steel magnetized needles are mounted on a float, with a compass card attached around the float. The needles are parallel, with their north-seeking end pointed in the same direction. The compass card has letters for cardinal headings—N.E.S.W. Each 30° interval of direction is represented by a number from which the last zero is omitted. Between the numbers, the card is graduated for each 5°. The float assembly, consisting of the magnetized needles, compass card, and float, is mounted on a pedestal and sealed in a chamber filled with an acid-free white kerosene.

This fluid serves two purposes. Due to buoyancy, part of the weight of the card is taken off the pivot that supports the card. The fluid also decreases oscillation and lubricates the pivot point on the pedestal. The pedestal is the mount for the float assembly and compass card. The float assembly is balanced on the pivot, which allows free rotation of the card and allows it to tilt at an angle up to 18°. At the rear of the compass bowl, a diaphragm is installed to allow for any expansion or contraction of the liquid, thus preventing the formation of bubbles or possible bursting of the case.

A glass face is on one side of the compass, and mounted behind the glass is a lubber or reference line by which compass indications are read. Two small compensating magnets are located in the top of the compass case to counteract deviation. These are adjustable by two set screws labeled N–S and E–W.

Compass Errors.—*Variation.*—The angular difference between true and magnetic north is referred to as magnetic variation. Figure 40 shows how variation is applied to true heading to derive magnetic heading.

Deviation.—The compass needles are affected not only by the earth's magnetic field, but also by magnetic fields generated when aircraft electrical equipment is operated and by metal components in the aircraft. These magnetic disturbances within the aircraft, called deviation, deflect the compass needles from alignment with magnetic north. Deviation varies according to the electrical components in use, and the magnetism changes with jolts from hard landings and installation of additional radio equipment.

To reduce this deviation, each compass is checked and compensated periodically by adjustment of the N–S/E–W magnets. The errors remaining after "swinging" the compass are recorded on a compass correction card mounted in the airplane. To fly compass headings, you refer to the compass correction card for corrected headings to steer.

Magnetic dip is the tendency of the compass needles to point down as well as to the magnetic pole. The resultant error is known as dip error,

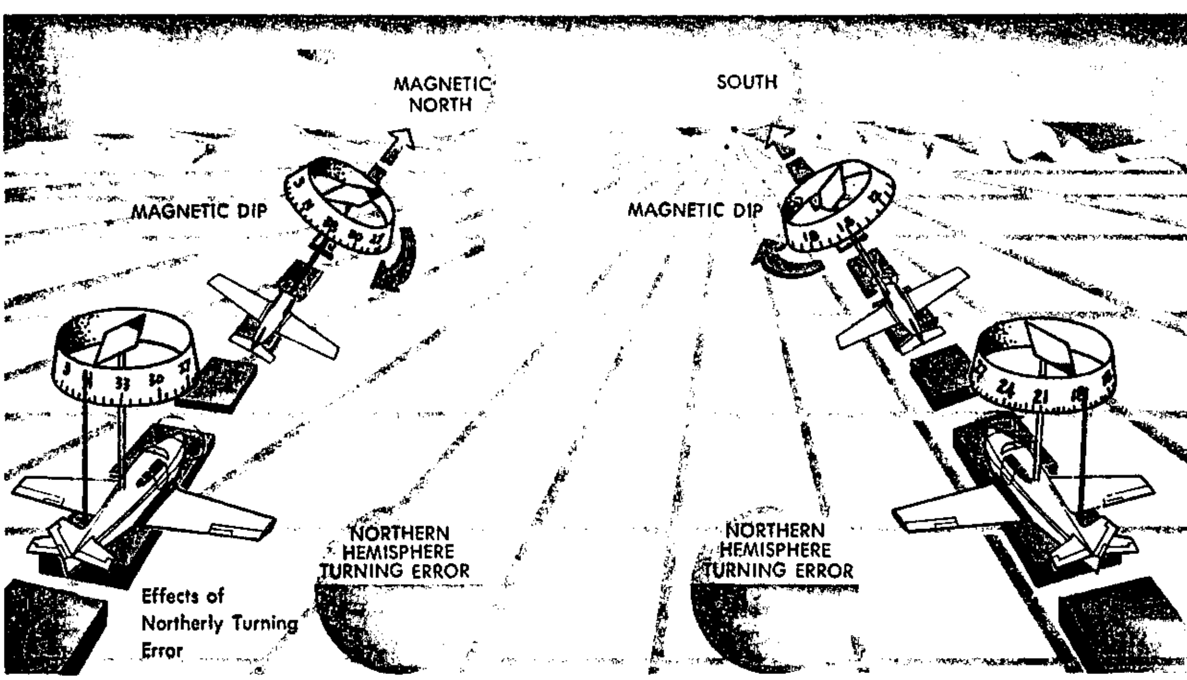


FIGURE 43. Northerly turning error.

greatest at the poles and zero at the magnetic equator.

Since the compass card is designed to respond only to the horizontal plane of the earth's magnetic field, it turns freely only in the horizontal plane. Any movement of the card from the horizontal results in dip errors. Discussion of these errors is limited to the northern hemisphere; the errors are reversed in the southern hemisphere.

Northerly turning error (Fig. 43) is the most pronounced of the dip errors. Due to the mounting of the magnetic compass, its center of gravity is below the pivot point on the pedestal and the card is well balanced in the fluid. When the aircraft is banked, the card is also banked as a result of centrifugal force. While the card is in the banked attitude, the vertical component of the earth's magnetic field causes the north-seeking ends of the compass to dip to the low side of the turn, giving an erroneous turn indication. This error is most apparent on headings of north and south. When making a turn from a heading of north, the compass briefly gives an indication of a turn in the opposite direction. When making a turn from south, it gives an indication of a turn in the correct direction but at a much faster rate than is actually occurring.

Acceleration error is also due to the dip of the earth's magnetic field. Because of the pendulous-type mounting, the aft end of the compass card is tilted upward when accelerating, and downward when decelerating during changes of airspeed. This deflection of the compass card from the horizontal results in an error which is most apparent on headings of east and west. When accelerating on either an east or west

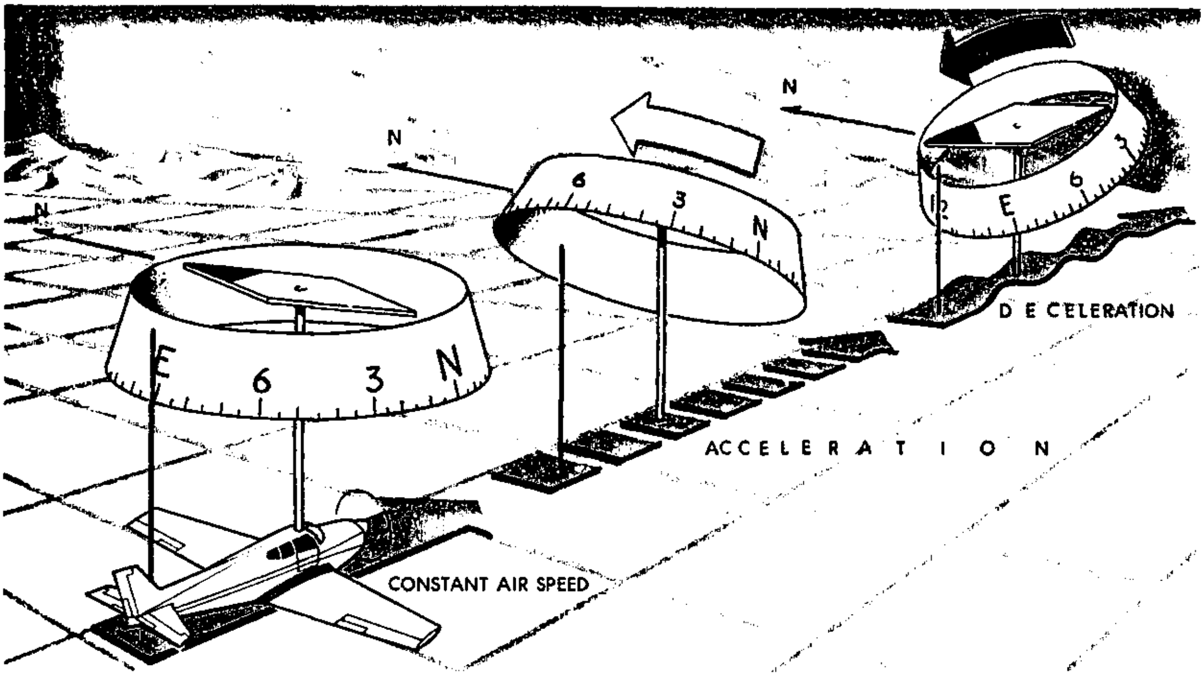


FIGURE 44. Acceleration error.

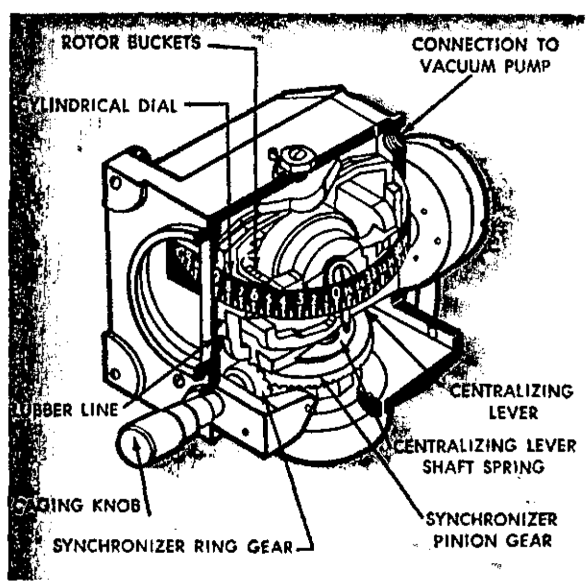


FIGURE 45. Heading indicator components (vacuum-driven).

heading (Fig. 44), the error appears as a turn indication toward north. When decelerating on either of these headings, the compass indicates a turn toward south. The word "ANDS" (Acceleration—North/Deceleration—South) may help you to remember the acceleration error.

Oscillation error results from erratic movement of the compass card which may be caused by turbulence or rough control technique. During oscillation, the compass is affected by all of the factors discussed. With proper training, the instrument can be effectively used despite the errors.

Vacuum-Driven Heading Indicator

The vacuum-driven heading indicator is the simplest of many types of gyro-controlled directional indicators designed to provide stable heading reference. Within limits, the directional gyro is not affected by the factors that induce errors in the magnetic compass.

The operation of the heading indicator (Fig. 45) depends upon the principle of rigidity in space of a universally mounted gyroscope. The rotor turns in a vertical plane. Fixed at right angles to the plane of the rotor (to the vertical gimbal) is a circular compass card. Since the rotor remains rigid in space, the points on the card hold the same position in space relative to the vertical plane. As the instrument case revolves about the vertical gimbal, the card provides clear and accurate heading references.

The source of power for the gyro is the engine-driven vacuum pump (or venturi) which sucks air from the rear of the instrument case. This causes air under atmospheric pressure to pass through the filtering system, thence through an air bearing into the hollow vertical gimbal ring. The air then passes through the air nozzle and jets, striking the rotor at a point just above the plane of the horizontal gimbal.

The speed of the rotor may vary from 10,000 to 18,000 rpm, depending on instrument design. For proper operation, the suction gauge reading can be as low as 3.5 and as high as 5.0 inches of mercury, with 4.0 the desired suction. Limits for adjustment of the vacuum are 3.75 and 4.25, or as specified in your aircraft operating handbook.

Erecting Mechanism.—During flight, precessing forces displace the rotor from the vertical plane. To compensate for precession and to provide better airflow distribution against the rotor buckets, the air is divided by two parallel jets at the tip of the nozzle (Fig. 46).

Each jet strikes the buckets at points equidistant from the center of the buckets when the rotor is perpendicular in its normal rotating plane. When the gyro precesses, both jets strike

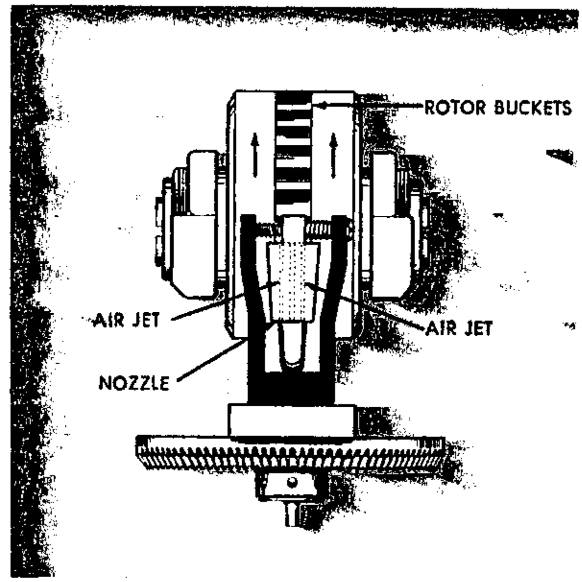


FIGURE 46. Erecting mechanism—vacuum-driven heading indicator.

one side of the buckets and cause the plane of the rotor to again become parallel to the flow of air from the jets.

Limitations.—The design of the vacuum-driven directional gyro imposes limitations on rotation about the gimbals preventing operation of the instrument in abnormal flight attitudes. If the plane of rotation of the rotor were able to become parallel to the base of the case, it would lose its ability to hold the card in a stationary position, since its axis would be in line with the vertical gimbal and the card would tend to spin with the rotor. The stop, or limiting factor, in the instrument is the caging arm. In the uncaged position, the caging arm rests on the bottom of the vertical gimbal ring and in that position restricts the movement of the vertical gimbal ring about the rotor or the horizontal gimbal. The caging arm is held against the bottom of the vertical gimbal ring by means of a small spring so that rough air cannot cause it to fly up and tumble the instrument. Beyond the normal operating limits—55° of pitch and bank—when the horizontal gimbal touches the stop, the precessional force causes the card to spin rapidly. This may be corrected by caging, resetting, and uncaging the instrument.

Errors.—The chief cause of precession, causing the card to creep or drift, is bearing friction. Normal movement of the gimbal rings produces friction, which is increased if the bearings are worn, dirty, or improperly lubricated. Other sources of precession error include unbalanced gyro components and the effect of the earth's rotation. The latter effect depends upon the position of the instrument in relation to the earth, and is not appreciable unless a flight involves considerable change in latitude.

An apparent error frequently results from misuse of the magnetic compass when the directional gyro is set. Unless magnetic deviations are applied, the indicator may appear to drift several degrees after a turn is completed. Another common error results from failure to maintain straight-and-level flight while reading the magnetic compass for the heading to set in the directional gyro. Errors in the magnetic compass induced by attitude changes are thus duplicated in the heading indicator.

The instrument should be checked at least every 15 minutes during flight and reset to the correct heading. An error of no more than 3° in 15 minutes is acceptable for normal operations.

Caging Mechanism.—The heading indicator can be adjusted by pushing in on the caging knob to mesh pinion and ring gears, thereby permitting rotation of the vertical gimbal and card. (Another type of caging mechanism utilizes friction between rubber and metal rings.) After setting, the gyro is uncaged by pulling out the caging knob to release the gimbals from the caging mechanism. Before setting the instrument during ground operations, allow 5 minutes after engine starting for the gyro to reach operating speed.

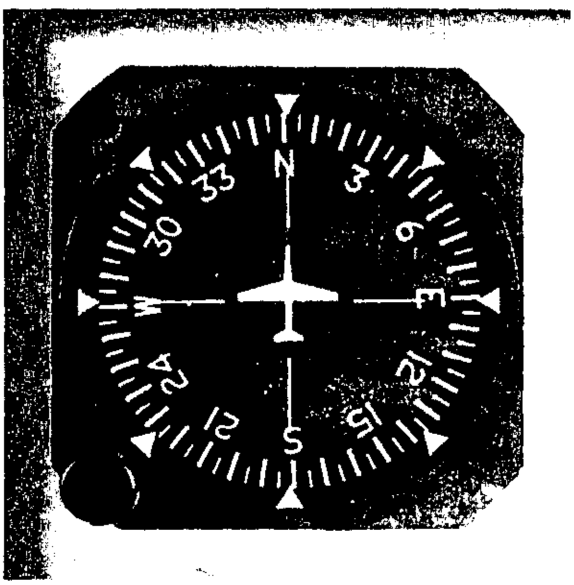


FIGURE 47. Azimuth directional gyro.

A refinement of the older vacuum-driven directional gyro, and considered easier to interpret, is the azimuth directional gyro shown in Figure 47.

The gyro assembly is identical to that of the type already discussed. However, instead of the horizontally mounted compass card, an azimuth card is mounted on the face of the instrument. The card, geared to the vertical gimbals, rotates as the aircraft turns. The aircraft heading is shown under the pointer on the nose of the miniature aircraft, inscribed on the glass cover of the instrument face. In addition to the nose index, additional 45°, 90°, and 180° indices are painted on the glass. Errors, pitch and bank limitations, and method of caging are the same as for the type previously discussed.

Remote Indicating Compass

Remote indicating compasses have been developed to compensate for the errors and reduce the limitations of the older type heading indicators.

Because of size, weight, cost, and other factors, these remoted systems are not found in many airplanes classed as light aircraft, but are becoming increasingly common in executive aircraft. The student of instrument flying should note this illustration of how errors in direction-seeking instruments can be overcome by design innovations that will eventually affect all instrument pilots. Figure 48 shows components of an improved gyro-stabilized magnetic compass system.

The *remote compass transmitter* (not shown) contains the flux valve unit which is the direction sensing device of the system. The flux valve unit is suspended by a universal joint and is weighted in such a manner as to normally maintain a horizontal plane. The flux valve unit detects the horizontal component (or lines of flux) of the earth's magnetic field. The universal suspension allows the flux valve to hang like a plumb bob and swing in a pendulous manner. The flux valve cannot rotate and is fixed to turn with the aircraft. Any change in direction of the aircraft results in a corresponding change of the transmitter in relation to the earth's magnetic field.

The *directional gyro* maintains a constant directional reference by utilizing the rigidity of a spinning gyro. The case of the directional gyro control unit rotates in azimuth about the directionally stabilized gyro as the aircraft turns. This means that as the aircraft rotates about the gyro, the turn information is relayed to the cockpit indicator. A torque motor operated by a liquid level switch is incorporated to maintain the gyro spin axis in a horizontal plane. The directional gyro maintains its reference to magnetic north by signals received from the remote compass transmitter.

The *directional indicator* receives heading information from the directional gyro control.

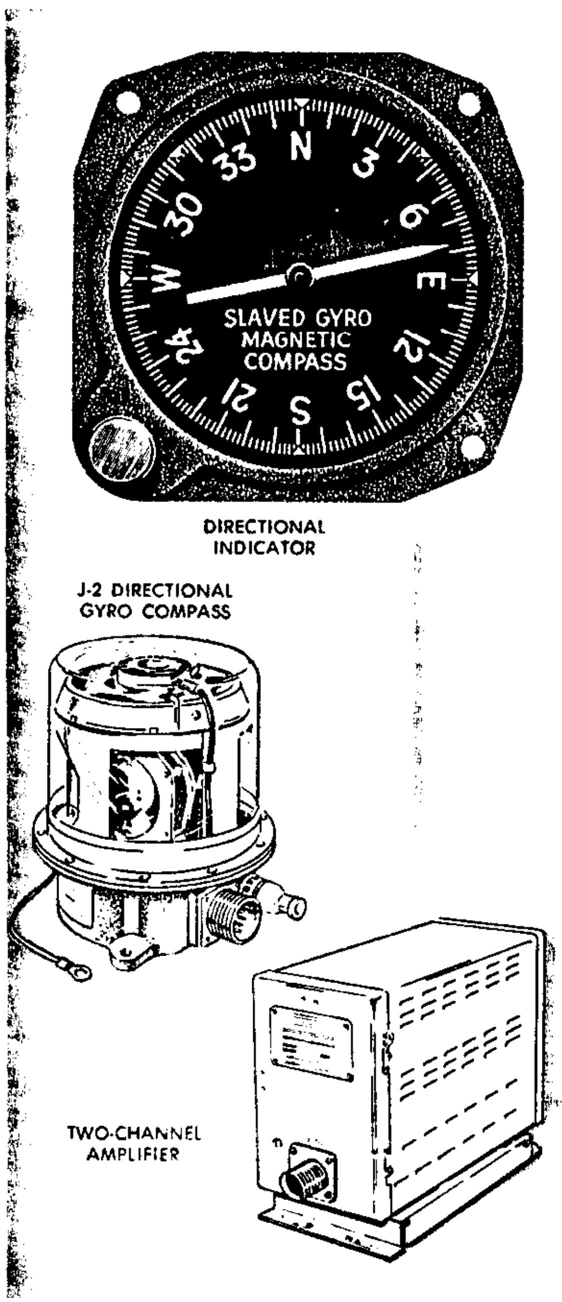


FIGURE 48. Slaved gyro magnetic compass.

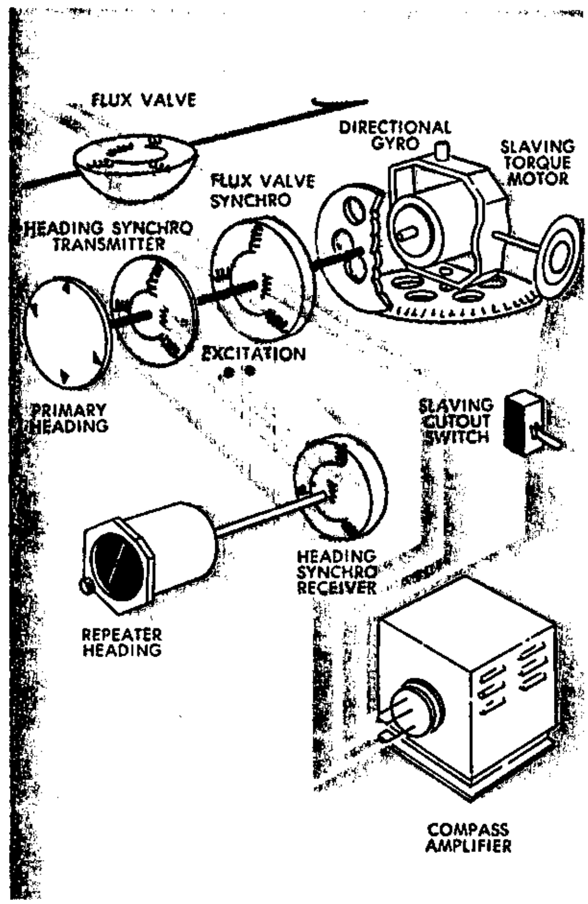


FIGURE 49. Slaved gyro components.

This information is presented in the form of magnetic heading of the aircraft. A set knob on the directional indicator is used to rotate the compass card and pointer for placing any desired heading under the top index.

The *amplifier* is the coordinating and distributing center of the system. Figures 49 and 50 show the operation of the compass system components and the flux valve unit. The flux valve unit picks up the lines of force concentrated in any one spoke segment of the unit. Note in the illustration how the concentration of lines of flux change from number one to numbers two and three as the aircraft changes heading from north to west. This concentration of lines of force, after being amplified, is relayed to the directional gyro control. These signals operate a torque motor in the directional gyro control. The torque motor precesses the gyro unit until it is aligned with the transmitter signal. If the gyro tends to become misaligned, this error is detected by a synchro as it moves out of phase with the transmitter. When this happens, the torque motor precesses the gyro back into phase. The gyro is thus always slaved to the earth's magnetic lines of force (which may be modified by the metallic structure of the aircraft).

The transmitter will relay accurate information only when it is in a horizontal plane. The flux valve unit of the remote compass transmitter remains pendulous through 30° in pitch and bank. During a coordinated turn, or when

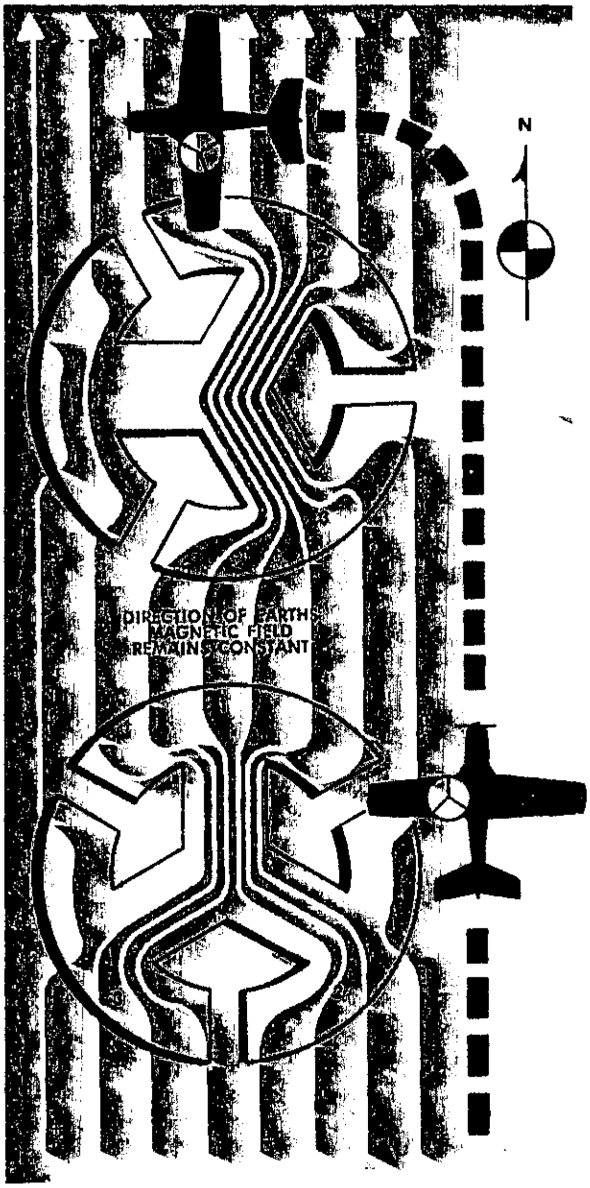


FIGURE 50. Operations of the flux valve unit.

the above limits are exceeded, the unit picks up false information, since the valve is no longer level with the earth's surface. These small errors and other errors induced by extreme aircraft attitudes are corrected rapidly when the aircraft resumes a level flight attitude.

The gyro is free to operate within 85° from the level flight attitude both in pitch and bank. When these limits are exceeded, the gyro strikes mechanical stops. This will cause erroneous indications to appear on the cockpit indicator until the directional gyro is again slaved to the magnetic meridian. Induced errors may be as large as 5°; however, the gyro will erect fully in 5 minutes or less.

The several advantages of the slaved gyro magnetic compass should be apparent. Dip error cannot occur because the instrument is gyro stabilized. No correction card is necessary since deviation is almost fully compensated. Except in extreme attitudes, precession errors can be disregarded, and the frequent resetting of the gyro is eliminated. A further advantage is that the card can be rotated to place a heading at any desired position. For example, rotation of a desired heading to the nose position reduces the attention needed to hold a heading, or to turn to it, since you normally orient yourself more easily with reference to the nose (north) position.

Radio Magnetic Indicator (RMI)

The radio magnetic indicator, or RMI, is beginning to appear on the instrument panels of modern general aviation aircraft. This instrument, shown in Figure 51, consists of a rotating compass card, a double-barred bearing indicator, and a single-barred bearing indicator. The compass card, actuated by the aircraft's compass system, rotates as the aircraft turns. The magnetic heading of the aircraft is always directly under the index at the top of the instrument, assuming no compass deviation error. The bearing pointers display ADF or VOR magnetic bearings to the selected station. In most installations, the double-barred bearing indicator gives the magnetic bearing to the VOR or VORTAC to which

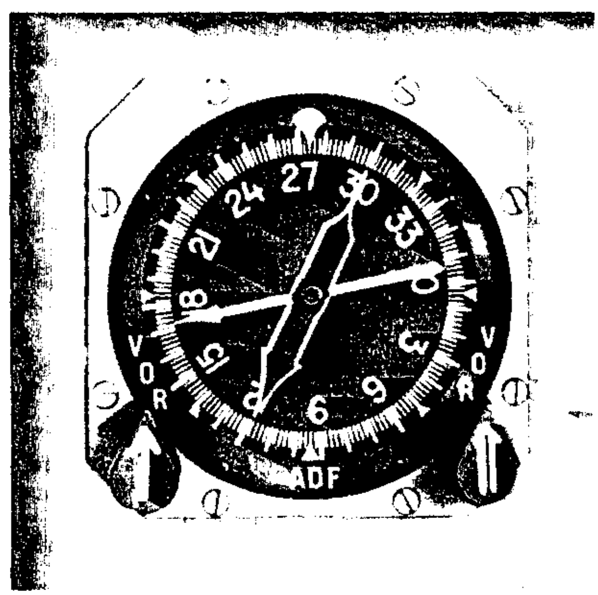


FIGURE 51. Radio magnetic indicator.

the receiver is tuned, and the single-barred indicator is an ADF needle which gives the magnetic bearing to the selected low frequency facility. The tail of the double-barred indicator tells you the radial you are on, and the tail of the single-barred indicator tells you your magnetic bearing from a low frequency station. Some RMI installations have selector switches which permit the pilot to use both indicators in conjunction with dual VOR receivers or both indicators as ADF needles. When used with area navigation equipment, the RMI can be set up to indicate either the bearing to the "waypoint" or to the VOR/DME station used to establish the "waypoint."

Pitot Static Instruments

Three other basic flight instruments are to be considered: *pressure altimeter, airspeed indicator,* and *vertical-speed indicator.* Each of these instruments operates in response to pressures through the pitot-static system. Because of the importance of these instruments for safe operation during instrument conditions, you should understand the construction, operation, and use of the pitot-static system and related instruments.

Pitot-static Systems.—Two types of systems are available. Both provide a source of static (atmospheric) pressure and impact (ram) pressure to the appropriate instruments. The difference in the systems is largely in the location of the static source (Fig. 52).

Of the two systems, the one more recently developed provides for location of the pitot and static sources at separate positions on the aircraft. *Impact pressure* is taken from the pitot tube, mounted parallel to the longitudinal axis and generally in line with the relative wind. The leading edge of the wing, nose section, or vertical stabilizer are the usual mounting positions, where there is a minimum disturbance of air due to motion of the aircraft. Electric heat-

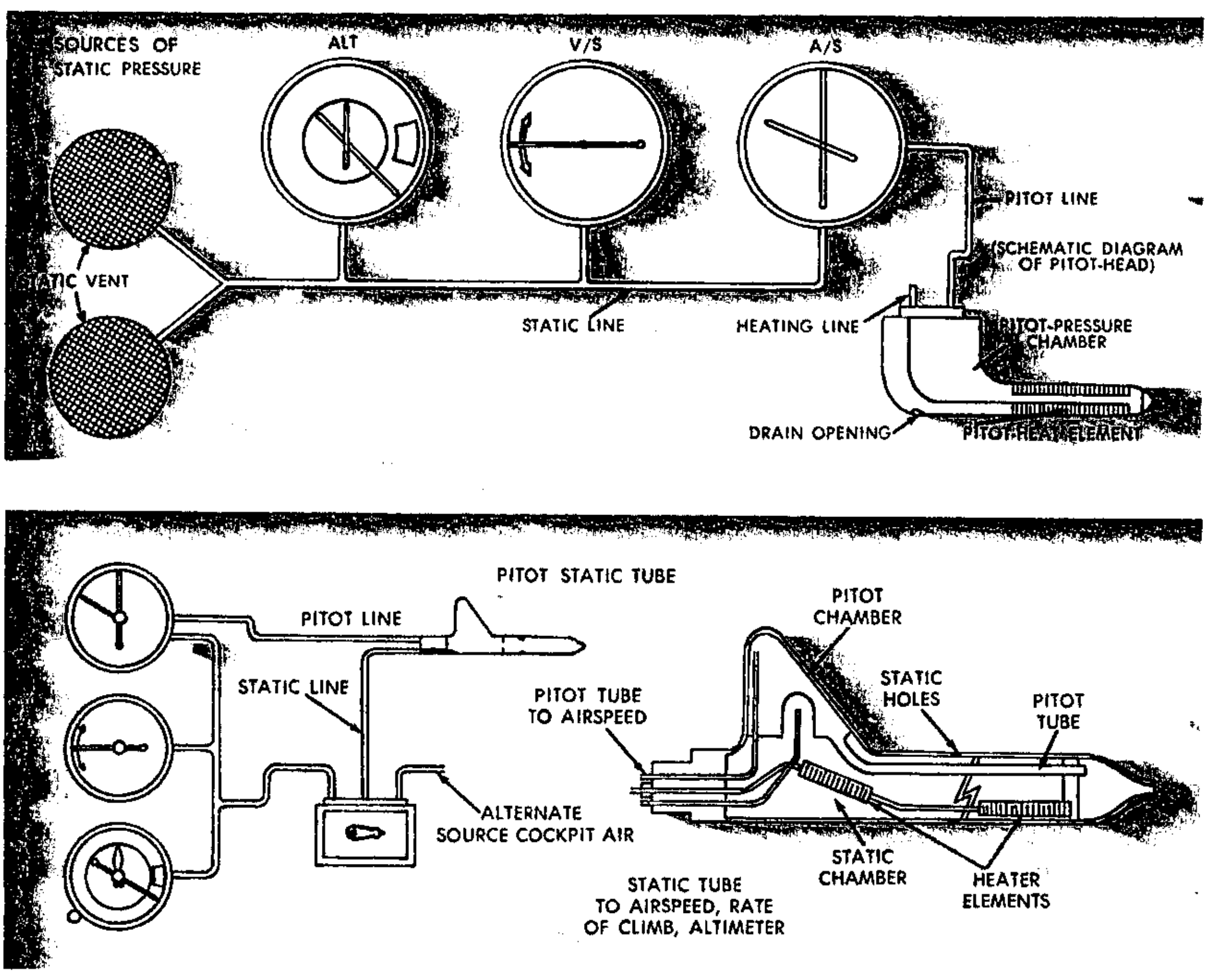


FIGURE 52. Pitot-static systems.

ing elements may be installed to remove ice from the pitot head.

Static pressure is taken from the static line attached to the pitot-static head or to a vent or vents mounted flush with the fuselage or nose section. On aircraft using the flush-type static source, there may be two vents, one on each side of the aircraft. These compensate for any possible variation in static pressure on the vents due to erratic changes in aircraft attitude. The vents are connected by a Y-type fitting. Clogging of the pitot opening by ice or dirt (or failure to remove the pitot cover) affects the airspeed indicator only.

Alternate Source of Static Pressure.—In many unpressurized aircraft equipped with a pitot-static tube, an alternate source of static pressure is provided for emergency use. If the alternate source is vented inside the airplane, where static pressure is usually lower than outside static pressure, selection of the alternate source may result in the following instrument indications: the altimeter reads higher than normal; indicated airspeed greater than normal; and the vertical-velocity indicator momentarily shows a climb.

All of these instruments, whether connected to a static source or to both static and pitot lines, operate in response to differences in air pressure that exist within each instrument. The pressure differential is due either to impact and static, or to static and trapped air pressures.

Altitude and Height Measurement

The word "altitude" conveys different meanings to different people involved in aviation. Used by itself, altitude simply means elevation with respect to any assumed reference level. To the aircraft designer, altitude is significant not so much in the sense of height as in the relationship between altitude and air density, which affects aircraft performance. To the National Ocean Survey, the surveyed altitude of ground obstructions above sea level is of critical importance, as the pilot depends upon the accuracy of chartered information for ground obstruction clearance. Of special importance is the measurement shown on your altimeter, since this is your immediate source of information in the cockpit. As a pilot, you are concerned with all of these meanings of altitude.

Different terms identify specific meanings of altitude (Fig. 53) and various methods of height measurement and computation are necessary to determine them. Altimetry thus involves more than simple measurement of height. Your correct use of the altimeter depends upon your understanding of two basic factors: (1) the reference levels from which height is measured; and (2) the operating principles and limitations of the measuring device. The importance of the reference levels will become apparent as you understand the types of altitude and the pressure altimeter, which is the type of measuring device commonly installed in light aircraft.

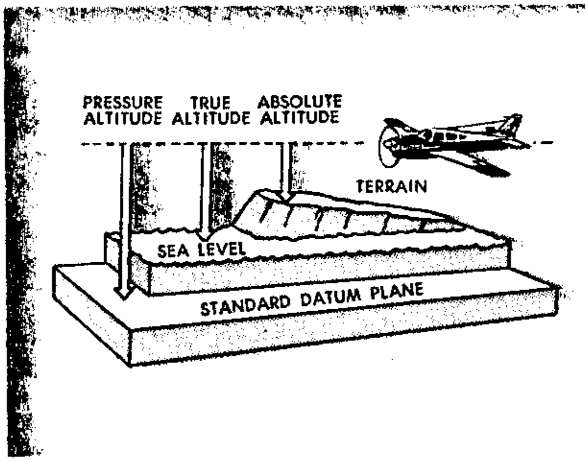


FIGURE 53. Types of altitude.

Types of Altitude.—*Indicated altitude* is the altitude read on your altimeter, assuming that the altimeter is correctly adjusted to show the approximate height of the aircraft above mean sea level (MSL). Altitudes assigned to aircraft in controlled airspace under Instrument Flight Rules are indicated altitudes, except for flights operating in the high altitude route structure.

Pressure altitude is the altitude read on your altimeter when the instrument is adjusted to indicate height above the Standard Datum Plane. The Standard Datum Plane is a theoretical level where the weight of the atmosphere is 29.92" of mercury as measured by a barometer. As atmospheric pressure changes, the Standard Datum Plane may be below, at, or above sea level. Pressure altitude is important as a basis for determining aircraft performance as well as for assigning flight levels to aircraft operating at high altitude.

Density altitude is pressure altitude corrected for nonstandard temperature. Under standard atmospheric conditions, each level of air in the atmosphere has a specific density, and under standard conditions, pressure altitude and density altitude identify the same level.

Since aircraft performance data at any level is based upon air density under standard day conditions, such performance data applies to air density levels that may not be identical with altimeter indications. Under conditions higher or lower than standard, these levels cannot be determined directly from the altimeter. For

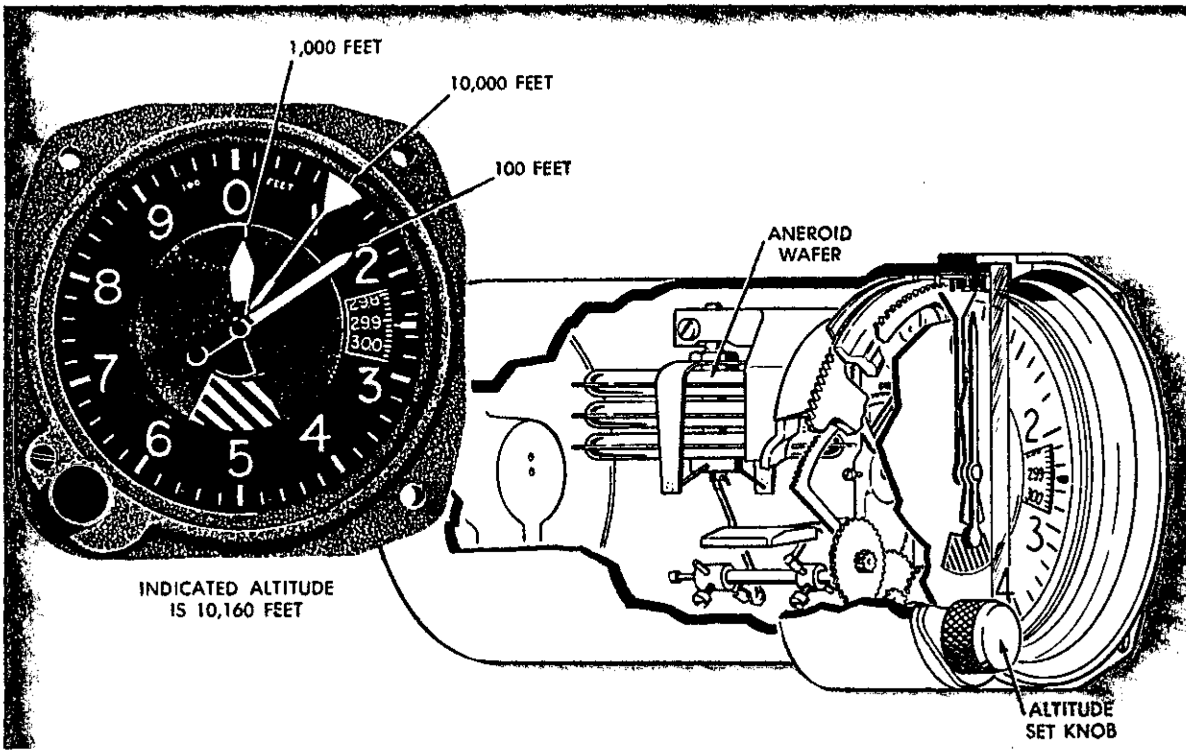


FIGURE 54. Altimeter components.

example, your altimeter, set at 29.92", indicates a pressure altitude of 5,000 feet. According to your aircraft flight manual, your ground run will require 790 feet under standard temperature conditions. However, the temperature is 20° C. above standard, and the expansion of air raises the density levels. Using temperature correction data from tables or graphs, or by deriving the density altitude with a computer, you find that the density level is above 7,000 feet, and your ground run will be closer to 1,000 feet.

Absolute altitude is height above the surface. This height may be indicated directly on a radio/radar altimeter, which measures the time interval of a vertical signal bounced from the aircraft to the ground and back. Absolute altitude is essential information for flights over mountainous areas and may be approximately computed from indicated altitude and chart elevation data.

True altitude is true height above sea level. This is a mathematical value determined by computer and therefore based upon standard atmospheric conditions assumed in the computer solution. If the temperature between the surface and the aircraft does not decrease at the standard rate of 2° per 1,000 feet, or if the pressure at flight level is nonstandard, reliance on a computer solution to determine obstruction clearance can be very hazardous.

Pressure Altimeter

The standard pressure altimeter installed in your airplane is far from satisfactory as an accurate instrument for measuring height, though the information it provides is essential for aircraft control and for maintaining terrain clearance and separation from other aircraft under instrument conditions. The limitations of the instrument are due primarily to the fact that its design and operation are based upon its response to conditions that rarely exist. Notwithstanding the limitations, you can use the altimeter as a satisfactory height-measuring instrument if you understand how it responds to nonstandard conditions.

Principle of Operation.—The pressure altimeter operates through the response of trapped air within the instrument to changes in atmospheric pressure. The atmosphere surrounding the earth exerts pressure because of its weight, decreasing at a predictable rate as altitude increases. The pressure altimeter is a barometer that senses changes in atmospheric pressure and, through a gearing mechanism, converts the pressure to an altitude indication in number of feet (Fig. 54).

The conversion is based upon a fixed set of values known as the U.S. Standard Atmosphere. As the following table shows, atmospheric conditions are standard when sea level pressure and temperature are 29.92 inches of mercury and 15° C., with a temperature lapse rate (rate of change with increasing altitude) of 2° per 1,000 feet.

U.S. Standard Atmosphere Values

Feet	*Pressure (in. of mercury)*	*Temperature (degrees Centigrade)*
16,000	16.21	−17
15,000	16.88	−15
14,000	17.57	−13
13,000	18.29	−11
12,000	19.03	−9
11,000	19.79	−7
10,000	20.58	−5
9000	21.38	−3
8000	22.22	−1
7000	23.09	1
6000	23.98	3
5000	24.89	5
4000	25.84	7
3000	26.81	9
2000	27.82	11
1000	28.86	13
Sea Level	29.92	15

Two essential facts—that conditions are rarely standard and that the altimeter presents you with standard information even when it senses nonstandard conditions—should stress the need for understanding how the altimeter works. The misinformation due to altimeter construction and atmospheric changes must be understood and compensated for.

The basic component of the pressure altimeter is the aneroid wafer (Fig. 55). A stack of these hollow, elastic metal wafers expands or contracts as atmospheric pressure changes, and through a shaft and gearing linkage, rotates the pointers on the dial of the instrument. For each pressure level, the aneroid assumes a definite size and causes the hands to indicate height above whatever pressure level is set into the altimeter setting window.

The *altimeter setting dial* provides a means of adjusting the altimeter for nonstandard pressure. For better understanding of the altimeter setting mechanism, assume an altimeter calibrated according to the standard values shown in the previous table, with no provision made for adjusting it for nonstandard conditions. You take off from a sea-level airport where standard conditions exist. On the runway your altimeter reads zero. You land where the field elevation is 2,000 feet and where the surface conditions are also standard. Your altimeter senses 27.82″ Hg and reads 2,000 feet as you land.

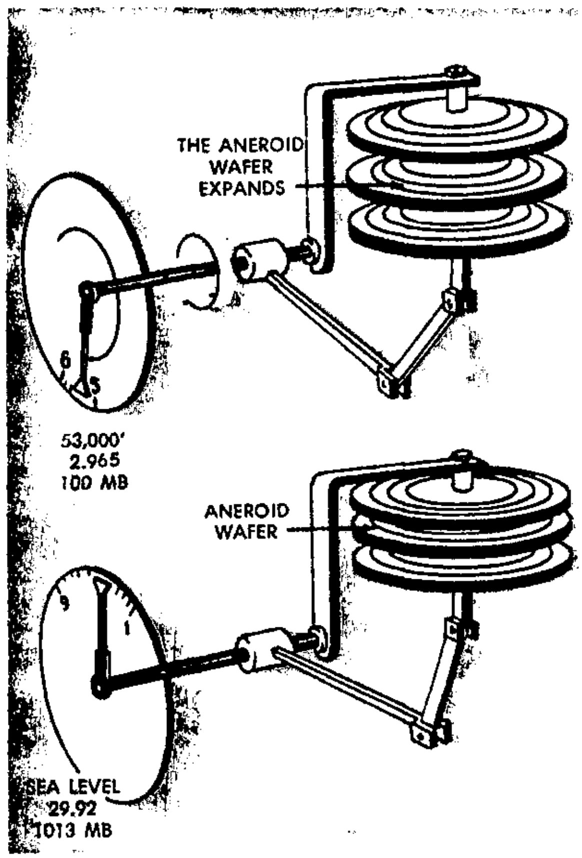


FIGURE 55. Operation of the altimeter.

Suppose, on the other hand, that the pressure and temperature conditions at the same destination airport had changed to 26.81″ Hg/9° C. Your altimeter on touchdown would sense lower pressure and read 3,000 feet. On an instrument approach under these nonstandard conditions, an unadjusted altimeter would indicate 1,000 feet above the runway level on ground impact. By means of a setting knob, the barometric scale on the altimeter setting dial can be rotated so that the altimeter will read "sea level" when nonstandard pressure exists at sea level.

The scale is calibrated from 28.00″ to 31.00″ to include the extremes in barometric change at sea level. Rotating the setting knob simultaneously rotates the scale and the altimeter hands at a rate of 1″ per 1,000 feet of indicated change of altitude. For practical purposes, this ratio can be considered the standard pressure lapse rate below 5,000 feet. Assume that you adjust your altimeter setting dial to 29.92″ on an airport at 1,000-foot elevation, and observe an indicated altitude of 1,300 feet. Disregarding other sources of error, your altimeter must be sensing

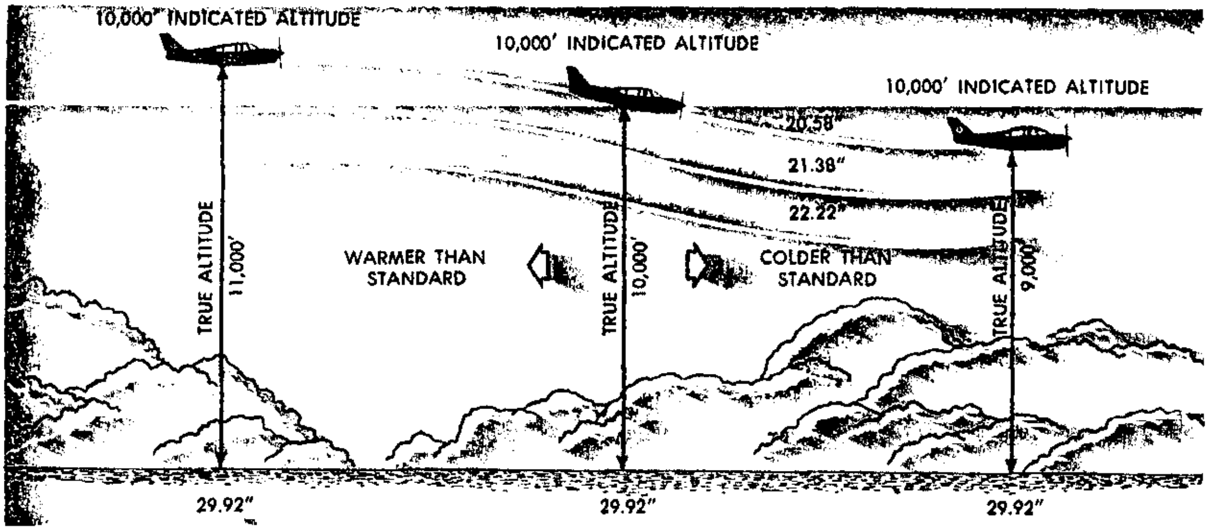


FIGURE 56. Nonstandard temperature and altimeter interpretation.

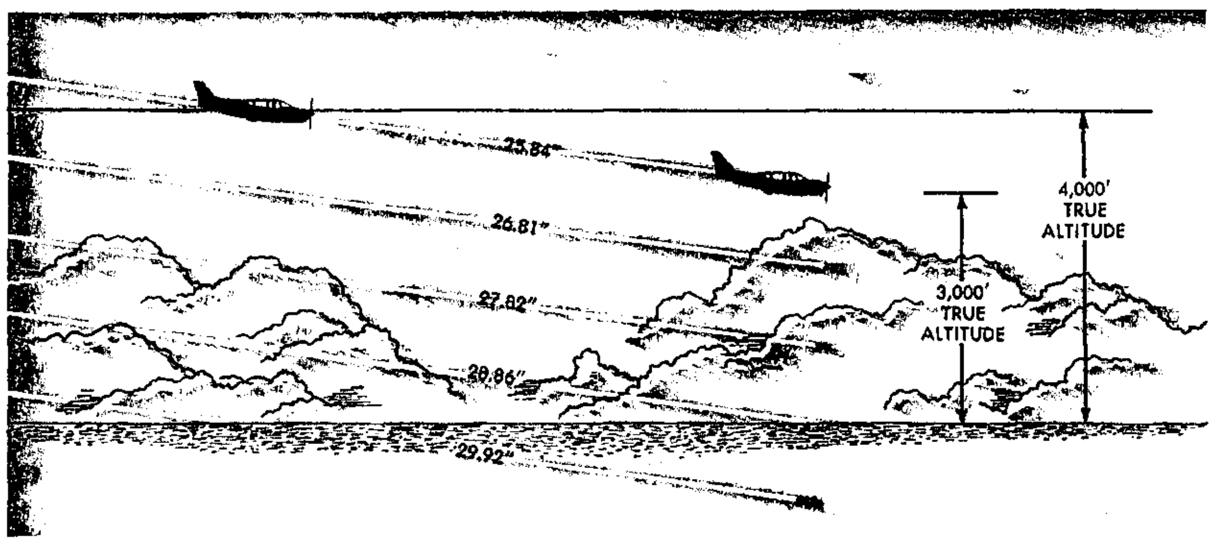


FIGURE 57. Nonstandard pressure and altimeter interpretation.

the pressure for which it is calibrated at 1,300 feet. By rotating the knob, you set the altimeter hands to 1,000 feet and the altimeter setting dial rotates to read 29.62" (1" per 1,000 feet equals 0.1" per 100 feet). Thus, rotation of the altimeter setting dial adjusts the altimeter hands to a desired indication for the size of the aneroid at existing pressure.

Effects of nonstandard conditions can result in a difference of as much as 2,000 feet between true and indicated altitude. Temperature variations expand or contract the atmosphere and raise or lower the pressure levels that the altimeter is designed to sense. On a warm day, the pressure level where the altimeter will indicate 4,000 feet is higher than it would be under standard conditions; on a cold day the pressure level is lower than standard. Figure 56 shows the relationship between indicated and true altitude with temperature variation.

Changes in surface pressure also affect the pressure levels at altitude, as shown in Figure 57. At any level, the effect of lower than standard pressure on an uncorrected altimeter is to place the aircraft lower than its altimeter indicates.

The *altimeter setting system* provides you with the means that must be used to correct your altimeter for pressure variations. The system is necessary to insure safe terrain clearance for instrument approaches and landings and to maintain vertical separation between aircraft during instrument weather conditions.

Each weather reporting station takes an hourly measurement of atmospheric pressure and, according to the surveyed elevation of the station, corrects the value obtained to sea level pressure. The resulting altimeter setting broadcast by each Flight Service Station is a computed correction for nonstandard surface pressure *only*, for a specific location and elevation. Consequently, altimeter indications based upon a local altimeter setting do not necessarily reflect height above mean sea level except in the vicinity of the reporting station and near the surface.

The setting does not compensate for nonstandard conditions aloft, especially for the effect of nonstandard temperature. Maintaining the correct reported altimeter settings as you fly cross-country at 5,000 feet indicated altitude does not mean that your aircraft is moving at a constant level of 5,000 feet above mean sea level. However, since instrument flight in controlled airspace is accomplished at assigned indicated altitudes, aircraft separation is maintained because all aircraft using the same altimeter setting are equally affected by nonstandard conditions at various levels.

Altimeter Errors. Most pressure altimeters are subject to mechanical, elastic, temperature, and installation errors. Although manufacturing and installation specifications, as well as the periodic tests and inspections required by regulations (FAR 43, Appendix E), act to reduce these errors —any scale error should be noted prior to flight. Scale error may be observed in the following manner:

1. Set the current reported altimeter setting on the altimeter setting scale.
2. Altimeter should now read field elevation if you are located on the same reference level used to establish the altimeter setting.
3. Note the variation between the known field elevation and the altimeter indication. If this variation is in the order of plus or minus 75 feet, the accuracy of the altimeter is questionable and the problem should be referred to an appropriately rated repair station for evaluation and possible correction.

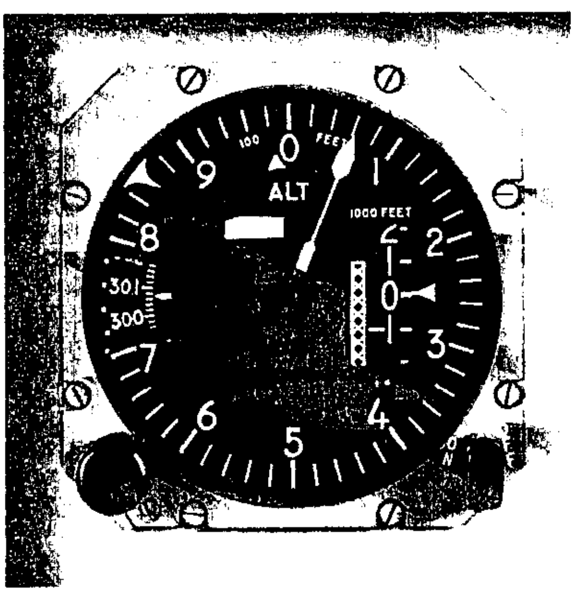


Figure 58.

Trends in pressure altimeter design are to be seen in Figures 58 and 59. Both instruments are similar, differing mainly in presentation of the altimeter setting scales. For improved readability, the instruments provide readout of altitude in "thousands" of feet on the drum, while the single needle indicates altitude in "hundreds" of feet.

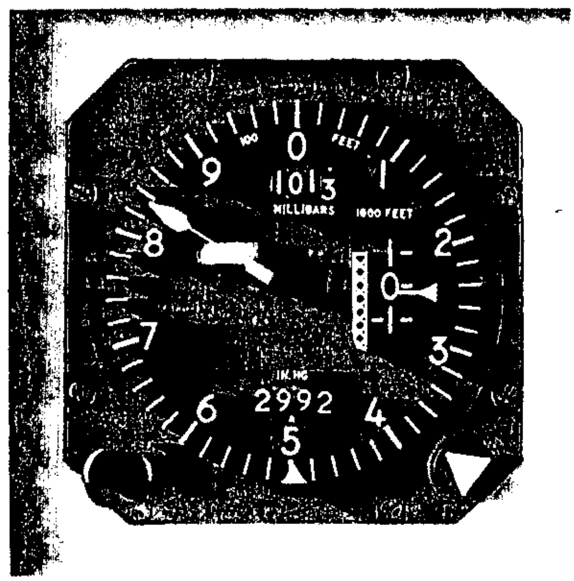


Figure 59.

Radar Altimeter

The radar altimeter, also known as ground avoidance radar, provides a continuous indication of aircraft height above the ground. The system is a "down-looking" device which measures accurately the distance between the aircraft and the highest object on the terrain. The time interval between a transmitted and received radio frequency signal is processed by an airborne computer and converted into an absolute altitude reading. The radar altimeter shown in Figure 60 has a digital readout. Another type has a dial presentation. A warning light and tone are provided in this model which alerts the pilot when the aircraft reaches a pre-selected altitude.

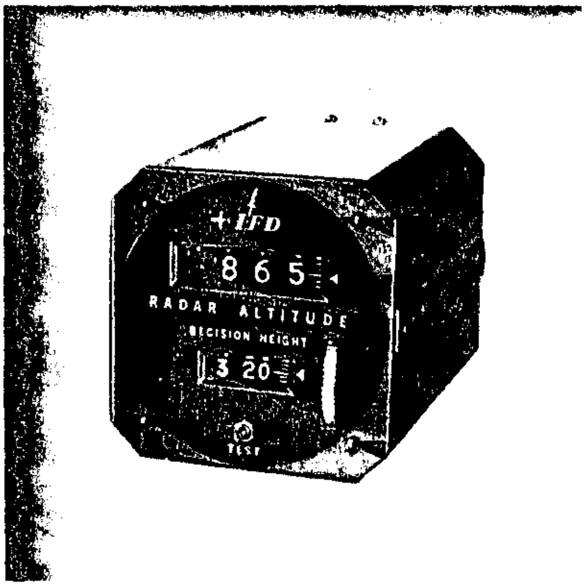


FIGURE 60. Radar altimeter.

Vertical-Speed Indicator

The vertical-speed indicator (also called the vertical-velocity or rate-of-climb indicator) is contained within a sealed case, connected to the static pressure line through a calibrated leak. As shown in Figure 61, changing pressures expand or contract a diaphragm, connected to the indicating needle through gears and levers. The instrument automatically compensates for changes in temperature. Although the vertical-speed indicator operates from the static pressure source, it is a differential pressure instrument. The differential pressure is established between the instantaneous static pressure in the diaphragm and the trapped static pressure within the case.

When the pressures are equalized in level flight, the needle reads zero. As static pressure in the diaphragm changes during entry to a climb or descent, the needle immediately shows a change of vertical direction. However, until the differential pressure stabilizes at a definite ratio, reliable rate indications cannot be read. Because of the restriction in air flow through the calibrated leak, a 6- to 9-second lag is required to equalize or stabilize the pressures.

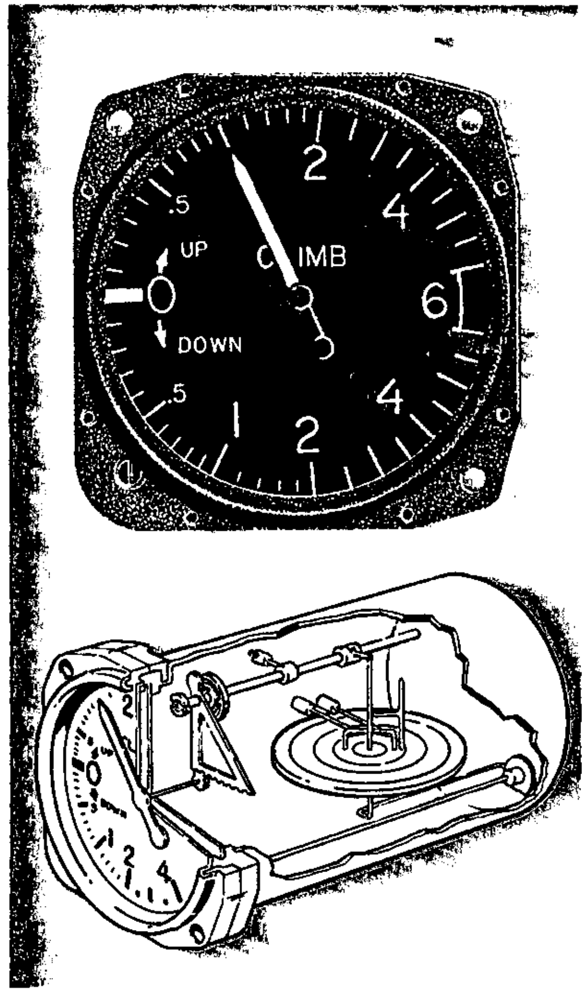


FIGURE 61. Vertical-speed indicator components.

Limitations in the use of the vertical-speed indicator are due to the calibrated leak. Sudden or abrupt changes in aircraft attitude cause erroneous instrument readings as the air flow fluctuates over the static ports. Both rough control technique and turbulent air result in unreliable needle indications. When used properly, the instrument provides reliable information to establish and maintain level flight and rate climbs or descents.

The *instantaneous vertical-speed indicator* is a recent development which incorporates acceleration pumps to eliminate the limitations associated with the calibrated leak. For example, during climb entry, vertical acceleration causes the pumps to supply extra air into the diaphragm to stabilize the pressure differential without the usual lag time. During level flight and steady rate climbs and descents, the instrument operates on the same principles as the earlier conventional type.

Adjustment.—The needle of the vertical velocity indicator should indicate zero when the aircraft is on the ground or maintaining a constant pressure level in flight. Most instruments can be adjusted to a zero reading by turning a screw on the lower left corner of the instrument case. If this adjustment cannot be made, you must allow for the error when interpreting the indications in flight.

Airspeed Indicator

The airspeed indicator is constructed to measure the difference between ram pressure from the pitot head and atmospheric pressure from the static source. The instrument (Fig. 62) is contained within a sealed case in which is mounted a diaphragm sensitive to pressure changes. The impact pressure line is connected directly to one side of the diaphragm, while the inside of the case is vented to the static source. As the aircraft accelerates or decelerates, expansion or contraction of one side of the diaphragm moves the indicator needle by means of gears and levers. The airspeed dial may show indicated airspeed, true airspeed, Mach (airspeed converted to a decimal fraction of the speed of sound), or a combination of these values calibrated in miles per hour or knots.

Airspeed Errors.—Airspeed, like altitude, is a general term that must be more specifically identified for its application to flying. The instrument is designed to provide speed information under specific limited conditions. Whenever the conditions alter, errors are introduced.

Position error is caused by the static ports sensing erroneous static pressure. The slipstream flow causes disturbances at the static ports preventing actual atmospheric measurement. The error varies with airspeed, altitude, and configuration and may be a plus or a minus value. The error may be determined by reference to an airspeed calibration chart or table. The chart or table may be posted near the airspeed indicator, or included in the Airplane Flight Manual or owner's handbook.

Density error is introduced by changes in altitude and temperature for which the instrument does not automatically compensate. The standard airspeed instrument cannot adjust for variations from sea-level standard atmosphere conditions.

Compressibility error is caused by the packing of air into the pitot tube at high airspeeds, resulting in higher than normal readings. Below approximately 180 knots and at low altitudes the error is negligible.

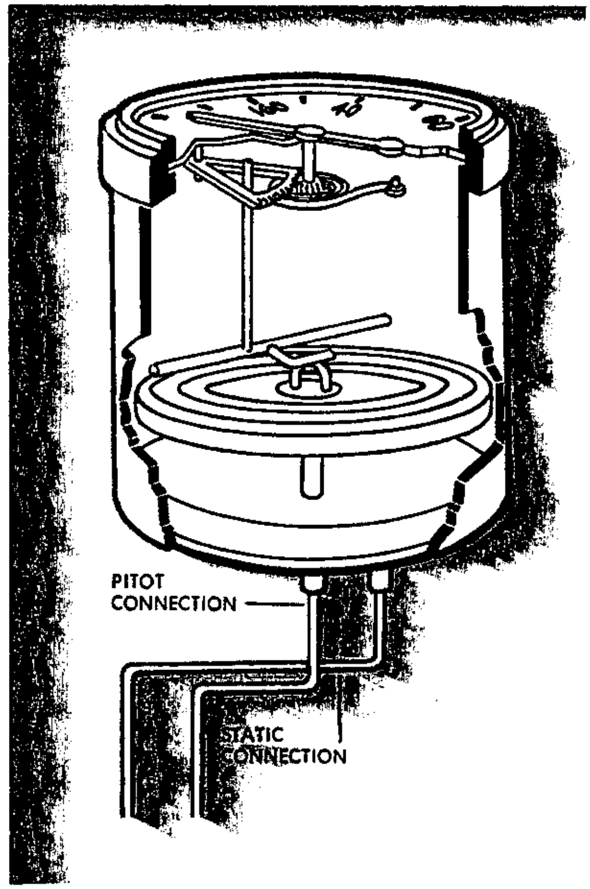


FIGURE 62. Airspeed indicator components.

Types of Airspeed

Indicated airspeed is the value read on the face of a standard airspeed indicator. The indicator is calibrated to reflect standard atmosphere adiabatic compressible flow at sea level corrected for airspeed system errors. It can be read in miles per hour or in knots, depending upon the scale of the dial.

Calibrated airspeed is the indicated airspeed of an aircraft, corrected for position and instrument error. Calibrated airspeed is equal to true airspeed in standard atmosphere at sea level.

Equivalent airspeed is the calibrated airspeed of an aircraft corrected for adiabatic compressible flow for the particular altitude. Equivalent airspeed is equal to calibrated airspeed in standard atmosphere at sea level; it is significant to pilots of high speed aircraft, but relatively unimportant to the average light plane pilot.

True airspeed is the airspeed of an aircraft relative to undisturbed air. It is equivalent airspeed corrected for air-density variation from the standard value at sea level. True airspeed increases with altitude when indicated airspeed remains the same.

Mach number is the ratio of true airspeed to the speed of sound.

True Airspeed Indicator

The *true airspeed indicator* combines computer operation and indicator in one instrument to provide both true and indicated airspeed (within the cruising speed range).

Figure 63 illustrates the current trend in the design of flight instruments which reduce pilot workload. With the adjusting knob, pressure altitude is set opposite outside air temperature. The needle then shows indicated airspeed in both knots and miles per hour, and true airspeed in m.p.h. More advanced true airspeed indicators contain diaphragms which respond to barometric pressure, free air temperature, and impact pressure. These factors are mechanically resolved to provide true airspeed indications.

Mach Indicator

The Mach indicator is found on more recently developed high performance aircraft. It indicates the ratio of aircraft true airspeed to the speed of sound at flight altitude. The Mach pointer is actuated mechanically by the pressure differential between impact air and static air pressure. In computing a true airspeed from indicated airspeed, air density must be taken into account. This requires a correction for temperature and altitude. With a Mach number, these corrections are unnecessary because the existing temperature at flight level determines the speed of sound at flight level. The Mach number is determined by the speed of sound, which in turn is determined by air density; thus, Mach is always a valid index to the speed of the aircraft.

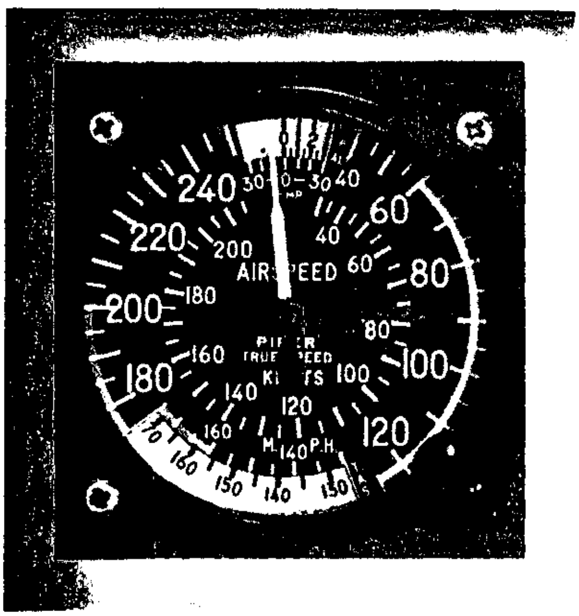


Figure 63. True airspeed indicator.

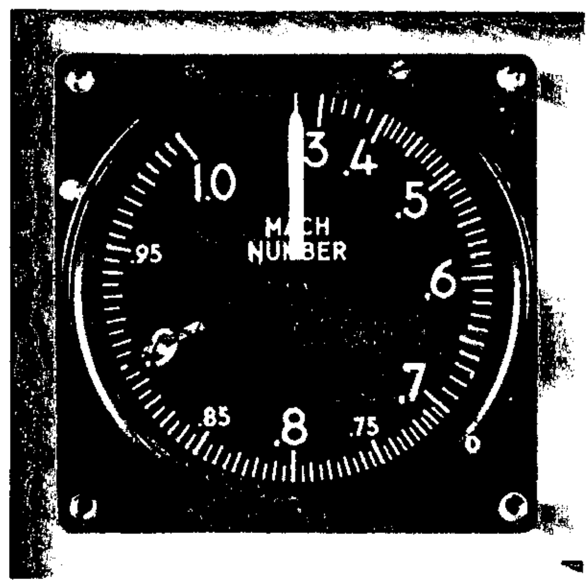
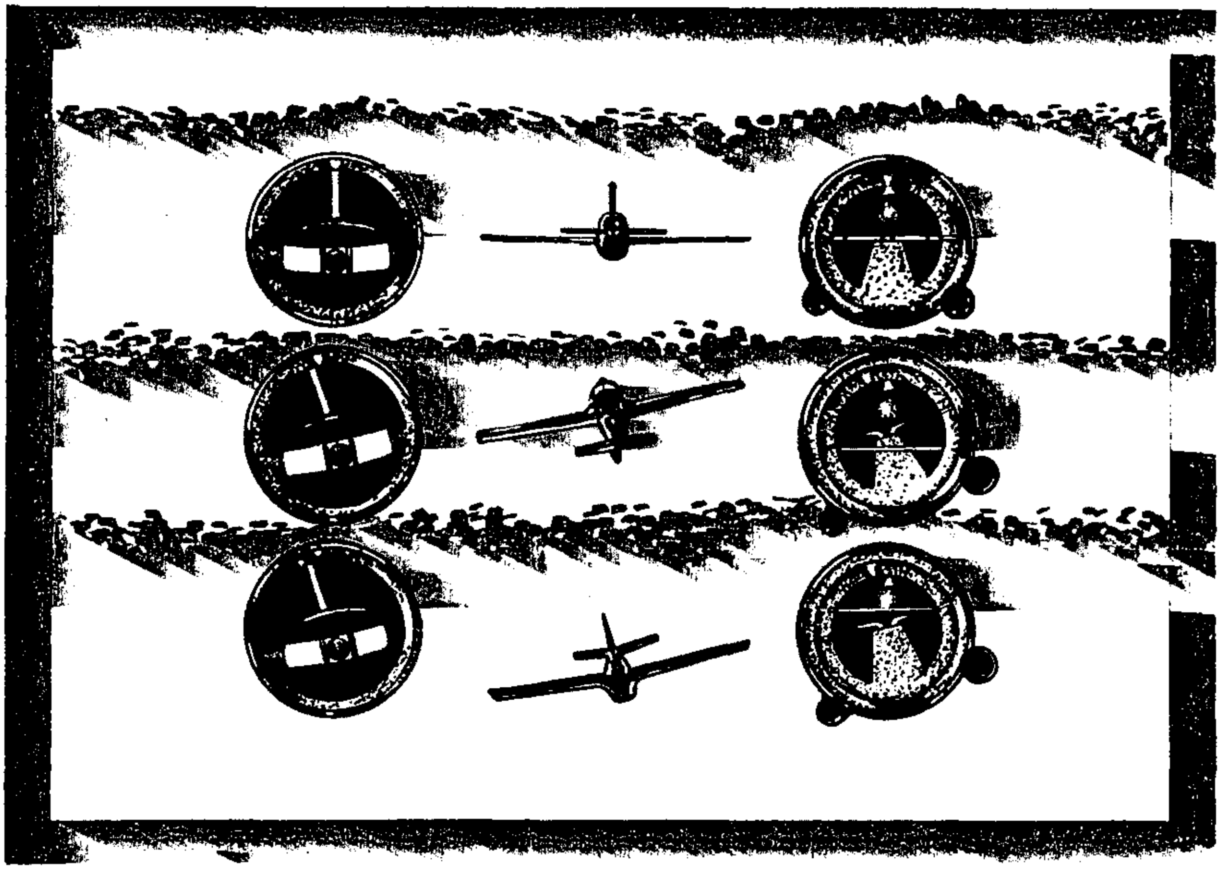


Figure 64. Mach indicator.



V. ATTITUDE INSTRUMENT FLYING

Attitude instrument flying may be defined in general terms as the control of an aircraft's spatial position by the use of instruments rather than by outside visual reference.

Any flight, regardless of the aircraft used or route flown, consists of basic maneuvers. In visual flight, you control aircraft attitude with relation to the natural horizon by using certain reference points on the aircraft. In instrument flight, you control aircraft attitude by reference to the flight instruments. A proper interpretation of the flight instruments will give you essentially the same information that outside references do in visual flight. Once you learn the role of all instruments in establishing and maintaining a desired aircraft attitude, you are better equipped to control the aircraft in emergency situations involving failure of one or more key instruments.

There are at least two basic methods in use for learning attitude instrument flying. Both methods involve the use of the same instruments, and both use the same responses for attitude control. They differ in their reliance on the attitude indicator and consequently on the use and interpretation of other instruments.

One method presents the problem of attitude control essentially from this standpoint: aircraft performance depends upon how you control the attitude and thrust relationship of the aircraft. The first group of instruments presents existing performance information. The altimeter, for example, shows the altitude, or altitude changes, resulting from power and attitude control. The airspeed indicator, vertical-speed indicator, heading indicator, and turn-and-slip indicator likewise tell you what the aircraft is doing with respect to speed, vertical movement, direction, rate of direction change and trim. This group of instruments is therefore referred to as the performance instruments.

The second group of instruments presents information necessary to determine the power and

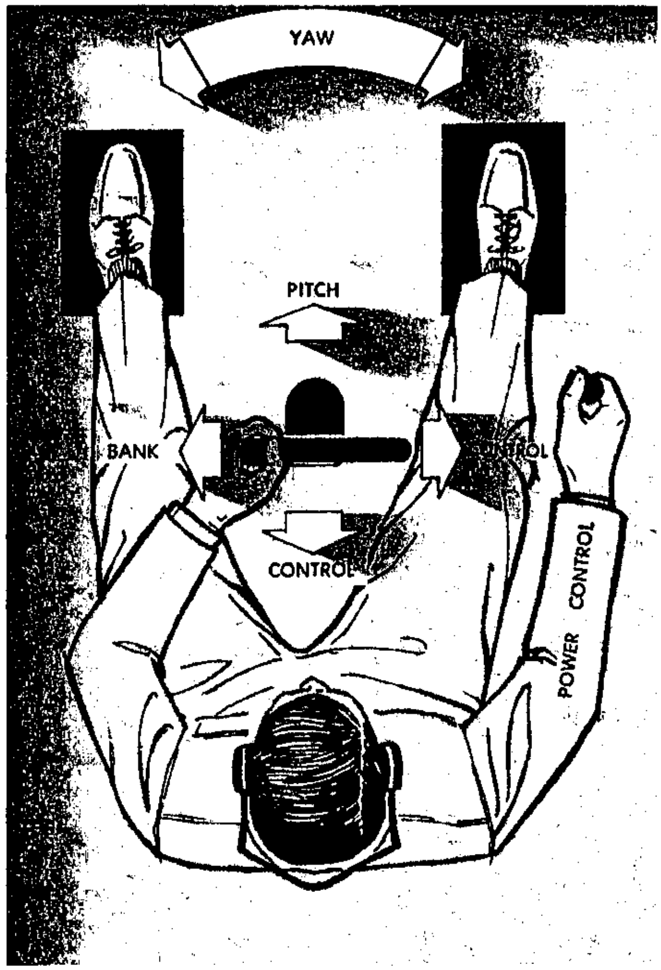


FIGURE 65. Attitude control.

attitude necessary for maintaining or changing aircraft performance. The attitude indicator and tachometer (or manifold pressure gauge and tachometer in combination) show you what pitch, bank, and power combination is controlling the performance shown on the other instruments. These are called control instruments.

The third group shows you where your flight path is with respect to the earth's surface, and therefore these are called navigation instruments.

Another basic method for presenting attitude instrument flying, groups the instruments as they relate to control function as well as aircraft performance. All aicraft maneuvers involve some degree of motion about the lateral (pitch), longitudinal (bank/roll), and vertical (yaw) axes. Attitude control is accordingly stressed in this handbook in terms of *pitch control, bank control, power control,* and *trim control* (Fig. 65). Instruments are therefore grouped as they relate to control function and aircraft performance as follows:

Pitch Instruments

Attitude Indicator
Altimeter
Airspeed Indicator
Vertical-Speed Indicator

Bank Instruments

Attitude Indicator
Heading Indicator
Turn-and-Slip Indicator

Power Instruments

Manifold Pressure Gauge (MP)
Tachometer/RPM
Airspeed Indicator
Engine Pressure Ratio (EPR)—Jet

For any aircraft maneuver or condition of flight, the pitch, bank, and power control requirements are most clearly indicated by certain key instruments. Those instruments which provide the most pertinent and essential information will be referred to as primary instruments. Supporting instruments back up and supplement the information shown on the primary instruments. Straight-and-level flight at a constant airspeed, for example, means that an exact altitude is to be maintained with zero bank (constant heading) at a constant airspeed. The pitch instrument, bank instrument, and power instrument which tell you whether you are maintaining this flight condition are the:

1. *Altimeter*—which supplies the most pertinent altitude information and is therefore primary for pitch.
2. *Heading Indicator*—which supplies the most pertinent bank or heading information ("banking" means turning) and is therefore primary for bank.
3. *Airspeed Indicator*—which supplies the most pertinent information concerning performance in level flight in terms of power output, and is therefore primary for power.

This concept of primary and supporting instruments in no way lessens the value of any particular flight instrument. The attitude indicator is the basic attitude reference. It is the only instrument which portrays instantly and directly the actual flight attitude. It should always be used, when available, in establishing and maintaining pitch and bank attitudes. The specific use of primary and supporting instruments will be better understood as the basic instrument maneuvers are presented in detail.

You will find the terms "direct indicating instrument" and "indirect indicating instrument" used in the following pages. A "direct" indication is the true and instantaneous reflection of aircraft pitch and bank attitude by the miniature aircraft relative to the horizon bar of the attitude indicator. The altimeter, airspeed indicator, and vertical-speed indicator give "indirect" indications of pitch attitude at a given power setting. The heading indicator and turn needle give "indirect" indications of bank attitude.

Included in the appendix of this handbook is a reproduction of the *Instrument Flight Instructor Lesson Guide* which is correlated with the material which follows.

NOTE.—The material in this chapter pertains primarily to fixed-wing aircraft; however, many concepts and techniques also apply to rotorcraft.

Fundamental Skills

During attitude instrument training, you must develop three fundamental skills involved in all instrument flight maneuvers: *instrument cross-check, instrument interpretation,* and *aircraft control.* Although you learn these skills separately and in deliberate sequence, a measure of your proficiency in precision flying will be your ability to integrate these skills into unified, smooth, positive control responses to maintain any prescribed flight path.

Cross-Check.—The first fundamental skill is cross-checking (also called "scanning" or "instrument coverage"). Cross-checking is the continuous and logical observation of instruments for attitude and performance information. In attitude instrument flying, the pilot maintains an attitude by reference to instruments that will produce the desired result in performance. Due to human error, instrument error, and aircraft performance differences in various atmospheric and loading conditions, it is impossible to establish an attitude and have performance remain constant for a long period of time. These variables make it necessary for the pilot to constantly check his instruments and make appropriate changes in aircraft attitude.

As a beginner, you may cross-check rapidly, looking *at* the instruments without knowing exactly what you are looking *for.* With increasing experience in basic instrument maneuvers and familiarity with the instrument indications associated with them, you will learn what to look for, when to look for it, and what response to make. As proficiency increases, you scan primarily from habit, suiting your scanning rate and sequence to the demands of the flight situation. You can expect to make many of the common scanning errors, both during training and at any subsequent time, if you fail to maintain basic instrument proficiency through practice.

The following cross-check faults are frequent problems:

1. *Fixation,* or staring at a single instrument, usually occurs for a good reason, but with poor results. For instance, you may find yourself staring at your altimeter which reads 200 feet below assigned altitude, wondering how the needle got there. While you gaze at the instrument, perhaps with increasing tension on the controls, a heading change occurs unnoticed, and more errors accumulate.

Another common fixation is likely when you initiate an attitude change. For example, you establish a shallow bank for a 90° turn and stare at the heading indicator throughout the turn, instead of maintaining your cross-check of other pertinent instruments. You know that the aircraft is turning and that you need not recheck the heading indicator for approximately 25 seconds after turn entry, yet you can't take your eyes off the instrument. The problem here may not be entirely due to cross-check error. It may be related to difficulties with one or both of the other fundamental skills. You may be fixating because of uncertainty about reading the heading indicator (interpretation) or because of inconsistency in rolling out of turns (control).

2. *Omission* of an instrument from your cross-check is another likely fault. It may be caused by failure to anticipate significant instrument indications following attitude changes. For example, on your roll out from a 180° steep turn, you establish straight and level flight with reference to the attitude indicator alone, neglecting to check the heading indicator for constant heading information. Because of precession error, the attitude indicator is giving you false information that you could have checked by quick reference to the other instrument.

3. *Emphasis* on a single instrument, instead of on the combination of instruments necessary for attitude information, is an understandable fault during initial stages of training. You naturally tend to rely on the instrument that you understand most readily, even when it provides erroneous or inadequate information. Until completely accurate and infallible instruments are devised, reliance on a single instrument is poor technique. For example, you can maintain reasonably close altitude control with the attitude indicator, but you cannot hold altitude with precision without including the altimeter in your cross-check.

Instrument Interpretation.—The second fundamental skill, instrument interpretation, requires the most thorough study and analysis. It begins with your understanding of each instrument's construction and operating principles. Then you must apply this knowledge to the performance of the aircraft you are flying, the particular maneuvers to be executed, the cross-check and control techniques applicable to that aircraft, and the flight conditions in which you are operating. For example, (Fig. 66), using full power in a light aircraft for a 5-minute climb from near sea level, the attitude indicator shows the miniature aircraft two bar widths (twice the thickness of the miniature aircraft wings) above the artificial horizon. The aircraft is climbing at 500 feet per minute as shown on the vertical-speed indicator, and at an airspeed of 90 knots, as shown on the airspeed indicator. With the power available in this particular aircraft and the attitude selected by the pilot, the performance is shown on the instruments.

Now set up the identical picture on the attitude indicator in a modern jet executive aircraft. With the same aircraft attitude as shown in the first example, the vertical-speed indicator in the jet reads 2,000 feet per minute, and the airspeed indicates 300 knots. As you learn the performance capabilities of the aircraft in which

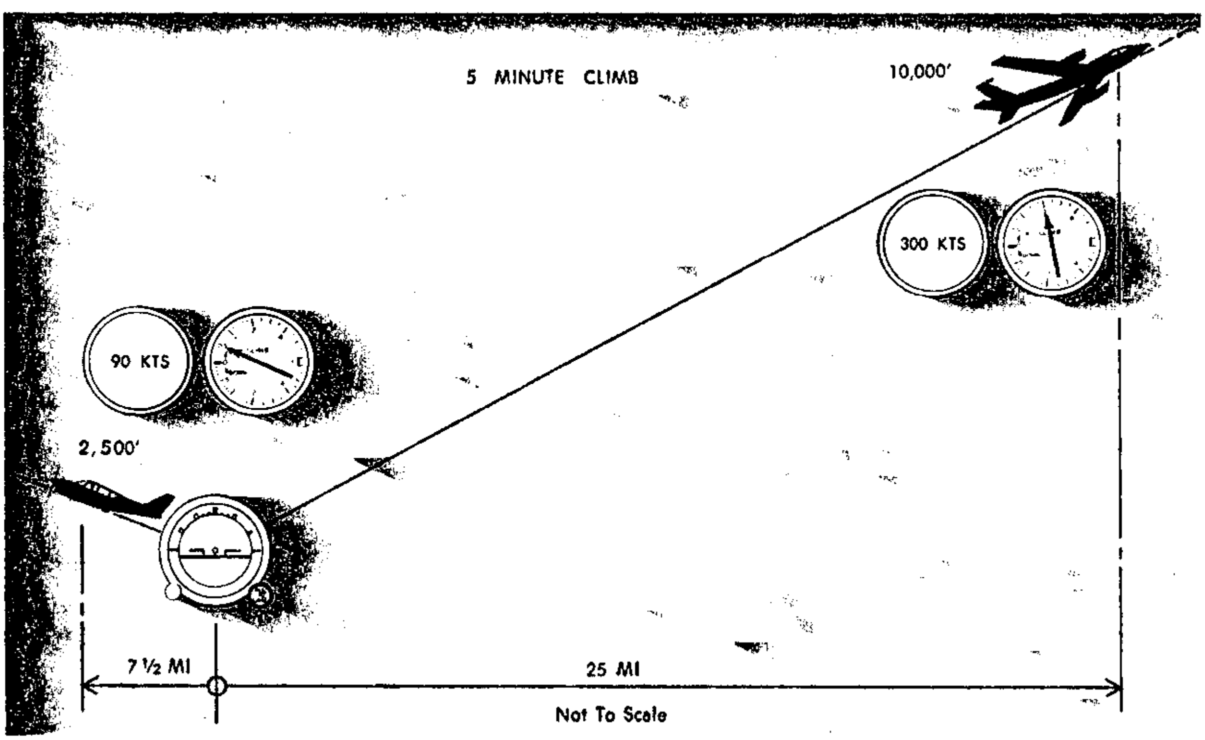


FIGURE 66. Power and attitude equal performance.

you are training, you will interpret the instrument indications appropriately in terms of the attitude of the aircraft. If the pitch attitude is to be determined, the airspeed indicator, altimeter, vertical-speed indicator, and attitude indicator provide the necessary information. If the bank attitude is to be determined, the heading indicator, turn and slip indicator, and attitude indicator must be interpreted.

For each maneuver, you will learn what performance to expect and the combination of instruments that you must interpret in order to control aircraft attitude during the maneuver.

Aircraft Control.—The third fundamental instrument flying skill is aircraft control. With the instruments substituted for outside references, the necessary control responses and thought processes are the same as those for controlling aircraft performance by means of outside references. Knowing the desired attitude of the aircraft with respect to the natural and artificial horizon, you maintain the attitude or change it by movement of the appropriate controls.

Aircraft control is composed of three components: pitch control, bank control, and power control.

1. *Pitch control* is controlling the rotation of the aircraft about the lateral axis by movement of the elevators. After interpreting the pitch attitude from the proper flight instruments, you exert control pressures to effect the desired pitch attitude with reference to the horizon.

2. *Bank control* is controlling the angle made by the wing and the horizon. After interpreting the bank attitude from the appropriate instruments, you exert the necessary pressures to move the ailerons and roll the aircraft about the longitudinal axis.

3. *Power control* is used when interpretation of the flight instruments indicates a need for a change in thrust.

Trim is used to relieve all possible control pressures held after a desired attitude has been attained. An improperly trimmed aircraft requires constant control pressures, produces tension, distracts your attention from cross-checking, and contributes to abrupt and erratic attitude control. The pressures you feel on the controls must be those *you* apply while controlling a planned change in aircraft attitude, not pressures held because you let the aircraft control you.

Preflight Instrument Check

Before any flight, especially a flight into instrument conditions, a thorough check should be made of all instruments and equipment in the aircraft. Your aircraft flight handbook lists the items to be checked. They may vary as to sequence and content from the checks shown below.

Before Starting Engine.—Although the following pre-start check might seem a waste of time, it can reveal conditions or defects which would make starting inadvisable.

1. Appropriate handbooks, charts, approach plates, computer, and flight log.
2. Radio equipment—switches off.
3. Suction gauge—proper markings.
4. Pitot cover—removed.
5. Airspeed indicator—proper reading.
6. Heading indicator—uncaged.
7. Attitude indicator—uncaged.
8. Turn-and-slip indicator—needle centered, tube full of fluid.
9. Vertical-speed indicator—zero indication.
10. Magnetic compass—full of fluid.
11. Clock—wind and set to the correct time.
12. Engine instruments—proper markings and readings.
13. De-icing and anti-icing equipment—availability and fluid quantity.

After Starting Engine.—Make the following checks.

1. *Suction Gauge or Electrical Indicators.*—Check the source of power for the gyro instruments. The suction developed should be appropriate for the instruments in that particular aircraft. If the gyros are electrically driven, check the generators and inverters for proper operation.

2. *Pitot Head.*—Heat checked.

3. *Magnetic Compass.*—Check the card for freedom of movement and be sure that the bowl is full of fluid. Determine compass accuracy by comparing the indicated heading against a known heading while the aircraft is stopped or taxiing straight. Remote Indicating Compasses should also be checked against known headings.

4. *Heading Indicator.*—Allow 5 minutes after starting engines for the gyro rotor of the vacuum-operated heading indicator to attain normal operating speed. Cage the gyro and uncage it, simultaneously pulling out and turning the knob. (If the card continues to turn, the gyro is not operating properly.) Before taxiing, or while taxiing straight, set the heading indicator to correspond with the magnetic compass heading. Before takeoff, recheck the heading indicator. If your magnetic compass and deviation card are accurate, the heading indicator should show the known taxiway or runway direction when the aircraft is aligned with them (within 5°).

Electric gyros should also be set and checked against known headings. Allow 3 minutes for the electric gyro to attain operating speed. A gyrosyn (slaved gyro) compass should be checked for slaving action and its indications compared with those of the magnetic compass.

5. *Attitude Indicator.*—Allow the same times as noted above for gyros to attain normal rotor speed. If the horizon bar erects to the horizontal position and remains at the correct position for the attitude of the aircraft, or if it begins to vibrate after this attitude is reached and then slowly stops vibrating altogether, the instrument is operating properly. If the horizon bar fails to remain in the horizontal position during straight taxiing, or tips in excess of 5° during taxi turns, the instrument is unreliable.

Adjust the miniature aircraft with reference to the horizon bar for the particular aircraft while on the ground. For some tricycle-geared aircraft, a slightly nose-low attitude on the ground will give a level flight attitude at normal cruising speed.

6. *Altimeter.*—With the altimeter set to the current reported altimeter setting, note any variation between the known field elevation and the altimeter indication. If the variation is in the order of plus or minus 75 feet, the accuracy of the altimeter is questionable and the problem should be referred to an appropriately rated repair station for evaluation and possible correction.

7. *Turn-and-Slip Indicator.*—Check the turn needle for right and left deflection and for positive return to the center position. The check can be made by depressing one side of the shock-mounted panel and releasing it, or by noting the indications during taxi turns. The ball should move freely in the tube and no bubbles should appear in the fluid.

8. *Vertical-Speed Indicator.*—The instrument should read zero. If it does not, tap the panel gently. If it stays off the zero reading and is not adjustable, the ground indication will have to be interpreted as the zero position in flight.

9. *Carburetor Heat.*—Check for proper operation and return to cold position.

10. *Engine Instruments.*—Check for proper readings.

11. *Radio Equipment.*—Check for proper operation and set as desired.

12. *De-Icing and Anti-Icing Equipment.*—Check operation.

Basic Maneuvers

Instrument flying techniques differ according to aircraft type, class, category, performance capability, and instrumentation. The procedures and techniques that follow will, therefore, need to be modified for application to different types of aircraft. Recommended procedures, performance data, operating limitations, and flight characteristics of a particular aircraft are available in your aircraft flight manual or owner's handbook for study before practicing the flight maneuvers.

The flight maneuvers discussed here assume a single-engine, propeller-driven light airplane with retractable gear and flaps and a panel with instruments representative of those discussed earlier under "Basic Flight Instruments." The sequence of maneuvers in the training curriculum, as well as the time necessary for their mastery, is also flexible. The instrument takeoff, for example, is not required on the flight check for the instrument rating. Whether or not it is worth your study and practice depends upon the flight instruments you have available and the weather conditions in which you expect to fly. With the exception of the instrument takeoff, all of the maneuvers can be performed on "partial panel," with the attitude gyro and heading indicator covered or inoperative.

Straight-and-Level Flight

Pitch Control.—The pitch attitude of an aircraft is the angle between the longitudinal axis of the aircraft and the actual horizon. In level flight, the pitch attitude varies with airspeed and with load. For training purposes, the latter factor can normally be disregarded in light aircraft. At a constant airspeed, there is only one specific pitch attitude for level flight. At low cruise speeds, the level flight attitude is nose-high (Fig. 67); at high cruise speeds, the level flight attitude is nose-low (Fig. 68). Figure 69 shows the attitude at normal cruise speeds.

The pitch instruments are the *attitude indicator*, the *altimeter*, the *vertical-speed indicator*, and the *airspeed indicator*.

The *attitude indicator* gives you a *direct* indication of pitch attitude. You attain the desired pitch attitude by raising or lowering the miniature aircraft in relation to the horizon bar by means of elevator control. This corresponds to the way you adjust pitch attitude in contact flight by raising or lowering the nose of the aircraft in relation to the natural horizon. However, unless the airspeed is constant, and until you have established and identified the level flight attitude for that airspeed, you have no way of knowing whether level flight, as indicated on the attitude indicator, is resulting in level flight as shown on the altimeter, vertical-speed indicator, and airspeed indicator. With the miniature aircraft of the attitude indicator properly adjusted on the ground before takeoff, it will show approximately level flight at normal cruise speed

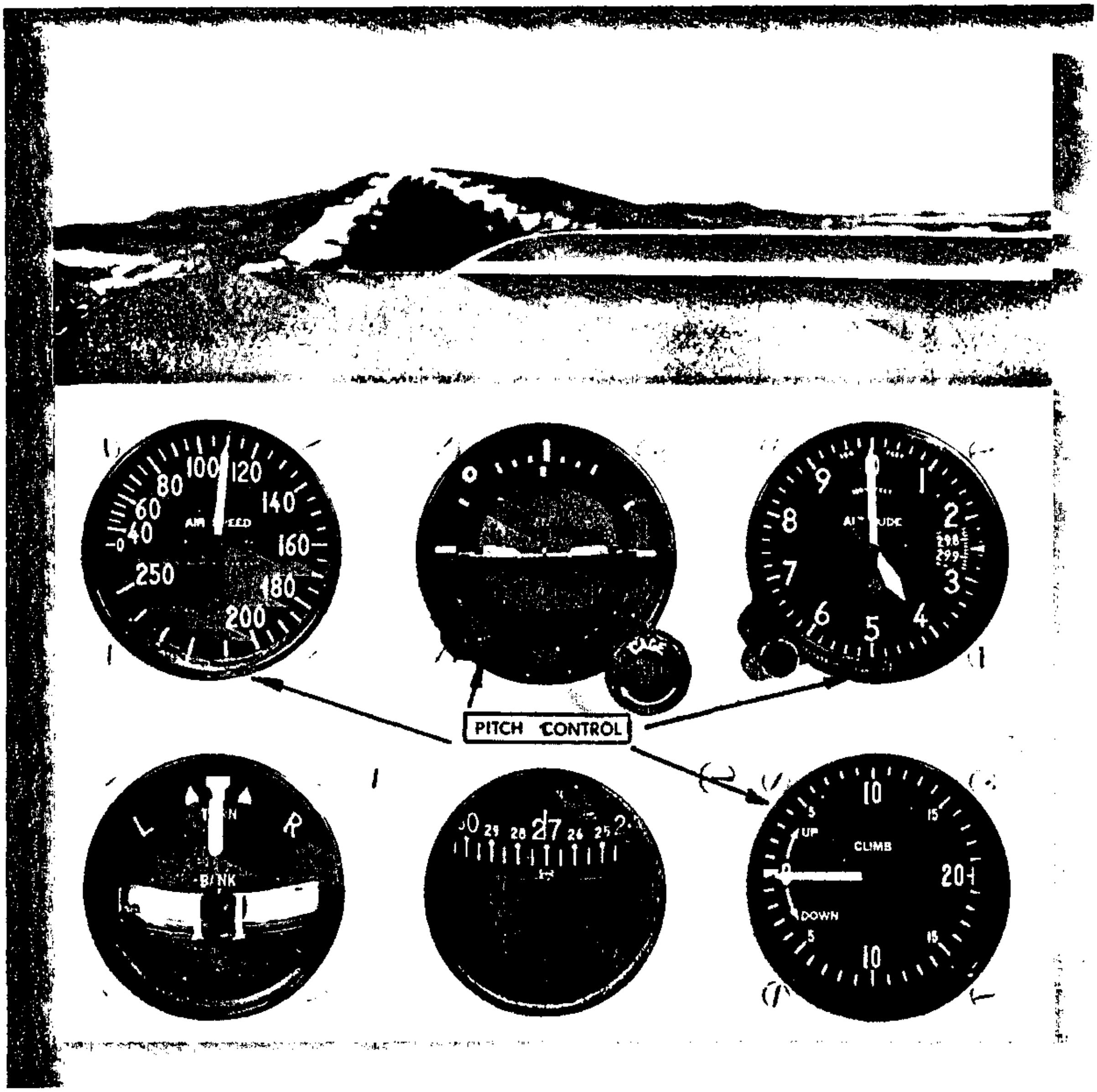


FIGURE 67. Pitch attitude and airspeed in level flight—low cruise speed.

when you complete your level-off from a climb. If further adjustment of the miniature aircraft is necessary, the other pitch instruments must be used to maintain level flight while the adjustment is made. Caging and uncaging the attitude indicator in flight, as well as the limitations of the instrument, have been discussed in Chapter IV, "Basic Flight Instruments."

In practicing pitch control for level flight, using only the attitude indicator, restrict the displacement of the horizon bar to a bar width up or down, a half-bar width, then a one-and-one-half bar width. One-, two-, and three-bar-width nose-high attitudes are shown in Figures 70-72.

Your instructor will demonstrate these normal pitch corrections while you compare the indications on the attitude indicator with the aircraft's position with respect to the natural horizon. Note that pitch attitude changes for corrections to level flight by reference to instruments are much smaller than those commonly used for contact flight. Note especially that, with the aircraft correctly trimmed for level flight, the elevator displacement and the control pressures necessary to effect these standard pitch changes are usually very slight. Just how much elevator control pressure to use is a problem you must solve for yourself, with a few helpful hints.

First, you cannot feel control pressure changes with a tight grip on the controls. Relaxing and learning to control "with your eyes and your head" instead of your muscles usually takes considerable conscious effort during early stages of instrument training.

Second, make the pitch changes smooth and small, yet with a positive pressure. Practice these small corrections until you can make pitch corrections up or down, "freezing" (holding constant) the one-half, full, and one-and-one-half bar widths on the attitude indicator.

Third, with the aircraft properly trimmed for level flight, momentarily release all of your pressure on the elevator control when you become aware of tenseness. This will remind you that the aircraft is stable and, except under turbulent conditions, will maintain level flight if you leave it alone. One of your most difficult initial training problems will be to resist the impulse to move the controls, even when your eyes tell you that no control change is called for.

At a constant thrust, any deviation from level

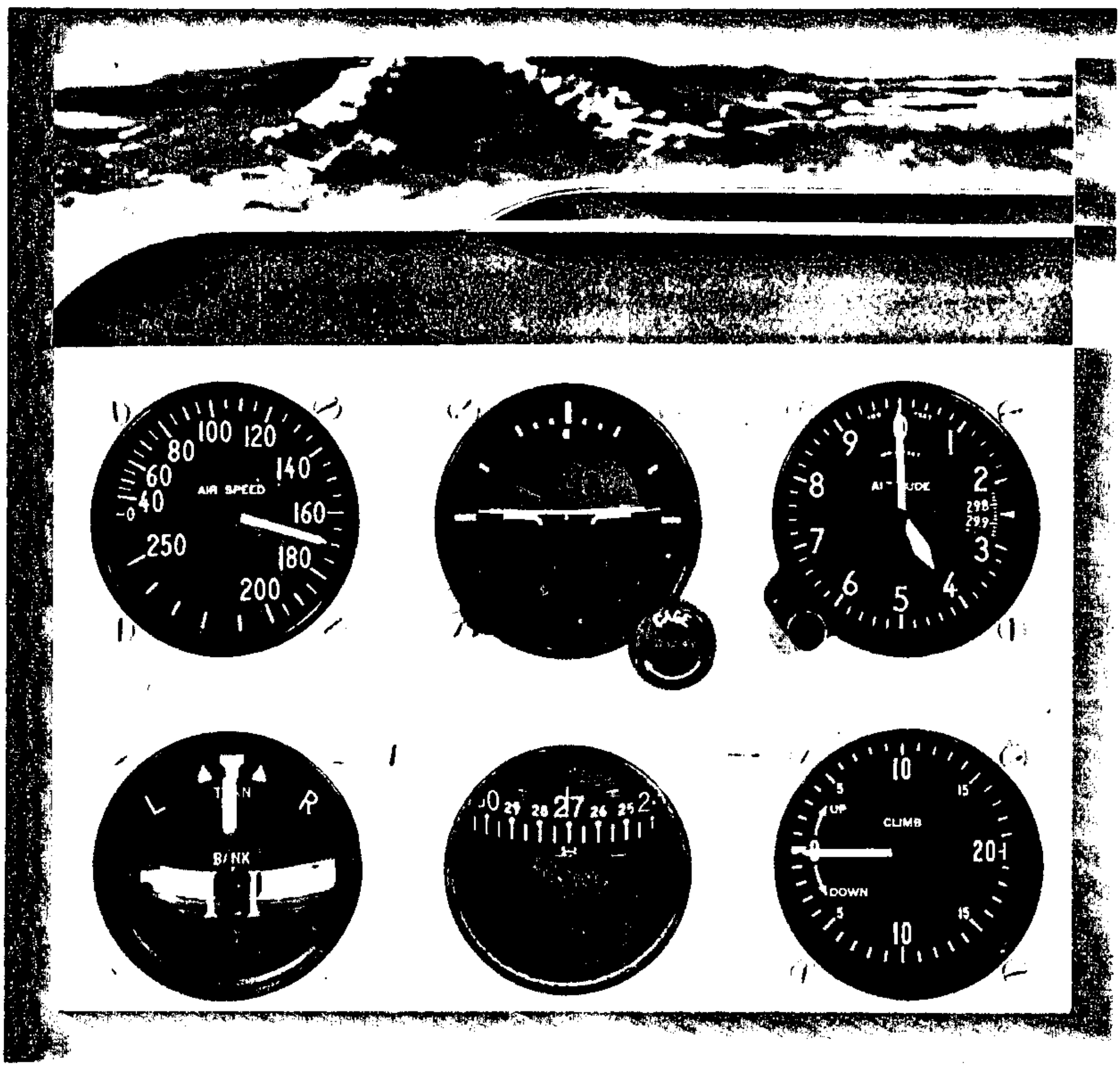


FIGURE 68. Pitch attitude and airspeed in level flight—high cruise speed.

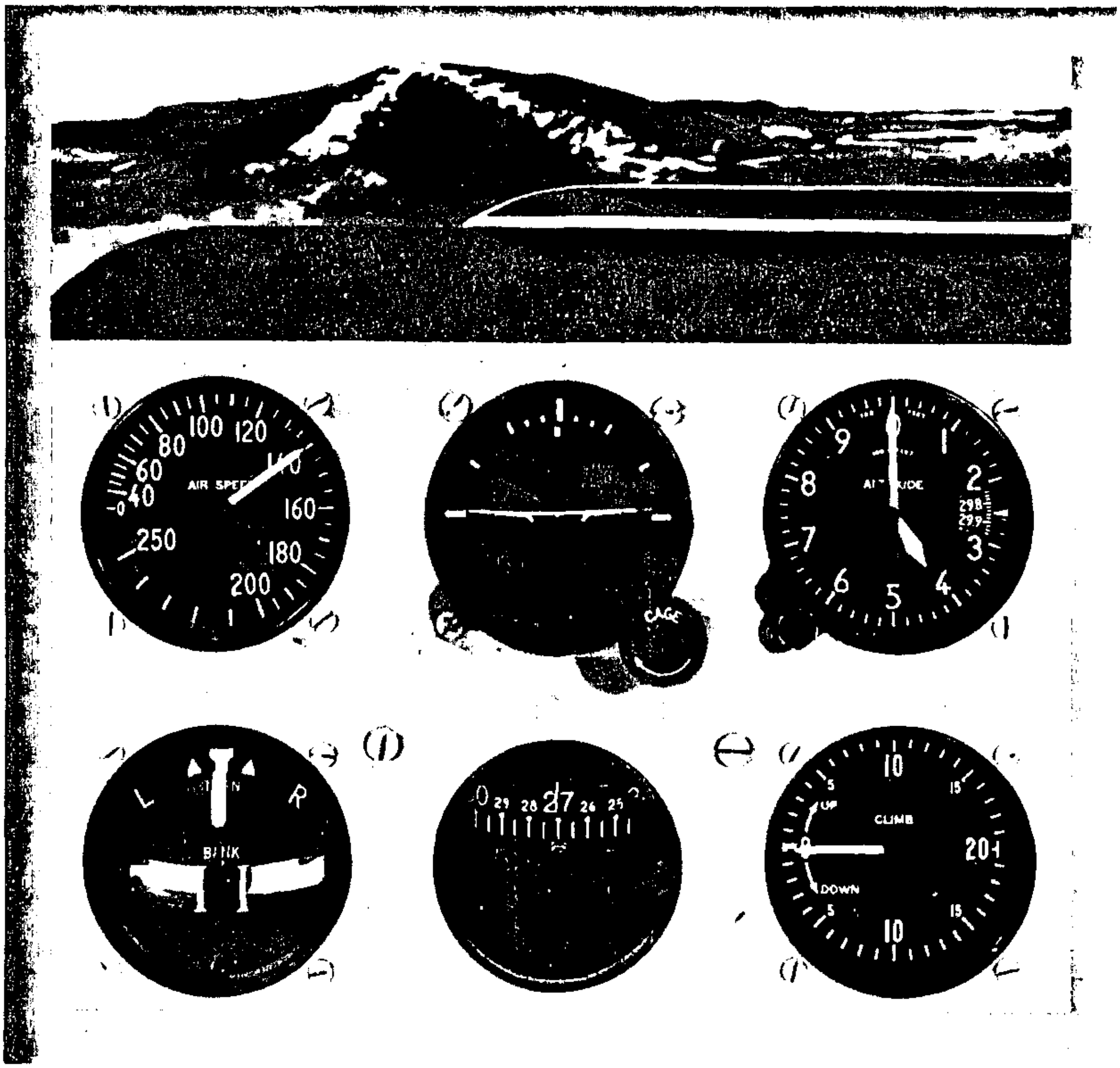


FIGURE 69. Pitch attitude and airspeed in level flight—normal cruise speed.

flight (except in turbulent air) must be the result of a pitch change. The *altimeter,* therefore, gives you an *indirect* indication of the pitch attitude in level flight, assuming constant power. Since the altitude should remain constant when the aircraft is in level flight, any deviation from the desired altitude shows the need for a pitch change. If you are gaining altitude (Fig. 73), the nose must be lowered (Fig. 74). How much? And how can it be done by reference to the altimeter alone?

The *rate* of movement of the altimeter needle is as important as its *direction* of movement in maintaining level flight without the use of the attitude indicator. An excessive pitch deviation from level flight results in a relatively rapid change of altitude; while a slight pitch deviation causes a slow change. Thus, if the altimeter needle moves rapidly clockwise, assume a considerable nose-high deviation from level flight attitude. Conversely, if the needle moves slowly counter-clockwise to indicate a slightly nose-low attitude, assume that the pitch correction necessary to regain the desired altitude is small. As you add the altimeter to the attitude indicator in your cross-check, you will learn to recognize the rate of movement of the altimeter needle for a given pitch change as shown on the attitude

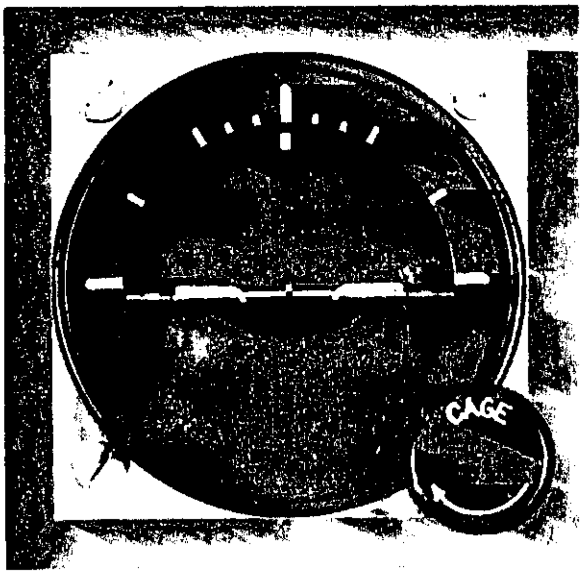


FIGURE 70. Pitch correction for level flight—one-bar width.

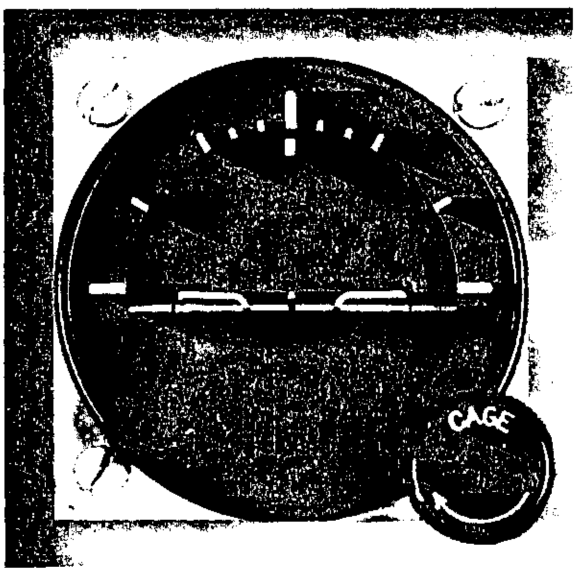


FIGURE 71. Pitch correction for level flight—two-bar width.

indicator.

If you are practicing precision control of pitch in an aircraft without an attitude indicator, make small pitch changes by visual reference to the natural horizon, and note the rate of movement of the altimeter. Note the pitch change giving the slowest steady rate of change on the altimeter. Then practice small pitch corrections until you can control them by interpretation and control of the rate of needle movement.

Your instructor may demonstrate an excessive

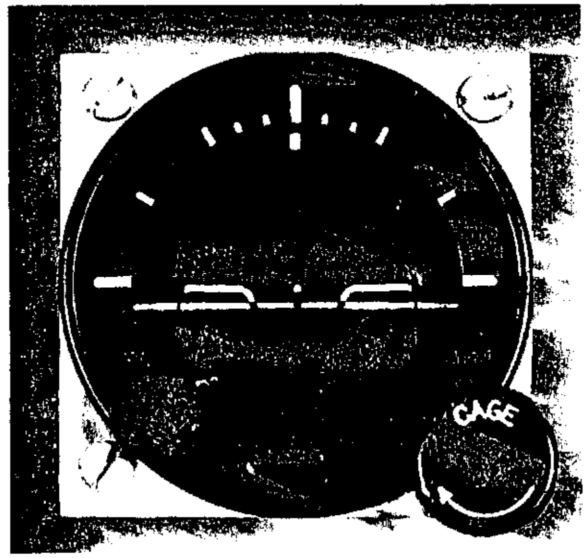


FIGURE 72. Pitch correction for level flight—three-bar width.

nose-down deviation (indicated by rapid movement of the altimeter needle) and then, as an example, show you the result of improper corrective technique. The normal impulse is to make a large pitch correction in a hurry, but this inevitably leads to overcontrolling: the needle slows down, then reverses direction, and finally indicates an excessive nose-high deviation. The result is tension on the controls, and erratic control response and increasingly extreme control movements. The correct technique, which is slower and smoother, will return the aircraft to the desired attitude more quickly, with positive control and no confusion.

When a pitch error is detected, corrective action should be taken promptly, but with light control pressures and with two distinct changes of attitude: first is a change of attitude to stop the needle movement, second is a change of attitude to return to the desired altitude.

When you observe needle movement indicating an altitude deviation, apply just enough elevator pressure to slow down the rate of needle movement. If it slows down abruptly, ease off some of the pressure unitl the needle continues to move, but slowly. Slow needle movement means that your aircraft attitude is close to level flight. Add a little more corrective pressure to stop the direction of needle movement. At this point you are in level flight; a reversal of needle movement means that you have passed through it. Relax your control pressures carefully as you continue to cross-check, since changing airspeed will cause changes in the effectiveness of a given control pressure. Next, adjust the pitch attitude with elevator pressure for the rate of change

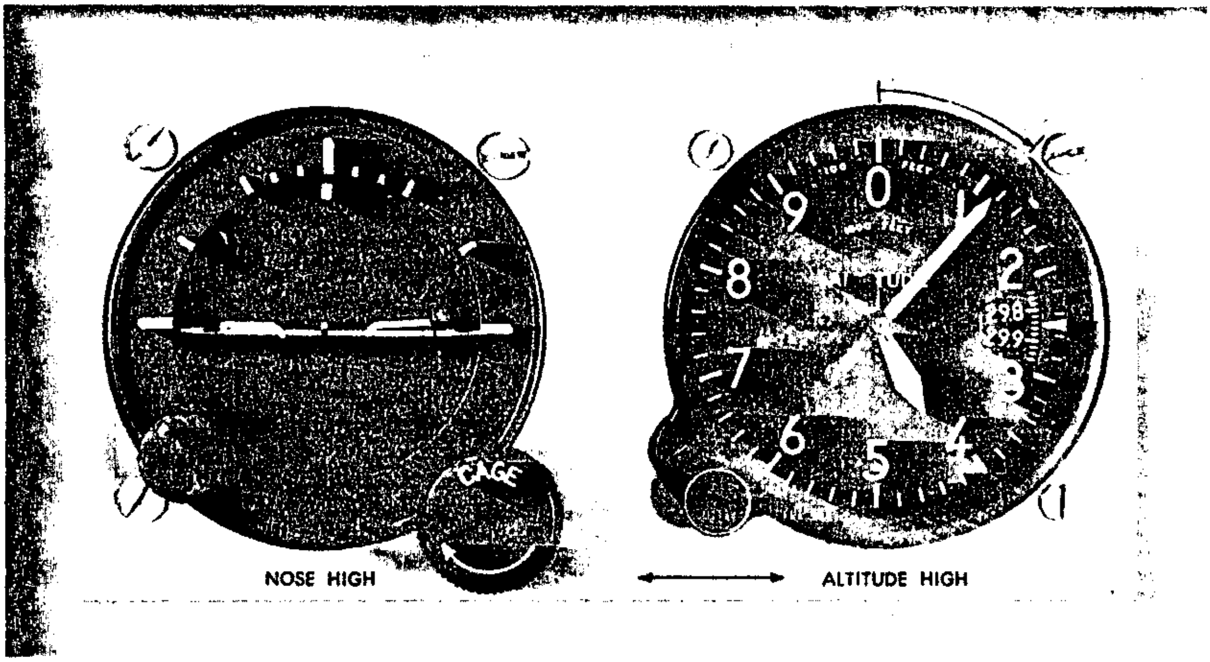


FIGURE 73. Using the altimeter for pitch interpretation—altitude increase.

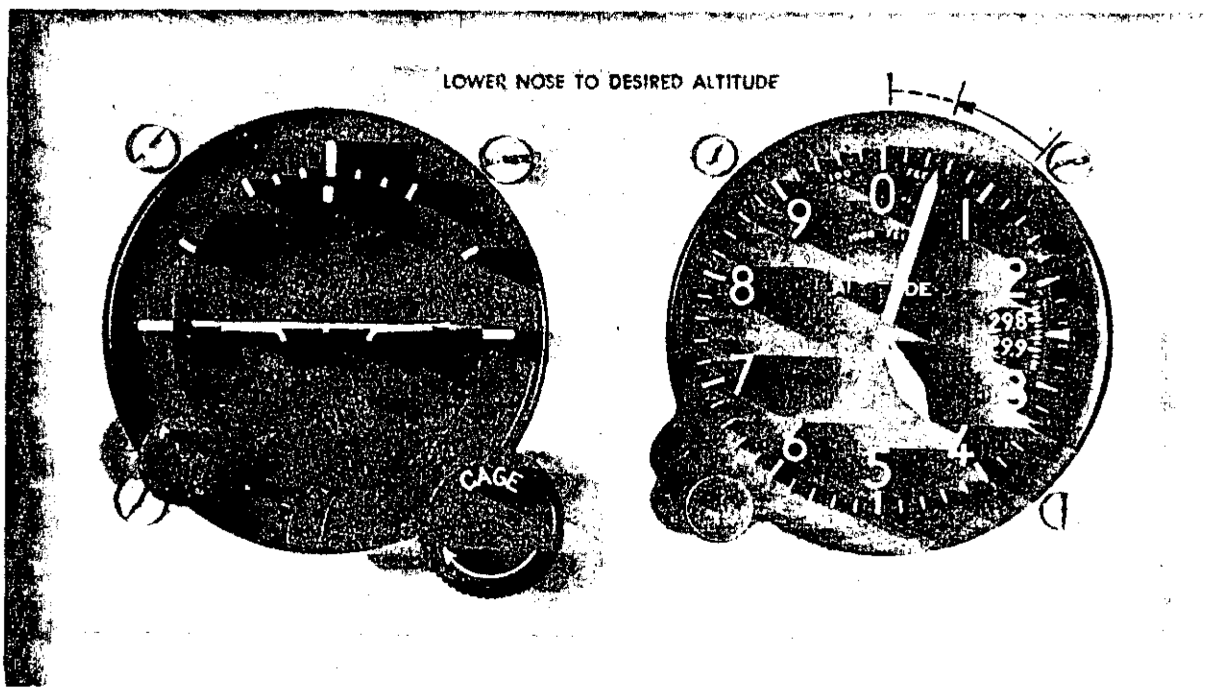


FIGURE 74. Pitch correction following altitude increase.

of altimeter needle movement that you have correlated with normal pitch corrections, and return to the desired altitude.

As a rule of thumb, for corrections of less than 100 feet (Fig. 75), use a half-bar-width correction (Fig. 76); for corrections in excess of 100 feet (Fig. 77), use a full-bar-width correction (Fig. 78).

Practice predetermined altitude changes using the altimeter alone, then in combination with the attitude indicator.

The *vertical-speed indicator* gives an *indirect* indication of pitch attitude and is both a trend and a rate instrument. As a trend instrument, it shows immediately the initial vertical movement of the aircraft, which, disregarding turbulence, can be considered a reflection of pitch change. To maintain level flight, use the vertical-speed indicator in conjunction with the altimeter and attitude indicator. Note any "up" or "down" trend of the needle from zero and apply a very light corrective elevator pressure. As the needle returns to zero, relax the corrective pressure. If your control pressures have been smooth and light, the needle will react immediately and slowly, and the altimeter will show little or no change of altitude.

Used as a rate instrument, the lag characteristics of the vertical-speed indicator must be considered.

Lag refers to the delay involved before the needle attains a stable indication following a pitch change. Lag is directly proportional to the speed and magnitude of a pitch change. If a slow, smooth pitch change is initiated, the needle will move, with minimum lag, to a point of deflection corresponding to the extent of the pitch change and then stabilize as the aerodynamic forces are balanced in the climb or descent. A large and abrupt pitch change will produce erratic needle movement and also introduce greater time delay (lag) before the needle stabilizes. Students are cautioned not to "chase the needle" when flight through turbulent conditions produces such erratic needle movements.

In using the vertical-speed indicator as a rate instrument and combining it with the altimeter and attitude indicator to maintain level flight, keep this in mind: the amount the altimeter has moved from the desired altitude governs the rate at which you should return to that altitude. A rule of thumb is to make an attitude change that will result in a vertical speed rate that is approximately double your error in altitude. For example, if off altitude 100 feet, your rate of return should be approximately 200 feet per minute. If off more than 100 feet, the correction should be correspondingly greater, but should never exceed the optimum rate of climb or descent for your aircraft at a given airspeed and configuration. A deviation of more than 200 feet per minute from the desired rate of return is considered overcontrolling. For example, if you are attempting to return to an altitude at a rate of 200 feet per minute, a rate in excess of 400 feet per minute indicates overcontrolling. While returning to an altitude, the vertical-speed indicator is the primary pitch instrument. Occasionally, the vertical-speed indicator is slightly out of calibration and may indicate a climb or

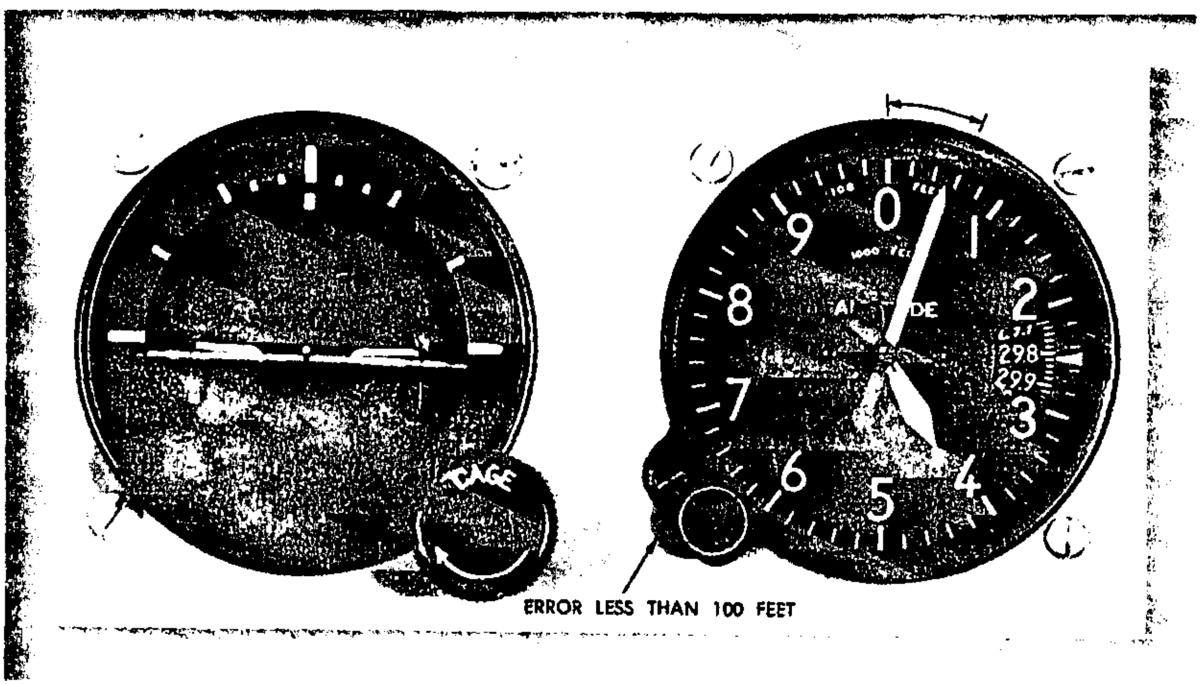


FIGURE 75. Altitude error—less than 100 feet.

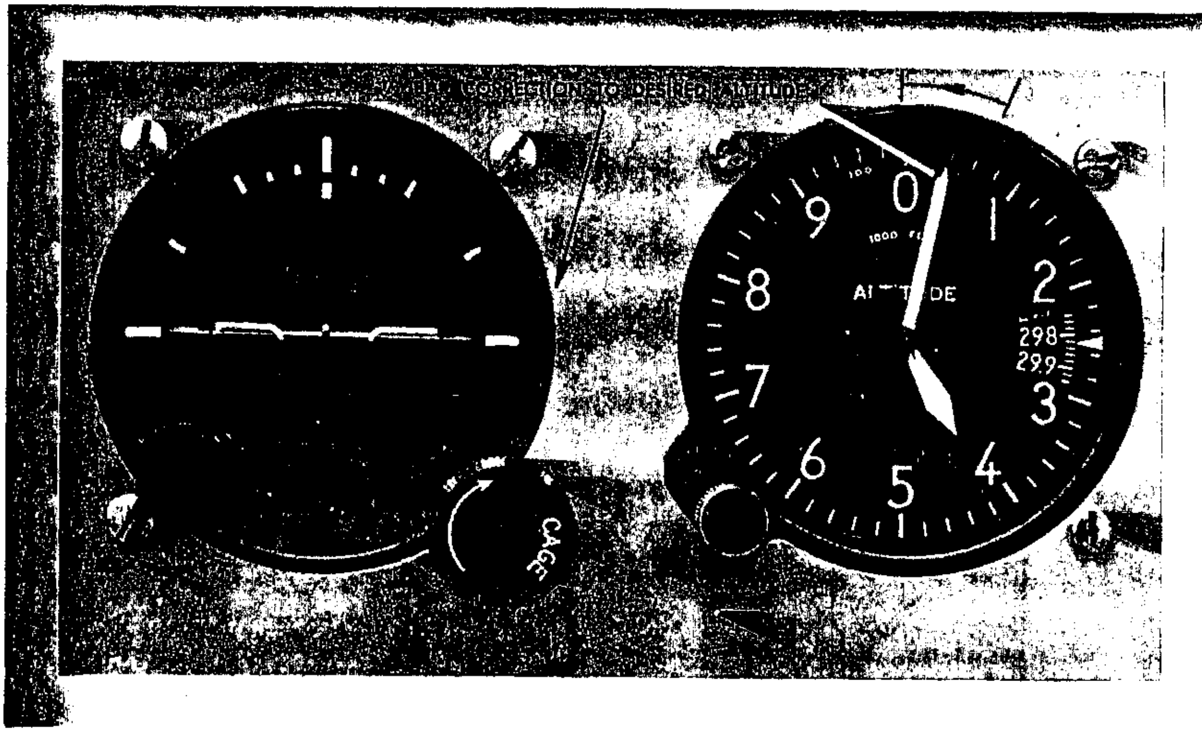


FIGURE 76. Pitch correction—less than 100 feet.

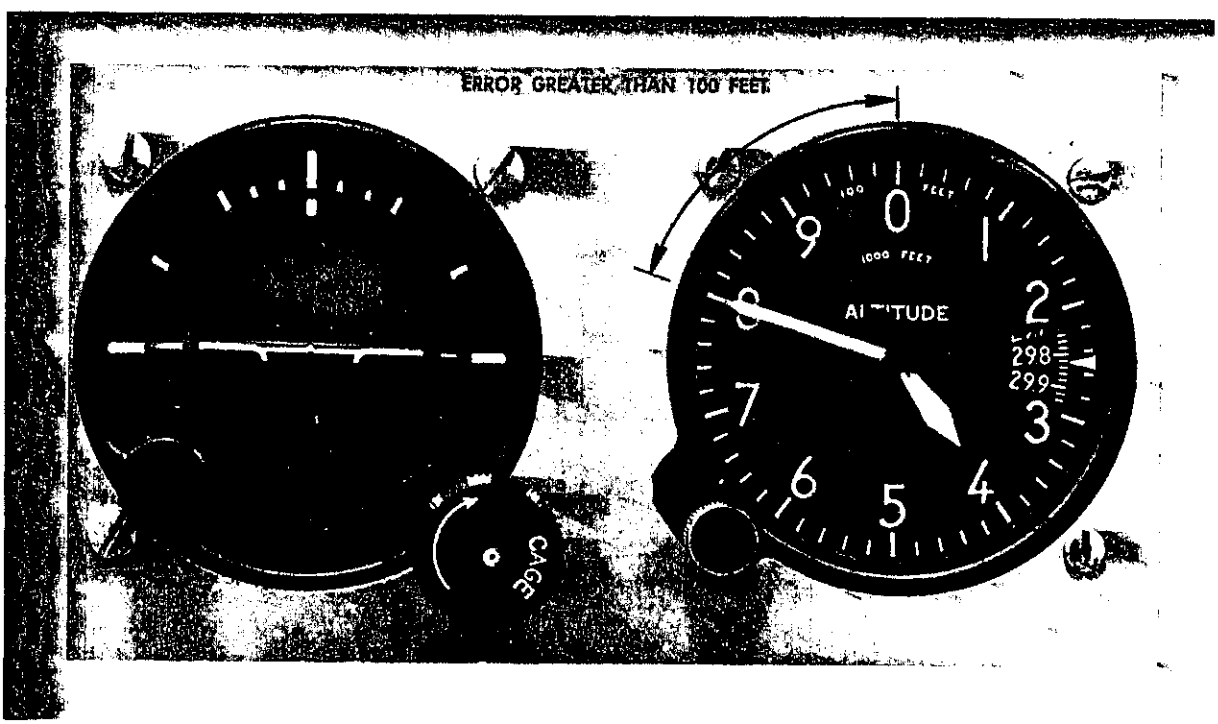


FIGURE 77. Altitude error—greater than 100 feet.

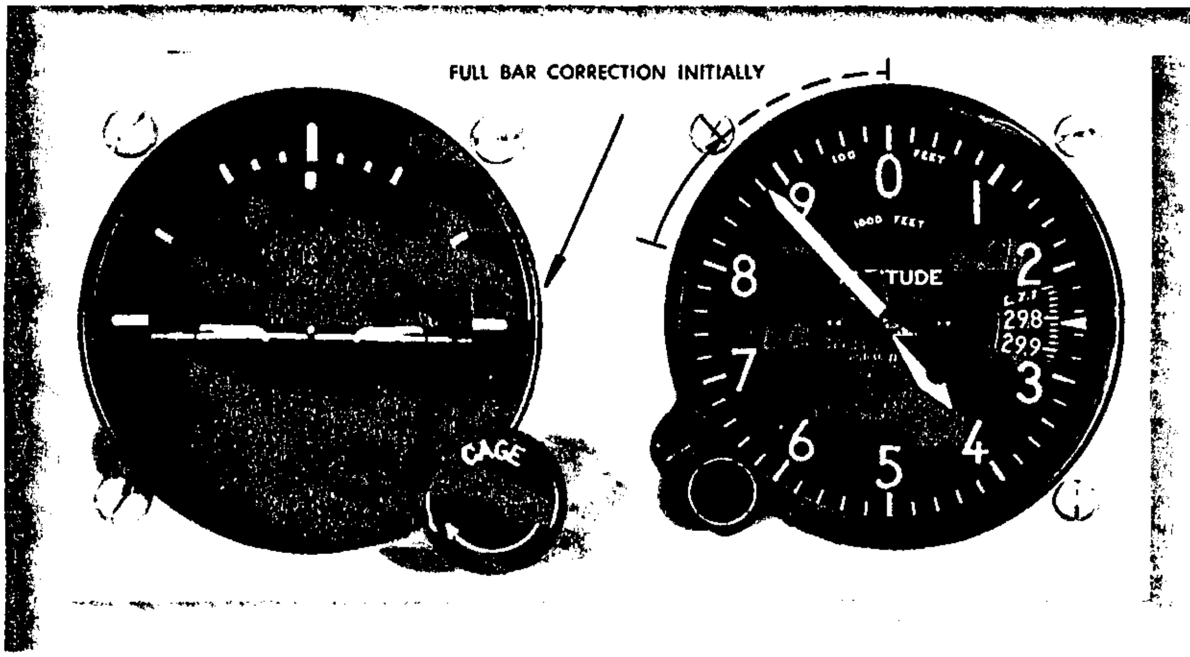


FIGURE 78. Pitch correction—greater than 100 feet.

descent when the aircraft is in level flight. If you cannot adjust the instrument, you must take the error into consideration when using it for pitch control. For example, if the needle indicates a descent of 200 feet per minute while in level flight, use this indication as the zero position.

The *airspeed indicator* presents an *indirect* in-indication of the pitch attitude. At a constant power setting and pitch attitude, the airspeed remains constant (Fig. 79). As the pitch attitude lowers, airspeed increases, and the nose should be raised (Fig. 80). As the pitch attitude rises, airspeed decreases, and the nose should be lowered (Fig. 81). A rapid change in airspeed indicates a large pitch change, and a slow change of airspeed indicates a small pitch change. The apparent lag in airspeed indications with pitch changes varies greatly among different aircraft and is due to the time required for the aircraft to accelerate or decelerate when the pitch attitude is changed. There is no appreciable lag due to the construction or operation of the instrument. Small pitch changes, smoothly executed, result in an immediate change of airspeed.

Pitch control in level flight is a question of scanning and interpretation of the instrument panel for whatever information the instruments present that will enable you to visualize and control pitch attitude. Regardless of individual differences in scanning technique, all pilots should use the instruments that give the best information for controlling the aircraft in any given maneuver. They also check the other instruments to aid in maintaining the important, or *primary*, instruments at the desired indication.

As noted previously, the primary instrument is the one that gives the most pertinent information for any particular maneuver. It is usually the one that you should hold at a constant indication. Which instrument, for example, is primary for pitch control in level flight? This question should be considered in the context of specific aircraft, weather conditions, pilot experience, operational conditions, and other factors. A supersonic aircraft, for instance, cannot be controlled without an attitude indicator. Attitude changes must be detected and interpreted instantly for immediate control action in high-performance aircraft. On the other hand, a reasonably proficient instrument pilot in a slower aircraft may rely more on the altimeter for primary pitch information, especially if he finds that too much reliance on the attitude indicator fails to provide the necessary precise attitude information. Whether he decides to regard the altimeter as primary, or the attitude indicator as primary is a question of which approach best helps him to control attitude.

In this handbook, the *altimeter* is normally considered as the primary pitch instrument during level flight.

Bank Control.—The bank attitude of an aircraft is the angle between the lateral axis of the aircraft and the natural horizon. To maintain a straight-and-level flight path, you must keep the wings of the aircraft level with the horizon (assuming that the aircraft is in coordinated flight). Any deviation from straight flight resulting from bank error should be corrected by *coordinated* aileron and rudder pressure.

The instruments used for bank control are the *attitude indicator,* the *heading indicator,* and the *turn-and-slip indicator* (Fig. 82).

The *attitude indicator* shows any change in bank attitude directly and instantly. On the standard attitude indicator, the angle of bank is shown pictorially by the relationship of the miniature aircraft to the artificial horizon bar, and by the alignment of the pointer with the banking scale at the top of the instrument. On the face of the standard 3″ instrument, small angles of bank can be difficult to detect by reference to the minature aircraft, especially if you lean to one side or move your seating position slightly. The position of the scale pointer is a good check against the apparent miniature aircraft position. Disregarding precession error, small deviations from straight, coordinated flight can be readily detected on the scale pointer. The banking index may be graduated as shown in Figure 83, or it may lack the 10° and 20° indexes. Refer to Chapter IV on "Basic Flight Instruments" for application of bank control techniques to types of attitude indicators other than the one illustrated here. Caging and uncaging, as well as the banking limitations of various types, are covered in that chapter.

Until you become accustomed to the use of the instrument, you may be bothered by the fact that the scale pointer moves in a direction opposite to the direction of bank shown by the miniature aircraft. A bank indication of 30° to the *right* of the zero, or nose position indicates a 30° *left* banking attitude. Errors due to the construction of this instrument are common and understandable, but the obvious advantage of the attitude indicator is that you get an immediate indication of both pitch and bank attitude in a single glance. Even with the precession errors associated with many attitude indicators, the quick attitude presentation requires less visual effort and time for positive control than do the other flight instruments.

The bank attitude of an aircraft in coordinated flight is shown *indirectly* on the *heading indicator,* since banking results in a turn and change in heading. A rapid movement of the heading indicator needle (or azimuth card in a directional gyro) indicates a large angle of bank, whereas a slow movement of the needle or card reflects a small angle of bank, assuming the same airspeed in both instances. If you note the rate of movement of the heading indicator for given degrees of bank shown on the attitude indicator, you will learn to look for important bank information on the heading indicator, especially when precession error in the attitude indicator requires a precise check of heading information to maintain straight flight.

When you note deviations from straight flight

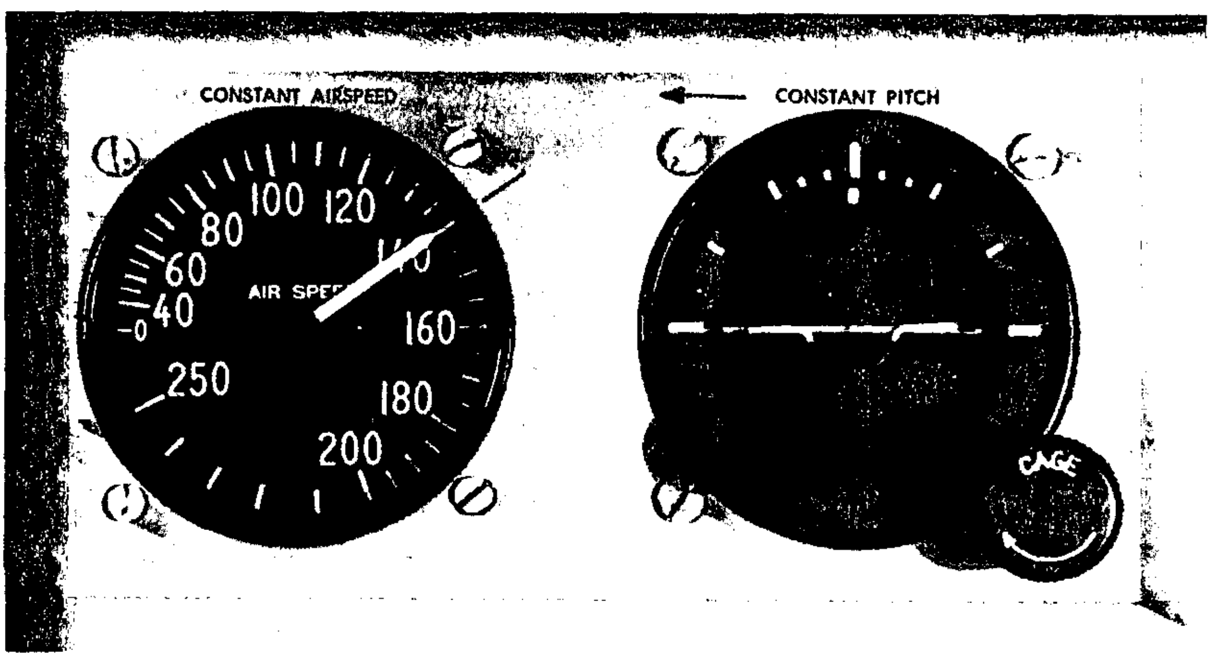


FIGURE 79. Constant power plus constant pitch equals constant airspeed.

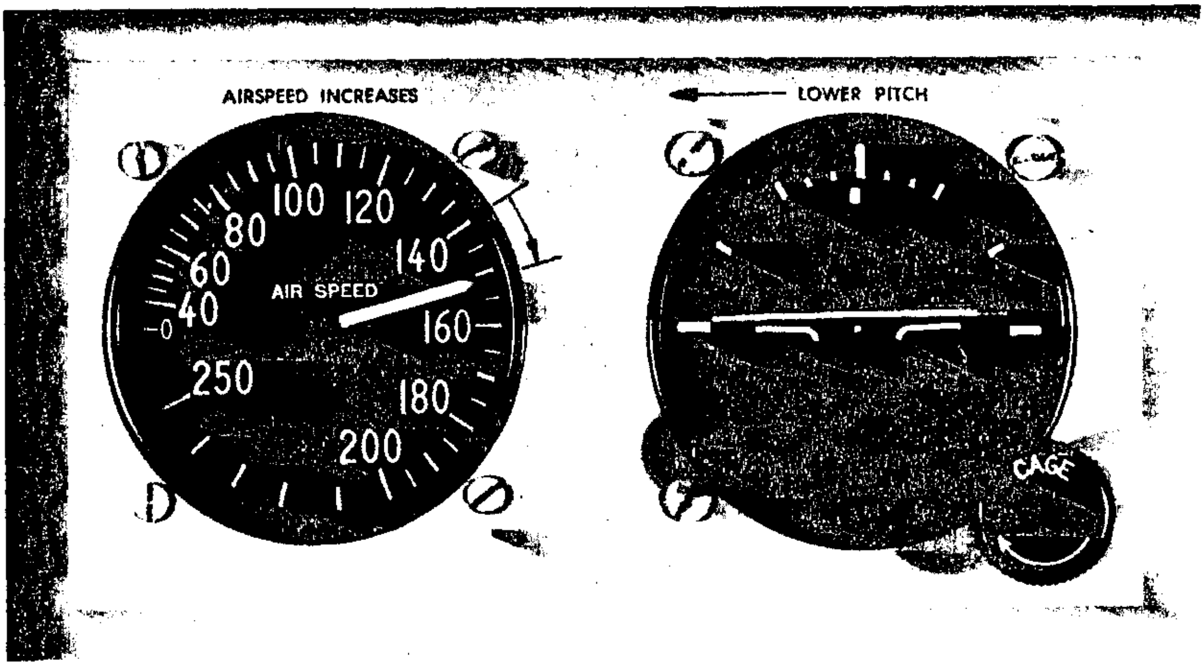


FIGURE 80. Constant power plus decreased pitch equals increased airspeed.

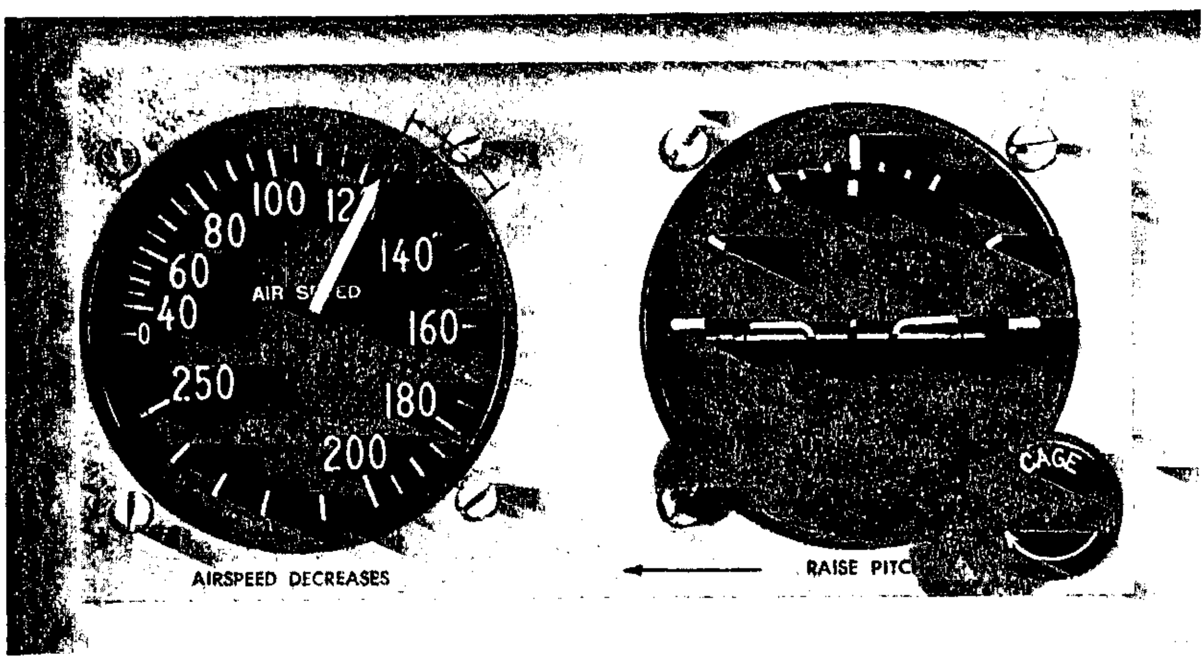


FIGURE 81. Constant power plus increased pitch equals decreased airspeed.

on the heading indicator, make your correction to the desired heading by using an angle of bank no greater than the number of degrees to be turned. In any case, limit your bank corrections to a bank angle no greater than that required for a standard-rate turn. Use of larger bank angles requires a very high level of proficiency, and normally results in overcontrolling and erratic bank control. For heading indicator limitations, refer to the chapter on "Basic Flight Instruments."

The *turn needle* of the *turn-and-slip indicator,*

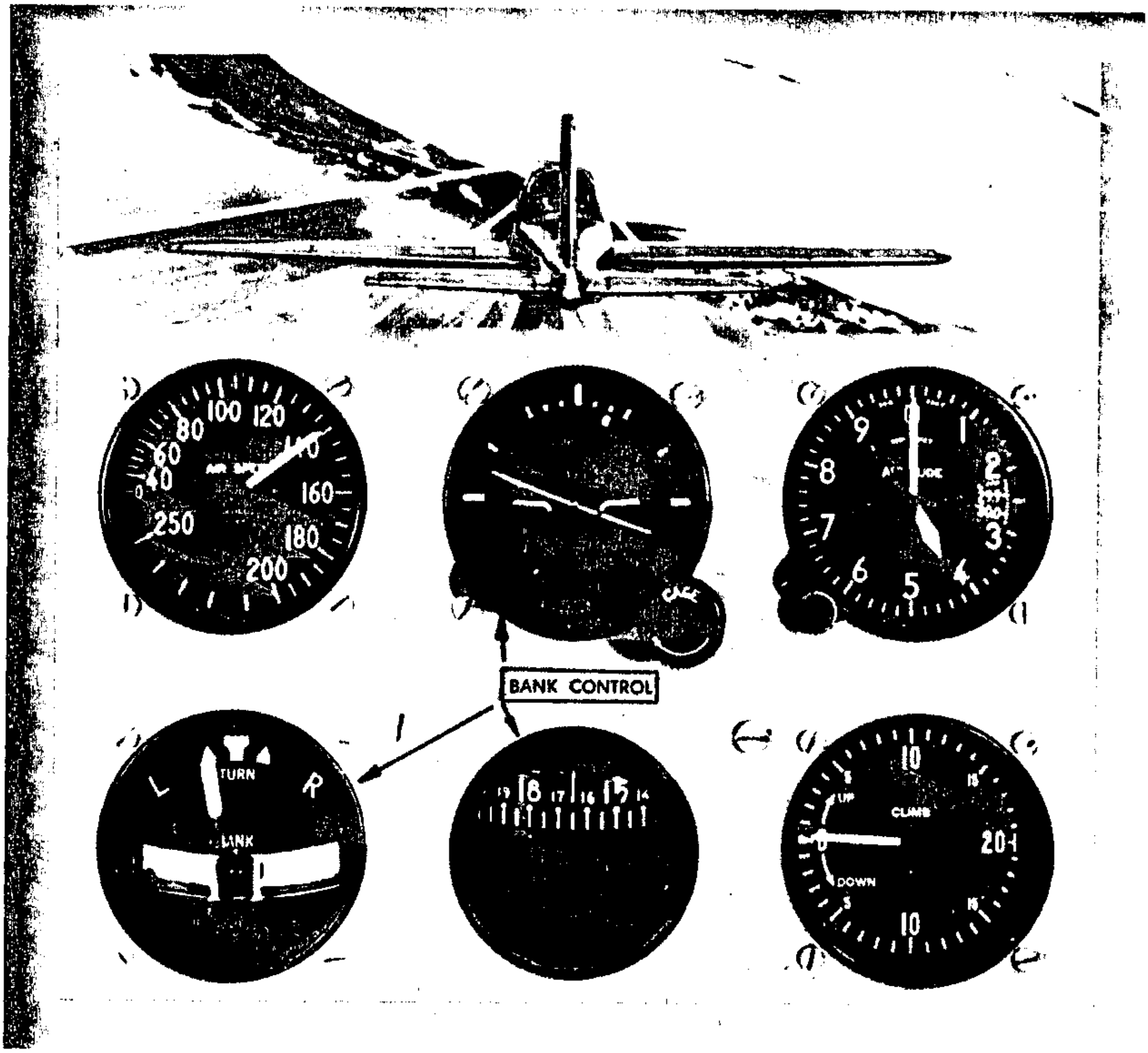


FIGURE 82. Instruments used for bank control.

gives you an *indirect* indication of the bank attitude of the aircraft. When the turn needle, properly adjusted, is exactly centered, the aircraft is in straight flight. When the needle is displaced from center, the aircraft is turning in the direction of the displacement. Thus, if the ball is centered, a left displacement of the turn needle means the left wing is low and the aircraft is in a left turn. Return to straight flight is accomplished by coordinated aileron and rudder pressures to recenter the needle. You must observe the turn needle closely to detect small deviations from the desired position. In turbulent air, the turn needle oscillates from side to side, therefore, you must interpolate or "average" the fluctuations to determine the bank attitude. When the deflection is greater on one side of center than the other, the aircraft is turning in that direction. The adjustment of the turn needle can be checked by placing the aircraft in straight flight by reference to the other bank instruments. If the turn needle indicates a deflection, you should interpret this position of the turn needle as the center position. Abrupt or uncoordinated use of aileron and rudder, as well as flight in turbulent air, causes oscillation of the turn needle, making it difficult to interpret. When using the instrument to maintain straight flight, control pressures must be applied very lightly and smoothly to avoid overcontrolling and oscillation of the needle.

The *ball* of the turn and slip indicator is

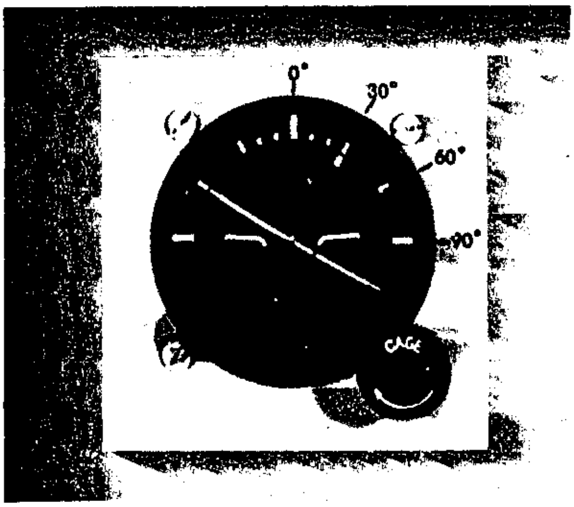


FIGURE 83. Bank interpretation with the attitude indicator.

actually a separate instrument, conveniently located under the turn needle because the two instruments are used together. The ball instrument indicates the quality of the turn. If the ball is off center, the aircraft is slipping or skidding, and the needle under these conditions is erroneous in its indications of bank attitude. Figures 84 and 85 show the instrument indications for slips and skids, respectively. If the wings are level and the aircraft is properly trimmed, the ball will remain in the center, and the aircraft will be in straight flight. If the ball is not centered, the aircraft is improperly trimmed (or you are holding rudder pressure against proper trim).

To maintain straight-and-level flight with proper trim, note the direction of ball displacement. If the ball is to the left of center and the left wing is low, apply left rudder pressure (or release right rudder pressure if you are holding it) to center the ball and correct the slip. At the same time apply right aileron pressure as necessary to level the wings, cross-checking the heading indicator and attitude indicator as you center the ball. If the wings are level and the ball is displaced from center, the aircraft is skidding. Note the direction of ball displacement and use the same corrective technique as for an indicated slip. Center the ball (left ball/left rudder, right ball/right rudder), use aileron as necessary for bank control, and retrim.

To trim the aircraft, using only the turn-and-slip indicator, use aileron pressure to center the needle and rudder pressure to center the ball. Hold these indications with control pressures, gradually releasing them as you apply rudder trim sufficient to relieve all rudder pressure.

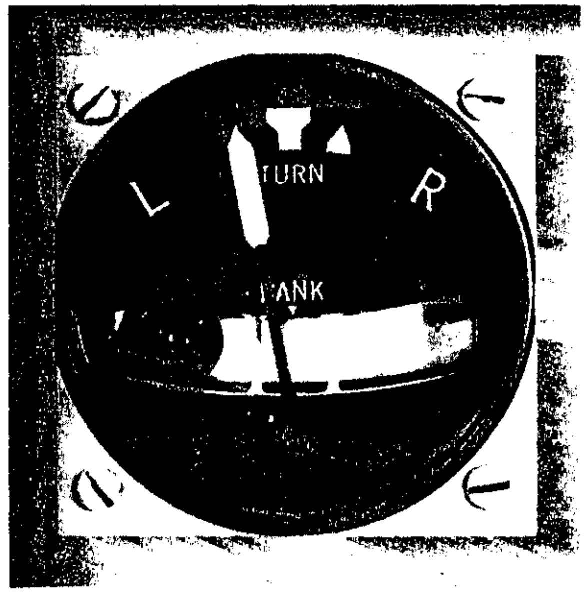


FIGURE 84. Slip indication.

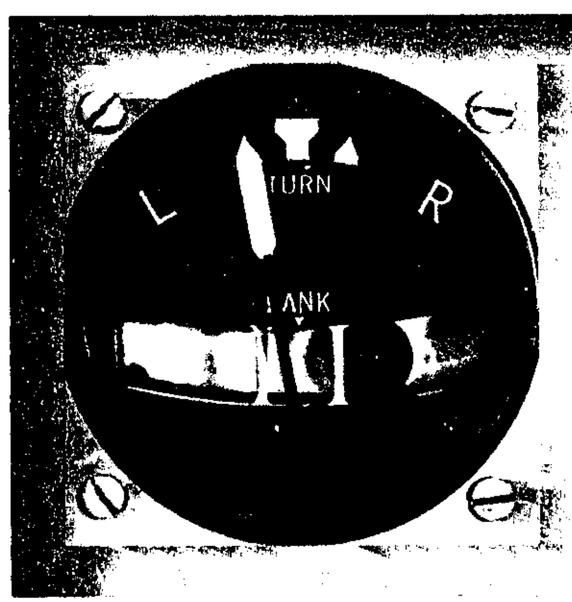


FIGURE 85. Skid indication.

Apply aileron trim if available to relieve aileron pressure. With a full instrument panel, maintain a wings-level attitude by reference to all available instruments while you trim the aircraft.

Power Control.—Power produces thrust which, with the appropriate angle of attack of the wing overcomes the forces of gravity, drag, and inertia to determine aircraft performance.

Power control must be related to its effect on altitude and airspeed, since any change in power setting results in a change in the airspeed or the altitude of the aircraft. At any given airspeed, the power setting determines whether the aircraft is in level flight, in a climb, or in a descent. If you increase the power while in straight-and-level flight and hold the airspeed constant, the aircraft will climb; and if you decrease the power while holding the airspeed constant, the aircraft will descend. On the other hand, if you hold *altitude* constant, the power applied will determine the airspeed.

The relationship between altitude and airspeed determines the need for a change in pitch or power. If the airspeed is off the desired value, always check the altimeter before deciding that a power change is necessary. If you think of altitude and airspeed as interchangeable, you can "trade" altitude for airspeed by lowering the nose, or convert airspeed to altitude by raising the nose. If your altitude is higher than desired and your airspeed low (Fig. 86), or vice versa, a change in pitch alone may return the aircraft to the desired altitude and airspeed. If both airspeed and altitude are high (Fig. 87) or if both are low, then a change in both pitch and power is necessary in order to return to the desired airspeed and altitude.

For changes in airspeed in straight-and-level flight, pitch, bank, and power must be *coordinated* in order to maintain constant altitude and heading. When power is changed to vary airspeed in straight-and-level flight, a single-engine propeller-driven aircraft tends to change attitude around all axes of movement. Therefore, to maintain constant altitude and heading, you will need to apply various control pressures in proportion to the change in power. When you add power to increase airspeed, the pitch instruments will show a climb unless you apply forward elevator control pressure as the airspeed changes. When you increase power, the aircraft tends to yaw and roll to the left unless you apply counteracting aileron and rudder pressures. The increased speed of cross-check required to keep ahead of these changes varies with the type of aircraft and its torque characteristics, the extent of power and speed change involved, and your technique in making the power change.

Power control and airspeed changes are much easier when you know in advance the approximate power settings necessary to maintain various airspeeds in straight-and-level flight. However, to change airspeed any appreciable amount, common procedure is to underpower or overpower on initial power changes to accelerate the rate of airspeed change. (For small speed changes, or in aircraft that decelerate or accelerate rapidly, overpowering or underpowering is unnecessary.)

Consider the example of an aircraft which requires 23 inches of manifold pressure to maintain a normal cruising airspeed of 140 knots, and 18 inches of manifold pressure to maintain an airspeed of 100 knots. The reduction in airspeed from 140 knots to 100 knots, while maintaining straight-and-level flight, is discussed below and illustrated in Figures 88, 89, and 90.

Instrument indications, prior to the power reduction, are shown in Figure 88. While the basic attitude is established and maintained on the attitude indicator, specific pitch, bank, and power control requirements are detected on these primary instruments:

Altimeter—Primary Pitch
Heading Indicator—Primary Bank
Airspeed Indicator—Primary Power

Supporting pitch and bank instruments are shown in the illustrations. Although not shown, the supporting power instrument is the manifold pressure gauge (or tachometer if the propeller is fixed pitch).

As you make a smooth power reduction to approximately 15″ Hg (underpower), the manifold pressure gauge becomes the primary power instrument (Fig. 89). With practice, you will be able to change a power setting with only a brief glance at the power instrument, by sensing the movement of the throttle, the change in sound, and the changes in the feel of control pressures.

As the thrust decreases, increase the speed of your cross-check and be ready to apply left rudder, back elevator, and aileron control pressure the instant the pitch and bank instruments show a deviation from altitude and heading. As you become proficient, you will learn to cross-check, interpret, and control the changes with no deviation of heading and altitude. Assuming smooth air and ideal control technique, as airspeed decreases, a proportionate increase in aircraft pitch attitude is required to maintain altitude. Similarly, effective torque control means counteracting yaw with rudder pressure.

As the power is reduced, the altimeter is primary for pitch, the heading indicator is primary for bank, and the manifold pressure gauge is momentarily primary for power (at 15″ Hg in this example). Control pressures should be trimmed off as the aircraft decelerates. As the airspeed approaches the desired airspeed of 100 knots, the manifold pressure is adjusted to ap-

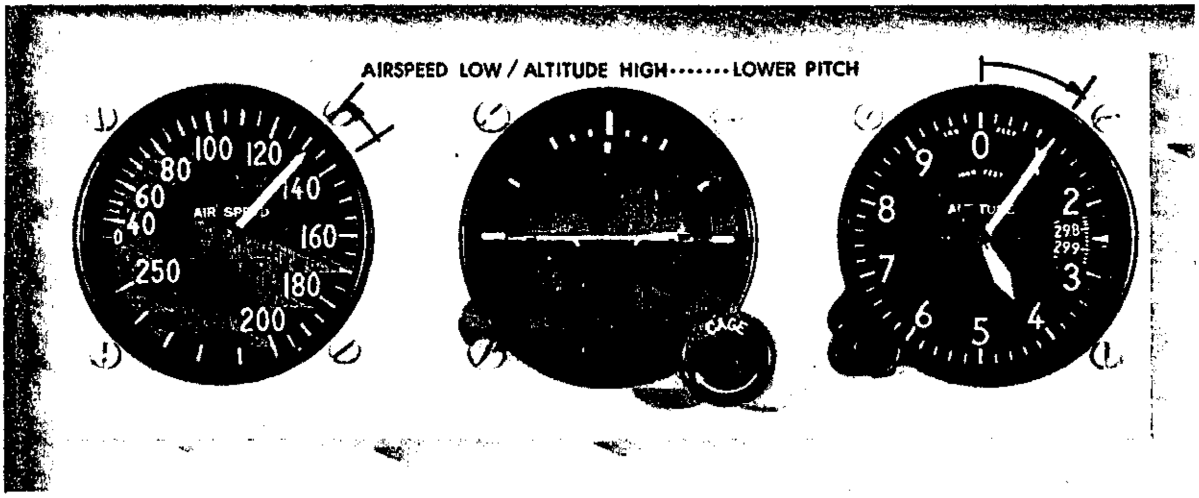


FIGURE 86. Airspeed low and altitude high (lower pitch).

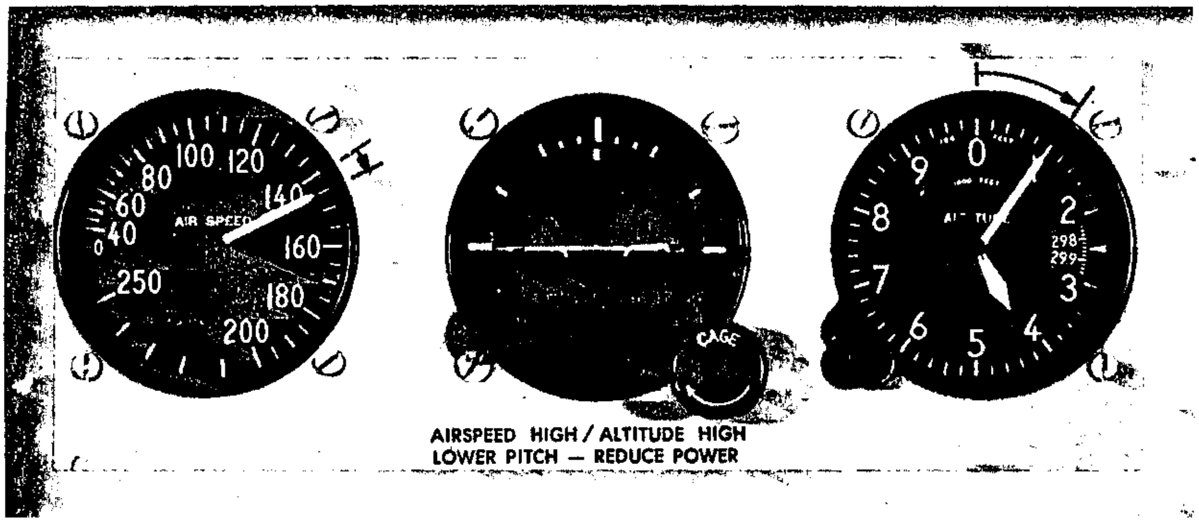


FIGURE 87. Airspeed and altitude high (lower pitch and reduce power).

proximately 18″ Hg and becomes the supporting power instrument. The airspeed indicator again becomes primary for power (Fig. 90).

Practice of airspeed changes in straight-and-level flight provides an excellent means of developing increased proficiency in all three basic instrument skills, and brings out some common errors to be expected during training in straight-and-level flight.

Having learned to control the aircraft in a "clean" configuration (minimum drag conditions), you can increase your proficiency in cross-check and control by practicing speed changes while extending or retracting the flaps and landing gear. While practicing, be sure you comply with the airspeed limitations specified in your Aircraft Flight Handbook for gear and flap operation.

Sudden and pronounced attitude changes may be necessary in order to maintain straight-and-level flight as the landing gear is extended and the flaps are lowered in some aircraft. The nose tends to pitch down with gear extension, and when flaps are lowered, lift increases momentarily (at partial flap settings) followed by a marked increase in drag as the flaps near maximum extension.

Control technique varies according to the lift and drag characteristics of each aircraft. Accordingly, knowledge of the power settings and trim changes associated with different combinations of airspeed and gear and flap configurations will reduce your instrument cross-check and interpretation problems.

For example, assume that in straight-and-level flight, an aircraft indicates 145 knots with power at 22″ manifold pressure/2,300 rpm, gear and flaps up. After reduction in airspeed, with gear and flaps fully extended, straight-and-level flight at the same altitude requires 25″ manifold pressure/2,500 rpm. Maximum gear extension speed is 125 knots; maximum flap extension speed is 105 knots. Airspeed reduction to 95 knots, gear and flaps down, can be made in the following manner:

1. Increase rpm to 2,500, since a high power setting will be used in full drag configuration.
2. Reduce manifold pressure to 10″. As the airspeed decreases, increase cross-check speed.
3. Make trim adjustments for an increased angle of attack and decrease in torque.
4. As you lower the gear at 125 knots, the nose may tend to pitch down and the rate of deceleration increases. Increase pitch attitude to maintain constant altitude, and trim off some of the back elevator pressures. If you lower full flaps at this point, your cross-check, interpretation, and control must be very rapid. A less difficult technique is to stabilize the airspeed and attitude with gear down before lowering the flaps.
5. Since 18″ manifold pressure will hold level flight at 95 knots with the gear down, increase power smoothly to that setting as the airspeed indicator shows approximately 100 knots, and retrim. The attitude indicator now shows approximately two-and-a-half-bar width nose high in straight-and-level flight.
6. Actuate the flap control and simultaneously increase power to the predetermined setting (25″) for the desired airspeed, and trim off the pressures necessary to hold constant altitude and heading. The attitude indicator now shows a bar-width nose low in straight-and-level flight at 95 knots.

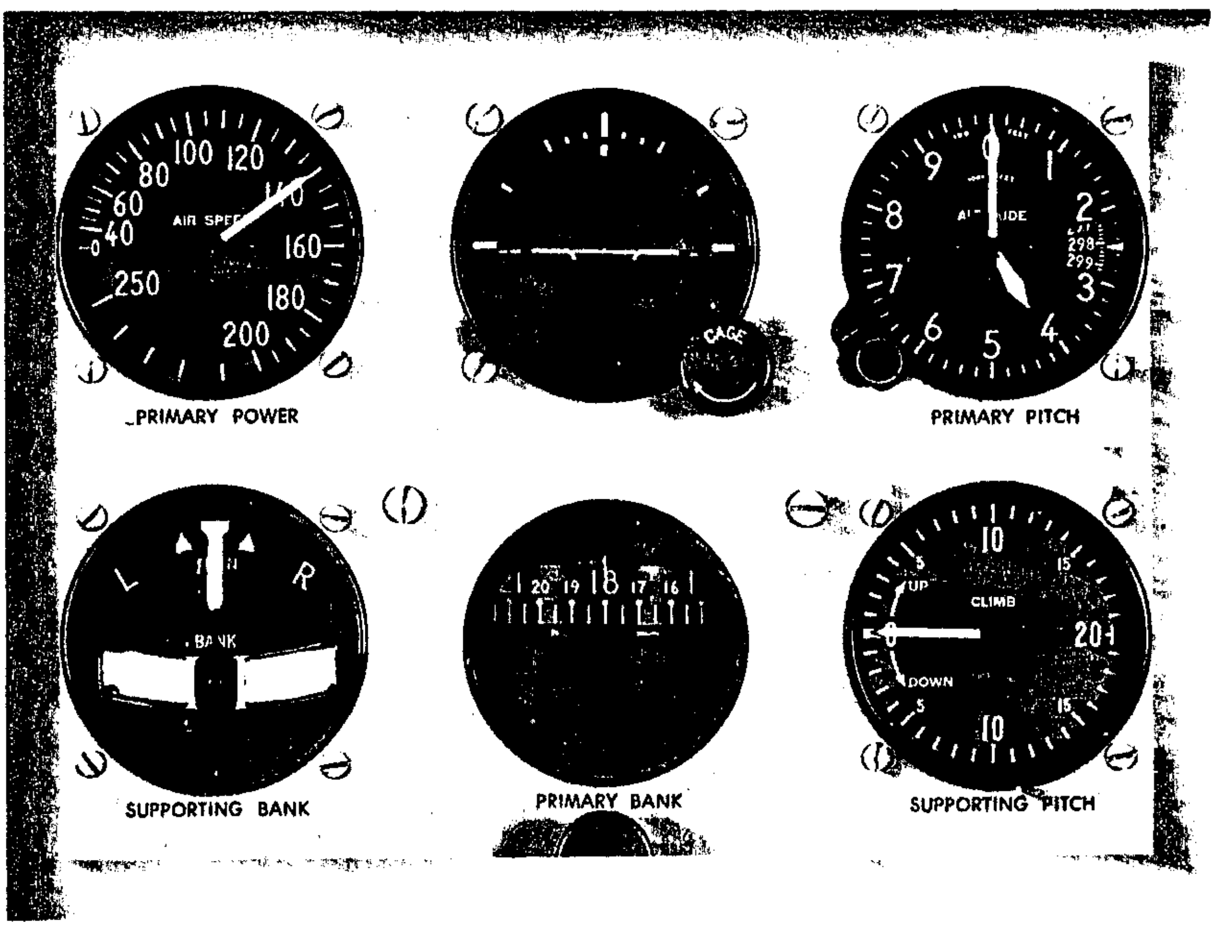


FIGURE 88. Straight-and-level flight (normal cruising speed).

When you can consistently maintain constant altitude and heading with smooth pitch, bank, power, and trim control during these pronounced changes in trim, you will have developed a high level of proficiency in the basic skills involved in straight-and-level flight.

Common Errors.—*Heading errors* usually result from the following faults:

1. Failure to cross-check the heading indicator, especially during changes in power or pitch attitude.
2. Misinterpretation of changes in heading, with resulting corrections in the wrong direction.
3. Failure to note, and remember, a preselected heading.
4. Failure to observe the *rate* of heading change and its relation to bank attitude.
5. Overcontrolling in response to heading changes, especially during changes in power settings.
6. Anticipating heading changes with premature application of rudder control.
7. Failure to correct small heading deviations. Unless *zero* error in heading is your goal, you will find yourself tolerating larger and larger deviations. Correction of a 1° error takes a lot less time and concentration than correction of a 20° error.
8. Correcting with improper bank attitude. If you correct a 10° heading error with a 20° bank correction, you can roll past the desired heading before you have the bank established, requiring another correction in the opposite direction. Don't multiply existing errors with errors in corrective technique.
9. Failure to note the cause of a previous heading error and thus repeating the same error. For example, your aircraft is out of trim, with a left-wing low tendency. You repeatedly correct for a slight left turn, yet do nothing about trim.
10. Failure to set the heading indicator properly, or failure to uncage it.

Pitch errors usually result from the following faults:

1. Improper adjustment of the miniature aircraft to the wings-level attitude. Following your initial level-off from a climb, check the attitude indicator and make any necessary adjustment in the miniature aircraft for level flight indication at normal cruise airspeed.
2. Insufficient cross-check and interpretation of pitch instruments. For example, the airspeed indication is low. Believing that you are in a

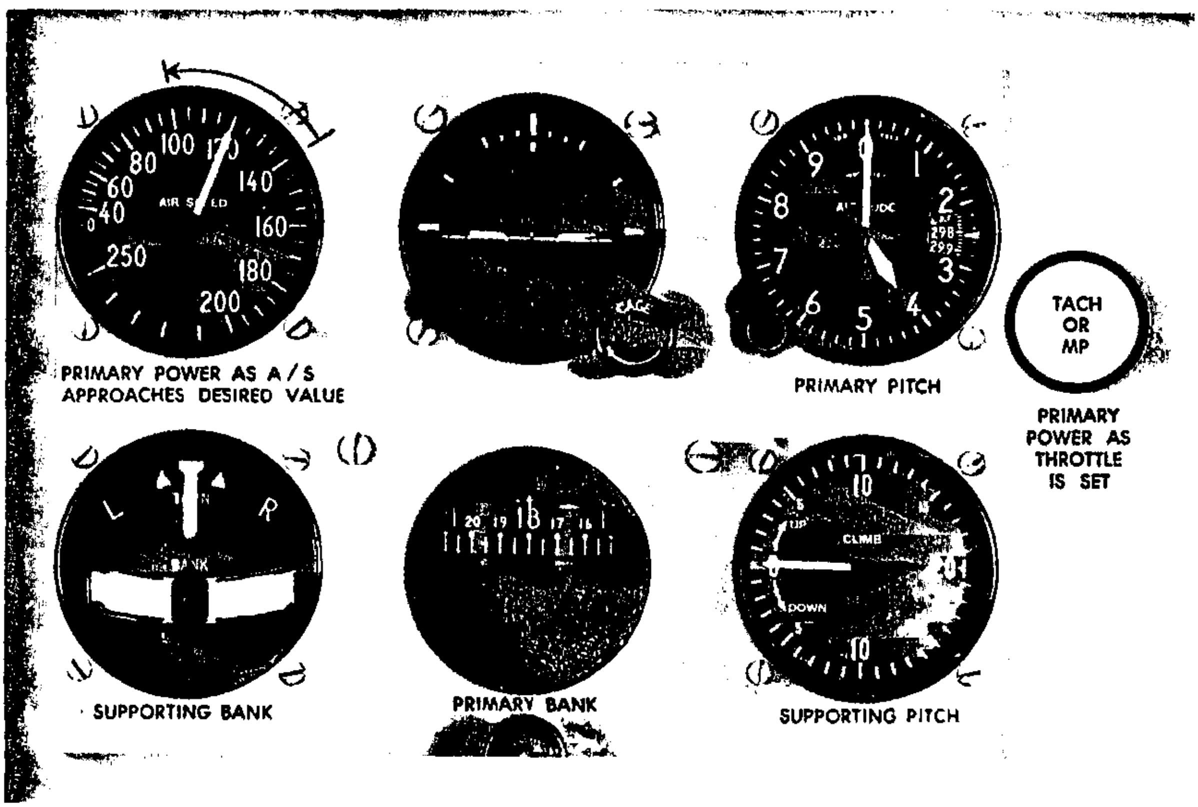


FIGURE 89. Straight-and-level flight (airspeed decreasing).

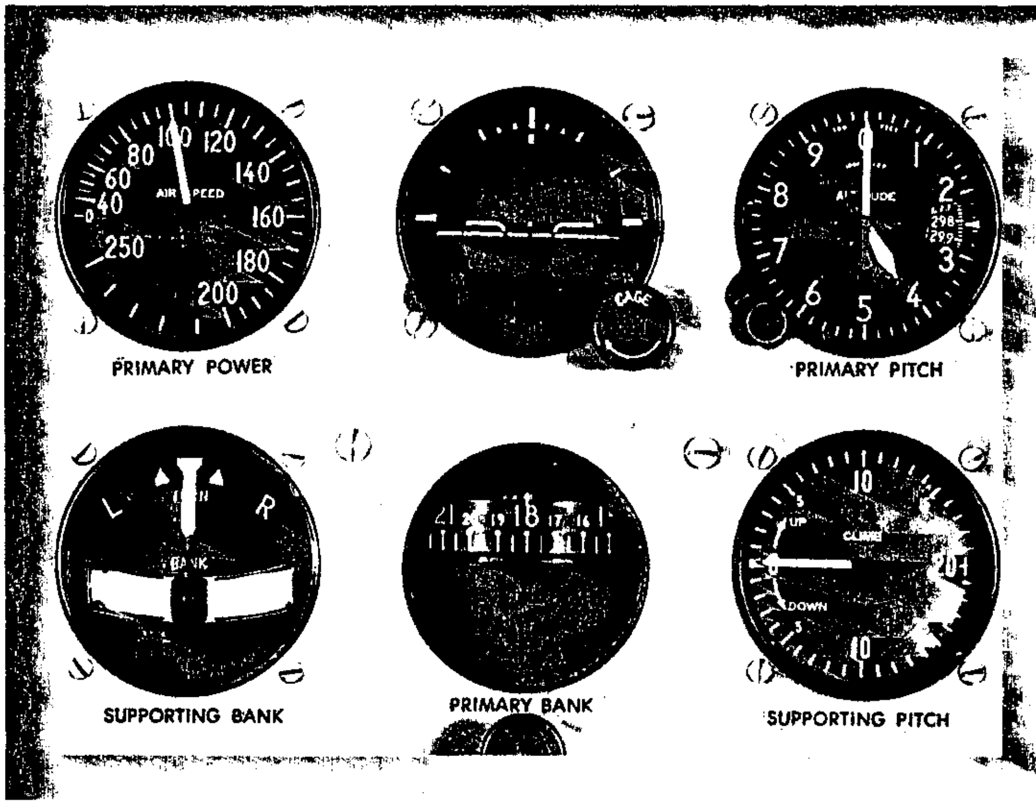


FIGURE 90. Straight-and-level flight (reduced airspeed stabilized).

nose-high attitude, you react with forward pressure without noting that a low power setting is the cause of the airspeed discrepancy. Increase your cross-check speed to include *all* relevant instrument indications *before* you make a control response.

3. Uncaging the attitude indicator when the aircraft is not in level flight. The altimeter and heading indicator must be *frozen* with airspeed indication at normal cruise when you pull out the caging knob, if you expect the instrument to read straight-and-level at normal cruise airspeed.

4. Failure to interpret the attitude indicator in terms of the existing airspeed.

5. Late pitch corrections. Students commonly like to leave well enough alone. When the altimeter shows a 20-foot error, there is a reluctance to correct it, perhaps because of fear of overcontrolling. If overcontrolling is the error, the more you practice small corrections and find out the cause of overcontrolling, the closer you will be able to hold your altitude. If you tolerate a deviation for fear of "rocking the boat," your errors will increase.

6. Chasing the vertical-speed indications. This tendency can be corrected by proper cross-check of other pitch instruments, as well as by increasing your understanding of the instrument characteristics.

7. Using excessive pitch corrections for the alitmeter deviation. Rushing a pitch correction by making a large pitch change generally aggravates the existing error and saves neither time nor effort.

8. Failure to maintain established pitch corrections. This is a common error associated with cross-check and trim errors. For example, having established a pitch change to correct an altitude error, you tend to slow down your cross-check, waiting for the aircraft to stabilize in the new pitch attitude. To maintain the attitude, you must continue to cross-check and trim off the pressures that you are holding.

9. Fixations during cross-check. After initiating a heading correction, for example, you become preoccupied with bank control and neglect to notice a pitch error. Likewise, during an airspeed change, unnecessary gazing at the power instrument is common. Bear in mind that a small error in power setting is of less consequence than large altitude and heading errors. The aircraft will not decelerate any

faster while you stare at the manifold pressure gauge than while you continue your cross-check.

Power errors usually result from the following faults:

1. Failure to know the power settings appropriate to various airspeeds or drag configurations.
2. Abrupt use of throttle.
3. Failure to "lead" the airspeed when making power changes. For example, during an airspeed reduction in level flight, especially with gear and flaps extended, adjust the throttle to maintain the slower speed *before* the airspeed reaches the desired speed. Otherwise, the aircraft will decelerate to a speed lower than that desired, resulting in further power adjustments. How much you lead the airspeed depends upon how fast the aircraft responds to power changes.
4. Fixation on airspeed or manifold pressure instruments during airspeed changes, resulting in erratic control of both airspeed and power.

Trim errors usually result from the following faults:

1. Improper adjustment of seat or rudder pedals for comfortable position of legs and feet. Tension in the ankles makes it difficult to relax rudder pressures.
2. Confusion as to operation of trim devices, which differ among various aircraft types. Some trim wheels are aligned appropriately with the aircraft axes; others are not. Some rotate in a direction contrary to what you expect.
3. Faulty sequence in trim technique. Trim should be used, not as a substitute for control with the wheel (stick) and rudders, but to relieve pressures already held to stabilize attitude. As you gain proficiency, you become familiar with trim settings, just as you do with power settings. With little conscious effort, you trim off pressures continually as they occur.
4. Excessive trim control. This induces control pressures that must be held until you retrim properly. Use trim frequently and in small amounts.
5. Failure to understand the cause of trim changes. If you do not understand the basic aerodynamics related to the basic instrument skills, you will be "behind the airplane" continually.

Straight Climbs and Descents

Climbs.—For a given power setting and load condition, there is only one attitude that will give the most efficient rate of climb. The airspeed and the climb power setting that will determine this climb attitude are given in the performance data found in your aircraft flight handbook. Details of the technique for entering a climb vary according to airspeed on entry and the type of climb (constant airspeed or constant rate) desired. (Heading and trim control are maintained as discussed under straight-and-level flight).

Entries.—To enter a constant airspeed climb from *cruising* airspeed, raise the nose of the miniature aircraft to the approximate nose-high indication appropriate to the predetermined climb speed. The attitude will vary according to the type aircraft you are flying. Apply light back elevator pressure to initiate and maintain the climb attitude. The pressures will vary as the aircraft decelerates. Power may be advanced to the climb power setting simultaneously with the pitch change, or after the pitch change is established and the airspeed approaches climb speed. If the transition from level flight to climb is smooth, the vertical-speed indicator will show an immediate trend upward, continue moving slowly, and will stop at a rate appropriate to the stabilized airspeed and attitude. (Primary and supporting instruments for the climb entry are shown in Figure 91.)

Once the aircraft stabilizes at a constant airspeed and attitude, the airspeed indicator is primary for pitch and the heading indicator remains primary for bank (Fig. 92). You will monitor the "Tach or MP" as the primary power instrument to ensure that the proper climb power setting is being maintained. If the climb attitude is correct for the power setting selected, the airspeed will stabilize at the desired speed. If the airspeed is low or high, make an appropriate small pitch correction.

To enter a constant airspeed climb from *climb* airspeed, first complete the airspeed reduction from cruise airspeed to climb speed in straight-and-level flight. The climb entry is then identical to entry from cruising airspeed, except that power must be increased simultaneously to the climb setting as the pitch attitude is increased. Climb entries on partial panel are more easily and accurately controlled if you enter the maneuver from climbing speed.

The technique for entering a constant rate climb is very similar to that used for entry to a constant airspeed climb from climb airspeed. As the power is increased to the approximate setting for the desired rate, simultaneously raise the nose of the miniature aircraft to the climbing attitude for the desired airspeed and rate of climb. As the power is increased, the airspeed indicator is primary for pitch control until the vertical speed approaches the desired value. As the vertical-speed needle stabilizes, it becomes primary for pitch control and the airspeed indicator becomes primary for power control (Fig. 93).

Pitch and power corrections must be quickly and closely coordinated. For example, if the vertical speed is correct, but the airspeed is low, add power. As the power is increased, the nose must be lowered slightly to maintain constant vertical speed. If the vertical speed is high and the airspeed is low (Fig. 94), lower the nose slightly and note the increase in airspeed to determine whether or not a power change is also necessary. Familiarity with the approximate power settings helps to keep your pitch and power corrections at a minimum.

Leveling off.—To level off from a climb and maintain an altitude, it is necessary to start the level-off before reaching the desired altitude. The amount of lead varies with rate of climb and pilot technique. If your aircraft is climbing at 1,000 feet per minute (fpm), it will continue to climb at a decreasing rate throughout the transition to level flight. An effective practice is to lead the altitude by 10 percent of the vertical speed shown (500 fpm/50-foot lead, 1,000 fpm/100-foot lead).

To level off at *cruising* airspeed, apply smooth, steady forward elevator pressure toward level flight attitude for the speed desired. As the attitude indicator shows the pitch change, the vertical-speed needle will move slowly toward zero, the altimeter needle will move more slowly, and the airspeed will show acceleration (Fig. 95). Once the altimeter, attitude indicator, and vertical-speed indicator show level flight, constant changes in pitch and torque control will have to be made as the airspeed increases. As the airspeed approaches cruising speed, reduce power to the cruise setting. The amount of lead depends upon the rate of acceleration of your aircraft.

To level off at *climbing* airspeed, the nose is lowered to the pitch attitude appropriate to that airspeed in level flight. Power is simultaneously reduced to the setting for that airspeed as the pitch attitude is lowered. If your power reduction is at a rate proportionate to the pitch change, the airspeed will remain constant.

Descents.—A descent can be made at a variety of airspeeds and attitudes by reducing power, adding drag, and lowering the nose to a predetermined attitude. Sooner or later the airspeed will stabilize at a constant value. Meanwhile, the only flight instrument providing a positive attitude reference, by itself, is the attitude indicator. Without the attitude indicator, as during a partial panel descent, the airspeed indicator, the altimeter, and the vertical-speed indicator

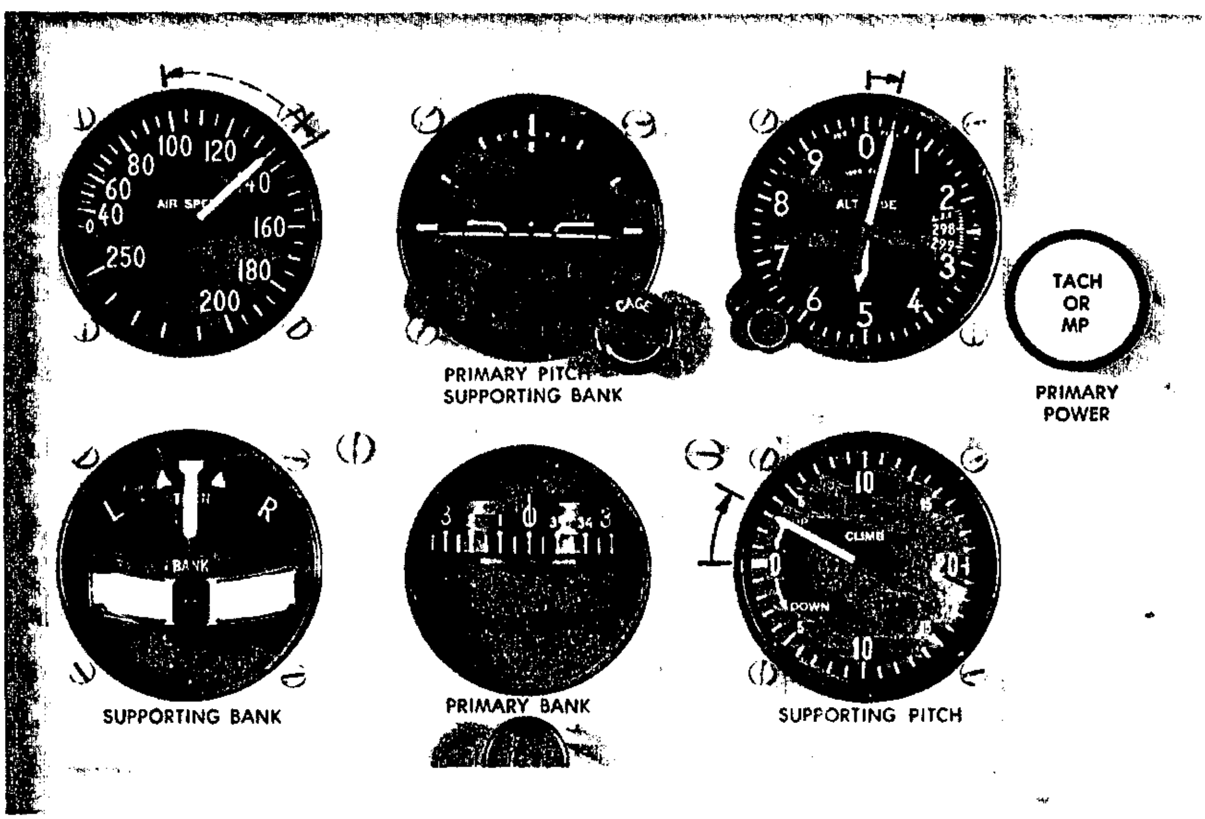


FIGURE 91. Climb entry for a constant airspeed climb.

will be showing varying rates of change until the aircraft decelerates to a constant airspeed at a constant attitude. During the transition, changes in control pressure and trim, as well as cross-check and interpretation, must be very accurate if you expect to maintain positive control.

Entry—The following method for entering descents is effective either with or without an attitude indicator. First, reduce airspeed to your selected descent airspeed while maintaining straight-and-level flight, then make a further reduction in power (to a predetermined setting). As the power is adjusted, simultaneously lower the nose to maintain constant airspeed, and trim off control pressures.

During a constant *airspeed* descent, any deviation from the desired airspeed calls for a pitch adjustment. For a constant *rate* descent, the entry is the same, but the vertical-speed indicator is primary for pitch control (after it stabilizes near the desired rate), and the airspeed indicator is primary for power control. Pitch and power must be closely coordinated, as in climbs, when corrections are made (Fig. 96).

Leveling off.—The level-off from a descent must be started before you reach the desired altitude. The amount of lead depends upon the rate of descent and control technique. With too little lead, you will tend to overshoot the selected altitude unless your technique is rapid. Assuming a 500-fpm rate of descent, lead the altitude by 100-150 feet for a level-off at airspeed higher than descending speed. At the lead point, add power to the appropriate level flight cruise setting (Fig. 97). Since the nose will tend to rise as the airspeed increases, hold forward elevator pressure to maintain the vertical speed at the descending rate until approximately 50 feet above the altitude, then smoothly adjust the pitch attitude to the level flight attitude for the airspeed selected.

To level off from a descent at descent airspeed, lead the desired altitude by approximately 50 feet, simultaneously adjusting the pitch attitude to level flight and adding power to a setting that will hold the airspeed constant (Fig. 98). Trim off the control pressures and continue with the normal straight-and-level flight cross-check.

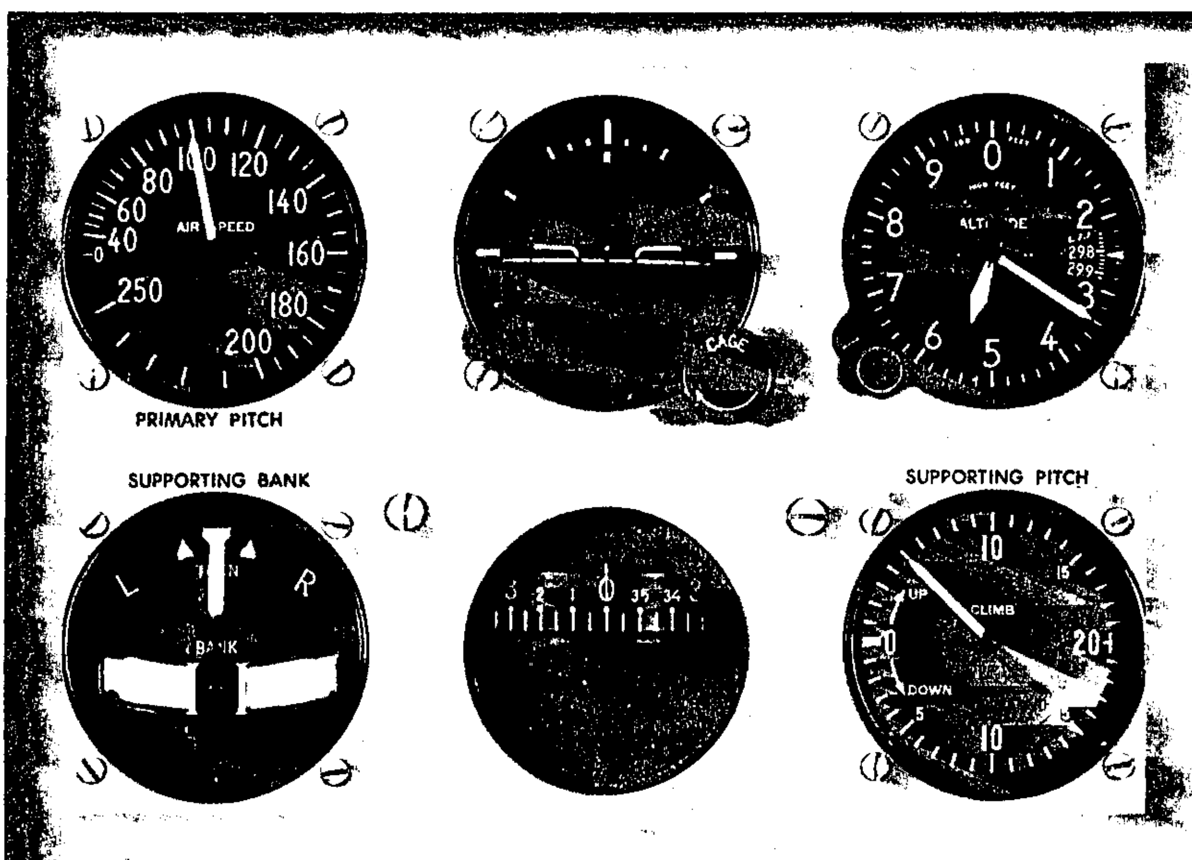


FIGURE 92. Stabilized climb at constant airspeed.

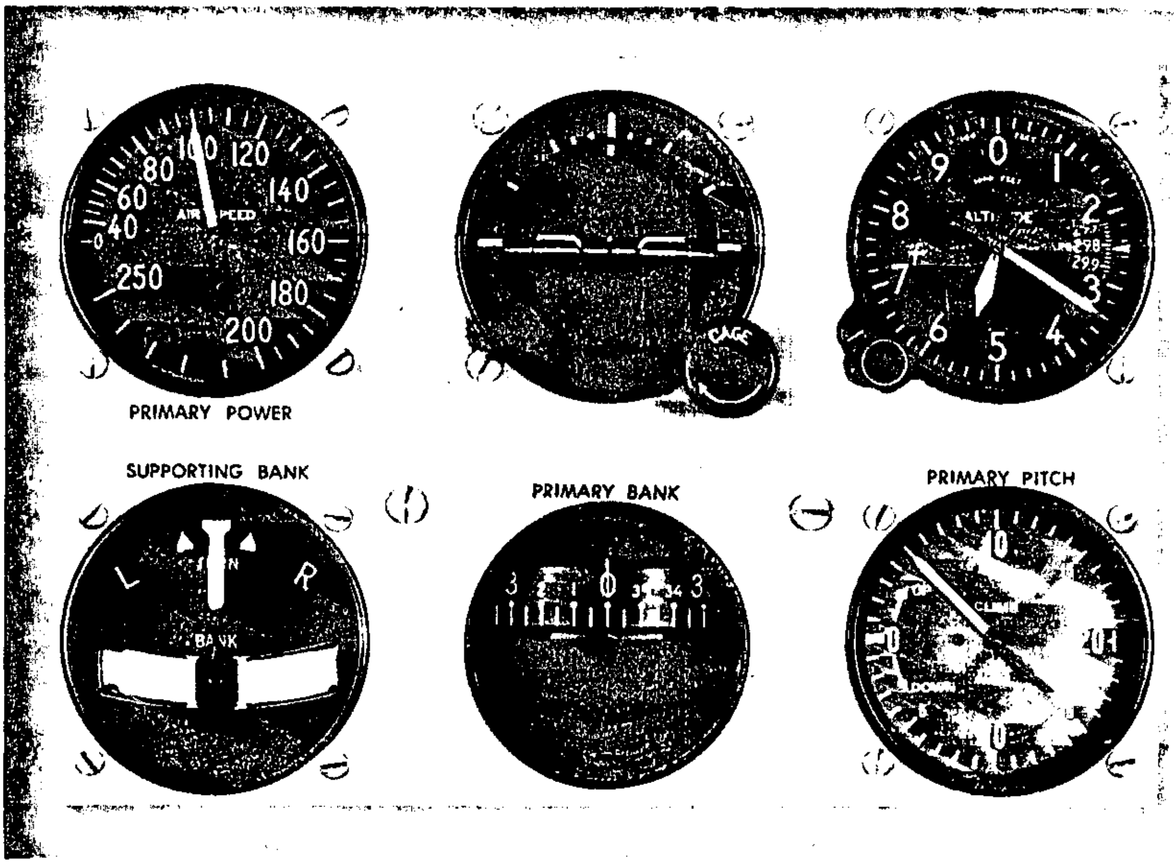


FIGURE 93. Stabilized climb at constant rate.

Common errors result from the following faults:

1. Overcontrolling pitch on climb entry. Until you know the pitch attitudes related to specific power settings used in climbs and descents, you will tend to make larger than necessary pitch adjustments. One of the most difficult habits to learn during instrument training is to *restrain* the impulse to disturb a flight attitude until you know what the result will be. Overcome your inclination to make a large control movement for a pitch change, and learn to apply small control pressures smoothly, cross-checking rapidly for the results of the change, and continuing with the pressures as your instruments show the desired results at a rate that you can interpret. Small pitch changes can be easily controlled, stopped, and corrected; large changes are more difficult to control.

2. Failure to vary the rate of cross-check during speed, power, or attitude changes on climb or descent entries.

3. Failure to maintain a new pitch attitude. For example, you raise the nose to the correct climb attitude, and as the airspeed decreases, you either overcontrol and further increase the pitch attitude, or allow the nose to lower. As control pressures change with airspeed changes, cross-check must be increased and pressures readjusted.

4. Failure to trim off pressures. Unless you trim, you will have difficulty determining whether control pressure changes are induced by aerodynamic changes or by your own movements.

5. Failure to learn and use proper power settings.

6. Failure to cross-check *both* airspeed and vertical-speed *before* making pitch or power adjustments.

7. Improper pitch and power coordination on slow-speed level offs, owing to slow cross-check of airspeed and altimeter indications.

8. Failure to cross-check the vertical-speed indicator against the other pitch control instruments, resulting in "chasing" the vertical speed.

9. Failure to note the rate of climb or descent to determine the lead for level offs, resulting in

overshooting or undershooting the desired altitude.

10. "Ballooning" (allowing the nose to pitch up) on level offs from descents, resulting from failure to maintain descending attitude with forward elevator pressure as power is increased to the level-flight cruise setting.

11. Failure to recognize the approaching straight-and-level flight indications as you level off. Until you have positively established straight-and-level flight, maintain an accelerated cross-check.

Turns

Standard Rate Turns.—To enter a standard-rate level turn, apply coordinated aileron and rudder pressures in the desired direction of turn. Students commonly roll into turns at a much too rapid rate. During initial training in turns, base your control pressures on your rate of cross-check and interpretation. There is nothing to be gained by maneuvering an aircraft faster than your capacity to keep up with the changes in instrument indications.

On the roll-in, use the attitude indicator to establish the approximate angle of bank, then check the turn needle for a standard-rate turn indication. Maintain the bank for this rate of turn, using the turn needle as the primary bank reference and the attitude indicator as the supporting bank instrument (Fig. 99). Note the exact angle of bank shown on the banking scale of the attitude indicator when the turn needle is directly under the standard rate index.

During the roll-in, check the altimeter, vertical-speed indicator, and attitude indicator for the pitch adjustments necessary as the vertical lift component decreases with increase in bank. If constant airspeed is to be maintained, the airspeed indicator becomes primary for power, and the throttle must be adjusted as drag increases. As the bank is established, trim off the pressures applied during pitch and power changes.

To recover to straight-and-level flight, apply coordinated aileron and rudder pressures oppo-

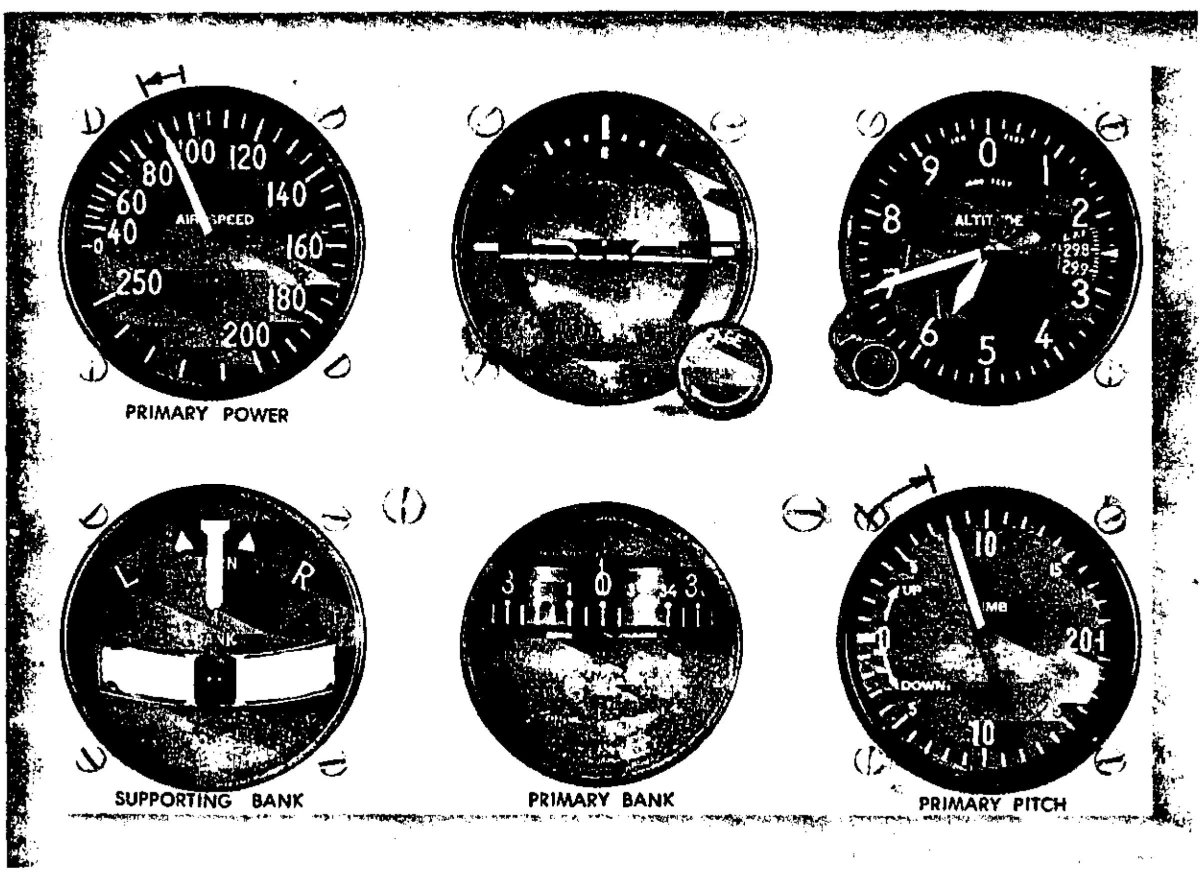


FIGURE 94. Airspeed low and vertical speed high—reduce pitch.

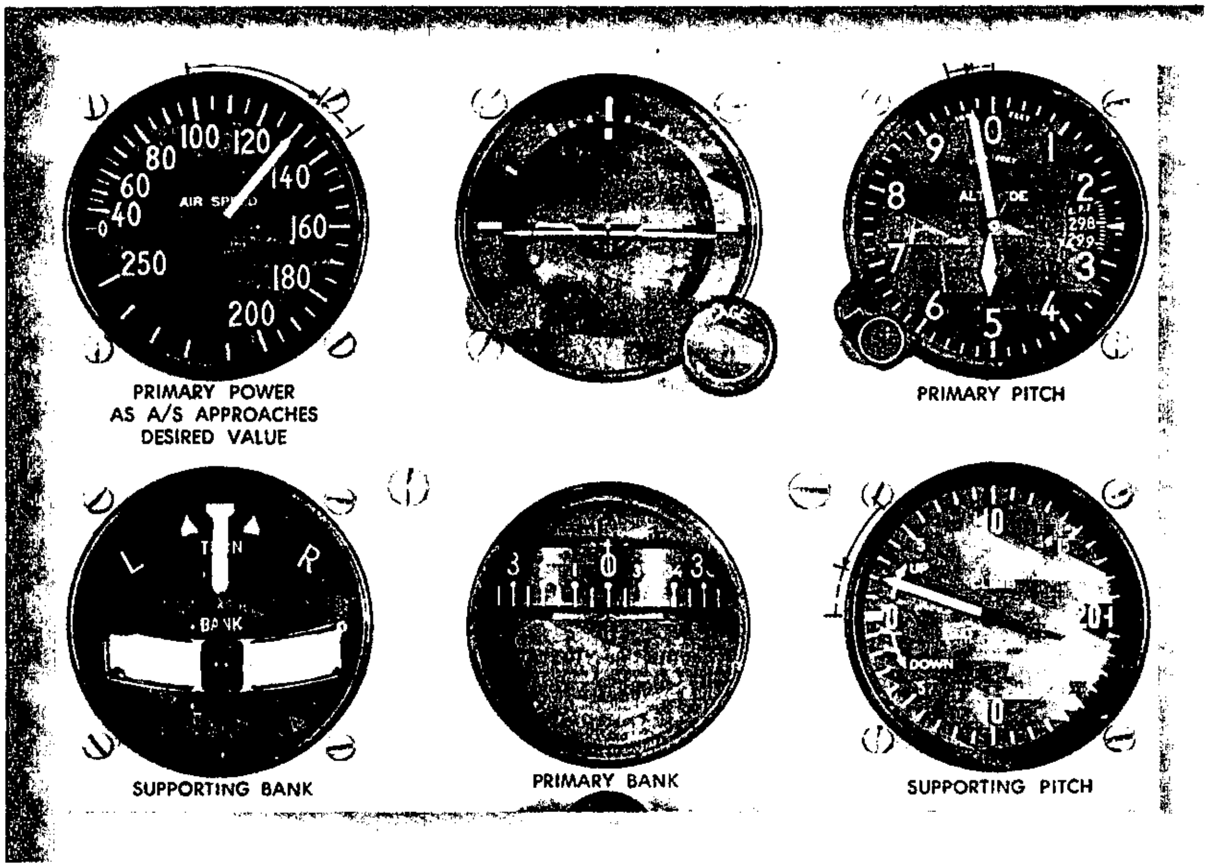


FIGURE 95. Level-off at cruising airspeed.

site the direction of turn. If you strive for the same rate of roll-out that you use to roll into the turn, you will encounter fewer problems in judging the lead necessary to roll out on exact headings, especially on partial panel maneuvers. As you initiate the turn recovery, the attitude indicator becomes the primary bank instrument. When the aircraft is approximately level, the heading indicator is the primary bank instrument as in straight-and-level flight. Pitch, power, and trim adjustments are made as changes in vertical lift component and airspeed occur. The ball should be checked throughout the turn, especially if control pressures are held instead of being trimmed off.

Some aircraft are very stable during turns, and slight trim adjustments permit "hands off" flight while the aircraft remains in the established attitude. Other aircraft require constant rapid cross-check and control during turns to correct overbanking tendencies. Due to the interrelationship of pitch, bank, and airspeed deviations during turns, your cross-check must be fast to prevent an accumulation of errors.

Turns to Predetermined Headings.—As long as an aircraft is in a coordinated bank, it continues to turn. Thus, the roll-out to a desired heading must be started before the heading is reached. The amount of lead varies with the relationship between the rate of turn, angle of bank, and rate of recovery. For small changes in heading, using an angle of bank not exceeding the number of degrees to be turned, lead the desired heading by one-half the number of degrees of bank used. For example, if you maintain a 10° bank during a change in heading, start the roll-out 5° before reaching the desired heading. For larger changes in heading, the amount of lead will vary since the angle of bank for a standard-rate turn varies with the True Airspeed. Practice with a lead of one-half the angle of bank until you have determined the precise lead suitable to your technique. If your rates of roll-in and roll-out are consistent, you can readily determine the precise amount of lead suitable to your particular roll-out technique by noting the amount that you consistently undershoot or overshoot the headings.

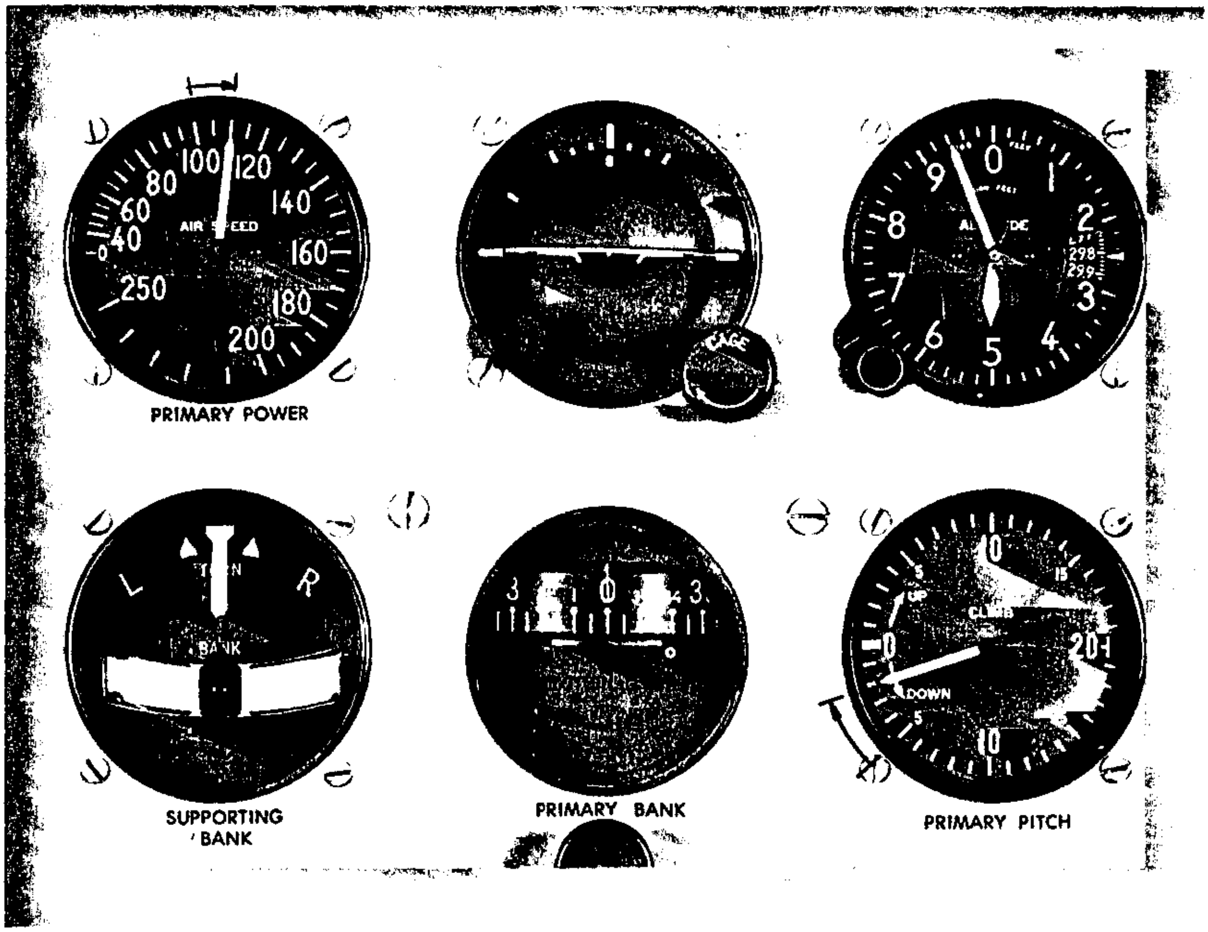


FIGURE 96. Constant rate descent, airspeed high—reduce power.

Timed Turns.—A timed turn is a turn in which the clock and the turn needle are used to change heading a definite number of degrees in a given time. For example, using a standard-rate turn (3° per second), an aircraft turns 45° in 15 seconds; using a half-standard-rate turn, the aircraft turns 45° in 30 seconds.

Before practicing timed turns, the turn needle must be calibrated to determine the accuracy of the needle indications (Fig. 100). Establish a standard-rate turn (a two-needle-width deflection on the 4-minute turn needle illustrated). As the sweep second hand of the clock passes a cardinal point (12, 3, 6, 9), check the heading on the heading indicator. Holding the indicated rate of turn constant, note the heading changes indicated at 10-second intervals. If the aircraft turns more or less than 30 degrees in that interval, a larger or smaller deflection of the needle is necessary to produce a standard-rate turn. When you have calibrated the needle during turns in each direction, note the corrected deflections, if any, and apply them during all timed turns.

You use the same cross-check and control technique in making timed turns that you use to execute turns to predetermined headings, except that you substitute the clock for the heading indicator. The turn needle is primary for bank control, the altimeter is primary for pitch control, and the airspeed indicator is primary for power control. Start the roll-in when the clock second hand passes a cardinal point, hold the turn at the calibrated standard-rate indication on the turn needle (or half-standard-rate for small changes in heading), and begin the roll-out when the computed number of seconds has elapsed. If the rates of roll-in and roll-out are the same, the time taken during entry and recovery need not be considered in the time computation.

If you practice timed turns with a full instrument panel, check the heading indicator for the accuracy of your turns. If you execute the turns

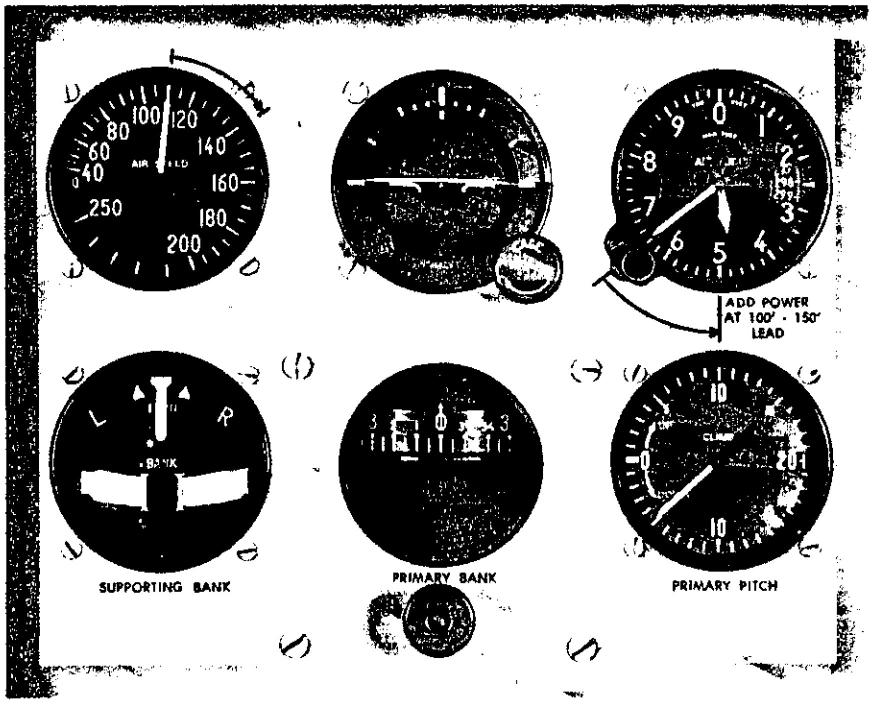


FIGURE 97. Level-off airspeed higher than descent airspeed.

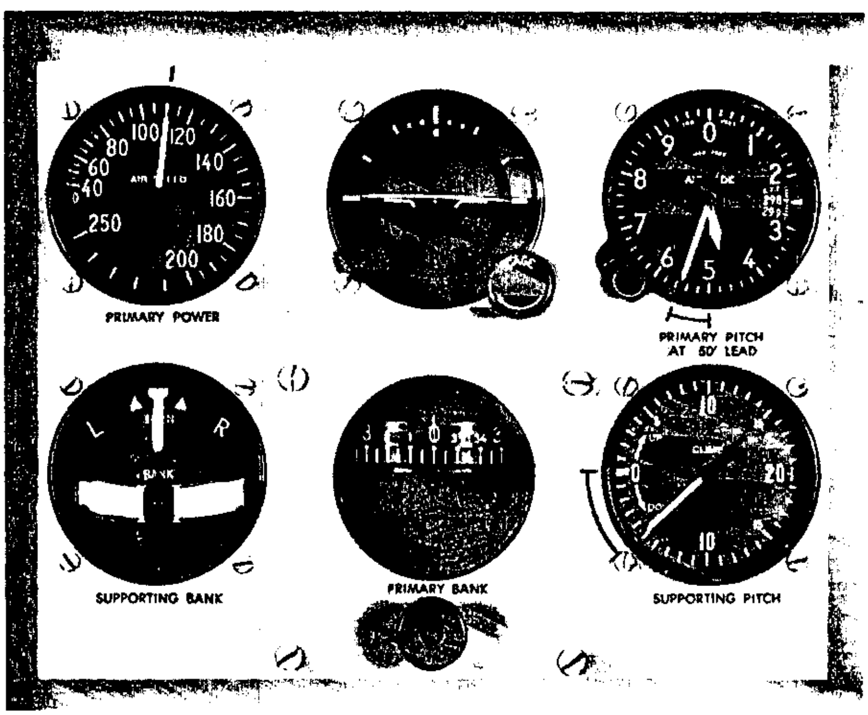


FIGURE 98. Level-off at descent airspeed.

without the gyro heading indicator, use the magnetic compass at the completion of the turn to check turn accuracy, taking compass deviation errors into consideration.

Compass Turns.—In most light aircraft, the magnetic compass is the only direction-indicating instrument independent of other aircraft instruments and power sources. Because of its operating characteristics, called compass errors, pilots are prone to use it only as a reference for setting the directional gyro, but a knowledge of magnetic compass characteristics will enable you to use the instrument to turn your aircraft to correct headings and maintain them. The construction and operation of the magnetic compass was discussed in Chapter IV. This information should be thoroughly understood before practicing compass turns.

Bear in mind the following points when making turns to magetic compass headings or when using the magnetic compass as a reference for setting the directional gyro:

1. If you are on a northerly heading and you start a turn to the east or west, the indication of the compass lags, or shows a turn in the opposite direction.

2. If you are on a southerly heading and you start a turn toward the east or west, the compass indication precedes the turn, showing a greater amount of turn than is actually occurring.

3. When you are on an east or west heading, the compass indicates correctly as you start a turn in either direction.

4. If you are on an easterly or westerly heading, acceleration results in a northerly turn indication; deceleration results in a southerly turn indication.

5. If you maintain a north or south heading, no error results from diving, climbing, or changing airspeed.

With an angle of bank between 15° and 18°, the amount of lead or lag to be used when turning to northerly or southerly headings varies with, and is approximately equal to, the latitude of the locality over which the turn is being made. When turning to a heading of north, the lead for roll-out must include the number of degrees of your latitude, *plus* the lead you nor-

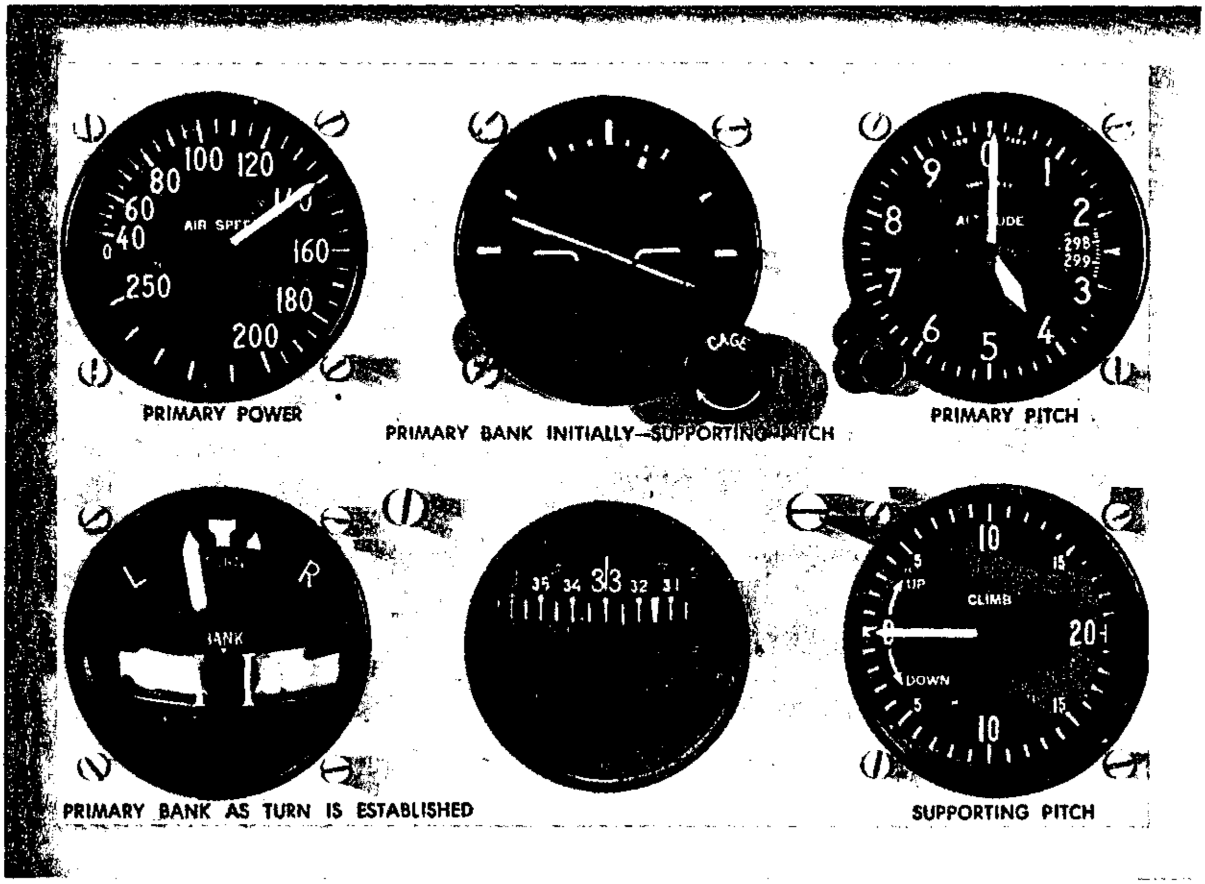


FIGURE 99. Standard rate turn, constant airspeed.

mally use in recovery from turns. During a turn to a south heading, maintain the turn until the compass *passes* south the number of degrees of your latitude, *minus* your normal roll-out lead (Fig. 101).

For example, when turning from an easterly direction to north, where the latitude is 30°, start the roll-out when the compass reads 37°, (30° plus one-half the 15° angle of bank, or whatever amount is appropriate for your rate of roll-out). When turning from an easterly direction to south, start the roll-out when the magnetic compass reads 203°, (180° plus 30° minus one-half the angle of bank). When making similar turns from a westerly direction, the appropriate points at which to begin your roll-out would be 323° for a turn to north, and 157° for a turn to south.

When turning to a heading of east or west from a northerly direction, start the roll-out approximately 10° to 12° before the east or west indication is reached. When turning to an east or west heading from a southerly direction, start the roll-out approximately 5° before the east or west indication is reached. When turning to other headings, the lead or lag must be interpolated.

Abrupt changes in attitude or airspeed and the resulting erratic movements of the compass card make accurate interpretations of the instrument very difficult. Proficiency in compass turns depends on knowledge of the compass characteristics, smooth control technique, and accurate bank and pitch control.

Steep Turns.—For purposes of instrument flight training in conventional aircraft, any turn greater than a standard-rate may be considered steep (Fig 102). The exact angle of bank at which a normal turn becomes steep is unimportant. What is important is that you learn to control the aircraft with bank attitudes in excess of those you normally use on instruments. Practice in steep turns will not only increase your proficiency in the basic instrument flying skills, but also enable you to react smoothly, quickly, and confidently to unexpected abnormal flight attitudes under instrument flight conditions.

Pronounced changes occur in the effects of

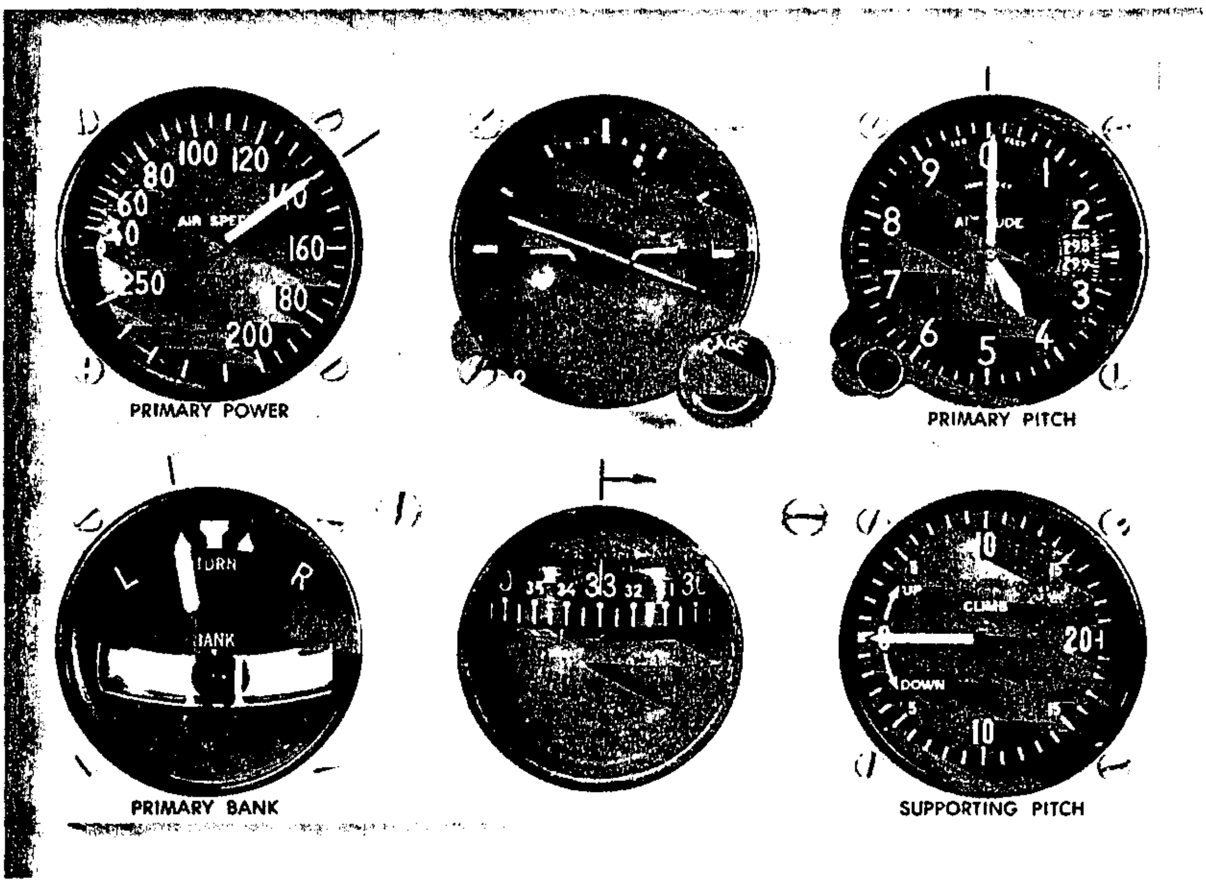


FIGURE 100. Turn needle calibration.

aerodynamic forces on aircraft control at progressively steepening bank attitudes. Skill in cross-check, interpretation, and control is increasingly necessary in proportion to the amount of these changes, though the techniques for entering, maintaining, and recovering from the turn are the same in principle for steep turns as for shallower turns.

Enter a steep turn exactly as you do a shallower turn, but prepare to cross-check rapidly as the turn steepens. Because of the greatly reduced vertical lift component, pitch control is usually the most difficult aspect of this maneuver. Unless immediately noted and corrected with a pitch increase, the loss of vertical lift results in rapid movement of the altimeter, vertical-speed, and airspeed needles. The faster the rate of bank change, the more suddenly the lift changes occur. If your cross-check is fast enough to note the immediate need for pitch changes, smooth, steady back elevator pressure will maintain constant altitude. However, if you overbank to excessively steep angles without adjusting pitch *as* the bank changes occur, pitch corrections require increasingly stronger elevator pressure. The loss of vertical lift and increase in wing loading finally reach a point where further application of back elevator pressure tightens the turn without raising the nose. (The effect of abrupt elevator control on wing loading and its effect on aircraft stalling speeds during steep turns was discussed in Chapter III.)

How do you recognize overbanking and a low pitch attitude? What should you do to correct it? If you observe a rapid downward movement of the altimeter needle or vertical-speed needle, together with an increase in airspeed, despite your application of back elevator pressure, you are in a diving spiral (Fig. 103). Immediately shallow the bank with smooth and coordinated aileron and rudder pressures, hold or slightly relax elevator pressure, and increase your cross-check of attitude indicator, altimeter, and vertical-speed indicator. Reduce power if the airspeed increase is rapid. When the vertical speed trends upward, the altimeter needle will move slower as the vertical lift increases. When you note that the elevator is effective in raising the nose, hold the bank attitude shown on the attitude indicator and adjust elevator control pressures smoothly for the nose-high attitude appropriate to the bank maintained. If your pitch control is consistently late on your entries to steep turns, roll out immediately to straight-and-level flight and analyze your errors. Practice shallower turns until you can keep up with the attitude changes and control responses required, then steepen the banks as you develop quicker and more accurate control technique.

The power necessary to maintain constant airspeed increases as the bank and drag increase. With practice, you quickly learn the power settings appropriate to specific bank attitudes, and can make adjustments without undue attention to airspeed and power instruments. During training in steep turns, as in any other maneuver, attend to "first things first." If you keep pitch relatively constant, you have more time to cross-check, interpret, and control for accurate airspeed and bank control.

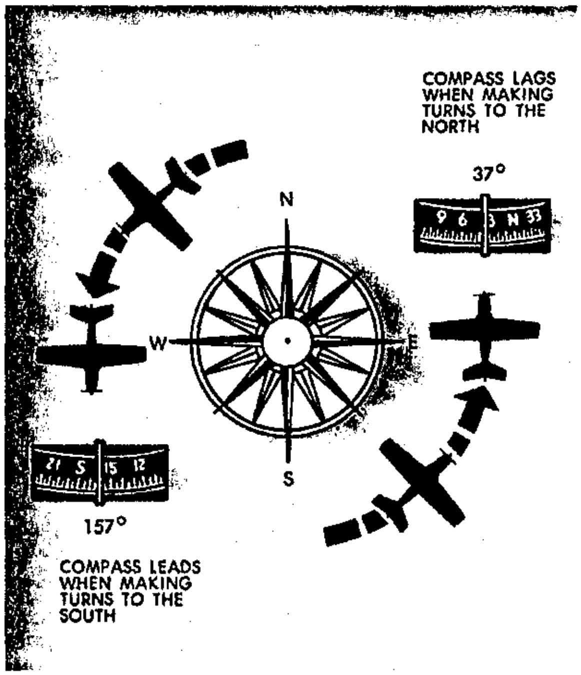


FIGURE 101. Northerly and southerly turn errors.

During recovery from steep turns to straight-and-level flight, elevator and power control must be coordinated with bank control in proportion to the changes in aerodynamic forces. Back elevator pressures must be released, and power decreased. The common errors associated with steep turns are the same as those discussed later in this section; however, remember, errors are more exaggerated, more difficult to correct, and more difficult to analyze unless your rates of entry and recovery are consistent with your level of proficiency in the three basic instrument flying skills.

Climbing and Descending Turns.—To execute climbing and descending turns, combine the techniques used in straight climbs and descents with the various turn techniques. The aerodynamic factors affecting lift and power control must be considered in determining power settings, and the rate of cross-check and interpretation must be increased to enable you to control bank as well as pitch changes.

Change of Airspeed in Turns.—Changing airspeed in turns is an effective maneuver for increasing your proficiency in all three basic instrument skills. Since the maneuver involves simultaneous changes in all components of control, proper execution requires rapid cross-check and interpretation as well as smooth control. Proficiency in the maneuver will also contribute to your confidence in the instruments during attitude and power changes involved in more complex maneuvers. Pitch and power control techniques are the same as those used during changes in airspeed in straight-and-level flight.

As discussed in Chapter III, the angle of bank necessary for a given rate of turn is proportional to the true airspeed. Since the turns are executed at standard-rate, the angle of bank must be varied in direct proportion to the airspeed change in order to maintain a constant rate of turn. During a reduction of airspeed, you must decrease the angle of bank and increase the pitch attitude to maintain altitude and a standard rate turn.

The altimeter and turn needle indications should remain constant throughout the turn. The altimeter is primary for pitch control and

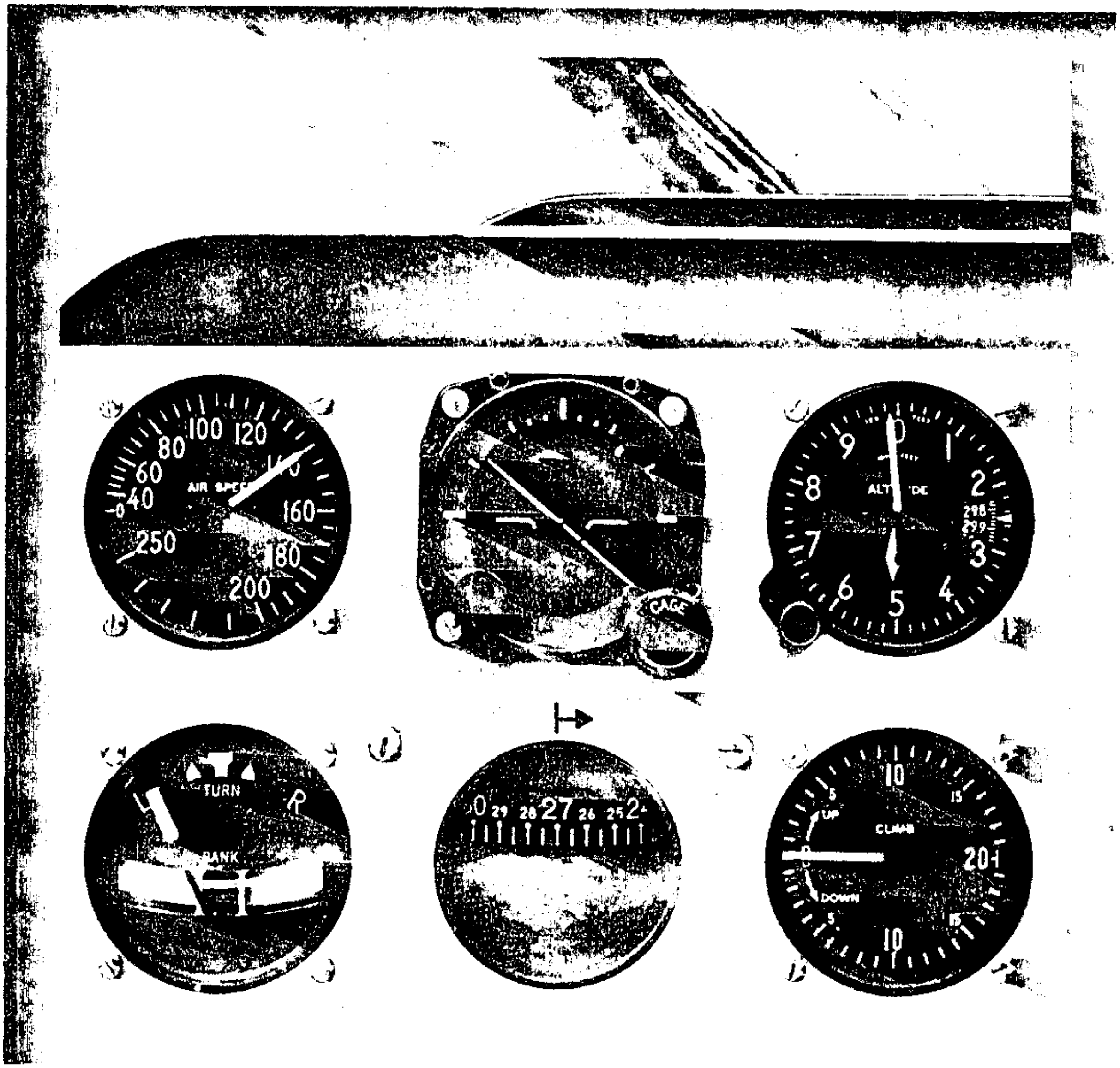


FIGURE 102. Steep left turn.

the turn needle is primary for bank control. The manifold pressure gauge (or tachometer) is primary for power control while the airspeed is changing. As the airspeed approaches the new indication, the airspeed indicator becomes primary for power control.

Two methods of changing airspeed in turns may be used. In the first method, airspeed is changed after the turn is established (Fig. 104); in the second method, the airspeed change is initiated simultaneously with the turn entry. The first method is easier, but regardless of the method used, the rate of cross-check must be increased as you reduce power. As the aircraft decelerates, check the altimeter and vertical-speed indicator for needed pitch changes and the bank instruments for needed bank changes. If the turn needle shows a deviation from the desired deflection, change the bank. Adjust pitch attitude to maintain altitude. When the airspeed approaches that desired, it becomes primary for power control and the manifold pressure gauge (or tachometer) is adjusted to maintain the desired airspeed. Trim is important throughout the maneuver to relieve control pressures.

Until your control technique is very smooth, frequent cross-check of the attitude indicator is essential to keep from overcontrolling and to provide approximate bank angles appropriate to the changing airspeeds.

Common Errors During Turns.—*Pitch errors* result from the following faults:

1. Preoccupation with bank control during turn entry and recovery. If it takes 5 seconds to roll into a turn, check the pitch instruments as you initiate the bank pressures. If your bank control pressure and rate of bank change are consistent, you will soon develop a sense of timing that tells you how long an attitude change will take. During the interval, you check pitch,

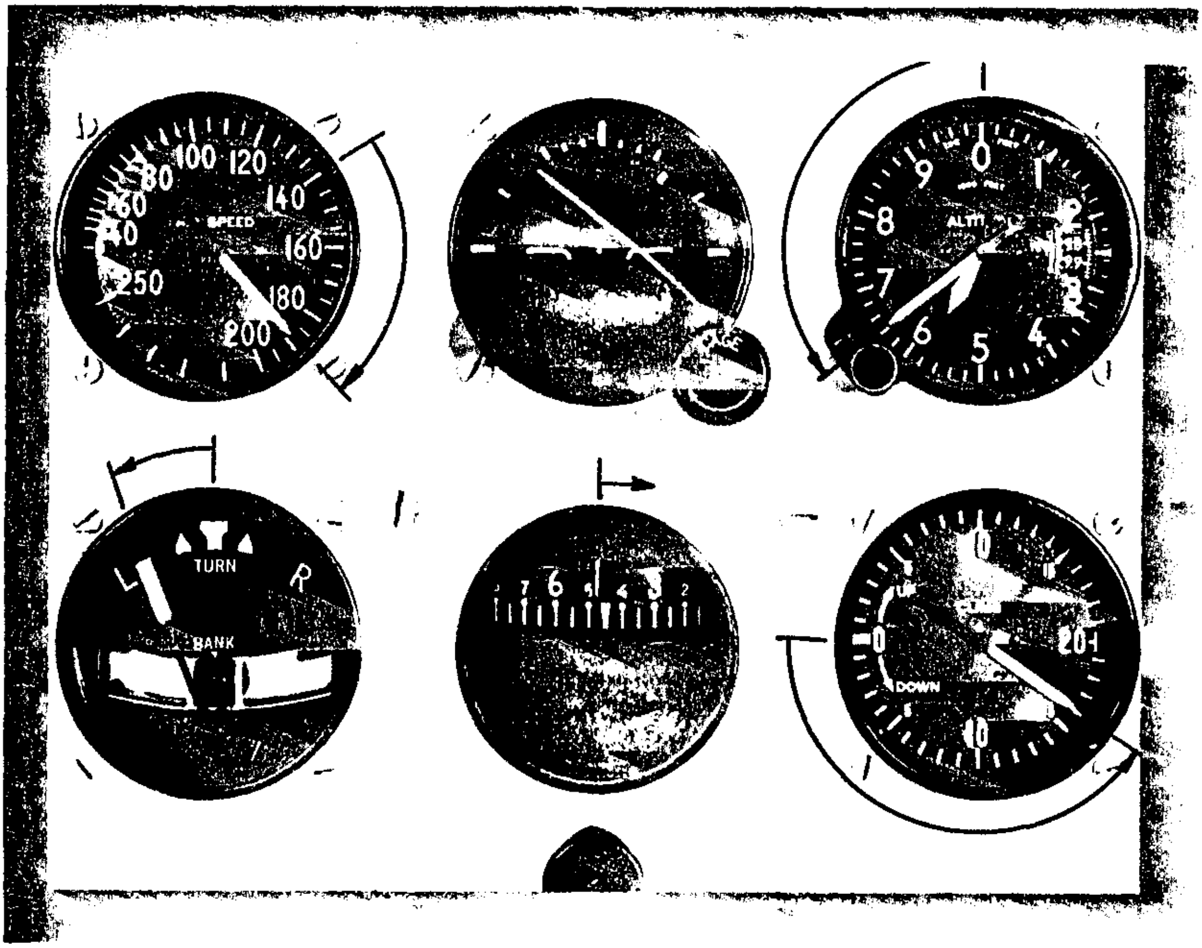


FIGURE 103. Diving spiral.

power, and trim—as well as bank—controlling the total attitude instead of one factor at a time.

2. Failure to understand or remember the necessity for changing the pitch attitude as the vertical lift component changes, resulting in consistent loss of altitude during entries.

3. Changing the pitch attitude before it is necessary. This fault is very likely if your cross-check is slow and your rate of entry too rapid. The error occurs during the turn entry due to a mechanical and premature application of back elevator control pressure.

4. Overcontrolling the pitch changes. This fault is commonly applied to the previous one.

5. Failure to properly adjust the pitch attitude as the vertical lift component increases during the roll-out, resulting in consistent gain in altitude on recovery to headings.

6. Failure to trim during turn entry and following turn recovery (if turn is prolonged).

7. Failure to maintain straight-and-level cross-check after roll-out. This error commonly follows a perfectly executed turn, which so amazes the student that he stares contentedly at the panel instead of getting on with the cross-check.

8. Erratic rates of bank change on entry and recovery, resulting in failure to cross-check the pitch instruments with a consistent technique appropriate to the changes in lift.

Bank and heading errors result from the following faults:

1. Overcontrolling, resulting in overbanking on turn entry, overshooting and undershooting headings, as well as aggravated pitch, airspeed, and trim errors.

2. Fixation on a single bank instrument. On a 90° change of heading, for example, leave the heading indicator out of your cross-check for approximately 20 seconds after establishing a standard-rate turn, since at 3° per second you won't approach the lead point until that time has elapsed. Make your cross-check selective; check what needs to be checked at the appropriate time.

3. Chasing the turn needle. The instrument will oscillate whenever bank or rudder control technique is abrupt. When you become conscious of chasing and overcontrolling this instrument, check the attitude indicator and hold pressure—or relax it, as required—to stabilize the bank attitude. Then note the turn needle position and make a smooth correction after it stabilizes.

4. Failure to check for precession of the horizon bar following recovery from a turn. If the heading indicator shows a change in heading when the attitude indicator shows level flight, the aircraft is turning. If the ball is centered, the attitude gyro has precessed; if the ball is not centered, the aircraft may be in a slipping or skidding turn. Center the ball with rudder pressure, check the attitude indicator and heading indicator, stop the heading change if it continues, and retrim.

5. Failure to use the proper degree of bank for the amount of heading change desired. Rolling into a 20° bank for a heading change of 10° will normally overshoot the heading. Use the bank attitude appropriate to the amount of heading change desired.

6. Failure to remember the heading you are turning to. This fault is likely when you rush the maneuver.

7. Turning in the wrong direction, due either to misreading or misinterpretation of the heading indicator or to confusion as to location of points on the compass. Turn in the shortest direction to reach a given heading, unless you have a specific reason to turn the long way around. Study the compass rose until you can visualize at least the positions of the eight major points around the azimuth. A number of memory "gimmicks" can be used to make quick computations for heading changes. For example, to turn from a heading of 305° to a heading of 110°, do you turn right or left for the shortest way around? Subtracting 200 from 305 and adding 20, you get 125° as the reciprocal of 305°; therefore, execute the turn to the right. Likewise, to figure the reciprocal of a heading less than 180°, add 200 and subtract 20. If you can compute more quickly using multiples of 100's and 10's than by adding or subtracting 180° from the actual heading, the method suggested above may save you time and confusion.

8. Failure to check the ball of the turn-and-slip instrument when interpreting the turn needle for bank information. The turn needle indicates only direction and rate of turn. Unless the ball is centered, you cannot assume that the turn is resulting from a banked attitude.

Power and airspeed errors result from the following faults:

1. Failure to cross-check the airspeed indicator as you make pitch changes.

2. Erratic use of power control. This may be due to improper throttle friction control, to inaccurate throttle settings, chasing the airspeed readings, abrupt or overcontrolled pitch and bank changes, or failure to recheck the airspeed to note the effect of a power adjustment.

3. Poor coordination of throttle control with pitch and bank changes, associated with slow cross-check or failure to understand the aerodynamic factors related to turns.

Trim errors result from the following faults:

1. Failure to recognize the need for a trim change may be due to slow cross-check and interpretation. For example, a turn entry at a rate too rapid for your cross-check leads to confusion

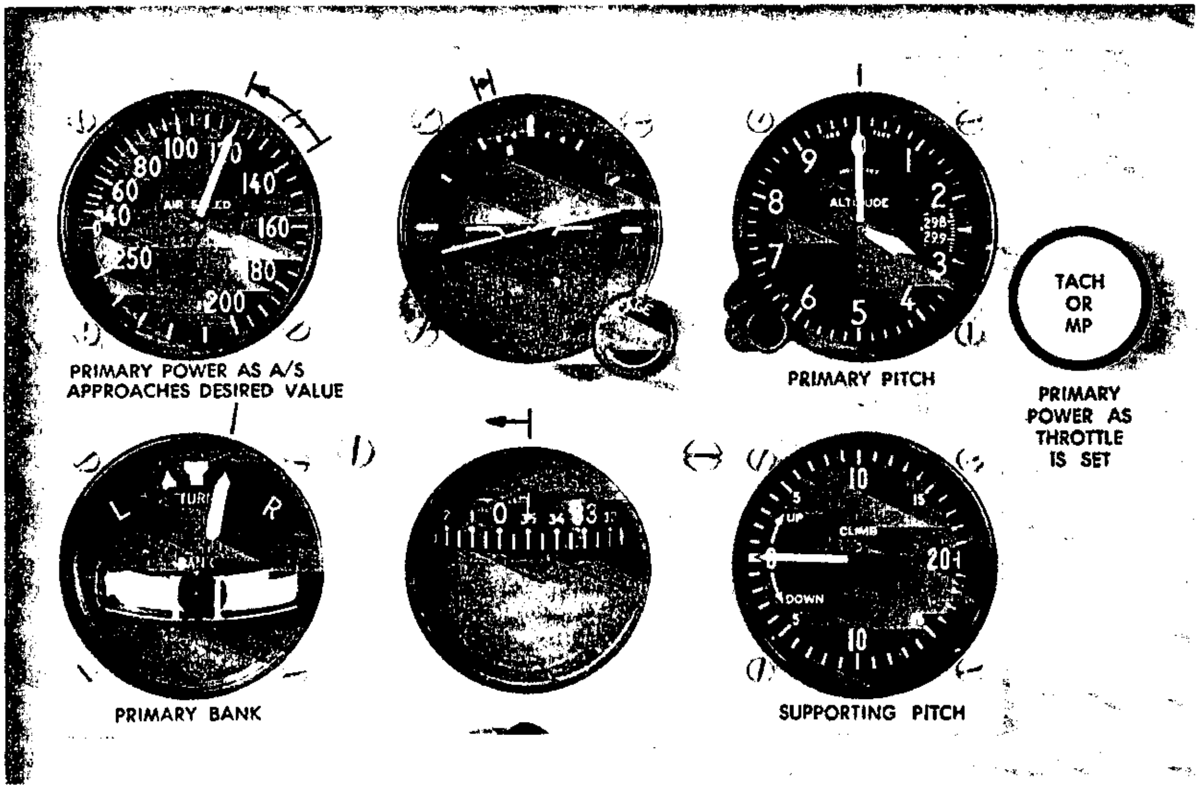


Figure 104. Change of airspeed in turn.

in cross-check and interpretation, with resulting tension on the controls.

2. Failure to understand the relationship between trim and attitude/power changes.

3. Chasing the turn needle and/or the vertical-speed needle. Overcontrolling leads to tension and prevents you from sensing the pressures to be trimmed off.

4. Failure to trim following power changes.

Errors During Compass Turns.—In addition to the faults discussed above, the following errors connected with compass turns should be noted:

1. Faulty understanding or computation of lead and lag.

2. Fixation on the compass during the roll-out. Until the aircraft is in straight-and-level, unaccelerated flight, there is no point in reading the indicated heading. Accordingly, after you initiate the roll-out, cross-check for straight-and-level flight *before* checking the accuracy of your turn.

Unusual Attitudes and Recoveries

An unusual attitude is any aircraft attitude not normally required for instrument flight. Unusual attitudes may result from a number of conditions, such as turbulence, disorientation, instrument failure, confusion, preoccupation with cockpit duties, carelessness in cross-checking, errors in instrument interpretation, or lack of proficiency in aircraft control. Since unusual attitudes are not intentional maneuvers during instrument flight, except in training, they are often unexpected, and the reaction of an inexperienced or inadequately trained pilot to an unexpected abnormal flight attitude is usually instinctive rather than intelligent and deliberate. He reacts with abrupt muscular effort, which is purposeless and even hazardous in turbulent conditions, at excessive speeds, or at low altitudes. However, with practice, the techniques for rapid and safe recovery from unusual attitudes can be learned.

When an unusual attitude is noted on your cross-check, the immediate problem is not how the aircraft got there, but what it is doing and how to get it back to straight-and-level flight as quickly as possible.

Recognizing Unusual Attitudes.—As a general rule, any time you note an instrument rate of movement or indication other than those you associate with the basic instrument flight maneuvers already learned, assume an unusual attitude and increase the speed of cross-check to confirm the attitude, instrument error, or instrument malfunction.

Nose-high attitudes (Fig. 105) are shown by the rate and direction of movement of the altimeter needle, vertical-speed needle, and airspeed needle, as well as the immediately recognizable indication of the attitude indicator (except in extreme attitudes). Nose-low attitudes (Fig. 106) are shown by the same instruments, but in the opposite direction.

Recovery From Unusual Attitudes.—In moderate unusual attitudes, the pilot can normally reorient himself by establishing a level flight indication on the attitude indicator. However, the pilot should not depend on this instrument for these reasons: If the attitude indicator is the spillable type, its upset limits may have been exceeded; it may have become inoperative due to mechanical malfunction; even if it is the nonspillable type instrument and is operating properly, its indications are very difficult to interpret in extreme attitudes. As soon as the unusual attitude is detected, the recovery should be initiated primarily by reference to the airspeed indicator, altimeter, vertical-speed indicator, and turn-and-slip indicator.

Nose-Low Attitudes.—If the airspeed is increasing, or is above the desired airspeed, reduce power to prevent excessive airspeed and loss of altitude. Correct the bank attitude with coordinated aileron and rudder pressure to straight flight by referring to the turn needle. Raise the nose to level flight attitude by smooth back elevator pressure. All components of control should be changed simultaneously for a smooth, proficient recovery. However, during initial training (or when your technique is rusty) a positive, confident recovery should be made "by the numbers," in the sequence given above. A very important point to remember is that the instinctive reaction to a nose-down attitude is to pull back on the elevator control. The possible result of this control response in a steep diving turn has been discussed previously.

After initial control has been applied, continue with a fast cross-check for possible overcontrolling, since the necessary initial control pressures may be large. As the rate of movement of altimeter and airspeed indicator needles decreases, the attitude is approaching level flight. When the needles stop and reverse direction, the aircraft is passing through level flight. As the indications of the airspeed indicator, altimeter, and turn-and-slip indicator stabilize, incorporate the attitude indicator into the cross-check. The attitude indicator, turn needle, and ball should be checked to determine bank attitude and corrective aileron and rudder pressures applied. The ball should be centered. If it is not, skidding and slipping sensations can easily aggravate disorientation and retard recovery. If you enter the unusual attitude from an assigned altitude (either by your instructor or Air Traffic Control if operating under Instrument Flight Rules), return to the original altitude *after* stabilizing in straight-and-level flight.

Nose-High Attitudes.—If the airspeed is decreasing or below the desired airspeed, increase power (as necessary in proportion to the observed deceleration), apply forward elevator pressure to lower the nose and prevent a stall, and correct the bank by applying coordinated aileron and rudder pressure to center the needle and ball. The corrective control applications are made almost simultaneously but in the sequence given above. As in the nose-low recovery, a level pitch attitude is indicated by the reversal and stabilization of the airspeed indicator and altimeter needles. Straight coordinated flight is indicated by the centered needle and ball of the turn-and-slip indicator.

Common errors associated with unusual attitudes include the following faults:

1. Failure to keep the aircraft properly trimmed. A cockpit interruption when you are holding pressures can easily lead to inadvertent entry into unusual attitudes.

2. Disorganized cockpit. Hunting for charts, logs, computers, etc., can seriously detract from your attention to the instruments.

3. Slow cross-check and fixations. Your impulse is to stop and stare when you note an instrument discrepancy, *unless* you have trained enough to develop the skill required for immediate recovery.

4. Attempting to recover by sensory sensations other than sight. The discussion of disorientation in Chapter II indicates the importance of trusting your instruments.

5. Failure to *practice* basic instrument skills once you have learned them. All of the errors noted in connection with basic instrument skills are aggravated during unusual attitude recoveries until the elementary skills have been mastered.

Instrument Takeoff

However remote you may consider the chance of your making an IFR departure under completely "blind" weather conditions, your competency in instrument takeoff will provide the proficiency and confidence necessary for use of flight instruments during departures under conditions of low visibility, rain, low ceilings, or disorientation at night. A sudden rapid transition from "visual" to "instrument" flight can result in serious disorientation and control problems.

Instrument takeoff techniques vary with different types of aircraft, but the method described below is applicable whether the aircraft is single- or twin-engine; tricycle-gear or conventional-gear.

Align the aircraft with the centerline of the runway with the nosewheel or tailwheel straight. (Your instructor may align the aircraft if he has been taxiing while you perform the instrument check under a hood or visor.) Lock the tailwheel, if so equipped, and hold the brakes firmly to avoid creeping while you prepare for takeoff. Set the heading indicator with the nose index on the 5° mark nearest the published runway heading, so that you can instantly detect slight changes in heading during the takeoff. Make certain that the instrument is uncaged by rotating the knob after uncaging and checking for constant heading indication. If you use an electric heading indicator with a rotatable needle, rotate the needle so that it points to the nose position, under the top index. Advance the throttle to an RPM that will provide partial rudder control. Release the brakes, advancing the power smoothly to takeoff setting. During the takeoff roll, hold the heading constant on the heading indicator by

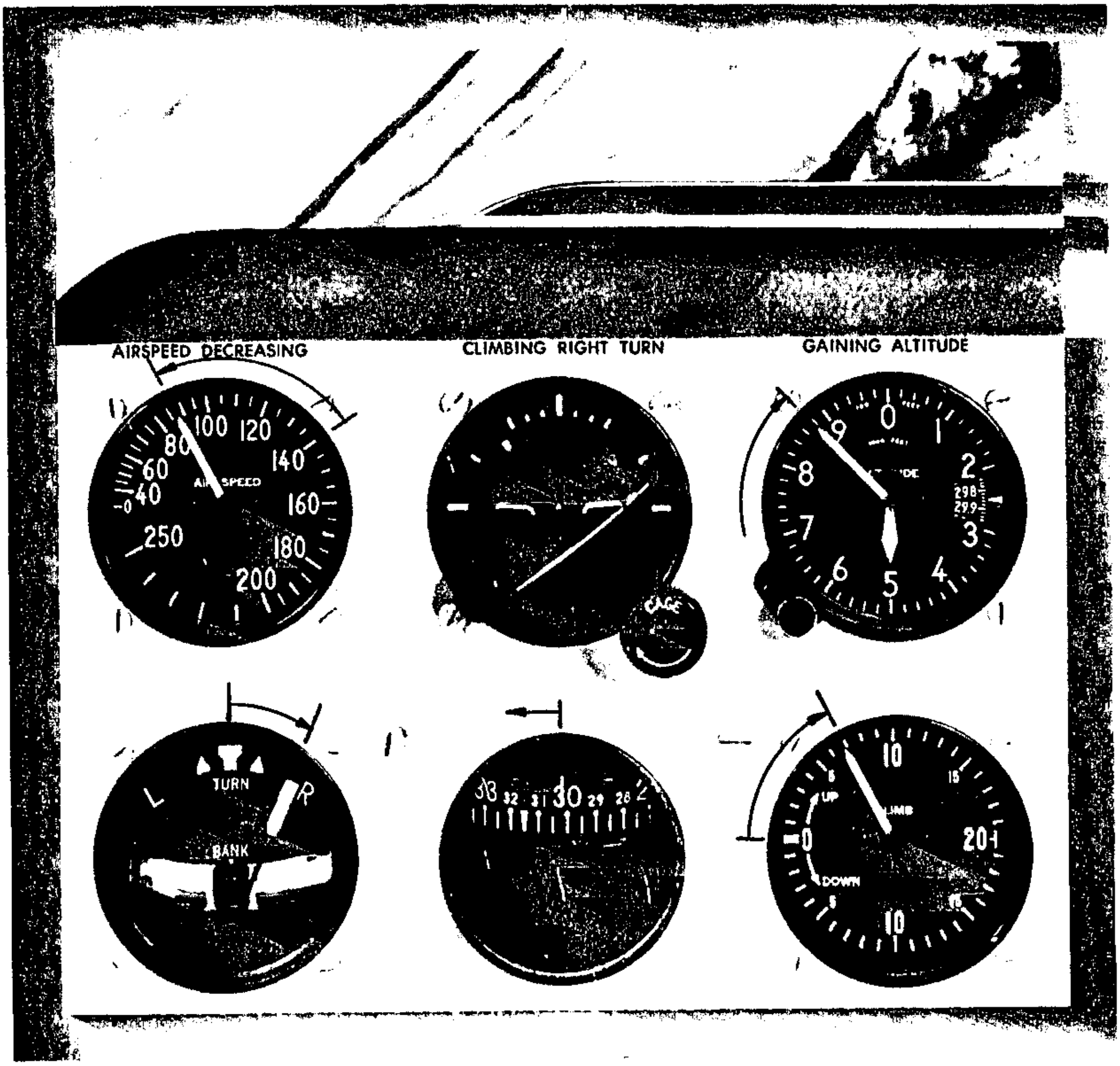


FIGURE 105. Unusual attitude—nose high.

FIGURE 106. Unusual attitude—nose low.

the use of rudder. In multiengine, propeller-driven aircraft, also use differential throttle to maintain direction. The use of brakes should be avoided, except as a last resort, as it usually results in over-controlling and extending the takeoff roll. Once you release the brakes, any deviation in heading must be corrected instantly.

As the aircraft accelerates, cross-check both heading indicator and airspeed indicator rapidly. As flying speed is approached (approximately 15-25 knots below takeoff speed), apply elevator control smoothly for the desired takeoff attitude on the attitude indicator. This is approximately a 2-bar-width climb indication for most light aircraft.

Continue with a rapid cross-check of heading indicator and attitude indicator as the aircraft leaves the ground. Do not pull it off; let it fly off while you hold the selected attitude constant. Maintain pitch and bank control by reference to the attitude indicator, and make coordinated corrections in heading when so indicated on the heading indicator. Cross-check the altimeter and vertical-speed indicator for a positive rate of climb (steady clockwise rotation of the altimeter needle at a rate that you can interpret with experience, and a stable rate of climb appropriate to the aircraft shown on the vertical-speed indicator).

When the altimeter shows a safe altitude (approximately 100 feet), raise the landing gear and flaps, maintaining attitude by reference to the attitude indicator. Because of control pressure changes during gear and flap operation, overcontrolling is likely unless you note pitch indications accurately and quickly. Trim off control pressures necessary to hold the stable climb attitude. Check the altimeter, vertical-speed indicator, and airspeed for a smooth acceleration to predetermined climb speed (altimeter and airspeed increasing, vertical-speed stable). At climb speed, reduce power to climb setting (unless full power is recommended for climb by your aircraft flight handbook) and trim.

Throughout the instrument takeoff, cross-check and interpretation must be rapid, and control positive and smooth. During liftoff, gear and flap retraction, and power reduction, the changing control reactions demand rapid scanning, adjustment of control pressures, and accurate trim changes.

Common errors during the instrument takeoff include the following:

1. Failure to perform an adequate cockpit check before the takeoff. Ridiculous as it seems, students have attempted instrument takeoffs with inoperative airspeed indicators (pitot tube obstructed), gyros caged, controls locked, and numerous other oversights due to haste or carelessness.

2. Improper alignment on the runway. This may result from improper brake application, allowing the aircraft to creep after alignment, or from alignment with nosewheel or tailwheel cocked. In any case, the result is a built-in directional control problem as the takeoff starts.

3. Improper application of power. Abrupt application of power complicates directional control. Add power with a smooth, uninterrupted motion.

4. Improper use of brakes. Incorrect seat or rudder pedal adjustment, with your feet in an uncomfortable position, frequently causes inadvertent application of brakes and excessive heading changes.

5. Overcontrolling rudder pedals. This fault may be caused by late recognition of heading changes, tension on the controls, misinterpretation of the heading indicator (and correcting in the wrong direction), failure to appreciate changing effectiveness of rudder control as the aircraft accelerates, and other factors. If heading changes are observed and corrected instantly with small movement of the rudder pedals, swerving tendencies can be reduced.

6. Failure to maintain attitude after becoming airborne. If you react to "seat-of-the-pants" sensations when the aircraft lifts off, your pitch control is guesswork. You may either allow excessive pitch up, or apply excessive forward elevator pressure, depending on your reaction to trim changes.

7. Inadequate cross-check. Fixations are likely during trim changes, attitude changes, gear and flap retractions, and power changes. Once you check an instrument or apply a control, continue the cross-check and note the effect of your control during the next cross-check sequence.

8. Inadequate interpretation of instruments. Failure to understand instrument indications *immediately* indicates that further study of the maneuver is necessary.

Basic Instrument Flight Patterns

After you have attained a reasonable degree of proficiency in the basic maneuvers, you can apply your skills to various combinations of individual maneuvers. All of the following practice patterns are directly applicable to operational instrument flying problems to be discussed in later chapters.

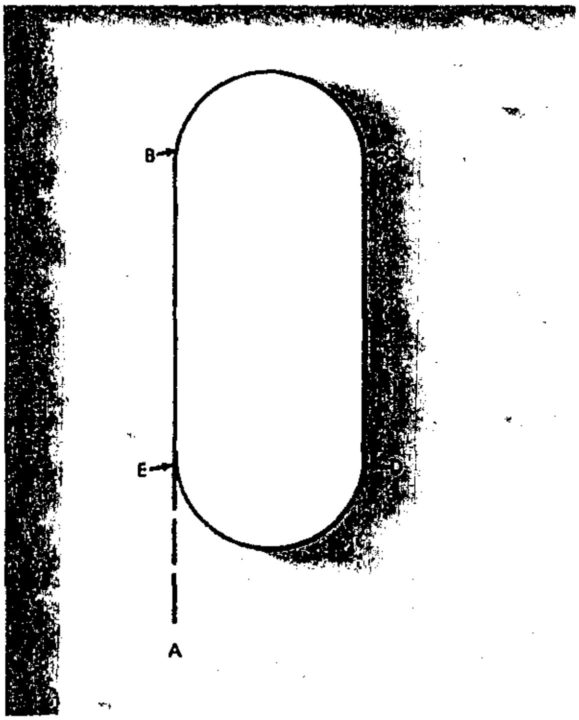


FIGURE 107. Holding pattern (entire pattern in level flight).

Steps—

1. Time 3 minutes straight-and-level flight from A to B. During this interval, reduce airspeed to holding speed (maximum 175 knots). Use any airspeed appropriate for your aircraft.
2. Start 180° standard-rate turn at B. Roll out at C on the reciprocal of your heading at A.
3. Time 1 minute straight-and-level flight from C to D.
4. Start 180° standard-rate level turn at D, rolling out on original heading.

NOTE.—This pattern is an exercise combining use of the clock with basic maneuvers. Holding procedures are covered in Chapter XI.

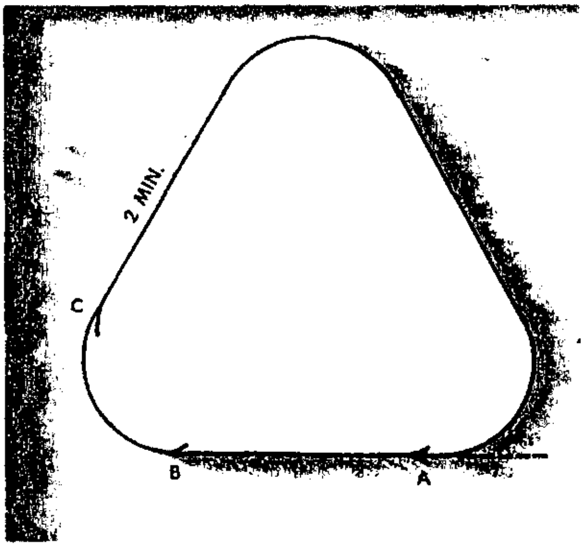


FIGURE 108. Emergency radar pattern (entire pattern in level flight).

Steps—

1. Start timing at A for 2 minutes straight-and-level flight from A to B.
2. At B, enter a half-standard-rate turn for heading change of 120° (80-second turn at 1½° per second). Roll out on the predetermined heading.
3. Complete the pattern as shown, with 2-minute legs in straight-and-level flight and 120° turns.
4. Another emergency radar pattern is the same except that turns are to the left.
5. Check the *Airman's Information Manual* for these emergency procedures. Know both patterns.

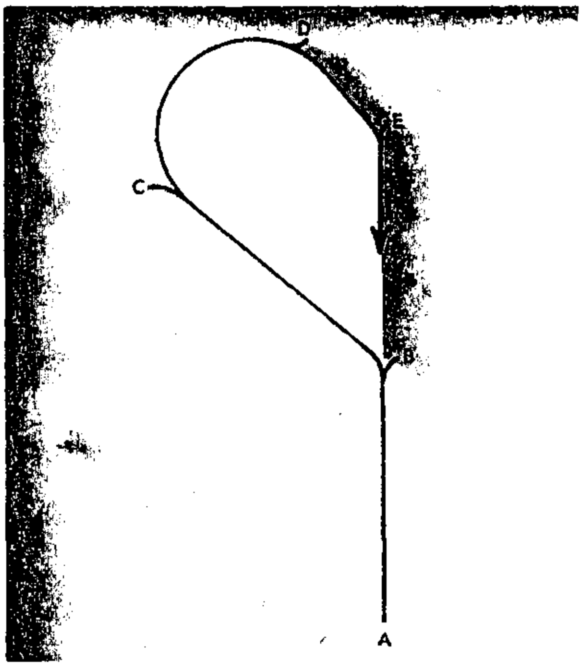


FIGURE 109. Standard procedure turn (entire pattern in level flight).

Steps—

1. Start timing at A for 2 minutes from A to B.
2. At B, turn 45° (standard-rate). After roll-out, fly 1 minute to C.
3. At C, turn 180°.
4. At completion of turn, time 45 seconds to E.
5. Start turn at E for 45° change of heading to reciprocal of heading at beginning of maneuver.

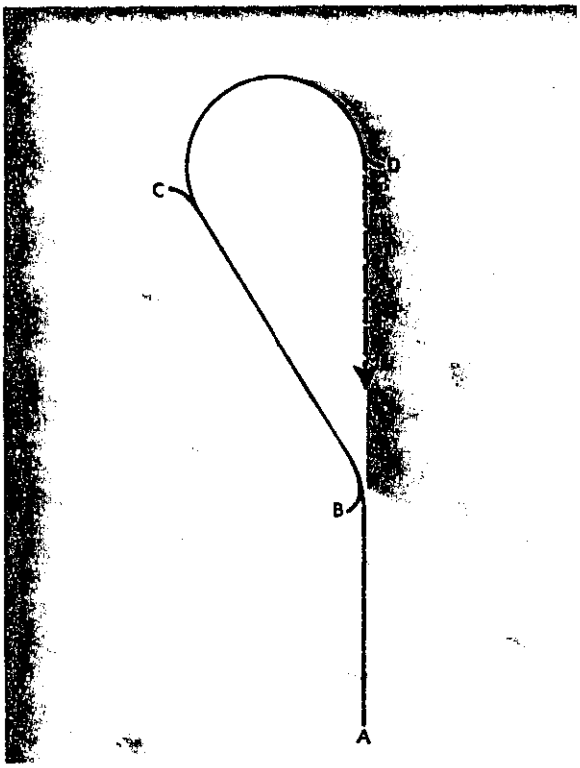


Figure 110. Tear-drop procedure turn.

Steps—

1. Start timing at A for 3 minutes between A and B. Reduce airspeed to holding speed in this interval.
2. At B, enter standard-rate turn for 30° change of heading. Time 1 minute from B to C.
3. At C, enter standard-rate turn for a 210° change of heading, rolling out on the reciprocal of the original entry heading.

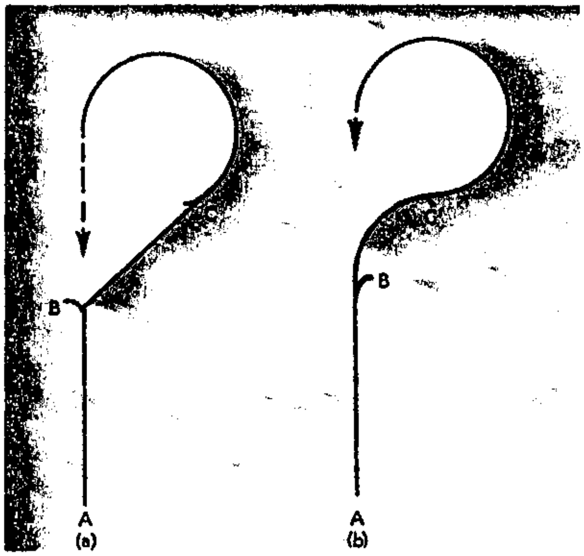


Figure 111. Low-visibility approach (applicable to circling, contact approach, or procedure turns).

Steps—

1. At A, start timing for 3 minutes from A to B. In this interval reduce airspeed to approach speed (approximately 150 percent of stalling speed) with the aircraft in landing configuration (gear down, flaps as desired).
2. At B, enter standard-rate turn for—
   (a) 45° change of heading, or
   (b) 80° change of heading.
3. Maintain straight-and-level flight for 40 seconds from roll-out to C.
4. At C, start a left turn for—
   (a) 225° change of heading, or
   (b) 260° change of heading, rolling out on the reciprocal of the original entry heading. On the 80/260 procedure, roll from the 80° turn immediately into the opposite 260° turn.
5. At the completion of the last turn, retract gear/flaps (if used) and enter a straight constant-airspeed climb.

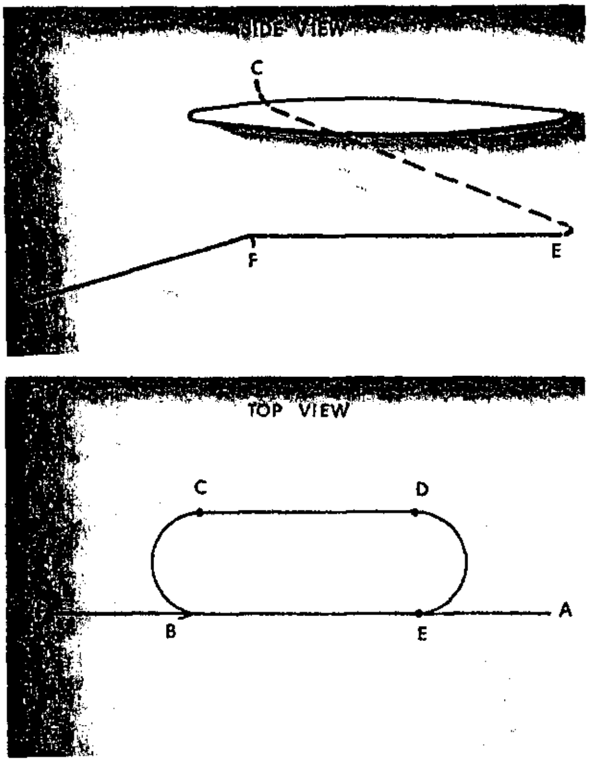


FIGURE 112. Low-visibility approach (all turns standard-rate to the right).

Steps—

1. From A to B, fly 3 minutes while establishing holding airspeed.
2. At B, enter 180° turn. Reduce airspeed to descent speed while in level flight.
3. At C, enter straight-rate descent (500 fpm). At end of 1 minute, turn 180°, continuing the 500 fpm descent.
4. Level off at descending speed on the inbound heading. At 500 fpm and 3° per second, you should be in straight-and-level flight at E.
5. Time 1 minute from E to F, lowering gear and flaps.
6. At F, enter a straight-rate descent (500 fpm). At the end of 500-foot descent, initiate a constant airspeed climb, retracting gear/flaps.

VI. ELECTRONIC AIDS TO INSTRUMENT FLYING

Until comparatively recent times, navigation and voice communications in aviation were distinctly separate aspects of cross-country flight. The pilot depended almost entirely on his own resources. Although ground facilities were sometimes available to provide useful local weather information, the pilot was the BOSS. He made all the decisions because the responsibility was his. Today he is still the boss of his aircraft, but modern air travel involves more decisions and responsibilities than he can handle by himself. While he navigates, he coordinates his flight progress by radio with a vast team of experts who are also responsible for decisions affecting his flight.

Navigation and communications are thus closely interrelated components of cross-country instrument flight in controlled airspace. The electronic ground and airborne aids, the operational procedures, and the rules are interdependent. Knowledge of the basic radio principles applicable to both communications and navigation equipment will increase your understanding of their use and limitations.

Basic Radio Principles

Wave Transmission.—Whether transmitted by sound, light, or electricity, energy moves in waves. A wave is a pulse of energy traveling through a medium by means of vibrations from particle to particle. For example, when a stone is dropped into the water, the energy of motion disturbs the water, causing the water to rise and fall. Energy waves travel outward from the source of disturbance, but the water itself does not move outward. This rise and fall above and below the normal undisturbed level can be pictured as a curved line (Fig. 113).

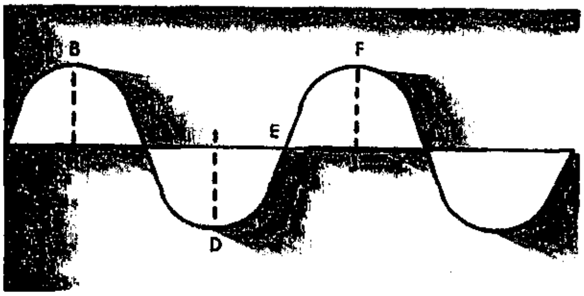


FIGURE 113. Wave transmission.

The *amplitude* of a wave is the linear distance measuring the extreme range of fluctuation from the highest or lowest point to the midpoint between them (BH, ID, FJ). A *cycle* is the interval between any two points measuring the completion of a single wave movement, referenced from any point on the wave to the corresponding point on the succeeding wave (A to E, B to F, C to G). *Wavelength* is the linear distance of a cycle, measured in units appropriate to the size of a wave (A to E). The *frequency* of a wave is the number of cycles completed in one unit of time. If 10 cycles are completed in one second, the wave frequency is 10 cycles per second. Since radio wave cycles per unit of time involve very high numbers, radio frequencies are expressed in kilo Hertz* (thousands of cycles per second) or Mega Hertz (millions of cycles per second). Thus, a frequency of 1,000 Hz equals 1 kHz, and 1,000 kHz equals 1 MHz.

Current is the flow of electrons through a conductor. Direct current (DC) flows only in one direction. Alternating current (AC) flows in one direction during a given time interval, then in the opposite direction for the same

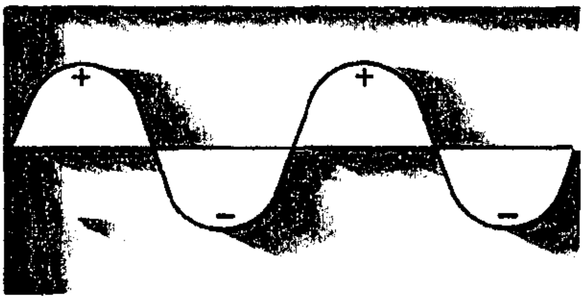


FIGURE 114. Alternating current.

* The Federal Aviation Administration, in conformance with worldwide practice, has formally adopted the term "Hertz" as the basic unit of frequency, meaning cycle or cycles per second. The standard abbreviations Hz (Hertz); kHz (kilo Hertz); and MHz (Mega Hertz) are therefore used in this publication.

interval, reversing continuously. An alternating current can be represented as a continuous change of direction of flow of electrons from positive to negative (Fig. 114).

Radio Waves.—When an electric current flows through a wire, a magnetic field is generated around the wire. When alternating current flows through a wire, the magnetic field alternately builds up and collapses. Radio waves are produced by sending a high-frequency alternating current through a conductor (antenna). The frequency of the wave radiated by the antenna is equal to the frequency, or number of cycles per second, of the alternating current. The velocity of the radiated wave is 186,000 miles per second.

Frequency Bands.—Radio frequencies extend from approximately 20 kilo Hertz to over 30,000 Mega Hertz. Since different groups of frequencies within this range produce different effects in transmission, radio frequencies are classified into groups or frequency bands, according to these differences.

Band	*Frequency Range*
Low-frequency (L/F)	30 to 300 kHz
Medium-frequency (M/F)	300 to 3000 kHz
High-frequency (H/F)	3000 kHz to 30 MHz
Very-high-frequency (VHF)	30 to 300 MHz
Ultra-high-frequency (UHF)	300 to 3000 MHz

Characteristics of Radio Wave Propagation.—All matter has a varying degree of conductivity or resistance to radio waves. The earth itself acts as the greatest resistor to radio waves. Radiated energy that travels near the ground induces a voltage in the ground that subtracts energy from the wave, decreasing the strength (attenuating) of the wave as the distance from the antenna becomes greater. Trees, buildings, and mineral deposits affect attenuation to varying degrees. Radiated energy in the upper atmosphere is likewise affected as the energy of radiation is absorbed by molecules of air, water, and dust. The characteristics of radio wave propagation vary according to the frequency of the radiated signal, determining the design, use, and limitations of both ground and airborne equipment.

Low-Frequency Radio Wave Propagation.—A radio wave radiates from an antenna in all directions. Part of the energy travels along the ground (ground wave) until its energy is dissipated. The remainder of the transmitted energy travels upward into space (sky wave) and would be lost if it were not reflected in the ionosphere by highly charged particles (ions) caused by the sun's radiation. Reflection of radio signals back to the earth permits reception of the signals at varying distances from the transmitter. The distance is determined by the height and density of the ionosphere and the angle at which the

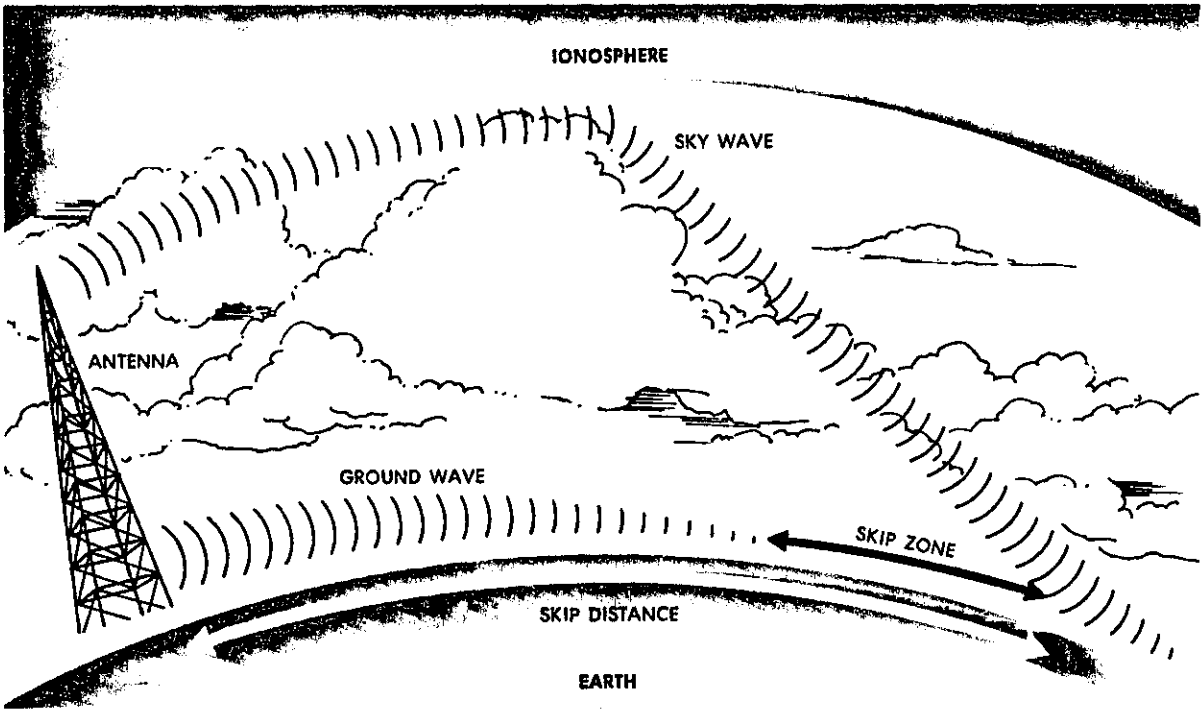


FIGURE 115. Low-frequency radio wave propagation.

radiated wave strikes the ionosphere. The height and density of the ionosphere varies with the time of day, seasons, and latitude since its composition is determined by solar radiation. See Figure 115.

The distance between the transmitting antenna and the point where the sky wave first returns to the ground is called the *skip distance* (Fig. 115). The distance between the point where the ground wave can no longer be received and the sky wave returned is called the *skip zone.* Since solar radiation varies the position and density of the ionosphere, great changes in skip distance occur at dawn and dusk when fading of signals is more prevalent.

High-Frequency Wave Propagation (3,000 kHz to 30 MHz).—The attenuation of the ground wave at frequencies above approximately 3,000 kHz is so great that the ground wave is of little use except at very short distances. The sky wave must be utilized, and since it reflects back and forth from sky to ground, it may be used over long distances (12,000 miles, for example).

Very-High-Frequency Propagation (30 to 300 MHz).—At frequencies above about 30 MHz, there is practically no ground wave propagation and ordinarily no reflection from the ionosphere. Thus, use of VHF signals is possible only if the transmitting and receiving antennas are raised sufficiently above the surface of the earth to allow the use of a direct wave. This type of radiation is known as "line-of-sight" transmission. Accordingly, the use of VHF/UHF radio waves is limited by the position of the receiver in relation to the transmitter (Fig. 116).

When using airborne VHF/UHF equipment, it is of the utmost importance that this limitation be understood. The range of VHF/UHF

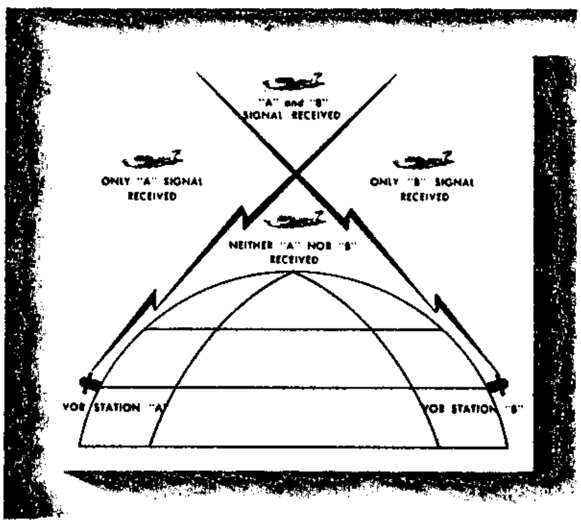


FIGURE 116. Line-of-sight transmission.

transmission increases with altitude, and may be approximately determined by the following simple method: Multiply the square root of the aircraft altitude in feet by 1.23 to find the VHF/UHF transmission range in nautical miles. For example, an aircraft flying 3,600 feet above flat terrain will receive VHF/UHF signals approximately 74 nautical miles from the transmitter.

Static Disturbance to Reception of Radio Waves

Static, whether it originates away from the aircraft in lightning discharges or from electrostatic discharges from the aircraft surfaces, distorts the radio wave and interferes with normal reception of both communications and navigation signals. Low-frequency airborne equipment is particularly subject to static disturbance. Signals in the higher frequency bands are static-free.

Precipitation static occurs when static electricity is generated on various aircraft surfaces in flight and is discharged onto other surfaces or into the air. An aircraft generally accumulates little or no static charge when flying in clear atmosphere. But an aircraft flying in particle-laden air may encounter precipitation static because of charged particles that (1) adhere to the aircraft, (2) create a charge through frictional contact, or (3) divide into charged fragments on impact with the aircraft surfaces.

At the lower altitudes and in moderate to heavy rain, precipitation static is common. It is often accompanied by St. Elmo's Fire, a corona discharge which lights up the aircraft surface areas where maximum static discharge occurs.

Precipitation static is also common in very high clouds or in dust storms, where high winds pick up and carry substantial amounts of solid particles. It can also result from atmospheric electrical fields in thunderstorm clouds. Ice crystal static is encountered in cirrus clouds, or in altostratus and nimbostratus clouds in the winter.

Frequency Interference.—Omni and localizer receivers used for enroute navigation and instrument approaches are susceptible to interference from FM radios, which operate in the VHF frequency range. The frequency oscillations in a portable FM radio operated in an aircraft will be picked up by the aircraft navigation receivers, distorting the navigation receiver information.

Additional irregularities in radio wave propagation, of particular significance in their effect on low-frequency receivers, will be discussed in connection with the use of the radio compass.

Transmission and Reception of Radio Signals

Some of the radio signal transmission characteristics related to ground and airborne equipment and its use are shown in Figure 117.

Basic Communication Equipment.—In order to transmit messages from one location to another by radio, the following basic equipment is needed (Fig. 118):

1. A transmitter to generate radio frequency (r-f) waves.
2. A microphone (or key) to control these energy waves.
3. A transmitting antenna suitable for radiation of the radio frequencies used.
4. A suitable receiving antenna to intercept some of the radio frequency waves.
5. A receiver to change the intercepted radio frequency waves into audio frequency waves.

BAND	RANGE		POWER REQUIRED	ANTENNA LENGTH REQUIREMENT
	DAY	NIGHT		
L-f	Long	Long	Very high	Long
M-f	Medium	Long	High to medium	Long
H-f (3 to 10 MHz)	Short	Medium to long	Medium	Medium
H-f (10 to 30 MHz)	Long	Short	Low	Short
V-h-f	Short	Short	Low	Very short

Long range: over 1,500 miles. Medium range: 200 to 1,500 miles.
Short range: under 200 miles.

FIGURE 117. Transmission characteristics of radio signals.

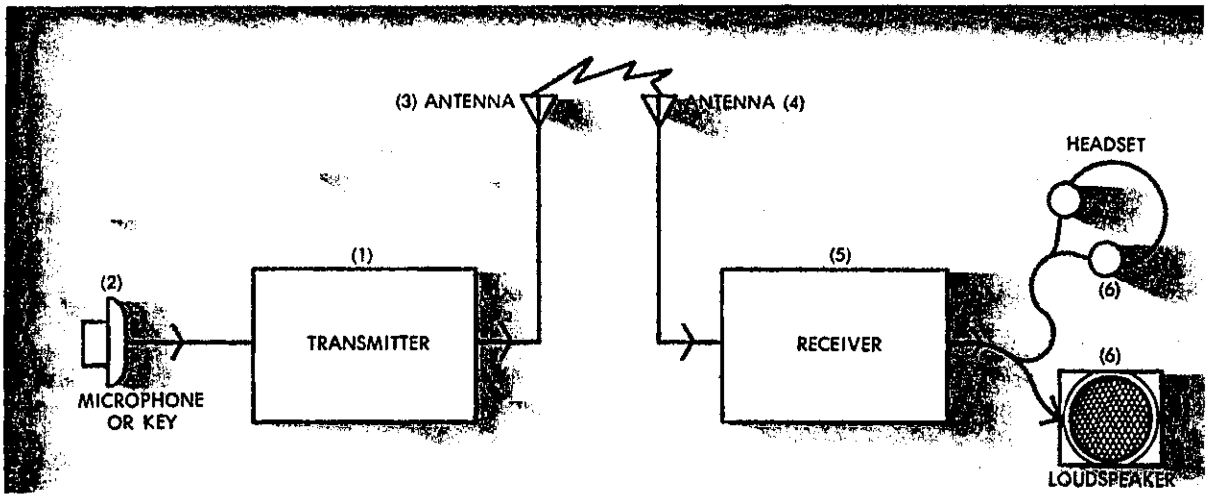


FIGURE 118. Basic communication equipment.

6. A speaker, or earphones, to change the audio frequency waves into audible sound.

Basic Navigation Equipment.—In order to transmit navigation signals from a ground facility to airborne navigation instruments, the following basic equipment is needed:

1. Signal-forming components to determine the character of the radio frequency signals generated.

2. A transmitter, to generate the radio frequency waves.

3. Transmitting antennas, suitable for radiation of the radio frequency signals used.

4. A receiving antenna, or antennas, to intercept the radio freqnency signals.

5. Aircraft receiver components, to select and interpret the navigation signals.

6. Instruments and devices for visual-audio presentation of radio navigation information.

The simplified diagram in Figure 119 shows how the navigation and communications equipment, both ground and airborne, are related.

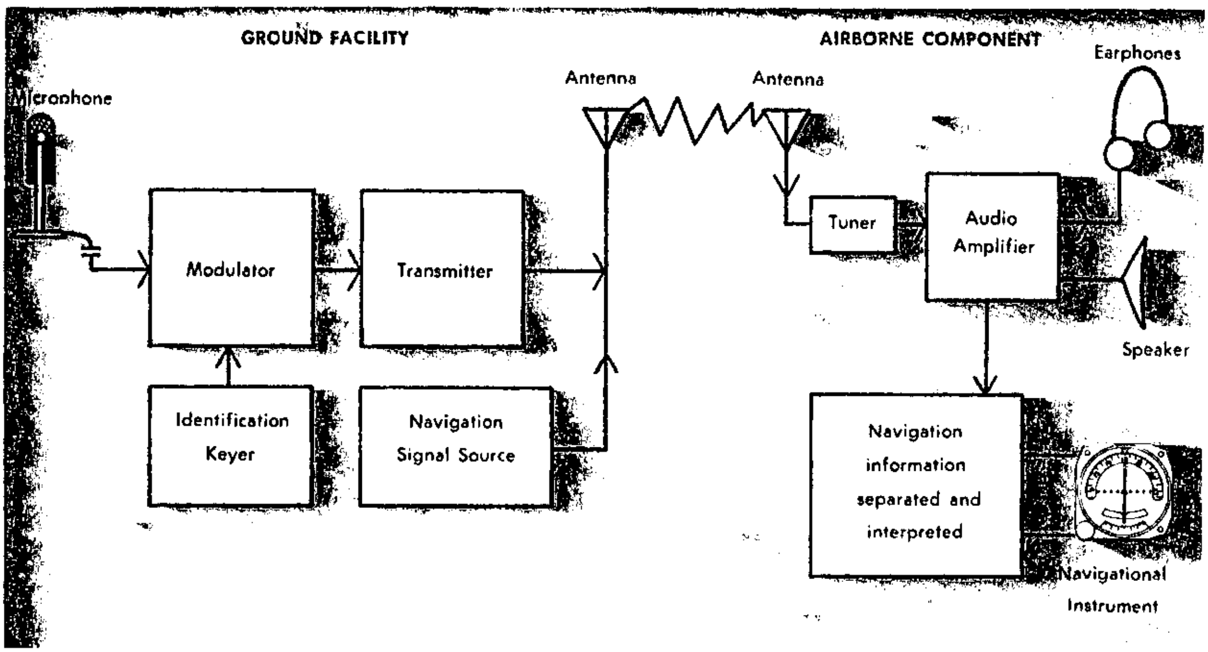


FIGURE 119. Basic navigation equipment.

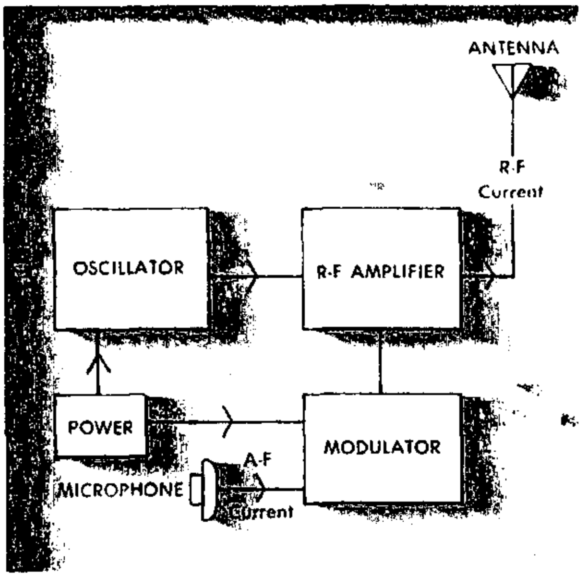


FIGURE 120. Amplitude modulation.

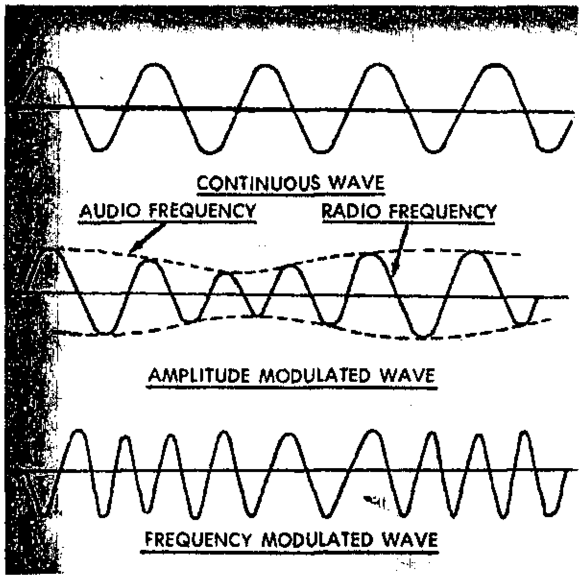


FIGURE 121. Wave modulation.

Modifying the Radiated Signal.—In order to use the radiated signal for communicating information, it is necessary that the signal be modified by the information to be transmitted. The modification can be done either by interrupting the signal (as in morse code), or by *modulating* the signal (Fig. 120). An unmodulated signal is called a *continuous wave* (cw). A modulated signal is commonly called a *modulated carrier wave* (mcw). Figure 121 illustrates a continuous wave, an amplitude modulated wave, and a frequency modulated wave.

Receiving the Radiated Signals.—Radio waves set up currents in receiving antennas, just as an alternating current is set up in any conductor placed near another conductor that carries alternating current. *Tuning* is the selection of the desired signal (frequency) and rejection of the undesired signals (Fig. 122). The tuning circuit in the receiver is adjusted to resonance at the frequency of the desired signal. Other frequencies are rejected by the tuning circuit, and the selected signal is allowed to flow to an *amplifier* which increases the strength of the signal. If the signal being received is a modulated carrier wave, the useful information which it carries must be detected. This process is called *demodulation* and is accomplished by the *detector.*

Radio Navigation Systems

In the broad sense of the term, radio navigation includes any method by which a pilot follows a predetermined flight path over the earth's surface by utilizing the properties of radio waves. The navigation can be conducted by any one or any combination of the following three basic systems:

1. Self-contained airborne systems entirely independent of ground facilities. The Doppler radar navigation system currently used for long over-water and transpolar flights is an example.
2. Ground facilities that continuously monitor and determine the exact aircraft position, on the basis of which the pilot is given navigational guidance by radio communications. Ground-controlled radar navigation is becoming increasingly important to instrument flight operations. Long range radar operated by Air Route Traffic Control Centers (ARTCC) can provide continuous navigational guidance to aircraft operating along most of the routes between major metropolitan terminals.
3. A combination of ground and airborne equipment, by means of which the ground facilities transmit signals to airborne instruments. The pilot determines and controls his ground track on the basis of the instrument indications.

The navigation systems in common use today are a combination of VOR (very-high-frequency omnidirectional range), and additional electronic aids and ground-controlled radar. The four-course low-frequency radio range, which for many years was the standard primary navigation aid, has been replaced by modern facilities, and will not be discussed in this text.

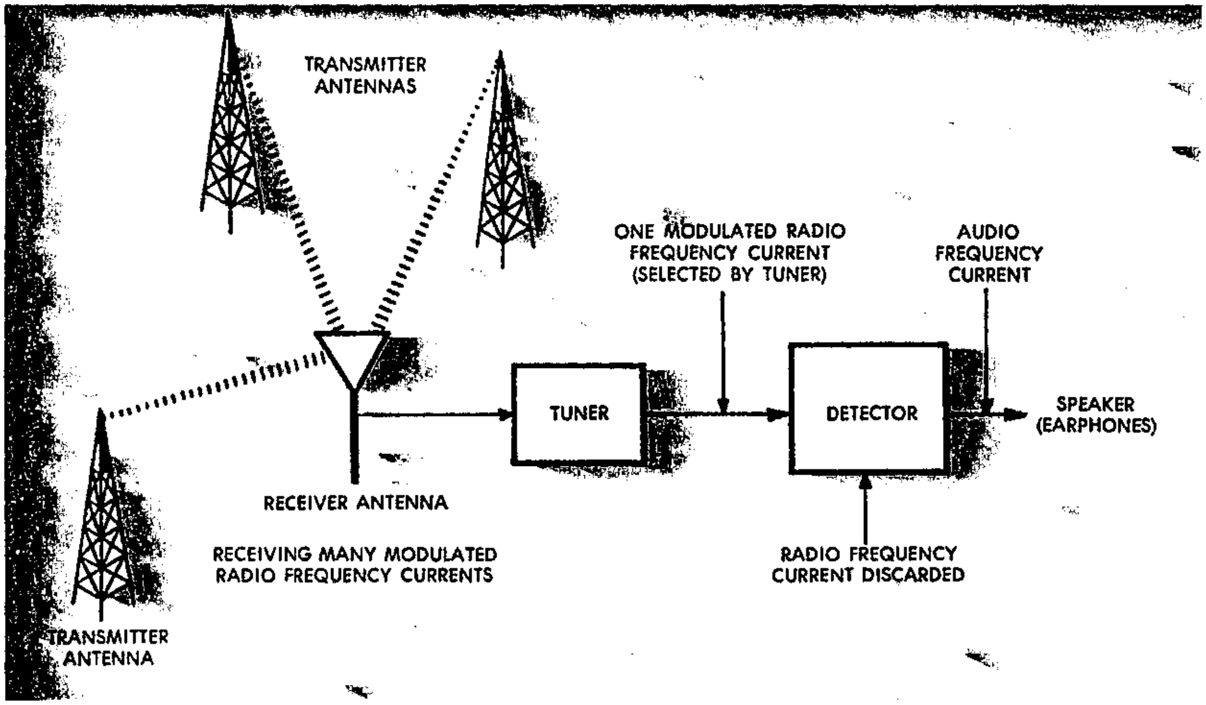


FIGURE 122. Transmission and reception of radio signals.

Very-High-Frequency Omnirange

The VOR, or omnirange, is the primary navigation facility for civil aviation in the National Airspace System. As a VHF facility, it eliminates atmospheric static interference and other limitations associated with the older low-frequency facilities that VOR has replaced. The VOR generates directional information and transmits it by ground equipment to the aircraft, providing 360 magnetic courses TO or FROM the VOR station. These courses are called *radials* and are oriented FROM the station (Fig. 123). For example, aircraft A (heading 180°) is inbound on the 360 radial; after crossing the station, the aircraft is outbound on the 180 radial at A-1. Aircraft B is shown crossing the 225 radial. Similarly, at any point around the station, an aircraft can be located somewhere on a VOR radial.

Principles of Operation.—VOR operation is based upon the principle that the phase difference between two AC voltages may be used to determine azimuth location. The principle may be more readily visualized by imagining two light signals, both at the same geographic position. The first light is a flashing (reference) signal, visible from any point around the com pass. The second light is a narrow beam (variable signal) that rotates continuously at a specific rate. Thus, an observer at any point around the circle sees the rotating beam only at the instant it sweeps past his position. Assume that the reference light flashes only when the

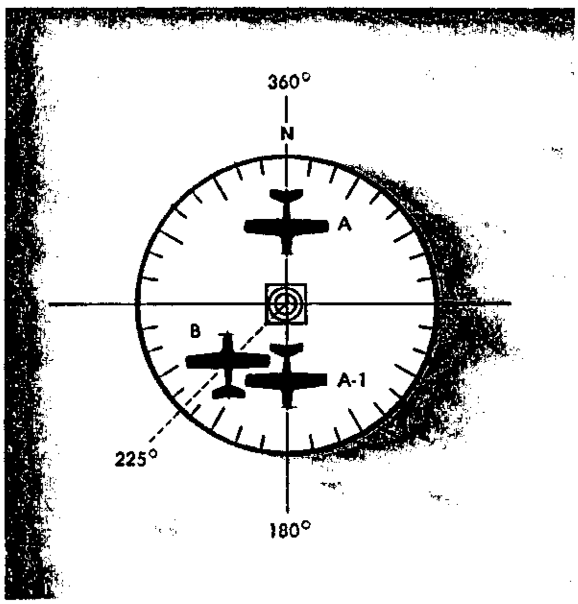


FIGURE 123. VOR radials.

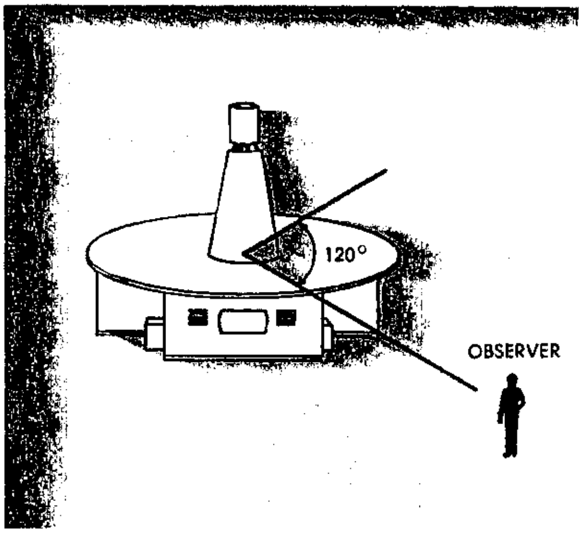


FIGURE 124. Variable and reference phase relationship—VOR.

rotating (variable) beam passes through magnetic north to indicate that the two signals are "in phase." If the rotating beam completes one revolution per minute, an observer can determine his bearing to the light sources from any point around the compass rose by noting the time interval between his observations of flashing and beam signals. For example, if the two signals are in phase at north (flashing), and he sees the rotating beam 20 seconds later, the variable signal has made 20/60 of a revolution. Thus, he must be viewing the beam from a position on the 120 radial (20/60 times 360° equals 120°), as shown in Figure 124. In terms of azimuth, the reference and variable signals are 120° "out of phase."

VOR Transmitter.—The VOR transmitter uses the same principle of phase comparison, rotating a signal electrically at 1,800 revolutions per minute. There are two navigation signal components contained in the transmitted signal. One of these signals has a constant phase at all points around the VOR and is called the *reference* signal. The other signal has a phase that changes one degree for each degree change in azimuth around the VOR and is called the *variable* signal. In all directions other than magnetic north, the two signals are out of phase. The omni receiver measures the phase difference electronically and presents the information to indicate bearing.

In addition to the navigation signals radiated by the VOR, provision is also made for voice transmission and automatic identification of the facility on the same radio frequency.

The VOR ground equipment is easily identified from the air as a small low building topped with a flat white disc upon which are located the antennas and a fiberglass antenna shelter (Fig. 125).

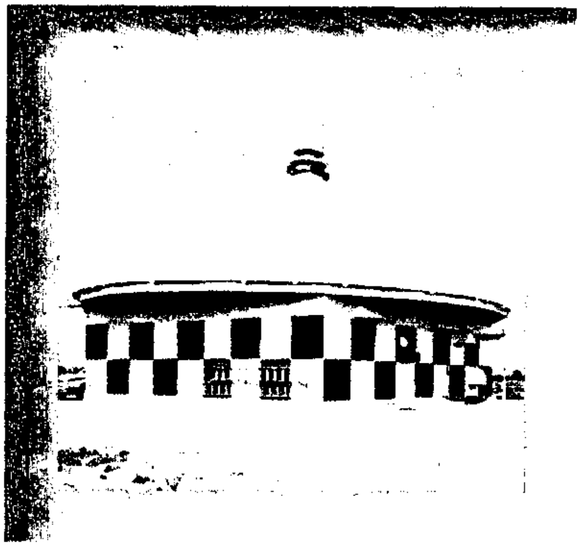


FIGURE 125. VOR transmitter.

The equipment includes an automatic monitoring system that is activated when the signal is interrupted or the phasing is changed. The monitor automatically turns off defective equipment, turns on the standby transmitter, and sounds an alarm in the control room, ensuring continuous reliable service to the users.

VOR Class Designations and Frequencies.—Omniranges are classified according to their operational uses. The standard VOR facility has a power output of approximately 200 watts, with a maximum usable range depending upon the aircraft altitude, class of facility, location and siting of the facility, terrain conditions within the usable area of the facility, and other factors. Above and beyond certain altitude and distance limits, signal interference from other VOR facilities and signal weakening make the signal unreliable. Areas of confusion between VOR stations can be recognized by an aural squeal and oscillation of the visual indicators in the aircraft.

H–VOR and L–VOR facilities operate on a frequency band from 112.0 to 118.0 MHz. The T–VOR is a short-range facility with a power output of approximately 50 watts, operating with channels every .2 MHz in the 108–112 MHz frequency range (108.2, 108.4, etc.). The T–VOR is installed primarily for use in terminal areas, on or adjacent to an airport, for instrument approaches.

VOR Irregularities.—Minor irregularities in VOR signals consist of course shifting, and may be slightly affected by the altitude of the aircraft. Slow movement of the deviation needle on the aircraft instrument is called *course bends;* fast deviations of the needle are called *course scalloping.* When preparing to fly over unfamiliar routes, you can check for VOR irregularities by referring to the appropriate flight-planning publications. These occasional defects are identified by FAA technical specialists to provide pilots with information on the current status of all VOR facilities. Enroute radials published as usable will not be displaced more than 2.5° from the theoretical location of the radial (allowable tolerance—1.5° for radials published for VOR approaches).

VOR Facility Information Itemized.—

1. Frequency range—108–118 MHz.
2. Course information—all directions: radials named FROM the VOR.
3. Coverage—at least 40 miles at normal minimum IFR altitudes.
4. Identification—standard 3-letter code every 5 seconds, or a combination of code and voice identification, with voice every 15 seconds.
5. Voice communication—the VOR can be used for normal voice communication without interference with the navigation information being radiated.
6. Heading insensitivity—the VOR information received by an aircraft is not influenced by aircraft attitude or direction of flight.

VOR Receiving Equipment

VOR signals can be received by a variety of airborne equipment. Tuning equipment and visual indicators representative of current design are shown in Figure 126. Irrespective of differences in dial design, method of tuning, separation of receiver components, and multipurpose designs, all VOR receivers have at least the essential components shown in the NAV/COMM receiver illustrated in the figure.

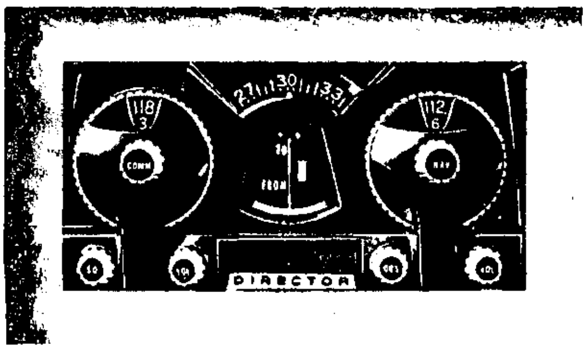


FIGURE 126. VOR receivers.

The components of a VOR receiver can be described as follows:

1. *Frequency selector.*—The frequency selector may be a knob or knobs or "crank," manually rotated to select any of the frequencies between 108.0–118.0 MHz.
2. *Course selector.*—By turning the OBS (Omni Bearing Selector), the desired course is selected. This may appear in a window or under an index.
3. *Course deviation indicator* (CDI).—The deviation indicator is composed of a dial, and a needle hinged to move laterally across the dial. The needle centers when the aircraft is on the selected radial or its reciprocal (Fig. 127). Full needle deflection from the center position to either side of the dial indicates the aircraft is 10° or more off course, assuming normal needle sensitivity.

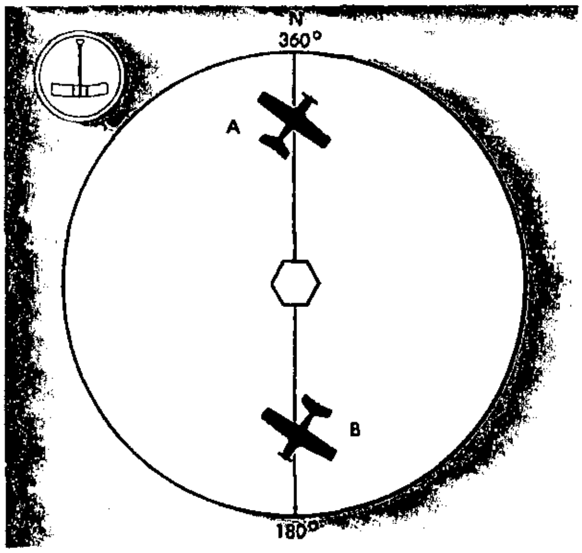


FIGURE 127. Course deviation indicator.

4. *TO/FROM indicator,* also called "sense indicator" and "ambiguity indicator." The TO/FROM indicator shows whether the selected course will take the aircraft TO or FROM the station. It does *NOT* indicate whether the *aircraft* is *heading* to or from the station (Fig. 128).
5. *Flags,* or other signal strength indicators. The device to indicate a usable or an unreliable signal may be an "OFF" flag that retracts from view when signal strength is sufficient for reliable instrument indications, or insufficient signal strength may be indicated by a blank TO/FROM window.

VOR flight procedures will be discussed in Chapter VII, "Using the Navigation Instruments."

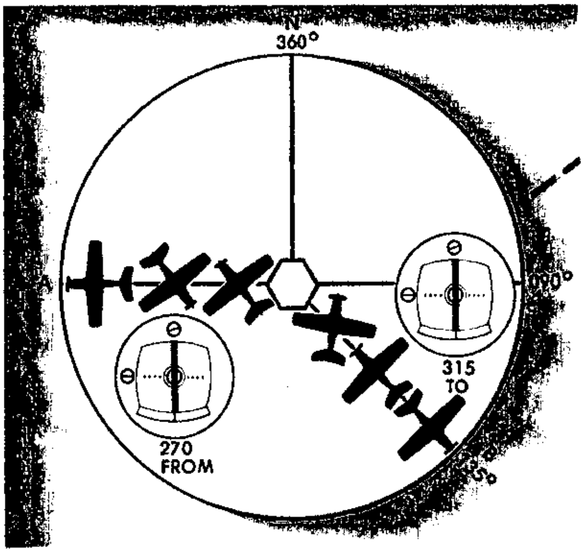


FIGURE 128. TO/FROM indicator.

Distance Measuring Equipment (DME)

Used in conjunction with the nationwide VOR system, distance measuring equipment (DME) has made it possible for you to know the exact geographic position of your aircraft immediately by observation of your VOR and DME indicating equipment. Without DME, you can determine your position by triangulation methods, using a single VOR receiver, dual VOR receivers, or a combination of VOR receiver(s) and low-frequency equipment. With DME and VOR equipment in combination, direct reading instruments tell you the distance and bearing to or from the station.

DME Equipment and Operating Principle.—The aircraft transmits an *interrogating signal,* made up of a pair of RF pulses, which is received by the DME *transponder* antenna at the ground facility. The signal triggers ground receiver equipment, and a second pair of pulses is generated and transmitted through the DME transponder antenna back to the interrogating aircraft. The airborne DME interrogating and indicating equipment measures the elapsed time between the second interrogating and reply pulses and converts this time measurement into a mileage reading on the instrument panel. This mileage is the direct distance from the aircraft to the DME ground facility and is commonly referred to as slant-range distance. The difference between a measured distance on the surface and the DME slant-range distance is known as slant-range error and is smallest at low altitude and long range. This error is greatest when the aircraft is directly over the ground facility, at which time the DME receiver will display altitude in nautical miles above the facility. Slant-range error is negligible if the aircraft is one mile or more from the ground facility for each 1,000 feet of altitude above the elevation of the facility. Lightweight DME equipment is reported by manufacturers to be accurate within plus or minus one-half mile or three percent of the distance, whichever is greater. Operation of the airborne equipment is simple, as illustrated in Figure 129. With the on/off volume switch, you turn on the receiving equipment and identify the DME station, co-located with the desired VOR or ILS (Instrument Landing System) facility. Tuning and identification is accomplished in the same manner as discussed in connection with VOR receivers.

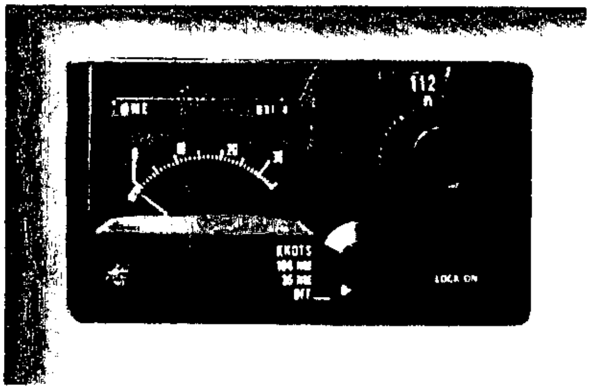


FIGURE 129. DME indicator.

Area Navigation

Area navigation is a system which allows a pilot to fly a selected course to a predetermined point without the need to overfly ground-based navigation facilities. Such navigation systems include doppler radar, inertial platform (a system which reads out latitude and longitude coordinates), and course line computers. The system which the general aviation pilot is most likely to encounter is the course line computer. This system is based on azimuth and distance information generated by the present VORTAC system. The advantages of VORTAC area navigation stem from the ability of the airborne computer to, in effect, locate the VORTAC wherever convenient, if it is within reception range (Figure 130).

These "phantom" stations are called "waypoints." A series of waypoints make up an area navigation (RNAV) route. At the present time, several RNAV routes have been established on

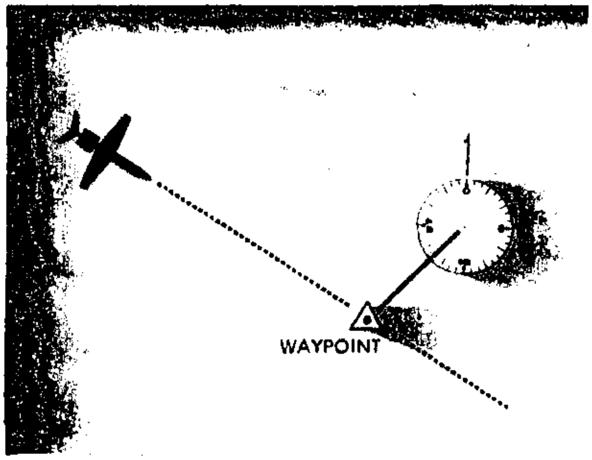


FIGURE 130. Aircraft/VORTAC/waypoint relationship.

an interim basis and are described in the *Airman's Information Manual,* Part 3. The cockpit display of one area navigation system is shown in Figure 131. Below is the "waypoint selector" which has the radial (180) and the distance (50.4 nautical miles) set in the top windows. Above is the guidance instrument with a selected track of 347 set in the window. This model features a symbolic aircraft and cross-pointers. Both the vertical and horizontal pointers move rectilinearly, the vertical pointer indicating across-track distance and the horizontal pointer indicating along-track distance. In Figure 131, the symbolic aircraft's heading, taken from the compass system, is 45° to left of the selected track of 347°. The aircraft is headed directly toward the waypoint which is symbolized by the intersection of the two pointers. Distance to the waypoint is 7 miles along-track and 6 miles across-track when each hash-mark represents 2 nautical miles. Distance to the waypoint may also be read on a conventional DME indicator.

Radar Systems

The FAA first began installing radar equipment at airports in the late 1940s. Further development of radar systems and their expanded use in the Air Traffic Control system have greatly modified and simplified instrument flying procedures. There are three basic types of radar systems used by the FAA: air surveillance radar systems (ASR or ARSR); precision approach radar systems (PAR); and airport surface detection equipment (ASDE).

Fundamental Principles of Radar.—Radar is based upon the precise timing of a returning RF echo from a target and the displaying of this information to the radar operator in such a manner that the distance and bearing to this

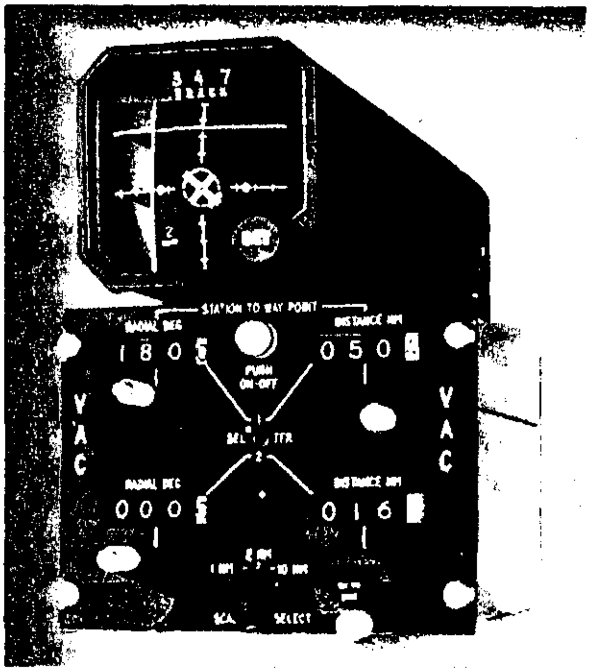


FIGURE 131. Area navigation cockpit installation.

target can be instantly determined. The radar transmitter must be capable of delivering extremely high power levels toward the airspace under surveillance, and the associated radar receiver must be able to detect extremely small signal levels of the returning echoes.

These requirements can be better appreciated when you realize that the effective size of a small airplane is comparable to a small doorway. The radar system may be expected to detect and display this plane from what small fraction of energy is reflected from this surface at ranges up to 200 miles under optitmum conditions. By means of a Microwave Link Relay System (Fig. 132), an unlimited number of radar transmitter sites can be remoted from the control center to provide navigational guidance along the air routes.

Primary Radar.—The surveillance system provides the controller with a map-like presentation upon which appears all the radar echoes of aircraft within detection range of the radar facility. By means of electronically generated range marks and azimuth-indicating devices, the controller can locate each radar target with respect to the radar facility, or can locate one radar target with respect to another. From direct-reading counters on his control panel, the controller determines the bearing and range of one aircraft target with respect to another.

Another device, a video mapping unit, generates an actual airway or airport map and presents it on the radar display equipment. Using the video mapping feature, the airport controller not only can view the aircraft targets, but will see these targets in relation to runways, navigation aids, and hazardous ground obstructions in the area.

The essential difference between Airport Surveillance Radar and Air Route Surveillance Radar is in the equipment required to provide greater maximum usable ranges. Airport surface detection equipment (ASDE) is also a surveillance system, but it scans the ground, rather than the air, for targets. At many major terminals, runways or taxiways may be as far as 2 miles from the controller's position. During all weather conditions, the ASDE equipment permits the controller to have radar-visual access to all parts of the airport although he may not be able (optically) to see the far ends of the airport (Fig. 133).

Use of the FAA primary radar facilities will be fully discussed in Chapter X, "Air Traffic Control."

Secondary Radar.—The surveillance radar system cannot identify one specific radar target found within a display presenting perhaps a dozen or more targets. This problem can be solved with Air Traffic Control Radar Beacon

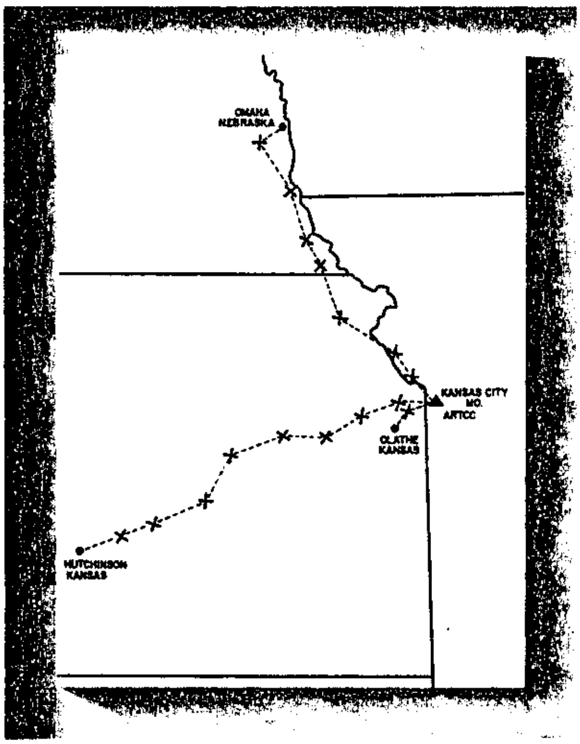


FIGURE 132. Microwave link relay system.

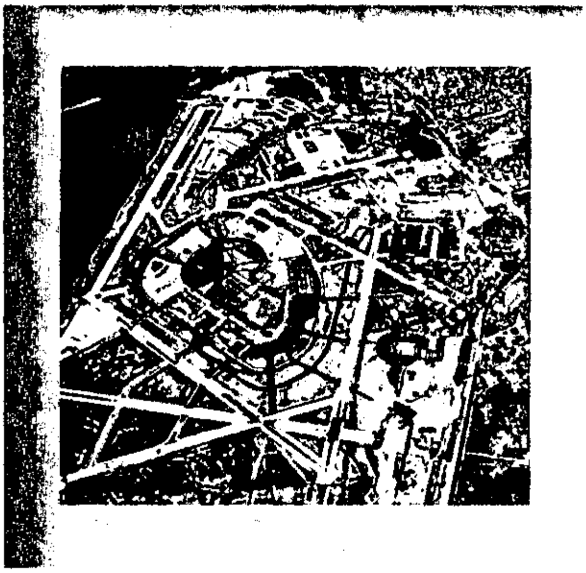


FIGURE 133. ASDE radar.

System (ATCRBS) equipment, which is becoming more prevalent in business aircraft installations. The ground equipment is an *interrogating unit*, with the beacon antenna mounted so as to scan with the surveillance antenna. The interrogating equipment transmits a coded pulse sequence that actuates the aircraft *transponder*. The transponder answers the coded sequence by transmitting a pre-selected coded sequence back to the ground equipment, providing positive aircraft identification as well as other special data. Figure 134 shows the ASR antenna with the associated interrogating unit on top.

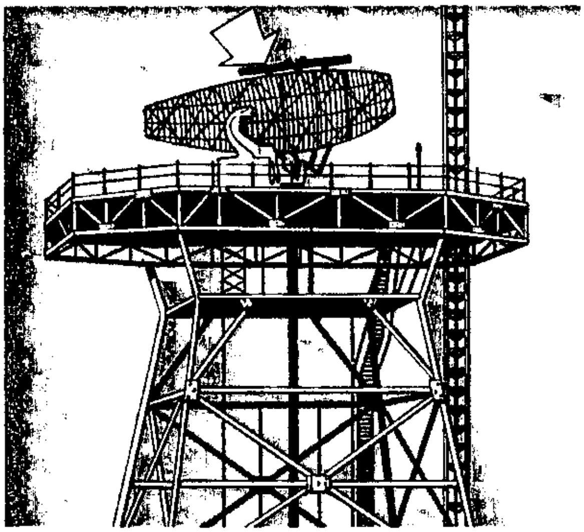


FIGURE 134. ASR and beacon antenna.

Low-Frequency Nondirectional Homing Beacons

The low-frequency nondirectional radio beacon, or homing, facility was one of the earliest electronic navigation aids adopted by the FAA. Homing beacons are installed at various locations to provide either navigation fixes or homing points. The typical homing beacon facility incorporates a low-frequency transmitter and an associated antenna system that provides a nondirectional radiation pattern. The transmitter, operating in the frequency range between 200–415 kHz, is amplitude-modulated with a 1,020 Hz audio tone to provide coded identification.

Types of "H" Facilities.—There are four types of nondirectional homing facilities in use:

1. HH facilities have a power output of 2,000 watts or greater; they are generally used with overwater routes.

2. H facilities have a power output of 50 to 2,000 watts.

3. MH facilities have a power output of less than 50 watts.

4. ILS compass locator facilities have a power output of 25 watts or less, and they are designated as LOM (Outer Locator) and LMM (Middle Locator), appropriate to the outer and middle marker beacon sites where they are located. Note: All middle locators at ILS middle marker sites are being decommissioned unless a specific operational requirement exists for their retention. See FAA Advisory Circular 170–7.

Principles of ADF Receiver Operation.—The airborne radio direction finder (ADF) used with the nondirectional homing beacon is a radio receiver that determines the bearing from the aircraft to the transmitting station. Use of the "H" facility requires a directional antenna for reception of the signals. A directional antenna is one that conducts radio signals more efficiently in one direction than in others. A single-wire vertical antenna ("sense" antenna) is nondirectional in that it conducts received or transmitted signals with equal efficiency in all directions. A loop of wire, or two wires suitably connected, have important directional characteristics for transmission or reception.

Directional antennas for ADF receivers are usually in the form of loops, which extract a portion of the signal energy. The position of the plane of the loop in reference to the station determines the induced voltages in the sides of the loop and the strength of the signal received through the antenna. Maximum signal strength is received when there is a maximum difference in the induced voltages in the sides of the loop (Fig. 135). Minimum signal strength (or null) exists when equal voltages are induced in both sides of the loop simultaneously and no current passes through the receiver.

Sense Antenna.—A sense antenna is also necessary for the operation of automatic direction finding equipment because the loop antenna, although it senses direction by comparison of voltages, cannot sense whether the station is behind or ahead, or to the left or right. This characteristic of loop reception is called *ambiguity*. By combining the properties of the loop antenna with those of a sense antenna, the direction of the incoming signal is resolved so that the ADF indicator continuously shows the relative bearing of the transmitting station to which tuned.

ADF Receiving Equipment.—Several different types of airborne direction finders are available. One type indicates only relative bearing to the station; another indicates both relative bearing and magnetic bearing to the station directly on the same dial. Some indicators have rotating dials and pointers, others have fixed dials. The receiver may include a tuning meter, and a manual control position on the function switch. The essentials are common to all ADF receivers, however, regardless of design detail. In addition to receiving navigation signals, ADF equipment also receives voice communications from L/MF transmitters.

A typical light-plane ADF receiver and indicator (Fig. 136) may include the following components:

1. *Frequency band selector*, permitting the use of any ground transmitter, within the frequency range shown. Commercial broadcasting stations as well as the nondirectional homing beacons can be used.

2. *Function switch*, to select either the sense antenna for tuning, or loop antenna for manual or automatic direction finding.

3. Tuning crank.

4. On-off switch and volume control.

5. CW switch, used to obtain better reception of unmodulated signals. The switch actuates a signal in the receiver which is added to the incoming signal producing a continuous tone. On some receivers, the switch is labelled "BFO," meaning "Beat Frequency Oscillator."

6. Loop switch which is operative when function switch is in "Loop" position. It is used to rotate the loop left or right to more accurately tune in weak stations and also to identify the aural null position of the incoming signal.

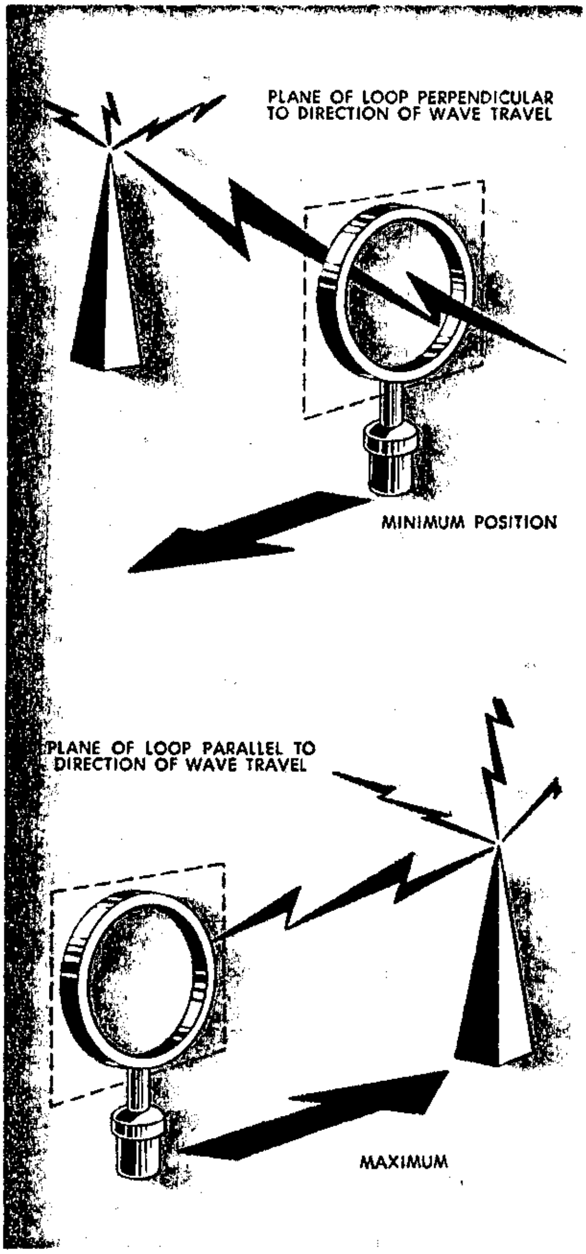


FIGURE 135. Loop antenna.

VHF and UHF Direction Finding Ground Equipment

Direction finding ground facilities use a cluster of vertical antennas which feed a rotating goniometer (angle-measuring device), causing an indicator to point towards an aircraft whose signal is being received. Used directly with ASR radar to locate and direct lost aircraft, the bearing information is presented both by a pointer and by a bright straight line on the radar display, starting from the location of the DF antenna and passing through the radar target representing the transmitting aircraft. Other than a VHF transmitter, no additional airborne equipment is needed to actuate the ground

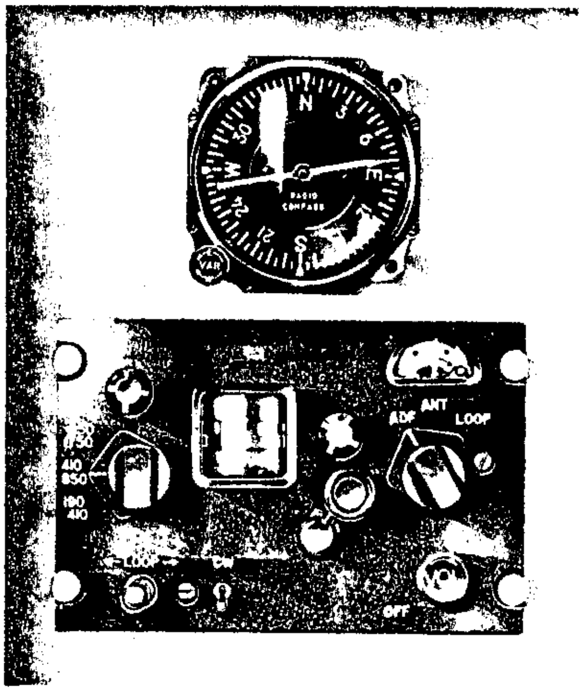


FIGURE 136. ADF receiver.

equipment. VHF/DF procedures are included in Chapter X, "Air Traffic Control."

Instrument Landing System

Although called an instrument landing system, the ILS (Fig. 137) provides a number of ground facilities, either as part of the basic system or associated with it, for several different types of instrument *approaches* to be discussed in a later chapter. At the present time, an instrument approach to *touchdown* is not yet authorized for civil aviation operations. However, the ILS permits approaches to landing under conditions of very low ceiling and visibility.

Ground Components

An instrument landing system consists of the following components:

1. *A localizer radio course* to furnish horizontal guidance to the airport runway.
2. *A glide slope radio course* to furnish vertical guidance along the correct descent angle to

the proper "touchdown" point on the runway.

3. *Two VHF marker beacons* (outer and middle) to provide accurate radio fixes along the approach path to the runway.

4. *Approach lights* are normally installed on the ILS runway to provide means for transition from instrument to visual flight.

The following supplementary elements, though not specific components of the system, may be incorporated into the system to increase safety and utility.

1. *Compass locators* to provide transition from enroute NAVAIDS to the ILS system; to assist in holding procedures, tracking the localizer course, identifying the marker beacon sites; and to provide a final approach fix for ADF approaches.

2. *Distance measuring equipment* (DME) colocated with the glide slope transmitter to provide positive distance-to-touchdown information.

3. *Supplementary lighting systems* to facilitate transition from instrument to outside visual references during the final stage of the approach.

Localizer

The localizer antenna array is located on the extended centerline of the instrument runway of an airport, remote enough from the opposite approach end of the runway to prevent the array from being a collision hazard.

This unit radiates a field pattern which develops a course down the centerline of the runway toward the middle and outer markers, and a similar course along the runway centerline in the opposite direction. These courses are called the "front" and "back" courses, respectively. The localizer is designed to provide an on-course signal at a minimum distance of 25 miles from the runway at a minimum altitude of 2,000 feet.

The radiated field pattern is modulated at two different frequencies. The right side of this pattern, looking along the normal approach path from the outer marker toward the runway, is modulated at 150 Hz. This is identified as the "blue sector" on maps and charts, as well as on some types of aircraft localizer receiver indicators. The left side of the radiated pattern is modulated at 90 Hz, and is identified as the "yellow sector." The on-course path is formed by equi-signal points between the two modulated sides of the pattern, and becomes increasingly narrow as the transmitter is approached.

The localizer course width is defined as the angular displacement at any point along the

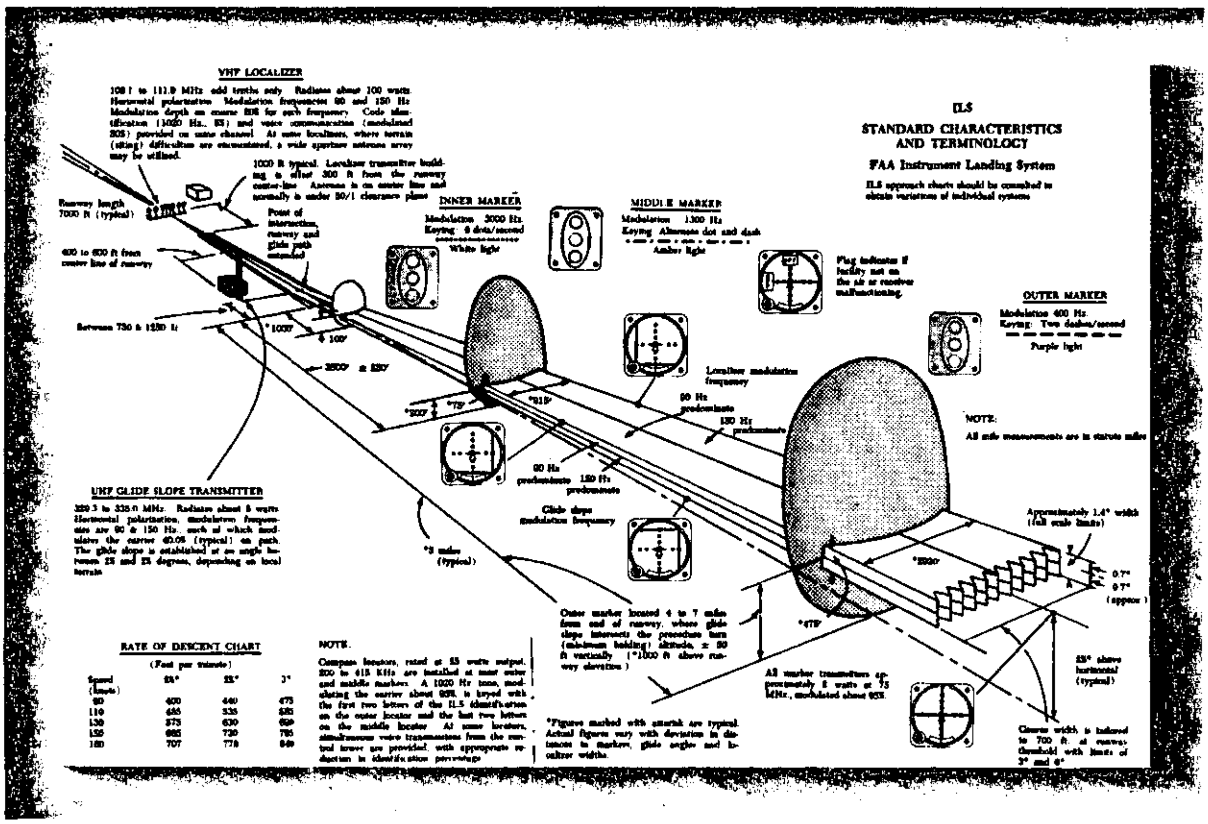


FIGURE 137. Instrument landing system.

course between a full "fly-left" and a full "fly-right" indication on the aircraft course deviation indicator (CDI or localizer needle). This course width is normally 5 degrees—but 4 degrees when associated with runways greater than 10,000 feet—and represents a lateral distance of 4,600 feet, 10 miles from the localizer array. The localizer course width at the point of aircraft touchdown is between 50 and 100 feet, depending upon the length of the runway. In addition, the FAA localizer provides a full "fly-left" or full "fly-right" to an aircraft well outside the on-course area, preventing the possibility of a "false course."

ILS Identification.—Each localizer facility is identified by a 3-letter coded designator transmitted at frequent regular intervals. The identification is always preceded by the coded letter "I" to identify the received signal as originating at the ILS facility. For example, the ILS localizer at Springfield, Mo., transmits the identifier "ISGF." The localizer includes a voice feature on its frequency for use by the associated Air Traffic Control facility in issuing approach and landing instructions. The frequency band of the localizer equipment is 108 to 112 MHz (odd tenths).

Glide Slope

The term "glide slope" means the complete radiation pattern generated by the glide slope facility. The term "glide path" means that portion of the glide slope that intersects the localizer. The glide slope equipment is housed in a building approximately 750 to 1,250 feet from the approach end of the runway, between 400 and 600 feet to one side of the centerline. The course projected by the glide slope equipment is essentially the same as would be generated by a localizer operating on its side, with the upper side of the course modulated at 90 Hz and the lower side at 150 Hz. However, these off-course selectors are not color identified as are the localizer sectors.

The glide slope is normally adjusted at an angle of approximately 2.5° to 3° above the horizontal, depending upon the approach path obstructions or hazards at individual airports. Normally this will result in the interception of the glide slope with the middle marker at an elevation of about 200 feet above the runway level. At locations where standard minimum obstruction clearance cannot be obtained with the normal maximum glide slope angle, the glide slope equipment is displaced inward from the standard location if the length of the runway permits.

Unlike the localizer, the glide slope transmitter radiates signals only in the direction of the final approach on the "front course." The system provides no vertical guidance for approaches on the "back course." The glide path is normally 1.4° thick. At 10 nautical miles from the point of touchdown, this represents a vertical distance of approximately 1,500 feet, narrowing to a few feet at touchdown.

False Courses.—In addition to the desired course, glide slope facilities inherently produce additional courses at higher vertical angles; the angle of the lowest of these "false courses" will occur at approximately 12.5°. However, if your approach is conducted at the altitudes specified on the appropriate approach chart, these false courses will not be encountered.

Marker Beacons

Two VHF marker beacons are used in the FAA ILS system. These are low-powered transmitters operating on a frequency of 75 MHz. The radiation patterns are generally fan-shaped with an elliptical cross-section with its minor axis parallel to the approach path and its major axis at right angles to the approach path.

The *Outer Marker* is located on the front course of the localizer path at a distance from the airport generally determined by the point at which the glide path intersects the minimum holding altitude, provided this point is within 4 to 7 miles from the airport. The 75 MHz carrier frequency is modulated with a 400 Hz audio tone and is keyed to emit dashes continuously at the rate of 2 per second.

The *Middle Marker* is located approximately 3,500 feet from the approach end of the runway, between the runway and the Outer Marker and on the centerline of the localizer course. The marker's 75 MHz carrier frequency is modulated with a 1,300 Hz audio tone, keyed to transmit alternating dots and dashes.

Compass Locators.—The Compass Locator is a low-powered nondirectional radio beacon opating in the 200–400 kHz frequency band. When used in conjunction with an ILS front course, the compass locator facilities are colocated with the Outer and Middle Marker facilities (shown as LOM and LMM on instrument approach charts). The coding indentification of the Outer Locator consists of the *first* two letters of the station indentifier; for example, the Outer Locator at Love Field, Dallas, Tex., (DAL) is identified as "DA." The Middle Locator at DAL is identified by the *last* two letters "AL."

Approach Lighting Systems

Normal approach and letdown on the ILS (Fig. 138) is divided into two distinct stages: the "instrument" approach using only radio guidance, and the "visual" stage, when visual contact with the ground is necessary for accuracy

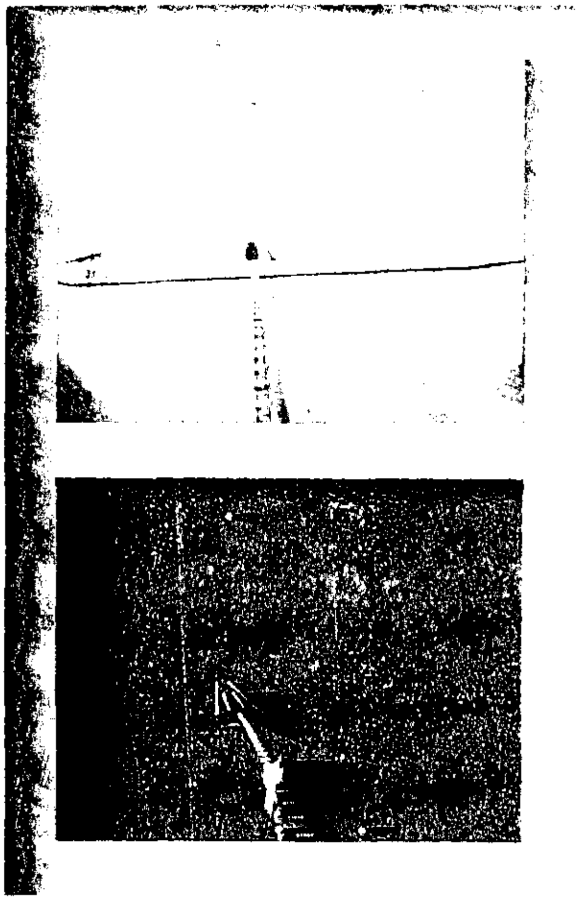


Figure 138. Approach light system.

and safety. The most critical period of an instrument approach, particularly during low ceiling/visibility conditions, is at the point when you must decide whether to land or execute a missed approach.

The purpose of the approach lighting system is to provide you with lights that will penetrate the atmosphere far enough from touchdown to give you directional, distance, and glide path information for safe visual transition. Checking the *Airman's Information Manual* for the particular type of lighting facilities at your destination airport is an important flight planning detail for any instrument flight. With reduced visibility, rapid orientation to a strange runway can be difficult, especially during a circling approach to an airport with minimum lighting facilities, or to a large terminal airport located in the midst of distracting lights.

The approach lighting system shown in Figure 138 is a common installation as you would see it when properly aligned from the runway end. The same approach is illustrated under day and night conditions.

A high-intensity flasher system is installed at many large airports. The flashers consist of a series of very brilliant blue-white bursts of light flashing in sequence along the approach lights, giving the effect of a ball of light traveling towards the runway.

Runway End Identifier Lights (REIL) are installed for rapid and positive identification of the approach end of an instrument runway. The system consists of a pair of synchronized flashing lights, one of which is located laterally on each side of the runway threshold facing the approach area.

The Visual Approach Slope Indicator (VASI) is designed to provide by outside visual reference the same information that the glide slope unit of an ILS provides electronically. It provides a visual light path within the approach zone, at a fixed plane inclined 2.5° to 4° from the horizontal. Course guidance is obtained by alignment with the runway lights. See Figure 138.

The standard VASI consists of 12 light source units arranged in light bars, with three units placed on each side of the runway 600 feet from the threshold, and three on each side of the runway 1,300 feet from the threshold. These are the downwind and upwind bars, respectively, with the touchdown reference point midway between. VASI is normally visible at the approximate range of the outer marker, further at night.

Principle of Operation.—VASI operates on the principle of color differentiation between red and white. Each light projects a beam having white in the upper part and red in the lower part. The units are so arranged that you will see them as illustrated in Figure 139.

ILS Receiving Equipment

For reception of electronic signals from all of the ILS transmitting facilities described, your airborne equipment will include the following receivers:

1. Localizer receiver.
2. Glide slope receiver.
3. Marker beacon receiver.
4. ADF receiver.
5. DME receiver.

Use of the ILS does not require all of these components, however. For example, an instrument approach on the ILS system may be made with only localizer and marker beacon receivers (sometimes called a "localizer approach"); with only localizer and ADF receivers; or with an ADF receiver only, using the locator as a primary approach aid. The authorized ceiling and visibility minimums will of course vary according to the ground and airborne equipment available and operating properly.

Localizer Receiver.—The typical light-plane VOR receiver is also a localizer receiver with common tuning and indicating equipment. Some receivers have separate function selector switches. Otherwise, tuning of VOR and localizer frequencies is accomplished with the same knobs and switches, and the CDI indicates "on course" as it does on a VOR radial.

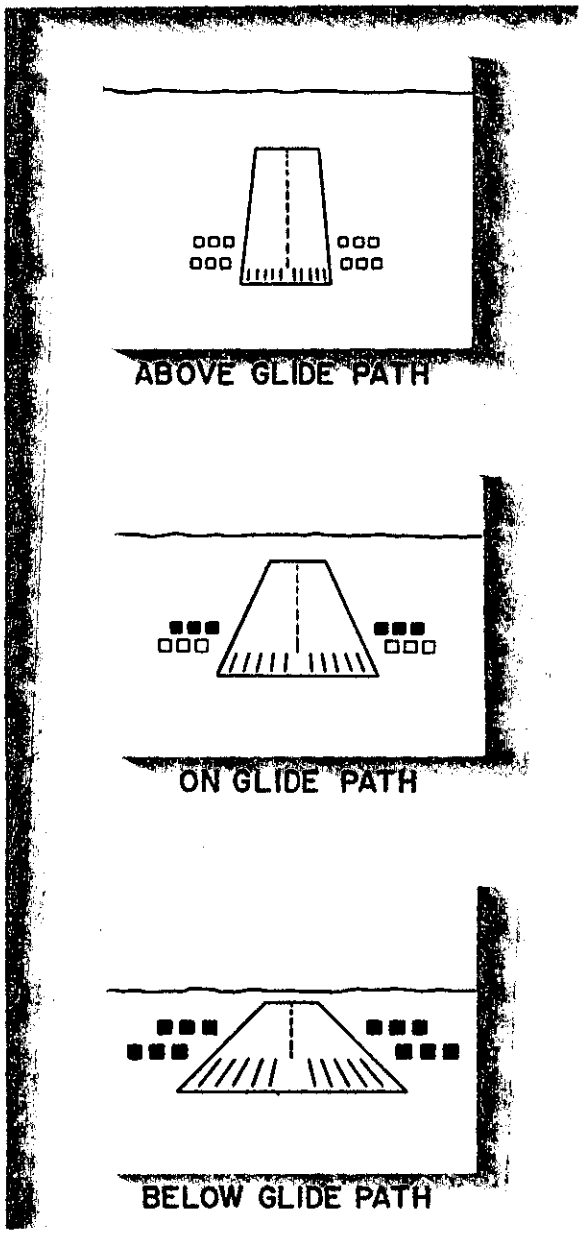


FIGURE 139. Visual approach slope indicator system.

Glide Slope Receiver.—Though some glide slope receivers are tuned separately, in a typical installation the glide slope is tuned automatically to the proper frequency when the localizer is tuned in. Each of the 20 localizer channels in the 108.1–111.9 MHz band is associated with a corresponding glide slope frequency of the 20 UHF glide slope channels available. The paired frequencies are shown in Figure 140.

Localizer/Glide Slope Indicator.—When the localizer indicator also includes a glide-slope needle, the instrument is often called a cross-pointer indicator. The crossed horizontal (glide-slope) and vertical (localizer) needles are free to move through standard 5-dot deflections to indicate position on the localizer course and glide path. See Figure 141.

Sequence or Channel Number	Localizer MHz	Glide Path MHz	Sequence or Channel Number	Localizer MHz	Glide Path MHz
1	110.3	335.0	11	108.1	334.7
2	109.9	333.8	12	108.3	334.1
3	109.5	332.6	13	108.5	329.9
4	110.1	334.4	14	108.7	330.5
5	109.7	333.2	15	108.9	329.3
6	109.3	332.0	16	111.1	331.7
7	109.1	331.4	17	111.3	332.3
8	110.9	330.8	18	111.5	332.9
9	110.7	330.2	19	111.7	333.5
10	110.5	329.6	20	111.9	331.1

FIGURE 140. Paired localizer/glide slope frequencies.

The *localizer needle* indicates, by deflection, the color sector in which the aircraft is flying, regardless of the position or heading of the aircraft. Rotation of the omni bearing selector has no effect on the operation of the localizer needle. Some indicators show blue and yellow sectors to the left and right of the centerline position of the needle; on instruments with no color shown, the needle deflects left in the blue sector, right in the yellow sector.

Thus, when the aircraft is inbound on the front course or outbound on the back course, the needle is deflected toward the on-course (A, Fig. 143) and you turn toward the needle to correct your track. Conversely, when the aircraft is inbound on the back course or outbound on the front course, you turn away from the direction of needle deflection to reach the center of the localizer course (B, Fig. 143). With an ADF tuned to the outer compass locator, orientation on the localizer course is simplified (C, Fig. 143). The problem of orientation with respect to both the localizer course and VOR radials will be discussed in Chapter VII, "Using the Navigation Instruments."

The localizer course is very narrow, resulting in high sensitivity of the needle. Full-scale deflection shows when the aircraft is 2.5° to either side of the centerline. This sensitivity permits accurate orientation to the landing runway. With no more than a ¼-scale deflection maintained, your aircraft will be aligned with the runway. High needle sensitivity also tends to encourage overcontrolling, until you learn to apply correct basic flying techniques for smooth control of the aircraft.

Deflection of the *glide slope needle* indicates the position of the aircraft with respect to the glide path (Fig. 142). When the aircraft is above the glide path, the needle is deflected downward. When the aircraft is below the glide path, the needle is deflected upward.

When the aircraft is on the glide path, the needle is horizontal, overlying the reference dots. Since the glide path is much sharper than the localizer course (approximately 1.4° from full

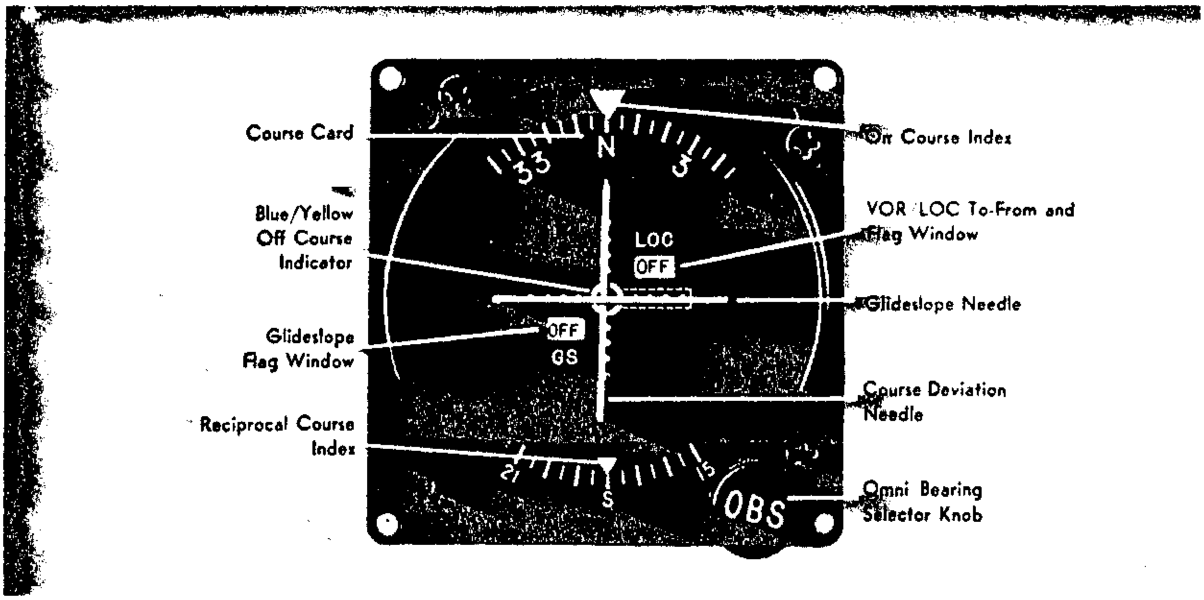


FIGURE 141. Localizer—glide slope indicator.

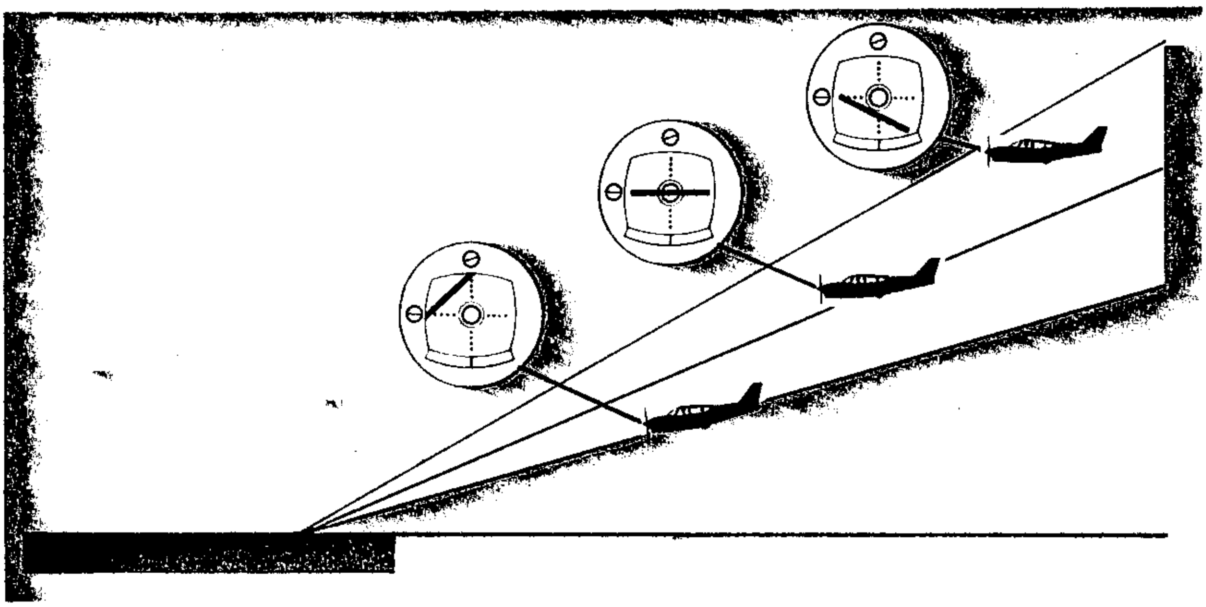


FIGURE 142. Glide slope receiver indications.

"up" to full "down" deflection), the needle is very sensitive to displacement of the aircraft from on-path alignment. With the proper rate of descent established on glide slope interception, very small corrections keep the aircraft aligned.

The localizer and glide slope *warning flags* disappear from view on the indicator when sufficient voltage is received to actuate the needles. The flags show when an unstable signal or receiver malfunction occurs.

Marker Beacon Receiver

The 75 MHz marker beacon receiver (Fig. 144) provides both aural and visual indication of passage over a VHF marker beacon. The white light is actuated over a "Z" or fan marker, accompanied by a high-pitched hum. The blue and yellow lights identify passage over the outer and middle markers on the ILS approach, with the aural identifying codes already discussed.

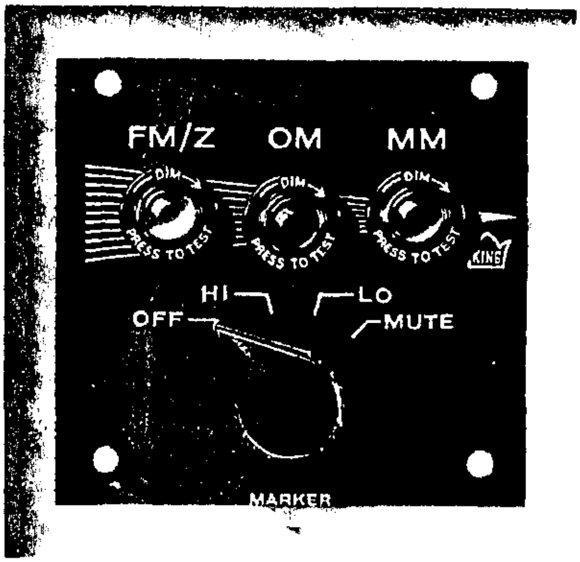


FIGURE 144. Marker beacon receiver.

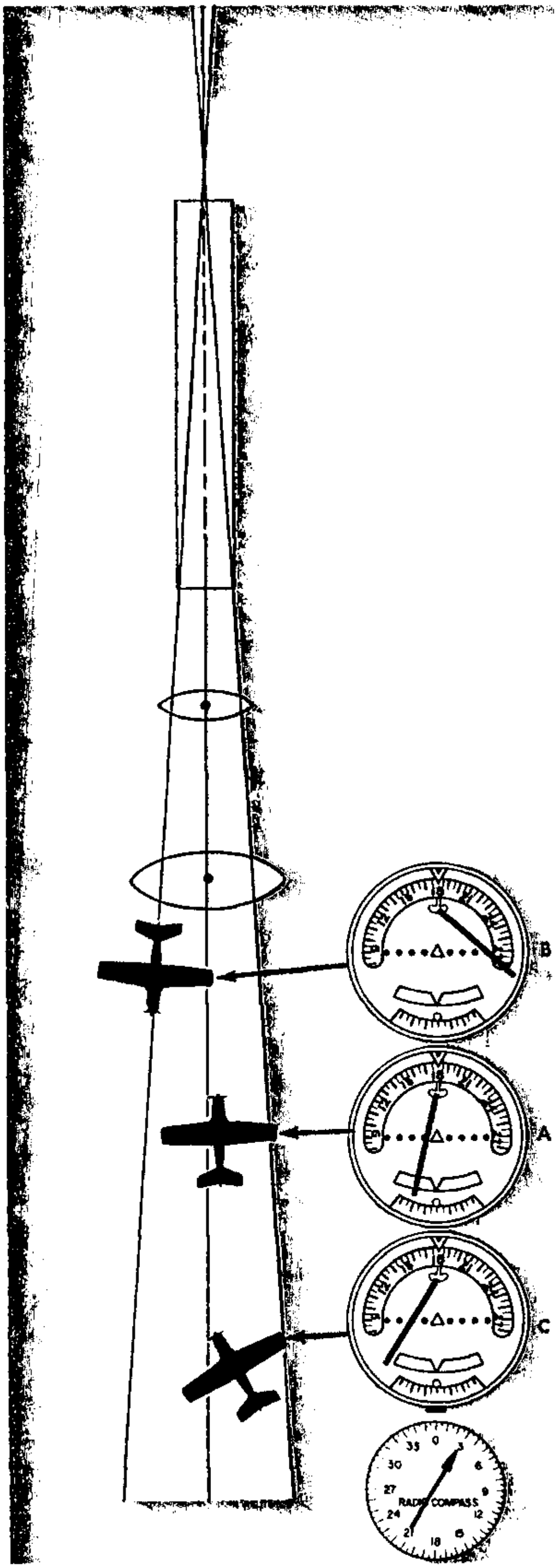


FIGURE 143. Localizer receiver indications.

VII. USING THE NAVIGATION INSTRUMENTS

VOR Receiver

One VOR receiver, used correctly and operating properly, will provide positive and accurate course guidance between most airports on or off Federal Airways. Dual VOR receivers will reduce your enroute workload considerably. VOR in combination with DME will provide the navigational information that, without these aids, requires constant division of attention between basic aircraft control, computation, navigation, and coordination with Air Traffic Control.

There are several common misconceptions about Omni, including the notions that the VOR receiver *automatically* solves your problems of course orientation and drift correction; that a "TO" indication always means that your aircraft is heading toward the station; that you always turn toward the direction of needle displacement to intercept a desired course; or that a fluctuating TO/FROM indication necessarily means station passage. As you will see, each component of the VOR indicator and tuning apparatus operates in relation to the other components. The indicator provides precisely the information you set it up to measure, *the position of your aircraft antenna with respect to a selected magnetic course to or from the VOR transmitter.* Correctly used, omni simplifies your navigation problems and reduces the time and effort necessary for their solution.

The following discussion assumes the VOR receiver illustrated in Figure 145; it may differ in minor details from many of the several designs in common use.

Tuning.—The *ON / OFF / Volume Control* turns on the navigation receiver and controls the audio volume. The volume control has no effect on the operation of the VOR indicator. With the volume set at a comfortable level, the station is

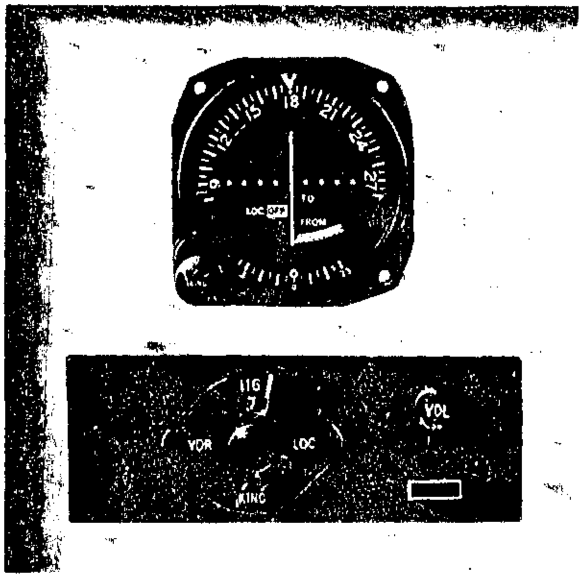


FIGURE 145. VOR/localizer receiver.

identified by code or automatic voice transmission. Positive identification of the transmitting VOR station is important, since a Flight Service Station (FSS) may transmit messages simultaneously over a number of "remoted" VOR facilities. If you hear "Jonesville Area Radio" transmitting a weather broadcast, you may be tuned to Jonesville Omni or to any of a number of VOR stations remoted from Jonesville FSS. If no station identification signal is heard, the facility has been taken over by maintainance for tune-up or repair.

Frequency Selection.—The large outer ring selects Mega Hertz; the small center knob selects tenth-Mega Hertz. Airways charts show VOR frequencies as well as the coded identification you listen for.

Omni-Bearing Selector (OBS).—The OBS knob drives the omni-bearing dial for selection of any desired radial under the course index, with the reciprocal of the course shown under the lower index. With the receiver warmed up and a usable signal received, the "OFF" flag will disappear, and the course deviation indicator (CDI) will move to a stable position. If a steady flag does not appear in either the "TO" or "FROM" window and the CDI shows full deflection, rotate the OBS knob until the CDI centers and a positive "TO" or "FROM" is indicated. The needle will eventually center by rotation of the OBS and dial in either direction.

To center the needle quickly, note the "TO" or "FROM" indication. With a "TO" indication, rotate the OBS *to*ward the deflection, counterclockwise with a left deflection and clockwise with a right deflection. With a "FROM" indication, rotate the OBS away from the deflection to center the CDI.

Receiver Checks.—VOR receiver checks are required as specified in Federal Aviation Regulation Part 91.

In addition to the receiver tolerance checks in the Regulation, *course sensitivity* may be checked by noting the number of degrees of change in the course selected as you rotate the OBS to move the CDI from center to the last dot on either side. This should be between 10° and 12°.

Competent pilots check their VOR receivers frequently and carefully, not only for maximum permissible tolerance limits, but for errors indicated in a specific instrument. For example, the tolerance limit between the two indicated bearings on a dual VOR receiver check is 4°. Assume that you are checking your receivers at a designated check point on the ground, located on the 090 radial of "X" VOR. The OBS on your #1 receiver shows 094, needle centered; the OBS on #2 receiver shows 098, needle centered. Add a possible 2° deviation of the actual location of the 090 radial from its theoretical location, and assume further that your #2 receiver course sensitivity check shows a 15° change. After adding up the possible cumulative errors, an experienced pilot would not rely on his #2 receiver for accurate navigation information.

Orientation

CDI Interpretation.—With your receiver properly tuned and checked, rotate the OBS knob until the needle centers. Assume that the needle centers with the 180° course under the index (Fig. 146). Your aircraft can be on any heading and at any point over the north/south reference line shown, except over the station or close to it. Approaching inbound from point "I" to point "S", the CDI will deviate from side to side as the aircraft passes directly over the station where no signal is received. Likewise a centered CDI with any other course shown under the index locates your aircraft over either the selected radial or its reciprocal.

TO/FROM Interpretation.—With a course of 180° selected under the index, a "TO" indication shows, regardless of heading, whenever your aircraft is located within the approximate hemispherical area north of the 90/270 reference line. A "FROM" indication appears when the aircraft is located south of the approximate 90/270 reference line. Movement across the 90/270 area is indicated by an ambiguous TO/FROM signal. In this area, the resultant of the opposing reference and variable signals, which actuate the

TO/FROM indicator, is insufficient to produce a positive "TO" or "FROM" indication. At a speed of 150 knots, the approximate times to cross this area at various distances from the station (Fig. 147) are as follows:

Distance from station (in nautical miles)	*Width (zone of confusion at 3000 AGL) (time in seconds)*
½	8
1	10
3	25
5	50

Likewise, with any given course under the index, a "TO" will show whenever your aircraft is located in the hemispherical area approximately 90° on either side of the selected course. "FROM" will show in the other hemisphere. Note that the course index is at the *bottom* of the dial shown in Figure 148.

CDI and TO/FROM Interpretation.—As Figure 148 shows, the position of the CDI tells you that: You are on a specific radial (or its reciprocal); or you are to the right or left of it, *with respect to the* course selected.

Movement of the CDI, in conjunction with heading information, tells you:

1. Of impending station passage.
2. Wind drift.
3. Approximate distance from the VOR station. Drift correction and time/distance checks will be discussed later in this chapter.

The TO/FROM indicator locates you in one of two hemispherical areas, depending on the course selected, or in an area of weak signal strength.

To determine the radial on which you are located:

1. Note the TO/FROM reading.
2. If the reading is "FROM", center the CDI by rotation of the OBS knob opposite the direction of CDI deflection. When the needle centers, read the radial under the course selector index.
3. If the reading is "TO", rotate the OBS knob in the direction of CDI deflection until "FROM" appears and proceed as in the previous step.

To determine the inbound course to the station from your present position:

1. Read the inbound magnetic course directly from the reciprocal window, following determination of the radial (if your indicator has no reciprocal window, compute the inbound course arithmetically).
2. Rotate the reciprocal to the opposite course index to change the "FROM" to a "TO" reading, and the needle will center, provided your aircraft has not moved to another radial. If so, recenter the needle with small adjustments, unless you are close to the station and crossing radials rapidly.
3. To proceed to the station, turn to the heading indicated under the course index.

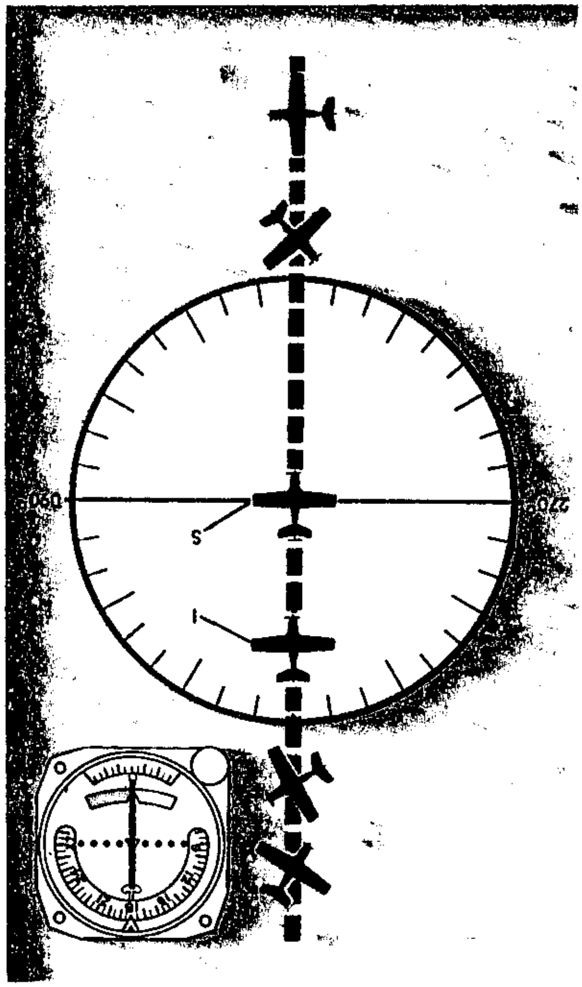


FIGURE 146. CDI interpretation.

Tracking—VOR

Tracking, in contrast to homing, involves drift correction sufficient to maintain a direct course to or from a transmitting station. The course selected for tracking inbound is the course shown under the course index with the TO/FROM indicator showing "TO". If you are off course to the left, the CDI is deflected right; if you are off course to the right, the CDI is deflected to the left. Turning toward the needle returns the aircraft to the course centerline and centers the needle.

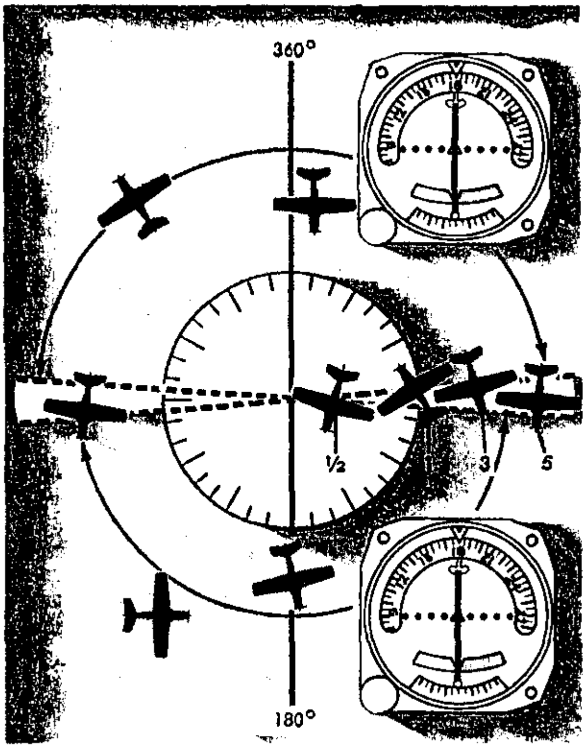


Figure 147. TO/FROM interpretation.

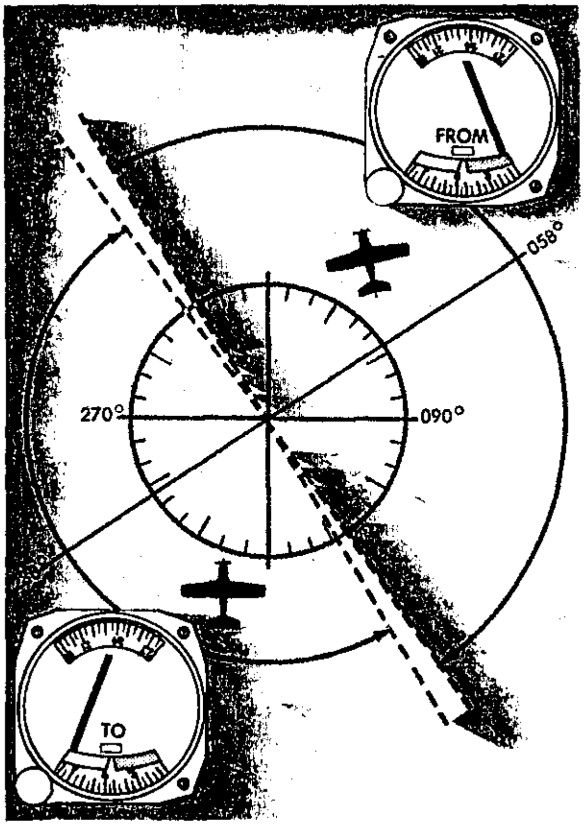


Figure 148. VOR orientation.

To track inbound with the wind unknown, proceed in the following steps (Fig. 149). Outbound tracking procedures are the same.

1. With the CDI centered, maintain the heading corresponding to the selected course.
2. As you hold the heading, observe the CDI for deflection to left or right. Direction of CDI deflection from centerline shows the direction of the cross-wind component. The illustration shows a left deflection, therefore left crosswind.

(Note the indications with the *reciprocal* of the inbound course set on the OBS. The indicator correctly shows "FROM", and the aircraft to the left of the centerline with *reference to the selected* course. Sometimes called "reverse sensing" this CDI deflection indicates a turn *away* from the needle for direct return to the course centerline, and illustrates the importance of correlating heading and course selection. VOR tracking can be accomplished with "reverse sensing," but errors in orientation can easily result.)

3. Turn 20° toward the needle and hold the heading correction until the needle centers.
4. Reduce the drift correction to 10° left of the course setting, and note whether this drift-correction angle keeps the CDI centered. Subsequent left or right needle deflection indicates an excessive or insufficient drift-correction angle, requiring further bracketing. With the proper drift-correction angle established, the CDI will remain centered until the aircraft is close to the station. Approach to the station is indicated by flickering of the TO/FROM indicator and CDI as the aircraft flies into the "zone of confusion" (no-signal area). Station passage is shown by complete reversal of the TO/FROM indicator. The extent of the zone of confusion, an inverted cone, increases with altitude. Thus, flight through the zone of confusion varies from a few seconds at low levels to as much as 2 minutes at high altitude.

5–6. Following station passage and TO/FROM reversal, correction to course centerline is still toward the needle. Note that the extent of CDI deflection is, by itself, no indication of the amount of aircraft displacement from the course centerline. A large CDI deflection immediately following station passage calls for no heading correction until the CDI stabilizes; at 20 miles out, a two-dot deflection may require a large correction angle for return to centerline.

The rate of movement of the CDI during course bracketing is thus an approximate index of distance from the station. For accurate radial interception and course following, the data given in Figure 150 may be helpful.

Assuming a receiver with normal course sensitivity and full-scale deflection at 5 dots:

> Aircraft displacement from course is approximately *200 ft. per dot per nautical mile.* For example, at 30 nautical miles from the station, one dot deflection indicates approximately one nmi displacement of the aircraft from the course centerline.

Time/Distance Checks by VOR.—Time and distance from a VOR station can be determined by several methods involving practical application of formulas or elementary geometry. These time/distance computations are approximations since wind drift is not considered in the solutions.

Wing-Tip Bearing Change.—The formula solution is applied to the elapsed time for a predetermined change in azimuth, or relative bearing, from the aircraft to a station located at 90° from the aircraft heading (Fig. 151).

Determine time/distance to station by the following steps. After tuning and identifying the VOR station:

1. Determine the radial on which you are located.
2. Turn inbound and recenter the needle if necessary.
3. Turn 80° right, or left, of the inbound course, rotating the OBS to the nearest 10° increment *opposite* the direction of turn.
4. Maintain heading. When the CDI centers, note the time.
5. Maintaining the same heading, rotate the OBS 10° in the same direction as in step 3, above.
6. Note the elapsed time when the CDI again centers.
7. Time/distance from the station is determined from the following formulas:

$$\text{(a) Time to station} = \frac{60 \times \text{minutes flown between bearing change}}{\text{degrees of bearing change}}$$

$$\text{(b) Distance to station} = \frac{\text{TAS} \times \text{minutes flown}}{\text{degrees of bearing change}}$$

By analysis of the time formula, above, you can derive the following rules of thumb:

Degrees of bearing change:	*Time to station*
10	6 × time (in minutes) of bearing change
5	12 × time (in minutes) of bearing change
20	3 × time (in minutes) of bearing change

Even more simply, for a 10° bearing change, note the elapsed time in seconds. One-tenth of this time is the time in minutes to the station. For example, if a 10° wing-tip bearing change takes 80 seconds, you are 8 minutes from the

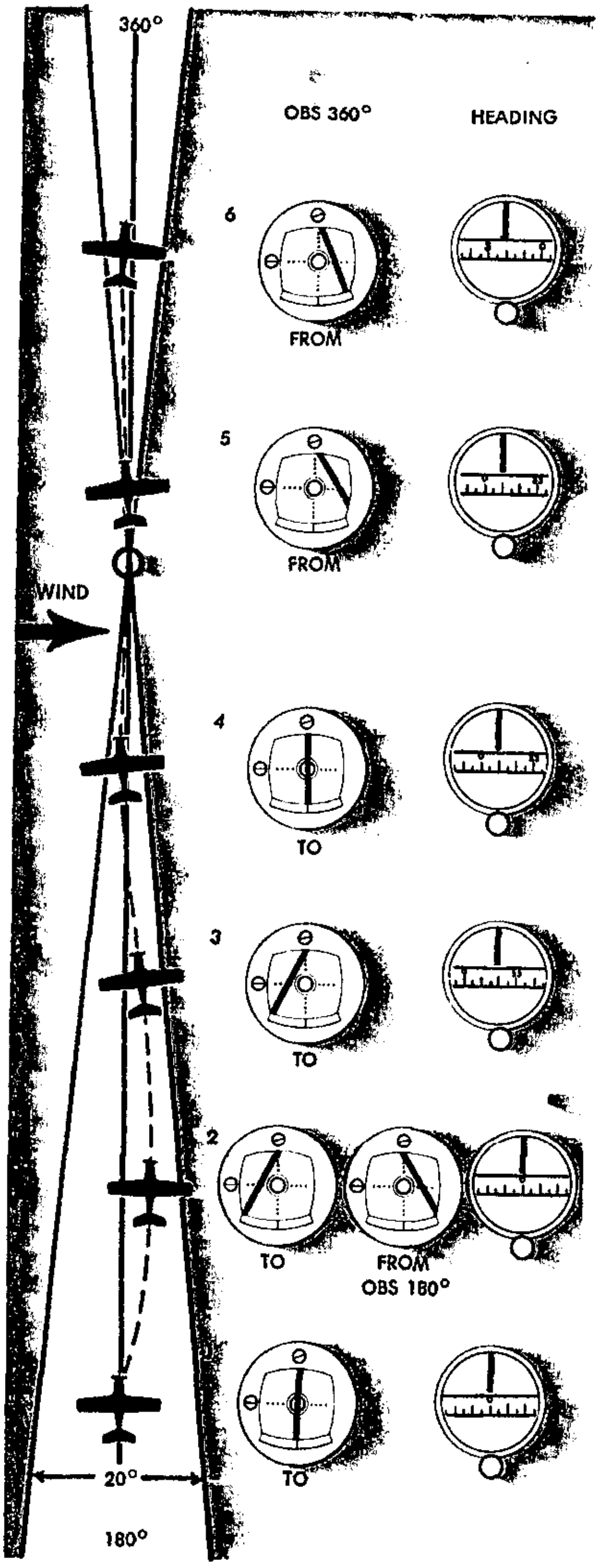


Figure 149. VOR tracking.

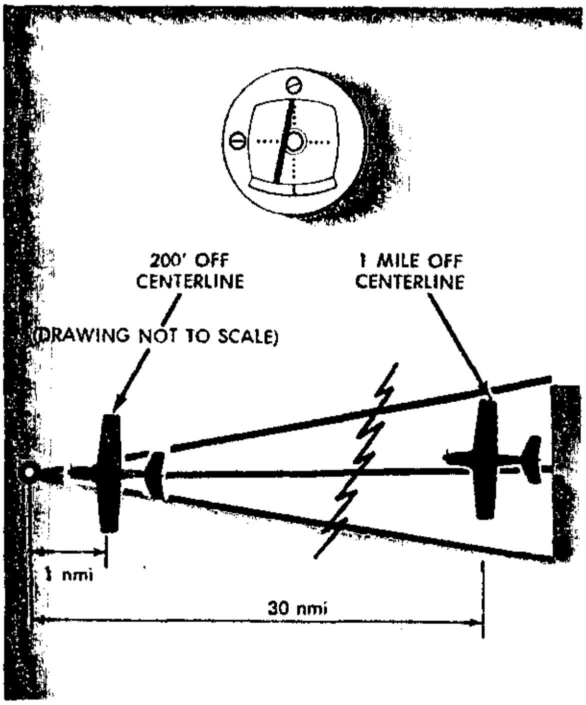


Figure 150. CDI deflection and aircraft displacement from course.

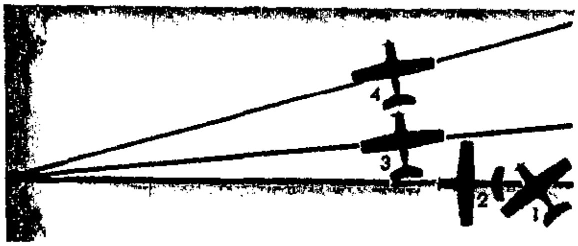


Figure 151. Time-distance check (VOR); wing-tip bearing change.

station. The amount of bearing change flown should vary, depending upon the distance of the aircraft from the station and groundspeed crossing radials.

Isosceles Triangle Method (Fig. 152).—Time/distance to station can also be found by application of the isosceles triangle principle (i.e., if two angles of a triangle are equal, two of the sides are also equal), as follows:

1. With the aircraft established on a radial, inbound, rotate the OSB 10° to the left.
2. Turn 10° to the right and note the time.
3. Maintain constant heading until the CDI centers, and note the elapsed time.
4. Time to station is the same as the time taken to complete the 10° change of bearing.

Track Interception—VOR

If your desired course is not the one that you are flying, you must orient yourself with respect to the VOR station and the course to be flown and work a track interception problem. The following steps may be used to intercept a predetermined track, either inbound or outbound: (Steps 1–3 may be omitted if you turn directly to intercept course without initially turning to parallel the desired course.)

1. Turn to a heading to parallel the desired course, in the same direction as the course to be flown.
2. Determine the difference between the radial to be intercepted and the radial on which you are located.
3. Double the difference to determine the interception angle which will be not less than 20° or greater than 90°.
4. Rotate the OBS to the desired radial or inbound course.
5. Turn to the interception heading.
6. Hold this magnetic heading constant until the CDI centers, indicating that the aircraft is on course. (With practice in judging the varying rates of closure with the course centerline, you learn to lead the turn to prevent overshooting the course.)
7. Turn to the magnetic heading corresponding to the selected course, and follow tracking procedures inbound or outbound.

Track interceptions are illustrated in Figures 153 and 154 with instrument indications shown at various stages.

Application of Basic VOR Procedures (Fig. 155).—Assume that you are tracking inbound on the 247 radial of VOR "A", using a single VOR receiver. You expect to hold at intersection "H" and transition from VOR "A" to the Outer Compass Locator for a localizer approach on the instrument landing system shown.

Plotting Position (VOR).—Since magnetic bearings are read directly from the VOR indicator, you can easily establish a fix on the 247 radial of VOR "A" by identifying the intersecting radial of VOR "B" and plotting your position on the Enroute Chart. At point "F", your receiver will read "FROM" with the OBS set on 210 and the CDI centered. With your position established and time noted, the distance from "F" to the holding fix "H" can be measured on the Enroute Chart and your ETA at "H" confirmed or revised.

Holding (VOR).—If your VOR equipment is limited to one receiver, it is especially important that you establish your inbound heading for accurate course following while you orient yourself to the 177 radial of VOR "B." To prevent

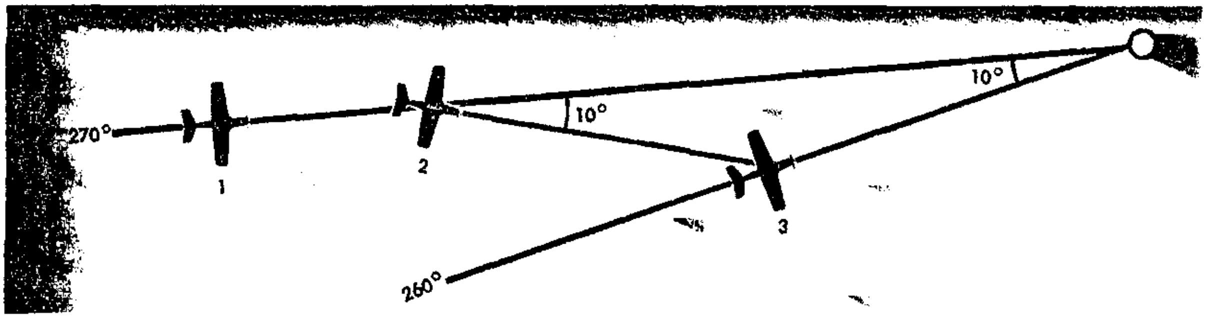


FIGURE 152. Time-distance check (VOR); isosceles triangle method.

overshooting the fix for holding entry, your position checks and tuning will have to be done accurately and quickly. You can easily misinterpret your position with respect to the 177 radial if you fail to set the OBS correctly. When establishing a fix or intersection by means of VOR stations on either side of your course, the

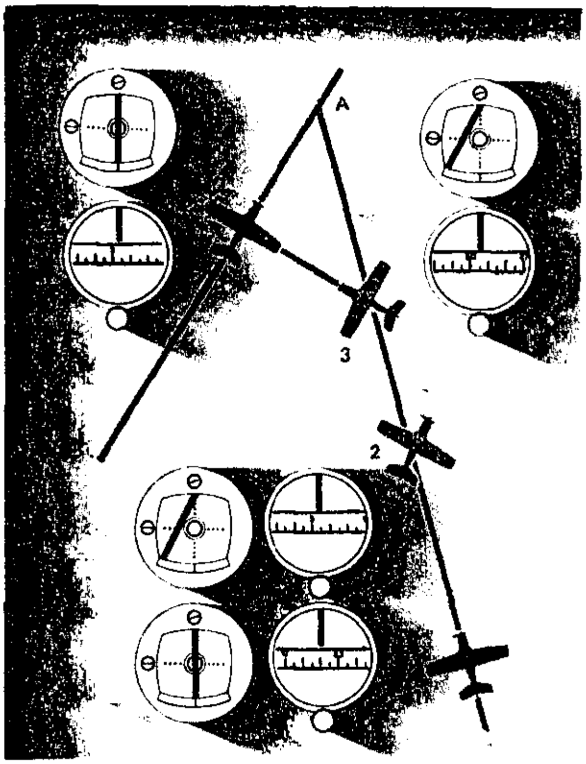


FIGURE 153. Track interception (VOR).
Intercept the 205 radial of VOR A, inbound—
1. Present position, inbound on 160 radial.
2. Turn right to parallel inbound course. (205° plus 180° equals 025°) Difference between 160 and 205 equals 45°. (double 45 for interception angle of 90°) Turn to 295° (205° plus 90°).
3. Maintain heading of 295° until 205 radial is intercepted (OBS 025, needle centered).
4. Track inbound on 205 radial.

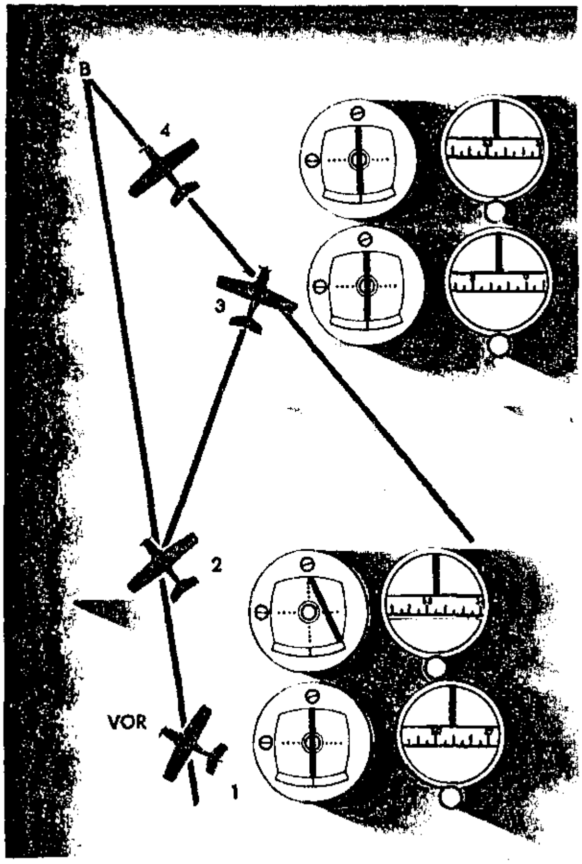


FIGURE 154. Track interception (VOR).
Intercept the 146 radial of VOR B, inbound—
1. Present position, crossing 171 radial.
2. Turn right to parallel inbound course. (146° plus 180° equals 326°)
Difference between 146 and 171 equals 25°.
(double 25 for interception angle of 50°)
Turn to 016° (326° plus 50°).
3. 146 radial is intercepted when CDI centers with OBS at 326; turn to inbound heading of 326.
4. Track inbound on 146 radial.

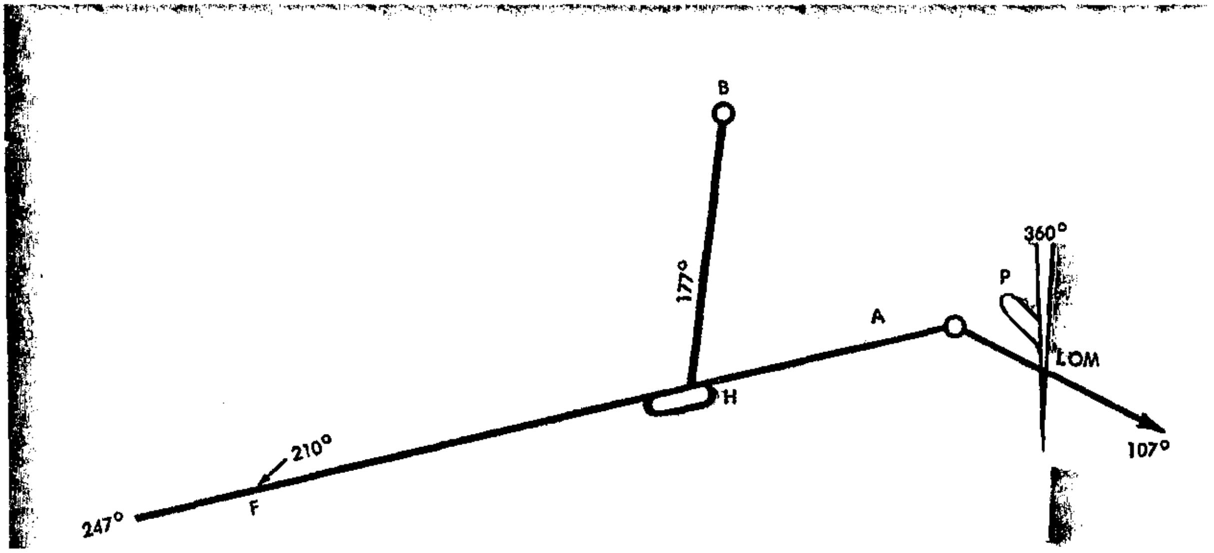


FIGURE 155. Application of VOR procedures.

TO/FROM indicator will read "FROM" and the CDI will *always* be deflected *toward* the station as you approach the fix, if the OBS is set with the *radial* (not the reciprocal) under the index (Fig. 156).

Roll into a standard-rate turn to the right as the CDI centers. As you roll out on the outbound heading, check the CDI to determine the position of the 177 radial. Then tune in VOR "A", setting the OBS on 067. If you drift toward the holding radial on the outbound leg, the CDI will move from left deflection toward the center.

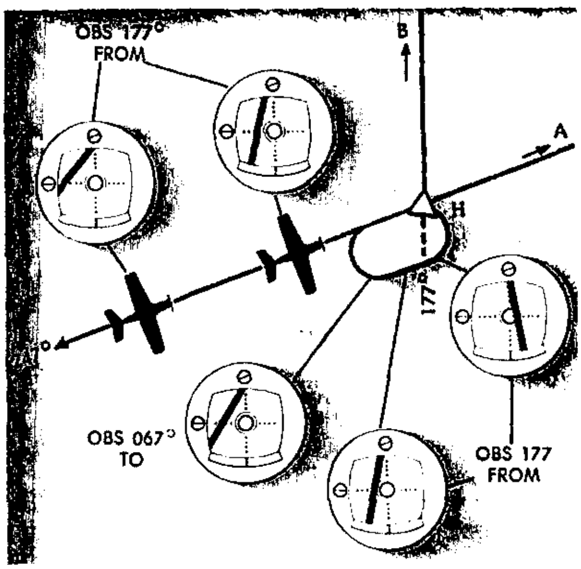


FIGURE 156. Holding; VOR receiver indications.

Transition and Localizer Approach

Where radar vectors are available on approach control frequencies, you will normally be vectored to the final approach course without executing a procedure turn. Assume in this instance that you are doing your own navigating. Over VOR "A", note the time of reversal from a "TO" to a "FROM" indication, and turn to transition from the outer fix to the outer compass locator (LOM) on the 107 radial. Transition bearings and distances are shown on Approach and Landing Charts, enabling you to estimate time from outer fixes to final approach fixes. Position over the LOM can be established with either an ADF receiver or marker beacon receiver. When the ADF needle or marker beacon receiver indicates passage over the final approach fix, turn left to intercept and track outbound on the localizer front course. See Figure 157.

Because of the narrow localizer course width, overcontrolling of heading corrections is a common error during localizer course tracking. Unless the CDI shows a full deflection, heading corrections in 5° increments (or less) should keep you close to the centerline. The sooner you establish the correct drift-correction angle, the easier it will be to track without chasing the localizer needle.

Time from the LOM to procedure turn entry depends upon the type of procedure turn to be executed, type of aircraft, wind velocity, and distance restrictions shown on the Approach and Landing Chart. CDI deflections during a stand-

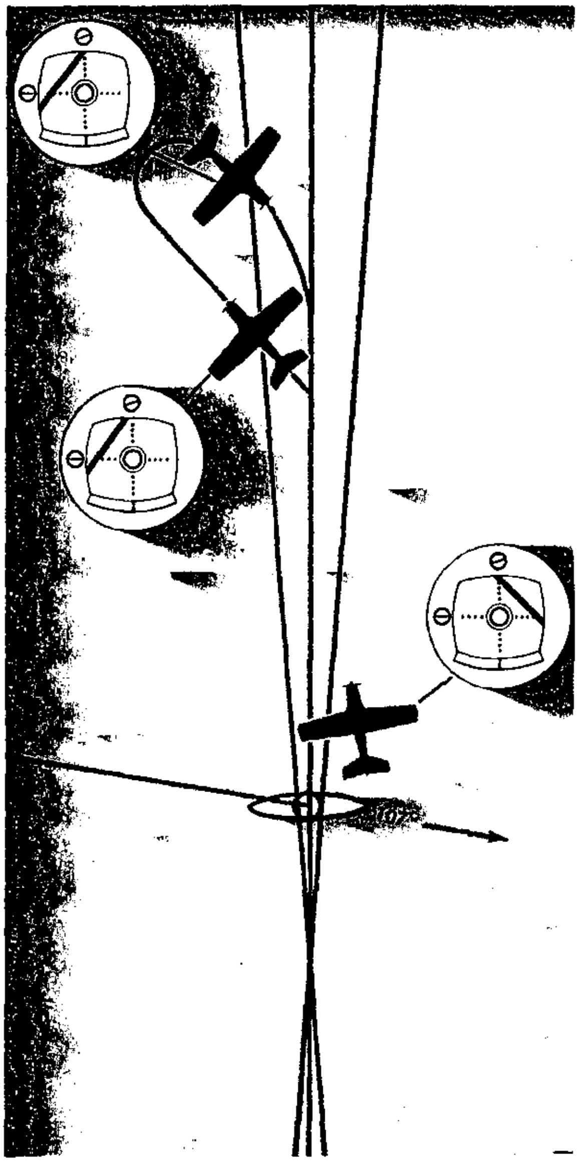


FIGURE 157. Transition to localizer course.

ard procedure turn on the front course are illustrated in Figure 157. When turning inbound into the localizer course, cross-check of the CDI should be frequent to prevent overshooting the course centerline. If your interception angle is 45° as shown, start the turn to the inbound course as soon as the CDI moves from the full deflection position.

Once you have reached the localizer centerline, maintain the inbound heading until the CDI moves off center. Drift corrections should be small and reduced proportionately as the course narrows. By the time you reach the outer marker, your drift correction should be established accurately enough on a well executed approach to permit completion of the approach with heading corrections no greater than 2°.

The heaviest demand on pilot technique occurs during descent from the outer marker to the middle marker, when you maintain the localizer course, adjust pitch attitude to maintain the proper rate of descent, and adjust power to maintain proper airspeed. Simultaneously, the altimeter must be checked and preparation made for visual transition to land or for a missed approach. The need for accurate instrument interpretation and aircraft control can be appreciated, in the complete ILS, by noting the relationship between CDI/glide path needle indications and aircraft displacement from the localizer and glide path centerlines. See Figures 158 and 159.

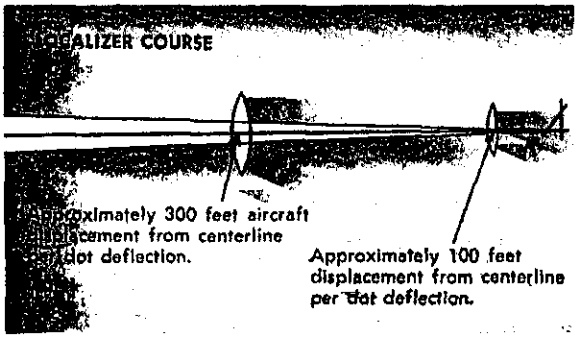


FIGURE 158. Localizer receiver indications and aircraft displacement.

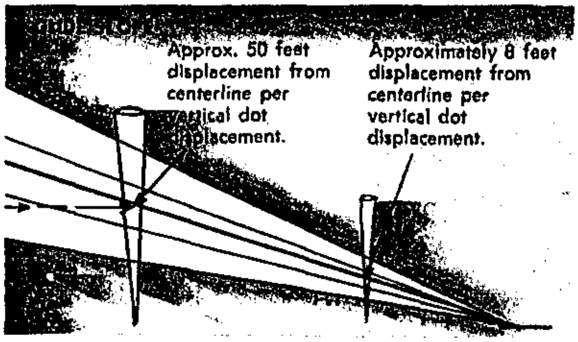


FIGURE 159. Glide slope receiver indications and aircraft displacement.

Automatic Direction Finder (ADF)

Knowledge of ADF procedures offers several advantages to the instrument pilot, although many seldom use ADF equipment because of the relatively simpler operation and interpretation of VHF equipment. ADF provides: (a) a backup navigation system in the event of VHF equipment failure; (b) a means of monitoring position enroute and providing data for plotting fixes; (c) a navigation system for use in areas and at altitudes where VOR "line-of-sight" signals are unreliable; (d) radio communications (receiver only) on the ground where VHF reception is impossible. Weather broadcasts and clearances can be received, for example, at points outside VHF signal range; and (e) auxiliary and standby navigation information on instrument approaches.

Selection of Station (Fig. 160).—The receiver illustrated can be tuned to any station transmitting between 190–1,750 kHz. Included in this range are "H" facilities shown on Enroute Low-Altitude Charts and standard broadcasting stations listed in the *Airman's Information Manual.* Listings in the AIM include the most powerful commercial broadcasting stations in areas where airports are located, together with call letters, frequencies, power, location, and hours of operation. Whenever possible, "clear channel" stations should be used to minimize signal interference from stations transmitting on adjacent frequencies. Accurate tuning can be difficult if local stations with closely grouped frequencies are selected. When using a commercial broadcasting station for ADF work, bear in mind that station identification is usually given only at 15-minute intervals.

Tuning.—Tuning details vary among the many types of ADF receivers. The equipment brochure provided with any particular receiver will clarify differences between your equipment and the ADF illustrated in Figure 160.

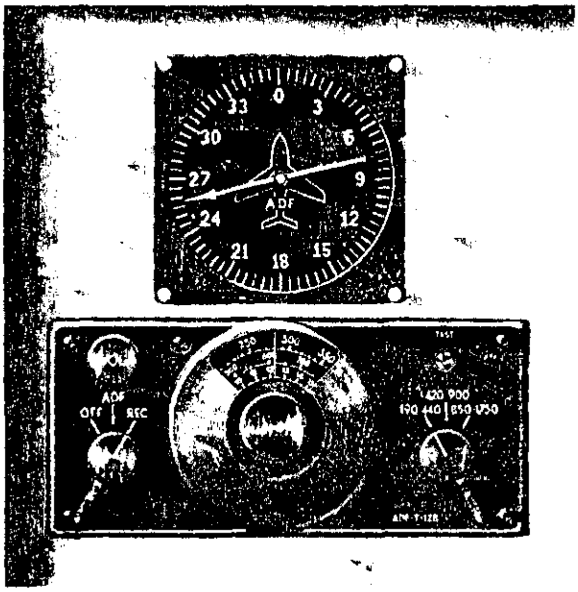


FIGURE 160. ADF receiver.

The station is tuned with the following steps:

1. Adjust the frequency band selector to the desired band.

2. Rotate the volume knob clockwise to approximately half the range.

3. Select "REC" position on the function switch. This selects the sense antenna for tuning the station for use of the receiver as a nondirectional radio receiver. Tuning with the function switch on "ADF" (automatic) position results in unnecessary hunting of the ADF needle as various station signals are received.

4. Rotate the frequency selector to the desired frequency. If a tuning meter is installed with the receiver, it is essential to tune for maximum tuning meter deflection. Without a tuning meter, adjust the frequency selector for maximum signal clarity and identify the station.

5. Select the "ADF" position on the function switch. The ADF needle will rotate until it points to the station. Note the bearing indicated on the ADF dial and push the "test" button. This will rotate the needle clockwise until the test button is released. If the station is tuned properly and the signal is reliable, the needle will return to the bearing previously noted.

6. Adjust the volume to the desired level. Volume adjustment has no effect on operation of the ADF needle.

ADF Orientation.—Unlike the VOR receiver, which indicates magnetic bearing TO or FROM the station without reference to aircraft heading, the ADF needle points TO the station, regardless of aircraft heading or position. The *relative* bearing indicated is thus the angular relationship between the aircraft heading and the station, measured clockwise from the nose of the aircraft.

A bearing is simply the direction of a straight line between the aircraft and station, or vice-versa. The bearing line measured clockwise from the nose of the airplane is a *relative bearing;* measured clockwise from true north, it is a *true bearing;* measured clockwise from magnetic north, it is a *magnetic bearing* (Fig. 161 and Fig. 162). As the illustrations show, a true, magnetic, or compass heading is measured clockwise from the appropriate north, and a relative bearing is measured clockwise from the nose of the airplane. Thus, the true, magnetic, or compass bearing to the station is the sum of true, magnetic, or compass heading, respectively, and the relative bearing.

You will probably orient yourself more readily if you think in terms of nose/tail and left/right needle indications, visualing the ADF dial in terms of the longitudinal axis of the aircraft. When the needle points to 0°, the nose of the aircraft points directly to the station; with the pointer on 210°, the station is 30° to the left of the tail; with the pointer on 090°, the station if off the right wing tip (Fig. 163). Thus, to

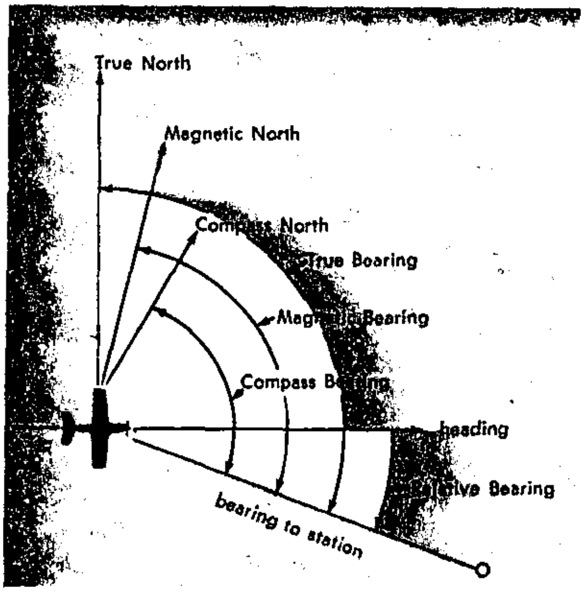


FIGURE 161. ADF bearings.
True bearing to station = TH + rel. bearing.
Magnetic bearing to station = MH + rel. bearing.
Station to aircraft bearings are true, magnetic or con pass bearings ± 180°.

turn directly toward station A, turn left 150 since the needle points to the left of the nose/ta line 30° from the tail position. Station B is 90

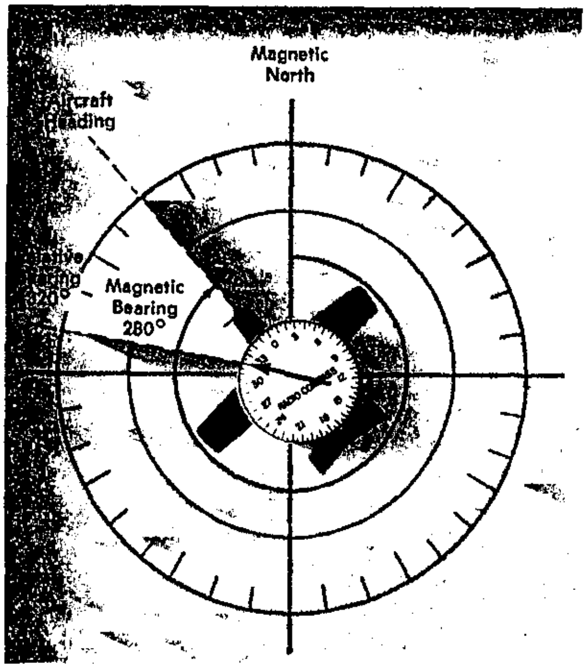


FIGURE 162. ADF bearing computations.
Magnetic bearing to station = magnetic heading (320°) + rel. bearing (320°) = 640° or 280° (whenever the total is greater than 360°, subtract 360 from the bearing).

to the right; therefore turn right 90° to head directly toward the station.

Note that (a) the relative bearing shown on the ADF dial does not, by itself, indicate aircraft position, and (b) the relative bearing must be

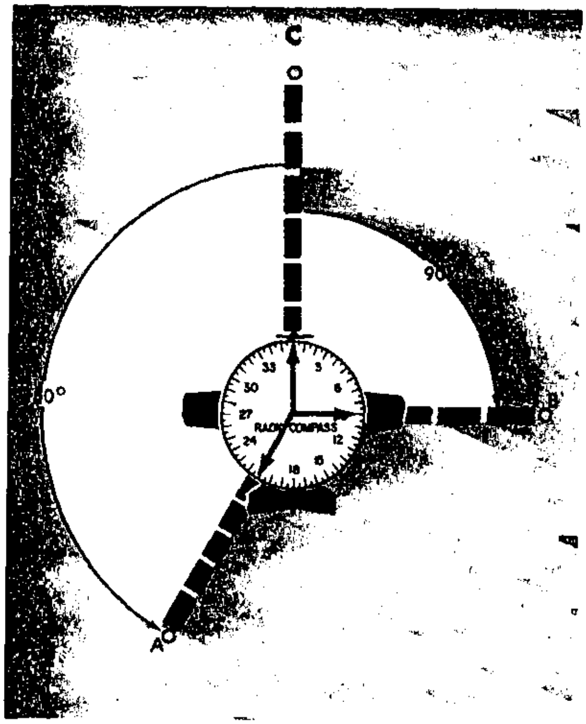


FIGURE 163. ADF relative bearings.

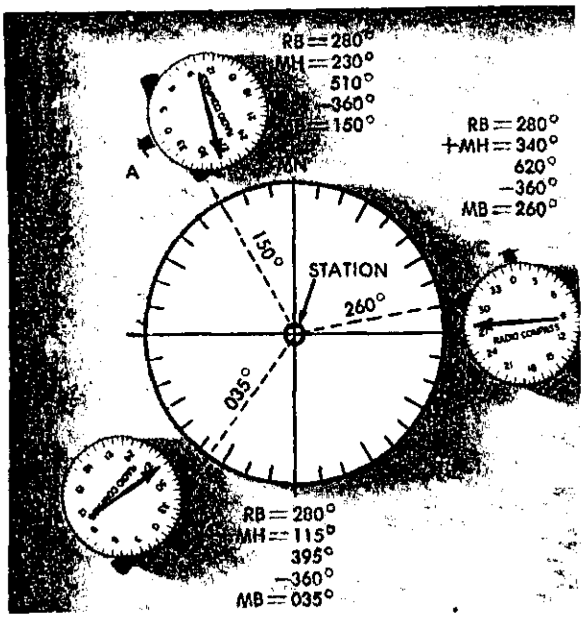


FIGURE 164. Determining magnetic bearing to station with ADF.

related to aircraft heading to determine direction to or from the station (Fig. 164).

Figure 164 shows only one of several methods of determining bearings—or lines of position—between aircraft and station. Visualizing the 80° left-of-nose indication at all three positions shown, the magnetic bearing to station can be determined by subtracting the left deflection from the magnetic heading:

	A	B	C
Magnetic heading	230°	115°	340°
Minus left deflection	80°	80°	80°
Magnetic bearing	150°	035°	260°

Homing.—ADF homing is flying the aircraft on any heading required to keep the azimuth needle on 0° until the selected station has been reached (Fig. 165). To head the aircraft toward the station, turn to the heading that will zero the ADF needle. The heading indicator, rather than the ADF, should be used to make the turn because of inherent dip error in the radio compass during turns. At the completion of the initial turn toward the station, check the ADF needle and, if necessary, zero it with small corrections.

For example, Figure 165 shows an initial magnetic heading of 050° and a relative bearing of 302°. A left turn of approximately 60° should zero the needle, heading 350°. After the needle is zeroed, it will remain so unless the heading is changed or crosswind affects the aircraft track. If there is no wind, the aircraft will follow a straight track to the station, assuming constant heading. If a crosswind drifts the aircraft, the homing track will be a curve as you keep the ADF needle zeroed.

Approach to the station is indicated by increasingly frequent heading corrections to zero the needle, especially when a strong crosswind exists, and by side-to-side needle deflections very close to the station. Passage directly over the station is shown by a 180° reversal of the ADF needle to the tail position; passage on either side and close to the station is shown by a rapid swing of the needle as it continues to point to the station. Homing is easy, though seldom used during instrument flying. Competent pilots control track by more precise procedures.

Tracking.—A straight geographic flight path can be followed to or from a low (or medium) frequency facility by establishing a heading that will maintain the desired track regardless of wind effect. ADF tracking procedures involve interpretation of the heading indicator and azimuth needle to intercept and hold a desired magnetic bearing.

Inbound Tracking.—To track inbound, turn to the heading that will zero the ADF needle. As you hold this heading, deflection of the ADF needle to left or right shows a crosswind (needle

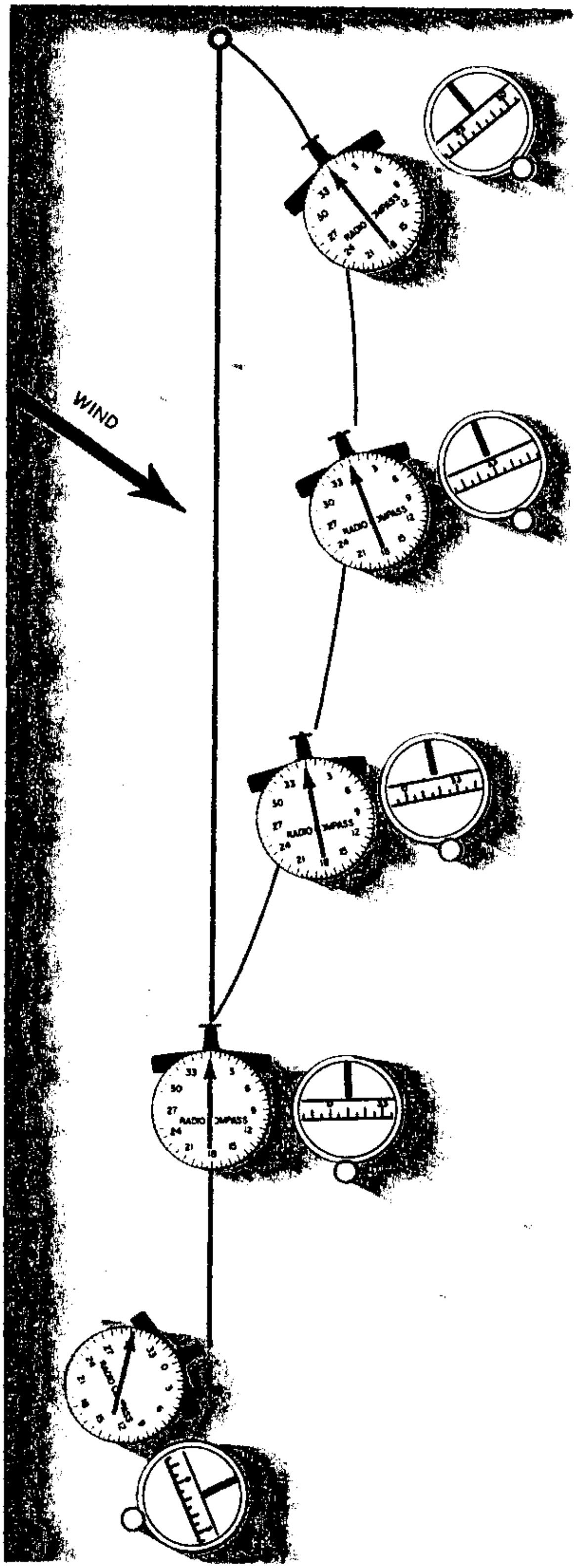


FIGURE 165. ADF homing.

left/wind from left; needle right/wind from right). When a definite change in azimuth (2°–5°) shows that the aircraft has drifted off course, turn in the direction of needle deflection (into the wind) to re-intercept the initial inbound bearing. The angle of interception must always be greater than the number of degrees of drift. The magnitude of any intercepting turn depends upon the observed *rate* of bearing change, true airspeed, and how quickly you want to return to course.

A rapid rate of bearing change, *while heading is constant,* indicates either a strong crosswind or proximity to the station, or both. For example, if you are 60 miles from the station with a 3° left deflection, your aircraft is 3 miles to the right of the desired course. In a slow aircraft, use a large interception angle for quick return to the course. In a very fast aircraft, the same interception angle could result in overshooting the desired course. Likewise, the same 3° needle deflection closer to the station means less deviation from the desired course, and smaller angles of interception result in rapid return to course. Again, when the aircraft is 60 miles from the station, a rapid rate of bearing change indicates a strong crosswind; at half that distance, the same rate of bearing change means twice the crosswind effect, or conversely, at half the distance, the same wind effect results in double the rate of bearing change.

At a given angle of interception and with a given wind, rate of closure with the desired track varies directly with true airspeed. At 150 knots TAS as compared with 100 knots TAS, the effectiveness of a given interception angle is proportionately greater for the same wind at the same distance from the station. Having determined the angle of interception for return to the

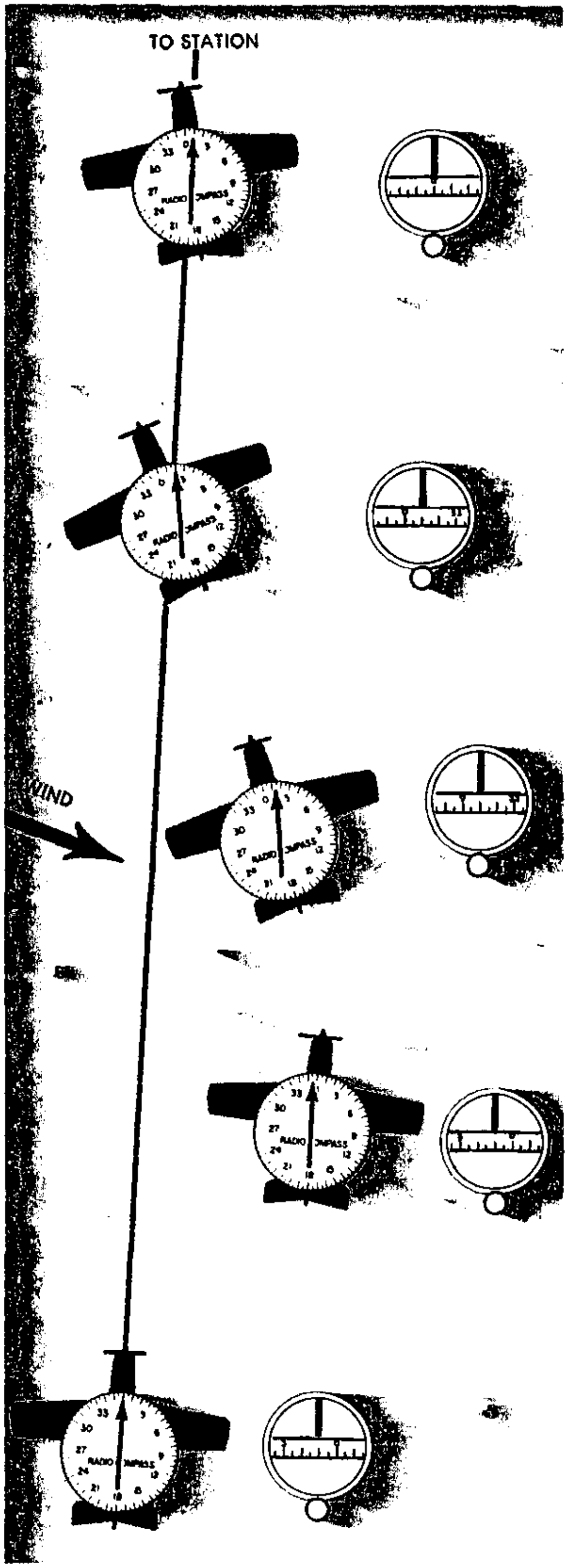


FIGURE 166. ADF tracking—inbound.

1. Turn the aircraft to zero the azimuth needle. Maintain this heading until off-course drift is indicated by left or right needle deflection.
2. When a 5° change in needle deflection is observed, turn 20° in the direction of needle deflection.
3. When the needle is deflected 20° (deflection = interception angle), track has been intercepted. Lead the interception as noted in discussion of tracking. Turn 10° toward the inbound course. You are now inbound with a 10° left drift correction angle.
4. If you observe off-course deflection in the original direction, turn again to the original interception heading.
5. When the desired course has been reintercepted, turn 5° toward the inbound course, proceeding inbound with a 15° drift correction.
6. If the initial 10° drift correction is excessive, as shown by needle deflection away from the wind, turn to parallel the desired course and let the wind drift you back on course. When the needle is again zeroed, turn into the wind with a reduced drift correction angle.

desired track, turn toward the track by that amount. As you make the turn with the heading indicator, the azimuth needle rotates opposite the direction of turn, and as the interception angle is established, the needle points to the side of the zero position opposite the direction of turn. As you approach the course on a constant interception heading, the ADF needle continues to rotate as the relative bearing changes. When the needle deflection from zero equals the angle of interception, the aircraft is on the desired track. If you begin the turn to the magnetic bearing of the desired track when these angles are equal, you will overshoot the track. In such a case, you can either drift back to track and then establish an estimated drift correction angle, or bracket the track with successively smaller interception angles.

A quicker technique is to lead the turn to the inbound heading before the track is intercepted. The amount of lead depends upon the distance from station, rate of closure observed as you approach the desired track, number of degrees to be turned, and rate of turn. Since these factors are variable, you will develop effective lead estimates as you become familiar with particular aircraft and practice ADF tracking.

After you are back on track, holding an estimated correction for wind drift, you remain on the desired track as long as the azimuth needle is deflected from zero, opposite the direction of drift correction, an amount equal to the drift correction angle. If the needle moves further from the nose position, the drift correction is excessive. Reduce the correction angle allowing the aircraft to drift back on course. This is indicated for any drift correction (or interception) angle when ADF needle deflection and drift correction angle are equal. If the estimated drift correction is insufficient, the azimuth needle will move toward the nose, requiring a further correction to regain track. With careful attention to headings, effective drift correction angles can be established with very little bracketing.

Station Approach and Station Passage.—The same suggestions apply to ADF tracking as have been mentioned in connection with ADF homing and VOR/Localizer procedures. The closer you are to the station, the more aggravated are your errors in drift correction and basic instrument flying technique, unless you recognize station approach and prevent yourself from overcontrolling the observed track deviations.

When you are close to the station, slight deviations from the desired track result in large deflections of the azimuth needle. It is important, therefore, that the correct drift correction angle be established as soon as possible after interception of an inbound course. With the course "pinned down" and heading corrections kept at a minimum, you will be more alert to signs of station approach than you would be if you were busy "chasing" headings and ADF deflections. Make small heading corrections (not over 5°) as soon as the needle shows a deviation from course, until it begins to rotate steadily toward a wing-tip position or shows erratic left/right oscillations. At this point, hold your last corrected heading constant, and time station passage when the needle shows either wing-tip position or settles at or near the 180° position. The time interval from the first indications of station proximity to positive station passage varies with altitude—a few seconds at low levels to 3 minutes at high altitude. Inbound tracking steps are illustrated in Figure 166.

Outbound Tracking.—Procedures for tracking outbound are identical to those used for inbound tracking. However, the direction of the azimuth needle deflections are different from those noted during inbound track interceptions, as shown in Figure 167. When tracking *inbound*, a change of heading toward the desired track results in movement of the azimuth needle *toward* zero. When tracking *outbound*, a change of heading toward the desired track results in needle movement further *away* from the 180° position.

Time/Distance Checks (ADF).—Time and distance to a station may be calculated with radio-compass procedures similar to the VOR procedures already discussed. A variety of methods commonly used are variations of the basic procedures that follow.

Wing-Tip Bearing Change.—To determine the time/distance to the station, use the following steps:

1. After tuning in the station, determine the relative bearing from the position of the ADF needle.

2. Turn the number of degrees necessary to place the needle on 090° or 270°.

3. Note the time, and fly a constant magnetic heading for a specific number of degrees of bearing change. The amount of change flown varies with the observed rate of bearing change. For example, a 10° change at a considerable distance from the station may take unnecessarily long; the time/distance check can be accomplished in this case by timing a 5° change.

4. Apply the observed time interval to the formula, or calculate the time to station by rule of thumb if a 10° bearing change is used (*see* Time/Distance Checks by VOR). For example, you are flying a magnetic heading of 180°, TAS 130 knots, ADF relative bearing 090°. Maintaining the magnetic heading for 4 minutes, you

observe a relative bearing of 100°. Approximate time to station is as follows:

By formula:

$$\text{Minutes to station} = \frac{60 \times \text{minutes between bearing change}}{\text{Degrees of bearing change}}$$
$$= \frac{60 \times 4}{10}$$
$$= 24 \text{ minutes}$$

By rule of thumb (for 10° change):

$$\text{Minutes to station} = 6 \times \text{time in minutes between bearing change.}$$
$$= 6 \times 4$$
$$= 24 \text{ minutes}$$

$$\text{or Minutes to station} = \frac{\text{time in seconds}}{10}$$
$$= \frac{240}{10}$$
$$= 24 \text{ minutes}$$

To determine the distance from the station, use the formula (see Time/Distance Checks by VOR) or the following computer method:

1. Place the speed index opposite True Air Speed.
2. Read distance from station on miles scale opposite time from station on minutes scale.

Other time/distance checks are applications of the isosceles triangle principle:

Bow-to-beam bearing gives time to station by the following steps:

1. Turn the number of degrees necessary to place the ADF needle on 045° (or 315°).
2. Maintain heading until the needle is on 090° (or 270°).
3. Time/distance flown equals time/distance to station.

The Double-the-angle-on-bow method involves the following steps:

1. Tune in a station between 10° and 45° off the nose position, and note the relative bearing.
2. Fly a constant magnetic heading until the angle on the nose doubles.
3. The time/distance required to double the angle on the nose equals the time/distance to the station.

The accuracy of time/distance checks involves a number of variables, including existing wind, accuracy of timing, and heading control. Time checks, especially those involving a rapid rate of bearing change, demand very precise techniques in basic instrument flying while you maintain heading and check elapsed time.

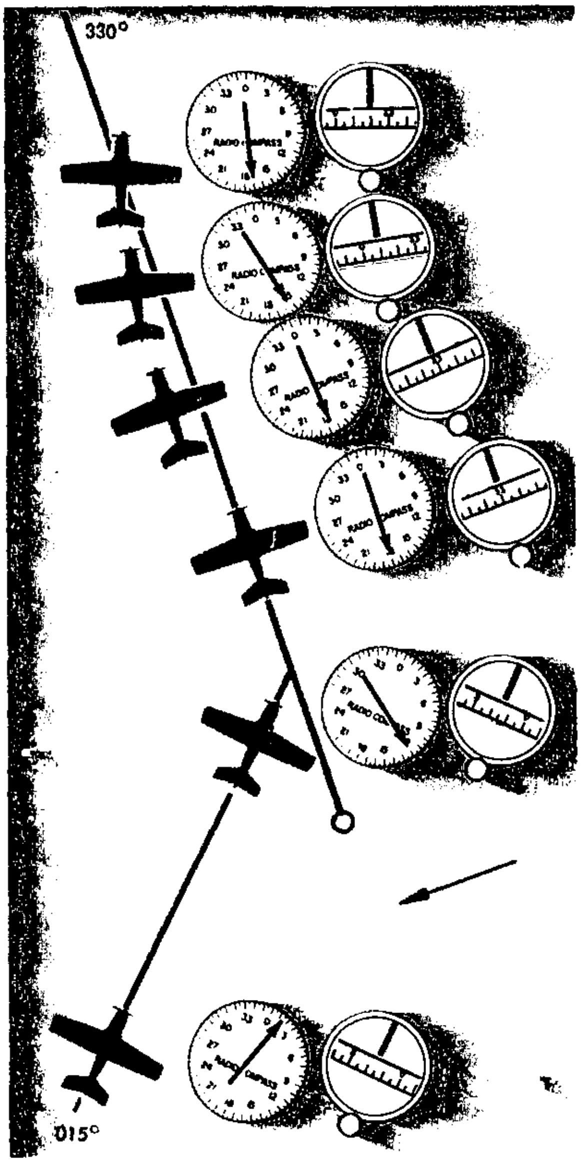


FIGURE 167. ADF tracking—outbound.

Interception of Predetermined Magnetic Bearings

Basic ADF orientation, tracking, and time/distance procedures may be applied to the problem of intercepting a specified inbound or outbound magnetic bearing. To intercept an *inbound* magnetic bearing, the following steps may be used (Fig. 168):

1. Determine your position in relation to the station by turning to the magnetic heading of the bearing to be intercepted.
2. Note whether the station is to the right or left of the nose position. Determine the number

of degrees of needle deflection from the zero position, and double this amount for the interception angle.

3. Turn the aircraft toward the desired magnetic bearing the number of degrees determined for the interception angle.

4. Maintain the interception heading until the needle is deflected the same number of degrees from the zero position as the angle of interception (minus lead appropriate to the rate of bearing change).

5. Turn inbound and continue with tracking procedures.

Note that this method combines inbound course interception with a time estimate to the station, since the interception leg and the inbound leg are equal sides of an isosceles triangle. The time from the completion of the turn to the interception heading (075°) until interception of the desired inbound bearing is equal to the time-to-station (double-the-angle-on-bow).

Interception of an *outbound* magnetic bearing can be accomplished by the same procedures as for the inbound intercept, except that you substitute the 180° position for the zero position on the azimuth needle.

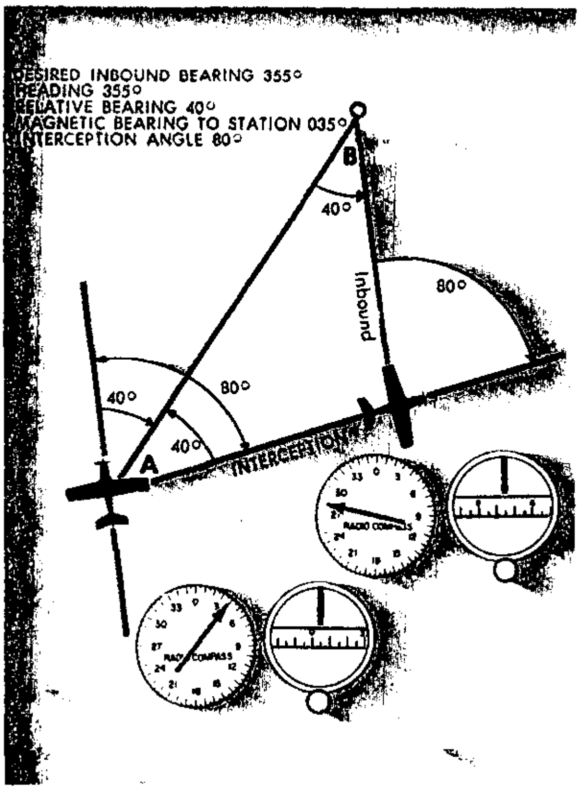


FIGURE 168. Interception of predetermined magnetic bearing.

Application of Basic ADF Procedures

Assume that you have departed airport "X" to fly direct to a destination airport via an inbound magnetic bearing of 020° to the "H" facility located on the airport. See Figure 169.

1. You intercept the desired inbound magnetic bearing at a 45° angle and establish the inbound track with a 10° left drift correction angle, heading 010°.

2. *Plotting Position.*—Tuning in commercial broadcasting station "A", note the time as the ADF needle indicates 100°. With a 10° left drift correction angle, your position is 90° to the station. The fix can be directly located on the inbound track line drawn on your aeronautical chart. Move your plotter along the track line until the 090 reference line intersects the station.

3. You establish another fix by tuning in a nondirectional beacon at "B", noting 9 minutes elapsed time as the ADF shows a relative bearing of 328°. Adding the relative bearing and magnetic heading, the magnetic bearing to the station is 338°. To plot the fix on your chart, the magnetic bearing must be converted to a true bearing *from* the station. Assuming 14°E variation, the true bearing from the station is 172°, which fixes your position 21 nautical miles from the one established 9 minutes earlier. From this data you compute groundspeed as 140 knots and estimate arrival time at your destination after measurement of the remaining distance.

4. Holding may be accomplished on any inbound bearing to the radio facility, though an enroute holding pattern is usually aligned with the magnetic bearing being tracked. In the example shown, the radio beacon is both your enroute navigation aid and the fix used for your ADF approach. The holding pattern in this instance would normally be aligned with the final approach course to the airport to facilitate letdown and low approach to the field. The ADF approach combines the basic procedures you have already studied—orientation, tracking inbound and outbound, and interception of predetermined bearings.

Figure 170 illustrates a standard holding pattern (dotted line shows holding entry), as well as the procedure turn for approach to the airport. Holding may or may not be necessary, depending upon traffic and weather conditions. If you hold as illustrated, your entry would be as specified in the *Airman's Information Manual* under "Air Traffic Control." The appropriate communications procedures are explained in a later chapter of this text. Assuming a 10° left drift correction angle as you track inbound on the 020° magnetic bearing, proceed as follows:

a. Turn to parallel the outbound course as the ADF needle indicates station passage, applying drift correction appropriate to the known wind. Note the time.

b. Fly the outbound heading for approximately one minute, observing the ADF needle for drift toward, or away from, the inbound holding course. If you apply a 10° left drift correction angle, drift away from course will be shown by movement of the needle farther from the 180° position or by failure of the needle to move toward the tail position as you proceed outbound.

c. Turn toward the inbound course, rolling out on a 125° magnetic heading for a 45° interception of the inbound course. Note the relative bearing immediately. If it is greater than 045°, you have overshot the inbound course and may have difficulty establishing the track before passing the station.

d. Lead the turn to the inbound course (170°) and roll out with drift correction. If you are on course, your drift correction angle will be equal and opposite to the ADF needle displacement from zero.

e. Track inbound, using small corrections. The quicker you establish the desired track, the fewer your holding problems since both basic flight techniques and procedural details will keep you busy.

f. Turn outbound on station passage, noting the time. With no wind, timing the outbound leg would begin as you roll out on a 350° heading with the ADF needle reading 090°. With the wind as shown, your track would be closer to the station than shown in the diagram.

g. Roll out on an outbound heading with a drift correction angle equal to double the amount of inbound drift correction. As you begin outbound timing for one minute, your ADF will indicate approximately 110°, assuming a 20° left drift correction angle. As you maintain the outbound heading, the needle moves toward the 180° position. With experience, you learn to recognize drift by rate of movement of the ADF needle—rapidly toward the tail position if you drift inward or a strong tailwind exists; slowly toward the tail if you drift outward or a strong headwind exists.

h. With correct inbound and outbound drift correction angles, your ADF should read zero, plus or minus the appropriate drift correction angle, as you complete the turn to track inbound.

i. The approach is normally begun directly

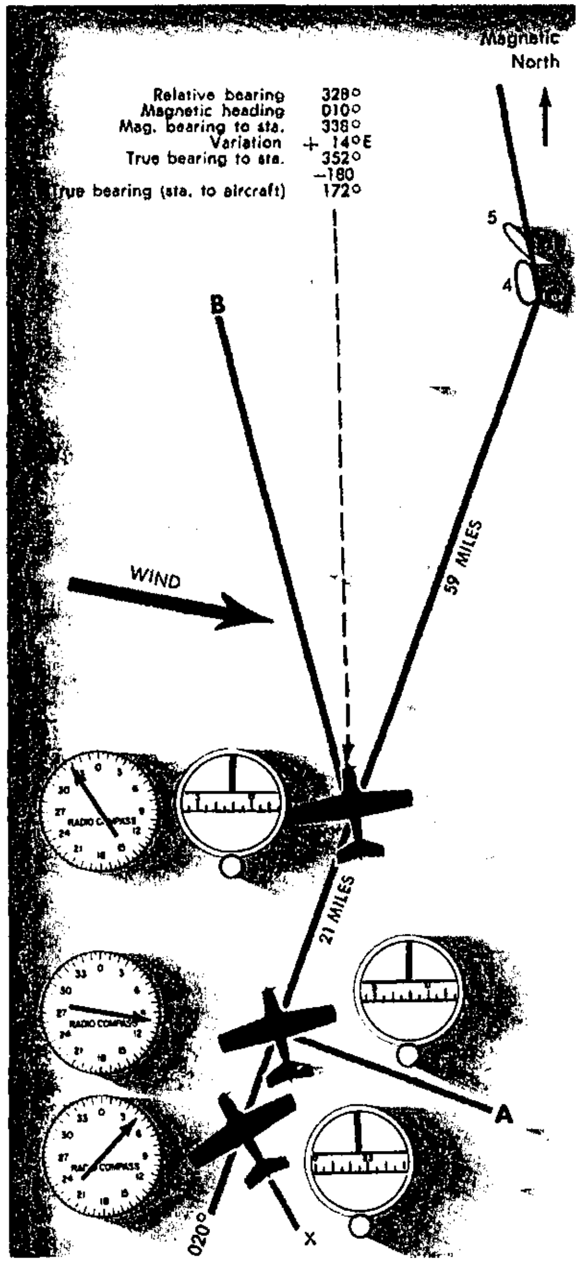


FIGURE 169. Application of ADF procedures.

from the holding pattern, tracking inbound as you descend and execute a low approach to the field.

5. *Procedure Turn and Low Approach.*—Unless the approach is made from a holding pattern aligned with the final approach course, a course reversal is necessary to proceed from the outbound course to final approach to the field. For execution of the procedure turn and approach

shown in Figure 170, the Standard Instrument Approach Chart for this airport and approach would be used. At this point, you are concerned with the application of basic navigational techniques to the problem. The associated procedures are shown on the illustration.

To track outbound and reverse course to the final approach, proceed as follows:

a. On station passage, note the time, and turn outbound to intercept the 350° magnetic bearing.

b. Start the procedure turn to 305° as soon as practicable, normally within 2 minutes of station passage. Hold the 305° heading for 40 seconds to 1 minute, depending upon the existing wind.

c. Turn inbound to intercept and track the 170° magnetic bearing to the field.

The suggestions discussed earlier with respect to station approach are of particular importance during the low approach. An ADF instrument approach executed without additional navigation airborne equipment or radar assistance demands a high level of skill in the use of both basic flight and navigation instruments, as well as facility with communications procedures. It is essential that you be thoroughly familiar with courses, altitudes, and procedural details well *before* you execute the approach in order that you be able to visualize the details in their necessary sequence.

Common Errors in the Use of Navigation Instruments

Other than the specific errors outlined below, the errors underlying most confusion while learning navigation techniques relate to skill in the use of basic flight instruments. You cannot read a VOR or ADF indication while you fumble with pitch, bank, power, and trim control any more than you can read a highway sign or follow a cloverleaf intersection while you stare at your automobile brake pedal.

Mastery of basic flight maneuvers is prerequisite to their application on the aerial highways.

VOR Errors

1. Careless tuning and identification of station.
2. Failure to check receiver for accuracy/sensitivity.
3. Turning in the wrong direction during an orientation. This error is common until you visualize position rather than heading.
4. Failure to check the ambiguity indicator,

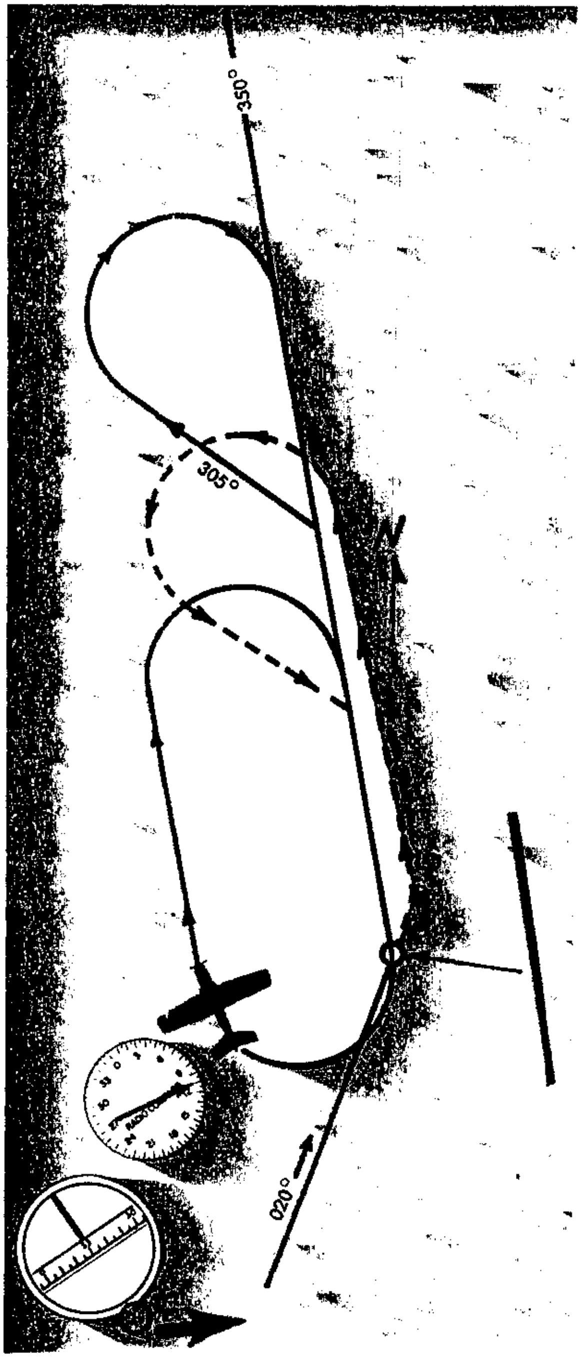


FIGURE 170. Transition to ADF approach.

1. Check radio contact with Air Traffic Control before arrival over station. Maintain assigned altitude, or if cleared for approach, descend to initial approach altitude.
2. Turn outbound, reduce speed if necessary, note time, report station passage to ATC, and perform prelanding check.
3. Descend to procedure turn altitude given on AL chart.
4. Procedure turn in direction shown on AL chart.
5. *Inbound,* descend to final approach altitude.
6. *Inbound,* report VFR and complete approach to landing. If field is below minimums report and execute missed approach shown on AL chart.

particularly during course reversals, with resulting "reverse sensing" and corrections in the wrong direction.

5. Failure to parallel the desired radial on a track interception problem. Without this step, orientation to the desired radial can be confusing. Since you think in left/right terms, aligning your aircraft position to the radial/course is essential.

6. Incorrect rotation of the course-selector (OBS) on a time/distance problem.

7. Overshooting and undershooting radials on interception problems. Factors affecting lead should be thoroughly understood, especially on close-in course interception.

8. Overcontrolling corrections during tracking, especially close to the station.

9. Misinterpretation of station passage. On VOR receivers equipped without an ON/OFF flag, a voice communication on the VOR frequency will cause the same to/from fluctuations on the ambiguity meter as shown on station passage. Read the *whole* receiver—TO/FROM, CDI, and OBS—before you make a decision.

10. Chasing the CDI, resulting in homing instead of tracking. Careless heading control and failure to bracket wind corrections makes this error common.

ILS Errors

1. Failure to understand the fundamentals of ILS ground equipment, particularly the differences in course dimensions. Since the VOR receiver is used on the localizer course, the assumption is sometimes made that interception and tracking techniques are identical when tracking localizer courses and VOR radials. Remember that the CDI sensing is sharper and faster on the localizer course.

2. Disorientation during transition to the ILS due to poor planning and reliance on one receiver instead of on all available airborne equipment. Use all the assistance you have available; the single receiver you may be relying on may fail you at a busy time.

3. Disorientation on the localizer course, basically due to the first error noted above.

4. Incorrect localizer interception angles. A large interception angle usually results in overshooting and often disorientation. Turn to the localizer course heading immediately upon the first indication of needle movement, using a small interception angle whenever possible. An ADF receiver is an excellent aid to orientation during an ILS approach.

5. Chasing the CDI and glide path needles, especially when the approach is not sufficiently studied before the flight. Flying the proper headings, altitudes, rate of descent, times and power configuration settings is impossible if your mind is on studying the approach plate.

ADF Errors

1. Improper tuning and station identification. Homing or tracking to the wrong station has been done by many students.

2. Dependence on homing rather than proper tracking, commonly results from reliance on the ADF indications instead of correlating them with heading indications.

3. Poor orientation, due to failure to follow proper steps in orientation and tracking.

4. Careless interception angles, very likely if you rush the initial orientation procedure.

5. Overshooting and undershooting predetermined magnetic bearings, often due to forgetting the course interception angles used.

6. Failure to maintain selected headings. Any heading change is accompanied by an ADF needle change. The instruments must be read in combination *before* any interpretation is made.

7. Failure to understand the limitations of the radio compass and the factors that affect its use.

8. Overcontrolling track corrections close to the station (chasing the ADF needle), due to failure to understand or recognize station approach.

VIII. RADIO COMMUNICATIONS FACILITIES AND EQUIPMENT

What communications equipment do you need for IFR operations? In uncontrolled airspace, none is required by regulation. What you need is up to your own judgment.

For operations under IFR in controlled airspace, two regulations relate directly to the minimum communications equipment:

a. (FAR 91.33) Your aircraft must be equipped with a two-way radio communications system appropriate to the ground facilities being used.

b. (FAR 91.125) The pilot in command shall have a continuous listening watch maintained on the appropriate frequency and shall report by radio as required.

Information on making radio reports and on the functions and services of Air Traffic Control agencies are considered in Chapter X.

Ground Facilities

For civil IFR operations in controlled airspace, the ground facilities available for radio communication include the following components of Air Traffic Control:

1. Ground control.
2. Tower control.
3. Departure control.
4. Enroute control.
5. Arrival control.

Communications with these controlling units are normally conducted on VHF frequencies between 108 MHz and 136 MHz. A complete list of VHF frequencies can be found in the *Airman's Information Manual.*

The frequencies with which you should be familiar are listed below. The ILS and VOR frequencies listed may be used as receiving frequencies for communications as well as for navigation.

AIR NAVIGATION AIDS

108.1–111.9 MHz: ILS localizer with simultaneous radiotelephone channel operating on odd-tenth decimal frequencies (108.1, 108.3 etc.)
108.2–111.8 MHz: VOR's operating on even-tenth decimal frequencies (108.2, 108.4 etc.).
112.0–117.9 MHz: Airway track guidance (VORs)

COMMUNICATIONS

118.0–121.4 MHz: Air Traffic Control Communications
121.5 MHz: Emergency (World-Wide)
121.6–121.95 MHz: Airport Utility (Ground Control)
122.0 MHz: FSS's, Weather, Selected Locations, Private Aircraft and Air Carriers
122.1 MHz: Private Aircraft to Flight Service Stations
122.2, 122.3 MHz: FSS's, Private Aircraft, Selected Locations
122.4, 122.5, 122.7 MHz: Private Aircraft to Towers
122.6 MHz: FSS's, Private Aircraft
122.8, 123.0, 122.85, 122.95 MHz: Aeronautical Advisory Stations (UNICOM)
122.9 MHz: Aeronautical Multicom Stations
123.05 MHz: Aeronautical Advisory Stations (UNICOM) Heliports
123.1–123.55 MHz: Flight Test and Flying School
123.6 MHz: FSS's, Airport Advisory Service
123.6–128.8 MHz: Air Traffic Control Communications
128.85–132.0 MHz: Aeronautical Enroute Stations (Air Carrier)
132.05–135.95 MHz: Air Traffic Control Communications

Airborne Equipment

An aircraft equipped to communicate on all available VHF frequencies will have 360 transmitting frequencies (118.0–136.00 MHz with 50 kHz spacing) and 560 receiving frequencies (108.00–136.00 MHz with 50 kHz spacing), covering the entire VHF aircraft radio spectrum. For training, however, you need only a transmitter and receiver suitable for communications with the ground facilities in your training area. Any lightweight equipment which provides the minimum standard frequencies included in the table above, may be sufficient for training but may be inadequate for the instrument rated pilot.

Communications equipment of more recent design reflects the concern of manufacturers for the operational needs of the instrument pilot. Under the best conditions, a pilot flying on instruments must think, decide, and move quickly. Equipment design that contributes to indecision, uncertainty or fatigue creates unnecessary problems when the pilot is flying by reference to instruments.

"One and One-half" Systems

Figure 171 illustrates a dual-purpose radio typical of the "one and one-half" systems. These systems incorporate communications and navigation radios in a single compact unit. This is a welcome change from the older installations that required an extensive cockpit search to locate switches, selectors, and associated indicators and too much time to tune and operate. The "one and one-half" radio enables you to communicate with the necessary ground facilities on the transceiver (combined tranmitter/receiver) while simultaneously tuned on the separate "one-half" of the set to a VOR station. This radio has controls that are easily identifiable and crystal-tuned frequencies that can be selected with only a glance or two for tuning.

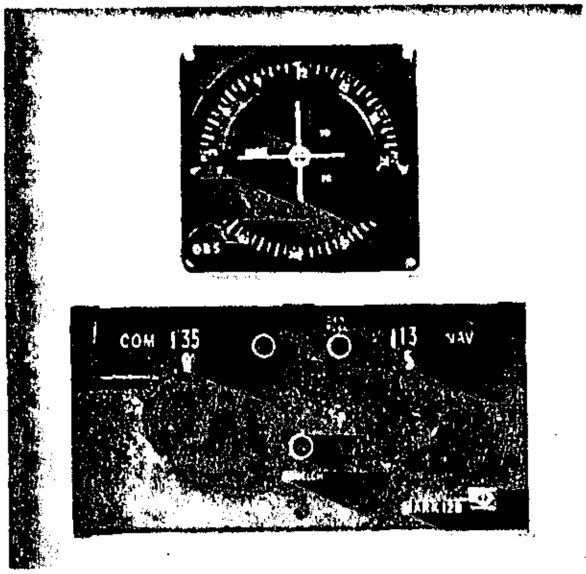


FIGURE 171. "One and one-half" system.

Operation of the communications section of these radios is simple. The volume switch on the left is the ON/OFF switch for both COMM and NAV sections. The squelch knob is rotated to cut down the background noise generated by the radio tubes. While the set is warming up, set the squelch knob fully clockwise; then turn the control counterclockwise to increase the squelch until the background noise is cut out. Further increase of the squelch setting will decrease receiver sensitivity. If you are tuning in a weak signal, decrease the squelch. Otherwise, once the control is established at a comfortable level, no further adjustment is necessary except to make an occasional check of receiver sensitivity. Tranmit/receive frequencies are selected by rotation of the inner and outer knobs on the COMM side of the set.

The "one and one-half" system described has the following communication/navigation frequency coverage:

Communications

Transmit/receive 360 channels (118.0–135.95 MHz)

Navigation

All VOR and localizer frequencies (108.0–117.9 MHz)

Expanded NAV/COMM Systems

The advantages of the "one and one-half" system can be expanded with installation of additional radios and centralized control units for rapid selection of receivers and transmitters. The "building block" concept, from which most

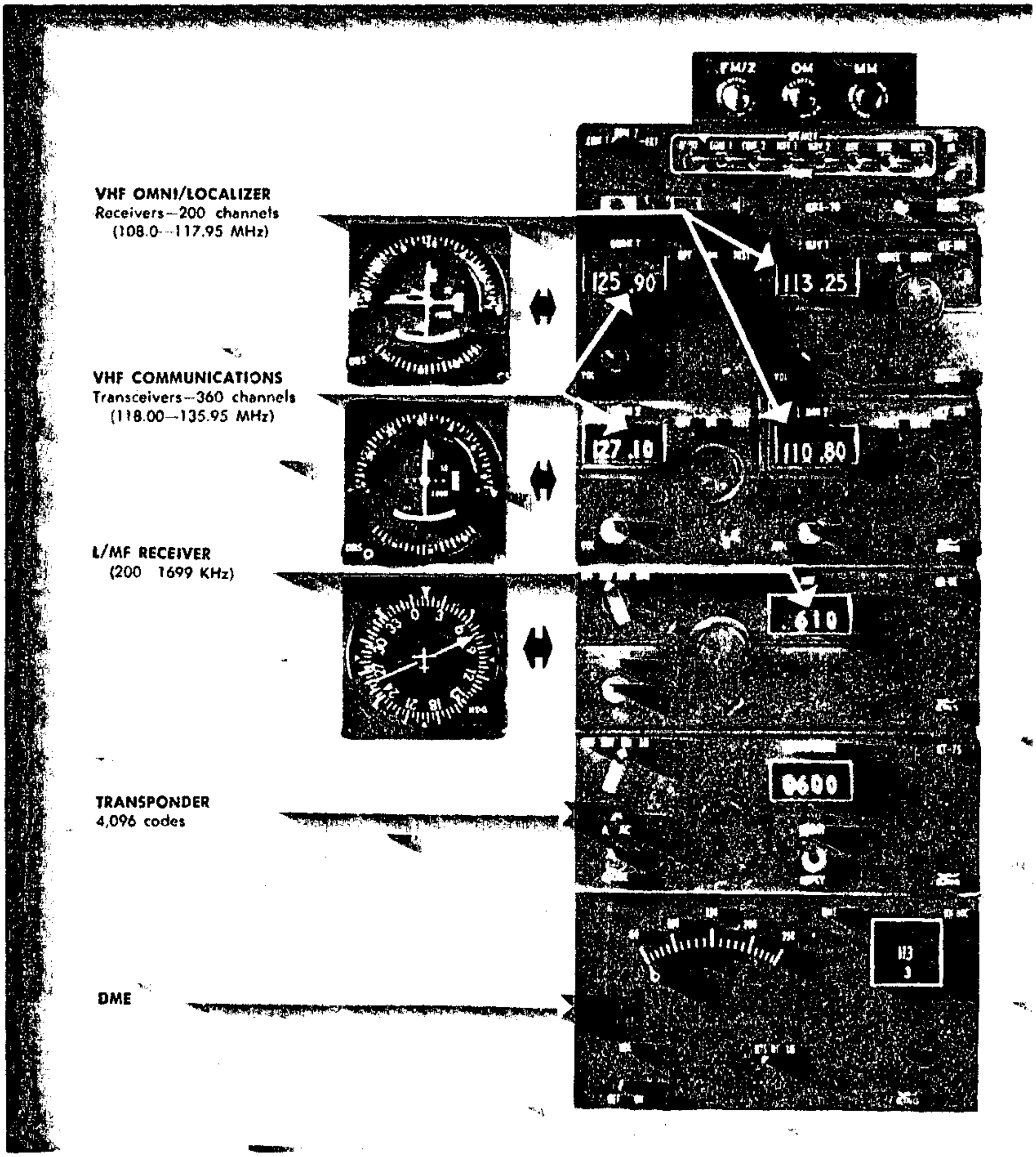


FIGURE 172. Full navigation-communications panel.

light aircraft radio design evolves, provides for progressive expansion of your equipment as your training and operational needs increase. For example, if you depart under IFR from an uncontrolled airport and proceed via Victor airway to another uncontrolled airport, your communication/navigation needs may be as little as one VOR frequency and one transmitting frequency for communication with FSS.

When you progress to all-weather IFR flying in and out of unfamiliar terminal areas, your workload can be excessive unless you have sufficient standby equipment for frequent changes of communications channels. Figure 172 shows how communications equipment can be grouped for quick reference and operation with minimum distraction from the problem of aircraft control.

Radiotelephone Procedure

From the time you contact ground control for taxi instructions the effectiveness of your coordination with Air Traffic Control will depend upon your competence in communications and your knowledge of traffic procedures under Instrument Flight Rules. Many students have no serious difficulty in learning basic aircraft control and radio navigation, but stumble through even the simplest radio communications. During the initial phase of training in Air Traffic Control procedures and radiotelephone techniques, some students experience difficulty.

Why should talking and listening to a controller pose any problems? The average person takes his speaking and listening habits for granted and has had no occasion to develop specialized skills associated with radio communications. Studies of listening comprehension show that most people listen with low efficiency, even when consciously attempting to remember what they hear. The poor listener is easily distracted. From habit he tolerates conditions unfavorable to concentration. His mind wanders when he hears anything unexpected or difficult to understand. He is inclined to be more concerned with what he is about to say than with what he should be listening to. When in a confusing situation he is more easily aroused emotionally, and may have trouble comprehending what he hears.

These deficiencies are intensified for the pilot in a busy air traffic environment. In addition to attending to cockpit duties demanding rapid division of attention, quick judgment, concentration, and careful planning, you the pilot must be continuously alert to communications from Air Traffic Control. You should be prepared to listen and to transmit in the brief and unmistakably clear terms vital to orderly control.

You attain proficiency in radiotelephone technique just as you do in developing any other skill. You should first recognize that radio communications under Instrument Flight Rules, though not difficult, require speaking and listening habits different from those you have been accustomed to. Skill in transmitting and listening will come rapidly once you have studied and practiced the basic terminology.

The FAA controller is intensively trained to speak clearly and concisely in an abbreviated terminology understandable to airmen, but somewhat unintelligible to others. He uses standard words and phrases to save time, reduce radio congestion, and lessen the chances of misunderstanding and confusion. However, the most competent controller won't "get through" to you under the best conditions unless you are ready to listen and understand.

Communication is a two-way effort, and the controller expects you to work toward the same level of competency that he strives to achieve. Tape recordings comparing transmissions by professional pilots and inexperienced or inadequately trained general aviation pilots illustrate the need for effective radiotelephone technique. In a typical instance, an airline pilot reported his position in 5 seconds; whereas a private pilot reporting the same fix took 4 minutes to transmit essentially the same information. The difference lay, not in equipment and flight experience, but in communication technique. The novice forgot to tune his radio properly before transmitting, interrupted other transmissions, repeated unnecessary data, forgot other essential information, requested instructions repeatedly, and created the general impression of cockpit disorganization. As encouragement to the novice who is embarrassed and concerned about broadcasting his inexperience, let him remember that every pilot had to make a beginning and was not expected at first to communicate like a veteran airline pilot. But the private pilot who learns and practices standardized words and phrases until they become part of his normal radio vocabulary will be able to communicate effectively even under adverse reception conditions.

Phonetic Alphabet

It is often necessary in transmitting to identify certain letters and/or groups of letters, or to spell out difficult words, since certain sounds have low intelligibility when mixed with a background of other noises. The standard phonetic alphabet (Fig. 173) identifies each letter of the alphabet with a word that is easily understood. These words are pronounced to make the message clear when individual letters are transmitted, and are used to spell out words that are hard to understand on the air.

Phonetic alphabet		Numerals
A—Alpha	N—November	0—Zero
B—Bravo	O—Oscar	1—Wun
C—Charlie	P—Papa	2—Too
D—Delta	Q—Quebec***	3—Tree
E—Echo	R—Romeo	4—Fo-wer
F—Foxtrot	S—Sierra	5—Fife
G—Golf	T—Tango	6—Six
H—Hotel	U—Uniform	7—Seven
I—India	V—Victor	8—Ait
J—Juliett	W—Whiskey	9—Ni-ner
K—Kilo*	X—X-ray	
L—Lima**	Y—Yankee	
M—Mike	Z—Zulu	

* Key-lo ** Lee-mah ***Keh-beck

FIGURE 173. Phonetic alphabet.

Use of Numbers

Numbers are usually of extreme importance in radio messages and are difficult to hear among other noises. The standard pronunciations in Figure 173 have been adopted because they have been found most intelligible.

a. Normally, numbers are transmitted by speaking each number separately. For example, 3284 is spoken as "tree too ait fo-wer."

b. There are certain exceptions to the above rule. Figures indicating hundreds and thousands in round numbers, up to and including 9,000 are spoken in hundreds or thousands as appropriate. 500 is spoken as "fife hundred"; 1,200 as "wun thousand too hundred." Beginning with 10,000, the individual digits in thousands of feet are spoken. For 13,000, say "wun tree thousand", for 14,500, say "wun-fo-wer thousand fife hundred."

c. Aircraft identification numbers are spoken as individual digits/letters. 1234Q is spoken as "wun too tree fo-wer Keh-beck."

d. Time is stated in four digits according to the 24-hour clock. The first two digits indicate the hour; the last two, minutes after the hour (Fig. 174), as in "wun niner too zero"; "zero niner fo-wer fife."

e. Field elevations are transmitted with each number spoken separately, as in Figure 174.

Procedural Words and Phrases

The words and phrases in Figure 175 should be studied and practiced until they are readily and easily used and clearly enunciated. To pilots and controllers, their meanings are very specific. Careless or incorrect use can cause both delay and confusion.

Voice Control

Students inexperienced in the use of the microphone are usually surprised at the quality of their own transmissions when they are taped and played back. Words quite clear when spoken directly to another person can be almost unintelligible over the radio. Effective radiotelephone technique sounds self-conscious and unnatural when you practice it, both because the terminology is new and because you are habitually more concerned with *what* you are saying than in *how* it sounds. Maximum readable radiotelephone transmissions depend on the following factors:

1. *Volume.*—Clarity increases with volume up to a level just short of shouting. Speaking loudly, without extreme effort or noticeably straining the voice, results in maximum intelligibility. To be understood, the spoken sound must be louder at the face of the microphone than the surrounding noises. Open the mouth so the tone will carry to the microphone. A higher-pitched tone is easier to hear than a lower one. A distinct and easily readable side tone in your earphones or speaker is a reliable index of correct volume.

2. *Tempo.*—Effective rate of speech varies with the speaker, the nature of the message, and conditions of transmission and reception. Note the following suggestions for improving your rate of transmission:

a. Talk slowly enough so that each word and phrase is spoken distinctly, particularly key words and phrases.

b. Talk slowly enough so the listener will have time, not only to hear, but to absorb the meaning.

3. *Pronunciation and Phrasing.*—As you notice the differences in the transmission of various pilots and controllers, you can readily identify those with exceptional skill. They sound natural and unhurried. The words are grouped for easy readability. They pronounce every word clearly and distinctly without apparent effort, without unnecessary words, and without "uh's" and "ah's." They create the impression of competence that any expert conveys after enough study and practice.

Practice

Many excellent audio training aids are available for practicing radiotelephone procedures. With tapes or records, a microphone, and writing materials, you can develop communications skills under excellent simulated conditions. Practice until you can transmit concisely, hear accurately, and listen critically. Hearing is largely a matter of having an adequate receiver and knowing how to tune it. Critical listening is a more compli-

Time	Field elevation
0000—Zero Zero Zero Zero	10 ft.—Field elevation Wun Zero.
0920—Zero Niner Too Zero	75 ft.—Field elevation Seven Fife.
1200—Wun Too Zero Zero	583 ft.—Field elevation Fife Ait Tree.
1645—Wun Six Fower Fife	600 ft.—Field elevation Six Zero Zero.
	1,250 ft.—Field elevation Wun Too Fife Zero.
	2,500 ft.—Field elevation Too Fife Zero Zero.

FIGURE 174. Expressing time and field elevation.

Word or phrase	Meanings
Acknowledge	Let me know that you have received and understand this message.
Affirmative	Yes.
Correction	An error has been made in this transmission. The correct version is....................
Go ahead	Proceed with your message.
How do you hear me?	Self explanatory.
I say again	Self explanatory.
Negative	That is not correct.
Out	This conversation is ended and no response is expected.
Over	My transmission is ended and I expect a response from you.
Read back	Repeat all of this message back to me exactly as received after I have given "over."
Roger	I have received all of your last transmission. (To acknowledge receipt; shall not be used for any other purpose.)
Say again	Self explanatory.
Speak slower	Self explanatory.
Stand by	If used by itself it means, I must pause for a few seconds. If the pause is longer than a few seconds or if "standby" is used to prevent another station from transmitting, it must be followed by the word "out."
That is correct	Self explanatory.
Verify	Check with the originator.
Words twice	As a request—Communication is difficult: Please say every word twice.

FIGURE 175. Radiotelephone words and phrases.

cated skill. You are ready to listen to a controller when you are thoroughly familiar with your communications equipment and are ready to copy his transmission, evaluate what he says, and if necessary read it back to him without neglecting any other cockpit duties that may demand your attention. Study of Air Traffic Control procedures under Instrument Flight Rules will enable you to "keep ahead" of communications—just as you keep ahead of your basic flying and navigation—by knowing what is ahead of you and attending to details in the proper sequence at the appropriate time.

Reminders on Use of Equipment

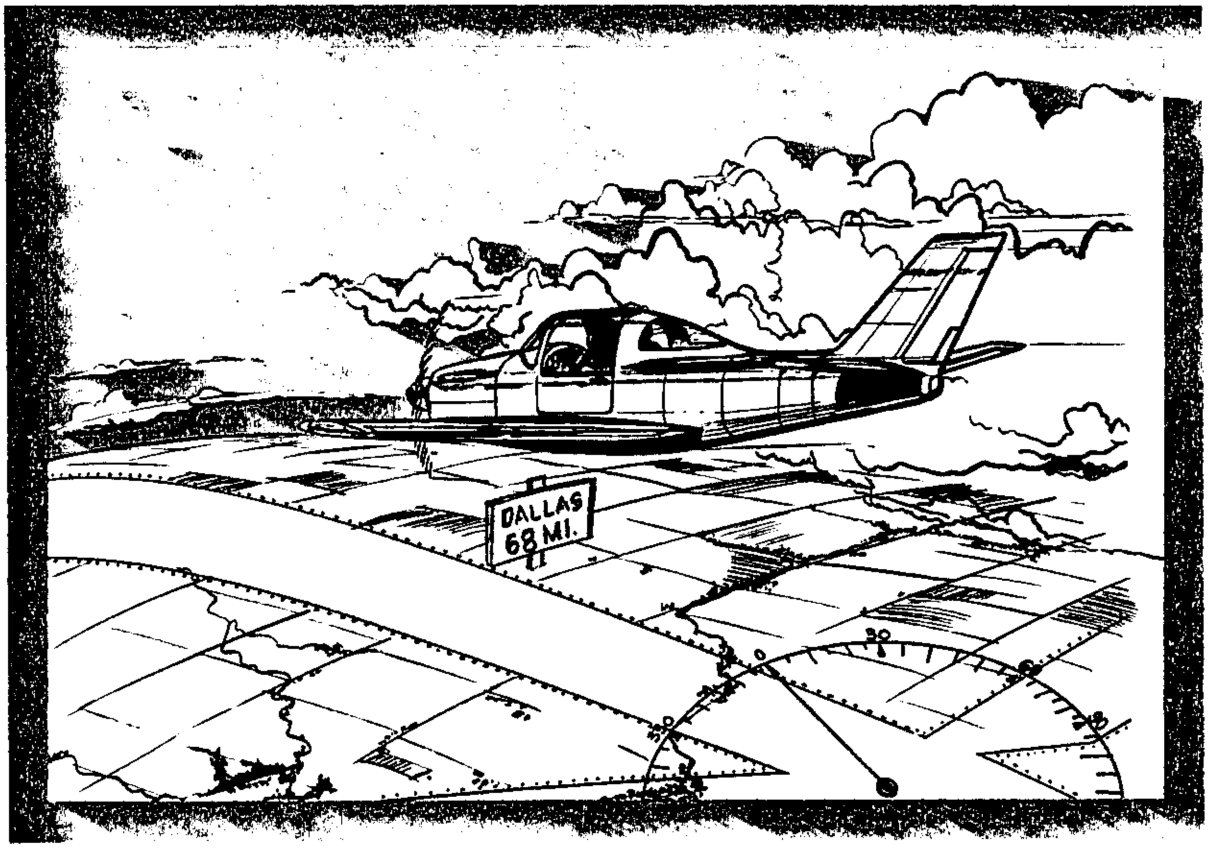
1. Maintain a "readiness" to communicate. With your flight log handy, charts in order, and other necessary materials readily available, you can eliminate fumbling and confusion. You cannot organize an intelligible message, or listen to one, in a disorganized cockpit.

2. Know your radiotelephone equipment and practice tuning it. Check the knobs, switches and selectors *before* you transmit. Monitor the frequency you are using before transmitting. If you hear nothing on a normally busy terminal frequency, for example, check your volume control; you may be interrupting another transmission.

3. Check your clock before transmitting to Flight Service. Other pilots are listening to scheduled weather broadcasts beginning at 15 minutes past the hour.

4. Never subordinate aircraft control to communications. Don't turn your aircraft loose in your haste to transmit.

5. Learn to take notes as you listen. Make written notes of times, altitudes, and other information as you hear it. You have enough to think about in planning ahead without having to waste time thinking back.



IX. THE FEDERAL AIRWAYS SYSTEM AND CONTROLLED AIRSPACE

System Details

Up to this point, your instrument training has been concerned largely with problems within the cockpit. While you have been acquiring proficiency in the use of basic flight instruments and NAV/COM equipment, your instructor has kept a watchful eye on other traffic. He has told you what maneuvers to execute, what radials to fly, when and where to go. Instrument flying would be relatively simple if your instrument training ended with mastery of these basic techniques and with a safety pilot aboard to keep you headed in the right direction, safely separated from other traffic. Your problem now is to learn how to use the facilities, services, and procedures established by the Air Traffic System to provide directional guidance, terrain clearance, and safe separation for aircraft operating under Instrument Flight Rules. The extent of this system and the facilities maintained for airspace users can be appreciated by visualizing the tremendous expansion of aviation since 1903 when only one airplane used the national airspace.

Figure 176 shows the low-frequency radio facilities serving the Los Angeles-Oakland area in 1934. The navaids provided only one route between those two terminals via the Los Angeles, Fresno, and Oakland range legs.

In 1964, 30 years later, the system in this area included the VOR facilities and routes shown in Figure 177 as well as instrument approach aids, radar coverage, and numerous other facilities and services.

By the 1960's, the Nation's air fleet approached 150,000 aircraft, with as many as 70,000 people

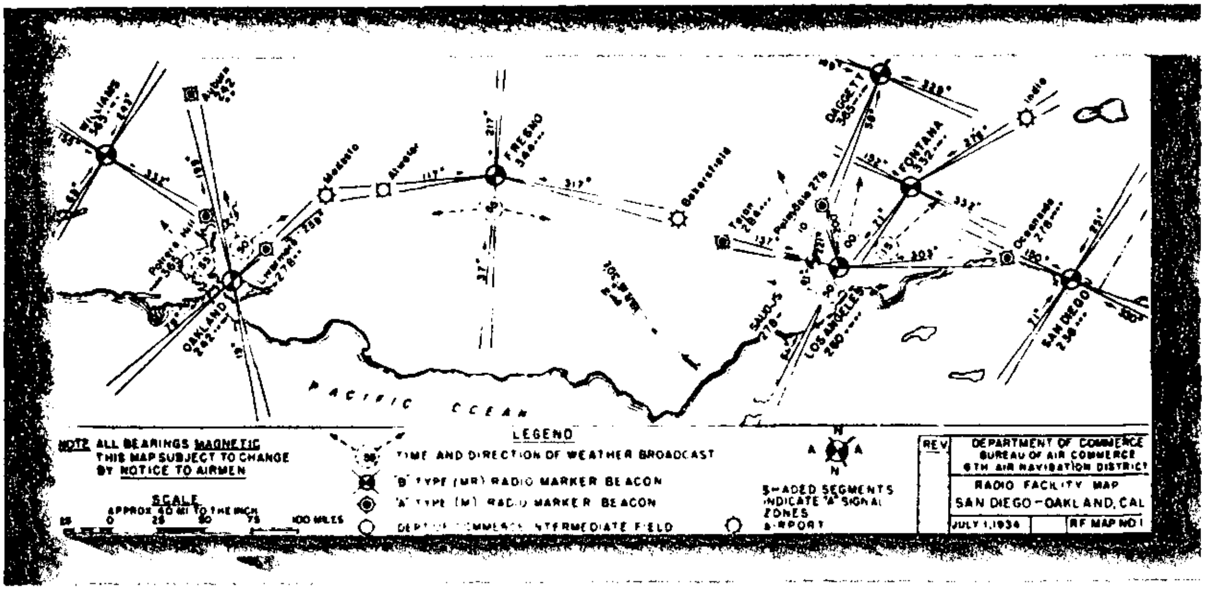


FIGURE 176. Navaids during the 1930's.

aloft at any busy hour, most of them converging on, or departing from, major metropolitan areas. In 1969, the 2,110 navigation aids needed to keep these aircraft moving safely throughout the 50 States were listed as follows (exclusive of non-directional homing beacons, standard broadcasting stations, precision approach radar systems, and non-Federal or special use aids):

- 27 Air Route Traffic Control Centers (includes 2 Center/RAPCONS and 1 Center/Tower).
- 90 Air Route Surveillance Radar (ARSR).
- 155 Airport Surveillance Radar (ASR)—(includes 36 military radars which provide service for civil airports).
- 952 VOR/VORTACS—(includes 27 non-Federal and 42 military which have been incorporated into the "Common System").
- 279 Instrument Landing Systems (ILS).
- 256 Approach Light Systems with Sequence Flashers (ALS).
- 351 Towers and Combined Station/Towers (CS/T—includes 30 non-Federal).

The airways system resembles its automotive counterpart in many ways. Whether you travel by Federal airway or Federal highway, the system must provide a controlling agency, procedural rules, directional guidance, highways between population centers, and a means of access between highways and terminals. The components of the Air Traffic System, the controlling agency, and the procedures established for your use of the system are discussed in this and the following chapter. In a later chapter, you will apply what you have learned to a sample flight planning problem.

Federal Airways

The Federal airways network is based upon the electronic aids already discussed. The navigation system has three component parts: the pilot, the airborne receiver, and the ground navigation facility. When the recognized errors which each contributes are considered, a total system accuracy can be determined. When this accuracy is applied, the area in which obstruction clearance should be provided becomes apparent. Inherent in this concept is the premise that the pilot fly, as closely as possible, the prescribed courses and altitudes.

Obstruction clearance criteria are based on the airborne receiver contributing not more than ±4.2° error to the total system error. Pilot performance must assure a tracking accuracy within ±2.5° (quarter scale) needle deflection. Where these standards are not assured by the pilot, the safety and accuracy normally provided by the criteria are impaired. The VOR and VORTAC facilities are the foundation of the system (Fig. 178). Connecting these facilities is the network of routes forming the Victor Airway System.

Each Federal Airway is based on a centerline that extends from one navigation aid or intersection to another navigation aid (or through several navigation aids or intersections) specified for that airway. The infinite number of radials transmitted by the VOR permits 360 possible separate airway courses to or from the facility, one for each degree of azimuth. Thus, a given VOR located within approvimately 100 miles of several other VORs may be used to establish

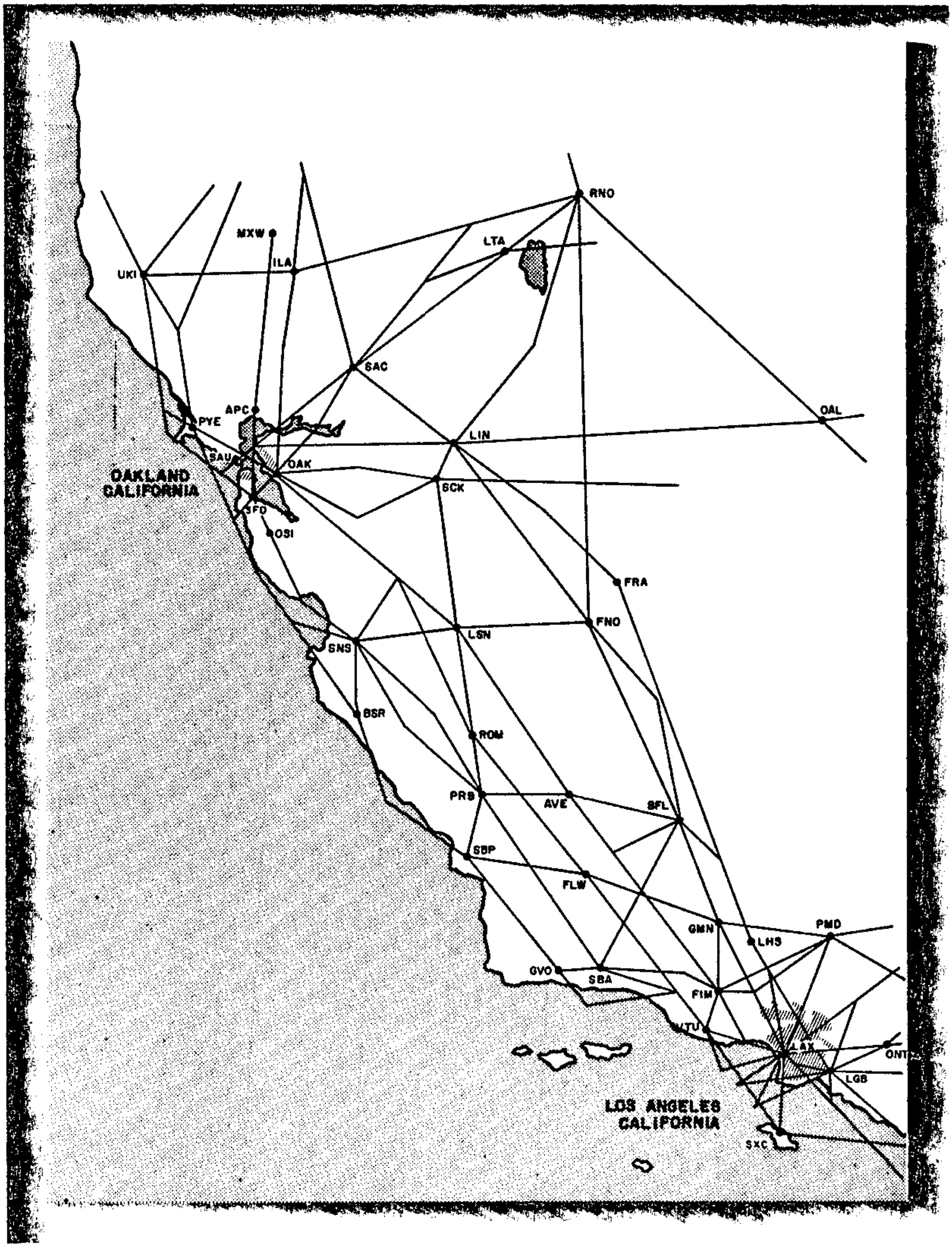


FIGURE 177. Navaids during the 1960's.

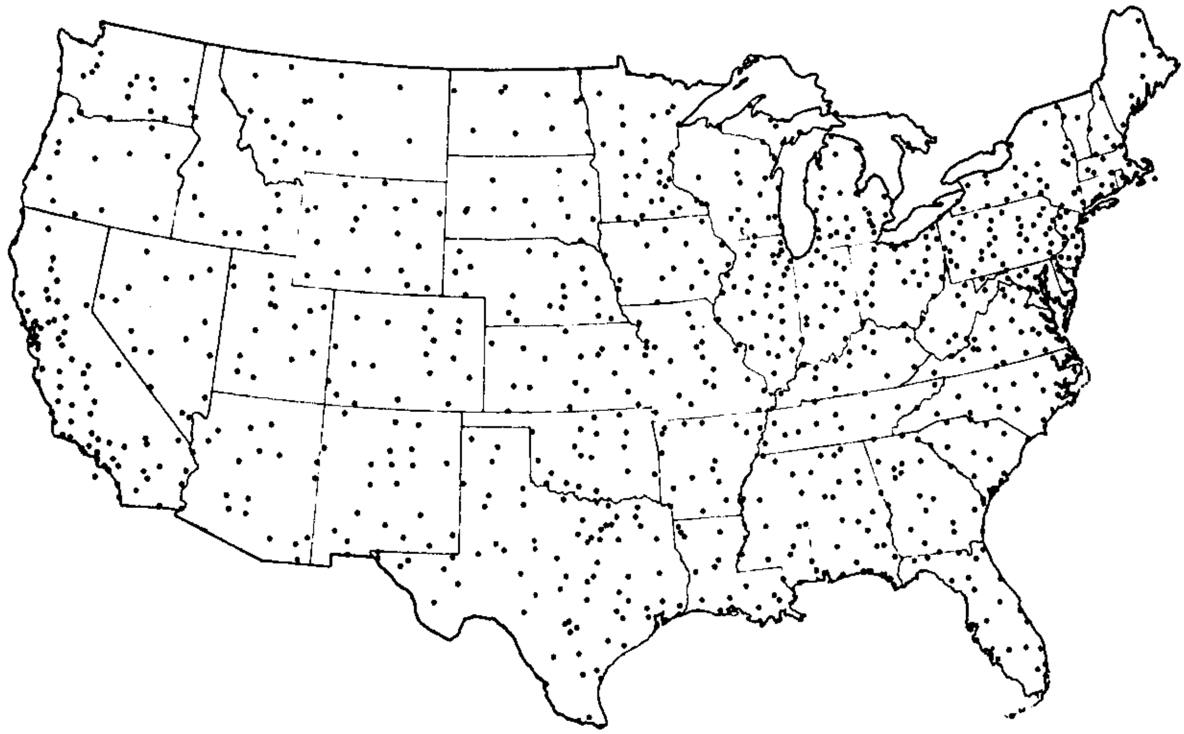


FIGURE 178. VOR and VORTAC facilities in 1971.

many different airways. For example, 11 radials at Houston VORTAC define 19 different low-altitude airways (Fig. 179).

The enroute airspace structure consists of three strata: Airways (generally 700 feet or 1,200 feet above the surface up to but not including 18,000 MSL), the Jet Route structure (18,000 feet to flight level 450–45,000 feet), and the airspace above FL 450, which is for point-to-point operation.

To the extent possible, these route systems have been aligned in an overlying manner to facilitate transition between each. At certain airports, Standard Terminal Arrival Routes (STARs) have been established for application to arriving IFR aircraft.

Like highways, Victor Airways are designated by number—generally north/south airways are *odd*; east/west airways are *even*. When airways coincide on the same radial, the airway segment shows the numbers of all the airways on it. For example, the Houston 340 radial in the excerpt defines three airways, V–13–15E–477.

Alternate Victor Airways are used for lateral separation when traffic conditions require it, or as "one-way" routes for efficient control of traffic flow to and from terminal areas. For example, V–14 serves as a normal arrival route into Oklahoma City from Tulsa, Oklahoma. V–14N, lying to the north of V–14, is an alternate arrival route from Tulsa. V–14S, to the south of V–14, is a normal departure route from Oklahoma City.

Preferred Routes have been established between major terminals to guide pilots in planning their routes of flight, to minimize route changes, and to aid in the orderly management of air traffic using Federal airways.

Terminal Routes (Standard Terminal Arrival Routes [STARs] and Standard Instrument Departures [SIDs])—These Standard Routes have been established and published as an air traffic control aid in certain complex terminal areas. They help reduce verbiage on clearance delivery and control frequencies and provide the pilot with a description of his terminal routing. SIDs are currently published in the National Ocean Survey SID booklet. STARs are currently published in AIM Part 3. Instructions for pilot use of these coded routes are contained in the AIM. Certain complex terminal areas are covered by Area Charts.

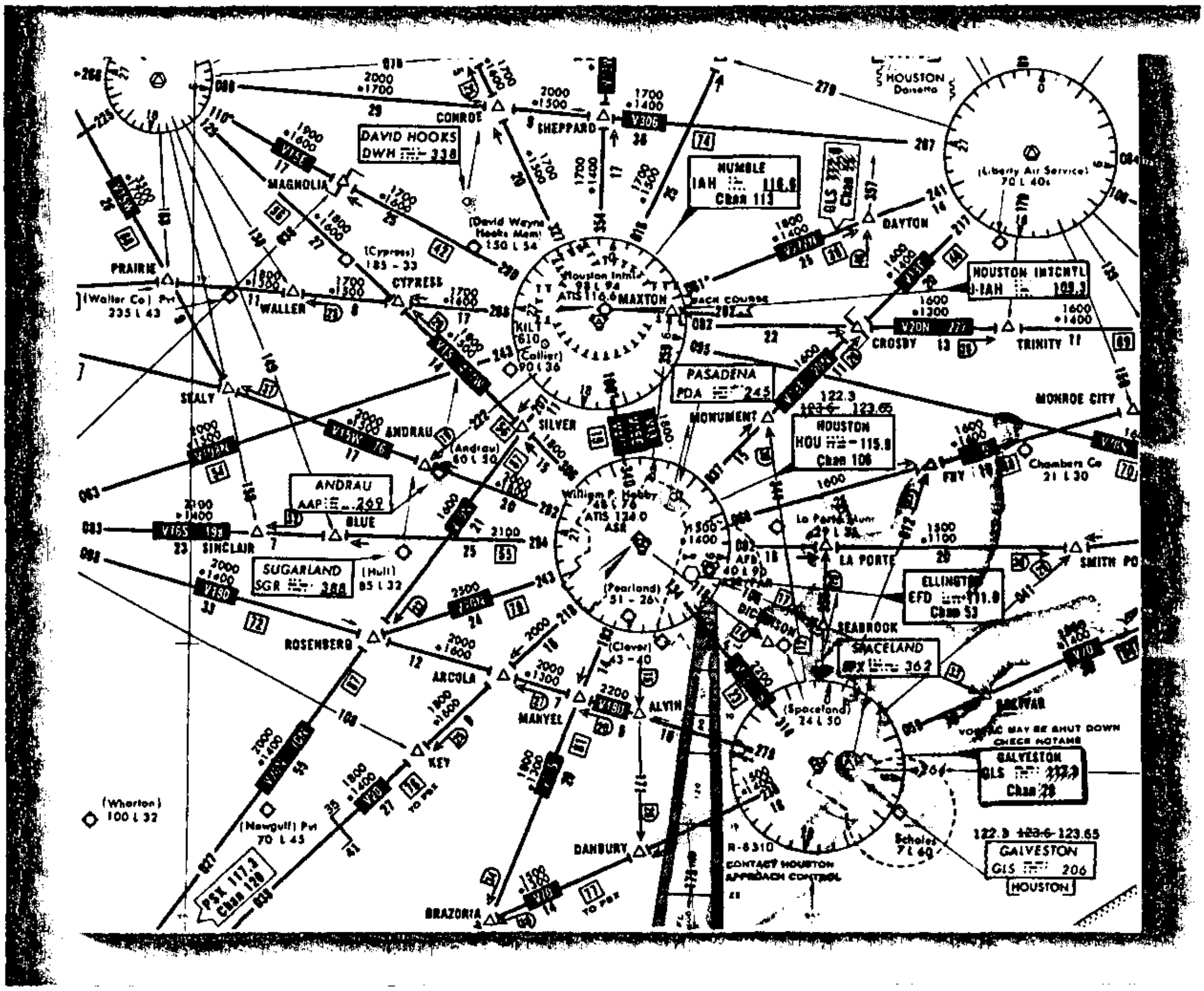


FIGURE 179. VOR radials and airways.

Controlled Airspace

Traffic separation on the Federal airways, terminal routes, and in the vicinity of airports requires the definition of the airspace in which control is necessary. Such airspace is called controlled airspace, which includes the airspace designated as control zone, transition area, control area, and continental control area, within which some or all aircraft may be subject to air traffic control. Figure 180 is a three dimensional portrayal of certain features of the airspace structure.

Control Zones extend upward from the earth's surface, terminating at the continental control area. A control zone is normally a circular area of 5 miles radius and may include one or more airports. Extensions are provided where necessary for instrument approach and departure paths.

Transition Areas consist of controlled airspace extending upward from 700 feet or more above the surface of the earth when designated in conjunction with an airport for which an approved instrument approach procedure has been prescribed; or from 1,200 feet or more above the surface of the earth when designated in conjunction with airway route structures or segments. Unless otherwise limited, transition areas terminate at the base of the overlying controlled airspace.

Control Areas include the following airspace in the Federal Airways structure:

a. The airspace within parallel boundary lines 4 nautical miles on each side of the centerline of the airway, and where the changeover point is more than 51 miles from either of the navigation aids, the airspace between lines diverging at 4.5 degrees from the centerline at the navigation aid most distant from the changeover point (either NAVAID when equidistant from this point) ex-

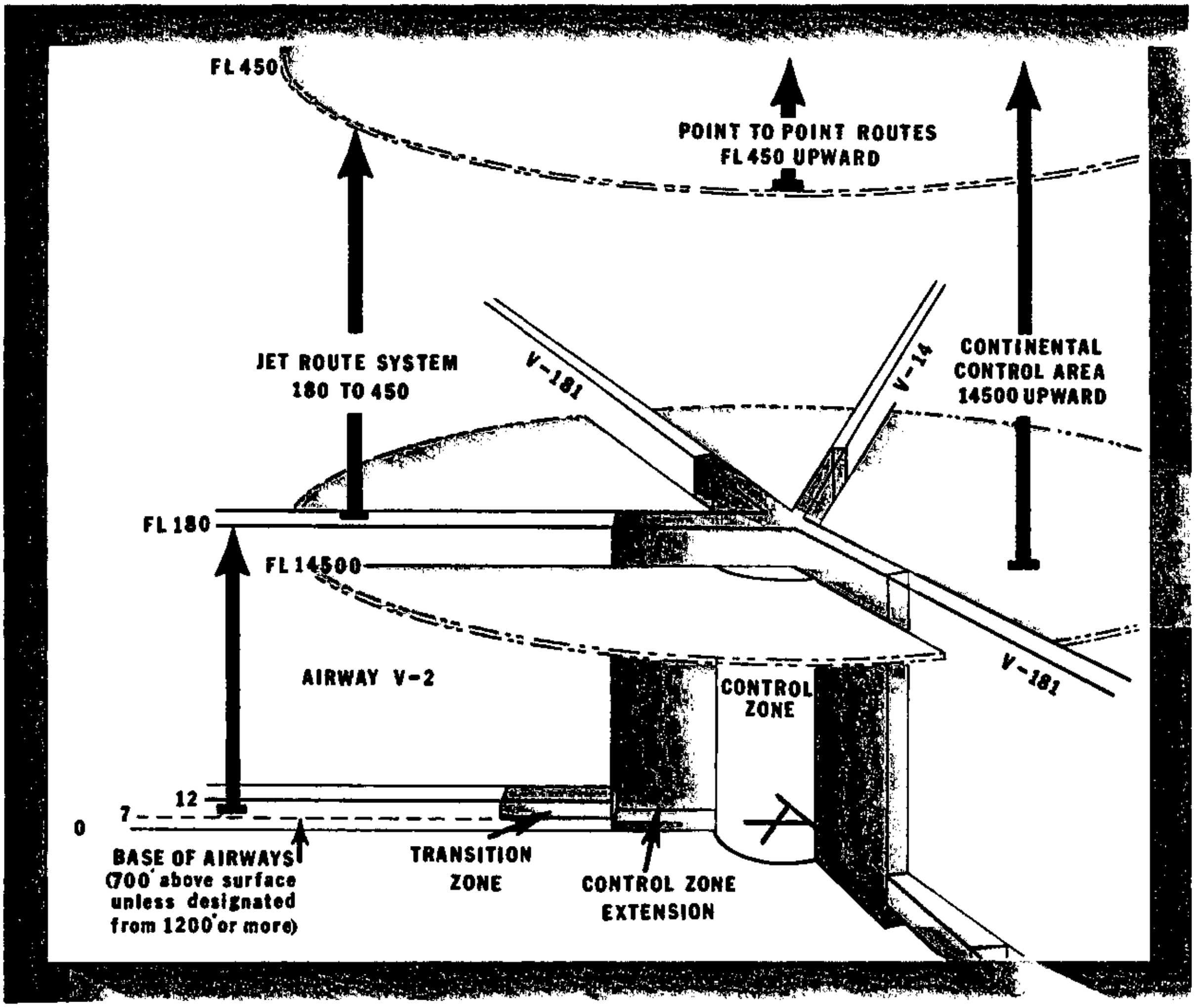


FIGURE 180. Controlled airspace.

tending until they intersect with the bisector of the angle of the centerlines at the changeover point, and the airspace between the lines connecting these points and the other navigation aid.

b. The airspace that extends upward from 700 feet (unless designated from 1,200 feet or more) above the surface of the earth.

c. Unless otherwise designated, the airspace between a main and associated alternate VOR Federal Airway, with the vertical extent of this area corresponding to the vertical extent of the main airway.

Control areas do not include the airspace of the Continental Control Area. They may or may not include all or part of the airspace within a restricted area.

Additional Control Areas and Control Area Extensions are airspace of individually defined dimensions which may be found in Subpart E of Part 71 of the Federal Aviation Regulations.

The Continental Control Area consists of the airspace of the 48 conterminous States, part of Alaska, and the District of Columbia at and above 14,500 MSL, but does not include—

a. The airspace less than 1,500 feet above the surface of the earth; or

b. Prohibited and restricted areas, other than restricted area military climb corridors and other special restricted areas designated by regulation.

Radio Navigation Charts

Radio navigation data are shown on many types of aeronautical charts, including the Sectional and WAC charts familiar to the VFR pilot. More specialized charts, compiled and printed by the National Ocean Survey, include several types for use by the instrument pilot.

Standard Instrument Departure (SID) Charts re designed to expedite clearance delivery and o facilitate transition between takeoff and enoute operations. These charts, published in a ound book, provide departure routing clearnce in graphic and textual form. *Enroute Low lltitude Charts* provide aeronautical informaion for enroute navigation (IFR) in the low ltitude stratum. *Area Charts,* which are part f this series, furnish terminal data in a larger cale in congested areas. *Enroute High Altitude 'harts* provide aeronautical information for enroute instrument navigation (IFR) in the high altitude stratum. *Instrument Approach Procedure Charts* portray the aeronautical data which is required to execute instrument approaches to airports. Each procedure is designated for use with a specific type navigational aid. These charts reflect criteria associated with the U.S. Standards for Terminal Instrument Approach Procedures (TERPS). Detailed information regarding their use is contained in Advisory Circular 90-1A which is reproduced in the following pages in this chapter.

CIVIL USE OF U. S. GOVERNMENT INSTRUMENT APPROACH PROCEDURE CHARTS

(Reproduced from AC 90-1A, effective 4/10/68)

1. APPLICATION. Civil Instrument Approach Procedures are established by the Federal Aviation Administration after careful analysis of obstructions, terrain features and navigational facilities. Narrative type procedures authorized by the FAA are published in the Federal Register as rule making action under Federal Aviation Regulations, Part 97. Based on this information, the U.S. Coast and Geodetic Survey, and other charting agencies, publish instrument approach charts as a service to the instrument pilot. FAR 91.116a requires use of specified procedures by all pilots approaching for landing under Instrument Flight Rules. Appropriate maneuvers, which include altitudes, courses, and other limitations, are prescribed in these procedures. They have been established for safe letdown during instrument flight conditions as a result of many years of accumulated experience. It is important that all pilots thoroughly understand these procedures and their use.

2. DEFINITIONS.

   a. MDA - "Minimum descent altitude" means the lowest altitude, expressed in feet above mean sea level, to which descent is authorized on final approach, where no electronic glide slope is provided, or during circle-to-land maneuvering in execution of a standard instrument approach procedure.

   b. DH - "Decision height", with respect to the operation of aircraft, means the height at which a decision must be made, during an ILS or PAR instrument approach, to either continue the approach or to execute a missed approach. This height is expressed in feet above mean sea level (MSL), and for Category II ILS operation the decision height is additionally expressed as a radio altimeter setting.

   c. HAA - "Height above airport" indicates the height of the MDA above the published airport elevation. HAA is published in conjunction with circling minimums for all types of approaches.

   d. HAT - "Height above touchdown" indicates the height of the DH or MDA above the highest runway elevation in the touchdown zone (first 3,000 feet of runway). HAT is published in conjunction with straight-in minimums.

   e. NoPT - means No Procedure Turn Required.

   f. "Precision approach procedure" means a standard instrument approach in which an electronic glide slope is provided (ILS or PAR).

   g. "Non-precision approach procedure" means a standard instrument approach in which no electronic glide slope is provided.

   h. Instrument approach procedure. An instrument approach procedure is one that is prescribed and approved for a specific airport by competent authority and published in an acceptable aeronautical information publication.

      (1) U.S. civil standard instrument approach procedures are approved by the FAA as prescribed under FAR Part 97 and are published in the Federal Register. For the convenience of the user, the aeronautical data prescribed in standard instrument approach procedures are portrayed on instrument approach procedure charts and may be obtained from Coast and Geodetic Survey and other publishers of aeronautical charts.

      (2) U.S. military standard instrument approach procedures are established and published by the Department of Defense and are contained in the DOD Flight Information Publication (FLIP). Civilian requests for military procedures should be directed to the Coast and Geodetic Survey, Washington Science Center, Attn: Distribution Division, Rockville, Maryland 20852.

(3) Special instrument approach procedures are approved by the FAA for individual operators and are not published in FAR Part 97 for public use.

(4) Foreign country standard instrument approach procedures are established and published as contained in that country's accepted Aeronautical Information Publication (AIP).

3. DISCUSSION OF MAJOR CHANGES.

a. Minimum Descent Altitude (MDA)/Decision Height (DH) Concept.

(1) IFR landing minimums. FAR sections 91.116 and 91.117, effective November 18, 1967, contain new rules applicable to landing minimums. Ceiling minimums are no longer prescribed in approach procedures as a landing limit. The published visibility is the required weather condition for landing as prescribed in FAR 91.116b. FAR 91 now allows approach down to the prescribed minimum descent altitude (MDA) or decision height (DH), as appropriate to the procedure being executed, without regard to reported ceiling.

(2) Descent below MDA or DH. No person may operate an aircraft below the prescribed minimum descent altitude or continue an approach below the decision height unless—

(a) The aircraft is in a position from which a normal approach can be made to the runway of intended landing; and

(b) The approach threshold of that runway, or approach lights or other markings identifiable with the approach end of that runway, is clearly visible to the pilot.

(c) If, upon arrival at the missed approach point, or at any time thereafter, any of the above requirements are not met, the pilot shall immediately execute the appropriate missed approach procedure.

NOTE: The former FAR authorization to descend 50 feet below the applicable minimum landing altitude when clear of clouds is eliminated.

(3) Conversion of ceiling MDA or DH. Effective November 18, 1967, the Federal Aviation Regulations were amended to provide that if the landing minimums in the instrument approach procedure are stated in terms of ceiling and visibility, the visibility minimum is the applicable landing minimum as prescribed in FAR 91.116b. A ceiling minimum shall be added to the field elevation, and that value is observed as the MDA or DH as appropriate to the procedure being executed.

(4) Publication of landing minimums. The new Government-produced charts always contain the following information listed in this order: MDA or DH, visibility, HAA or HAT, and military minimums (ceiling and visibility) for each aircraft approach category.

NOTE: Since the chart is used by both civil and military pilots, the ceiling, as well as visibility, required by the military will be published in parentheses. Civil operators should disregard this information.

(a) Following are examples of published landing minimums. (Extracted from sample chart Figure 5.)

1 Straight-in precision. An example of straight-in ILS minimums is shown below. The touchdown zone elevation is 965 feet, whereas the airport elevation is 983 feet.

STRAIGHT-IN TO RUNWAY 14	DH		VIS	HAT	MILITARY
S-ILS 14	1165	/	24	200	(200-½)

It should be noted that the visibility is separated from the DH by a slant line (/) when it is RVR, and separated by a hyphen (-) when it is meteorological visibility. This will help differentiate the two visibility values.

RVR is indicated in 100's of feet, and meteorological visibility is in statute miles. If RVR were not authorized, it would appear 1165-½.

2 Straight-in non-precision. When the ILS approach procedure is used but the aircraft does not have a glide slope receiver or the glide slope ground equipment is out of service, localizer minimums apply to the straight-in landing on that runway.

	MDA		VIS	HAT	MILITARY
S-LOCALIZER 14	1500	/	24	535	(600-½)

3 Circling. Visibility for circling is always in a meteorological value of statute miles. Height of the MDA above the airport elevation is provided by HAA.

	MDA		VIS	HAA	MILITARY
Circling	1640	–	1	657	(700-1)

b. Standard Take-off Minimums. FAR 91.116(c) prescribes take-off rules for FAR 121, 129, and 135 operators and establishes standard take-off visibility minimums as follows:

(1) Aircraft having two engines or less - one statute mile.

(2) Aircraft having more than two engines - one-half statute mile.

In cases where departure procedures or non-standard take-off minimums are prescribed, a symbol ▽ is shown on the chart indicating that the separate listing should be consulted. See figures 5, 13, and 17. Ceiling minimums are no longer prescribed for take-off except for those runways where a ceiling minimum is required to enable the pilot to see and avoid obstructions. The ceiling and visibility minimums previously prescribed apply until individual procedures are reissued under the new criteria.

c. Standard Alternate Minimums. Alternate minimums specified for an instrument approach procedure continue to require both ceiling and visibility minimums. FAR 91.83 establishes standard IFR alternate minimums as follows:

(1) Precision approach procedure: ceiling 600 feet and visibility - two statute miles.

(2) Non-precision approach procedure: ceiling 800 feet and visibility - two statute miles.

The standard IFR alternate minimums apply unless higher minimums are specified for the procedure used. These are denoted by a symbol △ on the chart indicating that the separate listing should be consulted. See figures 6, 14, and 18.

d. Inoperative Components, Visual Aids, and Adjustment of Landing Minimums.

(1) Components and Visual Aids.

(a) Precision approach procedure.

ILS (Instrument Landing System) basic components are localizer, glide slope, outer marker and middle marker. PAR (Precision Approach Radar) basic components are azimuth, range, and elevation information.

The following visual aids may supplement the ILS or PAR, and may provide lower visibility minimums:

ALS — Approach Lighting System, 3000' of Standard High Intensity Lights with Sequence Flashers.

SALS — Short Approach Lighting System, 1500' of Standard ALS.

SSALR — Simplified Short Approach Lighting System (1400' of High Intensity Light Bars) plus 1600' of Runway Alignment Indicator Lights (RAIL - Sequence Flashers).

MALSR — Medium Intensity Lighting of Simplified Short Approach Lighting System (1400' of Medium Intensity Light Bars) plus 1600' of Runway Alignment Indicator Lights (RAIL - Sequence Flashers).

TDZL Touchdown Zone Lights.
RCLS Runway Centerline Light System.
HIRL High Intensity Runway Edge Lights.
MIRL Medium Intensity Runway Edge Lights.

(b) Non-precision approach procedures.

The basic component is the facility providing course guidance, i.e., VOR, NDB, etc. In the case of VOR/DME type procedures, basic components are the VOR and DME facilities.

All of the visual aids listed under precision approach procedures may supplement non-precision procedures plus the following:

MALS Medium Intensity Approach Light System. Total 1400'.
RAIL Runway Alignment Indicator Light.
REIL Runway End Identifier Lights.

(2) Previous approach charts (old chart format). In many cases, minimums lower than those authorized in the straight-in line are authorized when lighting aids such as REIL, ALS, etc., are installed for the landing runway. Also, minimums higher than those authorized in its straight-in line are required when certain components of an ILS system are inoperative. This information concerning minimums is published as notes below the minimums section. (Figure 1.)

PREVIOUS APPROACH CHART PRESENTATION

MINIMA							FIELD EL
	65 knots or less 2 eng or less		Over 65 knots 2 eng or less		Over 65 knots Over 2 eng		
	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	
T	300-1	300-1	300-1	300-1	200-½	200-½	
C	500-1	500-1	500-1	500-1	500-1½	500-1½	
S 21	500-1	500-1	500-1	500-1	500-1	500-1	
A	800-2	800-2	800-2	800-2	800-2	800-2	
If Parkersburg FM received, the following minimums are authorized:							
S 21 •	400-1	400-1	400-1	400-1	400-1	400-1	
•400-¾ authorized, except for 4-engine turbojet aircraft, with operative REIL or high intensity runway lights.							

FACILITY TO AERODROME: 211° 5.8 NM					
TIME FROM FACILITY TO MISSED APPROACH					
KNOTS	90	100	110	130	150
MIN: SEC	3:52	3:29	3:10	2:41	2:19

(VOR)

MINIMA							FIELD ELE
	65 knots or less 2 eng or less		Over 65 knots 2 eng or less		Over 65 knots Over 2 eng		
	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	
T	300-1	300-1	300-1	300-1	200-½	200-½	
C •	600-1	600-1	600-1	600-1	600-1½	600-1½	
S 7L•	200-½	200-½	200-½	200-½	200-½	200-½	
A	600-2	600-2	600-2	600-2	600-2	600-2	
•400-1 required with any component of ILS inoperative, except 700-1 required when glide slope and 7-Mile DME Fix not utilized. †Except for 4-engine turbojet acft. 400-¾ authorized, with operative HIRL or 400-½ with operative ALS. If glide slope not utilized and 7-Mile DME Fix from PUB VOR received, the following minimums are authorized:							
C	600-1	600-1	600-1	600-1	600-1½	600-1½	
S 7L†	400-1	400-1	400-1	400-1	400-1	400-1	

RATE OF DESCENT ON GLIDE SLOPE					
KNOTS	90	100	110	130	150
FEET/MIN	475	530	585	690	795

(ILS)

Figure 1

(3) Inoperative Components or Visual Aids Table (Pertaining to new chart format).

(a) Since all air navigation facilities have a very low out-of-service time, the lowest landing minimums with all components and visual aids operating are published.

To determine landing minimums when components or aids of the system are inoperative or are not utilized, inoperative components or visual aids tables are published and appear on a separate sheet for insertion in the approach chart binders. This method was selected to reduce chart clutter.

INOPERATIVE COMPONENTS OR VISUAL AIDS TABLE

1 ILS and PAR with visibility of ½ mile (RVR 2400) or greater.

Inoperative Component or Aid	Increase DH	Increase Visibility	Approach Category
OM*, MM*	50 feet	By None	ABC
OM*, MM*	50 feet	By ¼ mile	D
ALS	50 feet	By ¼ mile	ABCD
SALS	50 feet	By ¼ mile	ABC

*Not applicable to PAR

2 ILS and PAR with visibility minimum of 1,800 or 2,000 feet RVR.

Inoperative Component or Aid	Increase DH	Increase Visibility	Approach Category
OM*, MM*	50 feet	To ½ mile	ABC
OM*, MM*	50 feet	To ¾ mile	D
ALS	50 feet	To ¾ mile	ABCD
HIRL, TDZL, RCLS	None	To ½ mile	ABCD
RVR	None	To ½ mile	ABCD

*Not applicable to PAR

3 VOR, VOR/DME, LOC, LDA, and ASR.

Inoperative Visual Aid	Increase MDA	Increase Visibility	Approach Category
ALS, SALS	None	By ½ mile	ABC
HIRL, MALS, REILS	None	By ½ mile	ABC

4 NDB (ADF) and RNG.

Inoperative Visual Aid	Increase MDA	Increase Visibility	Approach Category
ALS	None	By ¼ mile	ABC

5 LOC Approaches

Inoperative Component or Aid	Increase MDA	Increase Visibility	Approach Category
ALS, MM	None	By ¼ mile	D

Figure 2

(Reference should be made to the Coast and Geodetic Survey publications for current tables.)

(b) Application of the inoperative components or visual aids table. When using the revised approach charts, the minimums must be adjusted in accordance with the inoperative component or visual aids table. This will be done when a ground component or visual aid pertinent to the procedure is inoperative or not utilized.

With two or more components inoperative, only the greater or greatest increase in altitude or visibility is required; and the increases are not cumulative.

When a visual aid has been installed, but reduced visibility minimums have not been authorized, the above tables would not be used. The following note would appear below the minimums section.

Example: "Inoperative table does not apply to ALS or HIRL Runway 12R." (See figure 14.)

(c) The following general rules will always apply to inoperative components.

1 Operative runway lights are required for night operation.

2 When the facility providing course guidance is inoperative, the procedure is not authorized. On VOR/DME procedures: when either VOR or DME is inoperative, the procedure is not authorized.

3 When the ILS glide slope is inoperative or not utilized, the published straight-in localizer minimum applies.

4 Compass locator or precision radar may be substituted for the ILS outer or middle marker.

5 Surveillance radar may be a substitute for the ILS outer marker. DME, at the glide slope site, may be substituted for the outer marker when published on the ILS procedure.

6 Facilities that establish a stepdown fix, i.e., 75 MHz FM, off course VOR radial, etc. are not components of the basic approach procedure, and applicable minimums for use, both with or without identifying the stepdown fix, are published in the minimums section. (See example figure 14.)

7 Additional methods of identifying a fix may be used when authorized on the procedure.

8 Runway Visual Range (RVR) Minimums.

To authorize RVR minimums, the following components and visual aids must be available in addition to basic components of the approach procedure.

a Precision approach procedures.

(1) RVR reported for the runway.

(2) HIRL.

(3) All weather runway markings.

b Non-precision approach procedures.

(1) RVR reported for the runway.

(2) HIRL.

(3) Instrument runway markings.

c Inoperative RVR minimums. Where RVR visibility minimums are published and the runway markings become unusable, the necessary adjustment will be accomplished by NOTAM and by air traffic advisory.

If RVR minimums for take-off or landing are published in an instrument approach procedure, but RVR is inoperative and cannot be reported for the runway at that time, it is necessary that the RVR minimums which are specified in the procedure be converted and applied as ground visibility in accordance with the table below.

RVR	Visibility (statute miles)
1600 feet	1/4 mile
2400 feet	1/2 mile
3200 feet	5/8 mile
4000 feet	3/4 mile
4500 feet	7/8 mile
5000 feet	1 mile
6000 feet	1 1/4 mile

e. Aircraft Approach Categories. Minimums are specified for the various aircraft speed/weight combinations. Speeds are based upon a value 1.3 times the stalling speed of the aircraft in the landing configuration at maximum certificated gross landing weight. Thus they are COMPUTED values. See FAR 97.3 (b). An aircraft can fit into only one category, that being the highest category in which it meets either specification. For example, a 30,000 pound aircraft landing weight combined with a computed approach speed of 130 knots would place the aircraft in Category C. If it is necessary, however, to maneuver at speeds in excess of the upper limit of the speed range for each category, the minimum for the next higher approach category should be used. For example, a B-727-100 which falls in Category C, but is circling to land at a speed in excess of 140 knots, should use the approach category "D" minimum when circling to land. See following category limits and reference table.

Approach Category	Speed/Weight
A	Speed less than 91 knots; weight less than 30,001 pounds.
B	Speed 91 knots or more but less than 121 knots; weight 30,001 pounds or more but less than 60,001 pounds.
C	Speed 121 knots or more but less than 141 knots; weight 60,001 pounds or more but less than 150,001 pounds.
D	Speed 141 knots or more but less than 166 knots; weight 150,001 pounds or more.
E	Speed 166 knots or more; any weight.

Reference Table for Determining Aircraft Approach Categories.

Category A

1.3 V_{SO} less than 91 knots weight less than 30,001 pounds.

This Category includes civil single engine aircraft, light twins, and some of the heavier twins. Typical heavier aircraft in this Category are:

Make	AIRCRAFT Type/Model	SPEED IN KNOTS 1.3 V_{SO}	MAX. LANDING Weight (lbs.)
Aero Commander	680 F	87	8,000
Cessna	310 C	83	4,830
Beechcraft	Queenair 65	90	7,350
Douglas	DC-3	78	26,500

Category B

1.3 V_{SO} 91 knots or more but less than 121 knots; weight 30,001 pounds or more but less than 60,001 pounds.

This group includes most of the heavier twin-engine aircraft, some of which are listed as follows:

Make	AIRCRAFT Type/Model	SPEED IN KNOTS $1.3\ V_{SO}$	MAX. LANDING Weight (lbs.)
Grand Commander		92	8,500
Beechcraft	80	94	8,800
Beechcraft	65-90 Turboprop	100	8,835
Beechcraft	Super 18	97	9,500
Cessna	411 C	95	6,500
Convair	340	107	46,500
Convair	580	110	50,670
Fairchild	F-27	91	36,000

Category C

$1.3\ V_{SO}$ 121 knots or more but less than 141 knots; weight 60,001 pounds or more but less than 150,001 pounds.

This Category includes the four-engine propeller aircraft, and two and three engine turbojets, some of which are listed as follows:

Make	AIRCRAFT Type/Model	SPEED IN KNOTS $1.3\ V_{SO}$	MAX. LANDING Weight (lbs.)
Boeing	727-100	122	135,000
Caravelle	6	139	105,000
Douglas	DC-4	97	63,500
Douglas	DC-6	110	88,200
Douglas	DC-7	115	97,000
Douglas	DC-9-15	135	81,700
Douglas	DC-9-31	126	95,300
Jet Commander	1121	124	16,000
Lear Jet	24	125	11,800
Lear Jet	23	127	11,800
Lockheed	649, 749	93	89,500
Lockheed	1049	112	110,000
Lockheed	Jetstar	128	30,000
Lockheed	188	124	95,600

Category D

$1.3\ V_{SO}$ 141 knots or more but less than 166 knots; weight 150,001 pounds or more.

This Category includes the large four-engine turbojet aircraft, some of which are listed as follows:

Make	AIRCRAFT Type/Model	SPEED IN KNOTS $1.3\ V_{SO}$	MAX. LANDING Weight (lbs.)
Boeing	707/123B	133	190,000
Boeing	720/051B	131	175,000
Boeing	300B	126	207,000
Convair	880M	140	155,000
Convair	990A	160	202,000
Douglas	DC-8-21	136	155,000
Douglas	DC-8-61	144	240,000

f. Legend Pages contain the Plain View Symbols, Profile information, Aerodrome Sketch information, and General Information and Abbreviations. The following figures 3 and 4 are Legend Pages to the Coast and Geodetic Survey instrument approach procedures charts.

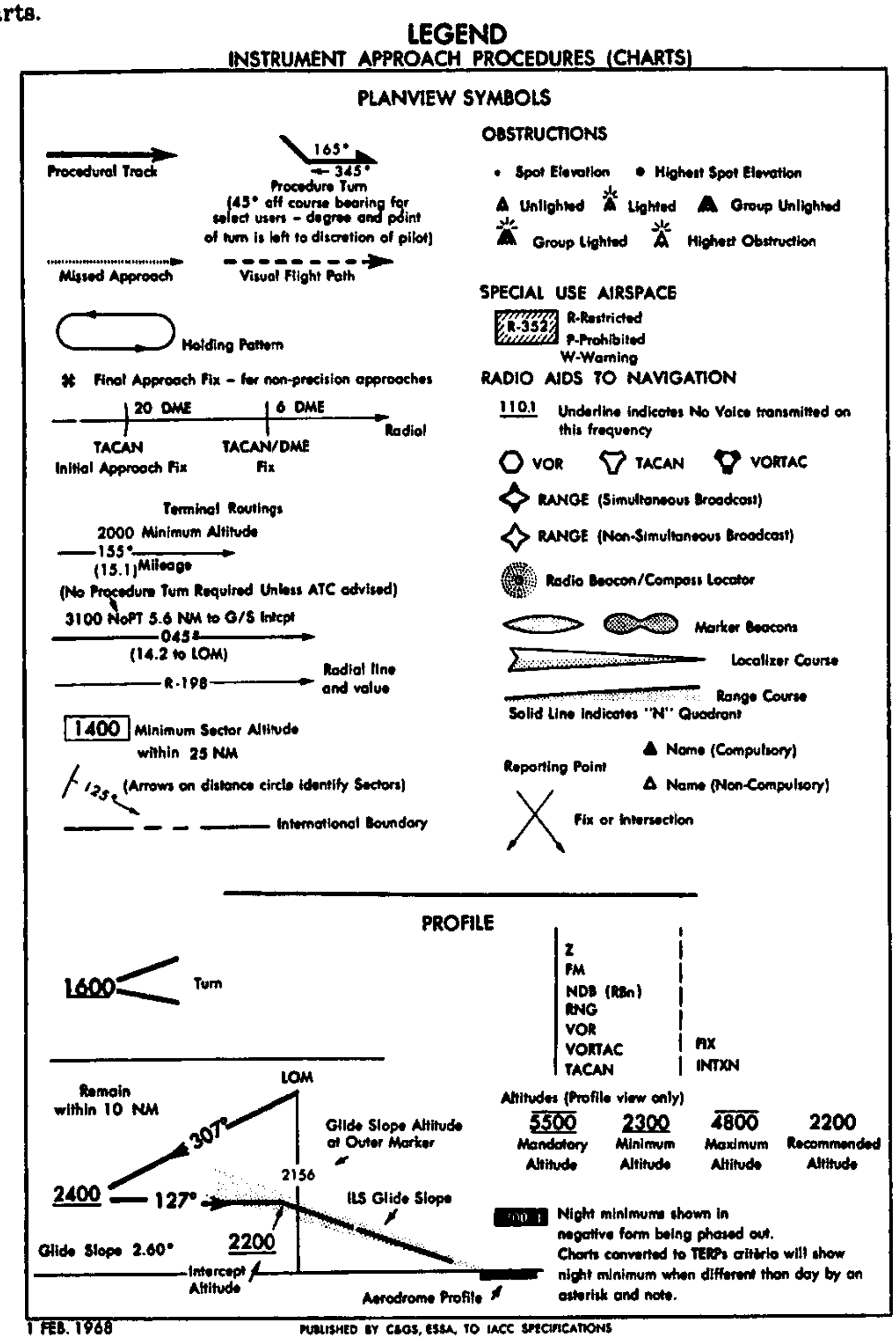


Figure 3

(Reference should be made to Coast and Geodetic Survey publications for the current Legend.)

LEGEND

INSTRUMENT APPROACH PROCEDURES (CHARTS)

AERODROME SKETCH

Runways

Hard Surface — Other Than Hard Surface — Hardstands/Taxiways

Closed Runways and Taxiways — Under Construction — Metal Surface

Over-run — Displaced Threshold

Arresting Gear

uni-directional — bi-directional — Jet Barrier

- Control Tower
  When Control Tower and Rotating Beacon are co-located, Beacon symbol will be used and further identified as TWR.

★ Rotating Aerodrome Beacon.

U.S. Navy Optical Landing System (OLS) "OLS" location is shown because of its height of approximately 7 feet and proximity to edge of runway may create an obstruction for some types of aircraft.

Ⓗ Helicopter Alighting Area (the prop type symbol is being phased out).

Approach light symbols are shown on a separate legend.

0.8% —➤ UP Total Runway Gradient (shown when runway gradient exceeds 0.3%)

0.8% —➤ DOWN Take-Off Gradient (shown when runway gradient for first 5000' exceeds 0.5%). This take-off gradient being phased out.

△ Indicates other than standard Alternate Minimums apply for U.S. Army and Civil, refer to tabulation.

▽ Indicates other than standard Take-off Minimums or departures procedures apply for Civil users Civil users refer to tabulation. DOD users refer to Service Directives and DOD produced civil SID publication.

S/S Sliding Scale applicable to U.S. Army

GENERAL INFORMATION & ABBREVIATIONS

All distances in nautical miles (except Visibility Data which is in statute miles and Runway Visual Range which is in hundreds of feet)

Runway dimensions in feet.

Elevations in feet Mean Sea Level.

All radials/bearings are Magnetic.

ADF . . . . Automatic Direction Finder
ALS . . . . Approach Light System.
BC . . . . Back Course.
CHAN . . . . Channel.
DH . . . . Decision Height.
DME . . . . Distance Measuring Equipment.
HAA . . . . Height Above Aerodrome.
HAT . . . . Height Above Touchdown.
HIRL . . . . High Intensity Runway Lights.
INTXN . . . . Intersection.
LDA . . . . Localizer Type Directional Aid
LDIN . . . . Lead in Light System
LOC . . . . Localizer
MALS . . . . Medium Intensity Approach Light System.
MDA . . . . Minimum Descent Altitude.
NDB . . . . Non-directional Radio Beacon.
NoPT . . . . No Procedure Turn Required Unless ATC advised.
PAR/ASR . . . . Published Radar Minimums at this Aerodrome.
Radar Required . . . . Radar vectoring required for this approach.
Radar Vectoring . . . . May be expected through any portion of the Nav Aid Approach, except final.
RAIL . . . . Runway Alignment Indicator Lights
RBn . . . . Radio Beacon.
REIL . . . . Runway End Identifier Lights.
RCLS . . . . Runway Centerline Light System
Runway Touchdown Zone . . First 3000' of Runway.
RVR . . . . Runway Visual Range.
SALS . . . . Short Approach Light System.
(S) SALS . . . . (Simplified) Short Approach Light System.
TAC . . . . TACAN
TDZ . . . . Touchdown Zone
TDZL . . . . Touchdown Zone Lights

1 FEB. 1968 — PUBLISHED BY C&GS, ESSA, TO IACC SPECIFICATIONS

Figure 4

(Reference should be made to Coast and Geodetic Survey publications for the current Legend.)

g. <u>Revised Format for Government-Produced Instrument Approach Procedure Charts.</u> Complete revision to instrument approach chart format has been made. Each chart consists of five sections: margin identification, plan view, profile view, landing minimum section (and notes), and aerodrome sketch. See figures 5 and 6 below.

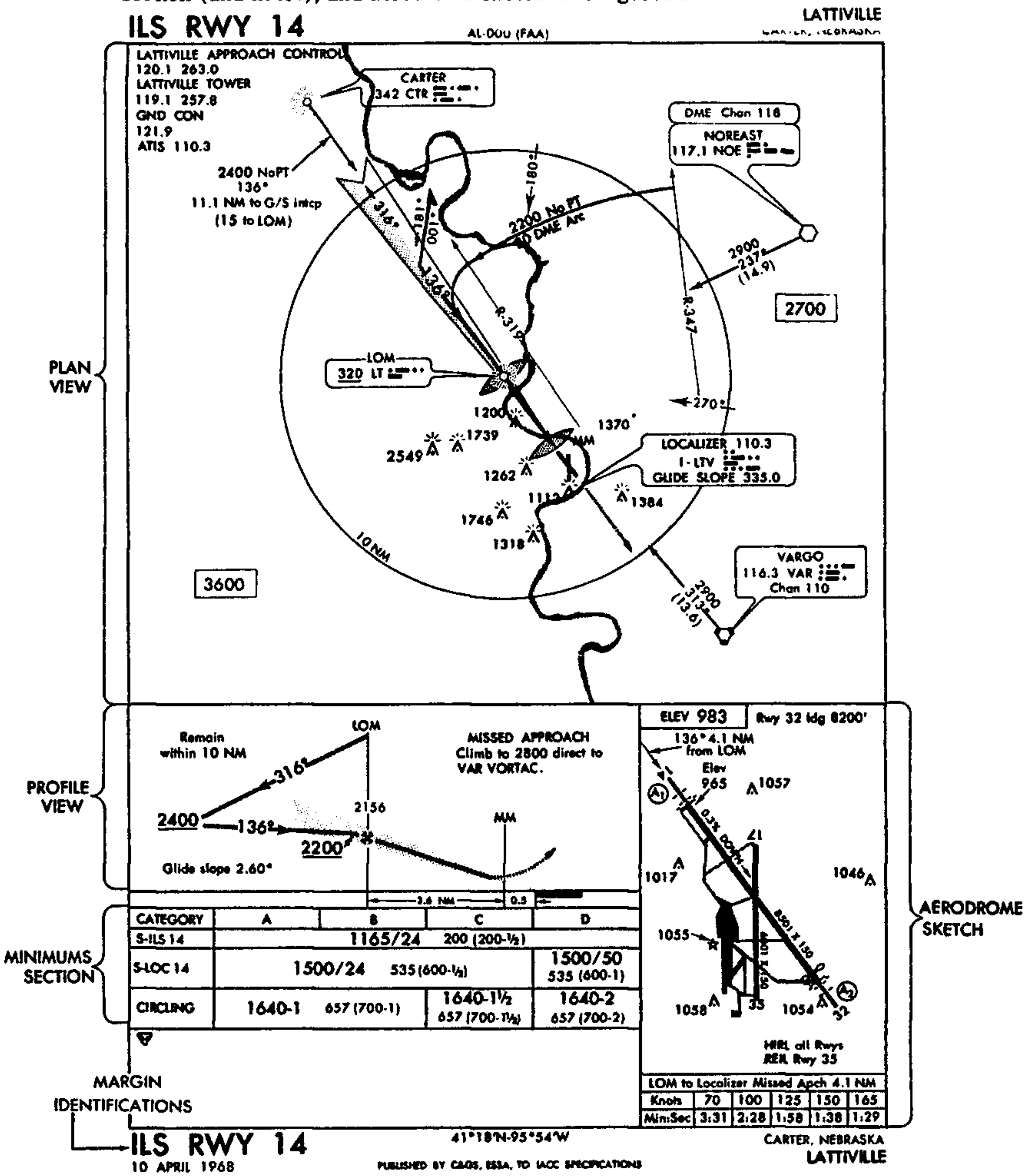
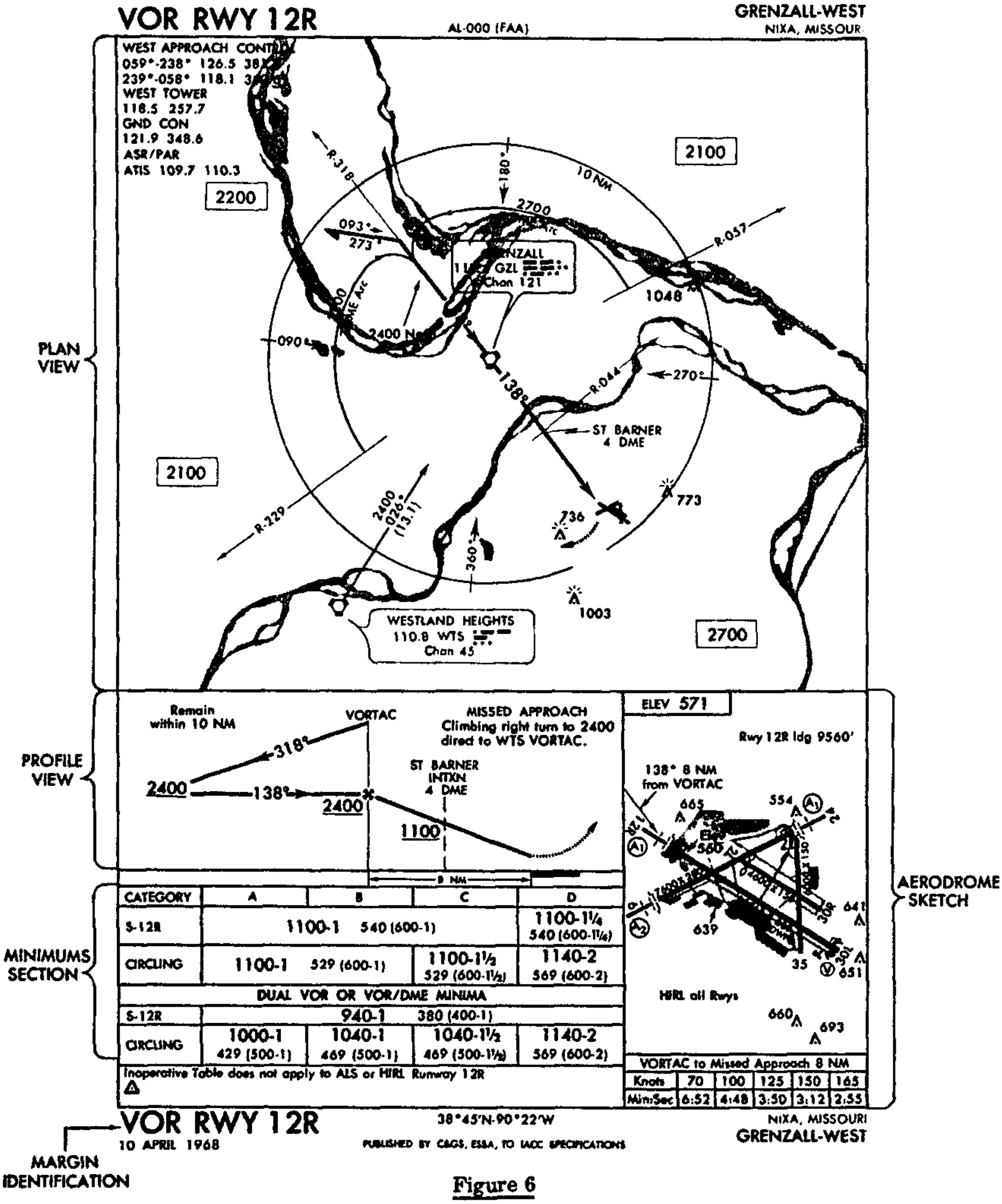


Figure 5



CATEGORY	A	B	C	D
S-12R	1100-1 540 (600-1)			1100-1¼ 540 (600-1¼)
CIRCLING	1100-1 529 (600-1)		1100-1½ 529 (600-1½)	1140-2 569 (600-2)
DUAL VOR OR VOR/DME MINIMA				
S-12R	940-1 380 (400-1)			
CIRCLING	1000-1 429 (500-1)	1040-1 469 (500-1)	1040-1½ 469 (500-1½)	1140-2 569 (600-2)

Inoperative Table does not apply to ALS or HIRL Runway 12R

VORTAC to Missed Approach 8 NM

Knots	70	100	125	150	165
Min:Sec	6:52	4:48	3:50	3:12	2:55

Figure 6

CONCENTRIC RINGS

These rings are used when it is necessary to chart facilities which lie beyond the chart area if the procedure was charted to scale. The rings are normally centered on the Approach Facility. Refer to (2) (a), (b), and (c) Page 17

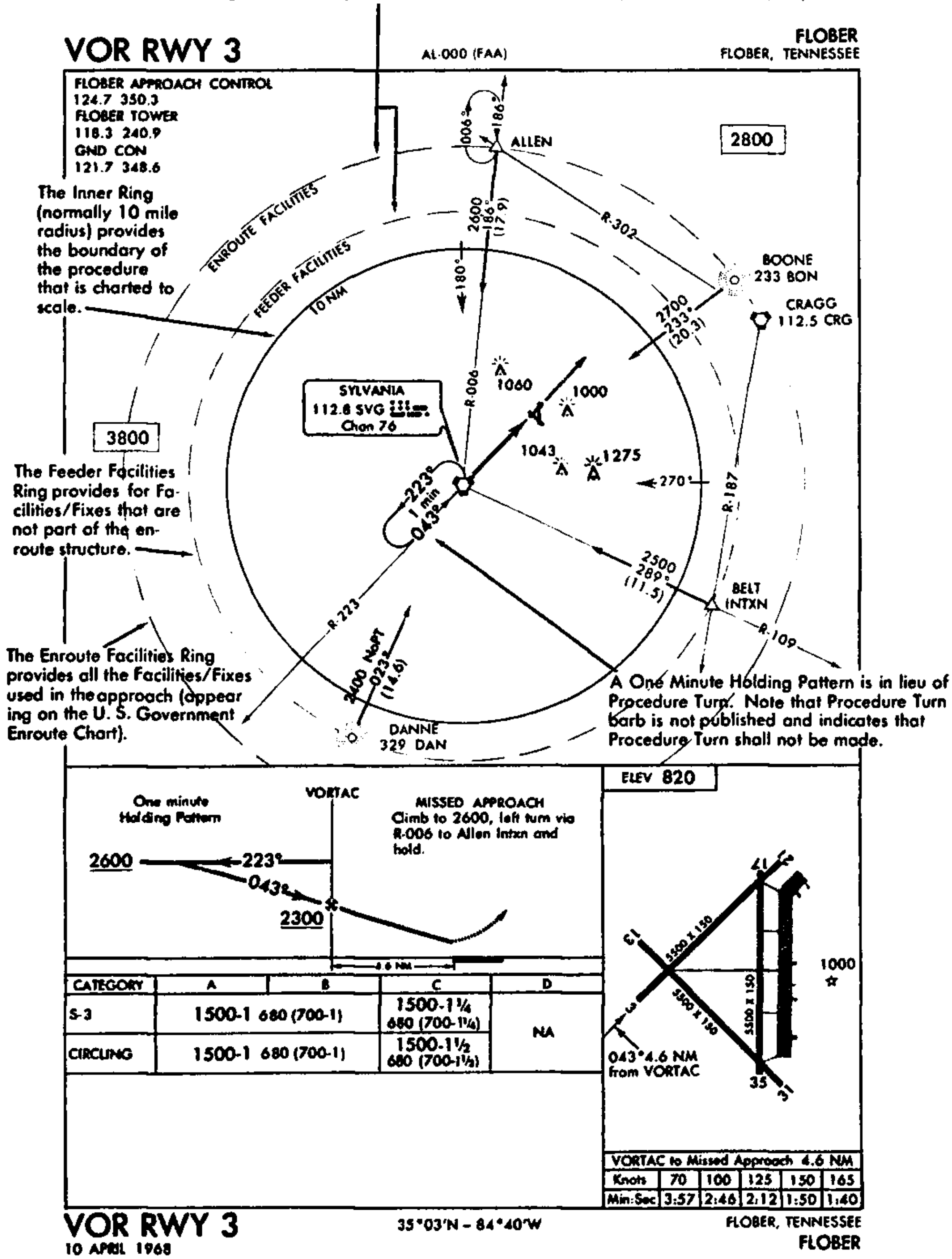
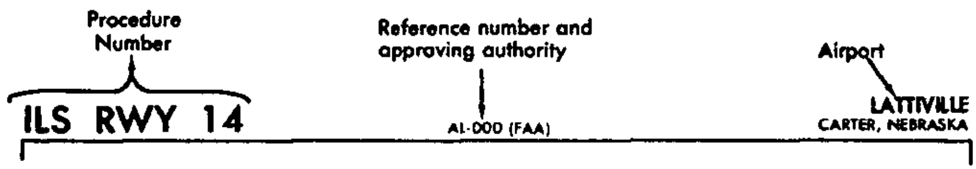


Figure 7

TOP MARGIN IDENTIFICATION



BOTTOM MARGIN IDENTIFICATION

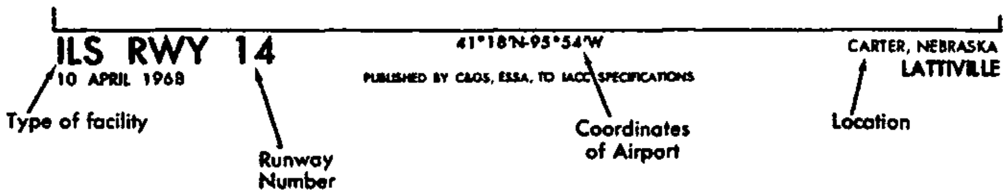


Figure 8

(1) Margin Identification.

(a) The procedure identification is derived from the type facility providing final approach course guidance and (1) runway number when the approach course is within 30° of the runway centerline, i.e., ILS Rwy 14, or (2) sequential number for the airport when the approach course is more than 30° from runway centerline, i.e., VOR-1, VOR-2, etc.

(b) Nondirectional Beacon (NDB), Localizer (LOC) and Localizer Type Directional Aid (LDA) are used to identify more accurately the type facility providing final approach course guidance.

1 "NDB" procedure number replaces ADF type procedure.

2 "LOC" procedure number indicates that a localizer provides course guidance and a glide slope (ground facility) has not been installed. (Includes ILS back course procedures.)

3 "LDA" procedure number is the same as localizer but is not aligned with the runway centerline. The approach chart should be examined to determine the direction and degrees of alignment away from runway centerline.

(c) VOR/DME procedure number means that both operative VOR and DME receivers and ground equipment in normal operation are required to use the procedure. As stated previously, in the VOR/DME procedure, when either the VOR or DME is inoperative, the procedure is not authorized.

(d) When DME arcs and DME fixes are authorized in a procedure and the procedure number does not include the three letter "DME" type of facility in the margin identification, the procedure may be used without utilizing the DME equipment.

(e) VORTAC type procedure is a VOR/DME procedure that is authorized for an aircraft equipped with either VOR/DME or TACAN receiver.

PLAN VIEW
Lattiville Airport
Carter, Nebraska

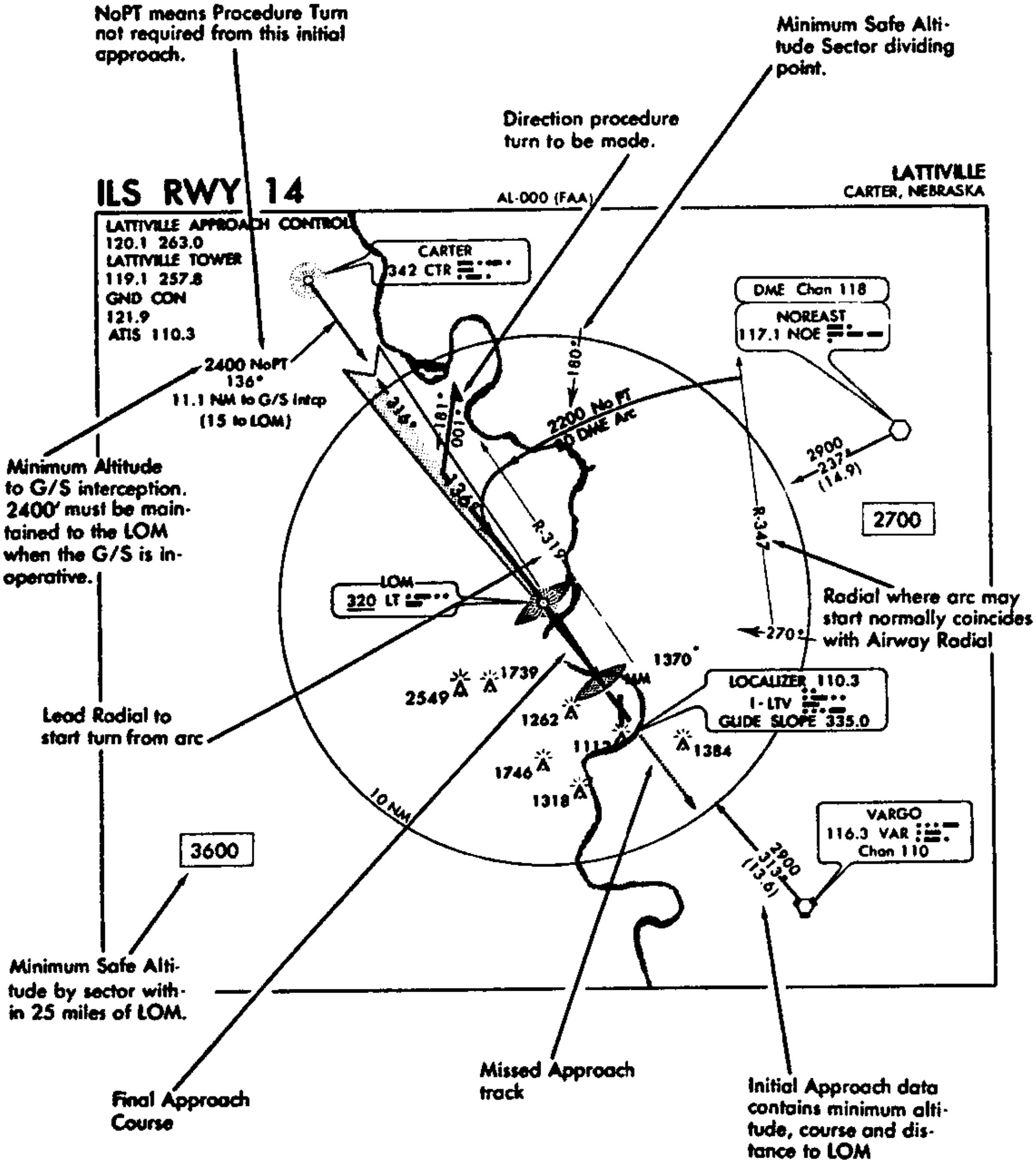


Figure 9

PLAN VIEW
Grenzall-West Airport
Nixa, Missouri

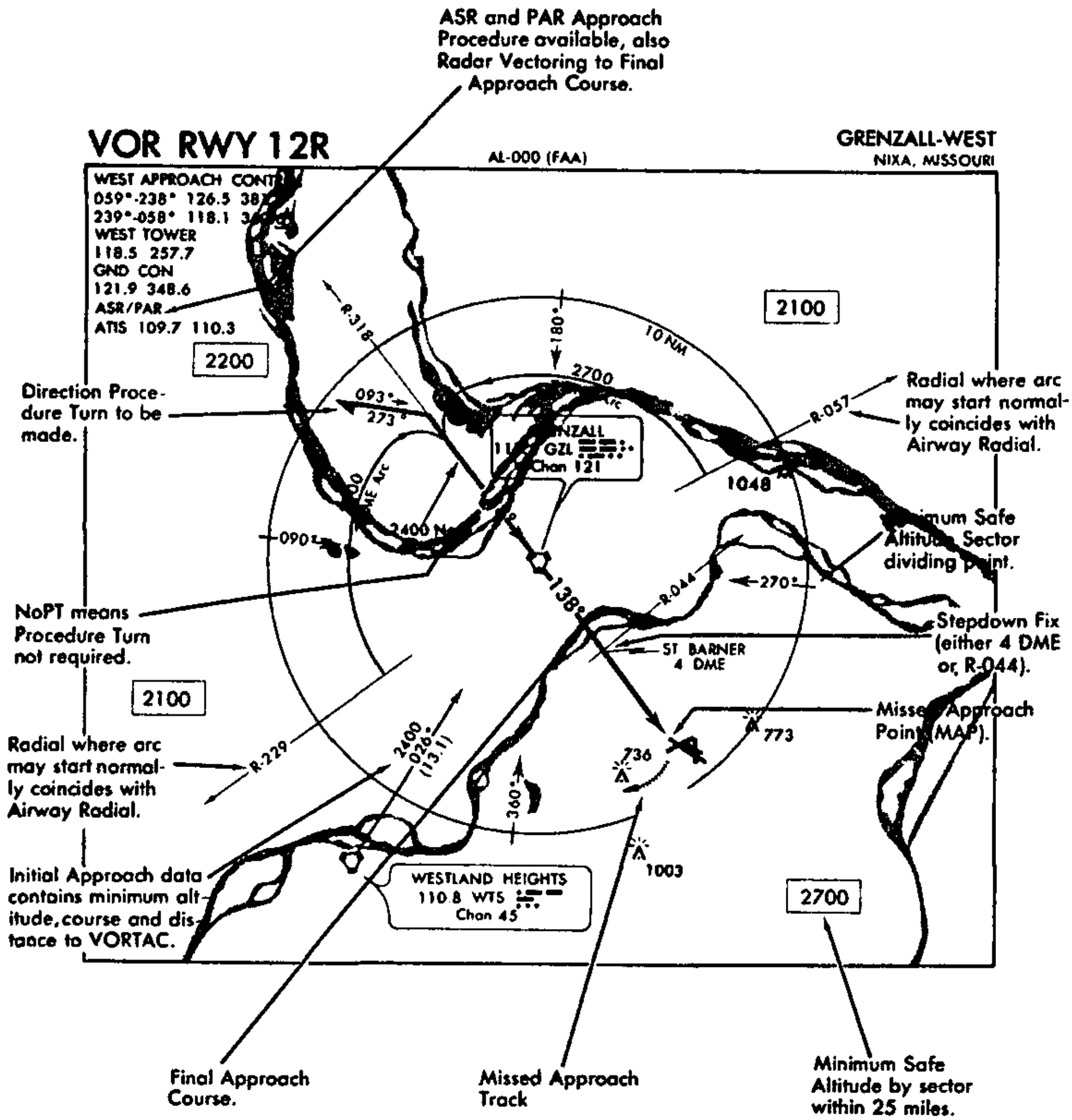


Figure 10

(2) Plan View (Figures 7, 9, and 10). This is a bird's eye view of the entire procedure. Information pertaining to the initial approach segment, including procedure turn, minimum safe altitude for each sector, courses prescribed for the final approach segment and obstructions, is portrayed in this section. Navigation and communication frequencies are also listed on the plan view.

(a) Format. Normally, all information within the plan view is shown to scale. Data shown within the 10 NM distance circle is always shown to scale. (See figure 7.) The dashed circles, called concentric rings, are used when all information necessary to the procedure will not fit to scale within the limits of the plan view area. These circles then serve as a means to systematically arrange this information in their relative position outside and beyond the 10 NM distance circle. These concentric rings are labeled Enroute Facilities and Feeder Facilities.

(b) Enroute Facilities Ring. (See figure 7.) Radio aids to navigation, fixes and intersections that are part of the Enroute Low Altitude Airway structure and used in the approach procedure are shown in their relative position on this Enroute Facilities Ring.

(c) Feeder Facilities Ring. (See figure 7.) Radio aids to navigation, fixes and intersections used by the air traffic controller to direct aircraft to intervening facilities/fixes between the enroute structure and the initial approach fix are shown in their relative position on this Feeder Facilities Ring.

(d) The availability of RADAR (see figure 10) is indicated below the communications information by the appropriate and applicable letters "ASR", "PAR", "ASR/PAR" or "RADAR VECTORING." These terms are applied as follows:

1 ASR - means Airport Surveillance Radar instrument approach procedures are available at the airport, and also that Radar Vectoring is available for the procedure.

2 PAR - means Precision Approach Radar instrument approach procedures are available.

3 RADAR VECTORING - means Radar Vectoring is available but radar instrument approach procedures are not available.

(e) The term "initial approach" is explained in section 97.3(c) (1) of Part 97 of the Federal Aviation Regulations. It is further explained in the FAA Handbook "U.S. Standard for Terminal Instrument Procedures (TERPS)", page 15, section 3, INITIAL APPROACH.

1 In the initial approach, the aircraft has departed the en route phase of flight, and is maneuvering to enter an intermediate or final segment of the instrument approach.

2 An initial approach may be made along prescribed routes within the terminal area which may be along an arc, radial, course, heading, radar vector, or a combination thereof. Procedure turns and high altitude teardrop penetrations are initial approach segments.

3 Initial approach information is portrayed in the plan view of instrument approach charts by course lines, with an arrow indicating the direction. Minimum altitude and distance between fixes is also shown with the magnetic course.

4 When the term "NoPT" appears, an intermediate approach is provided. These altitudes shown with the term "NoPT" cannot be used as an initial approach altitude for the purpose of determining alternate airports requirements under FAR 91.23(c) and 91.83(b).

(f) When an approach course is published on an ILS procedure that does not require a procedure turn (NoPT), the following applies.

1 In the case of a dog-leg track and no fix is depicted at the point of interception on the localizer course, the total distance is shown from the facility or fix to the LOM, or to an NDB associated with the ILS.

2 The minimum altitude applies until the glide slope is intercepted, at which point the aircraft descends on the glide slope.

3 When the glide slope is not utilized, this minimum altitude is maintained to the LOM (or to the NDB if appropriate).

4 In isolated instances, when proceeding NoPT to the LOM and the glide slope cannot be utilized, a procedure turn will be required to descend for a straight-in approach and landing. In these cases, the requirement for a procedure turn will be annotated on the Plan View of the procedure chart.

(g) Procedure turn is the maneuver prescribed when it is necessary to reverse direction to establish the aircraft inbound on an intermediate or final approach course. It is a required maneuver except when the symbol NoPT is shown, when RADAR VECTORING is provided, when a one minute holding pattern is published in lieu of a procedure turn, or when the procedure turn is not authorized. The altitude prescribed for the procedure turn is a minimum altitude until the aircraft is established on the inbound course. The maneuver must be completed within the distance specified in the profile view.

1 A barb indicates the direction or side of the outbound course on which the procedure turn is made. Headings are provided for course reversal using the 45° type procedure turn. However, the point at which the turn may be commenced and the type and rate of turn is left to the discretion of the pilot. Some of the options are the 45° procedure turn, the racetrack pattern, the tear-drop procedure turn, or the 80°— 260° course reversal. These maneuvers are diagrammed in the FAA Instrument Flying Handbook (AC 61-27A), and the steps numbered under the figures are intended for student practice under no-wind conditions.

2 Limitations on procedure turns.

a In the case of a radar initial approach to a final approach fix or position, or a timed approach from a holding fix, or where the procedure specifies "NoPT", no pilot may make a procedure turn unless, when he receives his final approach clearance, he so advises ATC and a clearance is received.

b When a tear-drop procedure turn is depicted and a course reversal is required, this type turn must be executed.

c When a one minute holding pattern replaces the procedure turn, the standard entry and the holding pattern must be followed except when RADAR VECTORING is provided or when NoPT is shown on the approach course. Diagrams of the holding pattern and entries into the pattern also are illustrated in the Handbook 61-27A. As in the procedure turn, the descent from the minimum holding pattern altitude to the final approach fix altitude (when lower) may not commence until the aircraft is established on the inbound course.

d The absence of the procedure turn barb in the Plan View indicates that a procedure turn is not authorized for that procedure.

3 A Procedure Turn is not required when the symbol NoPT appears on an approach course shown on the Plan View. If a procedure turn is desired, descent below the procedure turn altitude should not be made since some NoPT altitudes may be lower than the procedure turn altitude.

PROFILE VIEW (Precision)

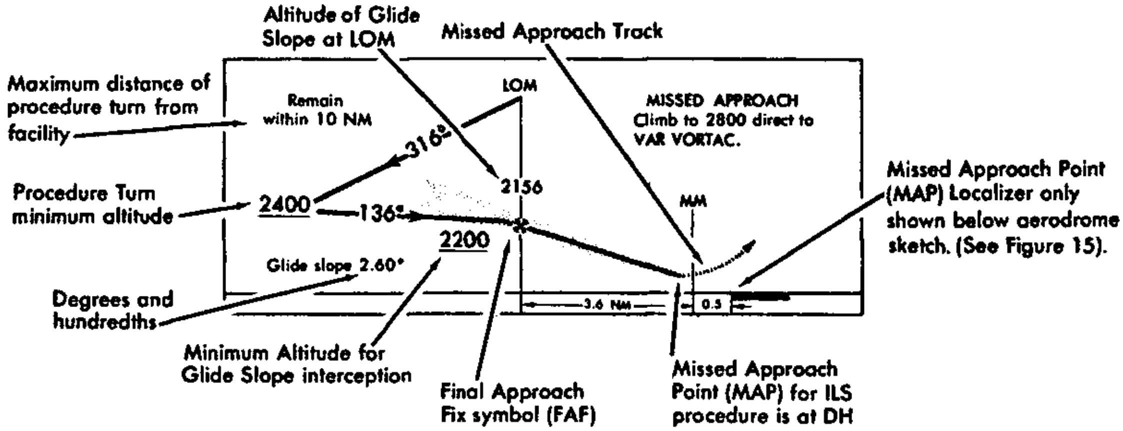


Figure 11

PROFILE VIEW (Non-precision)

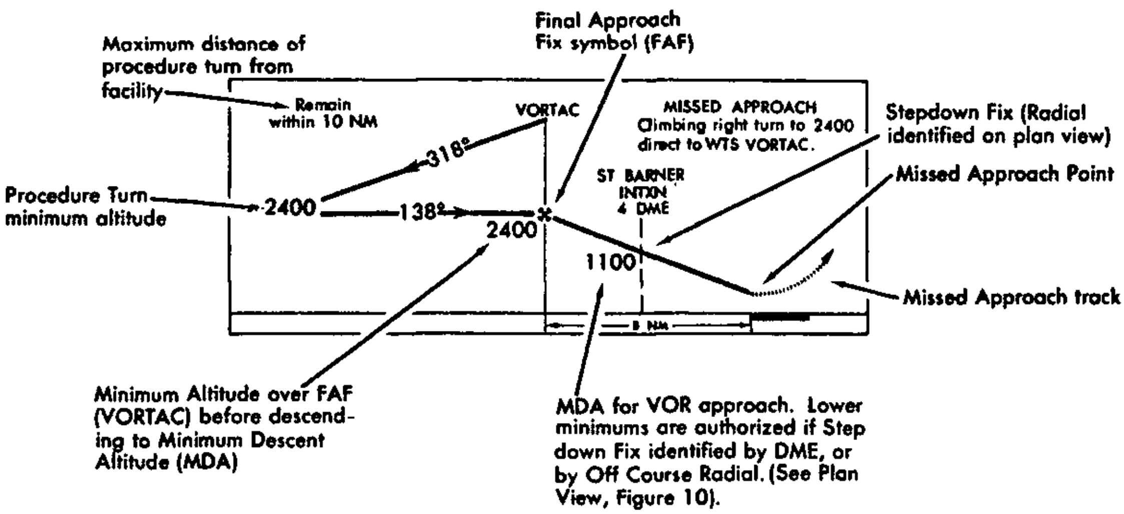


Figure 12

(3) Profile Views (Figures 11 and 12) show a side view of the procedures. These views include the minimum altitude and maximum distance for the procedure turn, altitudes over prescribed fixes, distances between fixes and the missed approach procedure.

(a) Precision approach glide slope intercept altitude. This is a minimum altitude for glide slope interception after completion of procedure turn. It applies to precision approaches and, except where otherwise prescribed, it also applies as a minimum altitude for crossing the final approach fix in case the glide slope is inoperative or not used.

(b) Stepdown fixes in non-precision procedures. A stepdown fix may be provided on the final, i.e., between the final approach fix and the airport for the purpose of authorizing a lower MDA after passing an obstruction. This stepdown fix may be made by an NDB bearing, fan marker, radar fix, radial from another VOR, or by a DME when provided for as shown in figure 12.

(c) Normally, there is only one stepdown fix between the final approach fix (FAF) and the missed approach point (MAP). If the stepdown fix cannot be identified for any reason, the altitude at the stepdown fix becomes the MDA for a straight-in landing. However, when circling under this condition, you must refer to the Minimums Section of the procedure for the applicable circling minimum. See figure 14 for example.

(d) Missed approach point (MAP). It should be specifically noted that the missed approach points are different for the complete ILS (with glide slope) and for the localizer only approach. The MAP for the ILS is at the decision height (DH) while the "localizer only" MAP is usually over the (straight-in) runway threshold. In some non-precision procedures, the MAP may be prior to reaching the runway threshold in order to clear obstructions in the missed approach climb-out area. In non-precision procedures, the pilot determines when he is at the missed approach point (MAP) by timing from the final approach fix (FAF). The FAF has been clearly identified by use of the maltese cross symbol in the profile section. The distance from FAF to MAP and time and speed table, for easy calculation, are found below the aerodrome sketches (figures 15 and 16). This does not apply to VOR/DME procedures, or when the facility is on the airport and the facility is the MAP.

MINIMUMS SECTION (and notes).

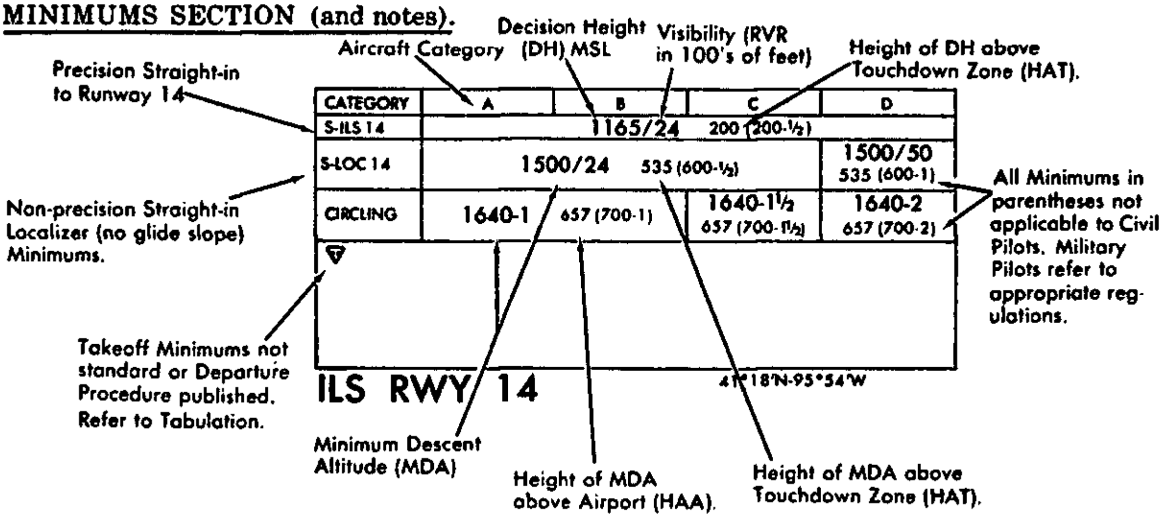


Figure 13

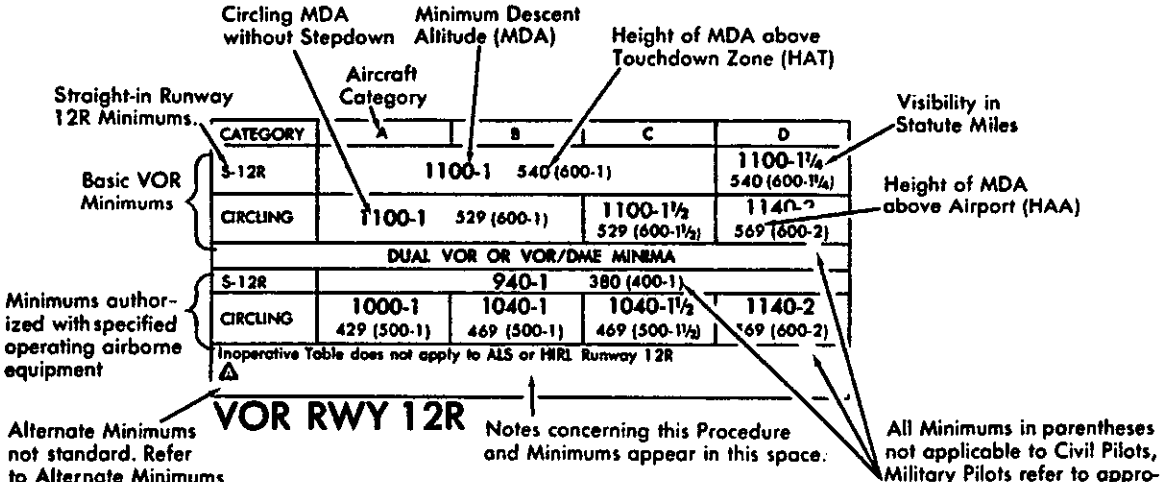


Figure 14

(4) Minimum Section.

(a) The same minimums apply to both day and night operations unless different minimums are specified at the bottom of the minimum box in the space provided for symbols or notes.

(b) The minimums for straight-in and circling appear directly under each aircraft category. When there is no division line between minimums for each category on the straight-in or circling lines, the minimums apply to two or more categories under the A, B, C, or D.

(For figure 13, the S-ILS 14 minimums apply to all four categories. The S-localizer 14 minimums are the same for Categories A, B, and C, and different for Category D. The circling minimums are the same for A and B and individually different for C and D.)

(c) The Nixa, Missouri, Grenzall West Airport, VOR Rwy 12R procedure (figures 12 and 14) authorizes minimums for aircraft with one VOR receiver. Lower minimums are authorized if the aircraft also has DME or dual VOR receivers and St. Barner Intersection is identified. (See figure 14 for dual minimums.)

(5) Aerodrome Data.

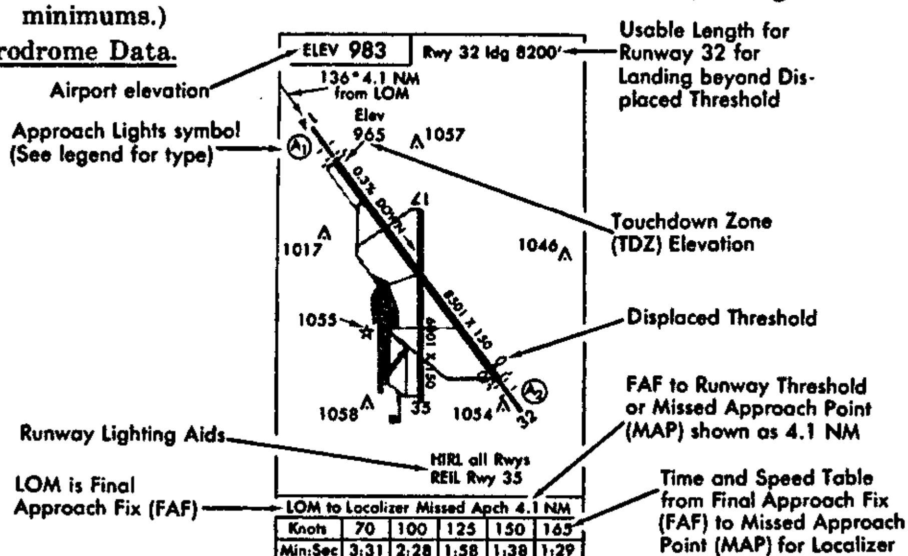


Figure 15

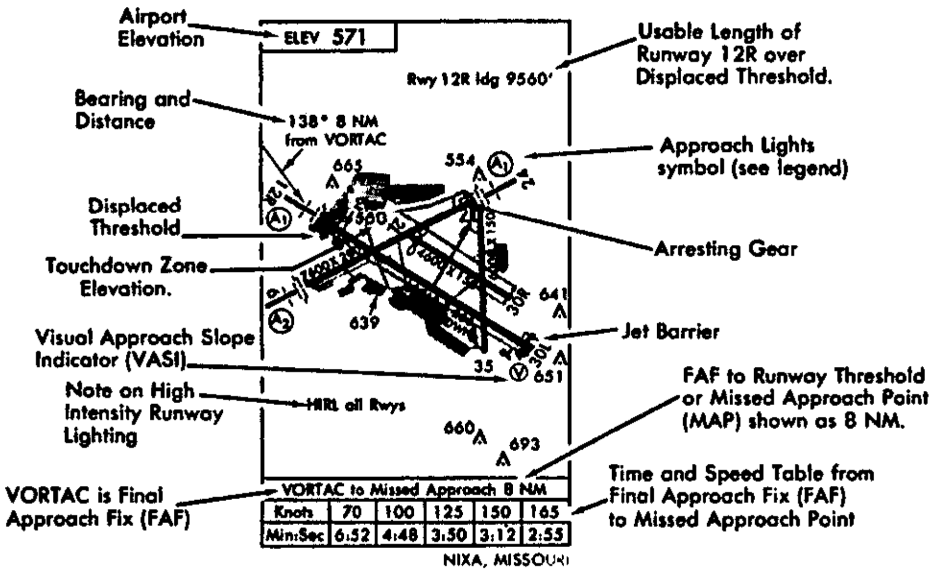


Figure 16

(6) General Information.

(a) During pre-flight planning prior to departure on an IFR flight plan, reference should be made to instrument approach charts to determine:

1 Take-off minimums.

2 Whether an IFR departure procedure for obstruction avoidance has been established.

Instrument approach charts in the old format have take-off minimums and departure procedures published on the chart. Procedures published under the revised format do not contain this information. Take-off minimums are standard (see paragraph 3.b.) unless the symbol ▼ is shown under the minimums box indicating that the separate listing should be consulted. Below is an example of this listing.

INSTRUMENT APPROACH PROCEDURES (CHARTS)
SOUTHEAST UNITED STATES

▼ IFR TAKE-OFF MINIMUMS AND DEPARTURE PROCEDURES

FAR 91.116(c) prescribes take-off rules for FAR 121, 129, and 135 operators and establishes standard take-off visibility minimums as follows:

(1) Aircraft having two engines or less – one statute mile.

(2) Aircraft having more than two engines – one-half statute mile.

Aerodromes within this geographical area with IFR take-off minimums other than standard are listed below alphabetically by aerodrome name. Departure procedures and/or ceiling and visibility minimums are established to assist pilots conducting IFR flight in avoiding obstructions during climb to the minimum enroute altitude.

Take-off minimums and departure procedures apply to all runways unless otherwise specified.

AERODROME NAME	TAKE-OFF MINIMUMS	AERODROME NAME	TAKE-OFF MINIMUMS
CARTER-LATTIVILLE Carter, Nebraska	500-2		

Figure 17

(b) When use of an alternate airport is required in filing an IFR flight plan (FAR 91.83), reference should be made to the instrument approach procedure to be used for the alternate selected to determine alternate airport minimums. Procedures charted in the old format have alternate minimums shown on the chart. Procedures charted in the new format do not contain this information. Alternate minimums are standard (see paragraph 3.c.) unless the symbol △ is shown under the minimums box indicating that alternate minimums are not standard and that the separate listing should be consulted. If the airport is not authorized for use as an alternate, the letters "NA" will follow the symbol under the minimum box. Below is an example of the Alternate Minimums listing.

NOTE: If the pilot elects to proceed to the selected alternate airport, the alternate ceiling and visibility minimums are disregarded, and the published landing minimum is applicable for the new destination utilizing facilities as appropriate to the procedure. In other words, the alternate airport becomes a new destination, and the pilot uses the landing minimum appropriate to the type of procedure selected.

INSTRUMENT APPROACH PROCEDURES (CHARTS)
WEST CENTRAL UNITED STATES

△ IFR ALTERNATE MINIMUMS

(Not applicable to USAF/USN)

Standard alternate minimums for nonprecision approaches are 800-2 (NDB, VOR, LOC, TACAN, LDA, VORTAC, VOR/DME or ASR); for precision approaches 600-2 (ILS or PAR). Aerodromes within this geographical area that require alternate minimums other than standard or alternate minimums with restrictions, are listed below. U. S. Army pilots refer to Army Reg. 95-2 for additional application. Civil pilots see FAR 91.83. USAF/USN pilots refer t- appropriate regulations.

AERODROME NAME	ALTERNATE MINIMUMS	AERODROME NAME	ALTERNATE MINIMUMS
NIXA GRENZALL ARPT Nixa, Missouri Categories A, B and C, 1100-2; category D, 1200-2	VOR Rwy 12R		

Figure 18

(c) The tables which appear as samples in (a) and (b) above are printed for area chart books, and should be kept with the Legend pages and Inoperative Components or Visual Aids Table at the front of each area chart book.

(d) Straight-in minimums are shown on instrument approach procedure charts when the final approach course of the instrument approach procedure is within 30° of the runway alignment and a normal descent can be made from the IFR altitude shown on the instrument approach procedures to the runway surface. When either the normal rate of descent or the runway alignment factor of 30° is exceeded, a straight-in minimum is not published and a circling minimum applies. The fact that a straight-in minimum is not published does not preclude the pilot from landing straight-in if he has the active runway in sight in sufficient time to make a normal landing. Under such conditions and when Air Traffic Control has cleared him for landing on that runway, he is not expected to circle even though only circling minimums are published. If he desires to circle at a controlled Airport, he should advise ATC.

(e) Circling Minimums. The circling minimums published on the instrument approach chart provide adequate obstruction clearance and the pilot should not descend below the circling altitude until the aircraft is in a position to make final descent for landing. Sound judgement and knowledge of his and the aircraft capabilities are the criteria for a pilot to determine the exact maneuver in each instance since the airport design, the aircraft position, altitude and airspeed must all be considered. The following basic rules apply.

1 Maneuver the shortest path to the base or downwind leg as appropriate under minimum weather conditions. There is no restriction from passing over the airport or other runways.

2 It should be recognized that many circling maneuvers may be made while VFR flying is in progress at the airport. Standard left turns or specific instruction from the controller for maneuvering must be considered when circling to land.

3 At airports without a control tower, it may be desirable to fly over the airport to determine wind and turn indicators, and to observe other traffic which may be on the runway or flying in the vicinity of the airport.

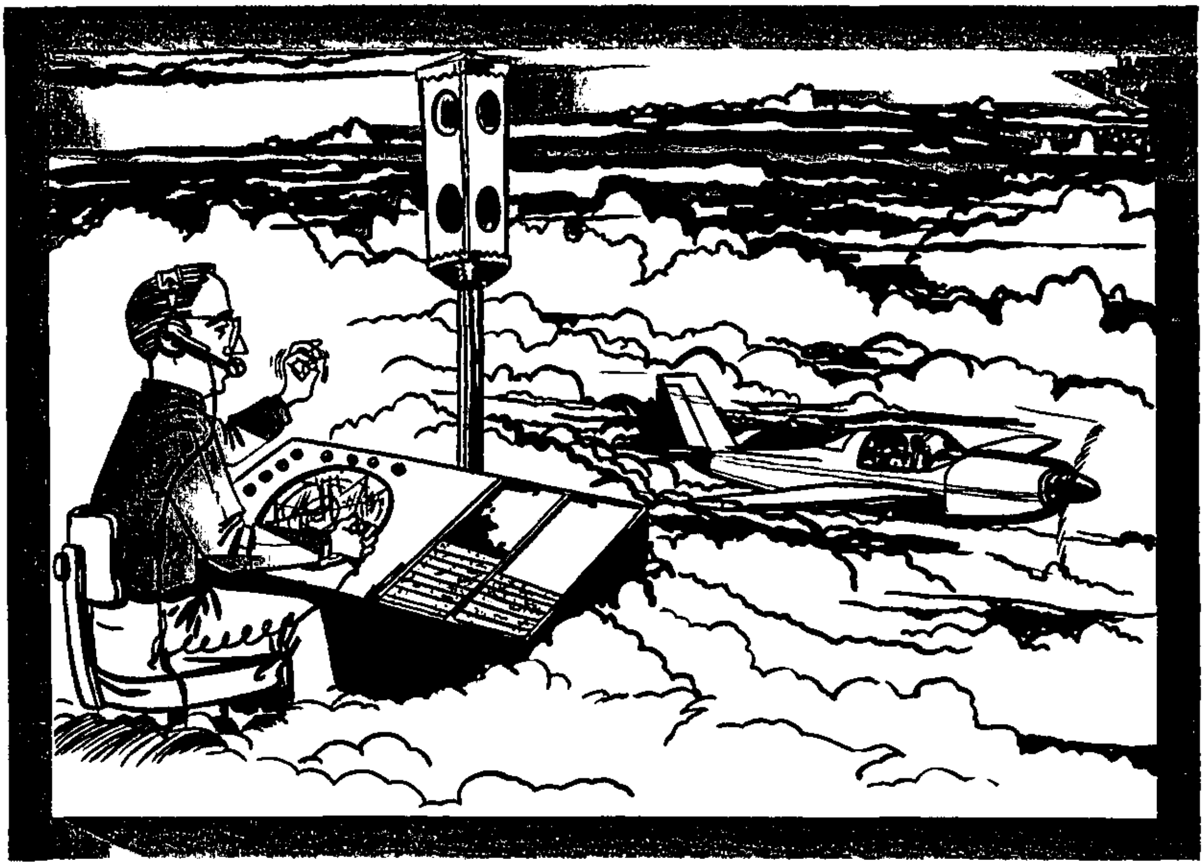
(f) When the missed approach procedure specifies holding at a facility or fix, holding shall be in accordance with the holding pattern depicted on the plan view, and at the minimum altitude in the missed approach instructions, unless a higher altitude is specified by ATC. An alternate missed approach procedure may also be given by ATC.

(g) There are various terms in the missed approach procedure which have specific meanings with respect to climbing to altitude, to execute a turn for obstruction avoidance, or for other reasons. Examples:

'Climb to' means a normal climb along the prescribed course.

'Climbing right turn' means climbing right turn as soon as safety permits, normally to avoid obstructions straight ahead.

'Climb to 2400 turn right' means climb to 2400 prior to making the right turn, normally to clear obstructions.



X. AIR TRAFFIC CONTROL

There is normally nothing very difficult involved in takeoff, climb, cruise from point to point, and descent solely by reference to instruments. The complications arise when you must execute these maneuvers at precise times, at specified altitudes, over designated routes and geographic positions, and in an orderly sequence with other aircraft. An understanding of the Air Traffic Control system will impress upon you the importance of the training necessary for you to apply the proficiency you have acquired in basic instrument flying and radio navigation techniques.

Federal regulation of civil aviation began with the Air Commerce Act of 1926 and the creation of the Aeronautics Branch in the U.S. Department of Commerce. The Department was concerned with the promotion of air safety, licensing of pilots, development of air navigation facilities, and issuing of flight information. Until the volume of air traffic increased, there was no need for air traffic control, since the likelihood of aircraft colliding in flight was remote.

The need for controlling air traffic was recognized in the 1930's as the aviation industry produced bigger, faster, and safer aircraft, and air transportation became an accepted mode of public travel. A number of large cities, concerned with regulating the increasing air traffic at their airports, built control towers and inaugurated a control service on, and in the immediate vicinity of, the airports. Airline companies, eager to expand and improve their operations, established control centers at Cleveland, Chicago and Newark to provide their pilots with position and estimated time of arrival information during instrument flights between those cities.

In 1936, the Federal Government assumed the responsibility for operation of the centers, employing eight controllers. As aviation has grown, so have the Federal Government functions and the agency charged with the promotion and safety of civil aviation. Today, at the beginning of the 1970's, approximately 23,000 ATC personnel provide direction and assistance to over 100 million flights annually.

The number of active aircraft has increased from 29,000, all flying at relatively slow and uniform speeds, to more than 100,000 aircraft operating at various speeds ranging to more than 1,000 miles per hour. The aerial highways have expanded from a few intercity routes to more than 187,000 miles of very high frequency routes utilizing approximately 1,000 VOR and VORTAC stations. A continued increase in traffic volume is expected during the coming decade.

The difficulties associated with mixed IFR and VFR traffic and with diverse pilot training and varying aircraft capabilities, the trend toward automated electronic equipment, and other aspects of control will have a profound effect on flight operations, under both Visual and Instrument Flight Rules.

As an instrument pilot normally operating under the jurisdiction of Air Traffic Control, your understanding of the present system and its operation will better enable you to make full use of ATC services.

Structure and Functions of Air Traffic Service

Air Traffic Service of FAA is responsible for three major general functions: developing plans, establishing standards, and implementing systerms for control of air traffic. The two specific functions of immediate concern to the instrument pilot are:

1. Providing preflight and inflight service to all pilots.
2. Keeping aircraft safely separated while operating in controlled airspace.

The preflight and inflight services to pilots are the responsibility of the Flight Service Stations (FSS). An extensive teletype and interphone system permits relay of information from many sources. Many of the services provided by tower and flight service personnel are familiar to the VFR pilot. Aircraft separation is the primary responsibility of both Airport Traffic Control Towers and Air Route Traffic Control Centers (ARTCC). Knowledge of the physical setup and services provided by each type of facility enables the instrument pilot to get information and assistance and to communicate with the appropriate controllers with confidence and efficiency.

Airport Traffic Control Towers

Jurisdiction.—The ATC tower is responsible for control of aircraft on and in the immediate vicinity of airports. Terminals handling a large traffic volume employ specialized personnel for operations; they use light signals, radio, and ASDE radar (Airport Surface Detection Equipment) for control of surface traffic. Less congested airports have fewer controllers to handle the workload with less specialization.

Organization of the tower operations falls into the following units:

Local Control is concerned mainly with VFR traffic in and around the traffic pattern and with ground traffic. The local controller works with the other IFR controllers to integrate VFR and IFR flights into a smooth, safe traffic flow in and out of the airport.

Ground Control directs the movement of aircraft on the airport surface, working closely with other tower positions. The controller relays clearances from ARTCC to departing IFR flights unless a special position is assigned that function.

Clearance Delivery is accomplished by a separate controller at most busy terminals where heavy ground traffic and frequent IFR departures require division of the workload.

Departure Control originates departure clearances and instructions to provide separation between departing and arriving IFR flights. Although the physical location of this controller varies at different terminals—in the tower at some locations, in separate radar installations at others—he coordinates closely with the Approach Controller and Local Controller.

Approach (Arrival) Control formulates and issues approach clearances and instructions to provide separation between arriving IFR aircraft, using radar if available.

Tower services provide:

1. Control of aircraft on, and in the vicinity of, the airport.
2. Coordination with pilots and Air Route Traffic Control Centers for IFR clearances.
3. Air traffic advisories to pilots concerning observed, reported, and estimated positions of aircraft that might present a hazard to a particular flight.
4. Flight assistance, including transmission of pilot reports and requests, and weather advisories.

Approach/Departure Control services provide:

1. Navigation assistance by radar vector for departing and arriving aircraft.
2. DF assistance to lost aircraft, and cooperation with other facilities in Search and Rescue operations.

Air Route Traffic Control Centers

Jurisdiction.—The primary function of the ARTCC is the direction of all aircraft operating under Instrument Filght Rules in controlled airspace. The Center has no jurisdiction over flights operating (1) under Visual Flight Rules on or off airways, (2) under Instrument Flight Rules outside of controlled airspace, and (3) below the floor of low-altitude Federal Airways.

Organization.—The ARTCC facilities are located throughout the continental United States at central points in areas over which they exercise control. Each Center controls IFR traffic within its own area and coordinates with adjacent Centers for the orderly flow of traffic from area to area. Each Center's control area is divided into Sectors, based upon traffic flow patterns and controller workload.

Each Sector Controller, with one or more assistants, is responsible for traffic within his sector. As an IFR flight departs, the affected Sector Controller follows the progress of the flight, maintaining a continuing written record of route, altitude, and time, and monitors the flight with long-range radar equipment when available. Each Sector Controller has a sector discrete frequency for direct communication with IFR flights within his sector. As an IFR flight progresses to adjacent sectors and centers, and finally to the destination terminal facility, the IFR pilot is requested to change to appropriate frequencies.

ARTCC Services provide:

1. Control of aircraft operating under Instrument Flight Rules in controlled airspace.
2. Air traffic advisories to aircraft concerning potential hazards to flight, anticipated delays, and any other data of importance to the pilot for the safe conduct of the flight.
3. Navigation assistance by radar vectors for detouring thunderstorms and expediting routing.
4. Transmission of pilot reports and weather advisories to enroute aircraft.
5. Flight assistance to aircraft in distress.

Flight Service Stations

Flight Service Stations provide preflight and inflight services to pilots. Although this type of facility has no air traffic control authority over either VFR or IFR traffic, it renders extensive assistance to all air traffic. Many of these services are familiar to the VFR pilot.

FSS Services provide:

1. Preflight weather briefings for both VFR and IFR flights. Using the latest aviation weather information, the pilot briefer is qualified to interpret and discuss airway weather, weather maps, forecasts, pilot reports, and other significant route information related to the pilot's flight planning.
2. Handling of flight plans. VFR flight plans are filed with the Flight Service Station, which forwards the flight plan data to the FSS at, or nearest, the destination airport. IFR flight plans filed with the Flight Service Station are forwarded to the Center having jurisdiction over the departing flight.
3. Weather reports (scheduled and on request) and weather advisories.
4. Airport data concerning uncontrolled airports, without tower control, information concerning enroute and terminal facilities, and other special information requested by the pilot.
5. Relay of communications between aircraft and Centers for aircraft not able to communicate directly with the Center, including IFR clearances to pilots and position reports to the Center.
6. Emergency and Rescue service to distressed or lost aircraft.

IFR Control Sequence

To illustrate the typical IFR flight sequence of control, follow an imaginary trip from Oklahoma City, Okla. (OKC), to Washington, D.C. (DCA).

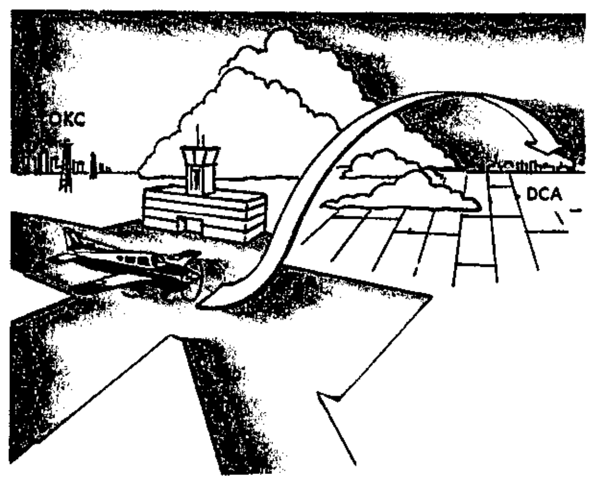


FIGURE 181. IFR—Oklahoma City to Washington, D.C.

The pilot of N543K has filed the flight plan, either in person or by telephone, with the OKC Flight Service Station giving the information necessary for the Center to coordinate his flight with other IFR traffic. (At airports where no Flight Service Station is available, the flight plan may be filed by local or long distance telephone to a Flight Service Station, an ATC Tower, or ARTCC.)

FIGURE 182. Filing the flight plan.

The OKC Flight Service Station then transmits pertinent flight plan data by interphone or teletype to the Fort Worth Air Route Traffic Control Center, which controls the departure point.

Upon receipt of the flight plan in the Fort Worth Center, a specialist at the Flight Data Position prepares flight progress strips for designated fixes along the route of flight within the Fort Worth Center's area of jurisdiction. The flight progress strips are held temporarily, with no time estimates or altitude entries made, until the flight is ready for takeoff.

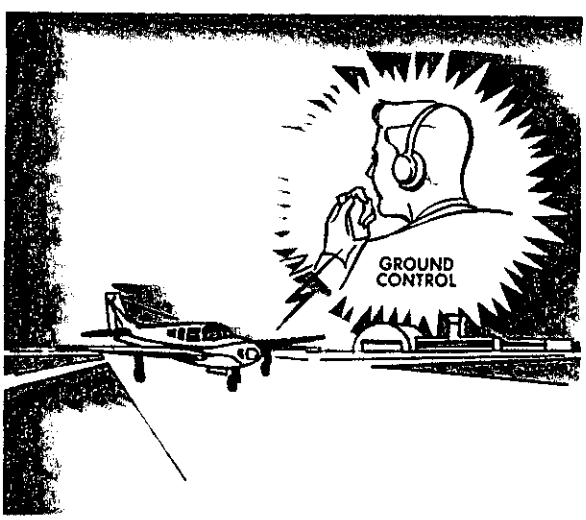


FIGURE 183. Copying the clearance.

Prior to taxiing, the pilot should call clearance delivery (if available at the airport) or ground control and request IFR clearance. If there is to be a delay, you would normally be so advised at this time. Airports with "Pre-Taxi Clearance Procedures" will probably have your clearance and issue it to you immediately. The clearance would be issued as follows:

NOVEMBER FIVE FOUR THREE KILO CLEARED TO THE WASHINGTON AIRPORT VIA VICTOR FOURTEEN SOUTH, TULSA, FLIGHT PLAN ROUTE. CROSS SHAWNEE INTERSECTION AT FIVE THOUSAND, MAINTAIN SEVEN THOUSAND. DEPARTURE CONTROL FREQUENCY WILL BE ONE TWO FOUR POINT SEVEN.

The pilot should copy this clearance and read it back substantially the same as issued. This clearance was originated in the Fort Worth Center and the clearance delivery controller is merely relaying it to you. However, he may add certain restrictions required by the Oklahoma City departure controller.

After receipt and acknowledgement of the IFR clearance, the pilot should contact ground control and request taxi clearance to the runway in use.

After engine run-up, the pilot changes to tower frequency (118.3), advises that he is ready for takeoff, and receives the following clearance:

NOVEMBER FIVE FOUR THREE KILO LEFT TURN AFTER TAKEOFF HEADING ZERO NINE ZERO, CLEARED FOR TAKEOFF.

Upon departure, the local controller notifies the Oklahoma City departure controller and the Fort Worth Center that N543K has departed.

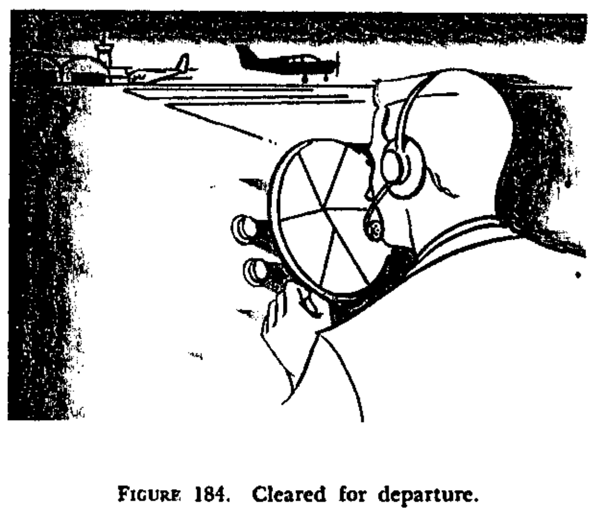


FIGURE 184. Cleared for departure.

When approximately ½ mile from end of runway, the local controller will advise:

NOVEMBER FIVE FOUR THREE KILO CONTACT DEPARTURE CONTROL.

The departure controller will radar identify your aircraft and issue further instructions to provide separation from other aircraft in the terminal area and establish you on your intended route.

NOVEMBER FIVE FOUR THREE KILO, OKLAHOMA CITY DEPARTURE CONTROL, RADAR CONTACT, FLY HEADING ZERO NINE ZERO TO INTERCEPT VICTOR FOURTEEN SOUTH.

The phrase "TO INTERCEPT VICTOR FOURTEEN SOUTH" indicates that the pilot should resume normal navigation upon intercepting the airway without further clearance. In the absence of instructions "TO INTERCEPT" the pilot should maintain the last assigned heading even though it will take him through the assigned airway. It is possible that the departure controller is using this means to provide separation from another aircraft. Normally, the controller would advise "NOVEMBER FIVE FOUR THREE KILO MAINTAIN HEADING ZERO NINE ZERO FOR VECTORS EAST OF VICTOR FOURTEEN SOUTH TO PASS TRAFFIC AHEAD," however, time does not always permit this advisory to be issued.

As N543K approaches Shawnee intersection, the pilot is advised to contact Fort Worth Center on a specified frequency. Since you have been radar identified, your correct initial call would be:

FORT WORTH CENTER THIS IS NOVEMBER FIVE FOUR THREE KILO LEAVING FIVE THOUSAND.

Fort Worth Center replies:

NOVEMBER FIVE FOUR THREE KILO, FORT WORTH CENTER, RADAR CONTACT, THREE MILES EAST OF SHAWNEE, REPORT LEAVING SIX THOUSAND.

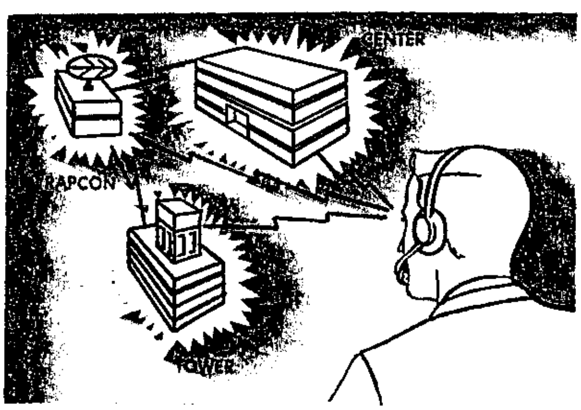


FIGURE 185. Enroute control.

Since N543K is operating in a radar environment, and has been advised "radar contact," his only reports would be those specifically requested by the controller; however, each time the aircraft is changed to a different control facility or to a different sector within a facility, the pilot should report his altitude on the initial call.

When advised "RADAR SERVICE TERMINATED" or "RADAR CONTACT LOST," the pilot should resume normal position reporting procedures.

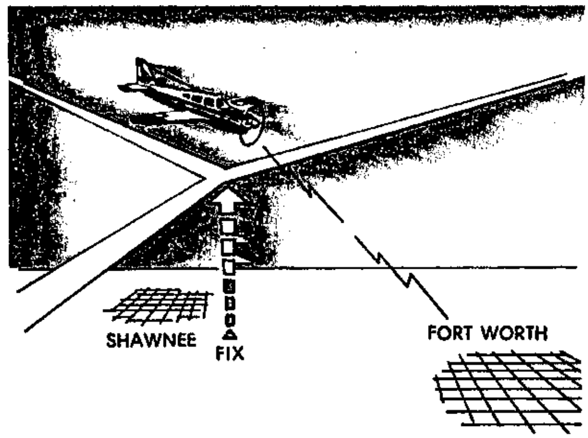


FIGURE 186. Position report.

As the flight progresses along airways, the flight data information is passed along from sector to sector within each Center, and from Center to Center along the route. Each controller receives advance notification of this flight and determines if there is any conflict with traffic within his sector. He is responsible for issuing control instructions which will provide standard separation between all aircraft under his control. This may be accomplished by route changes, altitude changes, requiring holding or providing radar vectors off course.

As the flight nears the Washington Terminal area, the Center controller initiates coordination with Washington approach control. As you enter the terminal area, the Center controller will effect what is known as a "Radar Hand-off" to Washington approach control. This is a method whereby one controller points out a target to another controller and thereby transfers control without an interruption in radar service. In the absence of a "Radar Handoff" it would be necessary for the approach controller to use one of several other means to identify your aircraft, such as identifying turns, position reports, or transponder.

When both controllers are satisfied with the identification of N543K, the pilot will be advised to contact Washington approach control on a specified frequency.

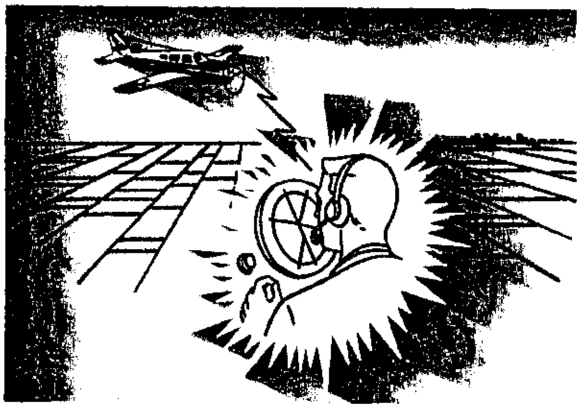


Figure 187. Positive identification by approach control.

Prior to this frequency change, the pilot should have determined that ATIS (Automatic Terminal Information Service) is available at Washington National Airport and he should have tuned in the proper frequency and listened to the information. If you have received the ATIS broadcast, you should advise the approach controller. The ATIS provides all the necessary approach, runway, NOTAM, and other pertinent information for landing at Washington National. The controller need provide only necessary control instructions. Your initial call to Washington approach control would be:

WASHINGTON APPROACH CONTROL, NOVEMBER FIVE FOUR THREE KILO SEVEN THOUSAND, INFORMATION BRAVO.

The approach controller's action now depends on the conditions and traffic at the airport. If no approach delay were expected, his reply to N543K would be:

NOVEMBER FIVE FOUR THREE KILO, WASHINGTON APPROACH CONTROL, RADAR CONTACT, FIVE MILES WEST OF HERNDON, FLY HEADING ONE TWO ZERO FOR VECTORS TO FINAL APPROACH COURSE, OVER.

(Note: ATIS information BRAVO advised that ILS approach to runway 36 would be expected.)

The approach controller will now provide radar navigation to position your aircraft so as to intercept the final approach course prior to the outer marker. You will be advised to descend in sufficient time to reach the proper glide path interception altitude. Your clearance for an ILS approach will be issued when the controller has provided proper spacing between N543K and other aircraft under his control and when N543K is on a course which will intercept the ILS course, outside the outer marker, on not more than a 30° angle. This clearance will be issued as follows:

NOVEMBER FIVE FOUR THREE KILO, THREE MILES FROM OUTER MARKER, CLEARED FOR ILS APPROACH, CONTACT TOWER ON ONE ONE EIGHT POINT FIVE OVER THE OUTER MARKER.

(Note: Pilot should not turn on the ILS course unless this clearance is received.)

N543K will now turn on the ILS when he intercepts it and will complete his approach to a landing or to the "MISSED APPROACH POINT." A procedure turn should not be made unless ATC is advised.

If the traffic conditions at the airport required a delay, the approach controller would have issued instructions to N543K to proceed to a holding point to hold until his turn for approach arrived. This clearance would have been:

NOVEMBER FIVE FOUR THREE KILO, WASHINGTON APPROACH CONTROL, RADAR CONTACT, FIVE MILES WEST OF HERNDON, MAINTAIN SEVEN THOUSAND, PROCEED DIRECT TO HERNDON VORTAC, HOLD WEST ON VICTOR FOUR. EXPECT APPROACH CLEARANCE AT 1135.

At the appropriate time, N543K would have been instructed to depart Herndon on a specific heading and would have been vectored to final approach as in the preceding example.

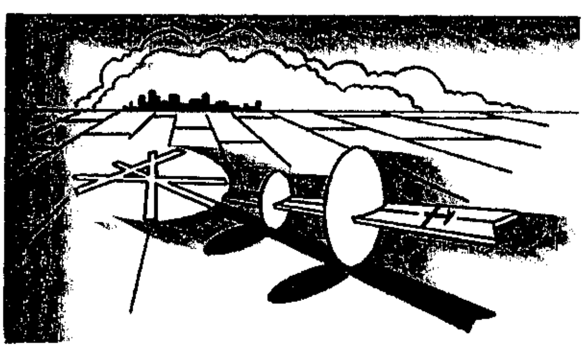


Figure 188. ILS approach.

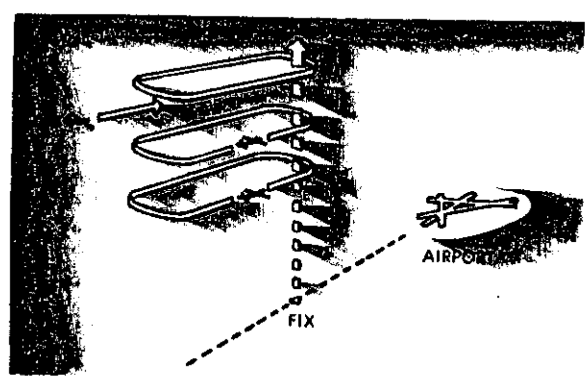


Figure 189. Stacking.

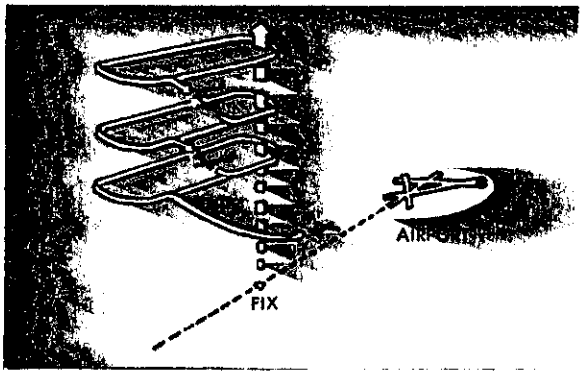


FIGURE 190. Shuttle.

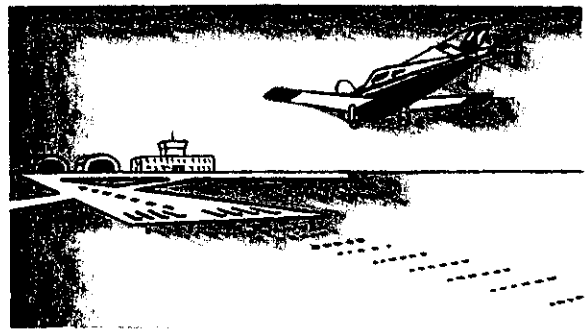
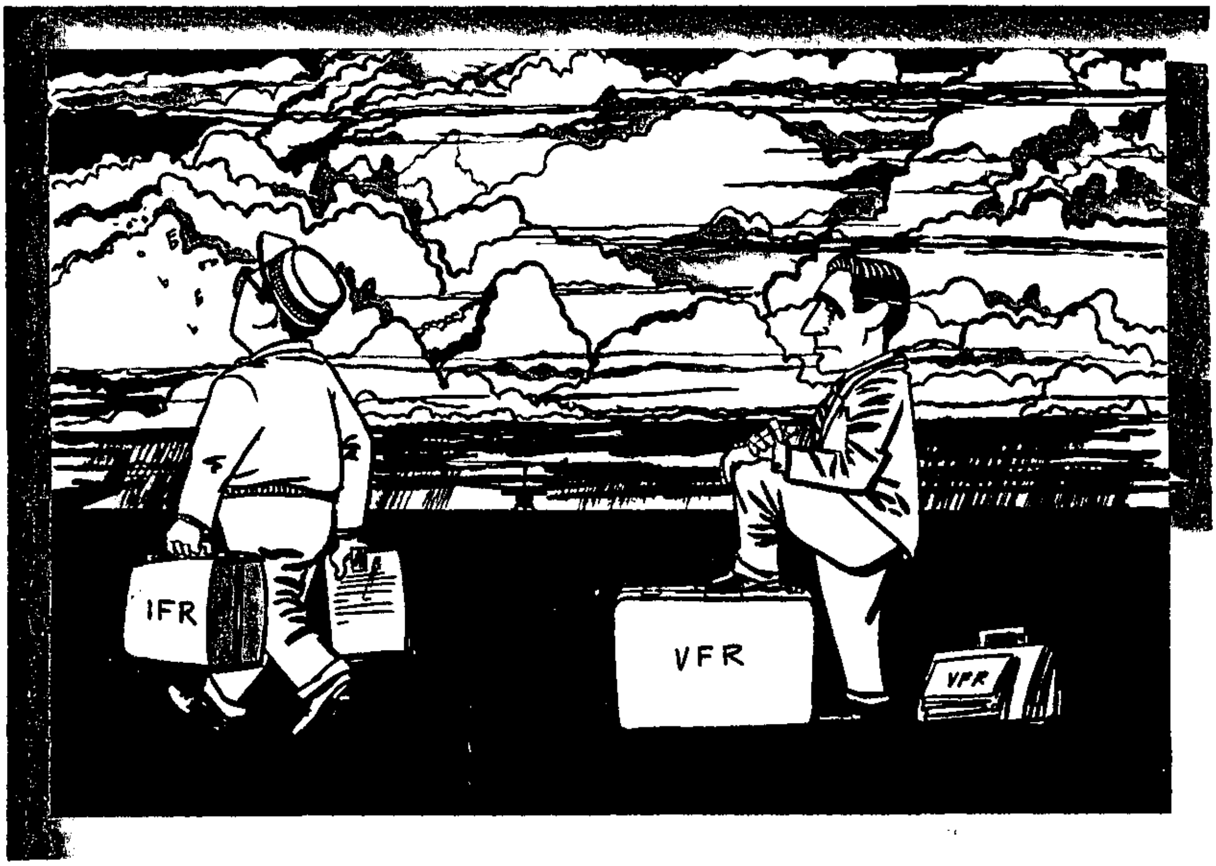


FIGURE 191. Cleared to land.

After the approach and landing is completed, the local controller will advise the pilot where to turn off the runway and when to contact ground control.

In summary, the foregoing picture of an IFR flight illustrates the need for adherence to carefully established procedures for safe, orderly, and expeditious traffic flow. The pilot and controller must know what to expect of each other, as well as knowing the details of their own special authority and responsibility. The controller, for example, must be aware of the performance capabilities of the various aircraft operating in the system for he must issue clearances and instructions with which the aircraft are capable of complying. Likewise, the instrument pilot should understand the overall traffic control problem and the standardized IFR control procedures so that he will not be caught unawares by an unexpected request or change in clearance. In fact, the experienced pilot usually knows beforehand what the controller will say and when he will say it. During periods of heavy traffic conditions, when clearances sometimes may seem complicated or unduly restrictive to the pilot, the utmost cooperation between the pilot and controller is especially required.



XI. ATC OPERATIONS AND PROCEDURES

Using the System

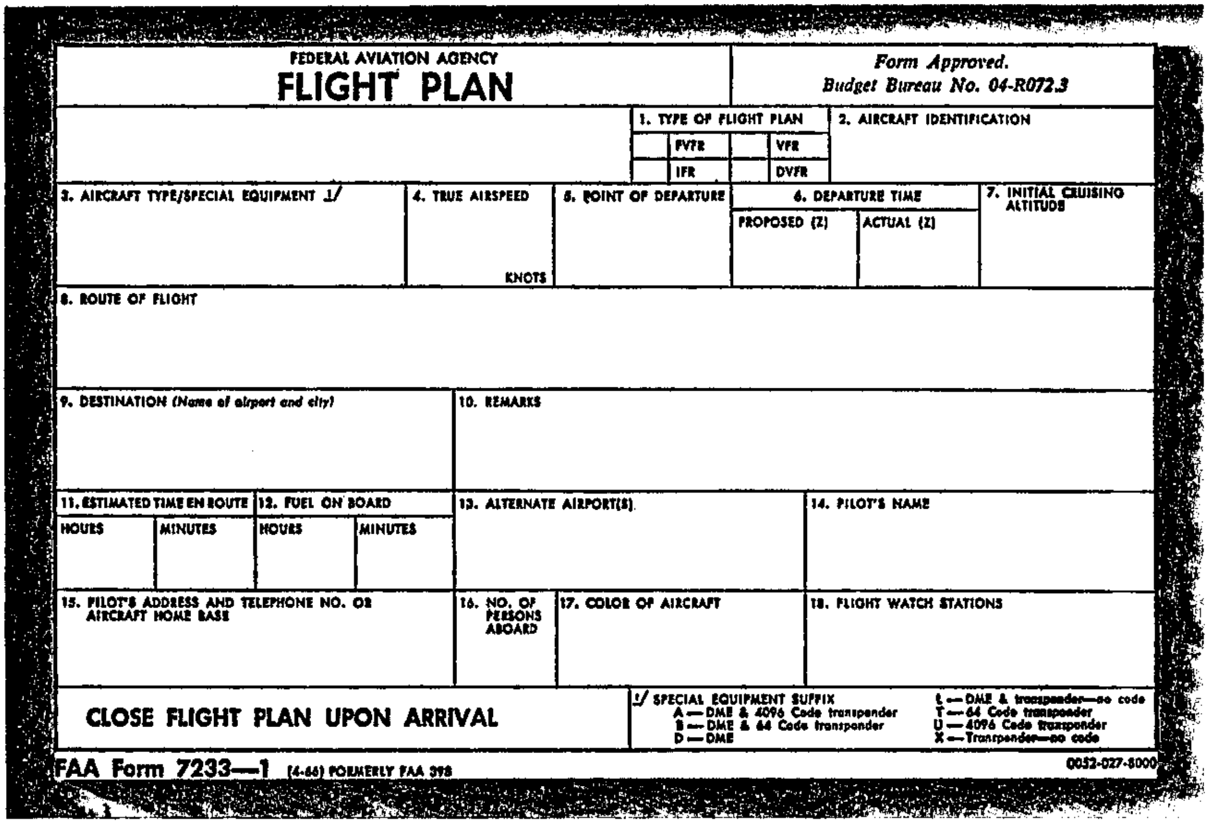
Once you understand the overall operation of the traffic control system, the many procedural details can be put into the appropriate sequence as you learn them. The problem now is to review the regulations and procedures involved in using the system under Instrument Flight Rules. Pilot responsibilities relating to air traffic control are stated in the Federal Aviation Regulations, Part 91, General Operating and Flight Rules.

More detailed procedures can be found under "Air Traffic Control" in the *Airman's Information Manual.* The instrument pilot should purchase copies of the Regulations and the *Airman's Information Manual* and maintain them with current revisions included in the subscription prices.

IFR Flight Plan

As specified in FAR 91, if you plan to operate an aircraft in controlled airspace under Instrument Flight Rules, you must file an IFR flight plan and receive an appropriate ATC clearance.

If your flight is to be in controlled airspace, your initial contact with Air Traffic Service involves your flight plan. The information to be entered on an IFR flight plan is listed in FAR 91, in the *Airman's Information Manual,* and on the Federal Aviation Agency Flight Plan, Form 7233-1 (Figure 192), which is available at Flight Service Stations, flight planning rooms in airport terminal buildings, and at other convenient locations. Following is an explanation of the data you need for a proposed IFR flight in the order of the 18 numbered blocks on the form.



FEDERAL AVIATION AGENCY

FLIGHT PLAN

Form Approved.
Budget Bureau No. 04-R072.3

1. TYPE OF FLIGHT PLAN: FVFR / VFR / IFR / DVFR

2. AIRCRAFT IDENTIFICATION

3. AIRCRAFT TYPE/SPECIAL EQUIPMENT 1/

4. TRUE AIRSPEED — KNOTS

5. POINT OF DEPARTURE

6. DEPARTURE TIME — PROPOSED (Z) / ACTUAL (Z)

7. INITIAL CRUISING ALTITUDE

8. ROUTE OF FLIGHT

9. DESTINATION (*Name of airport and city*)

10. REMARKS

11. ESTIMATED TIME EN ROUTE — HOURS / MINUTES

12. FUEL ON BOARD — HOURS / MINUTES

13. ALTERNATE AIRPORT(S)

14. PILOT'S NAME

15. PILOT'S ADDRESS AND TELEPHONE NO. OR AIRCRAFT HOME BASE

16. NO. OF PERSONS ABOARD

17. COLOR OF AIRCRAFT

18. FLIGHT WATCH STATIONS

CLOSE FLIGHT PLAN UPON ARRIVAL

1/ SPECIAL EQUIPMENT SUFFIX
A—DME & 4096 Code transponder
B—DME & 64 Code transponder
D—DME
L—DME & transponder—no code
T—64 Code transponder
U—4096 Code transponder
X—Transponder—no code

FAA Form 7233—1 (4-66) FORMERLY FAA 398 0052-027-8000

FIGURE 192. Flight Plan form.

Block 1. An IFR Flight Plan must be filed for flight in controlled airspace under Instrument Flight Rules, regardless of weather conditions. Filing an IFR Flight Plan means that—

a. You are requesting Air Traffic Control to provide separation from other IFR traffic in controlled airspace.

b. You possess a current and valid instrument rating.

c. Your aircraft is equipped for flight as prescribed in FAR 91 General Operating and Flight Rules.

d. You will conform to all provisions of the Instrument Flight Rules.

Many airline and general aviation pilots file IFR on all flights in controlled airspace, regardless of weather conditions. The newly rated instrument pilot should also file IFR for practice even though VFR weather conditions exist. Air Traffic Control will provide welcome assistance to controlled aircraft entering congested areas, and the practice and experience gained in flight planning and coordination with ATC should be part of transition training for flying under instrument weather conditions.

Block 2. The aircraft identification is the full serial number of the aircraft, e.g., N5432Z.

Block 3. Aircraft type data includes specific make and basic model, e.g., Cessna 182, Beech Baron, etc. This information identifies the performance characteristics of the aircraft for the controller. DME and transponder capability must be included in this block.

Block 4. The estimated true airspeed is the computed value at your requested cruising altitude, in knots.

Block 5. Point of Departure is the airport of departure. If you file IFR in flight, the point of departure is the radio navigation fix at which you request ATC to assume control.

Block 6. The departure time proposed should be at least 30 minutes after the flight plan is filed with Flight Service to allow the Center sufficient time to clear your route and formulate your clearance. The time entered is "Z" time (Greenwich Mean Time) based on the 24-hour clock. This identifies the time regardless of differences in local time at various ATC locations. To illustrate, a proposed 9:00 A.M. departure at Denver, Colo. (on Mountain Standard Time), is entered as 1600 on the flight plan. Note the hourly differences in the time belts:

Zulu		Z minus 5		Z minus 6		Z minus 7		Z minus 8
1600	=	1100EST	=	1000CST	=	0900MST	=	0800PST

If departure is from a controlled airport, the tower relays your takeoff time to Departure Control. If departure is from an airport without a control tower, you report the actual departure time by radio to Flight Service or as directed in your clearance.

Block 7. Initial cruising altitude is your requested altitude, but is not necessarily the altitude that ATC will assign. During your flight planning, you select altitudes on the basis of such factors as aircraft performance, favorable winds, precipitation, turbulence, minimum IFR altitudes for the route, etc. Without assuming an altitude, you cannot make the computations necessary for your flight plan. However, ATC assigns altitudes on the basis of your proposed departure time, your requested altitude, and the position of known traffic.

Block 8. Route of Flight should be described in accordance with detailed procedures found in the *Airman's Information Manual.* The route requested may not be the route assigned for reasons stated earlier.

Block 9. Destination (Airport and City), e.g., Wiley Post, Oklahoma City: Will Rogers, Oklahoma City; Tinker, Oklahoma City. Where a number of airports serve a metropolitan area, Approach Control must know the specific destination airport filed. The Controller must be informed well in advance of your arrival at the terminal area in order to vector you from an enroute position to the appropriate approach route in a complex system of arrival routings.

Block 10. Remarks. In this block enter your aircraft limitations as to radio frequencies, both for communications and radio navigation. This information is of utmost importance to Air Traffic Control in clearing your route, conducting communications, and controlling your arrival. If your communications equipment is limited, ATC will not request that you use frequencies normally utilized by better-equipped aircraft. Regulations require this entry so that there will be no confusion between pilot and controller as to navigation and communication capability. Desired altitude changes may also be listed in this block.

Block 11. Estimated Time Enroute is the estimated elapsed time from takeoff until over the point of first intended landing. Does this mean from takeoff to touchdown at the destination airport? If so, the complications involved in an accurate computed estimate would tax the patience of an expert. Assume that "over the point of first intended landing" means the final approach fix from which you intend to approach and land. Your estimated enroute time, then, is the sum of the following times:

a. Climb from takeoff to the initial cruising altitude requested.

b. Enroute time based upon the estimated true airspeed at altitudes requested in blocks 7 and 10 of your flight plan.

c. Time from the enroute navigation aid to the final approach fix from which you intend to land.

After a few practice IFR cross-country flights, during which ATC may request changes in altitude and routing, you may question the value of time-consuming pre-flight estimates. Why bother with careful estimates if you have to revise them in the air? Apart from the fact that a competent pilot constantly revises almost everything that he does in the air, careful flight planning is your guide to a safe arrival in the event of emergencies, which will be discussed later.

Block 12. FAR 91 requires that your fuel on board be based on the estimate of elapsed time from takoff to the first intended point of landing, thence to the alternate airport, if required, with a reserve of 45 minutes at normal cruising speed. An accurate estimate of the fuel required involves fuel consumption based upon the following time estimates:

a. Estimated enroute time in block 11 of your flight plan.

b. Estimated time from the final approach fix through the execution of a missed approach, thence to the alternate airport, if required.

c. 45 minutes reserve at normal cruise fuel consumption.

Block 13. FAR 91 contains the requirement for listing an alternate airport. Under certain specified forecast ceiling, visibility, and time period conditions, an alternate is not required.

Blocks 14–17. These entries are self-explanatory.

Block 18. Flight Watch Stations are not listed on an IFR Flight Plan.

Your Flight Plan completed, Flight Service relays to the Center the data you have entered in blocks 1 through 11. The other information has no bearing on control of your flight unless—

a. You execute a missed approach at your destination and request ATC clearance to your alternate, or

b. An emergency occurs during your flight that makes the additional data of importance in search and rescue operations. The completed Flight Plan form is retained at the Flight Service Station for later reference if necessary.

Filing in Flight

An IFR flight plan may be filed in the air under various conditions, including:

a. An IFR flight outside of controlled airspace prior to proceeding into IFR conditions in controlled airspace.

b. A flight on a VFR flight plan expecting IFR weather conditions enroute in controlled airspace.

c. A flight on a VFR flight plan enroute to a destination having high air traffic volume. Even in VFR weather conditions, more efficient handling is provided a flight on an IFR clearance. However, acceptance of an IFR clearance does not relieve the pilot of his responsibility to maintain separation from other traffic when operating in VFR conditions.

d. A flight departing under VFR conditions from an airport where no means of communication with Flight Service is available on the ground.

In any of these situations, the flight plan may be filed with the nearest Flight Service Station or directly with the Center. If the pilot files with Flight Service, he submits the information normally entered during pre-flight filing, except for "point of departure," together with his present position and altitude. The Center will then clear him from his present position or from a specified enroute navigation fix. If the pilot files direct with the Center, he reports his present position and altitude, and submits only the flight plan information normally relayed by Flight Service to the Center.

Clearances

Definition.—An Air Traffic Clearance is "an authorization by air traffic control, for the purpose of preventing collision between known IFR traffic, for an aircraft to proceed under specified traffic conditions within controlled airspace."

As the definition implies, an ATC clearance can be very simple or quite complicated, depending on traffic conditions. Your departure clearance will contain the following items, as required:

1. Aircraft identification.
2. Clearance limit.
3. Route of flight.
4. Altitude data.
5. Departure procedure.
6. Holding instructions.
7. Any special information.
8. Instructions for contacting the controlling facility, if direct communication is being maintained between pilot and controllers.

Examples: A flight filed for a short distance at relatively low altitude in an area of low traffic density might receive a clearance as follows:

SKYBIRD 1234D CLEARED TO THE DOEVILLE AIRPORT, DIRECT, CRUISE THREE THOUSAND.

The term "cruise" in such a clearance means that the pilot is cleared to the destination airport, to climb to 3,000 and descend at his discretion—that is, without further ATC clearance.

If a flight plan is filed, and the clearance received, through Flight Service by telephone, ATC would specify appropriate instructions as follows:

SKYBIRD 1234D CLEARED TO THE SKYLINE AIRPORT VIA THE CROSSVILLE 055 RADIAL VICTOR 18, MAINTAIN FIVE THOUSAND, CLEARANCE VOID IF NOT OFF BY 1330.

Under more complex traffic conditions, the clearance is more involved:

SKYBIRD 1234D CLEARED TO THE TULSA AIRPORT VIA VICTOR 14, TURN RIGHT AFTER DEPARTURE, PROCEED DIRECT TO THE OKLAHOMA CITY VORTAC. MAINTAIN THREE THOUSAND TO THE OKLAHOMA CITY VORTAC. HOLD WEST ON THE OKLAHOMA CITY 277 RADIAL. CLIMB TO FIVE THOUSAND IN THE HOLDING PATTERN BEFORE PROCEEDING ON COURSE. MAINTAIN FIVE THOUSAND UNTIL CROSSING THE PONCA CITY 167 RADIAL. CLIMB TO AND MAINTAIN SEVEN THOUSAND. DEPARTURE CONTROL FREQUENCY WILL BE 121.1.

None of the foregoing clearances are especially difficult to copy, understand, and comply with—assuming that you—

a. Have properly tuned your radio.
b. Are concentrating on what you hear.
c. Can copy fast enough to keep up with the clearance delivery.
d. Are familiar with the area.

Suppose, on the other hand, that you are awaiting departure clearance at a busy metropolitan terminal (your first IFR departure from this airport). On an average date, the tower at this airport controls departures at a rate of one every 2 minutes to maintain the required traffic flow. Sequenced behind you are a number of aircraft ready for departure, including jet transports burning 25 gallons of fuel per minute while they wait at idle power.

You request and receive the following clearance, called a Standard Instrument Departure (SID) (Fig. 193):

SKYBIRD 1234D CLEARED TO WORCHESTER MUNICIPAL AIRPORT, BAYVILLE EIGHT DEPARTURE, WATERBURY TRANSITION BDR, FLIGHT PLANNED ROUTE, MAINTAIN NINE THOUSAND, CONTACT NEW YORK CENTER 125.1 WHEN AIRBORNE.

This clearance can be copied readily in shorthand as the following:

WORA/BV-8BDR/FPR/M90 (NY 125.1)

The information contained in this clearance for a Standard Instrument Departure is an abbreviation of Air Traffic instructions too complicated and extensive for you to follow and copy, regardless of your proficiency in using clearance shorthand. Study of the route specified in the clearance shows the importance of the

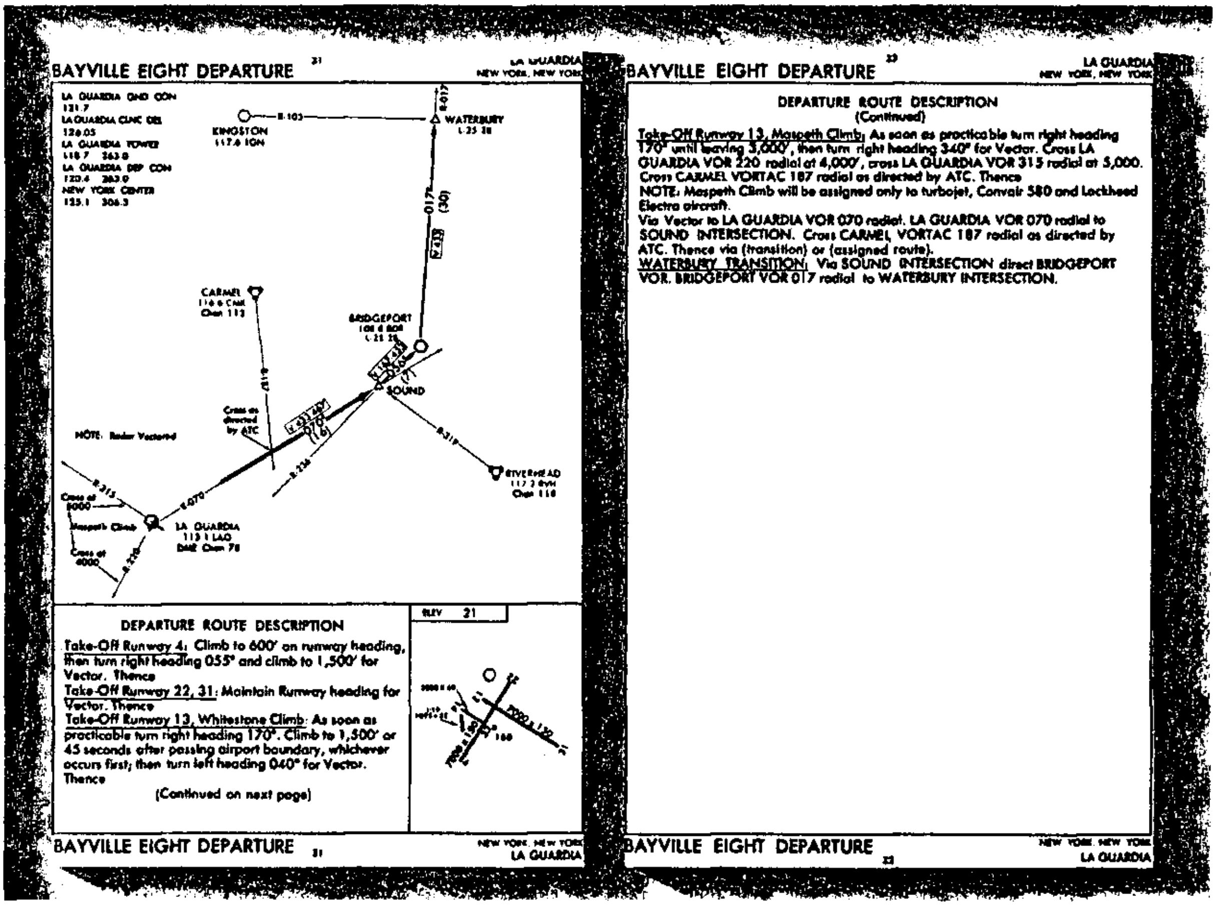


FIGURE 193. Standard Instrument Departure (SID).

Standard Instrument Departure. At common operating speeds in modern light aircraft, the clearance allows no time for extensive reference to your departure chart. You will be too busy flying your aircraft, navigating, and communicating with ATC to familiarize yourself with the clearance data after you have accepted it. You must know the locations of the specified navigation facilities, together with the route and point-to-point times, *before* accepting the clearance.

The Standard Instrument Departure, which you have available during pre-flight planning, enables you to study and understand the details of your departure before filing your IFR flight plan. It permits you to set up your communications and navigation equipment and to be ready for departure before requesting IFR clearance from the tower. The SID eliminates unnecessarily long delays in clearance delivery that would result in inconvenience and expense to airspace users as well as revisions in flight planning for pilots awaiting departure.

Regardless of the nature of your clearance, it is imperative that you are prepared to understand it, and having accepted it, comply with ATC instructions to the letter. It is your privilege to request a clearance different from that issued by ATC if you consider another course of action more practicable or if your aircraft equipment limitations or other considerations make acceptance of the clearance inadvisable. Though regulations do not require that you accept a clearance, they are very specific as to your *privileges and responsibilities.*

1. **Responsibility and authority of the pilot in command.**

(a) The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.

(b) In an emergency requiring immediate action, the pilot in command may deviate from a rule to the extent required to meet that emergency.

(c) Each pilot in command who deviates from a rule shall, upon the request of the Administrator, send a written report of that deviation to the Administrator.

2. **Compliance with ATC clearances and instructions.**

(a) When an ATC clearance has been obtained, no pilot in command may deviate from that clearance, except in an emergency, unless he obtains an amended clearance. However, except in positive controlled airspace, this paragraph does not prohibit him from cancelling an IFR flight plan if he is operating in VFR weather conditions.

(b) Except in an emergency, no person may, in an area in which air traffic control is exercised, operate a aircraft contrary to an ATC instruction.

(c) Each pilot in command who deviates, in an emergency, from an ATC clearance or instruction shall notify ATC of that deviation as soon as possible.

(d) Each pilot in command who (though not deviating from a rule of this subpart) is given priority by ATC in an emergency, shall, if requested by ATC, submit a detailed report of that emergency within 48 hours to the chief of that ATC facility.

An ATC clearance presupposes that you are equipped and will comply with the applicable Regulations (Part 91), as follows:

1. **Instruments and equipment IFR flight.** The following instruments and equipment are required: . . . Two-way radio communications system and navigational equipment appropriate to the ground facilities to be used. . . .

2. **IFR radio communications.** The pilot in command of each aircraft operated under IFR in controlled airspace shall have a continuous watch maintained on the appropriate frequency. . . .

3. **Course to be flown.** Unless otherwise authorized by ATC, no person may operate an aircraft within controlled airspace, under IFR, except as follows:

(a) On a Federal Airway, along the centerline of that airway.

(b) On any other route, along the direct course between the navigational aids or fixes defining that route.

However, this section does not prohibit maneuvering the aircraft to pass well clear of other air traffic or the maneuvering of the aircraft, in VFR conditions, to clear the intended flight path both before and during climb or descent.

Departure Procedures

Standard Instrument Departures (SIDs).—To simplify air traffic control clearances and relay and delivery procedures, Standard Instrument Departures have been established for the most frequently used departure routes in areas of high traffic activity. You will normally use a SID (Fig. 193) where such departures are available since this is advantageous to both users and Air Traffic Control. The following points are important to remember if you file IFR out of terminal areas where SIDs are in use:

1. SIDs are published in booklet form every eight weeks with every other issue of the National Ocean Survey Approach and Enroute Charts. Three booklets are issued, one for the eastern half of the United States, one for the western half, and one for Alaska. The descriptions are both graphic and textual. AIM, Part 1, describes SID procedures, and Part 3 lists currently published SIDs plus those newly approved, revised, or cancelled.

2. ATC will not issue a SID clearance unless requested by the pilot, except for military and air carrier pilots and certain other exceptions as noted in the AIM "Notices to Airmen."

3. Your request for a SID means that you are familiar with it and have it in the cockpit for reference. It is your responsibility to accept or refuse the clearance issued.

4. If you accept a SID in your clearance, you must comply with it, just as you comply with other ATC instructions.

Preferred Routes.—In the major terminal and enroute environments, preferred routes have been established to guide pilots in planning their routes of flight, to minimize route changes, and to aid in the orderly management of air traffic using the Federal Airways. You file via SID and preferred route for the same reasons that for long automobile trips you drive via expressway and interstate superhighway. The route is quicker, easier, and safer.

Radar-Controlled Departures.—On your IFR departures from airports in congested areas, you will normally receive navigational guidance from Departure Control by radar vector. When your departure is to be vectored immediately following takeoff, you will be advised before takeoff of the initial heading to be flown and the frequency on which you will contact Departure Control. This information is vital in the event that you experience (complete) loss of two-way radio communications during departure. This possibility will be considered later in this chapter under "Emergencies."

The radar departure is normally simple. Following takeoff, you contact Departure Control on the assigned frequency upon release from Tower Control. Awaiting your call-up, Departure Control verifies contact, tells you briefly the purpose of the vector (airway, point, or route to which you will be vectored), and gives headings, altitude, and climb instructions, and other information to move you quickly and safely out of the terminal area. You listen to instructions and fly basic instrument maneuvers (climbs, level-offs, turns to predetermined headings, and straight-and-level flight) until the controller tells you your position with respect to the route given in your clearance, whom to contact next, and to "resume normal navigation."

Departure Control will vector you either to a navigation facility or an enroute position appropriate to your departure clearance, or you will be transferred to another controller with further radar surveillance capabilities. It is just like having your instructor along to tell you what to do and when to do it. The procedure is so easy, in fact, that inexperienced pilots are often inclined to depend entirely on radar for navigational guidance, unconcerned about the consequences of loss of radar contact and indifferent to common-sense precautions associated with flight planning.

A radar-controlled departure does NOT relieve you of your responsibilities as pilot-in-command of your aircraft. You should be prepared before takeoff to conduct your own navigation according to your ATC clearance, with navigation receivers checked and properly tuned. While under radar control, you should monitor your instruments to ensure that you are continuously oriented to the route specified in your clearance and you should record the time over designated check points.

Departures from Uncontrolled Airports.—Occasionally, you will depart from airports which have neither a Tower nor Flight Service Station. Under these circumstances, it is desirable that you telephone your flight plan to the nearest FAA facility at least 30 minutes prior to your estimated departure time. If weather conditions permit, you could depart VFR and request IFR clearance as soon as radio contact is established with an FAA facility. If weather conditions made it undesirable to attempt to maintain VFR, you could again telephone the facility which took your flight plan and request clearance by telephone. In this case, the controller would probably issue a short range clearance pending establishment of radio contact and might also restrict your departure time to a certain period. For example:

CLEARANCE VOID IF NOT OFF BY 0900.

This would authorize you to depart within the allotted time period and proceed in accordance with your clearance. In the absence of any specific departure instructions, the pilot would be expected to proceed on course via the most direct route.

Enroute Procedures

Normal procedures enroute will vary according to your proposed route, the traffic environment, and the ATC facilities controlling your flight. Some IFR flights are under radar surveillance and control from departure to arrival; others rely entirely on pilot navigation. Flights proceeding from controlled to uncontrolled airspace are outside ATC jurisdiction as soon as the aircraft is outside of controlled airspace.

Where ATC has no jurisdiction, it does not issue an IFR clearance. It has no control over the flight; nor does the pilot have any assurance of separation from other traffic.

With the increasing use of the national airspace, the amount of uncontrolled airspace is diminishing, and the average pilot will normally file IFR via airways and under ATC control. For IFR flying in uncontrolled airspace, there are few regulations and procedures to comply with. The advantages are also few, and the hazards can be many. For rules governing altitudes and course to be flown in uncontrolled airspace, see FAR 91.

Enroute Separation.—For enroute control, Departure Control normally requests that you contact Air Route Traffic Control (the appropriate Center) on a specified frequency as you approach the limit of terminal radar jurisdiction. At this point Departure Control, in coordination with the Center, has provided you with standard separation from other aircraft on IFR clearances. Separation from other IFR aircraft is provided thus:

a. Vertically by assignment of different altitudes.

b. Longitudinally by controlling time separation between aircraft on the same course.

c. Laterally by assignment of different flight paths.

d. By radar—including all of the above.

ATC does NOT provide separation for an aircraft operating—

a. Outside controlled airspace.

b. On an IFR clearance:

(1) With "VFR conditions on top" authorized instead of a specific assigned altitude.

(2) Specifying climb or descent in "VFR conditions."

(3) At any time in VFR conditions, since uncontrolled VFR flights may be operating in the same airspace.

Of more importance to you are the reporting procedures by which you convey information to the Center Controller. With the data you transmit, he follows the progress of your flight by entering time/position/altitude information on a flight progress strip, relating your flight to the progress strips of other aircraft. The accuracy of your reports can affect the progress and safety of every other aircraft operating in the area on an IFR flight plan because ATC must correlate your reports with all the others to provide separation and expedite aircraft movements.

Reporting Requirements.—Federal Aviation

Regulations require pilots to maintain a listening watch on the appropriate frequency and unless operating under radar control, to furnish position reports over certain reporting points. Any unforecast weather conditions or other information related to the safety of flight must also be reported.

Position reports are required by all flights regardless of altitude, including those operating in accordance with a "VFR conditions-on-top" clearance, over each designated compulsory reporting point (shown as solid triangles) along the route being flown. Along direct routes, reports are required of all flights over each reporting point used to define the route of flight. Reports over an "on request" reporting point (shown as open triangles) are made only when requested by ATC.

Position Reports.—The use of standardized reporting procedures generally makes for faster and more effective communication. A standardized communication with ATC normally complies with the Radiotelephone Contact Procedure comprising call-up, reply, message, and acknowledgement or ending. Use this procedure when making position reports to a Flight Service Station for relay to the center controlling your flight. Your IFR position reports should include the following items:

1. Identification.
2. Position.
3. Time. Over a VOR, the time reported should be the time at which the first complete reversal of the TO/FROM indicator is noted. Over a nondirectional radio beacon, the time reported should be the time at which the ADF needles make a complete reversal, or indicates that you have passed the facility.
4. Altitude.
5. Type of flight plan, if your report is made to a Flight Service Station. This item is not required if your report is made direct to an ATC center or approach controller, both of whom already know that you are on an IFR flight plan.
6. Estimated time of arrival (ETA) over next reporting point.
7. The name only of the next succeeding (required) reporting point along the route of flight.
8. Remarks, when required.

During your early communications training, your reports will be clear and concise if you learn and adhere to the procedures outlined in the *Airman's Information Manual.* Often these procedures are abbreviated by both pilots and controllers when clarity and positive identification are not compromised. With increasing experience in ATC communications, you will readily learn to reduce verbiage when high radio congestion makes it advisable.

Enroute position reports are submitted normally to the ARTCC Controllers via direct controller-to-pilot communications channels, using the appropriate ARTCC frequencies listed on the enroute chart. Unless you indicate the limitation of your communications equipment, under "Remarks" on your IFR flight plan, ATC will expect direct pilot-to-center communications enroute, advising you of the frequency to be used and when a frequency change is required. Failure to provide ATC with frequency information on your flight plan contributes to radio congestion until ATC can assign you a frequency suitable to your equipment limitations.

In order to reduce congestion, pilots reporting direct to an ARTCC follow special voice procedures when making the initial call-up. Whenever an initial center contact is to be followed by a position report, the name of the reporting point should be included in the call-up. This alerts the controller that such information is forthcoming.

When a full position report is not required (for example, when a pilot has been instructed to contact a Center at a specified time or point other than at a compulsory reporting point), the pilot includes in his call-up an estimate for the next reporting point, his actual altitude and, if appropriate, the altitude to which climb or descent is being made. The controller simply acknowledges the contact and adds control instructions if required. Examples of such reports are given in the *Airman's Information Manual.*

Malfunction Reports.—Pilots of aircraft operated in controlled airspace under IFR are required to report immediately to ATC any of the following malfunctions of equipment occurring in flight:

(1) Loss of VOR, TACAN, or ADF receiver capability.
(2) Complete or partial loss of ILS receiver capability.
(3) Impairment of air/ground communications capability.

In each such report, pilots are expected to include aircraft identification, equipment affected, and degree to which IFR operational capability in the ATC system is impaired. The nature and extent of assistance desired from ATC must also be stated.

Additional reports.—The *Airman's Information Manual* specifies the following reports to ATC, without request by the controller:

1. The time and altitude/flight level reaching a holding fix or point to which cleared.
2. When vacating any previously assigned altitude/flight level for a newly assigned altitude/flight level.
3. When leaving any assigned holding fix or point.

4. When leaving final approach fix inbound on final approach.

5. When an approach has been missed. (Request clearance for specific action, i.e., to alternate airport, another approach, etc.)

6. A corrected estimate any time it becomes apparent that a previously submitted estimate to a reporting point will be in error in excess of 3 minutes.

7. That an altitude change will be made if operating on a clearance specifying "VFR conditions-on-top."

Arrival Procedures

ATC arrival procedures and your cockpit workload are affected by weather conditions, traffic density, aircraft equipment, and radar availability.

Standard Terminal Arrival Routes (STARs).—These routes have been established to simplify clearance delivery procedures to arriving aircraft at certain areas having high density traffic. STARs serve a purpose parallel to that of SIDs for departing traffic. Procedures are published in Part 1 of AIM and textual descriptions of current STARs are given in Part 3. Booklets such as those published for SIDs are not available at present.

Uncontrolled Airports (No Tower).—On a flight in an uncongested area into an airport with no tower, the controlling ARTCC advises you to contact the Flight Service Station at or near the destination airport for airport advisory information. This includes the current local altimeter setting, wind direction and velocity, runway information, and known traffic. Further reports are relayed by Flight Service to the Center until you have canceled your IFR flight plan.

Airports With Tower.—Your workload can be much greater on arrival at a terminal area where a combination of low ceiling and visibility, heavy traffic, and type of available approach aids requires considerable delay in the issuance of approach clearances. At an airport equipped with ILS facilities, the local controllers can normally handle an arrival every 2 minutes. At the same airport, with the ILS system unavailable and the VORTAC located 8 miles from the field, the arrival interval may be increased to 10 minutes.

Whatever the reasons for delaying instrument approaches—including arrival intervals, traffic density, deterioriating weather, missed approaches, etc.—holding may be necessary. The order of priority of issuance of approach clearances is normally established on a first-come-first-served basis. The first aircraft estimated over the fixes from which approaches are begun will be the first to receive an approach clearance, followed by the aircraft in the order of their estimated or actual times of arrival over the several fixes.

Holding.—"Holding" is maneuvering an aircraft along a predetermined flight path within prescribed airspace limits with respect to a geographic fix. The fix may be identified visually (without reference to instruments) as a specified location, or by reference to instruments as a radio facility or intersection of courses. VORs, radio beacons, and airway intersections are used as holding points.

The diagram in Figure 194 illustrates control procedures used when a number of aircraft are stacked at an approach fix (Outer Compass Locator) on an ILS front course, with additional aircraft holding in the stack at an outer fix (VOR). Successive arriving aircraft are cleared to the approach fix until the highest altitude/flight level to be assigned is occupied, and thereafter to the outer fix at an appropriate altitude/flight level above the highest level occupied at the approach fix. This permits aircraft subsequently cleared to the approach fix to proceed in descending flight. The illustration shows an interval of 2 minutes between successive approaches. The #1 and #2 aircraft have already passed the Outer Locator (LOM) on final approach, and the #3 aircraft has been cleared for approach and to depart the LOM 2 minutes after the #2 aircraft reported leaving the LOM inbound on final approach.

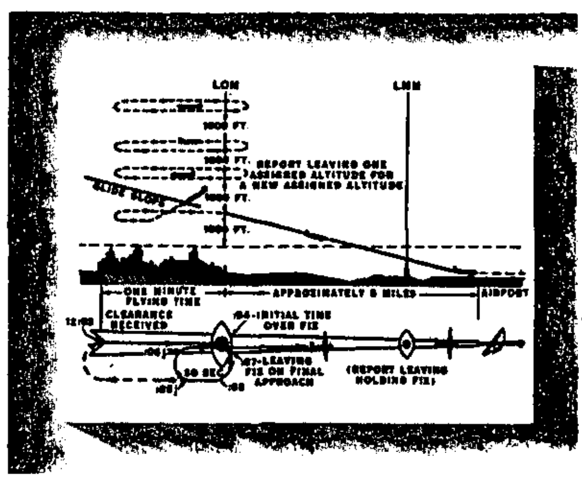


FIGURE 194. ATC procedures—timed approaches.

As Figure 194 shows, to fly a holding pattern involves a combination of simple basic maneuvers—two turns and two legs in straight-and-level flight or descending when cleared by ATC. Although these maneuvers are far less difficult than, for example, absolute-rate climbs or descent to predetermined headings and altitudes (see Chapter V, "Attitude Instrument Flying"), holding procedures are a common source of confusion and apprehension among instrument pilot trainees.

There are many reasons for this apprehension, among them the idea that holding implies uncertainty, delay, procedural complications, and generally an increased workload at a time when you are already busy reviewing the details of your instrument approach. Another reason involves the normal psychological pressure attending approach to your destination, when you become increasingly conscious of the fact that your margin of error is narrowing. The closer you get to touchdown, the more decisions you must make, and the decisions must be quick, positive, and accurate as you have fewer chances to correct the inaccuracies. Like any other flight problem, holding complications become routine after sufficient study of the procedures in their normal sequence.

Standard Holding Pattern (No Wind).—At or below 14,000 feet, the standard holding pattern (Fig. 195) is a racetrack pattern requiring ap-

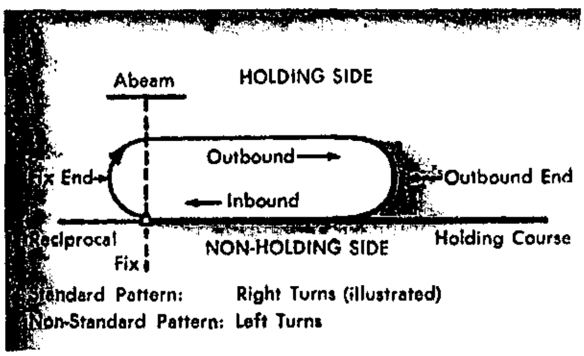


FIGURE 195. Standard holding pattern—no wind.

proximately 4 minutes to execute. The aircraft follows the specified course inbound to the holding fix, turns 180° to the right, flies a parallel straight course outbound for one minute, turns 180° to the right, and flies the inbound course to the fix.

Nonstandard Holding Pattern.—A nonstandard holding pattern is one in which fix end and outbound turns are made to the left. Your ATC clearance will always specify left turns when a nonstandard pattern is to be flown.

Standard Holding Pattern With Wind.—In compliance with the holding pattern procedures given in the *Airman's Information Manual,* the symmetrical racetrack pattern cannot be tracked when a wind exists. Pilots are expected to—

a. Execute all turns during entry to and while in the holding pattern at 3° per second, or a 30° bank angle, or a 25° bank angle if a flight director system is used; whichever requires the least bank angle.

b. Compensate for the effect of a known wind except when turning.

Figure 196 illustrates the holding track fol-

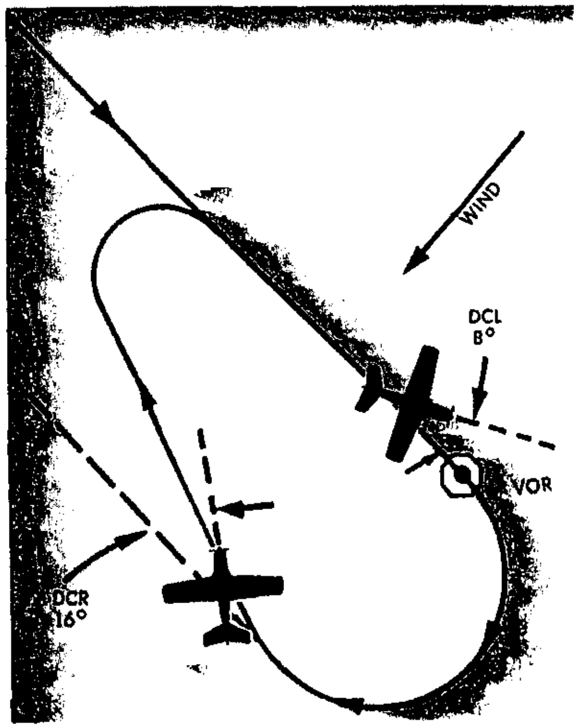


FIGURE 196. Drift correction in holding pattern.

lowed with a left crosswind. Further details of compensation for wind effect are given in the *Airman's Information Manual* and explained in this manual in Chapter VII, "Using the Navigation Instruments—Tracking."

The effect of wind is thus counteracted by correcting for drift on the inbound and outbound legs, and by applying time allowances to be discussed under "Time Factors."

Holding Instructions.—If you arrive at your clearance limit before receiving clearance beyond the fix, ATC expects you to maintain the last assigned altitude and execute a standard holding pattern on the course on which you approached the fix, until further clearance is received. Normally, when no delay is anticipated, ATC will issue further clearance as soon as practicable and, in any event, prior to your arrival at the clearance limit. If delay is anticipated, ATC will issue holding instructions at least 5 minutes before your estimated arrival at the fix. General Holding Instructions specify the following:

1. Direction of holding from the fix, using

magnetic directions and referring to one of eight general points of the compass (north, northeast, east, etc.).

2. Name of the holding fix.

3. Radial, course, or airway on which holding is to be accomplished.

4. Direction of holding pattern, if other than right turns. Detailed holding instructions are issued when deemed necessary by the Controller or requested by the pilot. In addition to the items specified under general holding instructions, the outbound leg length is always specifed in minutes, or miles DME, and the direction of holding pattern turns is included.

5. Outbound leg length in miles, if DME is to be used.

Suitable ATC instructions will also be issued whenever—

1. It is determined that delay will exceed 1 hour.

2. A revised EAC or EFC is necessary.

3. In a terminal area having a number of navigation aids and approach procedures, a clearance limit may not indicate clearly which approach procedures will be used. On initial contact, or as soon as possible thereafter, Approach Control will advise you of the type of approach you may anticipate.

4. Ceiling and/or visibility is reported as being at or below the highest "circling minimums" established for the airport concerned. ATC will transmit a report of current weather conditions, and subsequent changes, as necessary.

5. Aircraft are holding while awaiting approach clearance, and pilots thereof advise that reported weather conditions are below minimums applicable to their operation. In this event, ATC will issue suitable instructions to aircraft which desire either to continue holding while awaiting weather improvement or proceed to another airport.

Standard Entry Procedures.—The entry procedures given in the *Airman's Information Manual* evolved from extensive experimentation under a wide range of operational conditions. These standardized procedures should be followed to ensure that you remain within the boundaries of the prescribed holding airspace.

Maximum airspeed for propeller-driven aircraft holding below 14,000 feet is 175 knots Indicated Airspeed (for procedures appropriate to higher altitudes and high-speed aircraft, refer to the *Airman's Information Manual*). You are expected to reduce airspeed to 175 knots, or less if practicable, within approximately 3 minutes prior to ETA at the holding fix. The purpose of the speed limitation is to prevent overshooting the holding airspace limits, especially at locations where adjacent holding patterns are close together. The *exact* time at which you reduce speed is not important, so long as you arrive *at the fix* at your preselected holding speed within 3 minutes of your submitted ETA. If it takes more than 3 minutes for you to complete a speed reduction and ready yourself for identification of the fix, adjustment of navigation and communications equipment, entry to the pattern, and reporting, make the necessary time allowance.

Technique will vary with pilot experience, cockpit workload, aircraft performance, equipment used, and other factors. With crystal-tuned dual VOR receivers, dual transceivers, distance measuring equipment, Integrated Flight System (Flight Director), autopilot, and a copilot to share the workload, holding is far less of a problem than it would be for an inexperienced solo pilot holding with a single obsolescent VOR receiver without crystal tuning ("coffee grinder" receiver).

Entry.—Aircraft Heading on arrival at the fix determines the direction of entry turn. As Fig. 197 shows, entry procedures are oriented to a

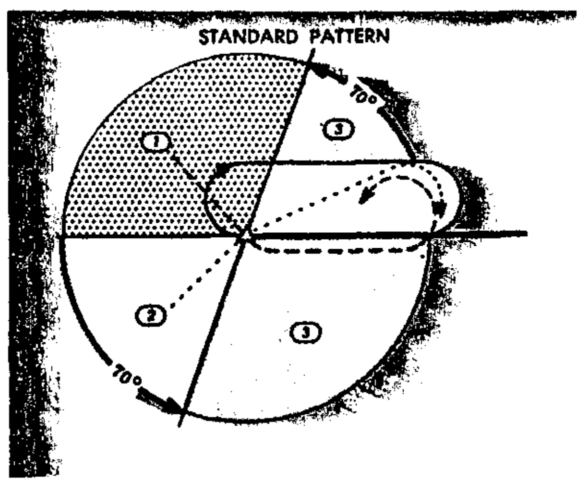


FIGURE 197. Holding pattern entry.

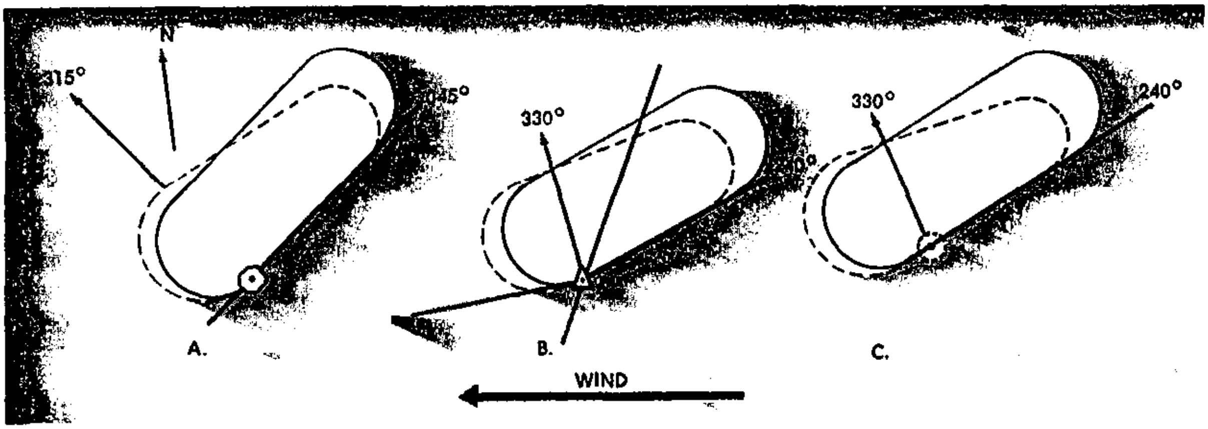
line at a 70° angle with the inbound course. This applies to both standard and nonstandard patterns.

Parallel procedure (Fig. 197, area 1)
Parallel holding course, turn left, and return to the holding fix or intercept inbound course.

Tear drop procedure (Fig. 197, area 2)
Proceed on outbound heading at a 30° angle (or less) with the holding course; turn right to intercept the holding course.

Direct entry procedure (Fig. 197, area 3)
Turn right and fly the pattern.

Turns.—Make all turns during entry and



VOR

Outbound timing starts when To/From indicator reverses.

AIRWAY INTERSECTION

Outbound timing starts at completion of outbound turn, since 330° magnetic bearing cannot be determined.

COMPASS LOCATOR

Outbound timing starts when ADF rel. bearing is 90° minus drift correction angle.

FIGURE 198. Holding—outbound timing.

holding at whichever of the following requires the lesser degree of bank:

1. 3° per second.
2. 30° bank angle.
3. 25° bank angle provided a flight director system is used.

Holding at speeds below 175 knots, 3° per second will require the lesser degree of bank.

Time factors.—

Entry time reported to ATC (see "Additional Reports" in this chapter) is the initial time of arrival over the fix.

Initial outbound leg is flown for 1 minute at or below 14,000 feet MSL. Timing for subsequent outbound legs should be adjusted as necessary to achieve proper inbound leg time.

Outbound timing begins *over* or *abeam* the fix, whichever occurs later. If the abeam position cannot be determined, start timing when turn to outbound is completed (Fig. 198).

No other time adjustments are necessary unless ATC specifies a time to leave the holding fix, as on a timed approach (see Fig. 194). Any necessary reduction in holding time will depend upon the time required to complete a circuit of the pattern. If, for example, a complete circuit requires 4½ minutes, and the fix departure time is 12 minutes after passage over the fix, fly two more patterns (9 minutes) and shorten the outbound leg on the last circuit to provide for a total of 1 minute except for the turns, which at 3° per second will take 2 minutes. Precise timing requires rapid cross-check and planning, in addition to the attention devoted to basic attitude control, tracking, and ATC communications.

Expect Approach Clearance times (EAC) and *Expect Further Clearance times* (EFC) require no time adjustment since the purpose for issuance of these times is to provide for possible loss of two-way radio communications. You will normally receive further clearance prior to your EAC or EFC. If you fail to receive it, request it.

Time leaving the holding fix must be known to ATC before succeeding aircraft can be cleared to the airspace you have vacated (see "Additional Reports" in this chapter). Leave the holding fix—

1. When ATC issues either further clearance enroute or approach clearance.
2. As prescribed in FAR 91 (for IFR operations; two-way radio communications failure and responsibility and authority of the pilot in command) or
3. After you have canceled your IFR flight plan, if you are holding in VFR conditions.

The diagram in Figure 199 shows the application of the foregoing procedures. Assume approach to the holding fix on the following ATC clearance, estimating Fox 1200:

SKYROD 234D HOLD EAST OF FOX INTERSECTION ON VICTOR 140. MAINTAIN SEVEN THOUSAND. EXPECT FURTHER CLEARANCE AT 1220.

Steps 1–10 show you overheading the fix inbound at 1203, with 17 minutes remaining to hold. If the first complete holding circuit takes 4 minutes, 30 seconds, you should therefore expect further clearance (1220) on the fourth circuit approximately 1 minute from the fix, inbound.

DME Holding.—The same entry and holding procedures apply to DME holding except dis-

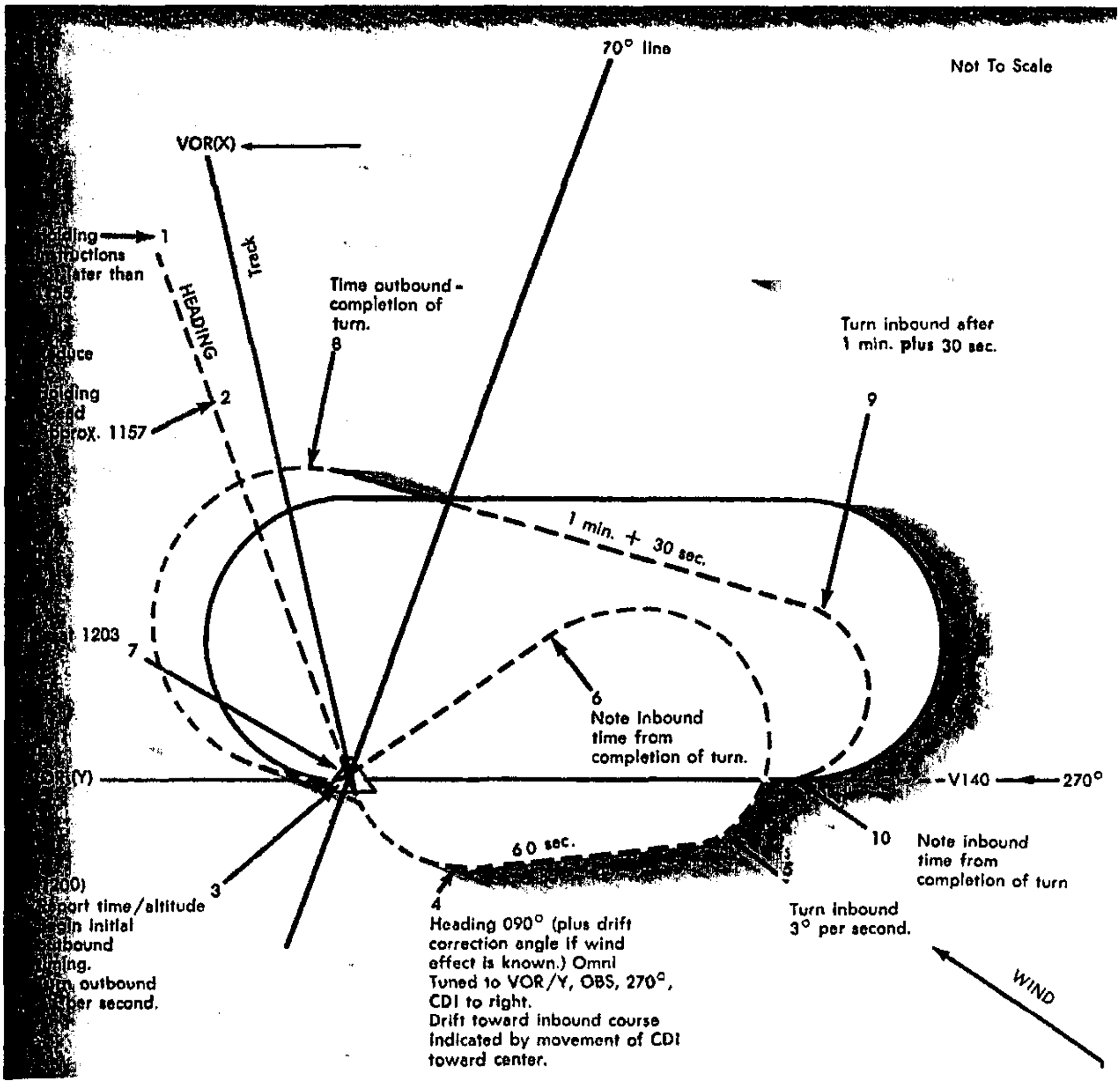


FIGURE 199. Holding at an intersection.

tances (nautical miles) are used instead of time values. The outbound course of the DME holding pattern is called the outbound leg of the pattern. The length of the outbound leg will be specified by the controller and the end of this leg is determined by the DME odometer reading.

Approaches

Instrument approaches to civil airports.—Unless otherwise authorized, each person operating an aircraft shall, when an instrument letdown to an airport is necessary, use a standard instrument approach procedure prescribed for that airport. Instrument approach procedures are depicted on National Ocean Survey Approach and Landing Charts. Newly established, revised, or canceled procedures are listed in the "Special" section of the *Airman's Information Manual.*

ATC approach procedures depend upon the facilities available at the terminal area, the type of instrument approach executed, and existing weather conditions. The ATC facilities, navigation aids, and associated frequencies appropriate to each standard instrument approach are given on the AL Chart. Individual charts are pub-

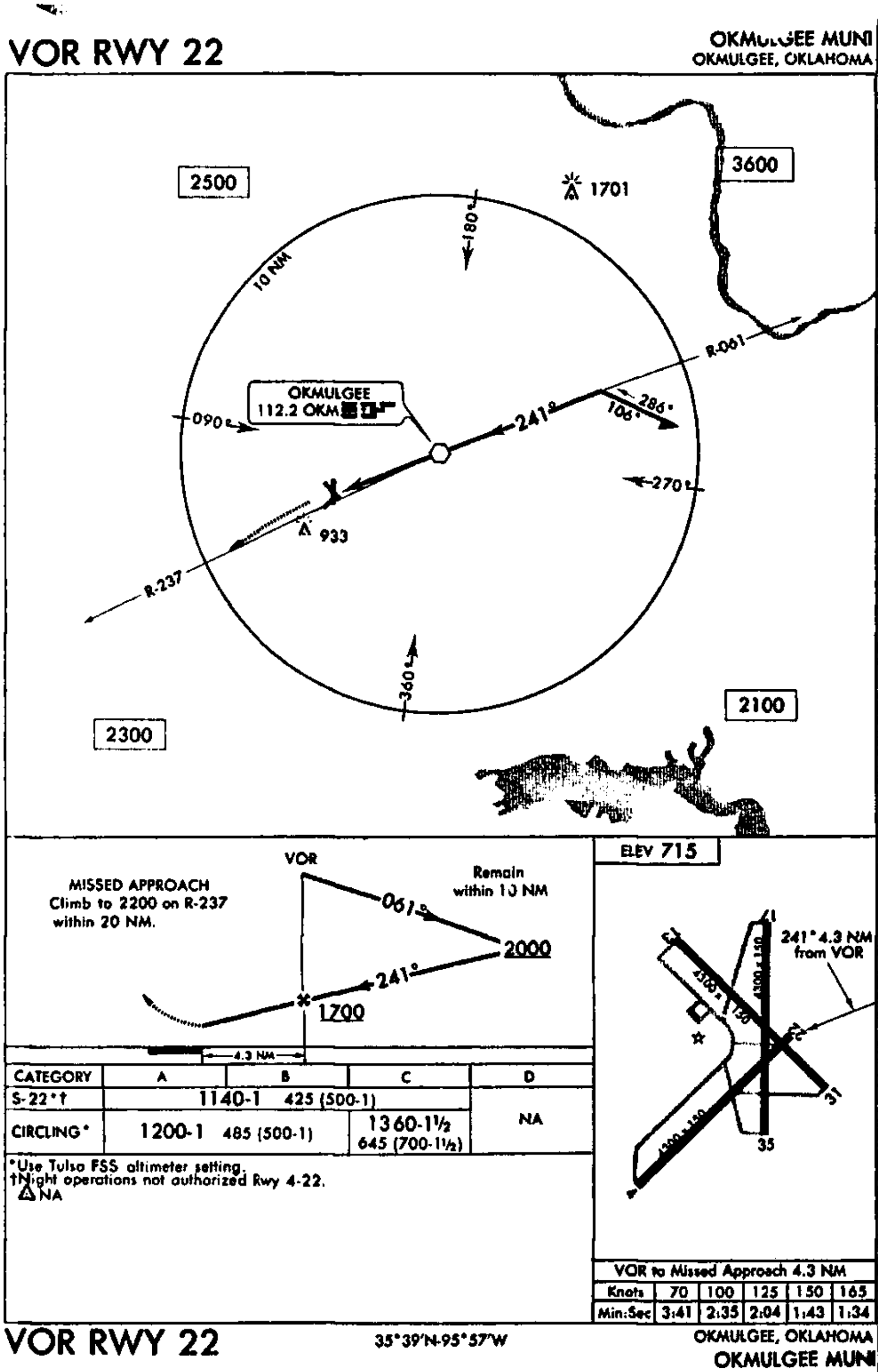


FIGURE 200. Instrument approach procedure chart—minimum ATC facilities.

lished for the standard approach procedures associated with the following types of facility:

1. Nondirectional homing beacon (ADF).
2. Very high frequency omnirange (VOR).
3. Very high frequency omnirange with distance measuring equipment (VORTAC).
4. Instrument landing system (ILS).

Radar approach procedures may be associated with any of the standard procedures listed above and do not require separate AL Charts. While executing a radar controlled approach, you monitor the standard approach chart appropriate to the approach specified by the controller and comply with the FAA radar ceiling and visibility minimums published as a separate section along with the standard instrument approach procedures.

Approach to an Airport Without Tower and Without AAS.—On an approach to an airport having minimum ATC facilities, it is of the utmost importance that you understand the details of the AL Chart to be used. Figure 200 prescribes the instrument approach for such an airport.

The chart shows the following information:

a. No ATC service of any kind is available at the airport. This can be determined by the absence of frequency information in the upper left corner of the chart plan view and the notation "NA" below the minimums box, which means the airport is *not* authorized for use as an alternate. No airport can be used as an alternate unless weather service is available through FSS, UNICOM, or a suitable commercial source.

b. The VOR is remotely controlled by Tulsa Flight Service Station.

From this information, you can anticipate the ATC procedures associated with your approach to Okmulgee. If you are arriving on a "cruise" clearance, ATC will not issue further clearance for approach and landing.

The term "cruise" removes the altitude restriction usually contained in a clearance and authorizes you to continue to your destination without further clearance. However, you are required to comply with communications and reporting procedures as on any other IFR clearance. If an approach clearance is required, ARTCC will authorize you to execute your choice of standard instrument approaches (more than one may be published for the airport) with the phrase "CLEARED FOR APPROACH" and the communications frequency change required, if any. Inbound from the procedure turn, you will have no contact with ATC. Accordingly, you must close your IFR flight plan before landing, if in VFR conditions, or by telephone after landing.

Unless the approach is begun from a holding pattern on the primary navigation facility (OKM VOR) or unless otherwise authorized by ATC, you are expected to execute the complete instrument approach procedure shown on the chart.

Approach to an Airport With AAS Only.—Figure 201 shows the approach procedure at an airport where a Flight Service Station is located. When direct communication between pilot and controller is no longer required, the enroute controller will clear you for an instrument approach and advise you to contact the FSS for airport advisory information. During this approach you will have the benefit of information concerning current weather, known traffic, and any other conditions affecting your flight.

The AIM lists McAlester as an airport with an FSS from which you can anticipate the procedures noted above.

Approach to an Airport With Tower but No Radar.—Where an AL Chart indicates an Approach Control without radar at your destination airport, ARTCC will clear you to an approach/outer fix with the following information and instructions:

1. Name of the fix.
2. Altitude to be maintained.
3. Holding information and expected approach clearance time, if appropriate.
4. Instructions regarding further communications, including:
   a. facility to be contacted.
   b. time and place of contact.
   c. frequency/ies to be used.

At the time of your first radio contact, or, in any event, prior to issuance of your approach clearance, approach control will inform you of the following:

1. Altimeter setting.
2. Wind direction and velocity.
3. Runway information.
4. If the landing runway is to be other than that aligned with the direction of the instrument approach, instructions to circle to the runway in use; and
5. Other information, as appropriate.

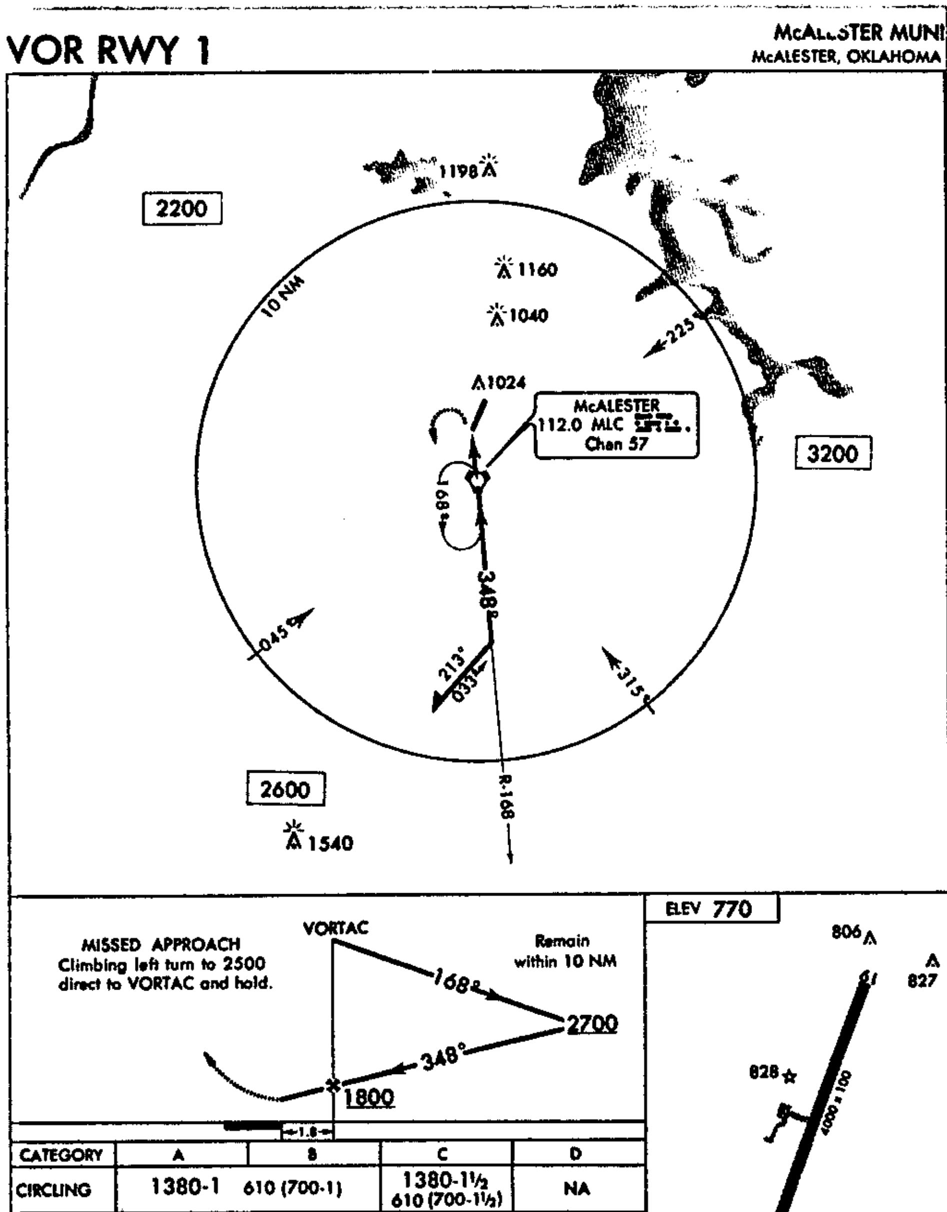
Other information, noted above, includes current weather affecting your approach and landing, as follows:

1. When ceiling and/or visibility is reported through official weather reports as being at or below the highest "circling minimums" established for the airport, approach control will report the current weather and subsequent changes.

2. When the official weather report indicates that weather conditions are below the minimums published for the approach being executed, or to be executed, approach control will—

a. Issue the weather report.

b. Advise you that the weather conditions are



CATEGORY	A	B	C	D
CIRCLING	1380-1	610 (700-1)	1380-1½ 610 (700-1½)	NA

VORTAC to Missed Approach 1.8 NM					
Knots	70	100	125	150	165
Min:Sec	1:33	1:05	0:52	0:43	0:39

FIGURE 201. Instrument approach procedure chart—Airport Advisory Service available.

below the published minimums and request your intentions.

c. Issue approach clearance, landing clearance, or other clearance and/or instructions, as appropriate, in accordance with your stated intentions and the traffic situation.

Although the instrument approach to a controlled airport is conducted with direct pilot-to-controller communications, without radar you are "on your own" in navigating and in maintaining separation from other aircraft unknown to the local controllers. Preflight study of the latest information about your destination airport and understanding of the details of the standard instrument approach procedures is essential for the execution of your approach.

Approach to a Controlled Airport With Radar Available—Use of radar in instrument approach procedures. When radar is approved at certain locations for ATC purposes, it may be used not only for surveillance and precision radar approaches, as applicable, but also may be used in conjunction with instrument approach procedures predicated on other types of radio navigational aids. Radar vectors may be authorized to provide course guidance through the segments of an approach procedure to the final approach fix or position. Upon reaching the final approach fix or position, the pilot will either complete his instrument approach in accordance with the procedure approved for the facility, or will continue a surveillance or precision radar approach to a landing.

FAA radar units operate continuously at the locations shown in the *Airman's Information Manual* and are available to all pilots.

Terminal area radar is authorized to control air traffic within the airspace encompassing the routes from outer fixes to the airport, missed approach courses, and the vector areas necessary to position, space, and control departing and arriving aircraft. Coordination between enroute radar control, approach control, and pilot is illustrated by reference to the excerpt from the Dallas-Ft. Worth Area Chart (Fig. 202) and the AL Chart for the ILS approach to runway 13 at Love Field (Fig. 203).

Assume that you are inbound to Dallas (Love Field) on an IFR flight plan filed via Ardmore (see area chart) Victor 15 Dallas. ATC has cleared you via V15W to Denton Intersection. You are conducting your own navigation, in direct contact with Ft. Worth ARTCC radar.

The available radar listed in the *Airman's Information Manual* for Love Field includes Radar Approach Control Services (IFR Arrival Control, IFR Departure Control, and Radar Traffic Information Service), and Surveillance Radar Approaches. From initial contact with radar to final authorized landing minimums, the instructions of the radar controller are mandatory except when—

1. Visual contact is established on final approach at or before descent to the authorized landing minimums, or

2. At pilot's discretion if it appears desirable to discontinue the approach.

Thus on this approach you will have maximum ATC assistance. Following radar identification of your flight between Ardmore and Denton, the Center instructs you to contact Dallas Approach Control. From Denton inbound, you will be vectored to the final approach serving the runway in use at Love Field unless radar contact is lost, complete loss of communications occurs, or you request nonradar routing. The dotted line on the area chart shows a typical radar routing to the Dallas outer compass locator from Denton, via Argyle and Lewisville Intersections and the Dallas ILS front course. The route from an outer fix to interception of the final approach course will be, in any case, the most direct route consistent with minimum radar vectoring altitudes, radar coverage, and other traffic.

Insofar as practicable, radar-vectored routes overlie navigation courses established by other navigation aids. This provides backup in the event of radar failure and reduces the amount of radar navigation service required. Instructions from Approach Control will include the following:

1. Notification whenever—

a. Radar identification is established or lost; or

b. Radar service being provided for your flight is discontinued.

2. Purpose of the vector.

3. Procedures to be followed in the event radio communications are lost while under radar vector.

4. If radar contact is lost, an appropriate clearance via navigational aids for an instrument approach, or an alternative clearance if necessary.

5. Prior to your arrival at the approach gate (a point not less than 5 miles from the approach end of the runway)—

a. Position of your aircraft with respect to the final approach fix.

b. The vector to intercept the final approach course, if required.

c. Clearance for approach.

d. Instructions to do one of the following—

(1) Report over the approach fix to the tower on the local control frequency.

(2) Establish radio communications with the tower on the local control frequency and report over the approach fix, or

(3) Establish radio communications on the

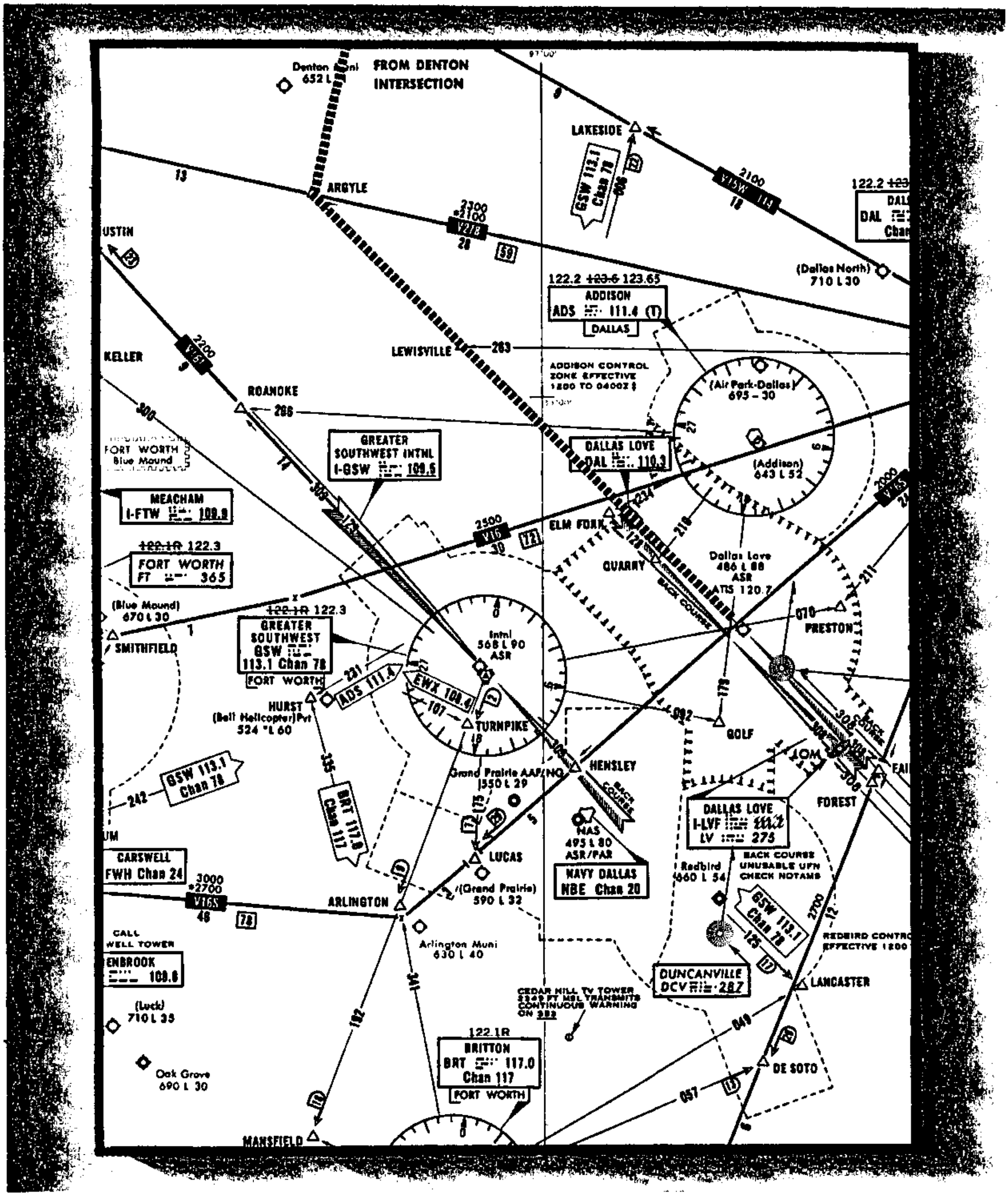


Figure 202. Terminal area ATC control.

final approach frequency if a surveillance or precision approach will be executed.

Surveillance Approach Radar.—Initial radar contact for either a surveillance or precision approach is made with airport surveillance radar. The pilot must comply promptly with all control instructions when conducting either type procedure.

You can determine the radar approach facilities (Surveillance and/or Precision) available at a specific airport by referring to the Airport/Facility Directory of AIM, Low Altitude Enroute Charts, and Instrument Approach Procedure Charts. Surveillance and precision radar minimums are listed in the pages titled, "FAA RADAR CEILING AND VISIBILITY MINIMUMS," in the first part of the Instrument Approach Chart booklet.

On a surveillance approach, the controller vectors you to a point where you can begin a descent to the airport or to a specific runway. Course guidance, and after passing the final approach fix, distance information are issued each mile from the runway/airport down to the last mile. If requested by the pilot, recommended altitudes may be issued each mile from the runway/airport down to the last mile, where the altitude is at or above the minimum descent altitude (MDA). The recommended altitudes on final approach decrease 300 feet each mile (approximate 3° descent slope). The pilot should adjust his rate of descent to achieve a rate consistent with recommended altitudes. If the MDA is reached before the missed approach point (MAP), the pilot should maintain this altitude to the MAP. The controller will advise the pilot when he reaches the MAP or one mile from the runway/airport whichever is greater, and if at this point the airport, runway or runway environment is not in sight, a missed approach should be commenced. If, on final, communication is lost for more than 15 seconds, the pilot should take over visually; if unable, he should execute the missed approach procedure.

Precision Approach Radar.—A PAR serves the same purpose as an Instrument Landing System (ILS) except guidance information is presented to the pilot through aural rather than visual means. If a PAR is available, it is normally aligned with an ILS.

The precision approach starts when the aircraft is within range of the precision radar and contact has been established with the PAR controller. Normally, this occurs approximately eight miles from touchdown, a point to which the pilot is vectored by surveillance radar or is positioned by a non-radar instrument approach procedure. Prior to glide path interception, the final approach airspeed and configuration should be established. When the controller advises the aircraft is intercepting the glide path, power and attitude should be adjusted to maintain a pre-determined rate of descent and airspeed. The rate of descent will vary with aircraft approach speeds and airport glide path angles, but will be near 500 feet per minute.

Prior to intercepting the glide path, the pilot will be advised of communications failure/missed approach procedures and told not to acknowledge further transmissions. The controller will give elevation information as, "slightly/well above" or "slightly/well below glide path" and course information as "slightly/well right" or "slightly/well left of course." Extreme accuracy in maintaining and correcting headings and rate of descent is essential. The controller will assume the last assigned heading is being maintained and will base further corrections on this assumption. Elevation and azimuth guidance is continued to the landing threshold of the runway, at which point the pilot will be instructed to take over visually. If the runway or runway environment is not in sight at the decision height (DH), a missed approach must be executed. If commuication is lost for more than 5 seconds on final, the pilot should take over visually; if unable, he should execute the missed approach procedure.

NOTE: Facilities for PAR approaches have been discontinued at a number of civil airports. Those remaining can be determined by referring to AIM.

No-Gyro Approach Under Radar Control.—If you should experience failure of your directional gyro or for other reasons need more positive radar guidance, ATC will provide a no-gyro vector or approach on request. Prior to commencing such an approach, you will be advised as to the type of approach (surveillance or precision approach and runway number) and the manner in which turn instructions will be issued. All turns are executed at standard rate, except on final approach; then at half standard rate. The controller tells you when to start and stop turns, recommends altitude information and otherwise provides guidance and information essential for the completion of your approach. You can execute this approach in an emergency with an operating communications receiver and primary flight instruments.

Compliance With Published Standard Instrument Approach Procedures.—Compliance with the approach procedures shown on the AL Charts provides necessary navigation guidance information for alignment with the final approach courses, as well as obstruction clearance. Under certain conditions, execution of the complete published procedure is not permissible.

In the case of a radar initial approach to a final approach fix or position, or a timed approach from a holding fix, or where the procedure specifies "NoPT" or "FINAL," no pilot may make a procedure turn unless, when he receives his final approach clearance, he so advises ATC. Execution of the procedure turn is not required in the following instances:

1. When the final approach can be executed from an established holding point on and aligned with the final approach course or from a final approach fix specified in the procedures.

2. When the symbol "NoPT" appears on the

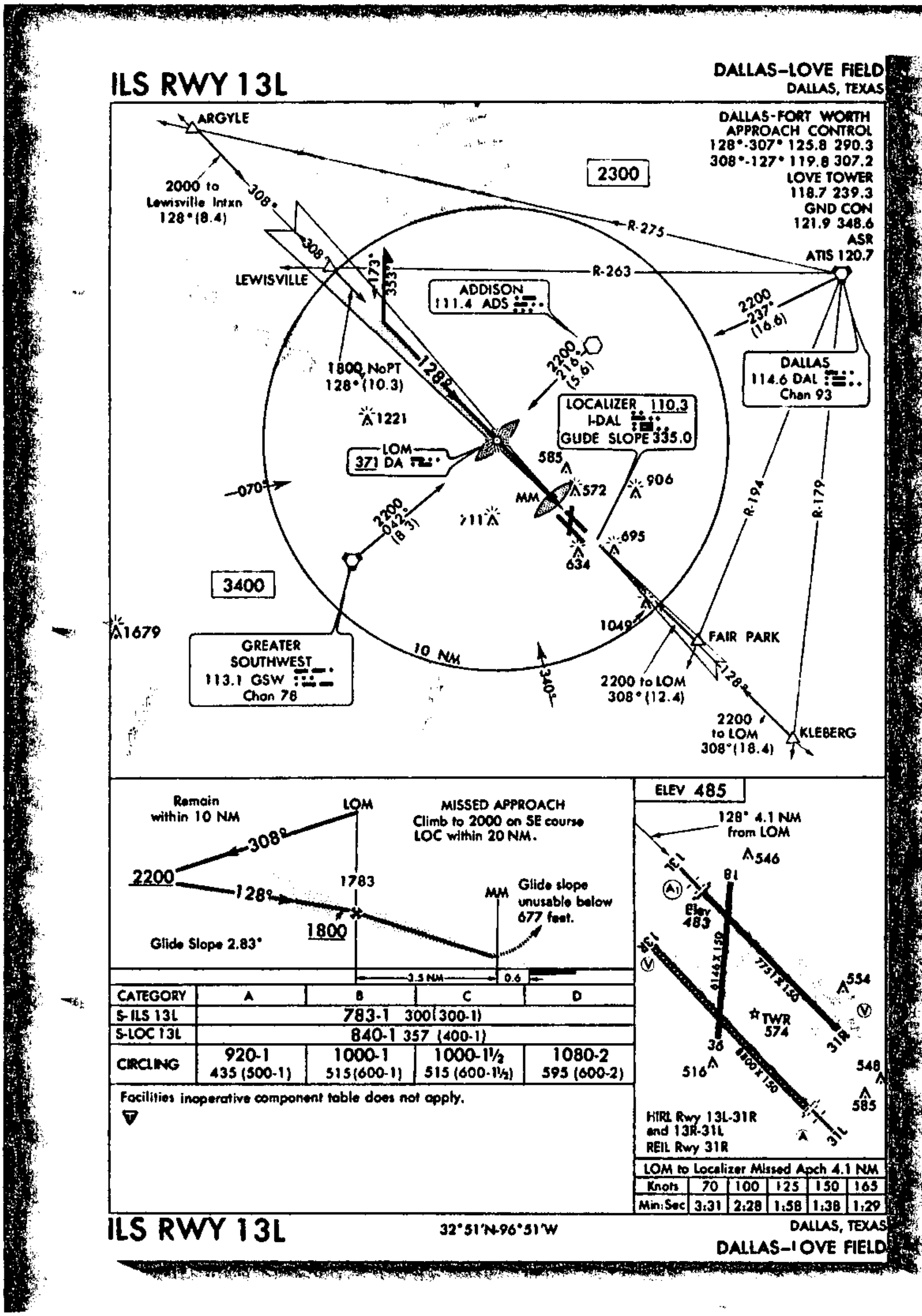


FIGURE 203. Instrument approach procedure chart—maximum ATC facilities.

approach course on the Plan View of the AL Chart.

3. When your approach clearance specifies "Cleared for straight-in (type of approach) approach."

4. When a contact approach has been requested by the pilot and approved by ATC. A "contact" approach is defined as an approach wherein an aircraft on an IFR flight plan, operating clear of clouds with at least 1-mile flight visibility and having received an air traffic control authorization, may deviate from the prescribed instrument approach procedure and proceed to the airport of destination by visual reference to the surface. Approval of your request for a contact approach does not constitute cancellation of your IFR flight plan, and the controller must issue alternative procedures in the event that conditions less than those specified for a contact approach are encountered following approval.

5. At any time you can complete the approach in VFR conditions and cancel your IFR flight plan. Unless you cancel, or unless otherwise authorized by ATC, you are required to comply with the prescribed instrument approach procedure, regardless of weather conditions.

Circling and Low-Visibility Approaches.—There are various methods for executing a circling approach, depending on aircraft performance, ceiling and visibility conditions, wind direction and velocity, final approach course alignment, distance from the final approach fix to the runway, and ATC instructions. During the circling approach, you maintain visual contact with the field and fly no lower than the published circling minimums until landing is assured. It is essential, then, that you understand maneuvering procedures and select one that will keep you oriented to the landing runway and clear of obstructions. Preflight study of the AL charts for your destination and alternate airports will indicate which procedure is most suitable, particularly at uncontrolled airports where no ATC guidance is provided. Methods for completing the circling approach are shown in Figure 204.

Approach "A" can be made when the runway is sighted in time for a turn to a downwind leg, with the runway kept in sight throughout the approach. Approaches "B" and "C" can be made when the runway is sighted late (night approach to a field with minimum lighting, for example). On either of these low-visibility approaches, you execute the turns both by outside references and by reference to instruments until completion of the turn for alignment with the landing runway. These are applications of procedure turns that you have already learned.

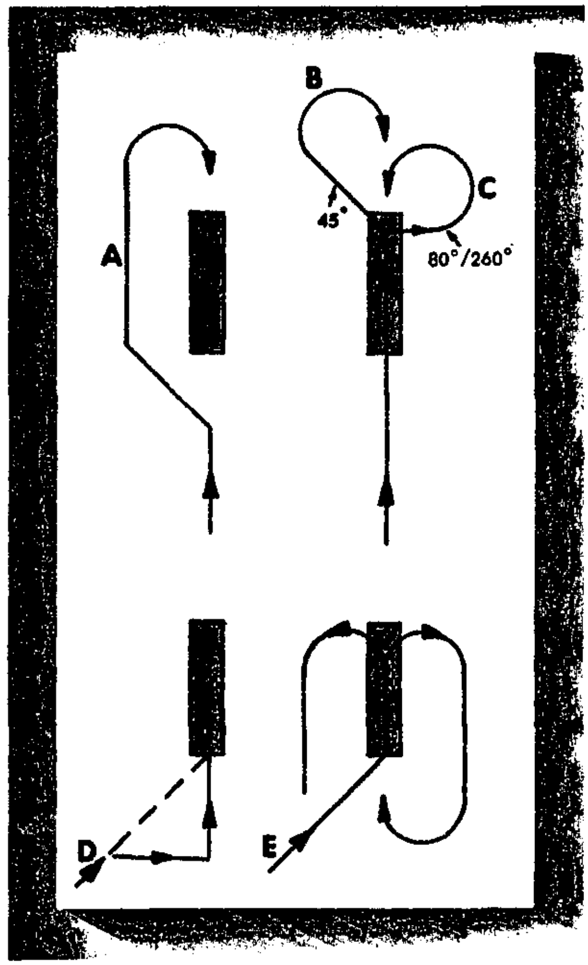


FIGURE 204. Circling approaches.

Missed Approaches

A missed approach procedure is formulated for each published instrument approach. The missed approach is normally made on a course that most nearly approximates a continuation of the final approach course. A missed approach will be initiated at the point where the aircraft has descended to authorized landing minimums at a specified distance from the facility if visual contact is not established, or if the landing has not been accomplished, or when directed by Air Traffic Control. The procedure is shown on the AL Chart in narrative and pictorial form. Since the execution of a missed approach occurs when your cockpit workload is at a maximum, the procedure should be studied and mastered before beginning the approach.

Applicable landing minimums are listed on the AL Chart under *circling* or "S" (straight-in). Straight-in minimums apply if landing is to be made on the runway aligned with the final approach course. Circling minimums apply when it is necessary to circle the airport or maneuver for landing, or when no straight-in minimums are specified on the AL Chart.

The following subjects are a partial review of those regulations published in FAR Part 91 which prescribes takeoff and landing minimums under IFR.

Landing minimums. Unless otherwise authorized by the Administrator, no person operating an aircraft (except a military aircraft of the United States) may land that aircraft using a standard instrument approach procedure prescribed in Part 97 of this chapter unless the visibility is at or above the landing minimum prescribed in that Part for the procedure used. If the landing minimum in a standard instrument approach procedure prescribed in Part 97 is stated in terms of ceiling and visibility, the visibility minimum applies. However, the ceiling minimum shall be added to the field elevation and that value observed as the MDA or DH, as appropriate to the procedure being executed.

Descent below MDA or DH. No person may operate an aircraft below the prescribed minimum descent altitude or continue an approach below the decision height unless—

(1) The aircraft is in a position from which a normal approach to the runway of intended landing can be made; and

(2) The approach threshold of that runway, or approach lights or other markings identifiable with the approach end of that runway, are clearly visible to the pilot.

If, upon arrival at the missed approach point or decision height, or at any time thereafter, any of the above requirements are not met, the pilot shall immediately execute the appropriate missed approach procedure.

Inoperative or unusable components and visual aids. The basic ground components of an ILS are the localizer, glide slope, outer marker, and middle marker. The approach lights are visual aids normally associated with the ILS. In addition, if an ILS approach procedure in Part 97 of this chapter prescribes a visibility minimum of 1,800 feet or 2,000 feet RVR, high intensity runway lights, touchdown zone lights, centerline lighting and marking and RVR are aids associated with the ILS for those minimums. Compass locator or precision radar may be substituted for the outer or middle marker. Surveillance radar may be substituted for the outer marker. Unless otherwise specified by the Administrator, if a ground component, visual aid, or RVR is inoperative, or unusable, or not utilized, the straight-in minimums prescribed in any approach procedure in Part 97 are raised in accordance with the following tables.* If the related airborne equipment for a ground component is inoperative or not utilized, the increased minimums applicable to the related ground component shall be used. If more than one component or aid is inoperative, or unusable, or not utilized, each minimum is raised to the highest minimum required by any one of the components or aids which is inoperative, or unusable, or not utilized.

*(*See Inoperative Components or Visual Aids Table in AC 90-1A on Page 166.)*

Missed Approach from ILS Front Course.—A missed approach is reported and executed in the following instances:

1. If, at the Decision Height (DH), the runway approach threshold, approach lights or other markings identifiable with the approach end of the runway, are not clearly visible to the pilot.
2. When directed by ATC.
3. If a landing is not accomplished.

Missed Approach While Under Radar Control.—Missed approach instructions will be issued by the controller before the final approach and the missed approach point, as required. Except when the controller directs otherwise prior to the final approach, you will report and execute a missed approach—

1. When communication on final approach is lost for more than 5 seconds during a PAR approach, or for more than 15 seconds during an ASR approach.
2. When directed by the controller.
3. When the runway approach threshold, approach lights or other markings identifiable with the approach end of the runway are not clearly visible at the Minimum Descent Altitude (MDA) 1 mile from the end of the runway on an ASR approach, or at the DH on a PAR approach.
4. If a landing is not accomplished.

Missed Approach—ILS Back Course, VOR and ADF Approaches.—For these, the missed approach procedures are related to the location of the final approach fix and are initiated in the following instances:

1. If, at the MDA and the missed approach point, the runway approach threshold, approach lights, or other markings identifiable with the approach end of the runway, are not clearly visible to the pilot.
2. When directed by ATC.
3. If a landing is not accomplished.

When the final approach fix is not located on the field, the missed approach procedure specifies the distance from the facility to the missed approach point. The "Aerodrome Data" on the AL Chart shows the time from the facility to missed approach at various ground speeds, which you must determine from airspeed, wind, and distance values. At this time, you report and execute a missed approach if you do not have applicable minimums.

Landing

The official weather report applicable to published minimums is the weather report, RVR reading and/or runway visibility report, as appropriate. Whenever the reported weather is below the published minimums for a particular approach, the controller will so advise you and request your intentions. Clearance to land will be based solely on your stated intentions and the traffic situations. If you request landing, the controller will qualify the landing clearances as follows:

CLEARED TO LAND IF YOU HAVE LANDING MINIMUMS

The decision to land under such circumstances is thus your own responsibility.

Canceling IFR Flight Plan

You may cancel an IFR flight plan at any time you are in VFR weather conditions unless you are flying in a positive control area. If a destination airport has a functional tower, the flight plan is closed automatically upon landing. At airports without a functional tower, close your flight plan through the Flight Service Station by radio or by telephone after arrival.

Emergencies

Many inflight emergency procedures are special procedures established to meet situations that have been foreseen and for which an immmediate solution is available as a standard procedure. Because of the number of variable factors involved, it is impossible to prescribe ATC procedures covering every possible inflight emergency. You are expected to know thoroughly the emergency procedures formulated to prevent emergencies from developing into accidents.

The emergency for which a published solution is available is just another procedure if you are properly prepared for it. FAR Part 91 prescribes procedures to follow in the event of communications failure.

Loss of Communications While Under Radar Control

If two-way radio communications are lost while you are under radar control, communications will be transmitted on all suitable air/-ground radio frequencies as well as on the voice feature of all available radio navigation or approach aids requesting you to acknowledge by executing suitable turns. If the turns are observed as directed, ATC so advises you, and radar control continues. If the radar controller observes no acknowledging turns, he assumes loss of receiver as well as transmitter capability. If, at this time, you are being vectored off the route specified in your last ATC clearance delivered prior to issuance of vectors, ATC expects you to proceed to such route by the most direct course practicable and then proceed in accordance with two-way radio failure procedures. Pilots of aircraft equipped with coded radar beacon transponders may alert ATC of their radio failure by adjusting their transponders to reply on Mode A/3, Code 7600.

Emergency Radar Flight Patterns

Radar controllers are on the alert for emergency radar flight patterns indicating two-way communication failure. The patterns designed to alert radar systems are as shown in Figure 205.

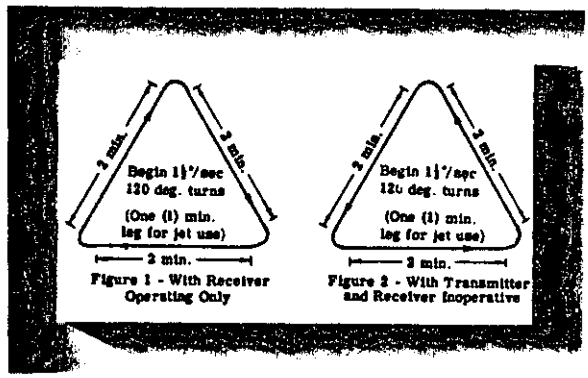


FIGURE 205. Emergency radar flight patterns.

VHF/UHF DF Steer

VHF/UHF equipment is installed at many locations equipped with airport surveillance radar to assist in:

1. Locating aircraft;

2. Obtaining an accurate bearing for the purpose of;

a. Vectoring an aircraft to an airport by the most direct route, when required.

b. Locating lost aircraft or aircraft in distress which are within communications range but outside the area of radar coverage. This information will furnish the controller with the proper heading required to bring aircraft within the antenna pattern of the surveillance radar equipment.

c. Obtaining and coordinating cross bearings to establish a fix in localities where the VHF/UHF communications range of two or more VHF/UHF DF installations overlap.

VHF/DF capability is indicated in the Airport/Facility Directory of AIM.

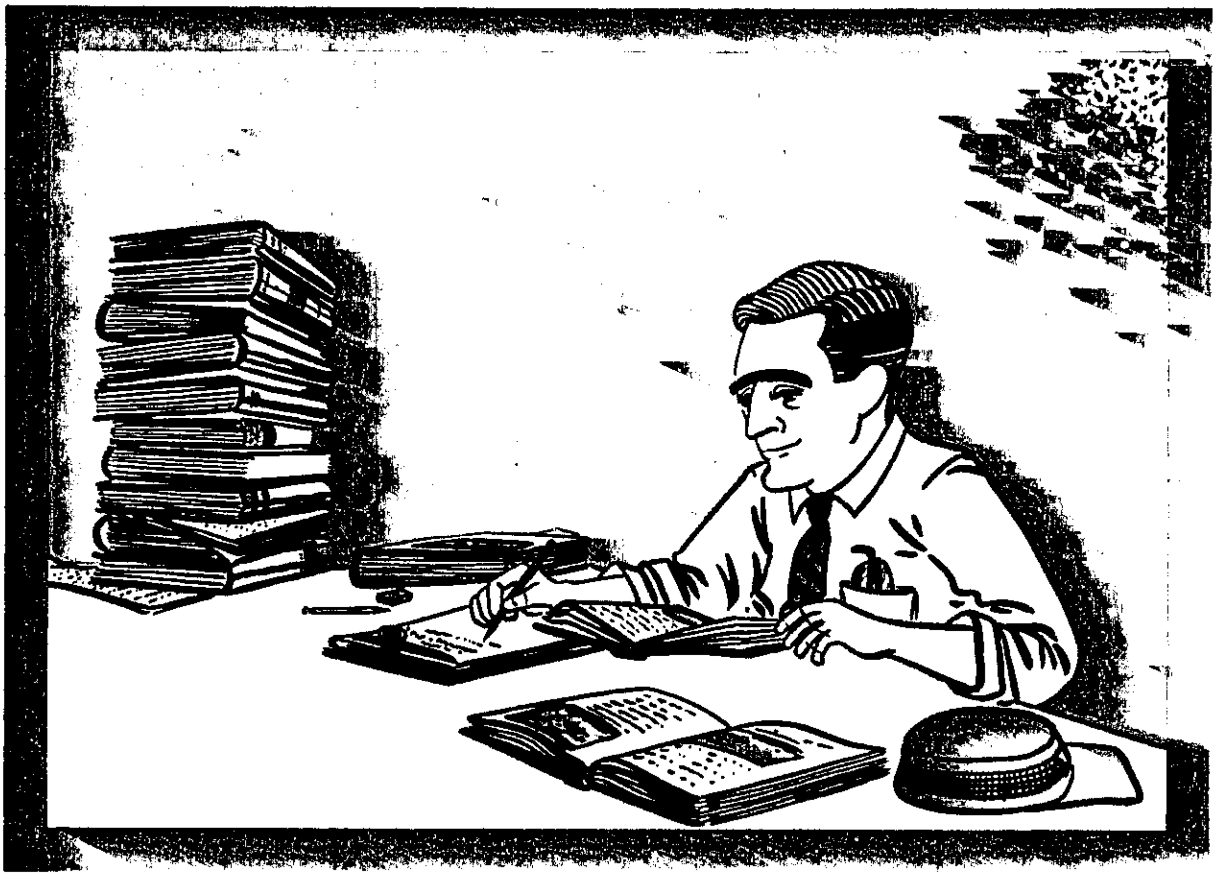
VHF/DF Homing Procedure

Request for an emergency DF steer is normally made on 121.5 MHz. If you cannot transmit on this frequency, request DF service on any standard frequency from any FAA tower or Flight Service Station. Such requests will be relayed without delay to the nearest VHF/DF facility in the DF network. Practice steers may also be obtained, using 121.5 MHz to establish initial contact. If an emergency exists, make the fact clear in your initial callup.

The following is a sample DF homing procedure:

1. (pilot)—"Boston Homer, this is Skyrod 1234 Delta, request homing (or "request emergency homing"), over."
2. (VHF/DF station)—"Skyrod 1234 Delta, this is Boston Homer, transmit for homing on —— MHz, over."
3. (pilot)—"Boston Homer, this is Skyrod 1234 Delta," (depress VHF tone button for two periods of 10-seconds each. If your aircraft is not equipped with a tone button, transmit a voice signal—steady ah-h-h—for the same periods at a volume as constant as possible), "Skyrod 1234 Delta, over."
4. (VHF/DF station)—"Skyrod 1234 Delta, this is Boston Homer, course with zero wind 060, over."
5. (pilot)—"Boston Homer, this is Skyrod 1234 Delta, course 060, out."

The course given is the magnetic direction you must steer to reach the DF station assuming zero wind. Bearing information (true bearing of your aircraft from the station) is available on request. During an emergency, the DF station will monitor your position and verify or revise course information as necessary. Remember that the accuracy of a VHF/DF steer is subject to line-of-sight limitations as to height and distance, as well as fluctuations in the volume of the tone you transmit.



XII. FLIGHT PLANNING

No single detailed procedure can be outlined that is applicable to the planning of all IFR flights. However, the basic elements of preflight action are common to all flight-planning problems, irrespective of the simplicity or complexity of the factors affecting the safe and orderly conduct of the flight. This chapter deals with the computations, sources of aeronautical information, and weather information used in preparation for flight under Instrument Flight Rules.

Your first exercise in flight planning may seem unnecessarily time-consuming and discouraging as you plod through computer operations and a mass of information in search of data relevant to your flight. With practice in the preparation of flight logs, you will become increasingly handy with the computer and familiar with the contents of the appropriate flight planning documents. The exercise that follows later in this chapter lists the steps involved in preparing for a typical IFR flight. At each stage of the exercise, the applicable regulations, charts, and other sources of information are listed. In *Aviation Weather,* you will find both the fundamental meteorological knowledge and operational weather information of importance to the instrument pilot.

Computer Operations

The amount of computer work necessary to plan an IFR flight depends on a number of factors, including flight plan requirements, weather, type of aircraft, route, ATC services available, and airborne equipment. Your flight plan will require airspeed, time, and fuel estimates normally derived by means of any one of many types of navigation computers.

Pilots are sometimes tempted to be careless about these estimates on the assumption that weather forecasts, routes, and altitudes are subject to change and therefore not worth the time spent on detailed and careful computer operations. If you are tempted to make haphazard "guestimates," bearing in mind that it is easier to revise a well-organized flight plan than to improvise in the air. Accurate flight-planned estimates reduce your enroute workload and provide greater safety in the event of enroute emergencies. In addition, weather conditions can keep you preoccupied enough with aircraft control, navigation, and coordination with Air Traffic Control without the added burden of inflight attention to computations overlooked or ignored during preflight planning. The more adverse the weather, the more thorough must be your preparation.

The computer solutions that follow are additional to those explained in the *Pilot's Handbook of Aeronautical Knowledge.* It is assumed that the applicant for the Instrument Rating understands the triangle of velocities and the operation of the calculator and wind faces discussed in that handbook. Computer solutions of many navigation problems beyond the scope of these handbooks can be found in the instructional booklet available with the purchase of your computer.

Computer Problems

Use of the 10 Index.—The 10 index on the minutes scale is used instead of the 60 index to solve the following rate-of-climb problems since rate-of-climb is expressed in feet per minute.

Problem 1. How much altitude is gained in 12 minutes at a rate of climb of 550 fpm?
Solution (Fig. 206).

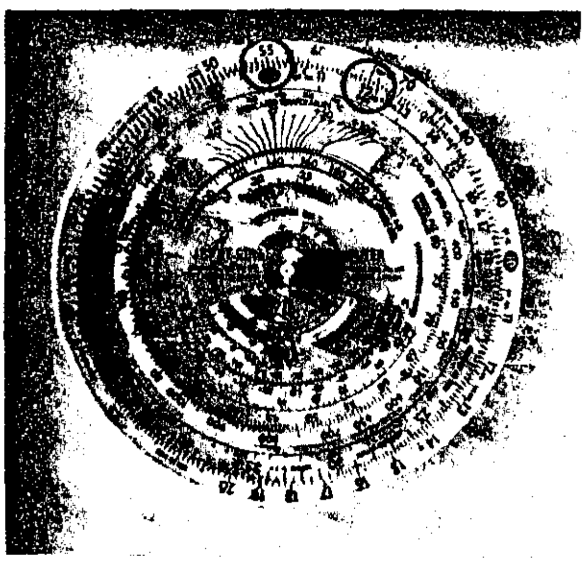


FIGURE 206.

a. Set the 10 index under 550 (outer scale).

b. Over 12 minutes (inner scale) read 6,600 feet, the altitude gained.

Problem 2. Your IFR clearance reads in part, "Cross X Intersection at 8,000 feet." Estimating the intersection in 6 minutes, what minimum average rate of climb must you make good from your present altitude of 3,500 feet in order to comply with the clearance?
Solution (Fig. 207).

a. 8,000 — 3,500 = 4,500 (number of feet to climb).

b. Set 45 (outer scale) over 6 (inner scale).

c. Over the 10 index (inner scale) read 750 fpm.

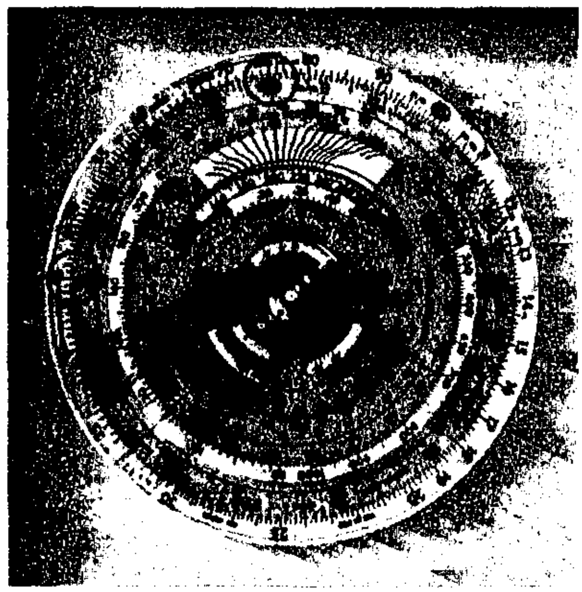


FIGURE 207.

Problem 3. What is the average rate-of-climb if your aircraft climbs from 1,350 feet to 7,500 feet in 9 minutes?
Solution (Fig. 208).

a. 7,500 — 1,350 = 6,150 (number of feet climbed).

b. Set 615 (outer scale) over 9 (inner scale).

c. Over the 10 index (inner scale) read 683 fpm.

Use of the 36 Index.—The number 36 on the inner scale is used for solutions of rate/time/distance problems when time must be computed in seconds and minutes instead of minutes and

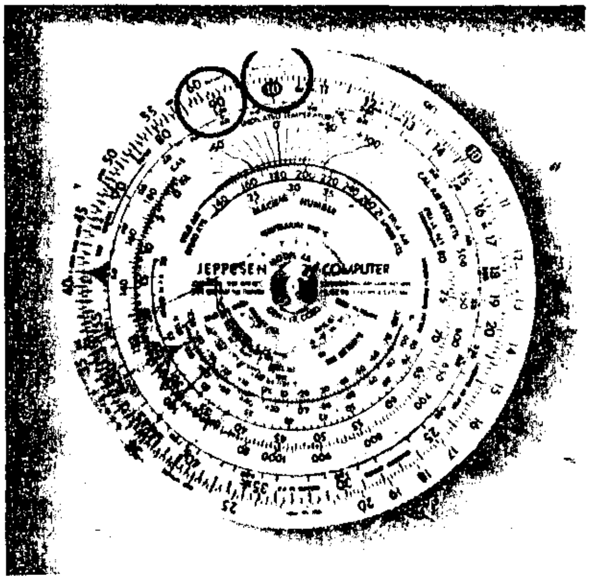


Figure 208.

hours. The computer solution is based on the following formula:

$$\frac{GS}{36} = \frac{\text{Distance}}{\text{Seconds}}$$

In the formula above, GS is groundspeed, 36 is the seconds per hour (3,600), distance is the miles or fraction of miles to be flown, and seconds is the time required to fly the distance.

Problem 4. What is the time required to fly from the outer marker to the middle marker if the ground speed is 90 knots and the distance between markers is 5 nmi?

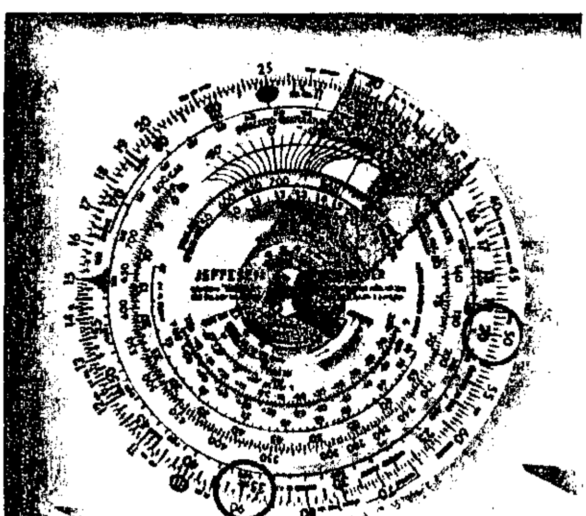


Figure 209.

Solution (Fig. 209).

a. Set 36 (inner scale) under the groundspeed (90) on the outer scale.

b. Under 5 (outer scale) read 200 seconds on the inner scale.

Altitude Computations

Density altitude is pressure altitude corrected for temperature. Since the aircraft performance data in your aircraft flight handbook is related to density altitude rather than indicated or true altitude, it is important that you understand how to compute this value. Both free air temperature and pressure altitude (indicated altitude when the altimeter is set at 29.92) are read directly from your aircraft instruments for computer solution of density altitude problems.

Problem 5. At a pressure altitude of 8,000 feet and a free air temperature of + 10° C., what is the density altitude?

Solution (Fig. 210).

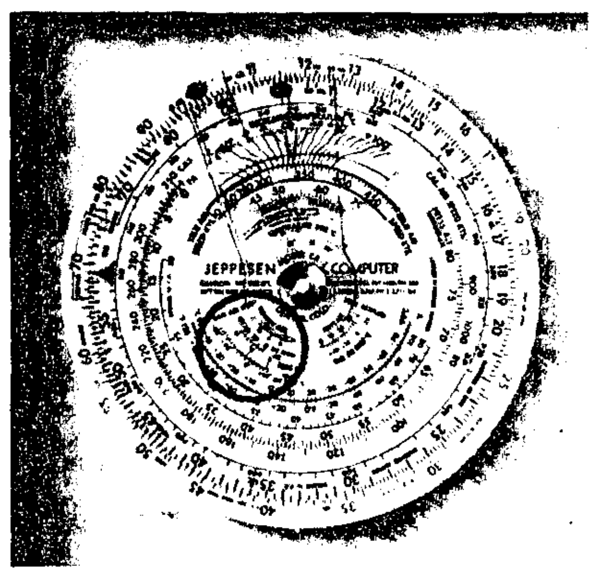


Figure 210.

a. Set the free air temperature (10°) opposite the pressure altitude (8,000).

b. Read the density altitude (9,200) in the density altitude window under the index.

True altitude, commonly called *corrected altitude* because it is computed from temperature and altimeter setting information subject to error, is at best an important approximation of height above sea level. As pointed out earlier, when nonstandard atmospheric conditions exist, computation of true altitude in very significant in the selection of an IFR altitude to guarantee terrain clearance in mountainous areas. True altitude is computed from three known values—indicated altitude (or calibrated altitude if available), pressure altitude, and free air temperature. A more accurate figure can be computed if the altitude of the reporting station is known and applied to the solution. Further, outside free air temperatures read in high-speed aircraft must be corrected for compressibility effect for an accurate true free air temperature value.

Problem 6. Your indicated altitude is 10,000 feet, the outside air temperature is — 15° C., and the pressure altitude is 9,000 feet. Find the true altitude.

Solution (Fig. 211).

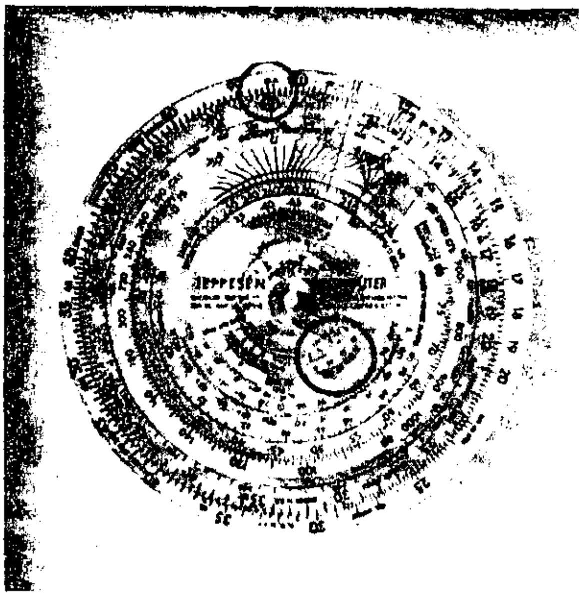


FIGURE 211.

a. Set the pressure altitude (9,000) opposite true air temperature (— 15° C.).

b. Opposite 10 (10,000 indicated altitude) on the minutes scale, read the true altitude (9,540) on the miles (outer) scale.

Problem 7. Find the true altitude when the following values are known:

Pressure altitude	10,000 feet
Free air temperature	— 10° C.
Indicated altitude	11,000 feet
Altitude of reporting station	4,500 feet

Solution (Fig. 212).

a. Set the pressure altitude (10,000) opposite the free air temperature (— 10° C.).

b. Subtract 4,500 feet (altitude of reporting station) from 11,000 feet (indicated altitude above MSL) to obtain indicated altitude above the ground (6,500 feet).

c. Opposite 6,500 on the inner scale, read 6,360 on the outer scale (true altitude above the ground).

d. Adding 6,360 and 4,500, true altitude above sea level is 10,860 feet.

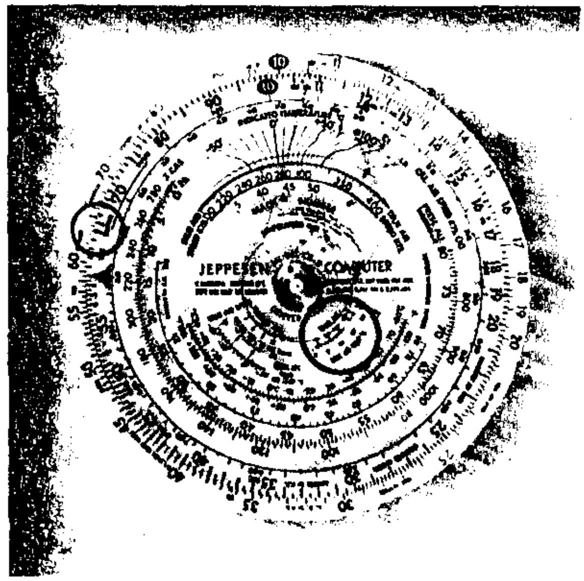


FIGURE 212.

Problem 8. Find the true altitude when the following values are known:

Pressure altitude	14,000 feet
Indicated outside air temperature	— 20° C.
Indicated altitude	15,000 feet
True airspeed	200 knots

Solution (Fig. 213).

At this true airspeed (which is well within the cruising range of many general aviation aircraft), the outside air temperature reads significantly in error. The correction to apply to the indicated temperature value may be obtained from tables or derived by computer solutions. One simple computer solution applies the constant 9,500 in the following formula:

$$\frac{\text{TAS}}{95} = \frac{\text{Temperature Correction}}{\text{TAS}}$$

a. Set the constant (95) on the inner scale opposite 200 (TAS) on the outer scale.

b. Opposite 200 on the inner scale, read the heat of compressibility error (4.2° C.) on the outer scale.

c. Since the heat of compressibility always results in an indicated reading warmer than the true temperature, adjust the indicated temperature 4.2° colder, for a true outside air temperature of −24.2° C.

d. Compute the true altitude as in problem 6 above, using the corrected temperature. The true altitude is 14,300 feet.

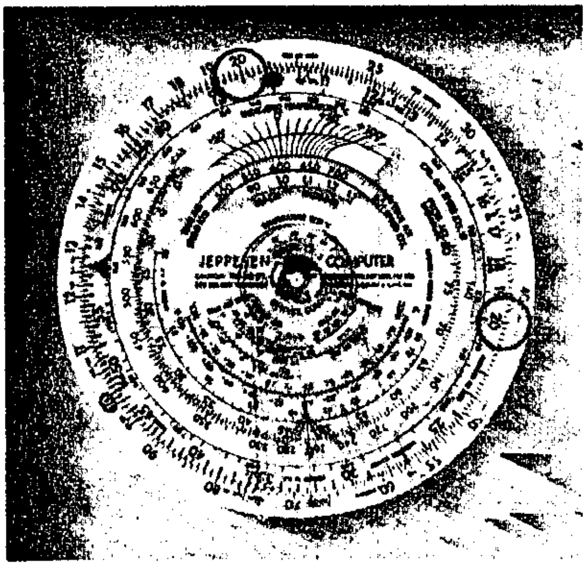


FIGURE 213.

Wind Face Problems.—The examples below show only one of the methods commonly used for the solution of problems on the grid side of your navigation computer. The pros and cons of these methods can be studied in various basic texts on the use of navigation computers.

Problem 9. Your true heading is 085°, true airspeed 150 knots, wind velocity 030/20 knots. Find track and groundspeed.

Solution (Figs. 214 and 215).

a. Set wind direction (030°) under the true index (see Fig. 214).

b. Locate the wind vector 20 units down from the grommet.

c. Rotate the compass rose to put the true heading (085°) under the true index (see Fig. 215).

d. Slide the card up or down until the true airspeed (150 knots) is under the grommet.

e. Read groundspeed (139 knots) on the speed circle that passes through the head of the wind vector.

f. Read the drift angle (7° right) by counting the number of degrees from the centerline to the head of the wind vector.

g. Compute track (092°) by applying the drift angle to the true heading.

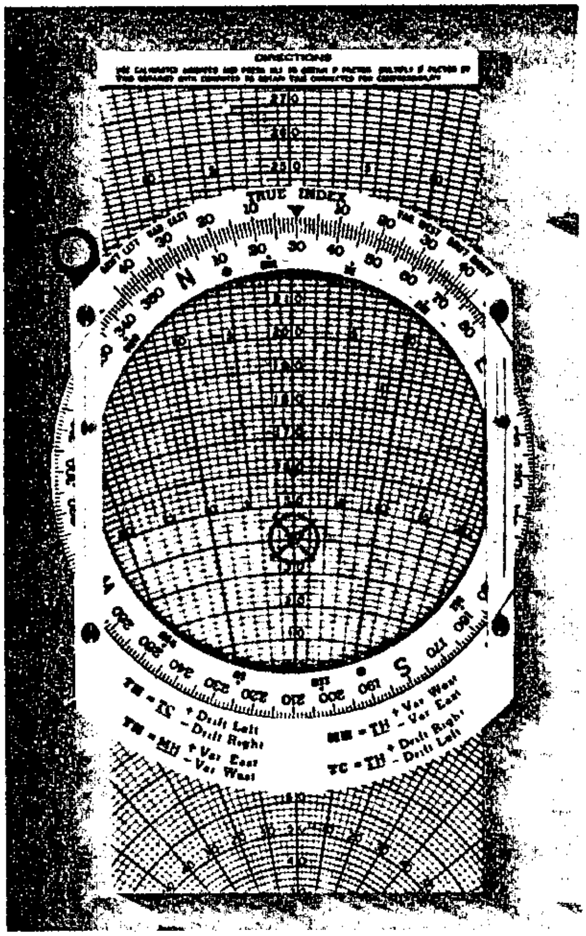


FIGURE 214.

Problem 10. Your true heading is 290°, true track 298°, true airspeed 145 knots, and groundspeed 160 knots. Find the wind velocity.

Solution (Figs. 216 and 217).

a. Set the true heading (290°) under the true index (see Fig. 216).

b. Set the true airspeed (145 knots) under the grommet.

c. Determine the drift angle (8° right) by noting the difference between heading and track. Locate the 8° trackline to the right of the centerline.

d. Locate the head of the wind vector at the intersection of the 8° trackline and the groundspeed circle (160 knots).

e. Rotate the compass rose until the head of the wind vector is on the centerline below the grommet. Read the wind direction (168°) under the true index (see Fig. 217).

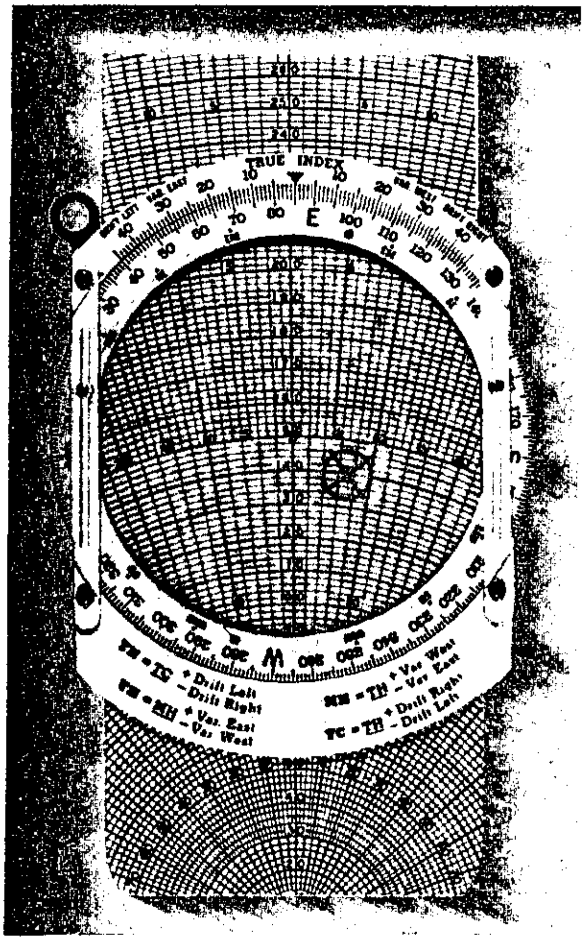


FIGURE 215.

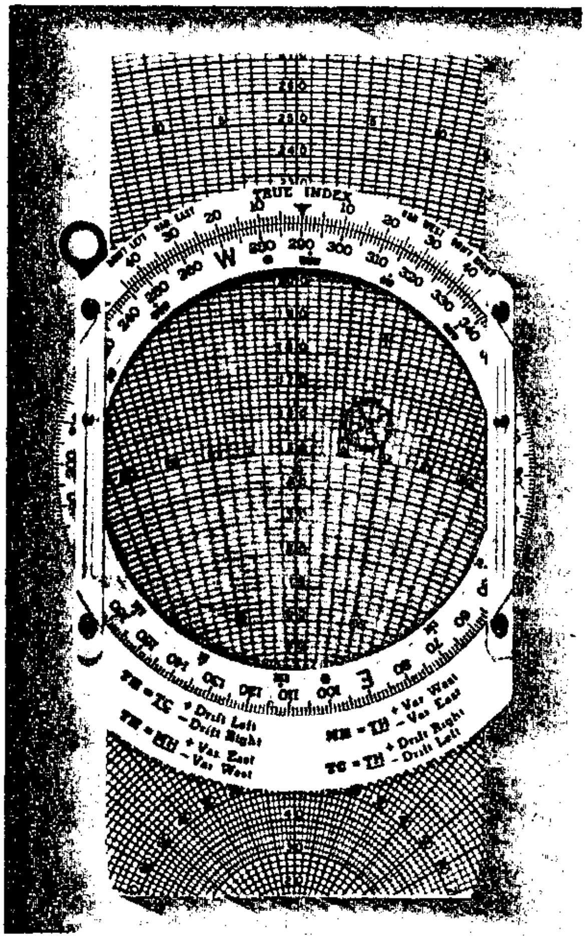


FIGURE 216.

f. Read the windspeed (26 knots) on the speed scale between the grommet and the head of the wind vector.

Sources of Flight Planning Information

In addition to the Enroute Charts, Area Charts, and Approach and Landing Charts discussed in Chapter IX, the FAA publishes the *Airman's Information Manual* for flight planning in the National Airspace System. The manual is issued in three Parts, with each revised on a periodic schedule. The revision cycle of each Part is based upon the relative stability of the different types of information presented. For availability see "Supplementary Reference Materials" in Chapter XIII, Appendix.

Because AIM is published for all airspace users, much of the information applies to flight operations of no more than casual interest to the instrument flying student familiar only with typical light plane equipment. For example, TACAN, CONSOLAN, and Jet Advisory Service data relating to navigation and radar equipment are of concern to pilots of military and large transport-type aircraft. Specific other information may be important to you only under occasional or rare circumstances. In this category are "Search and Rescue Procedures," "Visual Emergency Signals," "ADIZ Procedures," and "VHF Direction Finding Procedures and Facilities."

The sections of Part 1 entitled "Basic Flight Manual and ATC Procedures," applicable to VFR as well as IFR operations, contain basic operational information especially helpful to inexperienced pilots and those "rusty" on current procedures. Descriptions, diagrams, and general discussions about airport lighting and marking, altimeter settings, radar services, approach lighting systems, and navigation facilities help to clarify these important elements of aeronautical knowledge. Fi-

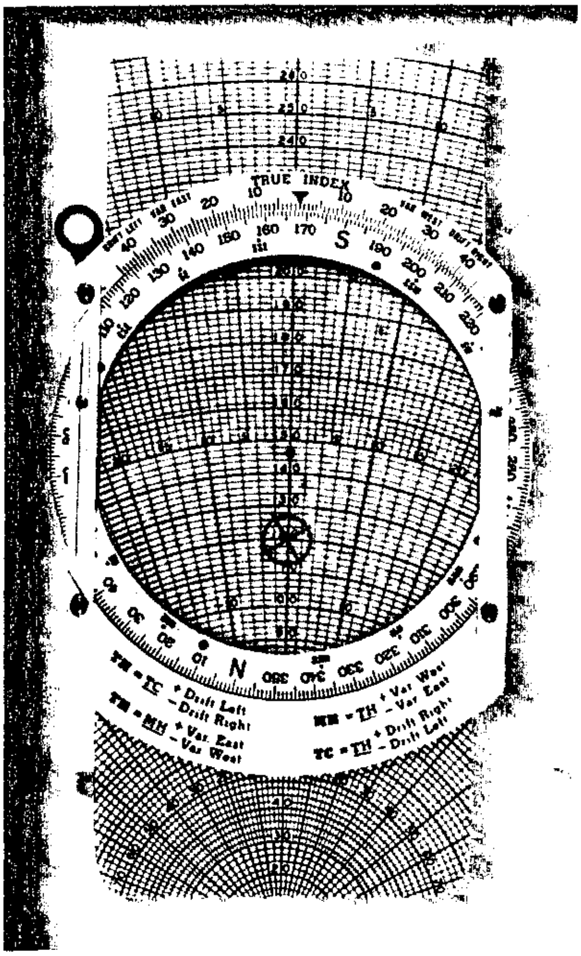


FIGURE 217.

nally, of more immediate importance for the planning and conduct of instrument flights are such listings as "Weather Reporting Stations," "Flight Service Stations," and "VOR Receiver Check Points," found in other parts of AIM. Review of the contents of AIM will help you to determine which sections are useful for frequent or occasional reference.

As you become familiar with this publication, you will be able to plan your IFR flights quickly and easily.

Preferred routes are designed to provide for the systematic flow of air traffic in the major terminal and enroute flight environments. The *Airman's Information Manual* lists the preferred routes from the major terminals alphabetically, to other major terminals in the airspace system. Although this routing is not mandatory, filing via preferred routes has obvious advantages. Flight planning is simplified because of the probability that the route filed will be approved by ATC. Further, the clearance for a flight via SID and preferred route is in brief form, eliminating the complicated route descriptions familiar to instrument pilots.

Since the preferred routes provide for the most efficient flow of traffic in and out of terminal areas, route changes and traffic delays are minimized. For example, when planning a flight from New Orleans, La., to Washington, D.C., you find a number of possible routes shown on the four Low-Altitude Charts to be used. A check of the preferred routes listed will show this entry (Fig. 218).

NEW ORLEANS METRO AREA

Dallas............	0000-2359 GMT Walker V114N AEX V114 GSW 081 Fitch (L-17, 13)
Dulles............	V20 SBV V39 GVE V39E Brandy (L-17, 18, 20, 22)
Kennedy..........	V20 V213 ENO V44 Beachwood (L-17, 18, 20, 22, 24)
Newark...........	V20 V213 ENO V29 V433 RockyHill (L-17, 18, 20, 22, 24)
Washington.......	V20 SBV V39 GVE V16 Ironsides (L-17, 18, 20, 22)

FIGURE 218.

The preferred route is V20 SBV V39 GVE V16 Ironsides. Ironsides is a fix within the Washington terminal area. The Enroute Low-Altitude Charts pertinent to the flight are in parentheses. By thorough study of the navigation and communications data appropriate to your selected route, you avoid uncertainty and confusion during IFR departures from busy terminal areas.

The "Notices to Airmen" list alphabetically by State, operation hazards and restrictions, navigation facility limitations, amendments to instrument flight procedures, and other current airspace data that should be checked during preflight planning, for either VFR or IFR operations.

The "Airport/Facility Directory" tabulates the facilities and services available at major airports which have terminal NAVAIDS and communications facilities. This listing, by State and city, includes runway data, radio frequencies, radar services, and terminal information essential to flight planning. Reference to this section provides a check as to availability of instrument landing facilities at your destination and alternate airport.

If your preliminary check of weather indicates marginal conditions, the facilities and services available at your destination will determine whether or not you can complete your flight. For complete instrument approach and landing data, refer to the "Instrument Approach and Landing Charts."

On the outside flap of each Enroute Low Altitude Chart are listed the Air Route Traffic Control Center/Remote Frequencies used by ATC for direct controller-to-pilot enroute control of IFR flights in the area covered by that chart. Figure 219 is an excerpt from the outside flap of charts L–13 and L–14.

AIR ROUTE TRAFFIC CONTROL CENTER / REMOTE CONTROL FREQUENCIES

ALBUQUERQUE CENTER
125.2
Amarillo 132.3 127.2

ATLANTA CENTER
125.2 124.1 120.3 118.9
Birmingham 135.6 127.5
Chattanooga 132.55 121.2

FORT WORTH CENTER
127.0 126.0 125.5 124.7
Abilene 124.4
Ardmore 128.1
Blue Mound 126.0
Farmerville 135.0
Hobart 128.4
Lubbock 128.45 127.7
Marshall 126.6
Midland 133.1 128.7 128.0
Oklahoma City 128.3 127.45
Texarkana 124.8
Wichita Falls 135.6

MEMPHIS CENTER
127.6 120.1 119.3
Columbus 127.1
Fayetteville 126.1
Graham 128.7
Greenville 132.5
Huntsville 120.8
Pine Bluff 127.75 127.2
Russellville 132.3
Walnut Ridge 127.4

Figure 219.

As your flight progresses from sector to sector, you will be advised of the frequency to be used and when the frequency change is required. If your communications equipment is limited, the limitations should be specified in your flight plan. The Sector Discrete Frequencies listed in Figure 219 for Albuquerque, Atlanta, Fort Worth, and Memphis Centers range from 119.3 to 135.6 MHz for control in the low altitude structure. Accordingly, if you have 90 channel capability (118.0–126.9 MHz), enter "VHF T/R 90 ch." under "Remarks" on your flight plan. This entry tells ATC that your flight enroute can be controlled directly by the centers on Sector Discrete Frequencies below 127.0 MHz.

If your equipment includes only the standard FSS VHF frequencies, enter this limitation on your flight plan so that the ARTCC will communicate to you through Flight Service. This information not only facilitates enroute communications; it also affects the separation standards (radar vs nonradar) applied to your flight. The use of radar separation minimums requires instantaneous interference-free controller-to-pilot communications.

NOTAMS

In addition to the basic flight information found in the publications already discussed, you will be interested in the current information concerning the National Airspace System as it is distributed for rapid dissemination through the Flight Service Stations.

NOTAMS are transmitted by teletype when the basic flight publications do not contain current information concerning:

1. A landing area condition which precludes safe operation of aircraft.
2. An unscheduled change in, or irregular operation of, any component of the National Airspace System which precludes the use of a facility for normal aircraft operations.
3. Any scheduled and published change to components of the National Airspace System that is rescheduled or modified.
4. New or modified instrument procedures or changes in operating minimums.

The example below shows a NOTAM given at the end of a Baltimore sequence report:

→BAL 4/2 QAPES

Decoded, the NOTAM says that the transmitting station is Baltimore, the NOTAM is the second issued since the beginning of the fourth month, and the Baltimore VOR range and associated voice facilities are out of service.

The Hourly Weather Sequence Reports at a particular Flight Service Station apply only to the area within approximately 400 miles of the station. NOTAM data beyond this radius can be obtained from the FSS by request.

Flight Planning Problem

The flight planning exercise presented here is not intended as an inflexible procedure for the instrument pilot to follow. Many factors affect the sequence of your preflight activity and the content of your flight log entries. For example, the preflight time and inflight attention to fuel consumption are minor problems for a 1-hour IFR flight in an aircraft with 5 hours of fuel aboard, as compared with fuel management problems in a jet aircraft on a maximum range IFR flight to a destination where the weather is just above minimums. In the first instance, your fuel problem involves only routine inflight checks on fuel consumption for subsequent planning purposes and the usual management of the aircraft fuel system. In the second case, there is little or no margin for error, either in preflight computations or enroute record.

The low-time instrument pilot can benefit from experience in the use of all the facilities and sources of information available to him. Through experience you will find a reliable basis for adapting planning methods to operational needs. The professional corporation pilot familiar with his proposed route and terminal facilities may be concerned primarily with weather and loading data. Other professional pilots limit their preflight computations to those necessary for the IFR flight plan (estimated true airspeed, estimated time enroute, and fuel on board). Then they prepare a tentative flight log suitable for quick and continuous inflight computations and revisions. Regardless of their experience and differences in planning methods, they overlook no detail that might invite unnecessary inflight problems.

The following problem involves preparation for an IFR training flight from Oklahoma City to Dallas (Love Field) via Okmulgee, then return to Oklahoma City. Instrument approaches are planned at Okmulgee and Love Field. The problem begins with the preliminary check with the weather forecaster and ends with the completed flight plan.

Although the 10 steps and the flight log may need adapting to your particular operational needs, they include the aeronautical knowledge applicable to an IFR flight in controlled airspace. Since the FAA written tests for the Instrument Rating are based on comparable problems, the exercise serves as a guide to detailed preparation for the tests. Each step discussed in the preflight action is related to the appropriate Federal Aviation Regulation and sources of information related to the planning procedure.

Aircraft equipment, performance and operating data, weight and balance information, and weather reports and forecasts are included. The Enroute Low Altitude Chart Segment on the last page of this handbook applies to this exercise. For completion of this exercise and further practice, you will need, in addition to the chart segment supplied with this handbook, the following "tools of the trade":

1. *Airman's Information Manual,* including Part 2, *Airport Directory*.
2. *Aviation Weather* AC 00–6.
3. A navigation computer.

AIRCRAFT DATA.—FASTFLIGHT N6864S

The aircraft is a 5- to 7-place twin-engine "Fastflight" typical of various light twins currently in use. It is appropriately equipped for instrument flight and has the following radio installations:

One L/MF receiver.
One automatic direction finder (ADF).
Dual VHF receivers (both with frequency range 108.0–126.9 MHz) with omni heads of the three-element type (course selector, course deviation indicator, and TO-FROM indicator) and instrument landing equipment (ILS-localizer and glide slope receivers).
One marker beacon receiver.
One 360 channel transceiver (range 118.0–135.9 MHz).
One 90 channel transmitter (range 118.0–126.9 MHz).

EMPTY WEIGHT.—As equipped, 4,940 lb.

MAXIMUM ALLOWABLE GROSS WEIGHT.—7,000 lb.

OIL CAPACITY.—10 gallons (5 gal./engine).

USABLE FUEL.—
Main, 156 gal.
Aux., 67 gal. (38.5 gal. in each of 2 aux.).

FUEL CONSUMPTION.—40 gal./hr. (20 gal./hr./engine).

BAGGAGE COMPARTMENT.—See Weight and Balance information.

CALIBRATED AIRSPEEDS.—

Climb	145 knots.
Cruise	165 knots.
Approach	110 knots.
Stall	85 knots.

ALTITUDES.—All flight altitudes will be in terms of MEAN SEA LEVEL (MSL) unless otherwise specified.

RADIO CALL.—Fastflight 6864S.

DE-ICING EQUIPMENT.—Aircraft is equipped with propeller anti-icing, and wing, and vertical and horizontal stabilizer de-icers.

COMPASS CORRECTION CARD—

FOR (MH)	0	30	60	90	120	150	180	210	240	270	300	330
STEER (CH)	1	30	58	90	122	153	179	210	240	272	300	330

Preflight Action

As you proceed with the preflight steps, refer to the flight logs and the sources listed within the brackets. Step 1, for example, refers you to (a) Federal Aviation Regulations, which specify what checks are *required* and (b) *Aviation Weather,* which explains the *meaning* of the weather information.

Step 1. Preliminary weather check.—Regardless of how good the current weather looks in your departure area, you may save planning time by making use of forecast services well in advance of your expected departure time. Usually, a detailed forecast is accurate for about 6 hours in advance. Beyond 24 hours, only general weather outlooks are possible. It is therefore important to know the types of forecasts available, their filing times, and their valid times. Familiarization with weather service facilities as you plan practice IFR flights in VFR weather conditions is excellent preparation for all-weather flying capability. [See FAR 91, *Aviation Weather,* and weather data on page 229.]

Step 2. Tentative route(s) to destination and alternate(s).—If possible, choose preferred routes and select more than one alternate if weather is marginal. Start preparation of flight log (Fig. 220). [FAR 91.83 (a) (5); Enroute Chart(s); *Airman's Information Manual;* Low Altitude Area Chart; Winds Aloft Forecasts.]

a. *Proposed Altitude.*—This will depend on factors such as aircraft performance and equipment, winds aloft, freezing level, turbulence, cloud tops, and minimum instrument altitudes. [FAR 91.119; FAR 91.121 (a) and (b).]

b. *Route and Check Points.*—The Dallas-Ft. Worth Area Chart (Fig. 202) shows normal arrival route (1) from Denton Intersection direct Argyle and Lewisville Intersections; and (2) from Denton Intersection V15W to Dallas VORTAC, then V16S to Dallas Love Airport. Either route may be used for flight planning. [FAR 91.123; Fig. 202; Enroute LA Chart segment inside back cover.]

c. *True or Magnetic Courses.*—The courses entered on the sample flight log are true courses. Some pilots reference their computations to true

FLIGHT LOG

Check Points: From	Check Points: To	Route / Altitude	True Crs.	Freq. / Intersections / Radial	True Air Speed	Winds Aloft Direction Velocity Temperature	Drift Correction Angle	Ground Speed	Leg Dist. / Dist. Remaining	ETE / Total Time	ETA / ATA	Fuel Used / Fuel Remaining	Reporting Frequencies
OKC	SHAWNEE	V14S / Climb	107°	116.7 / 357					28 / 415				
SHAWNEE	OKM	V15W / 5000	066°						63 / 352				
OKM	ADM	V15 / 6000	217°						110 / 242				
ADM	DENTON	V15W / 5000	178°	116.5 / 078					57 / 185				
DENTON	DAL	V15W / 5000	120°						29 / 156				
DAL	ADM	V15 / 6000	339°						76 / 80				
ADM	OKC	V163 / 6000	338°AV						80 / 0				
ALTERNATE													
OKC	SPS	V77 / 6000	205°AV						96				

REMARKS

NOTE:
(1) This log is provided to assist applicants in the orderly arrangement of flight planning data used in written examinations.
(2) The use of all or any part of this form is optional.
(3) Return this form to the monitor upon completing the examination.

AC Form 8200-6 (2-66) Formerly AC Form 1517.

Figure 220. Flight Log entries.

FLIGHT LOG

CHECK POINTS		ROUTE / ALTITUDE	TRUE CRS.	FREQ. / INTERSECTION / RADIAL	TRUE AIR SPEED	WINDS ALOFT DIRECTION VELOCITY TEMPERATURE	DRIFT CORRECTION ANGLE	GROUND SPEED	LEG DIST / DIST. REMAINING	ETE / TOTAL TIME	ETA / ATA	FUEL USED / FUEL REMAINING	REPORTING FREQUENCIES
FROM	TO												Total Fuel: 196 gals.
OKC	SHAWNEE	V14S / Climb	107°	116.7 / 357	150	2430	8°R	169	28 / 415	9.9 / 9.9	1640 /	6.6 / 189.4	
SHAWNEE	OKM	V15W / 5000	066°		177	2625/4	2°L	201	63 / 352	18.8 / 28.7		12.6 / 176.8	
OKM	ADM	V15 / 6000	217°		180	2626/2	6°R	160	110 / 242	41.2 / 1:09.9		27.5 / 149.3	
ADM	DENTON	V15W / 5000	178°	116.5 / 078	178	2730/8	10°R	177	57 / 185	19.3 / 1:29.2		12.9 / 136.4	
DENTON	DAL	V15W / 5000	120°		178	2730/8	5°R	204	29 / 156	8.5 / 1:36.7		5.7 / 130.7	
DAL	ADM	V15 / 6000	339°		182	2730/6	9°L	168	76 / 80	27.1 / 2:03.8		18.1 / 112.6	
ADM	OKC	V163 / 6000	338°AV		180	2626/2	8°L	173	80 / 0	27.7 / 2:31.5		18.5 / 94.1	
ALTERNATE													
OKC	SPS	V77 / 6000	205°AV		180	2626/2	7°R	164	96 /	35.2 /		23.5 /	

REMARKS

NOTE:
(1) This log is [illegible] to [illegible] applicants in the [illegible] of [illegible] of flight planning data used in written examinations.
(2) The use of all or any part of this form is optional.
(3) Return this form to the monitor upon completing the examination.

AC Form 8200-6 (2-66) Formerly AC Form 1517.

FIGURE 221. Completed Flight Log.

direction; others to magnetic. If you start with magnetic direction in your computations, winds aloft data must be corrected for variation; if you use winds aloft as reported or forecast (true direction/knots), magnetic courses shown on the chart must be corrected for variation.

d. *Distances.*—The first leg (28 nmi) entered on the log is measured from the departure airport (Will Rogers World International) to the first enroute fix. Note that the flight log shows DAL VORTAC as the destination fix for the second leg of the flight. You may log the 16 miles between the enroute facility and Love Field, and an additional 16 miles for return to the VORTAC following the instrument approach. The Dallas-Ft. Worth Area Chart shows DAL VORTAC as the route terminating fix. You can terminate your flight log at the VORTAC or at one of the compass locators serving Love Field. In either case, your flight plan will supply ATC with the necessary route data in the event of radio communications failure. In actual practice, the routes and mileages shown on the log are adequate. You can expect to be handed off to Approach Control before arrival at Denton and to be vectored to Love Field by a more direct route than planned on your log.

e. *Communications/navigation frequencies.*—You may wish to list the VOR frequencies with the check points. In this case the Ardmore and Bridgeport frequencies and radials used to establish those intersections are listed under "Reporting Frequencies." Enter the ARTCC Sector Discrete Frequency for Ft. Worth Center if your communications equipment is limited. With the 360-channel transceiver assumed for the flight, use this column to note frequencies as ATC assigns them enroute. It is a good idea to record Center Sector Discrete Frequencies for each Center involved in your flight. [FAR 91.125.]

Step 3. Low-Altitude Area Charts (if published for terminals on your flight). The dashed lines on the enroute chart segment show that area charts are published for Dallas, but not for Oklahoma City, Okmulgee, or Wichita Falls. Your ATC clearances are not likely to include unexpected fixes, routes, and procedures if you

FEDERAL AVIATION AGENCY

FLIGHT PLAN

Form Approved.
Budget Bureau No. 04-R072.3

1. TYPE OF FLIGHT PLAN				2. AIRCRAFT IDENTIFICATION
	FVFR		VFR	
X	IFR		DVFR	N6864S

3. AIRCRAFT TYPE/SPECIAL EQUIPMENT 1/	4. TRUE AIRSPEED	5. POINT OF DEPARTURE	6. DEPARTURE TIME PROPOSED (Z)	6. DEPARTURE TIME ACTUAL (Z)	7. INITIAL CRUISING ALTITUDE
Fastflight	180 KNOTS	Will Rogers OKC	1730		5000

8. ROUTE OF FLIGHT

V14S Shawnee Intersection, V15W OKM, V15 ADM, V15W DAL, V15 ADM, V163 OKC

9. DESTINATION (Name of airport and city)	10. REMARKS
Will Rogers OKC	Practice approaches at OKM, DAL, and OKC

11. ESTIMATED TIME EN ROUTE HOURS	11. MINUTES	12. FUEL ON BOARD HOURS	12. MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME
2	32	4	53	SPS Wichita Falls Air Terminal	J. Smith

15. PILOT'S ADDRESS AND TELEPHONE NO. OR AIRCRAFT HOME BASE	16. NO. OF PERSONS ABOARD	17. COLOR OF AIRCRAFT	18. FLIGHT WATCH STATIONS
Oklahoma City, Oklahoma	2	White--red trim	---

CLOSE FLIGHT PLAN UPON ARRIVAL

1/ SPECIAL EQUIPMENT SUFFIX
A—DME & 4096 Code transponder
B—DME & 64 Code transponder
D—DME
L—DME & transponder—no code
T—64 Code transponder
U—4096 Code transponder
X—Transponder—no code

FAA Form 7233—1 (4-66) FORMERLY FAA 398 0052-027-8000

FIGURE 222. Flight Plan entries.

know the following:

a. Departure and arrival routes.

b. Standard Instrument Departures (SIDs), if available.

c. Communications and navigation frequencies.

d. Normal route starting and/or terminating fixes.

[Enroute Chart (s); Low-Altitude Area Charts; *Airman's Information Manual.*]

Step 4. Current Instrument Approach Procedure Charts for—

a. Airport of departure (for the possibility of an emergency return after takeoff).

b. Destination (s).

c. Alternate airport (s).

[FAR 91.83; 91.116; AL Charts appropriate to your aircraft equipment. ILS chart for Love Field and VOR chart for Okmulgee are shown in Chapter XI, "ATC Operations and Procedures."]

Step 5. Current information on facilities and procedures related to your flight, including—

a. Notices to Airmen.

b. Special Notices.

c. Services available at destination (s) and alternate (s).

d. Airport conditions, including lighting, obstructions, and other notations under "remarks." [Current *Airman's Information Manual.*]

Step 6. Contact Weather Bureau or Flight Service Station for briefing. Departure, enroute, arrival, and alternate weather items of significance are presented to the pilot. [FAR 91.5; *Airman's Information Manual; Aviation Weather;* weather data in this chapter.]

Step 7. Complete the flight log (Fig. 220) *to include:—*

a. TAS, wind data, groundspeed.

b. Estimated time enroute.

c. Estimated time between reporting points and check points.

d. Fuel required.

On the completed flight log (Fig. 221) note that the enroute times are computed to the tenth of a minute. In actual practice, the figures are rounded off. Note also that the groundspeed from OKC to Shawnee is computed from an assumed average climb speed of 150 TAS and from the OKC forecast wind for 3,000 feet MSL. The other true airspeed values are based on 165 knots CAS and on the temperatures given in the winds aloft data for the flight planned altitudes. The only estimated arrival time logged is at Shawnee; other ETAs are added enroute.

The fuel *required* is computed as follows, based on an average consumption of 40 gph.:—

	Gallons
a. Enroute fuel (OKC-OKM-DAL-OKC)	101.5
b. Fuel to alternate	23.5
c. 45-minute reserve	30.0
d. 30-minute additional total allowance for approaches at OKM, DAL, and OKC	20.0
Total required	175.0

[FAR 91.23; Aircraft Flight Handbook data in this chapter; weather data for wind forecasts.]

Step 8. Compute weight and balance. To the empty weight and oil data given, enter weights for pilot, instructor, and fuel. Assume 196 gallons total fuel load. The moments are derived from the weight and balance chart (p. 230), and the minimum and maximum moments (shown under "limits" in the following table) are interpolations between 6,500 and 6,550 pounds. [FAR 91.31; Aircraft Flight Handbook data.]

	Pounds	Moment/1000
Empty weight	4,940	854.8
Oil	75	15.0
Pilot and Instructor (standard weight = 170 lbs.)	340	32.0
Fuel (156 gal. main tank)	936	175.0
Fuel (20 gal. each aux.)	240	43.0
Totals	6,531	1,119.8

Limits.—Minimum 1093 (1092.96)
Maximum 1139 (1138.96)

Step 9. Check teletype NOTAMS for the latest information concerning—

a. Status of navigation and communications facilities to be used enroute.

b. Status of terminal facilities at destination and alternate.

c. Any other information pertinent to your flight [FAR 91.5].

Step 10. Complete the flight plan (FAA Form 7233–1) and file with FSS at least 30 minutes before estimated departure time (Fig. 222).

Instrument Weather Flying

Your first flight under instrument conditions—like your first solo, first night flight, and first simulated instrument flight under the hood—will probably involve some normal apprehensions.

Notwithstanding your temperament, quality of your training, and the thoroughness of your flight planning, the decision to fly under instrument conditions is a commitment for which you *alone* are responsible. What affects your decision to go ahead with an IFR flight or to wait out a weather change for VFR conditions? Your instructor will probably elaborate on the following considerations affecting your judgment.

Flying Experience.—The more experience, the better—both VFR and IFR. Night flying promotes both instrument proficiency and confidence. Progressing from night flying under clear, moonlit conditions to flying without moonlight, natural horizon, or familiar landmarks, you learn to trust your instruments with a minimum dependence upon what you can see outside the aircraft. The more VFR experience you have in terminal areas with high traffic activity, the more capable you can become in dividing your attention between aircraft control, navigation, communications, and other cockpit duties.

The greater your total experience, the greater the number of unexpected situations you have behind you and the fewer surprises you can expect ahead. If you have had the benefit of instrument instruction under instrument weather conditions as well as under the hood, you may have noted that weather flying seemed routine to the instructor. This is the mark of a professional; the unusual is routine because he expects it and is ready for it before it happens.

Recency of experience is an equally important consideration. You may not act as pilot-in-command of an aircraft under IFR or in weather conditions less than VFR minimums unless within the previous 6 calendar months you have had at least 6 hours of instrument flight under actual or simulated instrument flight conditions, of which not more than 3 hours may be in a synthetic trainer. Whether the 6 hours are adequate preparation for *you* is another question.

Airborne Equipment and Ground Facilities.—Here again, regulations specify *minimum* equipment for filing an IFR flight plan. It is your own responsibility to decide on the adequacy of your aircraft and NAV/COM equipment for the conditions expected. A single-engine, well-equipped aircraft in excellent condition and flown by a competent pilot is obviously safer under instrument conditions than a twin, superbly equipped and in perfect condition, in the hands of a reckless or ill-prepared pilot. Whether your aircraft is single-engine or multiengine, its performance limitations, accessories, and general condition are directly related to the weather, route, altitude, and ground facilities pertinent to your flight, as well as to the cockpit workload you can expect.

Weather Conditions.—Departure, enroute, arrival, and alternate weather items that should be checked out before determining whether conditions are within your capabilities. Turbulence, icing, and ceiling/visibility at your destination and alternate should be evaluated in terms of their effect on your aircraft, route and altitude, and the cockpit workload that you can safely handle.

IFR flying is a team effort, using a network of facilities manned by many personnel. Your instrument rating puts you on this team, making air safety your responsibility also.

ØЗØ SA3Ø251700

HBR S 15⦶15 Ø95/46/35/36Ø8/979/WSHFT162Ø
SPS ⦶15+ Ø97/55/34/2514/98Ø
ADM S A8⊕3F 118/41/38/151Ø/987
OKC S M3⦶1L--F 114/36/35/14Ø8/984 R35VV11/2+
PNC A8⊕8 124/39/36/16Ø7/988/⊕47 LE47
TUL 14⦶12 115/5Ø/36/1814/987
GSW M7Ø⦶1Ø 1Ø3/54/45/1812/987

FA GSW 251245
11Z TUE-23Z TUE

TEX OKLA

HGTS ASL UNLESS NOTED

SYNOPSIS. COLD FRONT NEAR PONCA CITY CHILDRESS TUCUMCARI LINE WL MOV SWD NEAR FT SMITH FT WORTH SAN ANGELO LINE BY 23Z TUE.

FLT PRCTNS RCMDD ERN OKLA AND NERN TEX AND IN NWRN OKLA AND TEX PNHDL DUE TO LOW CIGS AND VSBYS AND TO ICG NW OKLA AND TEX PNHDL.

CLDS AND WX. S OF FRONT CLR OR THIN SCTD ABV 25 THSD EXCP OVR ERN OKLA AND NERN TEX DSIPTG C7-15⊕V⦶ LCLY C5⊕2F BCMG GENLY 10-20⦶V⦶ AGL BY 22Z AND CLRG BY 24Z. TOPS 30-40.

N OF FRONT INCRG C5-10⊕V⦶ TOPS 70 VSBY OCNLY 1-3 IN LGT RAIN OR PSBL WET SNW TEX PNHDL AND NWRN OKLA.

ICG. LGT MXD ICGICIP N OF FRONT. FRZG LVL 60 S OF FRONT LWRG TO 45 N OF FRONT.

TURBC. MDT OR GRTR CAT LKLY 200-400 ALG AND 100 MI S OF LUBBOCK SHREVEPORT LINE.

OTLK 23Z TUE-17Z WED. COLD FRONT WL CONT SWD TO LN NERN TEX TO W CNTRL TEX. INCRG C4-8⊕ S OF FRONT IN NERN TEX. GRDL CLRG TEX PNHDL AND NWRN OKLA. C10-20⦶V⊕ N OF FRONT WRN OKLA IN CNTRL AND W CNTRL TEX. PSBLY WDLY SCTD LGT RAIN VCNTY FRONT N CNTRL AND NERN TEX.

FT1 251645
17Z TUE-Ø5Z WED

SPS 2317G. 0130Z COLD FROPA 6Ø⦶ 3617G
GSW C1Ø⊕ 1815 ⊕V⦶. 19ØØZ C15⦶ 1915 ⦶V⦶. 2030Z O 2215.
DAL C1Ø⊕ 1815 ⊕V⦶. 19ØØZ C15⦶ 1915 ⦶V⦶. 2030Z O 2215.
OKC C4⊕2F 1815. 1800Z C6⦶7 1915 ⦶V⦶. 1900Z 1Ø⦶ 2Ø16. 2000Z O 2215. 2130Z COLD FROPA O 3515G. 2300Z C12⦶ 3615G ⦶V⊕
TUL 5⦶C12⦶ 1812. 1830Z C15⦶ 1912 ⦶V⦶. 2030Z 2Ø⦶ 2Ø15. 2200Z O 2215. 2230Z COLD FROPA C1Ø⦶ 3615G.

FD-1 WBC 251145
BASED ON 250000Z DATA
VALID 251800Z FOR USE 1200-2100Z.

FT	3000	6000	9000	12000	18000	24000
OKC	2430	2626+02	2729-01	2730-07	2740-21	2760-36
DAL	2522	2730+06	2730+00	2830-07	2832-20	2840-34

FL GSW 251235

AIRMET ALFA 2. OVR OKLA ALG AND W OF ENID ARDMORE LINE CIGS BLO 1 THSD FT WL SPRD TO NEAR TULSA MCALESTER LINE. CONDS ENDG BY 16Z.

PASSENGERS

SEAT NO.	WEIGHT	MOMENT/1000
Co-P	170	16
4	170	22
5	170	22
1	170	29
2	170	29
3	170	29

FUEL

GALS.	WEIGHT	MOMENT/1000
10	60	12
20	120	24
30	180	36
40	240	48
50	300	59
60	360	71
70	420	83
80	480	94
90	540	105
100	600	116
110	660	127
120	720	138
130	780	148
140	840	159
150	900	169
156	936	175

L & R OUTBOARD FUEL SYSTEM

GALS.	WEIGHT	MOMENT/1000
10	60	11
20	120	21
30	180	32
40	240	43
50	300	53
60	360	64
67	402	72

BAGGAGE

WEIGHT	MOMENT/1000
25	5
50	10
75	15
100	20
125	25
150	30
175	35
200	40
225	45

WEIGHTS AND MOMENTS TO DETERMINE ALLOWABLE LIMITS

167.40 Min. To 174.40 Max.
(Stay Within Min. and Max. Limits)

Weight	Minimum Moment/1000	Maximum Moment/1000
5500	921	959
5550	929	968
5600	937	977
5650	946	985
5700	954	994
5750	963	1003
5800	971	1012
5850	979	1020
5900	988	1029
5950	996	1038
6000	1004	1046
6050	1013	1055
6100	1021	1064
6150	1030	1073
6200	1038	1081
6250	1046	1090
6300	1055	1099
6350	1063	1107
6400	1071	1116
6450	1080	1125
6500	1088	1134
6550	1096	1142
6600	1105	1151
6650	1113	1160
6700	1122	1168
6750	1130	1177
6800	1138	1186
6850	1147	1195
6900	1155	1203
6950	1163	1212
7000	1172	1221

APPENDIX

Contents — *Page*

Clearance Shorthand

The shorthand system given here is recommended by the Federal Aviation Administration. Applicants for the Instrument Rating may use *any* shorthand system, in any language, which insures accurate compliance with ATC instructions. No shorthand system is required by regulation and no knowledge of shorthand is required for the written test; however, because of the vital necessity for safe coordination between the pilot and controller, clearance information should be unmistakably clear.

As an instrument pilot, you should make a written record of all ATC clearances and instructions that consist of more than a few words; and any portions that are complex, or about which there is any doubt, should be verified by a repeat back. Safety demands that you receive correctly and do not forget any part of your clearance.

Occasionally ATC will issue a clearance that differs from the original request. In such cases, the pilot must be particularly alert to be sure that he receives and understands the clearance given.

The following symbols and contractions represent words and phrases frequently used in clearances. Most of them are regularly used by ATC personnel. Learn them along with the location identifiers which you will use.

By using this shorthand, omitting the parenthetical words, you will be able, after some practice, to copy long clearances as fast as they are read.

Words and Phrases	*Shorthand*
ABOVE	ABV
ADVISE	ADV
AFTER (PASSING)	<
AIRPORT	A
(ALTERNATE INSTRUCTIONS)	( )
ALTITUDE 6,000–17,000	60-170
AND	&
APPROACH	AP
FINAL	F
OMNI	O
PRECISION	PAR
STRAIGHT-IN	SI
SURVEILLANCE	ASR
APPROACH CONTROL	APC
AT (USUALLY OMITTED)	
(ATC) ADVISES	CA
(ATC) CLEARS OR CLEARED	C
(ATC) REQUESTS	CR
BEARING	BEAR
BEFORE	>
BELOW	BLO
BOUND	B
EASTBOUND, etc.	EB
INBOUND	IB
OUTBOUND	OB
CLIMB (TO)	↑
CONTACT	CT
CONTACT DENVER APPROACH CONTROL	DEN
CONTACT DENVER CENTER	(DEN
COURSE	CRS
CROSS	X
CROSS CIVIL AIRWAYS	
CRUISE	→
DELAY INDEFINITE	DLI
DEPART	DEP
DESCEND (TO)	↓
DIRECT	DR
EACH	ea
EXPECT APPROACH CLEARANCE	EAC

Words and Phrases	*Shorthand*
EXPECT FURTHER CLEARANCE	EFC
FAN MARKER	FM
FLIGHT PLANNED ROUTE	FPR
FOR FURTHER CLEARANCE	FFC
FOR FURTHER HEADINGS	FFH
HEADING	HDG
HOLD (DIRECTION)	H-W
IF NOT POSSIBLE	or
INTERSECTION	XN
(ILS) LOCALIZER	L
MAINTAIN OR MAGNETIC	M
(MAINTAIN) VFR CONDITIONS ABOVE:	
ALL CLOUDS	$\frac{VFR}{\ }$
ALL HAZE	$\frac{VFR}{H}$
ALL DUST	$\frac{VFR}{D}$
ALL SMOKE	$\frac{VFR}{K}$
ALL FOG	$\frac{VFR}{F}$
OMNI (RANGE)	O
OUTER COMPASS LOCATOR	LOM
OUTER MARKER	OM
OVER (Iden.)	OKC-0
RADAR VECTOR	R V
RADIAL	RAD
REMAIN WELL TO LEFT SIDE	LS
REMAIN WELL TO RIGHT SIDE	RS
REPORT DEPARTING	RD

Words and Phrases	*Shorthand*
REPORT LEAVING	RL
REPORT ON COURSE	R-CRS
REPORT OVER	RO
REPORT PASSING	RP
REPORT REACHING	RR
REPORT STARTING PROCEDURE TURN	RSPT
REQUEST ALTITUDE CHANGES ENROUTE	RACE
REVERSE COURSE	RC
RUNWAY	RY
STANDARD JET PENETRATION	SJP
STANDBY	STBY
TAKEOFF (DIRECTION)	T→N
TOWER	Z
TRAFFIC IS	TFC
TRACK	TR
TURN LEFT AFTER TAKEOFF	LT
TURN RIGHT AFTER TAKEOFF	RT
UNTIL	/
UNTIL ADVISED (BY)	UA
UNTIL FURTHER ADVISE	UFA
VICTOR	V
WHILE IN CONTROL AREAS	Δ
WHILE IN CIVIL AIRWAYS	=

EXAMPLE

ATC clears (Iden.) to St. Louis Airport via Victor 16, Victor 9. Maintain one five thousand. Turn left after departure. Proceed direct Dallas Omni. Cross Dallas Omni at 3000. Report leaving 3, 4, and 5000.

C STL-A V16 V9. M 150. LT. DR DAL-OXDAL-O 30. RL 3, 4, 50.

Supplementary Reference Material

Persons studying for the instrument rating, as well as qualified instrument rated pilots, will find the publications and materials listed below to be useful in augmenting their knowledge of instrument flying.

In addition, there are many excellent textbooks, charts, and other reference materials available from commercial publishers.

Airman's Information Manual (AIM)

Part 1. *Basic Flight Manual and ATC Procedures;* issued quarterly, annual subscription $4 ($1 additional for foreign mailing).

Part 2. *Airport Directory*; issued semiannually; annual subscription $4 ($1 additional for foreign mailing).

Part 3. *Operational Data and Notices to Airmen;* issued every 28 days with supplementary *Notices to Airmen* (Part 3A) issued every 14 days; annual subscription $20 ($5 additional for foreign mailing).

Part 4. *Graphic Notices and Supplemental Data;* issued semiannually; annual subscription $1.50 (50 cents additional for foreign mailing).

Each Part is available on an annual subscription only. AIM Parts present all of the information necessary to plan and conduct a flight in the National Airspace System.

Federal Aviation Regulations

The subscription prices listed include automatic revision service to all Parts contained in the Volume ordered. The FAR Parts contained in each Volume are listed in the "Advisory Circular Checklist and Status of Federal Aviation Regulations."

		Price	*Additional for Foreign Mailing*
Volume I,	Part 1, Definitions and Abbreviations	$1.50	$0.50
Volume IX,	Part 61, Certification: Pilots and Flight Instructors	$6.00	$1.50
Volume VI,	Part 91, General Operating and Flight Rules	$5.50	$1.25
Volume XI,	Part 95, IFR Altitudes		
	Part 97, Standard Instrument Approach Procedures	$2.75	$0.75

ADVISORY CIRCULARS

Aviation Weather, AC 00-6, ($4—FAA 5.8/2: W 37)

This is a joint FAA/U.S. Weather Bureau publication which provides an expanded text for pilots and others whose interest in meteorology is primarily in its application to flying.

Flight Instructor's Handbook, AC 61-16 ($1.25—FAA 5.8/2: F 64/7).

This handbook has been prepared for the information and guidance of pilots preparing for the flight instructor certificate and for use as a reference by certificated flight and ground instructors. This handbook will be most useful to those preparing for the "Fundamentals of Instructing" section of the Ground Instructor Written Test.

Flight Test Guide—Instrument Pilot Airplane, AC 61-17A (10¢—TD 4.408: IN 7/2).

This guide is designed to assist the instrument pilot applicant in preparing for his instrument rating flight test. It describes applicable procedures and standards.

Instrument Rating (Airplane) Written Test Guide, AC 61-8B (70¢—TD 4.8: 7/4).

This guide points out the subject areas covered in the written test for an instrument rating and those phases of aviation knowledge in which an applicant should be informed. Sample examination questions and answers are presented.

Pilot's Weight and Balance Handbook, AC 91-23 (70¢—TD 4.408: P 64/3). Presented from the viewpoint of the pilot, this handbook pays particular attention to the aircraft loading problems of general aviation pilots when operating light aircraft, including twin-engine and air-taxi types. The text progresses from an explanation of basic fundamentals to the complex application of weight and balance principles in large aircraft operations.

In addition, the following Advisory Circulars pertain to areas of knowledge listed in the "Study Outline" and are free of charge: 00–17, 00–24, 20–32A, 60–4, 60–6, 90–1A, 90–12, 90–14A, 90–22B, 90–23A, 90–35, 90–36, 90–38A, 90–41, 90–46, 91–8A, 91–19, 91–30, 170–3B.

Instrument Pilot EXAM-O-GRAMS (Free).

These brief instructional aids are prepared on subject areas in which applicants for airman written examinations have shown a lack of knowledge. They are an excellent media for providing guidance information to applicants preparing for the various written tests.

CHARTS

Instrument Approach Procedure Charts.

All procedures may be purchased for any one airport. When ordering, designate by State, series, and chart number, thus: N.Y. AL-289.

Enroute Charts; Low- or High-Altitude.

These charts provide the necessary aeronautical information for enroute instrument navigation.

Low-Altitude Area Charts.

These charts supplement the Enroute Charts by providing arrival/departure data on a larger scale in high activity terminal areas.

How to Obtain Supplementary Reference Materials

All materials listed *except* EXAM-O-GRAMS, Charts, and some free Advisory Circulars may be obtained by forwarding a request and check or money order made payable to the "Superintendent of Documents" to any of the addresses listed below:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

GPO Bookstore
Federal Building
Room 1023
450 Golden Gate Avenue
San Francisco, Calif. 94102

GPO Bookstore
Federal Building
300 N. Los Angeles Street
Los Angeles, Calif. 90012

GPO Bookstore
Federal Office Building
Room 1463 14th Floor
219 South Dearborn Street
Chicago, Ill. 60604

GPO Bookstore
Room G25
John F. Kennedy Federal Building
Sudbury St.
Boston, Mass. 02203

GPO Bookstore
Federal Building
Room 135
601 East 12th Street
Kansas City, Mo. 64106

Order subscription and single publications separately. Orders for single publications should include the Superintendent of Documents catalog number as listed in the price line.

EXAM-O-GRAMS may be obtained free, in single copy, and names may be added to the mailing list by writing to:

FAA Aeronautical Center
Operations Branch, AC-240
P.O. Box 25082
Oklahoma City, Okla. 73125

Advisory Circulars

The "Advisory Circular Checklist and Status of Federal Aviation Regulations" and *free* Advisory Circulars as listed therein may be obtained from:

Department of Transportation
Federal Aviation Administration
Distribution Unit, TAD 484.3
Washington, D.C. 20590

Charts

The National Ocean Survey publishes and distributes aeronautical charts of the United States. Charts for foreign areas are published by the U.S. Air Force Aeronautical Chart and Information Center (ACIC) and are sold to civil users by the National Ocean Survey.

A "Catalog of Aeronautical Charts and Related Publications" listing their prices and instructions for ordering may be obtained free, on request, from:

Distribution Division (C-44)
National Ocean Survey
Washington, D.C. 20235

Orders for specific charts or publications should be accompanied by check or money order made payable to, "NOS, Dept. of Commerce."

Study Outline for the Instrument Pilot Written Test

This study outline covers the areas of aeronautical knowledge which pertain to Instrument Pilot Written Tests. The outline expands the general aeronautical knowledge requirements set forth in Federal Aviation Regulations Part 61, and is based on airman activity for flight under Instrument Flight Rules.

REFERENCE CODE:

AIM—Airman's Information Manual
EOG—IFR Exam-O-Gram
AW—Aviation Weather (AC 00–6)
FAR—Federal Aviation Regulations
IFH—Instrument Flying Handbook

I. PILOT RESPONSIBILITIES (FAR 61 and 91)

A. Authority and Limitations
1. Pilot-in-Command
2. Emergency action
(a) deviation from rules
(b) reports required

B. Certificates and Ratings
1. Instrument rating requirements
(a) when required
(b) written test unauthorized conduct
(c) retesting after failure
2. Medical certificates
3. Instrument flight time
(a) pilot logbooks
(b) recent flight experience
(c) simulated
4. Certificate reports
(a) change name
(b) lost certificates
(c) change address

C. Preflight Action for Flight (AIM–1, EOG–31)
1. Weather check
2. Fuel required
3. Alternate course of action
4. Delays

D. Preflight Action for Aircraft
1. Documents
(a) Airworthiness Certificate
(b) Registration Certificate
(c) Operating Limitations
(d) Aircraft Inspections
2. Equipment and Systems
(a) equipment required
(b) tests and inspections
(i) VOR receiver
(ii) altimeter system
3. Portable electronic devices

E. Flight Plan (AIM–1)
1. When required
2. Information required
3. Alternate airport
(a) when required
(b) minimums
4. Closing flight plan

F. Compliance With Clearance (EOG–6, AIM–1)
1. Communications reports
2. With communications failure
(a) route procedures
(b) malfunction reports
3. Emergency deviation
(a) detour thunderstorm
(b) change of altitude (icing or turbulence)
4. Mid-air collision avoidance (VFR EOG–22, 29, 48)

G. Terminal Area Limitations (AIM–1)
1. Terminal control area
2. Airport traffic area

3. Airport with tower
4. Airport without tower
5. Takeoff and landing minimums
6. IFR approaches
   (a) descent below MDA or DH
   (b) unusable components and aids
7. Aircraft speed

H. Enroute Limitations (AIM–1)
1. Minimum altitudes (EOG–8)
   (a) MEA
   (b) MOCA
   (c) MCA
   (d) MRA
   (e) MAA
2. Cruising altitudes
3. Courses to be flown
4. Altimeter settings
5. Special use airspace
   (a) restricted areas
   (b) positive control areas
   (c) jet advisory areas

I. Basic Knowledge

A. Physiological Factors (Ch. II–IFH, AIM–1)
1. Physiological altitude effects:
   aerotitis; aerosinusitis, hypoxia
2. Hypoxic effects:
   carbon monoxide; alcohol; hyperventilation; drugs
3. Sensations of instrument flying:
   motion; postural sense; sight
4. Spatial disorientation

B. Aerodynamic Factors (Ch. III–IFH, Pilot's Handbook of Aeronautical Knowledge)
1. Forces
2. Power/airspeed/vertical speed
3. Turns
   (a) forces in a turn
   (b) constant rate turns
   (c) rate/speed/angle of bank
   (d) coordination

C. Gyroscopic Instruments and Systems (Ch. IV–IFH)
1. Systems
   (a) vacuum
   (b) electric
2. Operating principles
3. Attitude Indicator (EOG–24)
   (a) preflight and flight limits
   (b) use
4. Turn Indicator
   (a) preflight and flight limits
   (b) use (EOG–18)
5. Directional Indicator
   (a) preflight and flight limits
   (b) use

D. Magnetic Compass (Ch. IV–IFH)
1. Types
2. Principles of operation
3. Use
4. Errors and corrections

E. Pitot-Static Instruments (Ch. IV–IFH)
1. Pitot static system
2. Altimeter (EOG–10)
   (a) principles of operation
   (b) use
      (i) altimeter settings (AIM–1)
      (ii) pressure altitude
      (iii) errors and corrections
   (c) altitude definitions
      (i) indicated
      (ii) pressure
      (iii) true
      (iv) absolute
      (v) density
3. Vertical speed indicator
   (a) principles of operation
   (b) use
   (c) limits and adjustment
4. Airspeed indicator
   (a) principles of operation
   (b) use
   (c) markings (VFR EOG–45)
   (d) airspeed definitions
      (i) indicated
      (ii) calibrated
      (iii) equivalent
      (iv) true

F. Attitude Instrument Flying (Ch. V–IFH)
1. Instruments
   (a) pitch
   (b) bank
   (c) power
2. Preflight instrument check
3. Basic maneuvers
   (a) straight and level
   (b) climbs and descents
   (c) turns (EOG–18)
   (d) unusual attitudes
   (e) flight patterns

G. Unusual Flight Conditions
1. Wake turbulence (AIM–1)
   (a) cause
   (b) avoidance

2. Thunderstorm encounter (page 110–AW)
3. Ice accumulation (pages 117, 124–AW)
   (a) structural
   (b) carburetor or induction system
   (c) frost
4. Clear air turbulence

H. Flight Planning Computer Operations (Ch. XII–IFH)
1. Slide rule face
   (a) groundspeed
      (i) time
      (ii) distance
   (b) fuel
      (i) time
      (ii) gallons or pounds
   (c) scale conversions (knots/m.p.h.)
   (d) airspeed conversions
      (i) calibrated
      (ii) equivalent
      (iii) true
   (e) altitude conversions pressure/density.
2. Wind correction face
   (a) headings
      (i) variation
      (ii) deviation
   (b) groundspeed

I. Density Altitude Chart (VFR EOG–33)
1. Altimeter setting/pressure alt. tables
2. Pressure alt./density alt.

J. Aircraft Performance (Aircraft Owner's Handbook) (VFR EOG–33, IFR EOG–32)
1. Performance Charts
   (a) cruise performance
      (i) altitude
      (ii) gross weight
      (iii) power settings (VFR EOG–38)
      (iv) fuel flow
   (b) takeoff distance
   (c) climb performance
      (i) best angle
      (ii) best rate
      (iii) balked landing
      (iv) single engine
   (d) landing distance
   (e) indicated/calibrated airspeed
2. Instrument markings
3. Placards

K. Aircraft Operating Limitations (document in aircraft) (EOG–21)
1. Weight and balance
   (a) c.g. or moment limits
   (b) passenger/baggage limits
   (c) fuel distribution
   (d) fuel burn
2. Instrument limit markings
3. Limiting placards
   (a) loading limits
   (b) gear and flap operation
   (c) maneuvering speed
4. Charts
   (a) turbulent air penetration
   (b) maximum safe crosswinds (VFR EOG–27)

L. Properties of the atmosphere
1. Composition (Ch. 1–AW)
2. Temperature (Ch. 2–AW)
   (a) measurements
   (b) temperatures aloft
3. Atmospheric pressure (Ch. 3–AW)
   (a) measurements
   (b) sea level pressure
   (c) pressure systems
   (d) altimeters
4. Wind (Ch. 4–AW)
   (a) circulation
   (b) systems
   (c) local variations
5. Moisture (Ch. 5–AW)
   (a) change of state
   (b) measurements
      (i) relative humidity
      (ii) dew point
   (c) condensation, supersaturation, and sublimation products
      (i) cloud and fog
      (ii) precipitation
      (iii) dew and frost

M. Stability
1. Atmosphere (Ch. 6–AW)
   (a) lapse rates
   (b) stability determinations
   (c) effects of stability and instability
2. Wind (Ch. 7–AW)
   (a) convection currents
   (b) obstructions to wind flow
   (c) shear
   (d) clear air turbulence
   (e) intensity

N. Air Masses and Fronts (Ch. 9 & 10–AW)
1. Sources
   (a) air mass
   (b) frontogenesis
2. Classification
   (a) air mass
   (b) front

3. Modification
4. Characteristics
5. Associated clouds (Ch. 8–AW)

O. IFR Weather Hazards
1. Thunderstorms (Ch. 11–AW, AIM 1)
(a) structure and formation
(b) turbulence
(c) hail
(d) lightning
2. Icing (Ch. 12–AW)
(a) types
(b) conditions for formation
3. Fog and obstruction to vision
(a) types
(b) formation

P. Weather Observations (Ch. 15–AW)
1. Aviation Weather Reports (SA) (EOG–5)
2. Pilot Weather Reports (UA)
3. Weather Radar Observations (SD)
4. Upper Air Observations
(a) RAWIN
(b) PIBAL

Q. Weather Charts (Ch. 16–AW)
1. Weather depiction (EOG–15)
2. Surface weather
3. Constant pressure
4. Radar summary (EOG–17)
5. Prognostic
(a) surface (EOG–16)
(b) constant pressure
(c) significant weather
(d) 12-hour upper wind

R. Aviation Weather Forecasts (Ch. 17–AW)
1. Terminal (EOG–5)
(a) 12-hour (FT1)
(b) 24-hour (FT2)
2. Area (FA) (EOG–5)
3. Winds aloft (FD) (EOG–5)
4. In-flight weather advisories (FL)
5. Severe weather
(a) hurricane advisories (WH)
(b) outlook (AC)
(c) forecast (WU)
6. Prognoses
(a) surface analysis (AS–2 and FS–1)
(b) regional prognosis (FN–1)

S. Interpretation of combined weather reports and forecasts

T. Weather Services (Ch. 14 and 18–AW, AIM–1)
1. National Weather Service
(a) telephone listings (AIM–2)
(b) pilot/forecaster (Enroute Chart)
2. FSS
(a) location (AIM–2)
(b) telephone listing (AIM–2)
(c) air/ground frequencies (AIM–3)
3. Scheduled broadcasts
(a) local ATIS
(b) NAV facilities
(c) transcribed weather broadcasts
4. Unscheduled broadcasts
(a) SIGMETS
(b) AIRMETS

III. FACILITIES

A. Airport Physical Facilities (AIM–3, 3A, Enroute and Approach Charts)
1. Service
(a) fuel
(b) Storage
(c) repair
(d) oxygen
2. Runways
(a) number and longest
(b) surface and load bearing capacity
(c) elevation
(d) traffic pattern
(e) obstructions
(f) markings (AIM–1, EOG–26, 28)
3. Lighting (AIM–1)
(a) rotating beacon
(b) runway lighting aids
(i) boundary
(ii) approach, REIL, and VASI
(iii) centerline
(iv) threshold
4. Unicom (AIM–3)
(a) controlled airport
(b) non-controlled airport

B. Basic Principles of Navigation Facilities (Ch. VI–IFH)
1. Radio ranges
(a) VOR, VORTAC
(b) homing beacons
(c) ILS
2. Aids
(a) marker beacons
(b) DF
(c) radar beacon

C. Use of Navigation Facilities (Ch. VII–IFH)
1. VOR (EOG–7, 14)
(a) accuracy check (EOG–22)
(i) VOT (AIM–3)

(ii) VOR receiver checkpoints (AIM–4)
(b) orientation
(i) position
(ii) airway intersection
(c) tracking

2. ADF
(a) orientation
(b) homing
(c) basic procedures (EOG–23)

3. ILS (Ch. VI–IFH)
(a) localizer
(b) glide slope
(c) marker beacons
(d) lighting aids

4. DME (Ch. VI–IFH)

5. Transponder (EOG–25)
(a) code
(b) mode
(c) output
(i) normal
(ii) low

D. Control Tower Facility (Ch. X–IFH, AIM–1, 3, 3A, 4)

1. Ground Control
(a) clearance delivery (AIM–1)
(b) taxi control (AIM–1)
(c) frequencies (AIM–3)

2. Departure Control
(a) radar services (AIM–1)
(b) frequencies (AIM–3)

3. Takeoff and landing control
(a) separation (AIM–1)
(b) frequencies (AIM–3)

4. Approach control
(a) radar (AIM–1)
(i) services
(ii) approaches
(iii) monitor
(b) non radar (AIM–1)
(c) frequencies (AIM–3)

5. VHF direction finding (AIM–1)

6. ATIS
(a) use
(b) frequencies (AIM–3)

7. Use of runways (AIM–1)

8. Light signals (AIM–1)

E. Flight Service Station facility

1. Weather Services (AIM–1)
(a) briefing (AIM–1)
(b) telephone listing (AIM–2)

2. Flight Plan Service (AIM–1)
(a) file and close
(b) enroute reporting
(c) communication frequencies (AIM–3, Enroute Chart)

3. Airport Advisory Service
(a) airport information (AIM–1)
(b) frequencies (AIM–3)

4. VHF direction finding (DF) (AIM–1)

F. Air Route Traffic Control Center (ARTCC) (Ch. X–IFH)

1. Traffic control
(a) geographic area (enroute chart)
(b) communication frequencies (Legend-Enroute Chart)

2. Advisories

3. Radar services

4. Distress assistance

G. Use of Communication Facilities

1. Communication phraseology (Ch. VIII–IFH, AIM–1)
(a) procedures (EOG–11)
(b) phonetic alphabet
(c) procedural words and phrases
(d) frequency discipline

2. Airborne equipment (Ch. VII, VIII–IFH)
(a) systems
(b) frequencies (AIM–3)

3. Clearances and control sequence (AIM–1, Ch. VIII, X–IFH, EOG–4)
(a) clearance shorthand (Ch. XIV–IFH)
(b) clearance items (AIM–1)

H. Status of Facilities and Airways

1. Airport/Facility Directory (AIM–3)
2. NOTAMS (AIM–3A)
3. Restrictions to Enroute Navigation
4. Aids (AIM–4)
5. Special Notices (AIM–4)
6. Preferred Routes (AIM–3)
7. SIDs and STARs (AIM–3)
8. Substitute Route Structure (AIM–3)
9. Area Navigation Routes (AIM–3)
10. Charts
(a) Enroute
(b) Area

IV. AIRSPACE AND AIRWAY ROUTE SYSTEM (Ch. IX–IFH)

A. Controlled Airspace (AIM–1, Enroute and Area Charts)

1. Airport Traffic Area
2. Control Zone
3. Control Area

4. Continental Control Area
5. Positive Control Area

B. Special Use Airspace (AIM III, Enroute and Area Charts)
   1. Prohibited Area
   2. Restricted Area and Climb Corridor
   3. Warning Area
   4. Intensive Student Jet Training Area
   5. Alert Area

C. National Security (AIM–1)
   1. ADIZ
   2. SCATANA

D. Victor (VOR) Airways (Low Altitude Enroute and Area Charts)
   1. Limits
      (a) width
      (b) base
      (c) top
   2. Radials and bearings
   3. Route identification
      (a) airway
      (b) military route
      (c) substitute route
      (d) unusable route
   4. Altitude limits (EOG–8)
      (a) MOCA
      (b) MEA
      (c) MRA
      (d) MCA
      (e) MAA
   5. Compulsory and noncompulsory reporting points
      (a) facilities
         (i) VOR/VORTAC
         (ii) NDB
      (b) intermediate fixes
         (i) VOR bearing intersections
         (ii) DME/VOR radial
   6. Segment limits
      (a) mileage breakdown
      (b) minimum altitude change
      (c) VOR changeover points
      (d) altimeter setting boundary
      (e) time zone boundary

E. Area Navigation (EOG–31)
   1. Area Navigation Routes (RNAV)
   2. Waypoints
   3. Ground facilities
   4. Airborne equipment
      (a) types
      (b) presentation
         (i) course line
         (ii) distance
         (iii) vertical

F. Direct Flights (AIM–1)

V. ATC Operations and Procedures (Ch. XI–IFH)

A. Pre-Takeoff Procedures
   1. Flight Plan (AIM–1)
   2. ATIS (AIM–1)
   3. Route Clearance (AIM–1)
      (a) pre-taxi clearance delivery
      (b) other clearance delivery
   4. Taxi (AIM–1)

B. Takeoff and Departure Procedures (AIM–1)
   1. Takeoff
   2. Departure
      (a) nonradar
      (b) radar vector
      (c) SIDs (SID Booklet)
   3. Altitude control
      (a) climb
      (b) crossing

C. Enroute Procedures (AIM–1)
   1. Normal Navigation
      (a) reporting
      (b) handoffs
   2. Radar Environment
      (a) reporting
      (b) handoffs
   3. Altitude
      (a) climb or descent
      (b) VFR on top
      (c) cruise
      (d) maintain
   4. Delays
      (a) clearance limit
      (b) holding
         (i) procedures (AIM–1)
         (ii) fixes (Enroute Chart)

D. Arrival
   1. STARs
   2. Radar vectors
   3. Holding

E. Approaches (Ch. VIII, IFH)
   1. VOR
   2. VOR/DME
   3. NDB
   4. ILS
      (a) localizer
      (b) back course
   5. Radar (AIM–1, EOG–27)
      (a) PAR
      (b) ASR

6. Contact and Visual
7. Missed Approaches

F. V/STOL Operations (when available)

G. Emergencies (AIM–1, EOG–2)
1. Lost
   (a) transponder code
   (b) triangle
   (c) emergency frequency
   (d) chaff
2. Forced landing or crash
   (a) beacon
   (b) air sea rescue (AIM–1)
3. Difficulty with communications
4. Malfunction of equipment
   (a) aircraft accessory
   (b) communication equipment
5. Part 430, Rules Pertaining to the Notification and Reporting of Aircraft Accidents, Incidents, and Overdue Aircraft, and Preservation of Aircraft Wreckage, Mail, Cargo, and Records
   (a) immediate notification
   (b) manner of notification
   (c) reports

H. Aernonautical Terms (FAR 1 and AIM–1, Glossary)

Instrument Flight Instructor Lesson Guide

Department of Transportation
Federal Aviation Administration

AERONAUTICAL CENTER
FAA ACADEMY

Preface

To the Instrument Flight Instructor

The Instrument Flight Instructor Lesson Guide has been prepared for use with the FAA Instrument Flying Handbook, AC 61-27B. The seventeen basic lessons in Attitude Instrument Flying are arranged in what is considered to be a logical learning sequence. To insure steady progress, teach the course lesson-by-lesson, and be sure the student has mastered each before advancing to the next. Lessons may be combined when giving refresher training. As all experienced instrument instructors know, the student will learn more rapidly during the early stage of his instrument training if he spends a considerable part of the time "open hood." The student is thus allowed to associate aircraft attitude relative to outside visual references with the indications of the various flight instruments individually and in combination. This teaching procedure makes it clear that the pilot uses exactly the same control techniques while flying by reference to instruments as he does in visual flying. Remember, the largest single learning factor in Attitude Instrument Flying is that of interpreting the flight instruments to determine the attitude of the aircraft.

To the Student Instrument Pilot

At the beginning of your instrument flight training, your instructor will brief you on the concept of Attitude Instrument Flying and explain each of the flight instruments used in Pitch Control, Bank Control, and Power Control. He will point out similarities each instrument has to outside references and explain the limits and errors inherent in each instrument. After a thorough demonstration, he will have you practice using each instrument individually and in combination with other instruments. This procedure is followed for the first three lessons on Pitch Control, Bank Control, and Power Control in level flight. After a short time, you will be making a logical cross-check and not merely scanning the instruments. Approximately 6 hours of flight time plus the necessary ground school is usually required to cover the first three basic lessons. Your instructor will monitor your progress closely during this early training to guide you in dividing your attention properly. The importance of this "division of attention" or "cross-check" cannot be emphasized too much. This, and proper instrument interpretation, enables the instrument pilot to accurately visualize the aircraft's attitude at all times. To properly understand this guide, the terms "Primary Instrument" and "Supporting Instrument" must be clearly understood. For clarification of these terms, refer to Chapter V of the FAA Instrument Flying Handbook AC 61-27B.

NOTE.—Power settings and aircraft performance figures used in this guide are for illustrative purposes only. Exact power settings and performance information must be obtained experimentally or from performance charts for each aircraft flown.

Contents