Branch

AFM 51-37

AIR FORCE MANUAL

FLYING TRAINING

INSTRUMENT FLYING

1 DECEMBER 1976

This manual and changes thereto are distributed through USAF publication distribution channels. Changes to this manual are published on an unscheduled "as necessary" basis. The nature of the information demands that flight procedures be applied only when the latest change to the manual is accurately posted. Use of procedural information from an obsolete publication could lead to a situation that is hazardous to flight. Users should consult the AFR 0-2, the OPR, the USAF Instrument Flight Center or other authoritative source to verify the currency of the manual.

DEPARTMENT OF THE AIR FORCE

FOREWORD

Today's worldwide operational requirements and complex mission profiles demand more from our pilots than ever before. An in-depth understanding of instrument procedures and techniques is mandatory if we expect to accomplish our ever changing mission.

From the experiences and guidance provided by early instrument flying pioneers, this manual has evolved into a source for basic fundamentals, procedures, and techniques necessary for safe and precise instrument flight. I urge that the knowledge and information contained in the manual be put to full use by all Air Force pilots.

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AF MANUAL 51-37
1 December 1976

Flying Training

Instrument Flying

This manual establishes standard USAF instrument flying procedures and techniques. It serves as a text for various USAF training courses. Aircrew members charged with the safe operation of USAF aircraft must be knowledgeable of the guidance contained herein. Since aircraft flight instrumentation and mission objectives are so varied, this manual is necessarily general regarding equipment and detailed accomplishment of maneuvers. The indiviudal aircraft flight manual should provide detailed instructions required for particular aircraft instrumentation or characteristics. This manual provides adequate guidance for instrument flight under most circumstances, but is not a substitute for sound judgment. Circumstances may require modification of prescribed procedures.

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CHAPTER 1

AIRCRAFT EQUIPMENT

SECTION A — PRESSURE INSTRUMENTS

1-1. Pitot and Static Systems. Speed, altitude, and vertical velocity are measured by sensing the pressures surrounding an aircraft. These pressures are furnished either directly to the instruments or to a central air data computer (CADC) by pitot and the static systems.

1-2. Pitot and Static Sensing Errors. Both the pitot and the static systems have inherent characteristics that affect the pressures supplied to the instruments. Examples are:

a. Compressibility Effect. The magnitude of this effect is the same for all aircraft flying at the same calibrated airspeed and density altitude. The effect is caused by air being compressed in the pitot tube inlet which results in a higher than actual airspeed reading in the cockpit. It is negligible below 10,000 feet and 200 knots calibrated airspeed (CAS). Above sea level, calibrated airspeed is always equal to or greater than equivalent airspeed. To correct for compressibility effect, refer to the performance data in the aircraft flight manual or apply the "F" factor found on most dead reckoning computers (figure 1-1). The effect applies only to standard airspeed indicators which are calibrated by the manufacturer to read correctly at sea level conditions. It does not apply to mach or true airspeed indicators as compressibility is considered in the calibration of the indicator.

b. Installation Error:

(1) Installation error is caused by static ports supplying erroneous static pressure to the instruments. The slip stream airflow causes disturbances at the static ports, introducing an error in atmospheric pressure measurement. It varies with type of aircraft, airspeed, angle of attack, and configuration. The amount and direction of this error is determined by flight test and is found in the performance section of the aircraft flight manual. Since this is a static pressure sensing error, it affects the indications of airspeed, mach, and altitude; *it does not* appreciably affect vertical velocity indications. The vertical velocity indicator will initially show this pressure change, then stabilize with the proper indication.

(2) The appropriate altimeter installation error correction must be applied at all times to ensure that

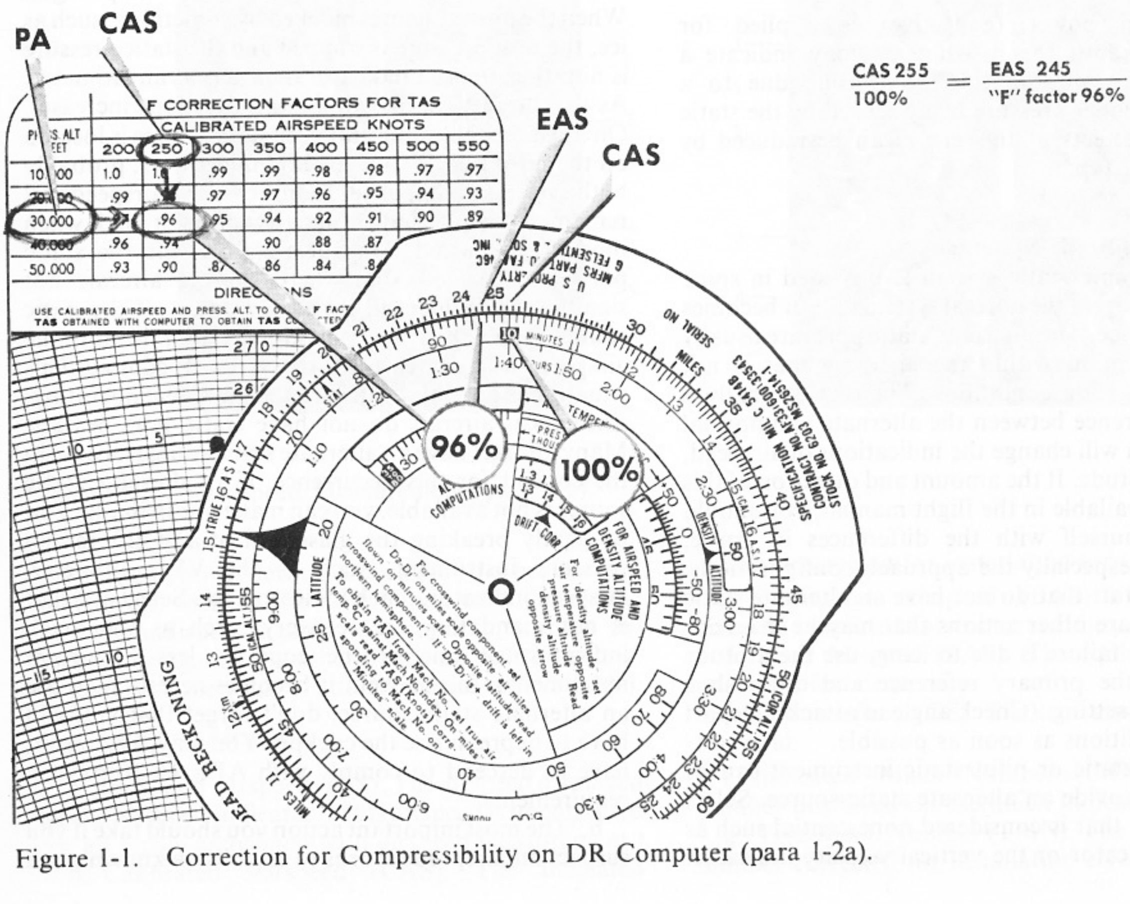


Figure 1-1. Correction for Compressibility on DR Computer (para 1-2a).

the aircraft is flying the proper attitude or flight level. (For example, an F-101 may have an error of -1,500 feet cruising at FL250. You will have to fly at an indicated altitude of FL235 because of installation error.) This error must be applied whether flying instrument flight rules (IFR) or visual flight rules (VFR) to ensure proper altitude separation between aircraft.

(3) The direction (positive or negative) of this error is found in the performance charts, but the directions for applying the error are sometimes confusing. Ensure that it is completely understood whether the correction value to be applied is to be added to or subtracted from the altimeter readout.

NOTE: Altimeter corrections for installation error are not required on aircraft equipped with a servo or pneumatic AIMS system unless operating in the secondary or nonservo mode (standby).

c. Reversal Error. This error is caused by a momentary static pressure change when the aircraft pitch attitude is changed. Examples are:

(1) When an aircraft is rotated for takeoff, the instruments may indicate a temporary descent and loss of altitude and airspeed due to a momentary higher pressure being sensed by the static system. The effects of this error can be minimized by smooth pitch changes.

(2) When power (collective) is applied for helicopter takeoff, the instruments may indicate a temporary descent and loss of altitude due to a momentary higher pressure being sensed by the static system. The effects of this error can be reduced by smooth power inputs.

1-3. Alternate Static System:

a. An alternate static system is provided in some aircraft in the event the normal system fails or becomes obstructed by ice. The alternate static ports are usually located at a point within the airframe that is not susceptible to icing conditions. There is normally a pressure difference between the alternate and normal systems which will change the indications of airspeed, mach, and altitude. If the amount and direction of this error is not available in the flight manual, you should familiarize yourself with the differences in cruise, letdown, and especially the approach configurations.

b. For aircraft that do not have an alternate static system, there are other actions that may be taken:

(1) If the failure is due to icing, use the attitude indicator as the primary reference and establish a known power setting. (Check angle of attack.) Depart the icing conditions as soon as possible.

(2) Any static or pitot static instrument can be modified to provide an alternate static source. Select an instrument that is considered nonessential such as the mach indicator or the vertical velocity indicator. Breaking the seal by pushing in on the glass will produce an alternate static source in the cockpit. Depressurize the cockpit and descend if necessary.

NOTE: When using an alternate static source, indicated readings *may* be higher than actual due to the venturi effect. The direction and magnitude of the error will vary with type of aircraft.

1-4. Central Air Data Computer (CADC). Many aircraft use electrically-operated vertical tape instruments as well as electrically-driven round dial counter-drum-pointer altimeters. To provide the necessary electrical signals to drive these instruments, a CADC or an altitude computer is used. These computers correct instrument displays for installation and scale errors. (Failure of instrument components receiving inputs from a CADC can result in the display of erroneous information without an accompanying warning flag or light.)

1-5. Speed Measurement (figure 1-2):

a. Airspeed measurements are a comparison of pitot (ram) pressure to static (ambient) pressure. The difference between these two pressures is differential (dynamic) pressure. The airspeed indicator measures this dynamic pressure by supplying pitot pressure to a flexible metallic diaphragm and static pressure to the airtight chamber which surrounds the diaphragm. When the pitot system is blocked by something, such as ice, the ram pressure is trapped and the static pressure is not, the airspeed indicator then acts as an altimeter. As the aircraft climbs, airspeed indications increase. On most supersonic aircraft, the static source is located on the pitot boom, so if the boom ices over, probably both systems are blocked. In this case the airspeed will remain constant, indicating the speed it had when blockage occurred. On subsonic aircraft the static ports are located somewhere on the aircraft not significantly influenced by the airstream. If the static source is blocked and the pitot boom is not, the airspeed will decrease as the aircraft climbs. This situation is possible even with the pitot heat operating, since most aircraft do not have static port heaters. Many aircraft have an alternate static source located in the cockpit for this occurrence. If an alternate static source is not available, you can make one in the cockpit by gently breaking the glass seal of any differential pressure instrument, such as the VVI, altimeter, airspeed indicator, mach indicator, etc. Select one that is not mandatory for recovery, such as the mach indicator, or one of the copilot's less important instruments. In the event it becomes necessary to use an alternate static source, don't forget that you will have to depressurize the cockpit. You may, as a result, have to descend to comply with AFR 60-16 oxygen requirements.

b. The most important action you should take if you suspect an airspeed error is to establish a known pitch

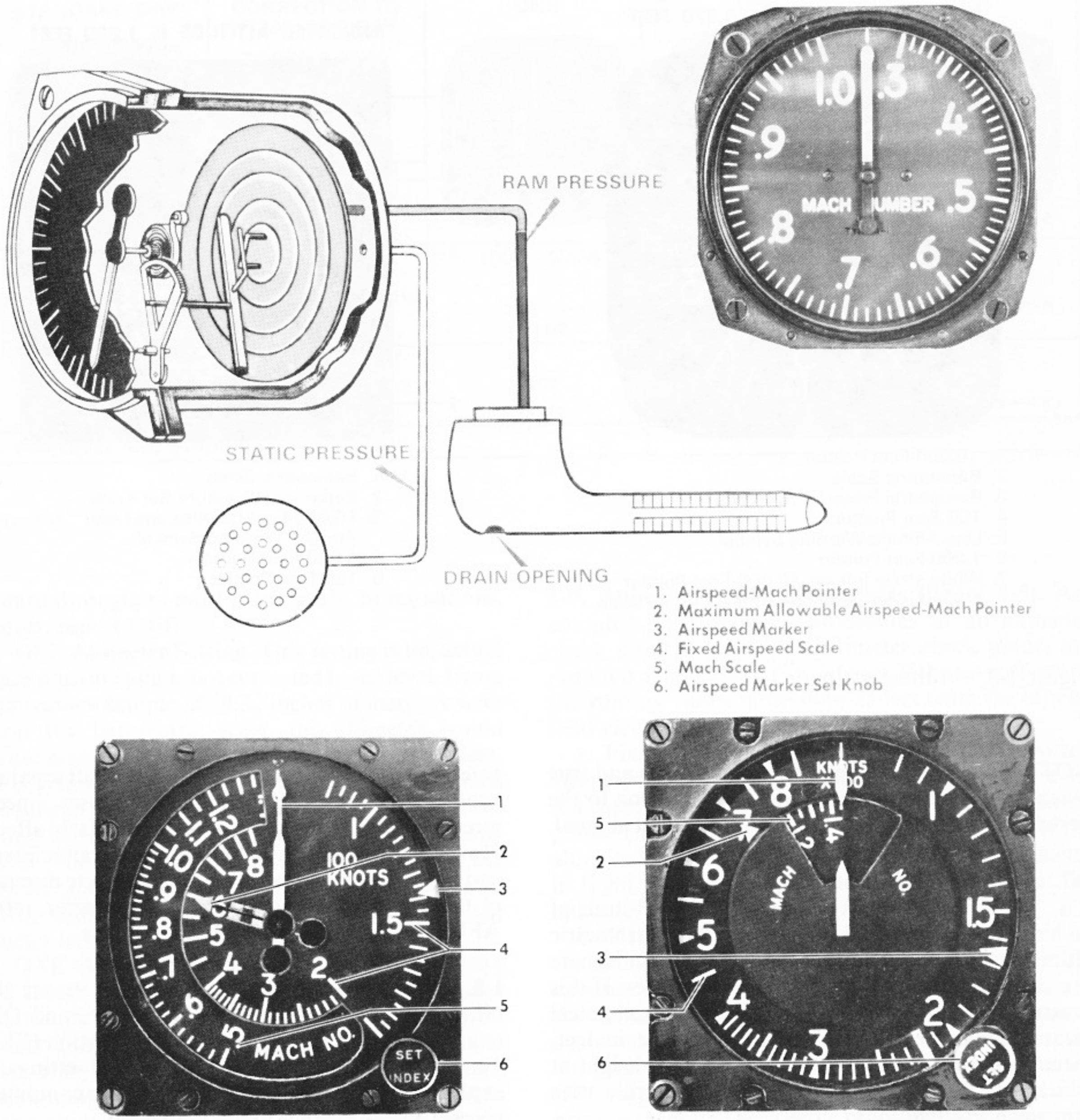


Figure 1-2. Air Speed Measurement (para 1-5).

attitude and power setting. Check the pitot heat on and if it is on, recheck the circuit breakers. Check the attitude indicator against the standby attitude indicator, or against the other pilot's attitude indicator. Cross-check the angle of attack indicator (if available).

1-6. Types of Airspeed:

a. Indicated Airspeed (IAS). The airspeed displayed by the airspeed indicator. (This airspeed is uncorrected for all errors associated with airspeed measurement.)

b. Calibrated Airspeed (CAS). The indicated airspeed corrected for installation error.

c. Equivalent Airspeed (EAS). The calibrated airspeed corrected for compressibility effect.

d. True Airspeed (TAS). The equivalent airspeed corrected for air density.

e. Groundspeed (GS). The true airspeed corrected for wind.

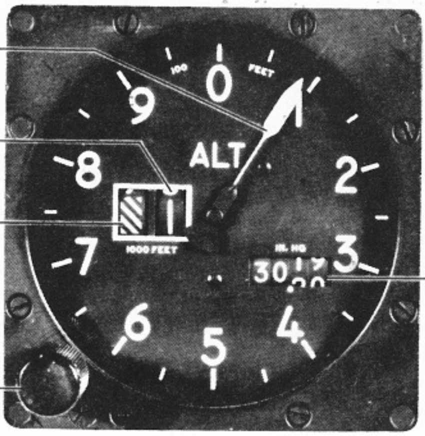
f. Indicated Mach Number (IMN). The mach number displayed on the mach indicator.

g. True Mach Number (TMN). The indicated mach number corrected for installation error.

INDICATED ALTITUDE IS 9,570 FEET

1. 10,000-Foot Pointer
2. Barometric Scale
3. Barometric Pressure Set Knob
4. 100-Foot Pointer
5. Low Altitude Warning Symbol
6. 1,000-Foot Pointer
7. White stripe follows 10,000-Foot Pointer around inner perimeter of the altitude scale.

INDICATED ALTITUDE IS 1,090 FEET



1. Barometric Scale
2. Barometric Pressure Set Knob
3. 10,000-Foot Counter and Low Altitude Warning Symbol
4. 1,000-Foot Counter
5. 100-Foot Pointer

Figure 1-3. Altimeters (para 1-7).

NOTE: Calibrated and equivalent airspeeds and true mach number can be determined by referring to the performance data section of the aircraft flight manual.

1-7. Altitude Measurement (figure 1-3):

a. There are many ways to measure the altitude of an aircraft; probably the simplest is with a barometric altimeter. The pressure of the earth's atmosphere decreases as height above the earth increases. If this pressure difference is measured by some mechanical means, it can be directly related to height in feet, meters, or other linear measurement. The height at which a particular pressure is sensed varies with atmospheric conditions.

b. A standard atmosphere chart provides a reference for altitude measurement. Barometric altimeters are designed to display altitude relative to the pressure difference shown on the chart. For example, if the barometric scale is referenced to 29.92" Hg (sea level, standard conditions) and the instrument is supplied with a static pressure of 20.58" Hg (pressure at 10,000 feet, standard conditions), the altimeter should indicate 10,000 feet. The pressure difference between the sea level and 10,000 feet on a standard day is 9.34 inches of mercury. Any time the altimeter senses this pressure difference between the barometric scale setting and the actual static pressure supplied to the instrument, it will indicate 10,000 feet. Since the actual height of these standard pressure levels varies with atmospheric conditions, the altimeter rarely indicates a true height. This does not cause any aircraft separation problem for air traffic control purposes since all aircraft flying in the same area are similarly affected. However, under certain conditions, terrain clearance can be a very real problem. (For a complete discussion of these atmospheric effects on the altimeter, refer to AFM 51-12 and AFP 60-19, volume II.)

1-8. Altimeter Settings (figure 1-4): There are three different altimeter settings (QNH, QFE, and QNE) referenced in Flight Information Publication (FLIP). To fully understand these different settings, an explanation of how altimeter settings are computed is necessary:

a. QNH Altimeter Setting. This setting is obtained by measuring the existing surface pressure and converting it to a pressure that would theoretically exist at sea level at that point. This is accomplished by adding the pressure change for elevation above sea level on a standard day. To illustrate this, consider an airport with an elevation of 1,000 feet (standard atmospheric value 28.86) and an actual observed surface pressure of 29.32 inches of mercury which is a pressure altitude variation (PAV) of 0.46 inches or 432 feet. To obtain the QNH altimeter setting, the pressure differential of 1.06" Hg (29.92" - 28.86") is added to the observed surface pressure (29.32" +1.06") resulting in an altimeter setting of 30.38" Hg. Theoretically, the altimeter will indicate 1,000 feet when 30.38" is set on the barometric scale. This QNH altimeter setting is

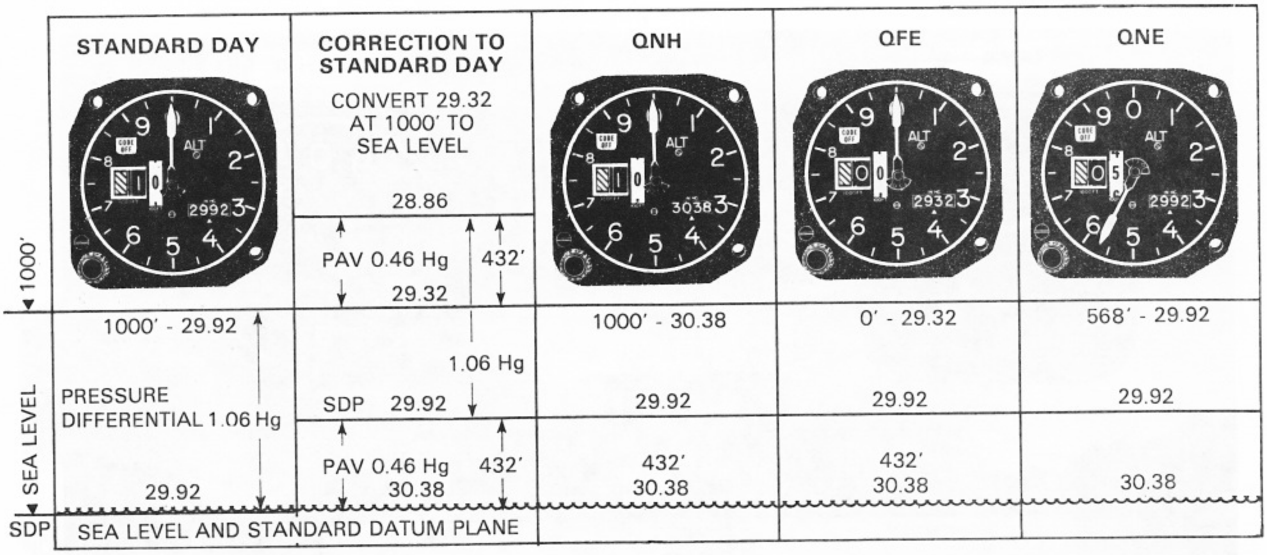


Figure 1-4. Altimeter Settings (para 1-8).

standard throughout most of the world. Some nations, however, report QFE.

b. QFE Altimeter Setting. This setting is the actual surface pressure and is not corrected to sea level. Using the previous example, if 29.32 inches of mercury were set on the barometric scale, the altimeter would indicate zero feet although field elevation is 1,000 feet. This is because there is no pressure difference between the altimeter reference on the barometric scale and the existing surface pressure that is sensed by the static system. The QNH altimeter setting results in the altimeter indicating height above mean sea level (MSL), while QFE altimeter setting results in the altimeter indicating height above field elevation.

c. QNE Altimeter Setting. This setting is always 29.92 inches of mercury and results in the altimeter indicating height above the standard datum plane or pressure altitude. This altimeter setting is used at and above transition altitude. In the United States, transition altitude is 18,000 feet MSL. Many nations use this altimeter setting for all flights above a specific transition altitude. In these cases, the minimum en route altitude for airways is based on the lowest barometric pressures ever recorded and obstacle height.

NOTE: Altimeter setting accuracy varies with the distance from where the surface pressure is measured and is considered reliable only when in the vicinity of where it was measured. Local pressure disturbances from wind flow around large buildings may also affect the accuracy of the altimeter. Both QNH and QFE settings may be reported in millibars of pressure rather than inches of mercury. You must then correct this setting to inches of mercury using the conversion tables found in FLIP.

1-9. Altimeter Setting Procedures (figure 1-5). Accomplish the following procedures at an altimeter check point if possible: (Altimeter check points are required at all US Air Force bases, if the takeoff end of the runway varies more than 25 feet from the official field elevation.)

a. Fixed Wing Procedure. Set the reported altimeter setting on the barometric scale. Compare the indicated altitude to the elevation of a known check point. The maximum allowable error is 75 feet. If the altimeter error exceeds 75 feet, do not use the altimeter in flight. No further corrections are necessary if the altimeter is within tolerance.

b. Helicopter Procedure. The altitude indicated on the altimeter may be in error if the altimeter check is conducted with the rotor turning. This error is due to the difference of pressure caused by the rotor downwash, the difference in pressure causes the altimeter to indicate lower than actual. Use one of the following procedures to obtain a valid altimeter check prior to takeoff. The specific procedure to use depends upon the situation and the sequence of items in the checklist for each particular helicopter model. (The overpressure condition resulting from the rotor downwash varies between helicopters (model or design). If this condition is significant, the aircraft flight manual should have this information.)

(1) Procedure Number 1. (Use this procedure if the check is completed prior to engine start at a known elevation and with a current altimeter setting.)

(a) Set the reported altimeter setting on the barometric scale.

(b) Compare the indicated altitude to the elevation of a known check point. The maximum allowable error is 75 feet. If the altimeter error exceeds 75 feet, do not accept the altimeter for flight.

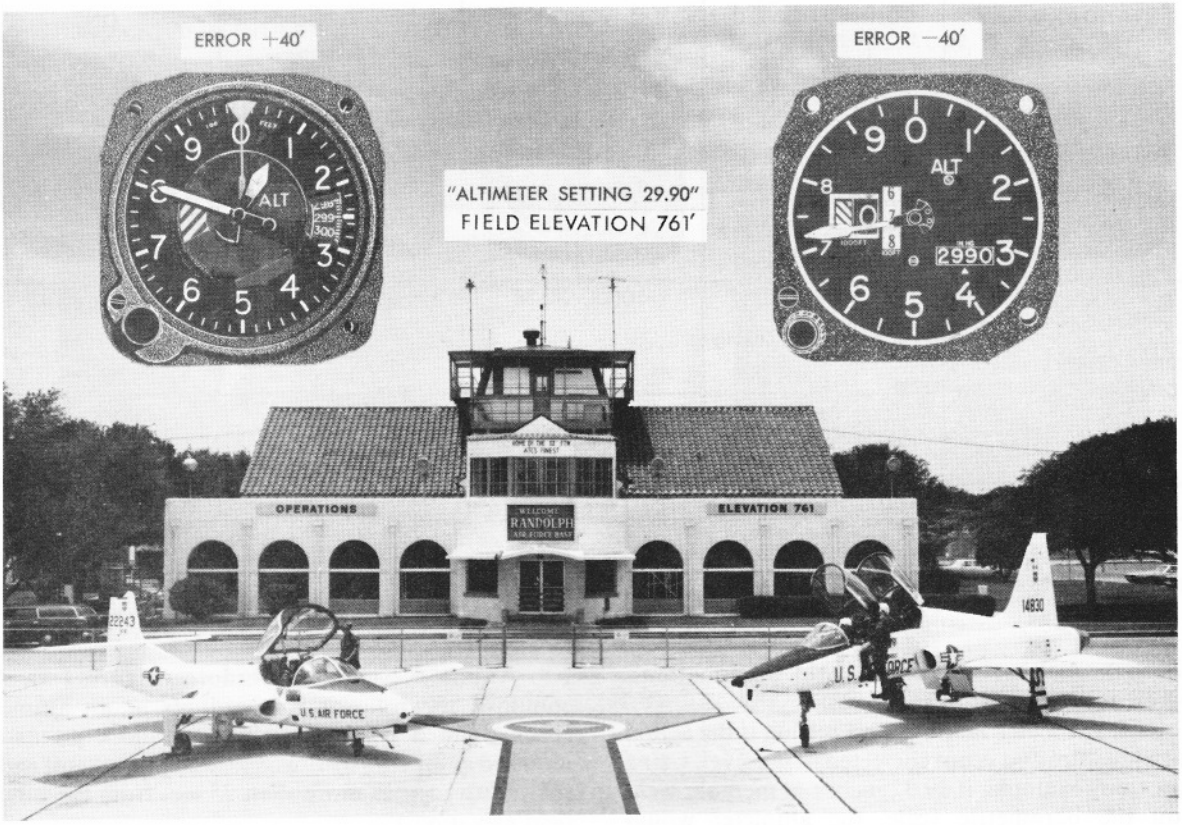


Figure 1-5. Setting the Altimeter (para 1-9).

(2) Procedure Number 2. (Use this procedure if a known elevation and a current altimeter setting is not obtained prior to engine start and rotor engagement.)

(a) Prior to the engine start, set the altimeter to the known elevation and note the barometric setting.

(b) After engine start, obtain and set the current altimeter setting on the barometric scale.

(c) Compare the current field barometric pressure set in the altimeter with altimeter setting noted prior to engine start. If the difference exceeds 0.075, do not accept the altimeter for flight.

(3) Procedure Number 3. (Use this procedure if the engines are started at an unknown elevation.)

(a) Taxi to a check point of known elevation and set the current altimeter setting on the barometric scale.

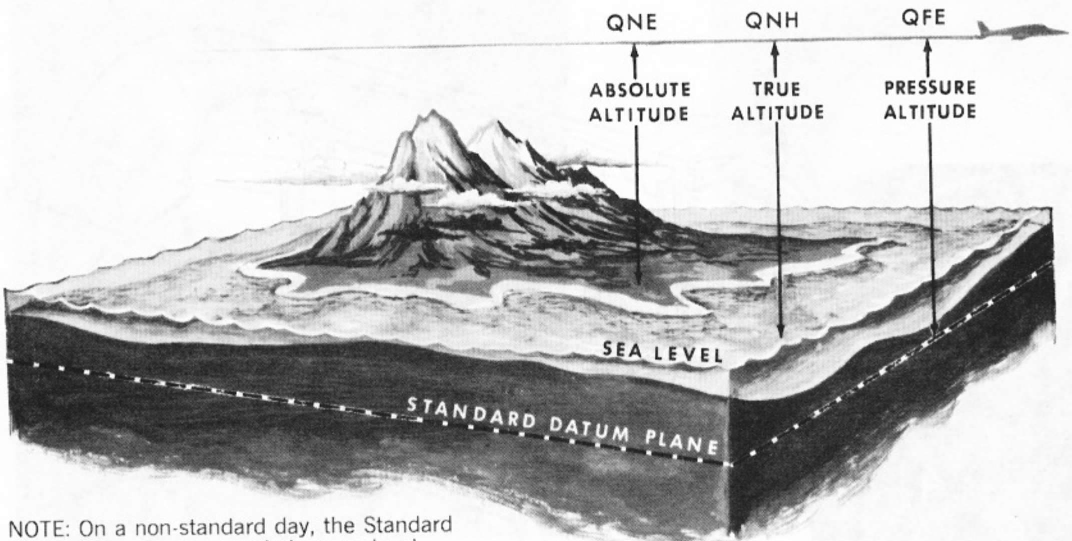
(b) Compare the indicated altitude to the elevation of a known check point. The maximum allowable error is 75 feet. If the altimeter error exceeds 75 feet, do not accept the altimeter for flight.

NOTE: Due to difference of pressure caused by rotor downwash, the altimeter will show a decrease after engine start with the rotor engaged. Consider this temporary altimeter error when determining tolerance limits. Do not reset the altimeter for this decrease.

1-10. Altimeter Errors. Although the altimeter is designed to very close tolerances, there are inherent errors which affect its accuracy. These are:

a. Scale Error. This error is caused by the aneroids not assuming the precise size designed for a particular pressure difference. It is irregular throughout the range of the instrument; that is, it might be -30 feet at 1,000 feet and +50 feet at 10,000 feet. The tolerances for this error become larger as the measured altitude is increased. At 40,000 feet an error of ±200 feet would be within tolerance. The amount of scale error actually encountered varies with each altimeter. Instrument maintenance personnel calibrate the altimeter prior to installation. No aircrew action is required.

b. Friction Error. This error is caused by friction in the moving parts of mechanical altimeters and causes lags in instrument indications. Usually, natural vibrations will resolve friction error in reciprocating engine aircraft. Jet engine aircraft usually have instrument panel vibrators installed to eliminate this error. If the vibrator is inoperative, lightly tapping the instrument at certain intervals may be necessary. These intervals must be determined by the proximity of the aircraft to minimum altitudes. There is an internal vibrator installed in counter-pointer and counter-drum-pointer altimeters. When operating in the



NOTE: On a non-standard day, the Standard Datum Plane is above or below sea level.

Figure 1-6. Types of Altitude (para 1-11).

nonelectrical mode with the internal vibrator inoperative, the 100-foot pointer has been known to "hang up."

c. Mechanical Error. This error is caused by misalignment or slippage in the gears or linkage connecting the aneroids to the pointers or in the shaft of the barometric set knob. It is checked by the altimeter setting procedure during the instrument cockpit check (chapter 4).

d. Hysteresis Error. This error is a lag in the altitude indications caused by the elastic properties of the materials used in the aneroids. It occurs after an aircraft has maintained a constant altitude for a period of time and then makes a large, rapid altitude change. The lag in indication occurs because it takes time for the aneroids to "catch up" to the new pressure environment. This error has been significantly reduced in modern altimeters and is considered negligible (less than 100 feet) at normal rates of descent for jet aircraft (4,000-6,000 fpm).

1-11. Types of Altitude (figure 1-6):

a. Absolute Altitude. The altitude above the terrain directly below the aircraft.

b. Pressure Altitude. The altitude above the standard datum plane (SDP). SDP is the pressure plane where air pressure is 29.92" Hg, corrected to plus 15°C.

c. Density Altitude. The pressure altitude corrected for temperature. Pressure and density altitudes are the same when conditions are standard (refer to standard atmosphere table). As the temperature rises above standard, the density of the air decreases resulting in an increase in density altitude.

d. Indicated Altitude. The altitude displayed on the altimeter.

e. Calibrated Altitude. The indicated altitude corrected for installation error.

f. True Altitude. The calibrated altitude corrected for nonstandard atmospheric conditions. It is the actual height above mean sea level.

g. Flight Level. A surface of constant atmospheric pressure related to the standard datum plane. In practice, it is calibrated altitude with 29.92" Hg reference on the barometric scale.

1-12. Vertical Velocity Measurement (figure 1-7): Vertical velocity indicators use "rate of change of static pressure" for measuring vertical rate. The rate of change of static pressure is obtained by supplying static pressure directly to a thin metalic diaphragm and through a calibrated orifice to an airtight case surrounding the diaphragm. As the aircraft climbs, the static pressure in the case is momentarily "trapped" by the calibrated orifice and the static pressure in the diaphragm is allowed to decrease immediately. This decrease causes the diaphragm to contract and through a mechanical linkage, the pointer indicates a climb. In a descent, the opposite is true. Case static pressure is momentarily "trapped" at the lower static pressure while the diaphragm expands because of the higher static pressure furnished and this expansion causes the pointer to indicate a descent. Because of this "delay" or "lag" caused by the calibrated orifice, it requires up to 9 seconds for the indications to stabilize. However, immediate trend information is available. Many of the "instantaneous" types of indicators use either a pitch gyro signal or an accelerometer signal for the initial indication and then stabilize the indication with barometric information.

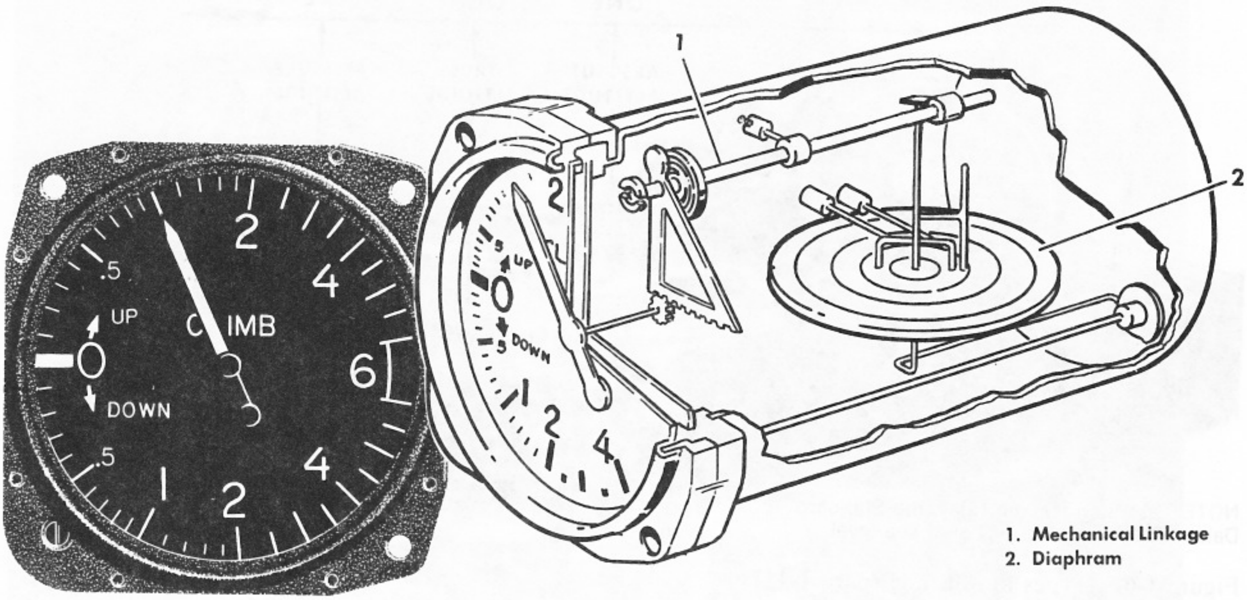


Figure 1-7. Vertical Velocity Indicator (para 1-12).

SECTION B - ATTITUDE INSTRUMENTS

1-13. Attitude Indicator (figures 1-8, 1-9, and 1-10). This indicator provides you with a substitute for the earth's horizon to maintain a desired aircraft attitude during instrument flight. This is accomplished by displaying an attitude sphere positioned by a self-contained gyro, remote gyro(s), or an inertial platform.

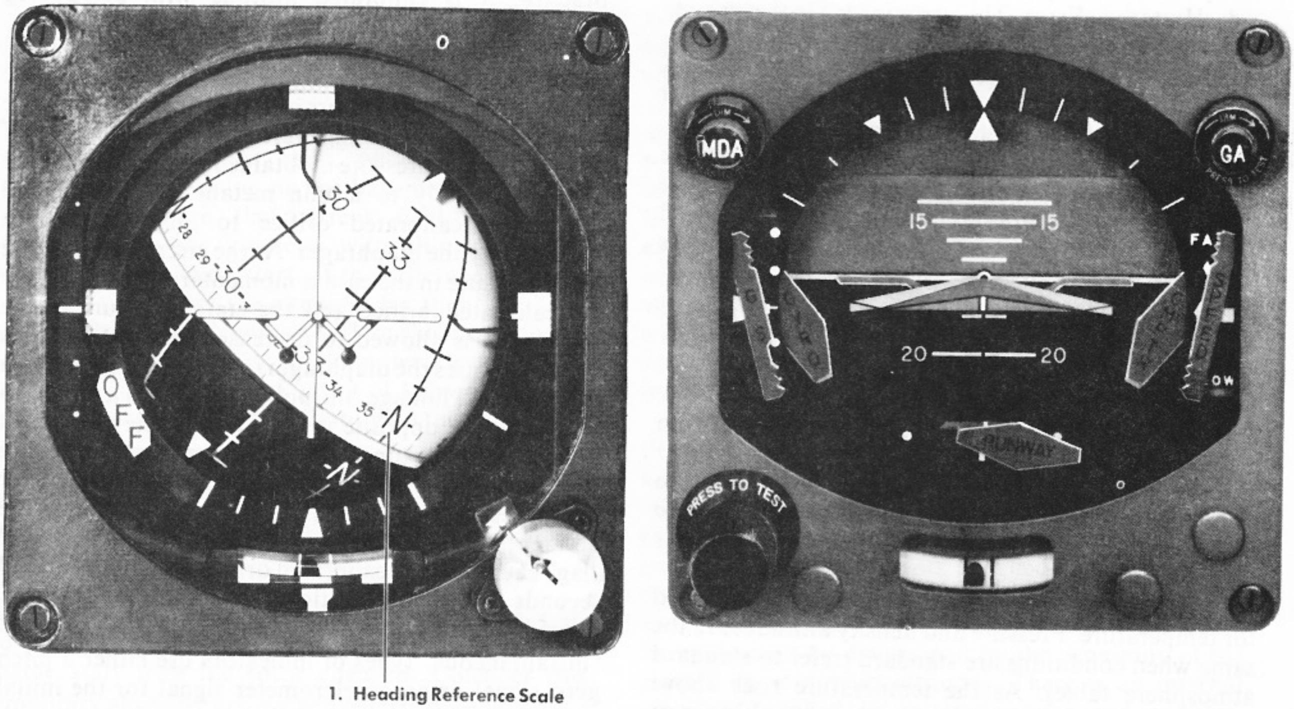
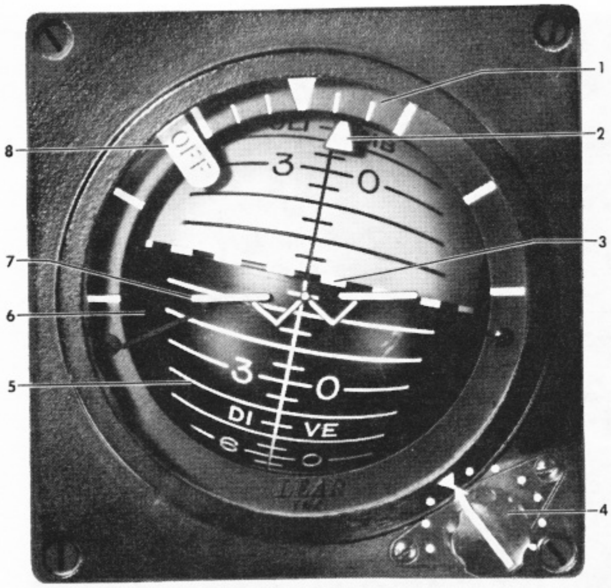
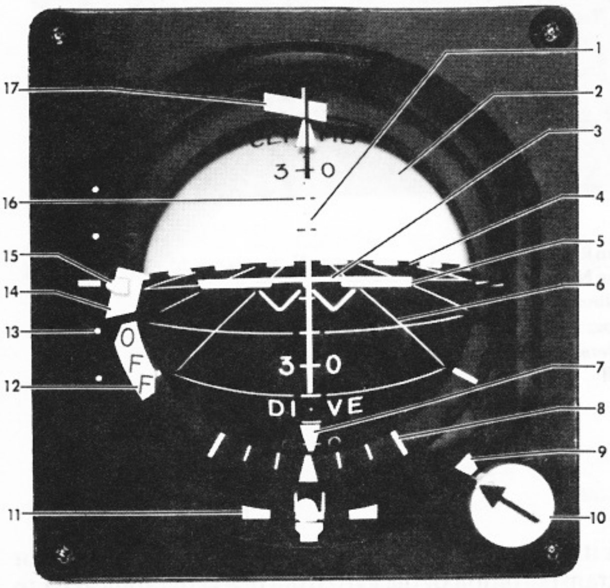


Figure 1-8. FD-109 and Three-Axis Attitude Director Indicator (para 1-13).



MM-1

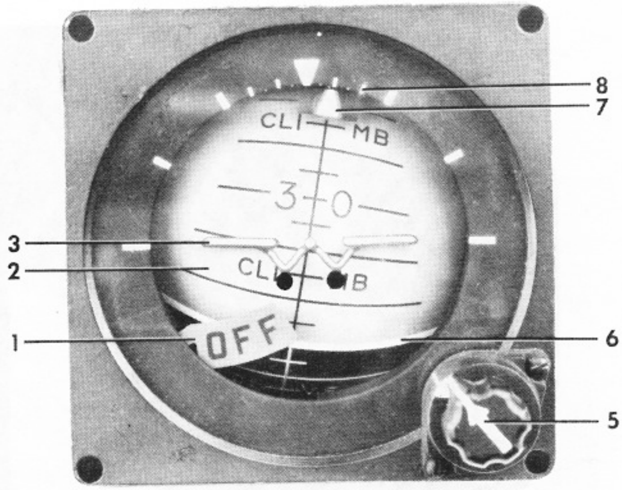
1. Bank Scale
2. Bank Pointer
3. Horizon Bar
4. Pitch Trim Knob
5. Pitch Reference Scale
6. Attitude Sphere
7. Miniature Aircraft
8. Attitude Warning Flag



ADI

1. Bank Steering Bar
2. Attitude Sphere
3. Pitch Steering Bar
4. Horizon Bar
5. Miniature Aircraft
6. Ground Perspective Lines
7. Bank Pointer
8. Bank Scale
9. Pitch Trim Index
10. Pitch Trim Knob
11. Turn and Slip Indicator
12. Attitude Warning Flag
13. Glide Slope Deviation Scale
14. Glide Slope Warning Flag
15. Glide Slope Indicator
16. Pitch Reference Scale
17. Course Warning Flag

Figure 1-9. MM-1 Attitude Indicator and Attitude Director Indicator (ADI) (para 1-13).



MM-3

1. Attitude Warning Flag
2. Attitude Sphere
3. Miniature Aircraft
4. Caging Knob
5. Pitch Trim Knob
6. Horizon Bar
7. Bank Pointer
8. Bank Scale

J-8

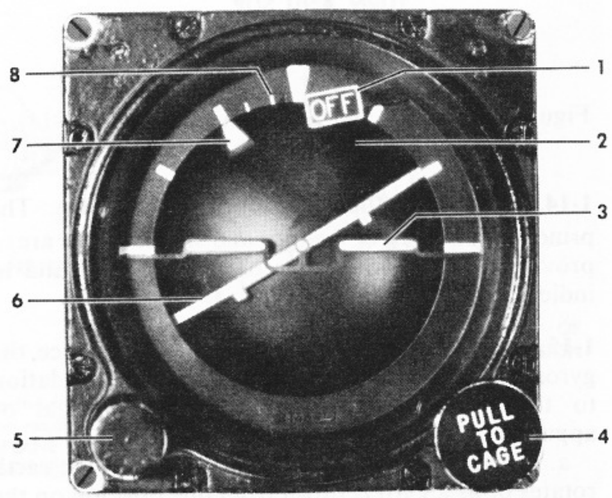
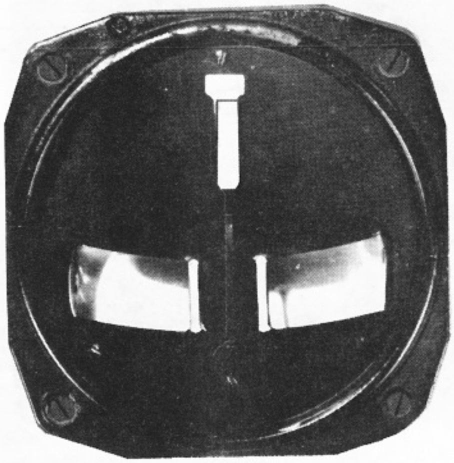
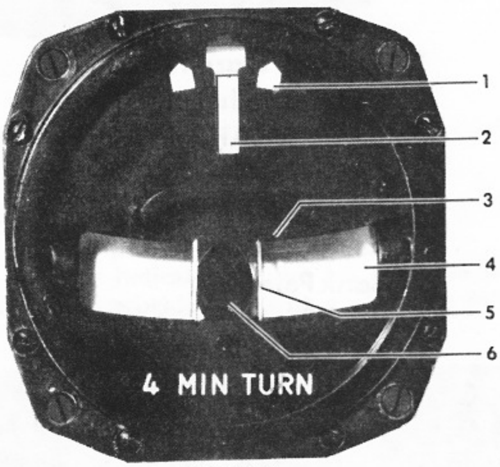


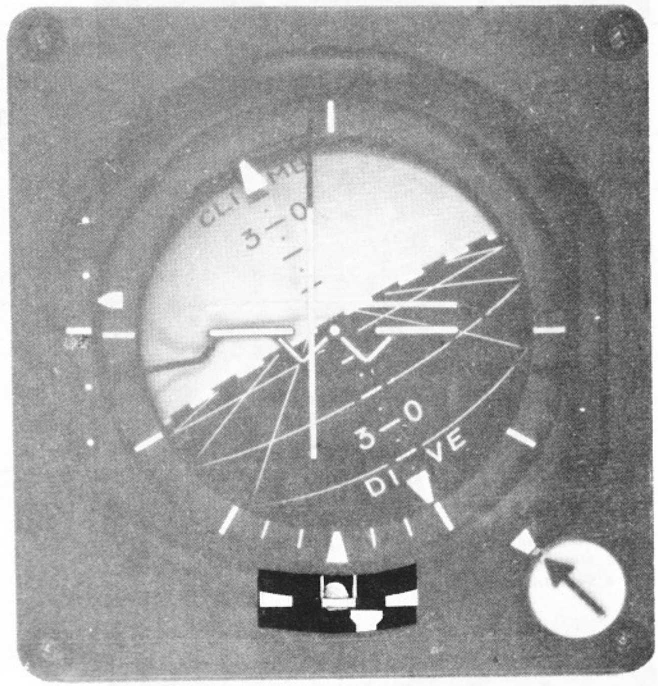
Figure 1-10. MM-3 and J-8 Attitude Indicators (para 1-13).



2 MINUTE
TURN AND SLIP
INDICATOR



4 MINUTE
TURN AND SLIP
INDICATOR



ADI 4 MINUTE
TURN AND SLIP
INDICATOR

1. Turn Rate Scale
2. Turn Needle
3. Inclinometer
4. Glass Tube
5. Reference Markers
6. Ball

Figure 1-11. Turn and Slip Indicators (para 1-14).

1-14. Turn and Slip Indicator (figure 1-11). The principal functions of the turn and slip indicator are to provide an alternate source of bank control and to indicate a need for a yaw trim.

1-15. Precession. To serve as an attitude reference, the gyroscope spin axis must remain aligned with relation to the earth's surface. Any movement (real or apparent) of the spin axis is called:

a. Apparent Precession (figure 1-12). As the earth rotates or as a gyro is flown from one position on the earth to another, the spin axis remains fixed in space. However, to an observer on the surface of the earth, the spin axis appears to change its orientation in space. Either the earth's rotation (earth rate precession) or transportation of the gyro from one geographical fix to another (earth transport precession) may cause apparent precession.

b. Real Precession. Movement of the gyro spin axis from its original alignment in space is real precession. It is caused by a force applied to the spin axis (figure 1-13). This force may be unintentional force such as rotor imbalance or bearing friction, or an intentional force applied by the erection mechanism or torque motor.

c. Erection Mechanisms. The erection mechanisms compensate for precession by keeping the gyros aligned with the earth's surface.

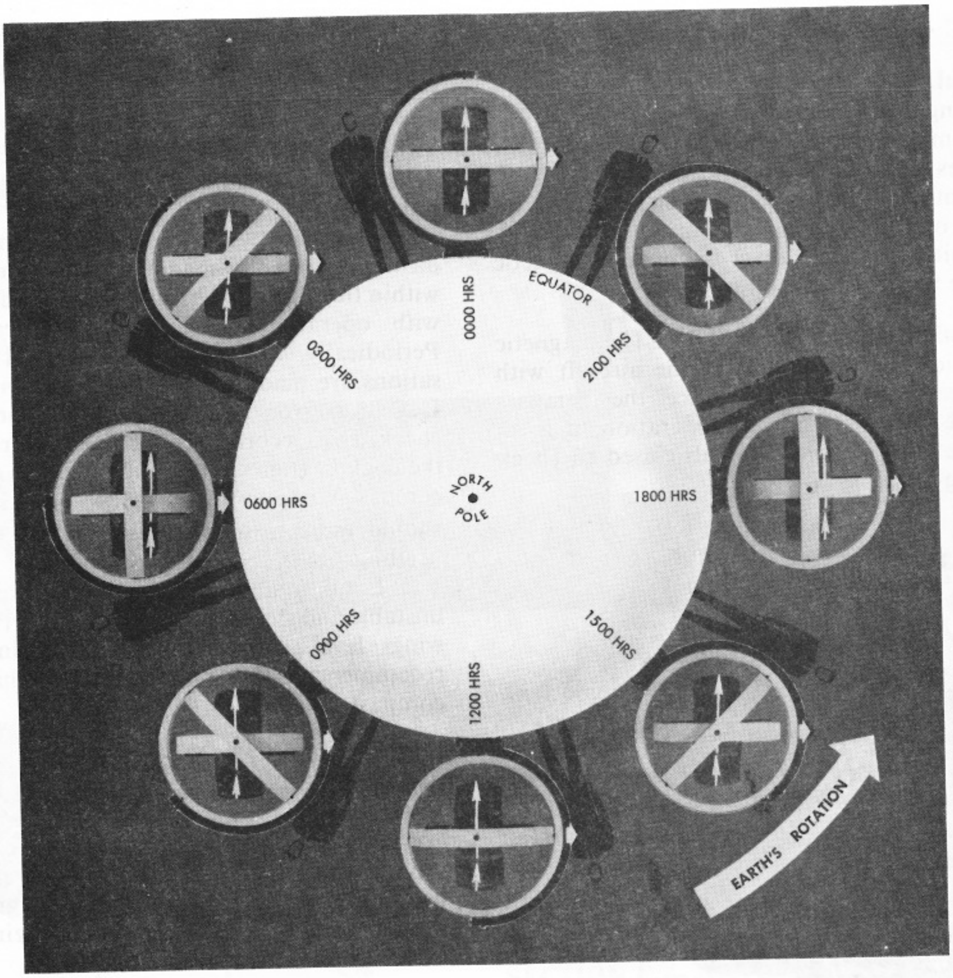
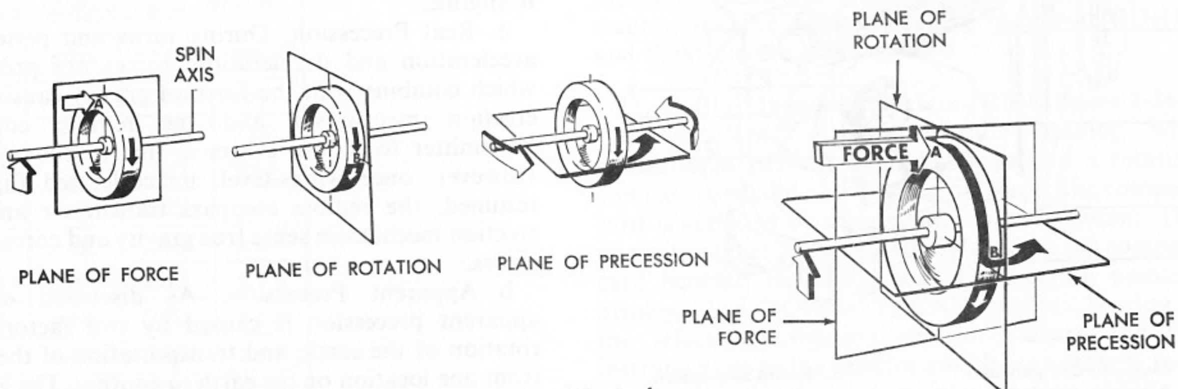


Figure 1-12. Apparent Precession (Earth Rate Precession) (para 1-15a).



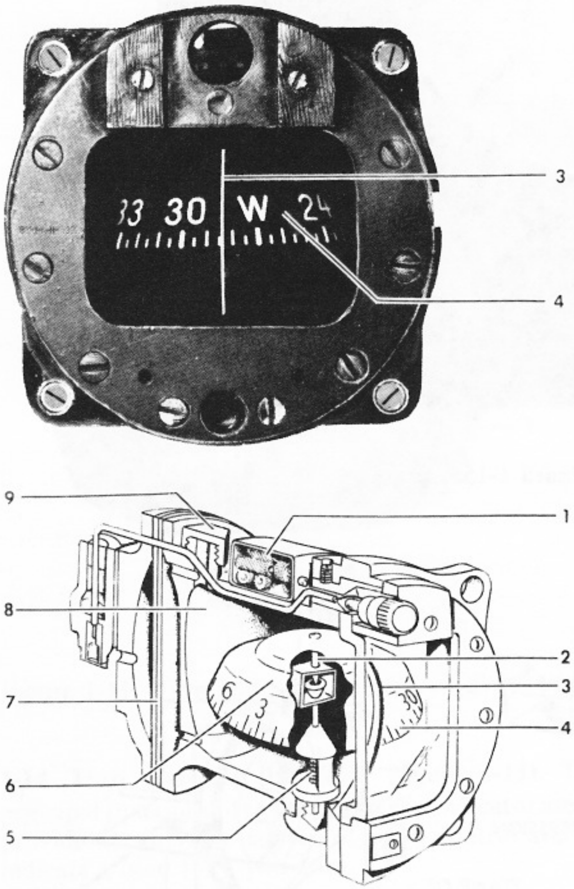
By applying an upward pressure on the GYRO SPIN AXIS, a deflective force is applied to the rim of gyro at point A (PLANE OF FORCE). The resultant force is 90° ahead in the direction of rotation to point B (PLANE OF ROTATION), which causes gyro to precess (PLANE OF PRECESSION).

Figure 1-13. Precession of a Gyroscope Resulting From Applied Deflective Force (para 1-15b).

SECTION C — HEADING SYSTEMS

1-16. General. Heading information is usually obtained by using the earth's magnetic lines of force. The magnetic compass, one of the first to convert the magnetic lines of force to aircraft heading information, is a self-contained instrument which operates independently of the electrical system. Other heading systems require electrical power to convert magnetic lines of force to aircraft heading.

1-17. Magnetic Compass (figure 1-14). The magnetic compass indicates the heading of the aircraft with reference to magnetic north. Since the compass requires no electrical power for operation, it is an emergency heading system. It is also used to check other heading systems.



1. Magnetic Compensator Assembly
2. Pivot Assembly
3. Lubber Line
4. Card
5. Spring Suspension
6. Float
7. Expansion Chamber
8. Liquid Chamber
9. Filler Plug

Figure 1-14. Magnetic Compass (para 1-17).

a. Variation (figure 1-15). The magnetic compass points to magnetic north. The angular difference between true and magnetic north is known as variation and it changes for different locations on the earth. Variation must be considered when converting true courses, true headings, or true winds to magnetic direction.

b. Deviation. This is an error in compass indications caused by magnetic disturbances originating within the aircraft. The magnitude of deviation varies with operation of different electrical equipment. Periodically, the compass is checked and compensations are made to reduce the amount of deviation. Deviation errors remaining after the compass has been checked are recorded on a compass correction card in the cockpit (figure 1-15). The STEER column on the compass correction card is the compass heading you should indicate to maintain the TO FLY magnetic heading.

c. Limitation. The magnetic compass is relatively unstable and should be read only when the aircraft is in wings level, unaccelerated flight. Timed turns are recommended when making heading changes with this compass (chapter 2).

1-18. Types of Heading Systems. There are many types of heading systems, but each may be classified as either slaved or nonslaved. The nonslaved system uses a gyro to supply the directional reference, while the slaved system uses the signals from a remote compass transmitter to orient the system to magnetic north. In both systems the gyro acts as a stabilizing component to reduce the inherent errors.

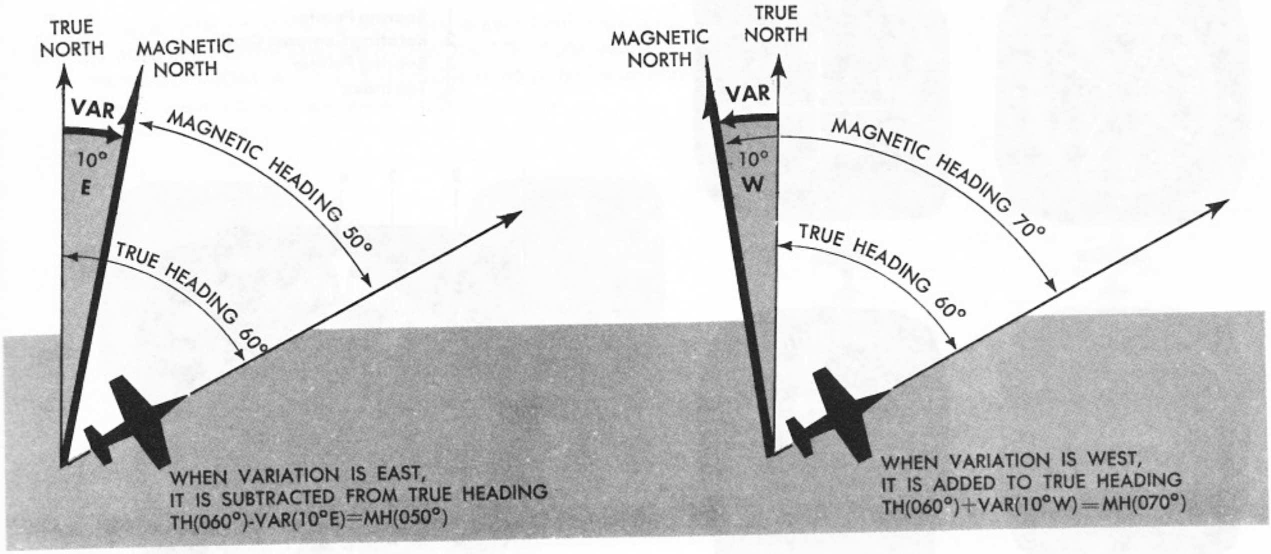
1-19. Heading System Errors. All heading systems are subject to errors produced by real and apparent precession. If provisions for correction are incorporated in the design of the system, these errors will be negligible.

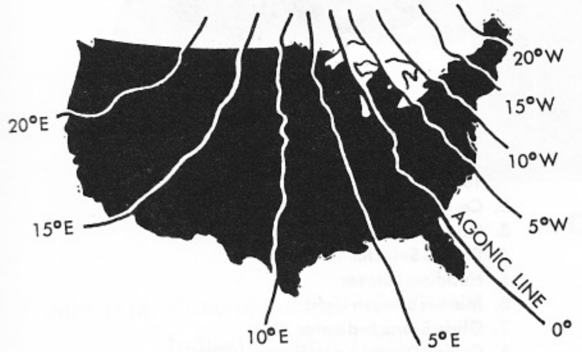
a. Real Precession. During turns and periods of acceleration and deceleration, forces are produced which combine with the force of gravity causing the erection mechanism and the remote compass transmitter to induce errors in the heading system. However, once wings-level, unaccelerated flight is resumed, the remote compass transmitter and the erection mechanism sense true gravity and correct any errors.

b. Apparent Precession. As discussed earlier, apparent precession is caused by two factors: the rotation of the earth; and transportation of the gyro from one location on the earth to another. The gyro is kept horizontal by the erection mechanism.

SECTION D — ANGLE OF ATTACK SYSTEMS

1-20. General. Angle of attack information is obtained by comparing the relative wind to the chord line of the wing. Its primary use in instrument flight is during the





B-16 COMPASS

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TO FLY	STEER	TO FLY	STEER
N	001	180	179
15	016	195	194
30	031	210	209
45	046	225	224
60	062	240	238
75	077	255	253
90	092	270	268
105	107	285	283
120	122	300	298
135	135	315	314
150	149	330	330
165	164	345	346

Figure 1-15. Magnetic Compass Variations and Correction Card.

final phase of an instrument approach. Maintaining the computed final approach airspeed, during unaccelerated (1 G) flight, should also maintain the approach angle of attack. The information can be used in the same manner as airspeed. This allows either angle of attack or airspeed to be flown while using the other indication as a backup. (Refer to the aircraft flight manual for specific guidance on the use of angle of attack.)

SECTION E — NAVIGATION INSTRUMENTS

1-21. General. The navigation instruments explained in this section are common to the majority of USAF aircraft. These instruments are the radio magnetic indicator (RMI), course indicator (CI), range indicator, bearing-distance-heading indicator (BDHI), and flight director (figure 1-16).

1-22. Radio Magnetic Indicator (RMI (figure 1-16):

a. The RMI displays aircraft heading with navigational bearing data. It consists of a rotating compass card and two bearing pointers. The compass card is actuated by the aircraft compass system. The aircraft magnetic heading is displayed on the compass card beneath the top index. The bearing pointers display ADF, VOR, or TACAN magnetic bearing to the selected navigation station. Placards on the instrument or near a selector switch are normally used to identify the bearing pointer display. VOR or TACAN *radials* are displayed under the tail of their respective bearing pointers. Bearing pointers *do not* function in relation to instrument landing system (ILS) signals.

b. If there is a malfunction in the compass sytem or compass card, the ADF bearing pointer continues to point to the station, and displays *relative bearing* only.

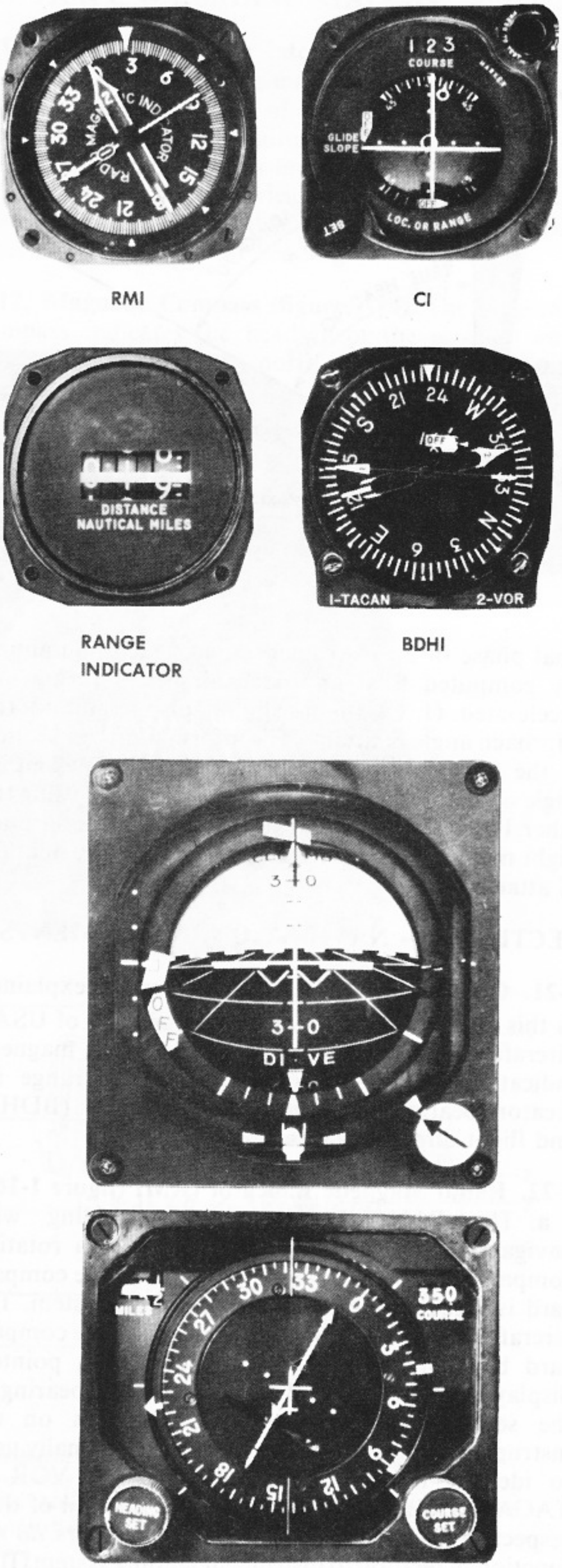
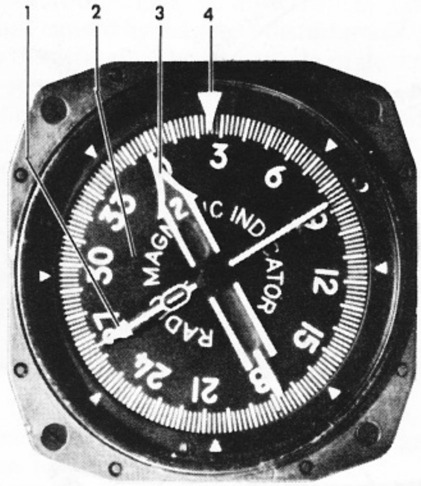


Figure 1-16. Navigation Instruments (para 1-21).

RMI (para. 1-22)

1. Bearing Pointer
2. Rotating Compass Card
3. Bearing Pointer
4. Top Index



CI (para. 1-23)

1. To-From Indicator
2. Course Deviation Scale
3. Glide Slope Deviation Scale
4. Course Selector Window
5. Heading Pointer
6. Marker Beacon Light
7. Glide Scope Indicator (GSI)
8. Course Deviation Indicator (CDI)
9. Course and Glide Slope Warning Flags
10. Course Set Knob

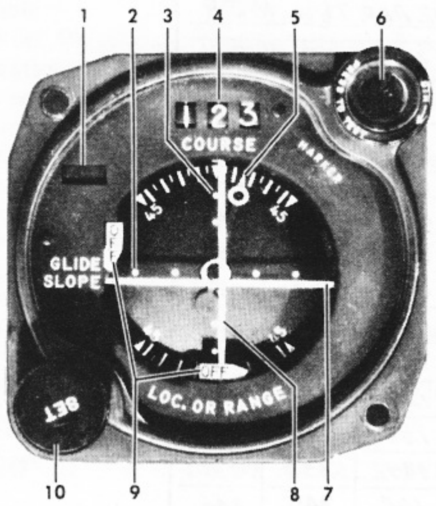
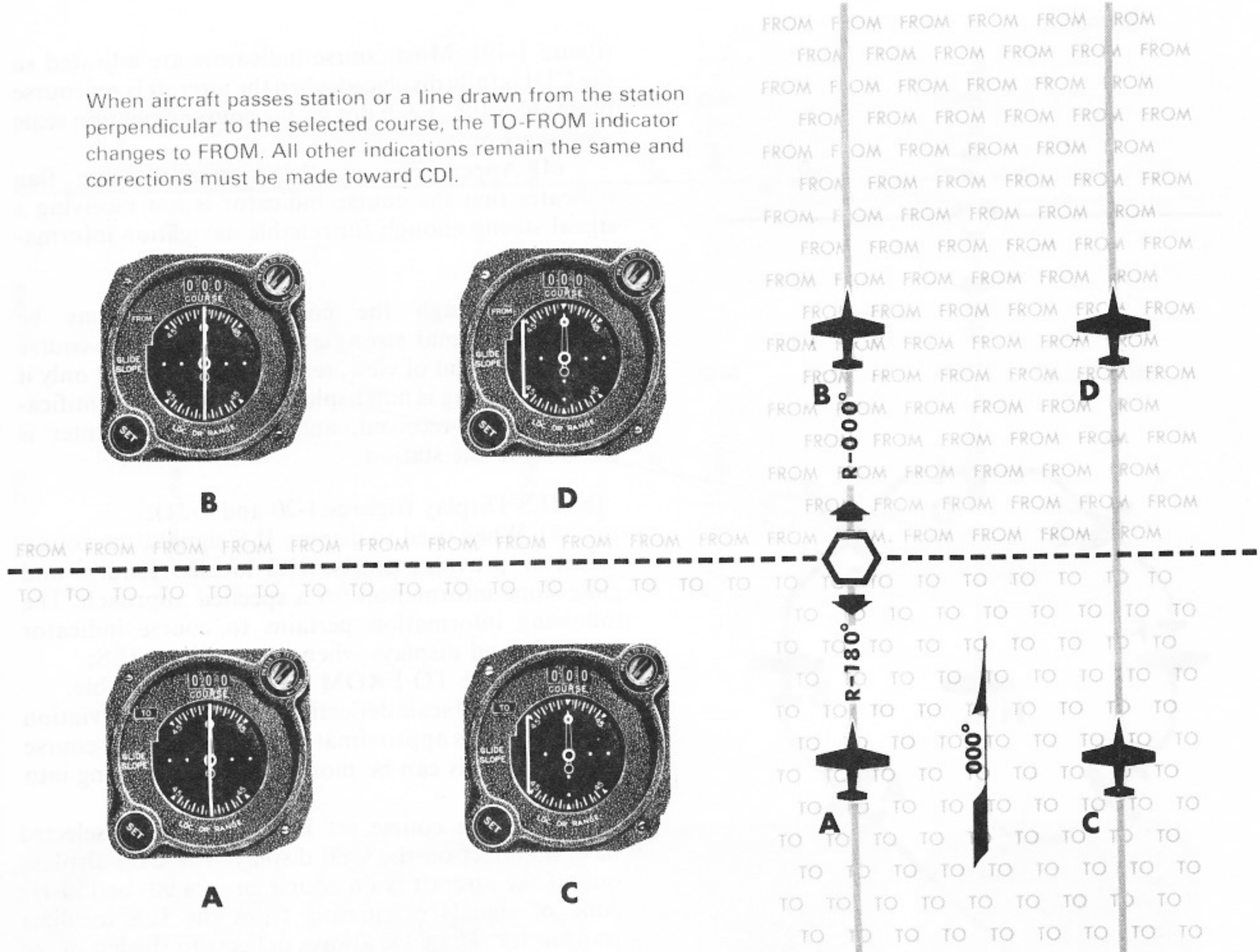


Figure 1-17. Radio Magnetic Indicator (RMI) and Course Indicator (CI).



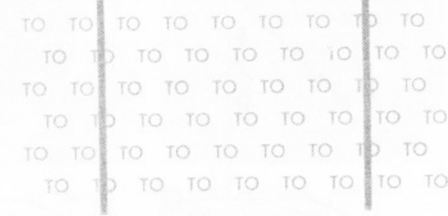


Figure 1-18. Principle of the TO-FROM Indicator (para 1-23a(2)).

With a malfunction in the compass system or compass card, the VOR or TACAN bearing *may* still indicate magnetic bearing. Until verified by radar or other navigational equipment, consider this bearing information unreliable.

NOTE: VOR and TACAN bearing pointers do not "point" to an area of maximum signal strength as does ADF. VOR and TACAN navigation receivers electronically measure the magnetic course which is displayed by the pointers.

1-23. Course Indicator (CI) (figure 1-17). The course indicator operates independently of the RMI. It displays aircraft heading and position relative to a selected VOR/TACAN course, and lateral and vertical position *relative* to an ILS localizer and glide slope.

a. VOR or TACAN Display:

(1) When the course indicator is used to display VOR or TACAN information, aircraft heading and position are indicated relative to a selected course. The desired course is set in the course selector window with the course set knob.

(2) The heading pointer, connected to the course set knob and the compass system, displays *aircraft heading relative to the selected course.* When the aircraft heading is the same as the course selected, the heading pointer indicates 0° heading deviation at the top of the course indicator. The heading deviation scales, at the top and bottom of the course indicator, are scaled in 5° increments up to 45°. The TO-FROM indicator indicates whether the course selected, if properly intercepted and flown, will take the aircraft to or from the station (figure 1-18). When the aircraft passes a line from the station perpendicular to the selected course, the TO-FROM indicator changes. *Aircraft heading has no effect on the TO-FROM indications.*

(3) The course deviation indicator (CDI) displays *aircraft course deviation relative to the course selected*

(figure 1-19). Most course indicators are adjusted so the CDI is fully displaced when the aircraft is off course more than 10°. Each dot on the course deviation scale represents 5°.

(4) Appearance of the course warning flag indicates that the course indicator is not receiving a signal strong enough for reliable navigation information.

NOTE: Although the course indicator may be receiving a signal strong enough to keep the course warning flag out of view, reliability is indicated only if the warning flag is not displayed, the station identification is being received, and the bearing pointer is pointing to the station.

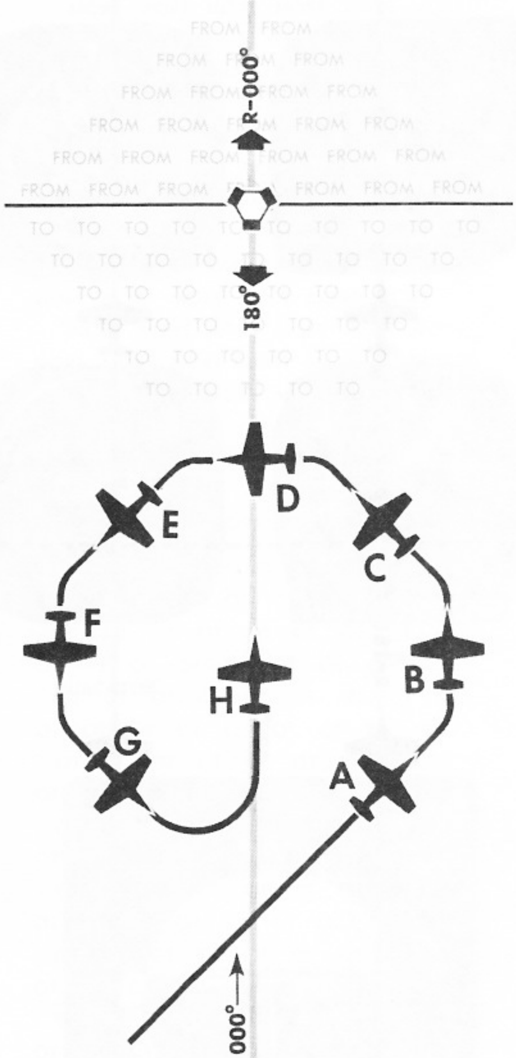
b. ILS Display (figures 1-20 and 1-21):

(1) When used to display ILS signals, the course indicator provides precise ILS localizer course and glide slope information for a specifed approach. The following information pertains to course indicator functions and displays when used with an ILS;

(a) The TO-FROM indicator is unusable.

(b) Full scale deflection on the course deviation scale represents approximately 2½° of localizer course deviation. (This can be more or less when flying into civil airports.)

(c) The course set knob and course selected have no effect on the CDI display. The CDI displays only if the aircraft is on course or in a 90- or 150-Hz zone of signals originating from the ILS localizer transmitter. The CDI always deflects to the left of the instrument case in the 150-Hz zone and to the right in the 90-Hz zone. It centers when the signal strength of both zones is equal. (Although the course selected has no effect on the CDI, *always* set the published inbound FRONT COURSE of the ILS in the course selector



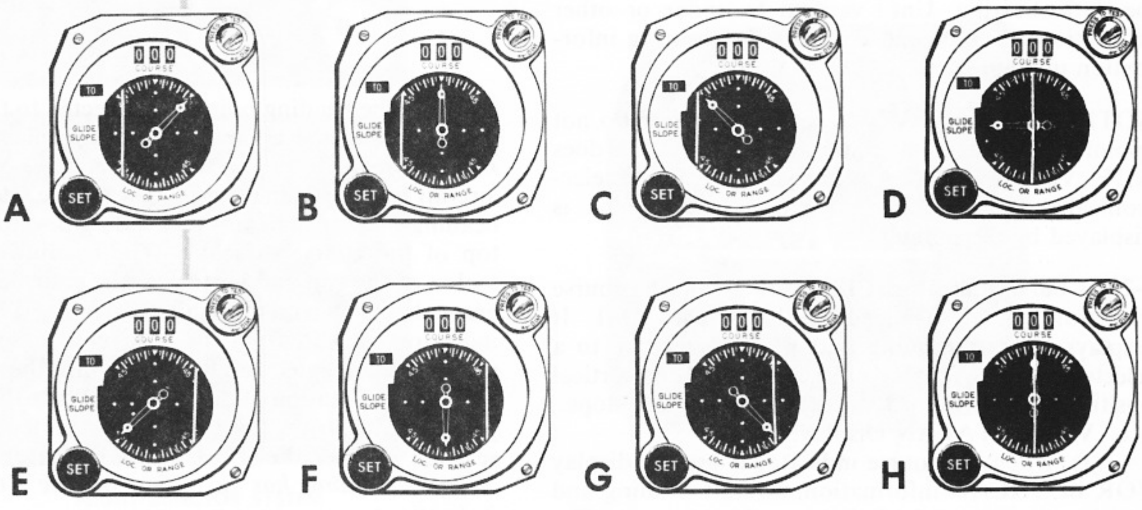


Figure 1-19. Course Indicator Displays in Relation to the Selected Course (para 1-23a(3)).

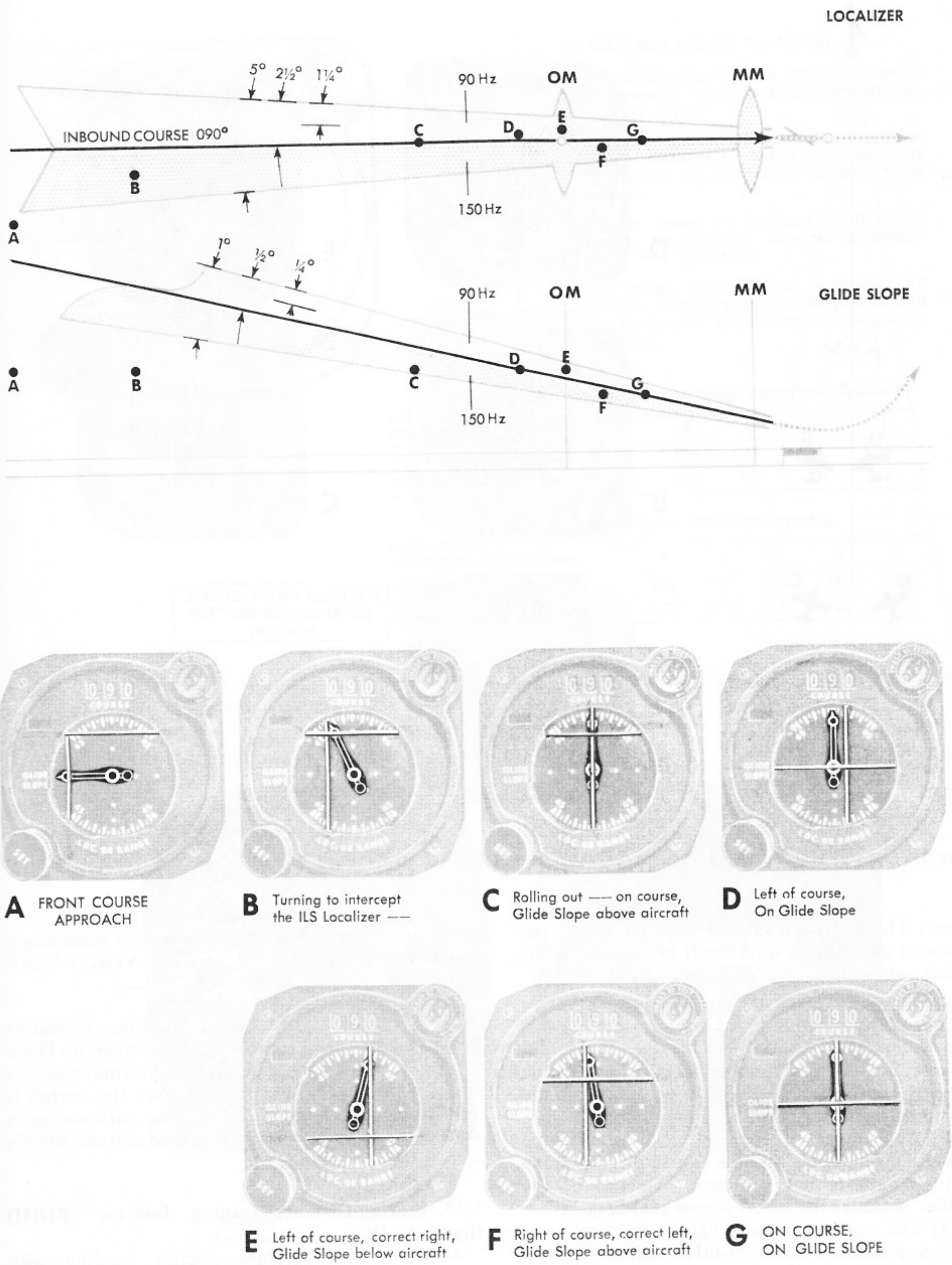


Figure 1-20. ILS Course Indicator Presentations (Front Course) (para 1-23b).

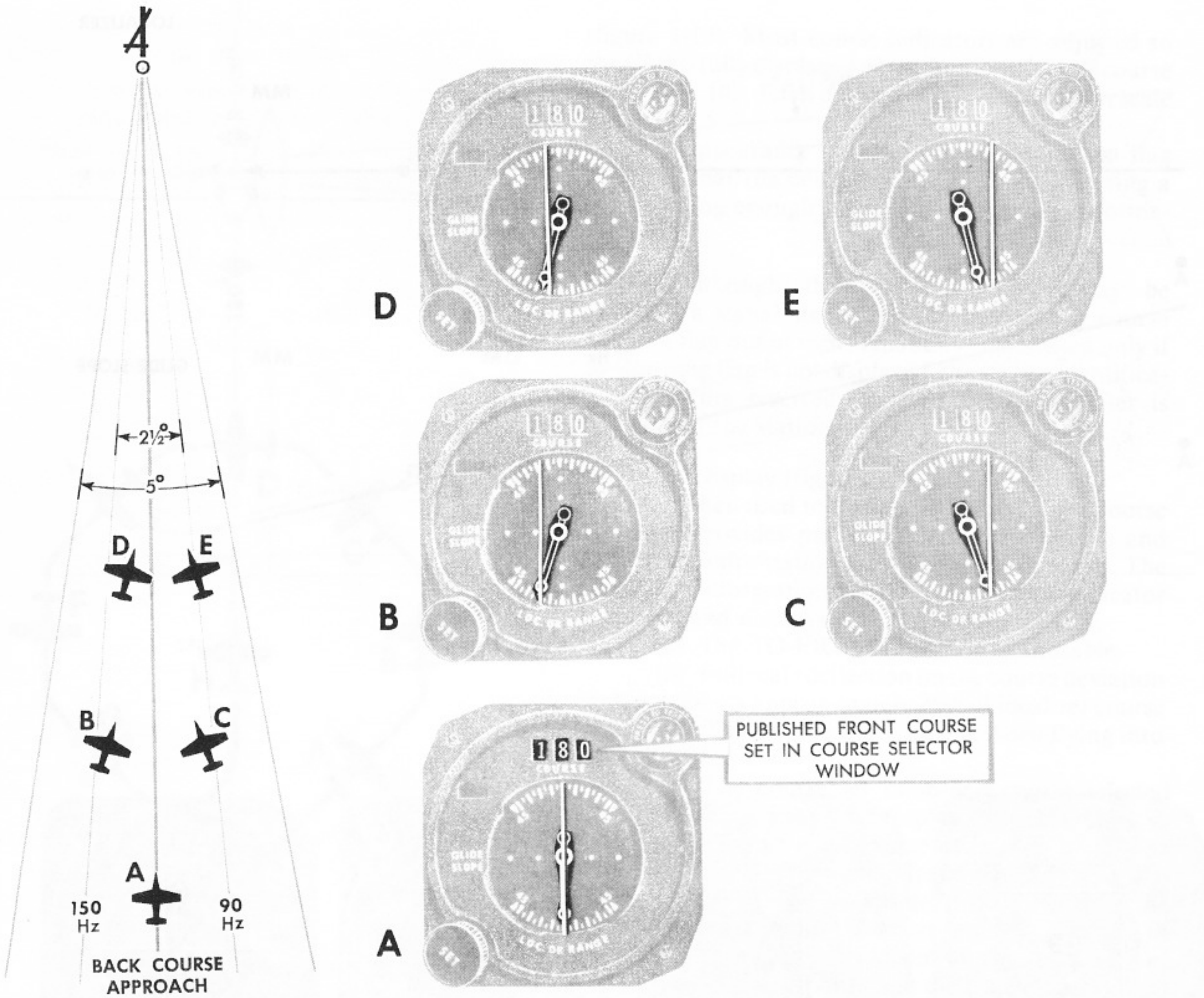


Figure 1-21. Localizer Course Indicator Presentations (Back Course) (para 1-23b).

window. The CDI is displaced with respect to the instrument case and is directional in relation to the *heading pointer*.)

(2) The glide slope indicator (GSI) displays glide slope position in relation to the aircraft. If the GSI is above center, the glide slope is above the aircraft and vice versa. Each dot on the glide slope deviation scale represents approximately 1/4° of deviation from the glide slope (figure 1-22).

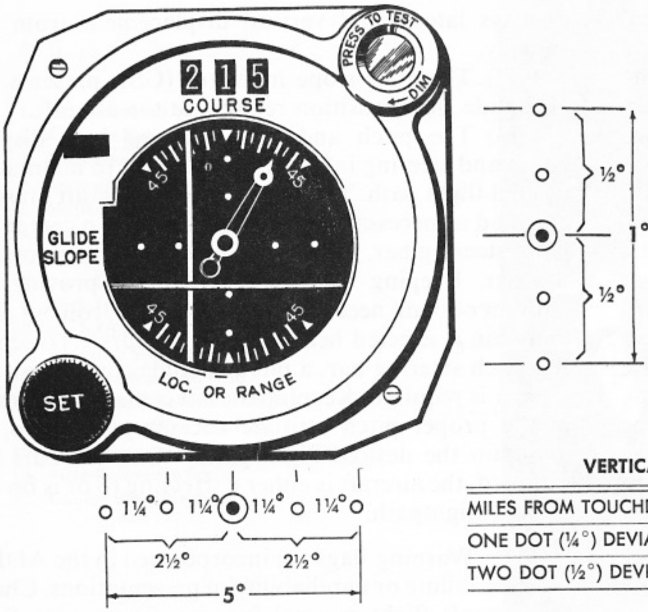
(3) Appearance of the course or glide slope warning flags indicates that the course or glide slope signal strength is not sufficient. Absence of the identifier indicates the signal is unreliable.

(4) The marker beacon light and aural tone indicates proximity to a 74-mHz marker beacon transmitter; for example, ILS outer marker (OM), middle marker (MM), Z marker, etc. As the aircraft flies through the marker beacon signal pattern, the light flashes and the aural tone sounds in Morse code indicating the type of beacon. The marker beacon light functions independently of ILS/VOR/TACAN signals.

1-24. Range Indicator (figure 1-23). Range indicators display slant range distance in nautical miles to a DME transponder. For practical purposes, you may consider this a horizontal distance except when the aircraft is very close to the station. DME range information is subject to line-of-sight restrictions and altitude directly affects the reception range.

1-25. Bearing-Distance-Heading Indictor (BDHI) (figure 1-23):

a. The BDHI displays aircraft heading with navigational bearing data and range information. Except for the range indicator, the BDHI is similar in appearance and function to the RMI previously described.



The GSI is more sensitive than the CDI.

1. Actual deviation figures may vary due to atmospheric conditions and transmitter-receiver errors.
2. Deviation figures do not take into consideration the distance an aircraft's main gear may be BELOW the location of its glide slope antenna.
3. Figures based on localizer width of 5°, runway length 8000', localizer transmitter 1000' from threshold.
4. Dot values shown in this illustration are valid for most aircraft. Consult your aircraft flight manual to ensure correct display interpretation.

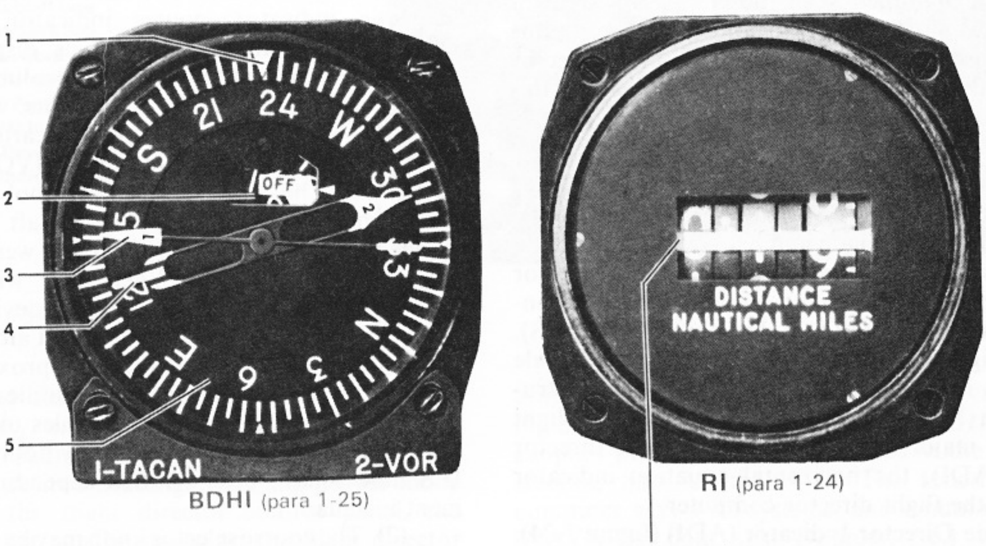
VERTICAL DEVIATION FROM GLIDE SLOPE

MILES FROM TOUCHDOWN	5	4	3	2	1
ONE DOT (¼°) DEVIATION	130'	104'	78'	52'	26'
TWO DOT (½°) DEVIATION	260'	208'	156'	104'	52'

LATERAL DEVIATION FROM LOCALIZER COURSE

MILES FROM TOUCHDOWN	5	4	3	2	1
ONE DOT (1¼°) DEVIATION	838'	706'	573'	441'	308'
TWO DOT (2½°) DEVIATION	1677'	1412'	1147'	882'	617'

Figure 1-22. Typical Course and Glide Slope Deviation Indications vs Actual Displacement Relative to Distance From Touchdown (para 1-23b (2)).



BDHI (para 1-25)

RI (para 1-24)

Range Warning Flag

1. Top Index
2. Range Indicator and Warning Flag
3. Bearing Pointer
4. Bearing Pointer
5. Rotating Compass Card

Figure 1-23. Range Indicator (RI) and Bearing Distance Heading Indicator (BDHI).

b. The BDHI consists of a rotating compass card, two bearing pointers, a range indicator, and a range warning flag. Some BDHIs also have a heading marker, a heading set knob, and a power warning flag.

c. The compass card is actuated by the aircraft compass system, which normally includes pilot-operated controls that permit the BDHI compass card to operate in a slaved or non-slaved direct gyro (DG) mode. In the slaved mode, the aircraft magnetic heading is displayed beneath the top index or lubber line. In the nonslaved DG mode, the compass card serves as a heading reference after being corrected to a known heading. The card is manually corrected for the DG mode by a switch on the compass control panel.

d. The heading marker, if incorporated, may be positioned on the compass card by use of the heading set knob. Once positioned, the marker remains fixed relative to the compass card. When the aircraft is on the selected heading, the heading marker is aligned beneath the upper lubber line.

e. The bearing pointers indicate the ADF, VOR, or TACAN magnetic bearing to the selected navigation station. Placards on the instrument or near a selector switch are used in most aircraft to identify the bearing pointer display.

NOTE: The bearing pointers do not function in relation to ILS signals.

f. If there is a malfunction in the compass system or compass card, an ADF bearing pointer continues to point to the station and displays relative bearing only.

g. With a malfunction in the compass system or compass card, TACAN/VOR pointers may continue to indicate proper magnetic bearings. Until verified by radar or other navigation equipment, consider this bearing information unreliable.

1-26. Flight Director. The flight director provides the pilot with displays of pitch and bank attitudes and the navigation situation of the aircraft. The flight director when combined with round dial performance instruments is termed the flight director system (FDS). When the flight director is combined with vertical scale instruments it is termed the integrated flight instrument system (IFIS). The three components of the flight director of major interest are the attitude director indicator (ADI), the horizontal situation indicator (HSI), and the flight director computer.

a. Attitude Director Indicator (ADI) (figure 1-24):

(1) The attitude director indicator consists of attitude indicator, turn and slip indicator, glide slope indicator, pitch and bank steering bars, attitude warning flag, glide slope warning flag, and course warning flag. Additional information displayed on some ADIs includes radar altitude information, approach speed deviation, and a runway symbol that displays lateral and vertical displacement from the runway.

(2) The glide slope indicator (GSI) presents the ILS glide slope position relative to the aircraft.

(3) The pitch and bank steering bars display command steering information to fly or to maintain a desired flight path. The attitude of the aircraft must be adjusted as necessary to center the bars. To center the bank steering bar, the aircraft must be banked toward the bar. Keeping the bar centered will provide the amount of bank necessary to roll in, turn, roll out, and maintain a selected heading or ILS course. To center the pitch steering bar, a pitch attitude change toward the bar is required. Keeping the bar centered will result in the proper pitch attitude necessary to fly to, or maintain the desired flight path. When the bars are centered, the aircraft is either correcting to or is on the desired flightpath.

NOTE: Warning flags are incorporated in the ADI to indicate failure or unreliability of presentations. Check the aircraft flight manual for specific warning flags applicable to your aircraft. In some ADIs, if power fails to the pitch and bank steering bars, no warning flags will appear, and the pitch and bank steering bars will center. Monitor the identifier to ensure that the signal is reliable. In most aircraft a warning flag appears when the signal strength is insufficient.

b. Horizontal Situation Indicator (HSI) (figure 1-23):

(1) The horizontal situation indicator is, in most respects, a combination of a heading indicator, radio magnetic indicator, course indicator, and range indicator. The aircraft heading is displayed on a rotating compass card under the upper lubber line. The card is calibrated in 5° increments. The bearing pointer(s) indicate the magnetic bearing from the aircraft to the selected ground station (VOR, TACAN, or ADF). The fixed aircraft symbol and course deviation indicator display the aircraft relative to a selected course as though the pilot were above the aircraft looking down. When used with VOR or TACAN, each dot on the course deviation scales indicates 5° of course deviation (most aircraft). When used with ILS, each dot indicates approximately 1¼° of localizer deviation. The range indicator displays slant range distance in nautical miles to the selected DME transponder and may or may not operate when ILS modes have been selected depending on equipment installation.

(2) The course selector knob may be used to select any of 360 courses. To select a desired course, rotate the head of the course arrow to the desired course on the compass card and check the course selector window for the precise setting. The TO-FROM indicator is a triangular-shaped pointer. When the indicator points to the head of the course arrow, it indicates that the course selected, if properly in-

ADI (para 1-26a)

1. Bank Steering Bar
2. Attitude Sphere
3. Pitch Steering Bar
4. Horizon Bar
5. Miniature Aircraft
6. Ground Perspective Lines
7. Bank Pointer
8. Bank Scale
9. Pitch Trim Index
10. Pitch Trim Knob
11. Turn and Slip Indicator
12. Attitude Warning Flag
13. Glide Slope Deviation Scale
14. Glide Slope Warning Flag
15. Glide Slope Indicator
16. Pitch Reference Scale
17. Course Warning Flag

HSI (para 1-26b)

18. Upper Lubber Line
19. Course Selector Window
20. Course Arrow (Head)
21. Course Deviation Indicator
22. Bearing Pointer (Tail)
23. Aircraft Symbol
24. Heading Marker
25. Course Set Knob
26. Lower Lubber Line
27. Heading Set Knob
28. Compass Card
29. Course Arrow (Tail)
30. Bearing Pointer
31. TO-FROM Indicator
32. Course Deviation Scale
33. Range Indicator and Warning Flag

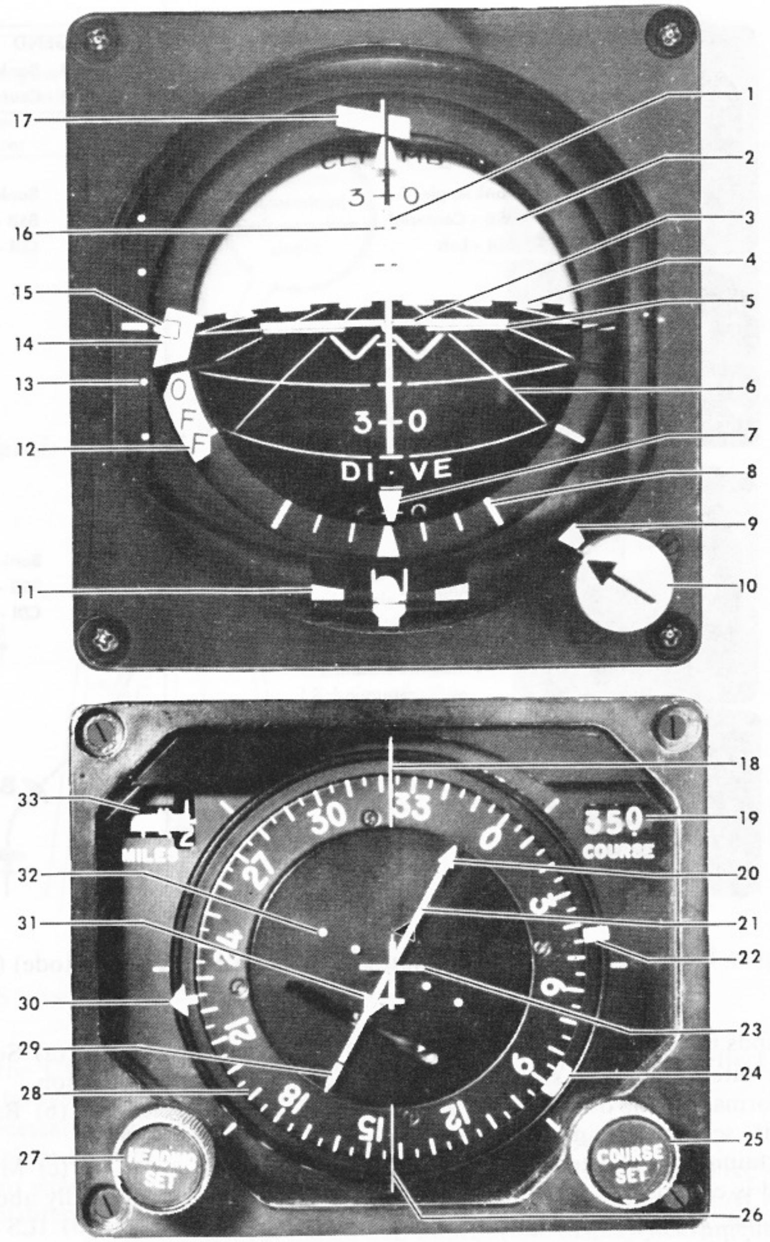


Figure 1-24. Typical Flight Director.

tercepted and flown, will take the aircraft to the selected facility, and vice versa.

(3) The heading set knob is used to set the heading marker to a desired heading. With the proper mode selected on the flight director control panel, the heading marker can be slaved to the flight director computer. Thus, when a heading is set, the bank steering bar will command the bank attitude required to turn to and maintain the selected heading.

c. Flight Director Computer:

(1) The flight director computer receives navigation information from the navigation systems, and attitude information from the attitude gyro. Depending on the modes available and selected, the computer supplies pitch or bank commands to the pitch/bank steering bars of the ADI. The functions of the computer vary with systems, and a number of inputs (NAVAIDs, data link, Doppler, etc.) may be electronically processed by the system.

(2) In some flight director systems the bank steering bar can be used for other maneuvers such as intercepting VOR, TACAN, and Doppler courses or performing data link intercepts. Pitch steering bar information can vary from terrain avoidance com-

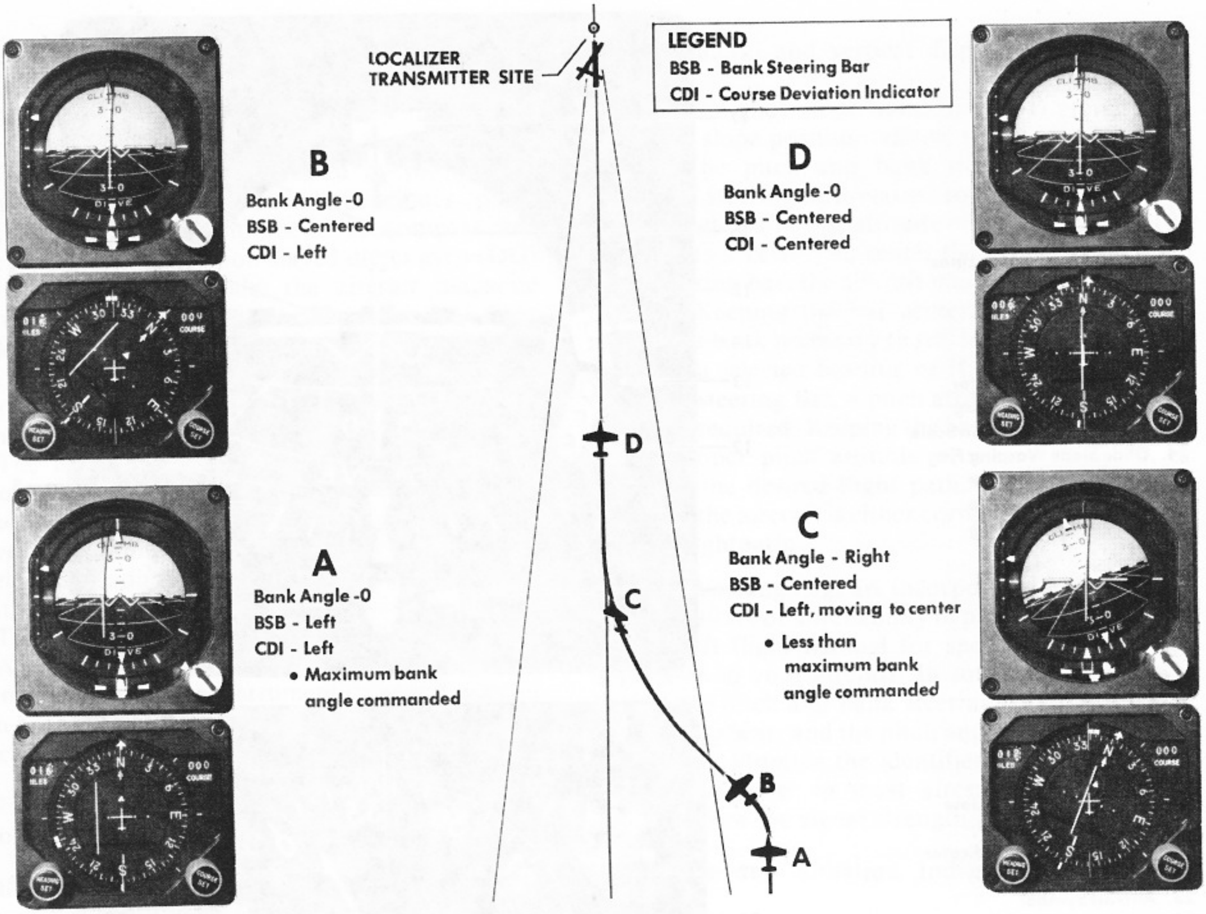


Figure 1-25. Flight Director Computer Inputs (ILS Intercept Mode) (para 1-26d(2)).

mands to commanding a selected altitude. In all cases the pitch and bank steering bars display command information and do not reflect actual aircraft position. This section is limited to command information pertaining to selected headings and ILS approaches and is common to most flight director systems. Refer to the appropriate flight manual for the specific capabilities of the system installed in your aircraft.

d. Flight Director Modes:

(1) Heading Mode. The heading mode selector usually has two positions: MANUAL and NORMAL. The MANUAL position is used to command the aircraft to a selected heading. The NORMAL position allows the automatic features of the flight director system to function as designed for each navigation mode that is selected and provides bank or bank and pitch steering commands to position the aircraft.

(2) ILS Intercept Mode (figure 1-25). This mode is designed to direct the aircraft to, place it upon, and maintain it on the localizer course. This is accomplished by positioning the bank steering bar to command the pilot to fly flight director computed headings.

(a) Some computers supply wind drift compensation.

(b) Bank angle commanded is usually 25° to 35°.

(c) Maximum intercept angle commanded is normally about 45°.

(3) ILS Final Approach Mode (figure 1-26). This mode is designed to maintain the aircraft on the localizer course, place it upon, and maintain it on the glide slope. This is accomplished by positioning the pitch and bank steering bars to command the pilot to fly flight director computed headings and pitch attitudes.

(a) Wind drift compensation is provided to maintain the aircraft on the final approach course.

(b) Bank angle commanded is a maximum of 15°.

(c) Maximum pitch attitude commanded is 10° to 17°.

e. ILS Display. As in the CI, the course set knob and course selected have no effect on the CDI display. The CDI displays only if the aircraft is on course or in a 90- or 150-Hz zone of signals originating from the ILS

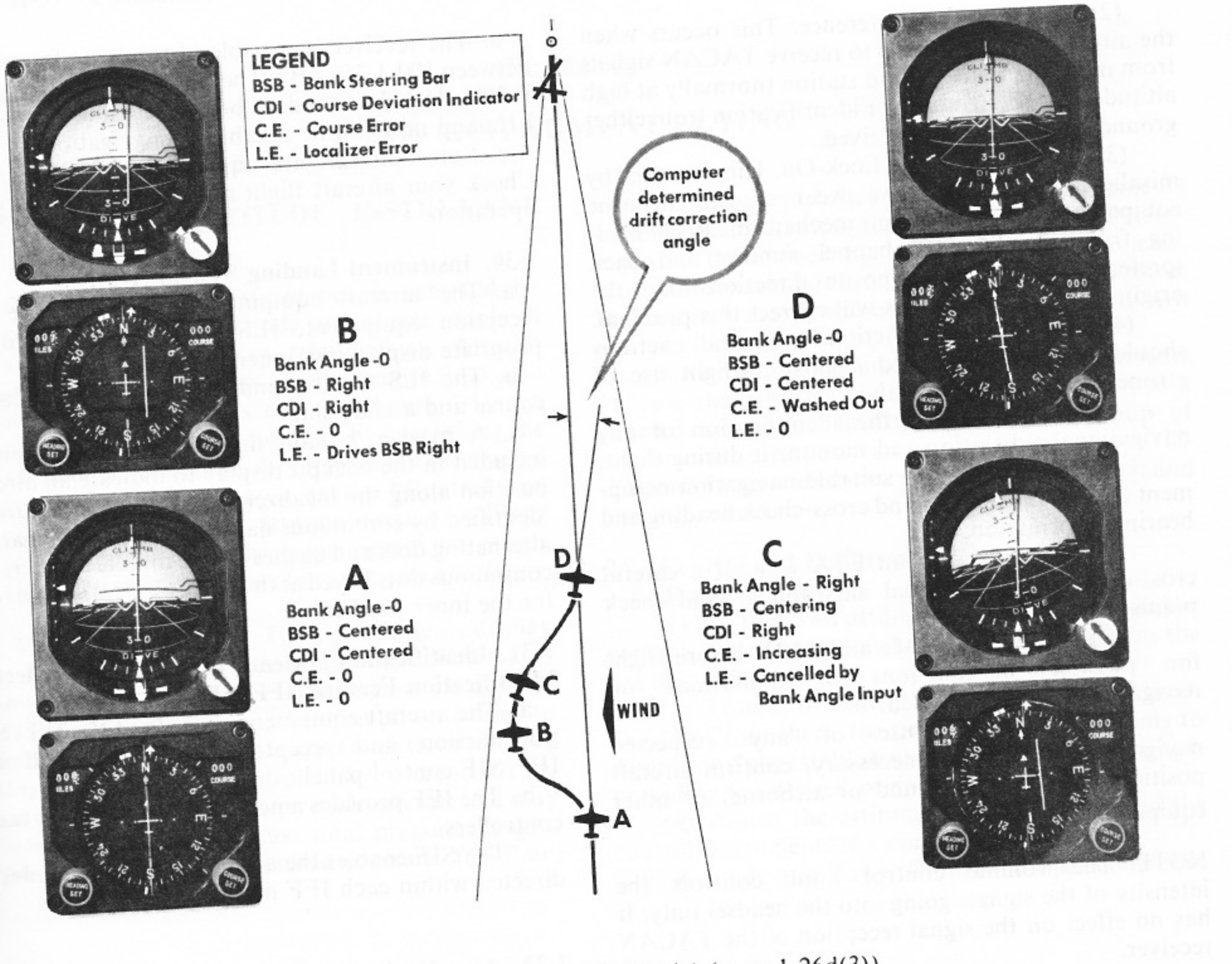


Figure 1-26. Flight Director Inputs (ILS Final Approach Mode) (para 1-26d(3)).

localizer transmitter. When on course the CDI will center regardless of the course selected; however, the CDI and course arrow will not necessarily be directional to the aircraft symbol. Set the published localizer front course in the course selector window in order to have the CDI and aircraft symbol directional.

SECTION F — NAVIGATION EQUIPMENT

1-27. VHF Omnidirectional Range (VOR):

a. The aircraft equipment consists of the VOR reception equipment, VOR control panel, and appropriate display instruments.

b. As a general rule the frequency band is divided as follows:

VOR . . . . 108.0—117.95 mHz
Communications . . 118.0—135.95 mHz

c. Since a large portion of the frequencies available on the VOR control panel may overlap the VHF communication frequency band, you may use the VOR receiver as the VHF communication receiver. (The volume control knob controls the intensity of the signals going into the headset only. It has no effect on the signal reception of the VOR receiver.)

1-28. Tactical Air Navigation (TACAN):

a. The aircraft equipment consists of the TACAN transmission and reception equipment, TACAN control panel, and appropriate display instruments.

b. TACAN operates in the UHF band. The TACAN system presently has a total of 126 two-way channels with provisions being developed for an additional 126 channels.

c. Several forms of TACAN equipment malfunctions or interference between ground stations can give false or erroneous TACAN information to navigation display equipment.

(1) Forty-degree Azimuth Error Lock-On. Due to the nature of the TACAN signal it is possible for the TACAN azimuth to lock on in multiples of 40° from the true bearing with no warning flag appearing. The pilot should cross-check other navigational aids (if available) to verify TACAN azimuth. Rechanneling the airborne receiver to deliberately cause unlock may correct the problem.

(2) Co-Channel Interference. This occurs when the aircraft is in a position to receive TACAN signals from more than one ground station (normally at high altitude). DME, azimuth, or identification from either ground station may be received.

(3) False or Incorrect Lock-On. This is caused by misalignment or excessive wear of the airborne equipment channel selection mechanism. Rechanneling from the selected channel number and back (preferably from the opposite direction than the original setting) sometimes will correct this problem.

(4) Precautionary Actions. Several actions should be taken to guard against in-flight use of erroneous navigation signals.

(a) Always check the identification of any navigational aid station and monitor it during flight.

(b) Always use all suitable navigation equipment aboard the aircraft and cross-check heading and bearing information.

(c) Never overfly an ETA without a careful cross-check of navigational aids and ground check points.

(d) Check NOTAMs and FLIP before flight for possible malfunctions or limitations on navigational aids to be used.

(e) Discontinue use of any suspected navigational aid and, if necessary, confirm aircraft position with radar (ground or airborne) or other equipment.

NOTE: The volume control knob controls the intensity of the signals going into the headset only. It has no effect on the signal reception of the TACAN receiver.

1-29. Automatic Direction Finding (ADF):

a. The aircraft equipment consists of the ADF equipment required to receive a nondirectional beacon (NDB), ADF control panel, and appropriate display instruments.

b. The receiver is capable of receiving frequencies between 100-1,750 kHz. The range used for navigation is 200-415 kHz. Standard broadcast band is 540-1,600 kHz and may not be reliable for navigation.

c. Some aircraft are equipped with UHF/ADF. Check your aircraft flight manual for capability and operation.

1-30. Instrument Landing System (ILS):

a. The aircraft equipment consists of the ILS reception equipment, ILS control panel, and appropriate display instruments.

b. The ILS receives and displays both a localizer course and a glide slope.

c. A marker beacon light and/or aural tone is included in the cockpit display to indicate an aircraft position along the localizer. The marker beacons are identified by continuous dashes for the outer marker, alternating dots and dashes for the middle marker, and continuous dots keyed at the rate of six dots per second for the inner marker.

1-31. Identification Friend or Foe and Selective Identification Feature (IFF/SIF):

a. The aircraft equipment consists of the IFF/SIF transmission and reception equipment and the IFF/SIF control panel.

b. The IFF provides a positive radar return to radar controllers.

c. The SIF enables the aircraft to transmit codes as directed within each IFF mode.

1-32. Area Navigation (RNAV). Equipment for area navigation may include Doppler radar, inertial, pictorial display or course line computers, or any other techniques or device that will ensure compatibility with the operational procedures and route widths prescribed. Also included are the associated control panels and appropriate display instruments.

Chapter 2

BASIC INSTRUMENT FLYING

SECTION A — ATTITUDE INSTRUMENT FLYING

2-1. General. Aircraft performance is achieved by controlling the aircraft attitude and power (angle of attack and thrust or drag relationship). Aircraft attitude is the relationship of the longitudinal and lateral axes to the earth's horizon (figure 2-1). An aircraft is flown in instrument flight by controlling the attitude and power as necessary to produce the desired performance. This is known as the "Control and Performance Concept" of attitude instrument flying and can be applied to any basic instrument maneuver. The three general categories of instruments are (figure 2-2):

a. Control Instruments. These instruments display attitude and power indications and are calibrated to permit attitude and power adjustments in definite amounts. In this discussion, the term power is used to replace the more technically correct term thrust or drag relationship. Power is controlled by reference to the power indicator(s). These vary with aircraft and may include tachometers, exhaust total pressure gauges, exhaust pressure ratio, manifold pressure, fuel flow, etc.

b. Performance Instruments. These instruments indicate the aircraft's actual performance. Performance is determined by reference to the altimeter, airspeed or mach indicator, vertical velocity indicator, heading indicator, angle of attack indicator, and turn and slip indicator.

c. Navigation Instruments. These instruments indicate the position of the aircraft in relation to a selected navigation facility or fix. This group of instruments includes various types of course indicators, range indicators, glide slope indicators, and bearing pointers.

2-2. Control and Performance Concept:

a. Procedural Steps:

(1) Establish an attitude or power setting on the control instrument(s) which should result in the desired performance.

(2) Trim until control pressures are neutralized.

(3) Cross-check the performance instruments to determine if the established attitude or power setting is providing the desired performance.

(4) Adjust the attitude or power setting on the control instruments if a correction is necessary.

b. Attitude and Power Control. Proper control of

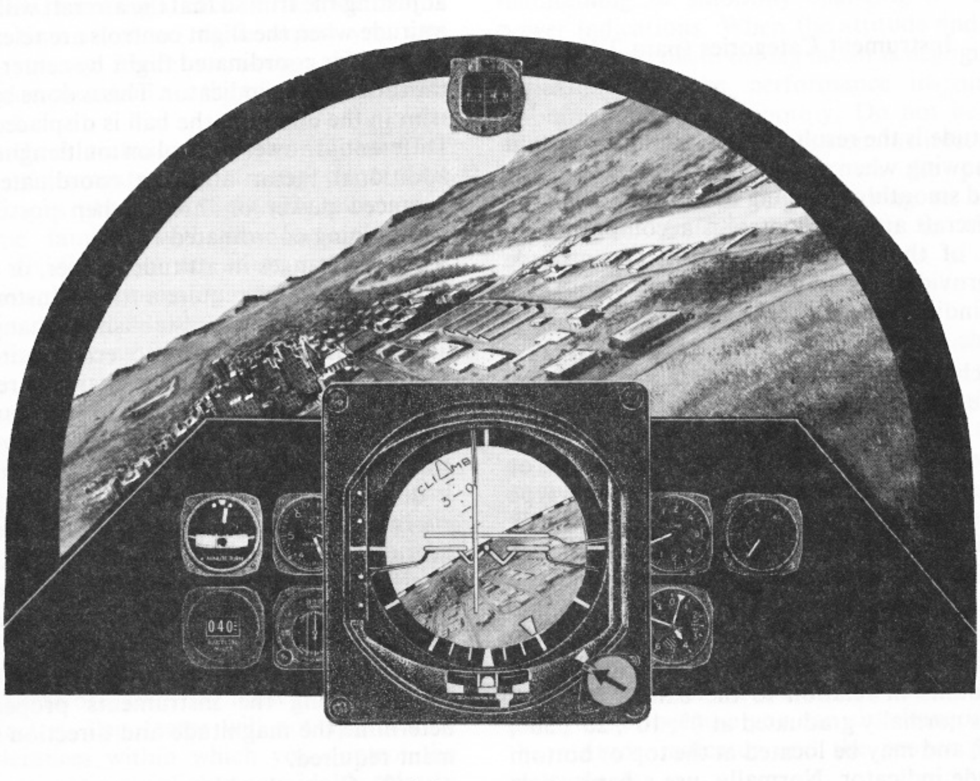


Figure 2-1. Attitude Instrument Flying (para 2-1).

	Control	Performance	Navigation
Power Indicators	●		
Attitude Indicators	●		
Angle of Attack Indicators		●	
Airspeed/Mach Indicators		●	
Altimeters		●	
Turn and Slip Indicators		●	
Vertical Velocity Indicators		●	
Horizontal Situation Indicators		●	●
Radio Magnetic Indicators		●	●
Bearing Distance Heading Indicators		●	●
Course Indicators			●
Range Indicators			●

Figure 2-2. Instrument Categories (para 2-1).

aircraft attitude is the result of maintaining a constant attitude, knowing when and how much to change the attitude, and smoothly changing the attitude a definite amount. Aircraft attitude control is accomplished by proper use of the attitude indicator. The attitude indicator provides an immediate, direct, and corresponding indication of any change in aircraft pitch or bank attitude.

(1) Pitch Control. Pitch changes are made by changing the "pitch attitude" of the miniature aircraft or fuselage dot definite amounts in relation to the horizon. These changes are referred to as bar widths or fractions thereof, or degrees depending upon the type of attitude indicator. A bar width is approximately 2° on most attitude indicators. The amount of deviation from the desired performance will determine the magnitude of the correction.

(2) Bank Control. Bank changes are made by changing the "bank attitude" or bank pointer(s) definite amounts in relation to the bank scale. The bank scale is normally graduated at 0°, 10°, 20°, 30°, 60°, and 90° and may be located at the top or bottom of the attitude indicator. Normally, use a bank angle which approximates the degrees to turn, not to exceed 30°.

(3) Power Control:

(a) Proper power control results from the ability to smoothly establish or maintain desired airspeeds in coordination with attitude changes. Power changes are made by throttle adjustments and reference to the power indicators. Power indicators are not affected by such factors as turbulence, improper trim, or inadvertent control pressures. Therefore, little attention is required to ensure that the power setting remains constant.

(b) From experience in an aircraft, you know approximately how far to move the throttle(s) to change the power a given amount. Therefore, you can make power changes primarily by throttle movement and then cross-check the indicators to establish a more precise setting. The key is to avoid overfixation on the indicators while setting the power. A knowledge of power settings for various flight conditions will help prevent overcontrolling power.

c. Trim Technique:

(1) Proper trim technique is essential for smooth and precise aircraft control during all phases of flight. By relieving all control pressures, you will find that it is much easier to hold a given attitude constant. Also, more attention can be devoted to the navigation instruments and additional cockpit duties.

(2) An aircraft is trimmed by applying control pressure(s) to establish a desired attitude and then adjusting the trim so that the aircraft will maintain that attitude when the flight controls are released. Trim the aircraft for coordinated flight by centering the ball of the turn and slip indicator. This is done by using rudder trim in the direction the ball is displaced from center. Differential power control on multiengine aircraft is an additional factor affecting coordinated flight. Use balanced power or thrust, when possible, to aid in maintaining coordinated flight.

(3) Changes in attitude, power, or configuration will in most cases require a trim adjustment. Independent use of trim to establish a change in aircraft attitude invariably leads to erratic aircraft control. Smooth and precise attitude changes are best attained by a combination of control pressures and trim adjustments. Trim adjustment, correctly used, is an aid to smooth aircraft control.

d. Cross-Check Technique (figure 2-3):

(1) The control and performance concept of attitude instrument flying requires you to establish an aircraft attitude or power setting on the control instrument which should result in the desired aircraft performance. Therefore, you must be able to recognize when a change in attitude or power is required. By cross-checking the instruments properly, you can determine the magnitude and direction of the adjustment required.

(2) Cross-checking is a proper division of

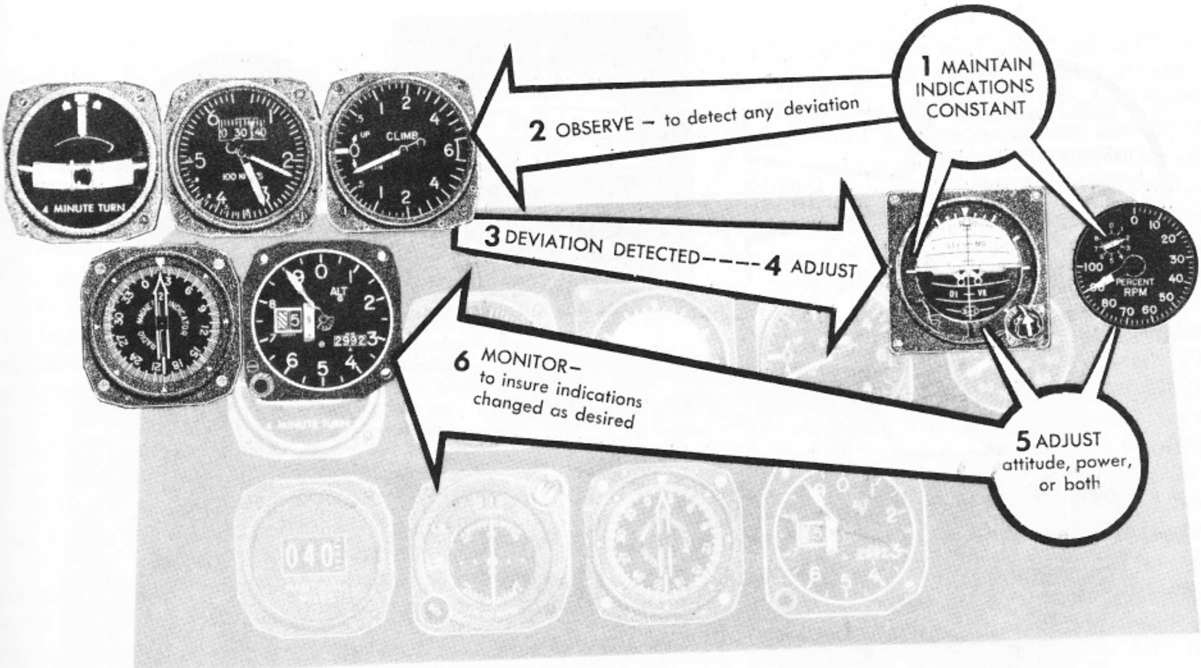


Figure 2-3. Instrument Cross-Check Technique (para 2-2d).

attention and the interpretation of the flight instruments. Attention must be efficiently divided between the control and performance instruments in a sequence that ensures comprehensive coverage of the flight instruments. Looking at each of the instruments at the proper time is of no value unless you can interpret what you see. Therefore, proper division of attention and interpretation are the two essential parts of a cross-check.

(3) Cross-check techniques or the sequence for checking the instruments vary among pilots and throughout various phases of flight. Therefore, you should become familiar with the factors to be considered in dividing your attention properly; and you should know the symptoms which will help you to recognize an incorrect cross-check technique.

e. Factors Influencing Instrument Cross-Checks (figure 2-4):

(1) Instruments Response to Attitude or Power Changes. A factor influencing cross-check technique is the characteristic manner in which instruments respond to changes of attitude or power. The control instruments provide direct and immediate indications of attitude or power changes. Changes in the indications on the performance instruments will lag slightly behind changes of attitude or power. This lag is due to inertia of the aircraft and the operating principles and mechanisms of the performance instruments. Therefore, some lag must be accepted as an inherent factor. This factor will not appreciably affect the tolerances within which you control the aircraft; however, at times a slight unavoidable delay in knowing the results of attitude or power changes will occur.

(2) Lag in Performance Instruments. Lag in the performance instruments should not interfere with maintaining or smoothly changing the attitude or power indications. When the attitude and power are properly controlled, the lag factor is negligible and the indications on the performance instruments will stabilize or change smoothly. Do not be lured into making a flight control movement in direct response to the lag in the indications on the performance instruments without first referring to the control instruments. Sufficient reference to the control instruments will minimize the effect of lag on the performance instruments and nullify the tendency to "chase" the indications.

(3) Location of Flight Instruments. Another factor influencing cross-check technique is the location of the flight instruments. In some aircraft the flight instruments are scattered over a wide area of the instrument panel, making it difficult to bring several instruments into your cross-check at the same time. Therefore, you must rapidly scan each instrument individually back and forth across the instrument panel. More advanced instrument systems, such as the flight director and integrated flight instrument systems, have reduced the required scan to a small area so you can see more of the flight instruments with one look. The task of cross-checking these instruments is much easier because you can simultaneously observe the attitude indicator and the proper performance instruments.

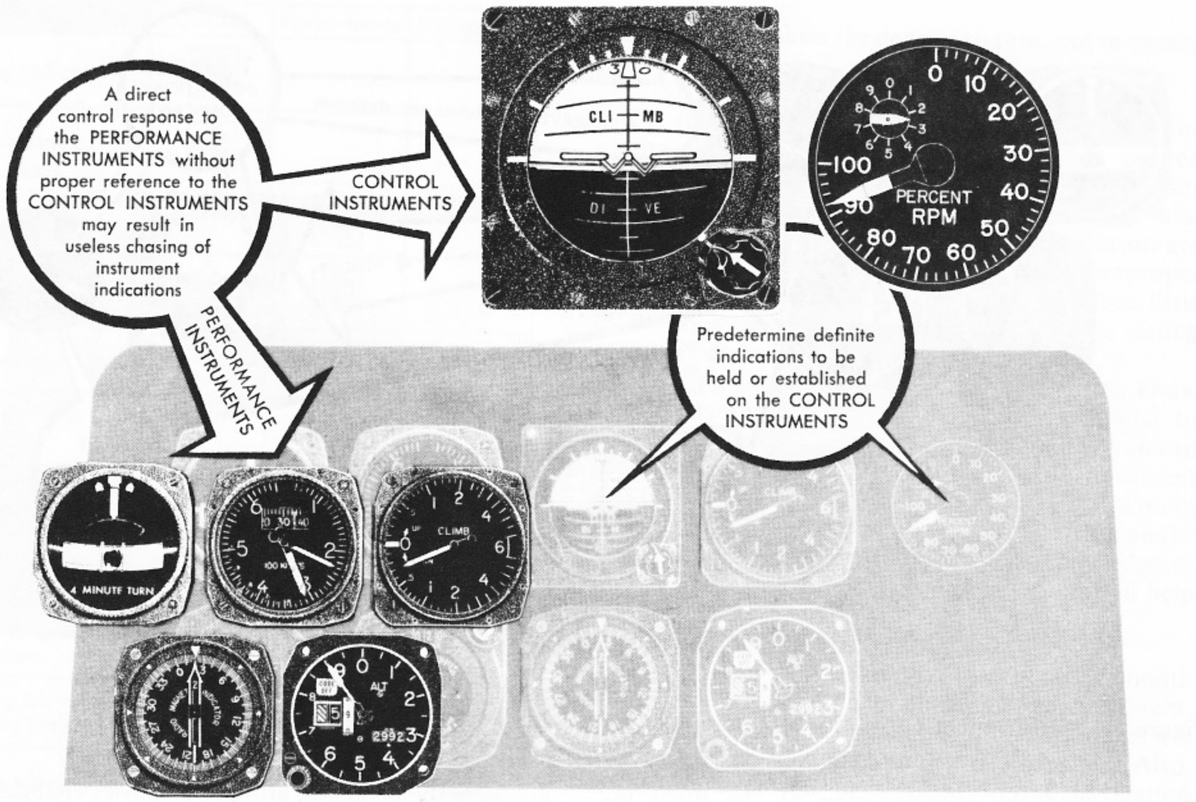


Figure 2-4. Factors Influencing Cross-Check Techniques (para 2-2e).

(4) Pilot's Ability. An important factor influencing cross-check technique is the ability of the pilot. All pilots do not interpret instrument presentations with the same speed; some are faster than others in understanding and evaluating what they see. One reason for this is that the natural ability of pilots varies. Another reason is that the experience levels are different. Pilots who are experienced and fly regularly will probably interpret their instruments more quickly than inexperienced pilots. Pilots who interpret their instruments quickly and correctly do not have to refer back to them for information as often as pilots who are slow to interpret. They are also able to bring several instruments into their cross-check with one glance, interpreting them simultaneously. Therefore, the speed with which they divide their attention does not have to be as rapid as the pilot's with less ability, who must scan the instruments rapidly to stay ahead of the aircraft.

(5) Observing Attitude Indicator. The attitude indicator is the only instrument which you should observe continuously for any appreciable length of time. Up to 10 seconds may be needed to accomplish an attitude change required for a normal turn. During this 10-second period, you may need to devote your attention almost exclusively to the attitude indicator to ensure good attitude control. The attitude indicator is the instrument that you should check the greatest number of times. This is shown by the following description of a normal cross-check. A pilot glances from the attitude indicator to a performance instrument; back to the attitude indicator; then a glance at another performance instrument; back to the attitude indicator, and so forth. This cross-check technique can be compared to a wagon wheel. The hub represents the attitude indicator and the spokes represent the performance instruments.

(a) The above example of a normal cross-check does not mean that it is the only method of cross-checking. Often you must compare the indications of one performance instrument against another before knowing when or how much to adjust the attitude or power. An effective cross-check technique may be one in which attention to the attitude indicator is inserted between glances at the performance instruments being compared. Devoting more attention to the attitude indicator is more desirable to minimize the effects of the fluctuations and lag indications of the performance instruments. This technique permits you to read any one performance instrument during a split-second glance and results in smooth and precise aircraft control.

(b) A proper and relative amount of attention must be given to *each* performance instrument. Pilots seldom fail to observe the one performance instrument whose indication is most important. The reverse is a common error because pilots often devote so much attention to one performance instrument that the others are omitted from the cross-check. Additionally, they often fail to cross-check the attitude indicator for proper aircraft control.

f. Cross-Check Analysis:

(1) An incorrect cross-check can be recognized by analyzing certain symptoms of aircraft control. Insufficient reference to the control instruments is readily recognizable. If you do not have some definite attitude and power indications in mind and the other instruments fluctuate erratically through the desired indications, then you are not referring sufficiently to the control instruments. Imprecise aircraft control usually results in "chasing" the indications.

(2) The problem of too much attention being devoted to the control instruments is rarely encountered, except for fixation on the power indicators. This is normally caused by your desire to maintain the performance indications within close tolerances. Too much attention to the control instruments can be recognized by the following symptoms. If you have a smooth, positive, and continuous control over the indications of the control instruments, a closer cross-check of the performance instruments is required.

(3) An incorrect cross-check can result in the omission of or insufficient reference to one or more instruments during the scanning process. You may omit some performance instrument(s) from the cross-check, although other performance instruments and the control instruments are being properly observed. For example, during a climb or descent, you may become so engrossed with pitch attitude control that you fail to observe an error in aircraft heading.

(4) The indications on some instruments are not as "eye-catching" as those on other instruments. For example, a 4° heading change is not as "eye-catching" as a 300 to 400 feet-per-minute change on the vertical velocity indicator. Through deliberate effort and proper habit, ensure that all the instruments are included in your cross-check. If this is accomplished, you will observe deviations on the performance instruments in their early stages.

(5) Analyzing the cross-check technique will assist you in improving an incorrect cross-check. A correct cross-check results in the continuous interpretation of the flight instruments which enables you to maintain proper aircraft control at all times. Remember, rapidly looking from one instrument to another without interpretation is of no value. Instrument systems and the location of the flight instruments vary. Pilot ability also varies. Therefore, you should develop your own rate and sequence of checking the instruments which will ensure a timely and correct interpretation of the flight instruments.

g. Adjusting Attitude and Power. As previously stated, the control and performance concept of attitude instrument flying requires the adjustment of aircraft attitude and power to achieve the desired performance. A change of aircraft attitude or power is required when any indication other than that desired is observed on the performance instruments. However, it is equally important for you to know what to change and how much pitch, bank, or power change is required.

(1) What To Change. Pitch attitude primarily controls altitude and the rate of climb or descent. Pitch attitude control may also be used to maintain airspeed during maneuvers requiring a fixed power setting. Bank attitude control is used to maintain a heading or a desired angle of bank during turns. Power controls airspeed except for maneuvers using a fixed power setting; for example, full power for a prolonged climb. (FOR HELICOPTER PILOTS ONLY: Power is used primarily to maintain an altitude or to control the rate of climb or descent. Pitch attitude control is used primarily for maintaining or changing the airspeed.)

(2) How Much To Change. How much to adjust the attitude or power is, initially, an estimate based on familiarity with the aircraft and the amount you desire to change on the performance instruments. After you make a change of attitude or power, observe the performance instruments to see if the desired change occurred. If not, further adjustment of attitude or power is required. Remember, even though changes are estimates, they must be made in exact increments.

SECTION B — INSTRUMENT FLIGHT MANEUVERS FOR FIXED WING AIRCRAFT.

2-3. General:

a. The maneuvers described in this section are those most commonly used during instrument flight (figure 2-5). Additional maneuvers or some modification of these maneuvers may be required for specific training requirements. The degree of proficiency attained in accomplishing these maneuvers will determine the ease by which you can adapt to actual instrument flight.

b. An instrument flight, regardless of its length or complexity, is a series of connected basic instrument flight maneuvers. Failure to consider each portion of the flight as a basic instrument maneuver often leads to erratic aircraft control.

2-4. Planning. The information received from the navigation instruments or an air traffic controller should be considered as advising you what maneuver to perform, when to perform it, or what adjustments, if any, are required. Instrument approach procedure charts and similar publications should be considered as pictorial presentations of a series of connected instrument flight maneuvers. Keeping these considerations in mind and calling upon previous practice,

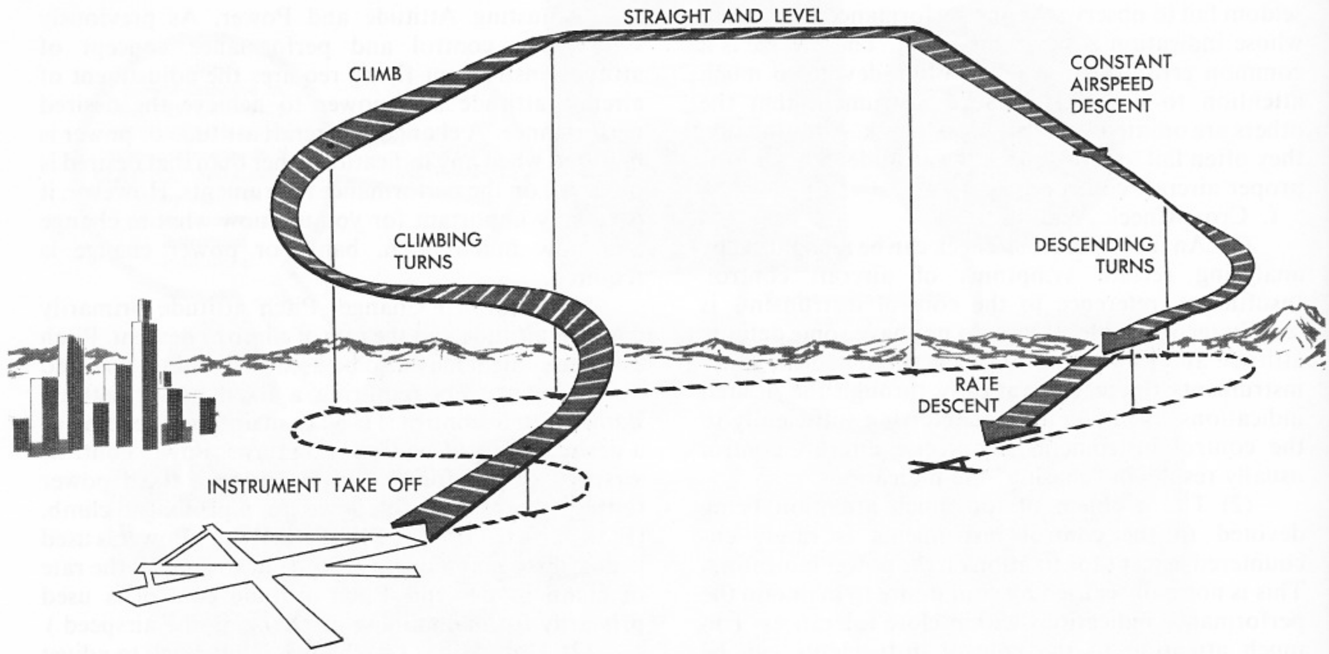


Figure 2-5. Typical Instrument Flight (para 2-3a).

you will find that you are always performing a familiar maneuver. By visualizing the next maneuver, you can plan ahead and know exactly what cross-check and aircraft control techniques to employ at the time of entry into the maneuver.

2-5. Individual Maneuvers:

a. Straight and Level Flight. Straight and level unaccelerated flight consists of maintaining desired altitude, heading, and airspeed. Use pitch attitude control to maintain or adjust the altitude. Use bank attitude control to maintain or adjust the heading. Use power control to maintain or adjust the airspeed.

(1) Maintaining a Desired Altitude:

(a) Maintaining a desired altitude requires the ability to maintain a specific pitch attitude and, when necessary, to smoothly and precisely adjust this attitude. This ability is developed through proper use of the attitude indicator and is simplified by good trim techniques.

(b) After leveling off at cruise airspeed, you may adjust the pitch trim knob on the attitude indicator so that the miniature aircraft is aligned with the horizon bar. This will aid in detecting small pitch changes. Subsequent readjustments may be required because of changes in aircraft gross weight and cruise airspeeds.

(c) The small pitch corrections required to maintain a desired altitude are made in fractions of a bar width or in degrees. You should become familiar with the vertical velocity changes which result when specific pitch adjustments are made at various airspeeds and configurations. Thus, you can determine what pitch attitude adjustment is required to produce the desired rate of correction when an altitude deviation is observed.

(d) A technique for predetermining the vertical velocity for a given pitch change depends upon TAS or mach number. One degree (normally 1/2 bar width) of pitch change will result in an approximate vertical velocity that is equivalent to miles per minute times 100. For example, at 300 KTAS or 5 NM per minute x 100, 1° of pitch change will result in approximately 500 fpm vertical velocity change. At 360 KTAS or 6 NM per minute x 100, 2° of pitch change will result in approximately 1200 fpm vertical velocity change. The mach indicator may be used in the same manner since .5 mach is approximately 5 miles per minute; .6 mach is 6 miles per minute; etc.

(e) When you make these pitch adjustments, the altimeter and vertical velocity indications will lag behind changes of pitch attitude on the attitude indicator. This lag should be recognized and accepted as an inherent error in pressure instruments. The error is even more pronounced at supersonic airspeeds. Because of this error, maintain the adjusted pitch attitude on the attitude indicator while waiting for changes on the altimeter and vertical velocity to occur. Do not make a snap decision that the adjusted pitch change is ineffective and be lured into overcontrolling the pitch attitude.

(f) With experience, you can usually estimate the suitability of a pitch adjustment by noting the initial rate of movement of the vertical velocity indicator. For example, assume a pitch adjustment has been made which is expected to result in 200 to 300 fpm rate of climb. If the initial rate of movement on the vertical velocity indicator is rapid and obviously will stabilize at a rate greater than desired, the pitch change was too large. Readjust the pitch attitude rather than wait for a stabilized indication on the vertical velocity indicator.

(g) When an aircraft first departs an altitude, an indication often appears on the vertical velocity indicator before one appears on the altimeter. By evaluating this initial rate of movement, you can estimate the amount of pitch change required on the attitude indicator and prevent large altitude deviations. If the estimated pitch change was correct, the vertical velocity will return to zero with a negligible change of altitude on the altimeter.

(h) When a deviation from the desired altitude occurs, exercise good judgment in determining a rate of correction. The correction must not be too large and cause the aircraft to "overshoot" the desired altitude, nor should it be so small that it is unnecessarily prolonged. As a guide, the pitch attitude change on the attitude indicator should produce a rate of vertical velocity approximately twice the size of the altitude deviation. For example, if the aircraft is 100 feet off the desired altitude, a 200 fpm rate of correction would be a suitable amount. Adjust the pitch an estimated amount to achieve this rate of correction. This estimated pitch change may require further adjustment after a stabilized vertical velocity is obtained.

(i) When approaching the desired altitude, determine a lead point on the altimeter for initiating a leveloff pitch attitude change. A suitable lead point prevents "overshooting" and permits a smooth transition to level flight. The amount of lead required varies with pilot technique and rate of correction. As a guide, the lead point on the altimeter should be approximately 10 percent of the vertical velocity. For example, if the rate of correction to the desired altitude

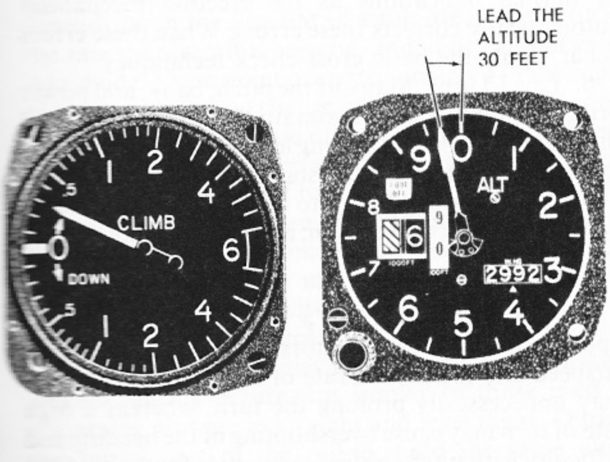


Figure 2-6. Leading the Leveloff (para 2-5a(1)(i)).

is 300 fpm, initiate the leveloff approximately 30 feet before reaching the desired altitude (figure 2-6).

(2) Maintaining a Desired Heading:

(a) Maintaining a desired heading is accomplished by maintaining a zero bank attitude in coordinated flight. Heading deviations are not normally as "eye-catching" as altitude deviations. Therefore, be aware of this characteristic and develop a habit of cross-checking the heading deviations. This is especially helpful if there are slight precession errors in the attitude indicator.

(b) When a deviation from the desired heading occurs, refer to the attitude indicator and smoothly establish a definite angle of bank which will produce a suitable rate of return. As a guide, the bank attitude change on the attitude indicator should equal the heading deviation in degrees not to exceed 30°. (For example, if the heading deviation is 10°, then 10° of bank would produce a suitable rate of correction.) This guide is particularly helpful during instrument approaches at relatively slow airspeeds. At higher true airspeeds, a larger angle of bank may be required to prevent a prolonged correciton. A correction to a heading deviation of 2° to 5° may be accomplished by application of rudder.

(3) Establishing and Maintaining Airspeed:

(a) Establishing or maintaining an airspeed is accomplished by referring to the airspeed or mach indicator and adjusting the power or aircraft attitude. A knowledge of the approximate power required to establish a desired airspeed will aid in making power adjustments. After the approximate power setting is established, a cross-check of the airspeed indicator will indicate if subsequent power adjustments are required. Make it a point to learn and remember the approximate power settings for the aircraft at various airspeeds and configurations used throughout a normal mission. Avoid overfixation on power indicators when setting the power.

(b) When an airspeed deviation is observed, make a power or pitch adjustment or a combination of both to correct back to the desired airspeed. For example, if below the desired altitude with a higher than desired airspeed, a proper pitch adjustment may regain both the desired airspeed and altitude. Conversely, a pitch adjustment if made when at the desired airspeed will induce the need for a power adjustment. This is more noticeable at slow airspeeds, particularly in jet aircraft.

(c) Changes of airspeed in straight and level flight are accomplished by adjusting the power or drag devices. To increase the airspeed, advance the power beyond the setting required to maintain the new airspeed (figure 2-7). As the airspeed increases, the aircraft gains lift and will have a tendency to climb. Adjust the pitch attitude as required to maintain altitude. When the airspeed approaches the desired indication, reduce the power to an estimated setting

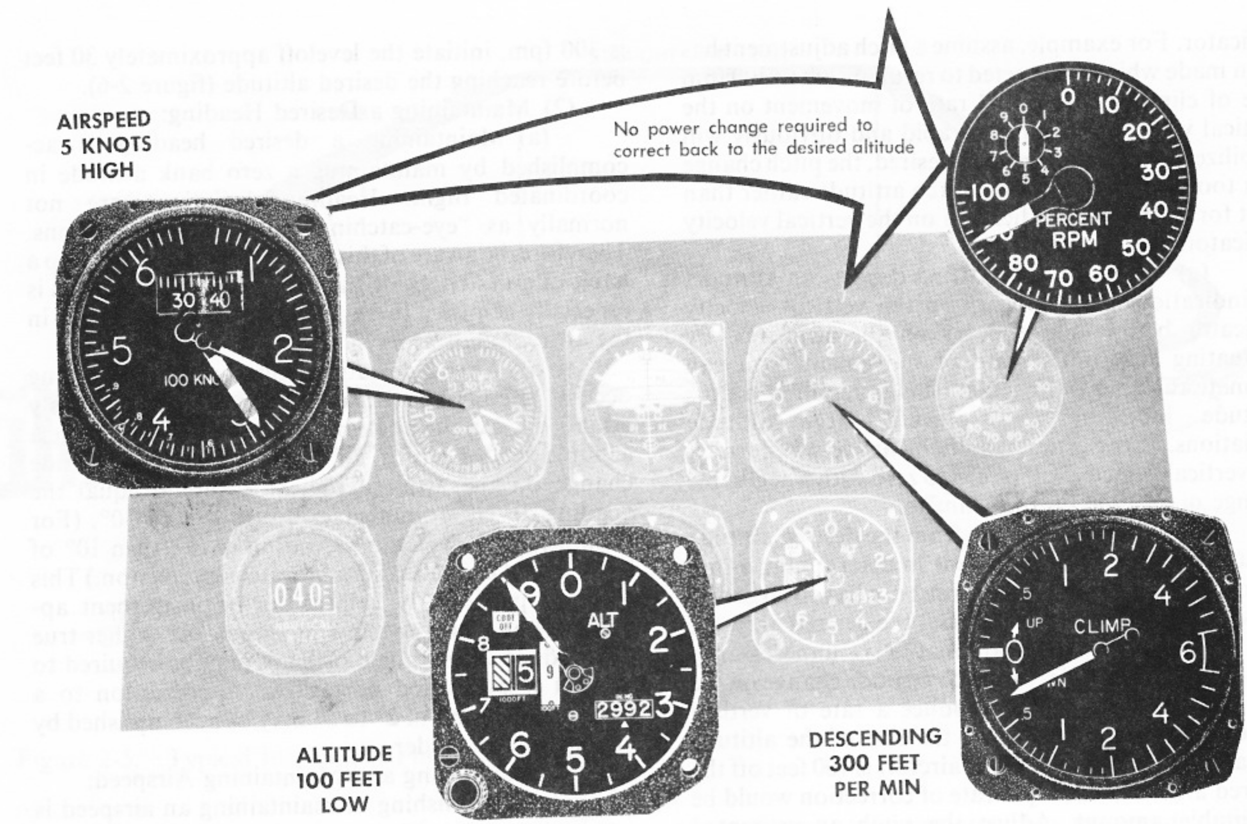


Figure 2-7. Use of Power (para 2-5a(3)(c)).

that will maintain the new airspeed. To reduce the airspeed, reduce the power below the setting estimated for maintaining the new desired airspeed. As the airspeed decreases, the aircraft loses lift and will have a tendency to descend. Adjust the pitch attitude as required to maintain altitude. When the airspeed approaches the desired indication, advance the power to an estimated setting that will maintain the new airspeed. If available, drag devices may be used for relatively large or rapid airspeed reductions. If used, it is normally best to reduce the power to the estimated setting that will maintain the new airspeed and then extend the drag device(s). Extending or retracing the drag devices may induce a pitch change. To overcome this tendency, note the pitch attitude on the attitude indicator just before operating the drag devices and then maintain that attitude constant as they are extended or retracted. When approaching the new airspeed, retract the drag devices and adjust power if required.

NOTE: Proper control of pitch and bank attitude requires you to recognize the effects of gyroscopic precession on attitude indicators. This precession is most noticeable following a turn or change of airspeed. As a result, small altitude and heading deviations may occur when a wings level attitude is established on the attitude indicator following these maneuvers. Therefore, you may have to establish a pitch or bank attitude other than that ordinarily expected. For example, to maintain straight and level flight after completing a normal turn, the attitude indicator may depict a slight turn, climb or descent, or a combination of both. The attitude indicator will gradually resume its normal indications as the erection mechanism automatically corrects these errors. When these errors occur, apply the basic cross-check techniques.

b. Level Turns. Many of the pitch, bank, and power principles discussed in maintaining straight and level flight apply while performing level turns. Performing a level turn requires an understanding of several factors: how to enter the turn; how to maintain bank, altitude, and airspeed during the turn; and how to recover from the turn.

(1) Bank Control:

(a) Before entering a turn you should decide upon a bank angle. Factors to consider are true airspeed and the desired rate of turn. A slow turn rate may unnecessarily prolong the turn, whereas a high rate of turn may cause overshooting of the heading and difficulty with pitch control. As a guide for turns of 30° or less (figure 2-8), the bank angle should approximate

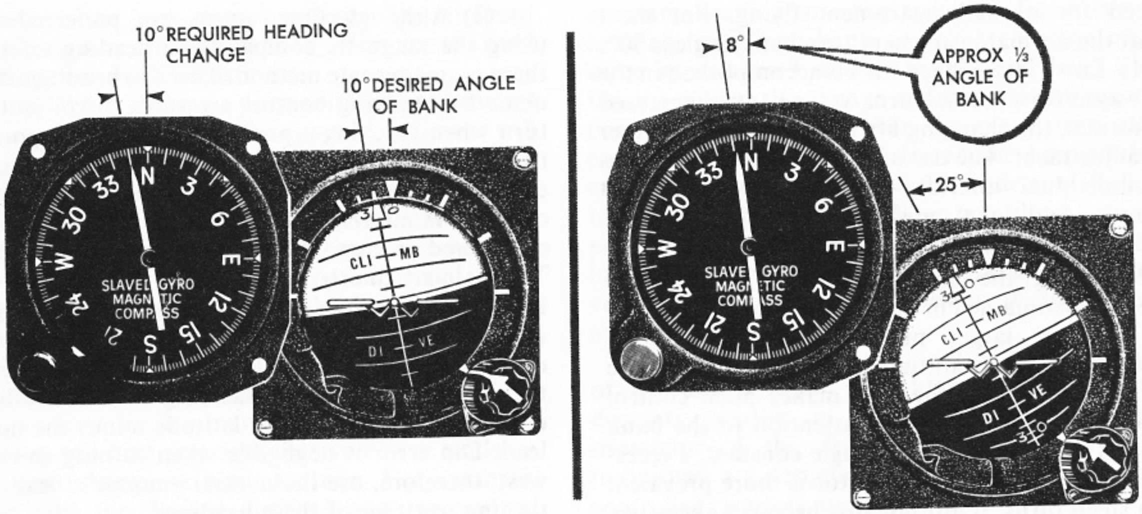


Figure 2-8. Level Turns (para 2-5b).

the number of degrees to be turned. For turns of more than 30°, use a bank angle of 30°. High turn airspeeds or flight manual procedures may require other angles of bank.

(b) To enter a turn, you should refer to the attitude indicator while applying smooth and coordinated control pressures to establish the desired angle of bank. Bank control should then be maintained throughout the turn by reference to the attitude indicator. Cross-check the heading indicator or turn needle to determine if the angle of bank is satisfactory. Trim may be helpful during prolonged turns to assist in aircraft control.

(c) To roll out of a turn on a desired heading, a lead point must be used. The amount of lead required depends upon the amount of bank used for the turn, the rate the aircraft is turning, and your roll-out rate. As a guide, a lead point of approximately 1/3 the angle of bank may be used (figure 2-8). With experience and practice a consistent rate of roll-out can be developed. A lead point can then be accurately estimated for any combination of angle of bank and rate of turn. Make a note of the rate of movement of the heading indicator during the turn. Estimate the lead required by comparing this rate of movement with the angle of bank and the rate of roll-out.

(2) Altitude Control:

(a) The techniques for maintaining a constant altitude during a turn are similar to those used in maintaing altitude in straight and level flight. During the initial part of the roll-in, hold the same pitch attitude as was used to maintain altitude with the wings level. As the bank is increased anticipate a tendency for the aircraft to lose altitude because of the change in lift vector. Adjust the pitch attitude as necessary by reference to the miniature aircraft relative to the artificial horizon. After the turn is established, small pitch adjustments may be required to correct for attitude indicator precession.

(b) When rolling out of a turn, anticipate a tendency for the aircraft to gain altitude. This results from a combination of an increase in the vertical component of lift and a failure to compensate for trim or back pressure used during the turn. Therefore, be aware of these factors, and monitor the pitch attitude during the roll-out in the same manner as during the roll-in. During roll-out, anticipate a decrease in pitch equal to the increase in pitch required during roll-in.

(3) Airspeed Control. The power control techniques for maintaining an airspeed during a turn are similar to those used during straight and level flight. Anticipate a tendency for the aircraft to lose airspeed in a turn. This is caused by induced drag resulting from the increased pitch attitude required to compensate for loss of vertical lift. The increased drag will require additional power to maintain airspeed during a turn. The additional power required will be less at high true airspeeds than at low true airspeeds. At low airspeeds, particularly in jet aircraft, a large power change may be required. If your response to this power change is slow, the airspeed may decrease rapidly to the point where a descent is required to regain the desired airspeed. Therefore, at low airspeeds, it may be desirable to add an estimated amount of power as the turn is established rather than waiting for the first indication of a loss in airspeed.

c. Steep Turns. A steep turn is considered to be a turn in which the angle of bank used in larger than that required for normal instrument flying. For most aircraft the normal instrument turn bank angle is 30°.

(1) Entry into a steep turn is accomplished in the same way as for a normal turn. As the bank is increased past normal, the changing lift vector requires a larger pitch adjustment. The use of trim in steep turns varies with individual aircraft characteristics and pilot technique. Additional power is required to maintain airspeed as the bank is increased.

(2) During the steep turn, pitch and power control are maintained in the same way as in a normal turn; however, larger pitch adjustments will be required for a given altitude deviation. Varying the angle of bank during the turn makes pitch control more difficult. Give sufficient attention to the bank pointer to maintain the bank angle constant. Precession error in the attitude indicator is more prevalent during steep turns. If altitude loss becomes excessive, reduce the angle of bank as necessary to regain positive pitch control.

(3) When rolling out of a steep turn, you should be alert to correct for the more than normal back trim, pitch attitude, and power used during the turn. Roll out at the same rate used with normal turns. The performance instruments must be cross-checked closely during roll-out, since the attitude indicator may have considerable precession error.

d. Timed Turns and Use of the Magnetic Compass. Heading indicator failure may require use of the magnetic compass for heading information. Remember that this instrument provides reliable information only during straight, level, and unaccelerated flight. Because of this limitation, timed turns are recommended when making heading changes by reference to the magnetic compass.

(1) A timed turn is accomplished by establishing a bank attitude on the attitude indicator which will result in a desired rate of turn as shown by the turn needle. A single needle width deflection on a 4-minute turn needle indicates 1½° per second rate of turn, while a double needle width deflection indicates 3° per second rate of turn. A fraction of the preceding amounts can be used to simplify the timing problem. For example, 2/3 needle width deflection indicates 1° per second rate of turn while 1 1/3 needle width indicates 2° per second rate of turn.

(2) The heading change is accomplished by maintaining the desired rate of turn for a predetermined time. Start timing when control pressures are applied to begin the turn. Control pressures are applied to roll out when the time has elapsed. As an example, assume that a 45° heading change is desired using a 4-minute turn needle. The aircraft's true airspeed is relatively high making it advisable to make a single needle width turn (1½° per second). In this case, 30 seconds should elapse from the time control pressures are applied to enter the turn until control pressures are applied to roll-out.

(3) Although timed turns are preferred when using the magnetic compass as a heading reference, there is an alternate method. Turns to headings can be made by applying control pressures to roll-out of a turn when reaching a predetermined "lead" point on the magnetic compass. When using the magnetic compass in this manner do not exceed 15° of bank in order to minimize dip error. Dip error must also be considered in computing the lead point for roll-out. This is particularly noticeable when turning to a heading of north or south. For example, turns to north require a normal lead point plus a number of degrees equal to the flight latitude. Turns to south require turning past the desired heading by the number of degrees equal to the flight latitude minus the normal lead. Dip error is negligible when turning to east or west; therefore, use the normal amount of lead when turning to either of these headings.

e. Climbs and Descents. Climbing and descending maneuvers are classified into two general types-*constant airspeed* and *constant rate*. The constant airspeed maneuver is accomplished by maintaining a constant power indication and varying the pitch attitude to maintain a specific airspeed. The constant rate maneuver is accomplished by varying both power and pitch to maintain constant a specific airspeed and vertical velocity. Either type of climb or descent may be performed while maintaining a constant heading or while turning. These maneuvers should be practiced using airspeeds, configurations, and altitudes corresponding to those which will be used in actual instrument flight.

(1) Constant Airspeed Climbs and Descents:

(a) Before entering the climb or descent, decide on a power setting and estimate the amount of pitch attitude change required to maintain the airspeed. Normally, the pitch and power changes are made simultaneously.

(b) The power change should be smooth, uninterrupted, and at a rate commensurate with the rate of pitch change. In some aircraft, even though a constant throttle setting is maintained, the power may change with altitude. Therefore, it may be necessary to occasionally cross-check the power indicator(s).

(c) While the power is being changed, refer to the attitude indicator and smoothly accomplish the estimated pitch change. Since smooth, slow power applications will also produce pitch changes, only slight control pressures are needed to establish the pitch change. Additionally, very little trim change is required since the airspeed is constant. With a moderate amount of practice, the pitch and power changes can be properly coordinated so the airspeed will remain within close limits as the climb or descent is entered.

NOTE: Remember, the initial pitch attitude change was an estimated amount to maintain the airspeed constant at the new power setting. The airspeed indicator must be cross-checked to determine the need for subsequent pitch adjustments.

(d) When making a pitch adjustment to correct for an airspeed deviation, the airspeed indicator will not reflect an immediate change. The results of pitch attitude changes can be determined more quickly by referring to the vertical velocity indicator. For example, while climbing you note that the airspeed is remaining slightly high and that a small pitch adjustment is required. If the pitch adjustment results in a small increase of vertical velocity, you know (even though the airspeed may not show a change) that the pitch correction was approximately correct.

(e) In a similar manner, the vertical velocity indication will help you note that you have made an inadvertent change in pitch attitude. For example, assume that the desired airspeed and the vertical velocity have been remaining constant but the pitch attitude is allowed to change. The vertical velocity indicator will generally show the result of this inadvertent pitch change more quickly than the airspeed indicator. Therefore, the vertical velocity indicator is an excellent aid in maintaining the airspeed constant.

(f) Upon approaching the desired altitude, select a predetermined leveloff lead point. Ten percent of the vertical velocity in feet is a good estimate for the leveloff lead point. At the leveloff lead point, smoothly adjust the power to an approximate setting required for level flight and simultaneously change the pitch attitude to maintain the desired altitude.

(2) Rate Climbs and Descents:

(a) Rate climbs and descents are accomplished by maintaining both a desired vertical velocity and airspeed. They are proficiency maneuvers designed to practice the techniques used during instrument approaches. Pitch attitude controls the desired vertical velocity, and power controls the desired airspeed. Proper control techniques require coordinated pitch and power changes or adjustments.

(b) Before initiating a rate climb or descent, estimate the amount of pitch change required to produce the desired vertical velocity and the amount of power change required to maintain the airspeed constant. Enter the climb or descent by simultaneously changing the pitch and power the predetermined amount. Cross-check the performance instruments to determine the resultant changes.

(c) A cross-check of the vertical velocity will indicate the need for subsequent pitch adjustments. A cross-check of the airspeed will indicate the need for subsequent power adjustments. When approaching the desired altitude, use normal leveloff techniques.

(3) Pitch and Bank Attitude Control During Climbing and Descending Turns. Constant airspeed or rate climbs and descents may be performed on a constant heading or while turning. (For a constant heading, pitch and bank control techniques are the same as discussed under straight and level flight.) During a turn the change in lift vector affects pitch control. For example, when entering a turn after a constant airspeed climb or descent has been established, the pitch attitude will have to be decreased slightly to maintain the airspeed. When entering a turn while performing a rate climb or descent, be prepared to increase the pitch attitude slightly to maintain the vertical velocity and add power to maintain the airspeed.

f. Leveloff. Leveloffs are required during all phases of instrument flight. The high rates of climbs or descents possible in some aircraft can cause an overshoot of the desired altitude. The following techniques are designed to allow for a precise, easily controlled, leveloff maneuver.

(1) At least 1000 feet below or above the desired altitude, reduce the pitch attitude to obtain a maximum of 1000 to 2000 fpm rate of climb or descent. Adjust the power to maintain the desired airspeed. A knowledge of approximate or known values of power and pitch simplifies aircraft control during this phase of flight. When the lead point for leveloff is reached, perform a normal leveloff.

NOTE: At 1000 feet below or above the desired altitude, a pitch change of one-half will normally provide a more controllable vertical velocity at the lead point for leveloff.

(2) The total pitch change required for leveloff can be estimated by dividing the vertical velocity by the mach number times 1000 (or miles per minute times 100). For example, an aircraft climbing or descending at .6 mach with a vertical velocity of 3600 fpm would require approximately 6° of pitch change to obtain a level flight attitude

$$\frac{3600 \text{ fpm}}{.6 \text{ Mach} \times 1000} = 6^\circ \text{ or } \frac{3600 \text{ fpm}}{6 \text{ mpm} \times 100} = 6^\circ.$$

(3) Upon approaching the desired altitude, select a predetermined leveloff lead point. As a guide, use 10 percent of the vertical velocity. Smoothly adjust the power to an approximate setting required for level flight, and simultaneously change the pitch attitude to maintain the desired altitude.

SECTION C — INSTRUMENT FLIGHT MANEUVERS FOR HELICOPTERS

2-6. General:

a. This section outlines techniques for accomplishing commonly used flight maneuvers for helicopters. Any instrument flight, regardless of how long or complex, is simply a series of connected basic flight maneuvers. Failure to consider each portion of the flight as a basic instrument maneuver often leads to erratic aircraft control. The maneuvers as described herein are general in nature; therefore, slight variations may be required for specific helicopters and in-flight situations. The degree of proficiency developed while accomplishing the maneuvers outlined will allow you to execute any variation or additional maneuver.

b. The procedural steps of the "Control and Performance Concept" apply to helicopters for all instrument maneuvers; however, collective (power) controls altitude or rate of altitude change and cyclic (attitude) controls airspeed. Adjusting pitch attitude in flight has an immediate effect on airspeed. It also results in an immediate, but much less pronounced, change in attitude. A change in power (collective) will have a pronounced effect on lift (altitude) with a lesser effect on thrust (airspeed).

2-7. Individual Maneuvers:

a. Straight and Level Flight. Straight and level unaccelerated flight consists of maintaining desired altitude, heading, and airspeed. Use power control to maintain or adjust the altitude; use pitch attitude to maintain or adjust the airspeed; and use bank control to maintain or adjust the heading.

(1) Establishing and Maintaining Altitude:

(a) Establishing or maintaining an altitude is accomplished by referring to the altimeter and vertical velocity indicator (VVI) for actual aircraft performance and adjusting the power or aircraft attitude to obtain or maintain the desired altitude. A knowledge of the approximate power required to establish a desired altitude or rate of change of vertical velocity will aid in making power adjustments. After the approximate power setting is established, a cross-check of the altimeter and the VVI will indicate if subsequent power adjustments are required. You should make it a point to learn and remember the approximate power settings for your aircraft at various altitudes, airspeeds, and configurations used throughout a normal mission.

(b) When an altitude deviation is observed, a power or pitch adjustment (or a combination of both) may be required to correct back to the desired altitude. For example, if below the desired altitude with a higher than desired airspeed, an increase in pitch may regain both the desired altitude and airspeed. Conversely, a pitch adjustment (if made at the desired altitude) will induce the need for a power adjustment.

(c) With experience, you can usually estimate the suitability of power adjustment by noting the initial rate of movement of the vertical velocity indicator. If the initial rate of movement on the VVI is rapid and obviously will stabilize at a rate greater than desired, the power change was too large. Readjust the power rather than wait for a stabilized indication on the VVI.

(d) When you first deviate from an altitude, an indication often appears on the vertical velocity indicator before appearing on the altimeter. By evaluating this initial rate of movement, you can estimate the amount of power change required to prevent large altitude deviations. If the estimated power change is correct, the vertical velocity will return to zero with a negligible change of altitude.

(e) When a deviation from the desired altitude occurs, determine a rate of vertical correction and apply a power change to correct back to the desired altitude. The correction must not be too large, resulting in the aircraft "overshooting" the desired altitude, nor should it be so small that the correction is unnecessarily prolonged. As a guide, the power change should produce a rate of vertical velocity approximately twice the value of the altitude deviation. For example, if the aircraft is 100 feet off the desired altitude, a 200 feet per minute rate of correction would be a suitable amount. By knowing the present rate of climb or descent and the results to be expected from a power change, you can closely estimate how much to change the power. The adjusted power must be held constant until the rate of correction is observed on the vertical velocity indicator. If it differs from that desired, then further adjustment of the power is required.

(f) When approaching the desired altitude, determine a lead point on the altimeter for initiating a level-off power change. A suitable lead point prevents "overshooting" and permits a smooth transition to level flight. The amount of lead required varies with pilot technique and rate of correction. As a guide, the lead point on the altimeter should be approximately 10 percent of the vertical velocity. For example, if the rate of correction to the desired altitude is 300 feet per minute, initiate the leveloff approximately 30 feet before reaching the desired altitude.

(g) Devoting too much attention to the vertical velocity indicator can lead to "chasing" its indications and result in erratic power control. Although the vertical velocity indicator is an important performance instrument, limitations, such as oscillations in rough air, lag, etc., should be thoroughly understood to prevent overcontrolling the power. For this reason, you must recognize and understand that sufficient reference to the power indicator is necessary to ensure smooth and precise power adjustments for effective altitude control.

(2) Maintaining a Desired Heading:

(a) Maintaining a desired heading is accomplished by maintaining a zero bank attitude and coordinated flight. Heading deviations are not normally as "eye-catching" as altitude deviations. Therefore, be aware of this characteristic and develop a habit of cross-checking the heading indicator frequently to prevent significant heading deviations.

(b) When a deviation from the desired heading occurs, refer to the attitude indicator and smoothly establish a definite angle of bank which will produce a suitable rate of return. As a guide, the bank attitude change on the attitude indicator should equal the heading deviation in degrees not to exceed a standard rate turn (unless compensating for wind in a holding pattern or as required on radar final). For example, if the heading deviation is 10°, then 10° of bank on the attitude indicator would produce a suitable rate of correction.

(3) Establishing and Maintaining a Desired Airspeed:

(a) Maintaining a desired airspeed requires the ability to maintain a specific pitch attitude and, when necessary, to smoothly and precisely adjust the attitude. This ability is developed through proper use of the attitude indicator and is simplified by good trim techniques.

(b) After leveling off at cruise airspeed, you may adjust the pitch trim knob on the attitude indicator so that the miniature aircraft is aligned with the horizon bar. This will aid in observing small pitch changes. Subsequent readjustments may be required because of the changes in aircraft center of gravity and cruise airspeeds.

(c) The small corrections required to maintain a desired airspeed are made in degrees of pitch. With practice you can determine what pitch attitude adjustments are required to produce the desired rate of correction.

(d) When you make these pitch adjustments, airspeed and vertical velocity indications will lag behind changes of pitch attitude. This lag should be recognized and accepted as an inherent error in the differential pressure instruments. Because of this error, do not make a premature decision that the pitch change is ineffective. This can lure you into overcontrolling the pitch attitude.

(e) Changes of airspeed in straight and level flight are accomplished by adjusting the pitch attitude and power. To increase airspeed, decrease the pitch attitude to a predetermined number of degrees and increase power to maintain altitude. When airspeed approaches the desired indication, adjust pitch to a setting that will maintain the new airspeed and adjust power to maintain altitude. To reduce airspeed, increase the pitch attitude to a predetermined number of degrees and reduce power to maintain altitude. When the airspeed approaches the desired indication, adjust pitch to a setting that will maintain the new airspeed and adjust power to maintain altitude.

b. Turns. Many of the pitch, bank, and power principles discussed in maintaining straight and level flight apply while performing level turns. Performing a level turn requires an understanding of the following factors: how to enter the turn; how to maintain bank, altitude, and airspeed during the turn; and how to recover from the turn.

(1) Bank Control:

(a) Prior to entering a turn, decide upon the angle of bank to be used. Factors to consider are true airspeed and the desired rate of turn. A slow turn rate may unnecessarily prolong the turn, whereas a high rate of turn may cause overshooting of the heading and difficulty with aircraft control. As a guide, for small turns (15° or less) the angle of bank should approximate the number of degrees to be turned. For turns of more than 15°, a standard rate turn is normally used.

(b) To enter a turn, refer to the attitude indicator while applying smooth, coordinated control pressures to establish the desired angle of bank. Bank control should then be maintained throughout the turn by reference to the attitude indicator. Cross-check the heading indicator or turn needle to determine if the rate of turn is satisfactory. Trim may be helpful during prolonged turns to assist in aircraft control.

(c) To roll out of a turn on a desired heading, a lead point must be used. The amount of lead required depends upon the amount of bank used for the turn, the rate the aircraft is turning, and the rate at which you roll out. As a guide, use a lead point on the heading indicator equal to approximately one-third of the angle of bank. With experience and practice, a consistent rate of roll-out can be developed. A lead point can then be accurately estimated for any combination of bank angle and rate of turn. Make a note of the rate of movement of the heading indicator during the turn. Estimate the lead required by comparing this rate of movement with the angle of bank and the rate of roll-out.

(2) Altitude Control:

(a) The techniques for maintaining a constant altitude during a turn are similar to those used in maintaining straight and level flight. During the initial part of the roll-in, hold the same pitch and power that was used to maintain altitude with the wings level. As the bank is increased, anticipate a tendency for the aircraft to lose altitude because of the change in lift vector. Adjust the power as necessary after referring to the vertical velocity indicator and altimeter. After the turn is established, small power adjustments may be required to maintain the desired altitude.

(b) When rolling out of a turn, anticipate a tendency to gain altitude due to an increase in the vertical component of lift. Therefore, be aware of this factor, anticipate its effect, and monitor pitch and power during roll-out in the same manner as during roll-in.

(3) Airspeed Control. The pitch control techniques for maintaining an airspeed during a turn are similar to those used during straight and level flight. Anticipate a tendency for the aircraft to lose airspeed in a turn. Accomplish changes of airspeed during a turn as described under straight and level flight.

(4) Steep Turns:

(a) A turn is considered to be a steep turn if the angle of bank used is larger than that required for normal instrument flying. Most helicopters use a standard rate turn.

(b) Entry into a steep turn is accomplished in the same way as for a normal turn. As the bank is increased past normal the change in lift vector occurs which requires an increase in power. The use of trim in steep turns varies with individual helicopter characteristics and pilot techniques. However, proper coordination will aid aircraft control and reduce pilot workload. Adjust pitch to maintain airspeed as the bank is increased.

(c) During the steep turn, pitch and power control are maintained in the same way as in a normal turn; however, larger power adjustments may be required for a given altitude deviation. Inadvertently varying the angle of bank during the turn makes altitude control more difficult. Give sufficient attention to the bank pointer to maintain a constant bank angle. Precession error in the attitude indicator is more prevalent during steep turns. If altitude loss becomes excessive, reduce the angle of bank as necessary to regain positive altitude control.

(d) When rolling out of a steep turn, be alert to correct for the more than normal trim, pitch, and power used during the turns. Roll out at the same rate used during normal turns. Proper pitch and bank attitude control requires you to recognize the effects of gyroscopic precession on attitude indicators. The precession is most noticeable following a turn or change of airspeed and varies between attitude indicators. As a result, small airspeed, altitude, and heading deviations may occur when a wings level attitude is established on the attitude indicator following maneuvers. Therefore, you may have to temporarily establish an adjusted pitch or bank attitude on the attitude indicator to maintain straight and level flight with reference to the performance instruments. The attitude indicator will gradually resume its normal indications as the erection mechanism automatically corrects these errors.

c. Climbs and Descents. Climbing and descending maneuvers are classified into two general types — *constant airspeed* and *constant rate.* The constant airspeed maneuver is accomplished by selecting a power setting and adjusting, if necessary, the pitch attitude to maintain a selected airspeed. The constant rate maneuver is accomplished by selecting a power setting to maintain a desired vertical velocity and, if necessary, adjusting the pitch attitude to maintain a selected airspeed. Either maneuver may be performed while maintaining a constant heading or while turning. These maneuvers should be practiced using airspeeds, configurations, and altitudes corresponding to those which will be used in actual instrument flight.

(1) Constant Airspeed Climbs and Descents:

(a) Before entering a climb or descent, decide what power setting will be required. If airspeed is to be changed in the climb, estimate the amount of pitch attitude change required to establish the desired airspeed if the pitch and power changes are to be made simultaneously. The power change should be smooth, uninterrupted and at a rate commensurate with the rate of pitch change. Only slight control pressures are needed to establish the pitch change.

(b) When making a pitch adjustment on the attitude indicator to correct for an airspeed deviation, the airspeed indicator will not reflect an immediate change. The results of pitch attitude changes can often be determined more quickly by cross-checking the change in vertical velocity indication. For example, while climbing, a pilot notes that his airspeed is remaining slightly high and realizes that a small pitch adjustment is required. If the pitch adjustment results in a small increase of vertical velocity, the pilot knows, even though his airspeed may not yet show a change, that his pitch correction was approximately correct. When properly used in attitude instrument flying, the vertical velocity indicator is an excellent aid in maintaining airspeed.

(c) Upon approaching the desired altitude, select a predetermined level-off point on the altimeter. As a guide, use 10 percent of the vertical velocity. Smoothly adjust the power to an approximate setting required for level flight and simultaneously adjust the pitch attitude, if required to maintain the desired airspeed.

(2) Rate Climbs and Descents:

(a) Rate climbs and descents are accomplished by maintaining both a desired vertical velocity and airspeed. They are proficiency maneuvers designed to practice the techniques used during instrument approaches. Pitch attitude control is used to establish and maintain the desired airspeed. Power control is used to maintain the desired vertical velocity. Proper control techniques require coordinated pitch and power changes or adjustments.

(b) Before initiating a rate climb or descent, estimate the amount of pitch change required to establish the desired airspeed and the amount of power change required to produce the desired vertical velocity. Enter the climb or descent by changing the power a predetermined amount and adjusting, if necessary, the pitch attitude to maintain or establish the selected airspeed. Cross-check the performance instruments to determine the resultant changes.

(c) Once established in a constant rate maneuver, deviations in desired VVI/airspeed must be properly interpreted. For example, VVI excursions can result because of incorrect power or inadvertent changes in pitch attitude (airspeed). Corrections are made on the control instruments with reference to the performance instruments. The rate climb or descent is terminated by using normal level-off procedures when approaching the desired altitude.

(3) Pitch and Bank Attitude Control During Climbing and Descending Turns. Constant airspeed or rate climbs and descents may be performed on a constant heading or while turning. When accomplished on a constant heading, pitch and bank control techniques are essentially the same as discussed under straight and level flight. When accomplished during a turn, a change in the lift vector affects power control. When entering a turn after a constant airspeed climb or descent has already been established, the attitude will have to be adjusted slightly to maintain a constant airspeed. When entering a turn while performing a rate climb or descent, be prepared to adjust power slightly to maintain the desired vertical velocity.

d. Emergency Descent. Basic instrument techniques may be used to safely perform an emergency descent in instrument meteorological conditions (IMC). There is no set procedure for executing an emergency descent. You must consider all variables when executing an emergency descent.

(1) Power-on Descent. If a long distance must be covered, then a constant airspeed descent could be selected using higher than normal airspeeds. If a short distance is to be covered, then a constant rate descent could be selected using high rates of descent and slower than normal airspeeds.

(2) Power-Off Descent (Autorotation). If an autorotation is required, enter by smoothly lowering the collective and closely cross-checking the control and performance instruments. Particular attention should be given to keeping the helicopter in coordinated flight. The autorotation is accomplished by using the techniques described for constant airspeed descents. Turns during autorotation are accomplished by using the same techniques as outlined in descending turns. You must determine the angle of bank required by considering the time and altitude available to accomplish the turn. The rotor rpm will tend to increase during turning autorotations and must be incorporated into the cross-check. Knowing the approximate ceiling will aid in determining when to begin a systematic scan for outside references. Crew coordination should be briefed prior to flight by the pilot in command.

SECTION D — UNUSUAL ATTITUDES

2-8. General:

a. An unusual attitude is an aircraft attitude occurring inadvertently. It may result from one factor or a combination of several factors such as turbulence, distraction of cockpit duties, instrument failure, inattention, spatial disorientation, lost wingman, and transition from VMC to IMC. In most instances these attitudes are mild enough to recover by reestablishing the proper attitude for the desired flight condition and resuming a normal cross-check.

WARNING: It is important to immediately transition to instrument references any time you become disoriented or when outside visual references become unreliable.

b. Techniques of recovery should be compatible with the severity of the unusual attitude, the characteristics of the aircraft, and the altitude available for the recovery. The procedures outlined in this section are not designed for recovery from controlled tactical maneuvers.

c. The following aerodynamic principles and considerations are applicable to the recovery from unusual attitudes:

(1) The elimination of a bank in a dive aids pitch control.

(2) The use of bank in a climb aids pitch control.

(3) Power and drag devices used properly aid airspeed control.

d. It should be emphasized that bank control will assist recovery.

2-9. Recognizing an Unusual Attitude. Normally, an unusual attitude is recognized in one of two ways — an unusual attitude "picture" on the attitude indicator or unusual performance on the performance instruments. Regardless of how the attitude is recognized, verify that an unusual attitude exists by comparing control and performance instrument indications prior to initiating recovery on the attitude indicator (figure 2-9). This precludes entering an unusual attitude as a result of making control movements to correct for erroneous instrument indications. During this process, the attitude must be correctly interpreted. Additional attitude indicating sources (standby attitude indicator, copilot's attitude indicator, etc.) should be used. In some aircraft the bank steering bar (manual mode) may aid in maintaining level flight (refer to flight manual). If there is any doubt as to proper attitude indicator operation, then recover using attitude indicator inoperative procedures. The following techniques will aid aircraft attitude interpretation on the attitude indicator.

a. For attitude indicators with a single bank pointer and bank scale at the top, the bank pointer can be considered a sky pointer. It always points up and should be in the upper half of the case. Rolling towards the bank pointer to place it in the upper half of the case will correct an inverted attitude.

b. For those attitude indicators with the bank scale at the bottom, rolling in the direction that will place the pitch reference scale right-side-up will correct an inverted attitude.

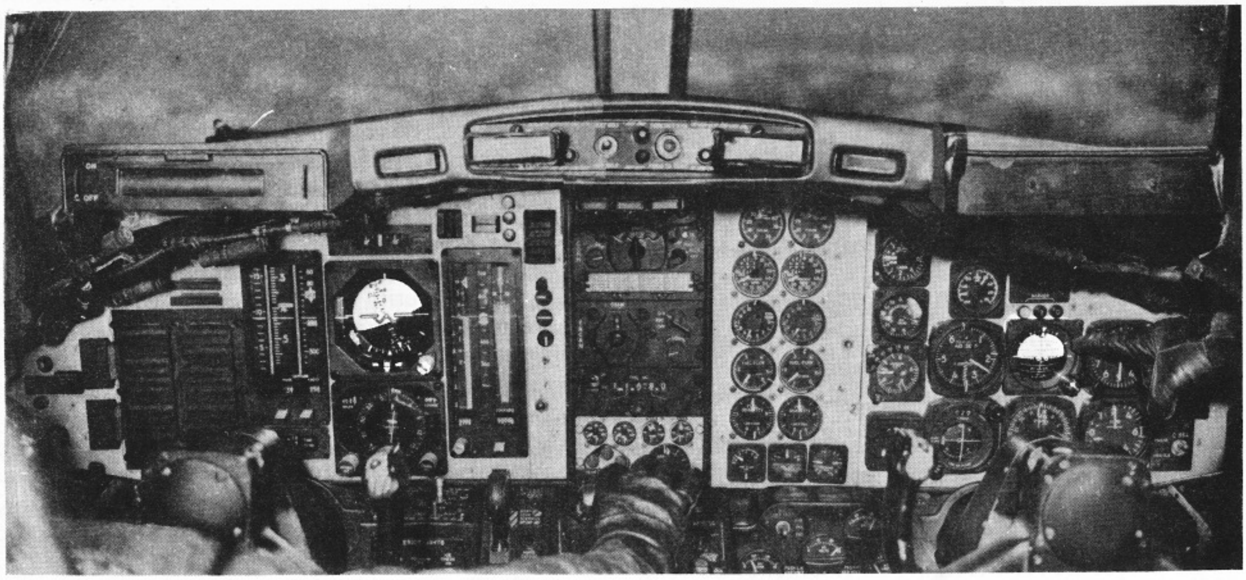


Figure 2-9. Verify That An Unusual Attitude Exists (para 2-9).

NOTE: Ease of pitch interpretation varies with the type of attitude indicator installed. Attitude indicators having pitch reference scales in degrees and grey or black attitude spheres can easily be interpreted for climb or dive indications. For those aircraft not so equipped, the airspeed indicator, altimeter, or vertical velocity indicator generally presents the most easily interpreted indication of a climb or a dive. Attitude interpretation is a skill that must be highly developed by practice in flight and on the ground in simulators or with mockups.

2-10. Recovery Procedures — Attitude Indicator(s) Operative:

a. Fixed-Wing Aircraft. Use the following procedures if specific unusual attitude recovery procedures are not contained in the flight manual:

(1) If diving, adjust power or drag devices as appropriate while rolling to a wings level, upright attitude and correct to level flight on the attitude indicator. Do not add back pressure until less than 90° of bank.

(2) If climbing, use power as required and bank as necessary to assist pitch control and to avoid negative G forces. As the fuselage dot of the miniature aircraft approaches the horizon bar, adjust pitch, bank, and power to complete recovery and establish the desired aircraft attitude. When recovering from a steep climb, care must be exercised in some aircraft to avoid exceeding bank limitations.

(3) During unusual attitude recoveries, coordinate the amount of bank and power used with the rate at which airspeed and pitch are being controlled. Bank and power used must be compatible with aircraft and engine characteristics.

b. Rotary-Wing Aircraft. Recoveries from helicopter unusual attitudes are unique due to rotary-wing aerodynamics as well as application of the control and performance concept to helicopter flight. Application of improper recovery techniques can result in blade stall, power settling, or an uncontrollable yaw if recovery is delayed. Due to these differences, unusual attitude recoveries for helicopters are decidedly different from fixed-wing recoveries. Use the following procedures if specific unusual attitude recovery procedures are not contained in the flight manual:

(1) If diving, consider altitude, acceleration limits, and the possibility of encountering blade stall. If altitude permits, avoid rolling pullouts. To recover from a diving unusual attitude, roll to a wings level indication then establish a level flight attitude on the attitude indicator. Adjust power as necessary and resume a normal cross-check.

(2) If climbing, consider pitch attitude and airspeed. If the inadvertent pitch attitude is not extreme (10° or less from level flight), smoothly lower the miniature aircraft back to a level flight indication, level the wings, and resume a normal cross-check using power as required. For extreme pitch attitudes (above 10°), bank the aircraft in the shorter direction toward the nearest 30° bank index. The amount of bank used should be commensurate with the pitch attitude and external conditions, but do not exceed 30° of bank in making the recovery. Allow the miniature aircraft to fall toward the horizon. When the aircraft symbol is on the horizon, level the wings and adjust the aircraft

attitude to a level flight indication. Use power as necessary throughout the recovery.

NOTE: In helicopters encountering an unusual attitude as a result of blade stall, collective (power) must be reduced before applying attitude corrections if the aircraft is in a climbing unusual attitude. This will aid in eliminating the possibility of aggravating the blade stall condition. To aid in avoiding blade stall in a diving unusual attitude recovery, reduce collective (power) and bank attitude before initiating a pitch change. In all cases avoid abnormal positive or negative G loading which could lead to additional unusual attitudes or aircraft structural damage.

2-11. Recovery Procedures — Attitude Indicator(s) Inoperative. With an inoperative attitude indicator, successful recovery from unusual attitudes depends greatly on pilot proficiency and early recognition of attitude indicator failure. For example, attitude indicator failure should be immediately suspected if control pressures are applied for a turn without corresponding attitude indicator changes. Another example would be satisfactory performance instrument indications that contradict the "picture" on the attitude indicator. Should an unusual attitude be encountered with an inoperative attitude indicator, the following procedures are recommended:

a. Determine whether the aircraft is in a climb or a dive by referring to the airspeed, altimeter, and vertical velocity indicators.

b. If diving, roll to center the turn needle and recover from the dive. Adjust power or drag devices as appropriate. (Disregarding vertical attitudes, rolling "away" from the turn needle and centering it will result in an upright attitude.)

c. If climbing, use power as required. If the airspeed is low or decreasing rapidly, pitch control may be aided by maintaining a turn of approximately standard rate on the turn needle until reaching level flight. If the turn needle in a flight director system is used, center the turn needle. This is because it is very difficult to determine between a standard rate turn and full needle deflection.

d. Upon reaching level flight, center the turn needle. The aircraft is level when the altimeter stops. The vertical velocity indicator lag error may cause it not to indicate level until the aircraft passes level flight.

NOTE: Spatial disorientation may become severe during the recovery from unusual attitudes with an inoperative attitude indicator. Extreme attitudes may result in an excessive loss of altitude and possible loss of aircraft control. Therefore, if a minimum safe altitude for unusual attitude recovery is not contained in the flight manual, decide upon an altitude at which recovery attempts will be discontinued and the aircraft abandoned. On aircraft equipped with an operative autopilot, it may be used to assist in a last chance recovery from unusual attitudes.

SECTION E — NAVIGATION PROCEDURES

2-12. Tuning. Individual aircraft flight manuals should provide detailed instructions regarding the proper procedures for using the navigation equipment installed. The following general guidance applies to all aircraft:

a. Tune to or select the desired frequency or channel. ADF NOTE: When possible use a nondirectional radio beacon. Commercial broadcasting stations should be used with caution because some have highly directional radiation patterns. Additionally, they are not flight-checked for navigational use. Positive identification of the commercial station being used is imperative.

b. Identify the station:

(1) VOR. The station identification may be a repeated three-letter Morse code group, or a three-letter Morse code group alternating with a recorded voice identifier.

(2) TACAN. The TACAN station transmits an aural three-letter Morse code identifier approximately each 35 seconds.

(3) ADF. The nondirectional radio beacon transmits a repeated two- or three-letter Morse code group depending on power output.

(4) ILS. the ILS localizer transmitter puts out a repeated four-letter Morse code group. The first letter of the identifier is always "I" to denote the facility as an ILS.

NOTE: Positively identify the selected station. Through human error or equipment malfunction, it is possible that the station intended to be selected is not the one being received. This may occur as the result of failing to select the correct frequency, or failure of the receiver to channelize to the new frequency.

c. Monitor station identification continuously while using it for navigation. The navigation signals are considered to be unreliable when the station identifier fails.

NOTE: Voice communication is possible on VOR, ILS, and ADF frequencies. Consult FLIP documents to determine the availability of specific stations.

d. Select proper position for the navigation system switches.

(1) Position the selector switches to display the desired information on the navigation instruments.

(2) Monitor the course warning flag (if installed) continuously to ensure adequate signal reception strength.

(3) Check the appropriate instrument indicator(s) for proper operation.

2-13. Homing to a Station. Tune and identify the station. Turn the aircraft in the shorter direction to place the head of the bearing pointer under the top index of the RMI/BDHI or upper lubber line of the HSI. Adjust aircraft heading, as necessary, to keep the bearing pointer under the top index or upper lubber line. Since homing does not incorporate wind drift correction, in a crosswind the aircraft follows a curved path to the station (figure 2-10). Therefore, homing should be used only when maintaining course is not required.

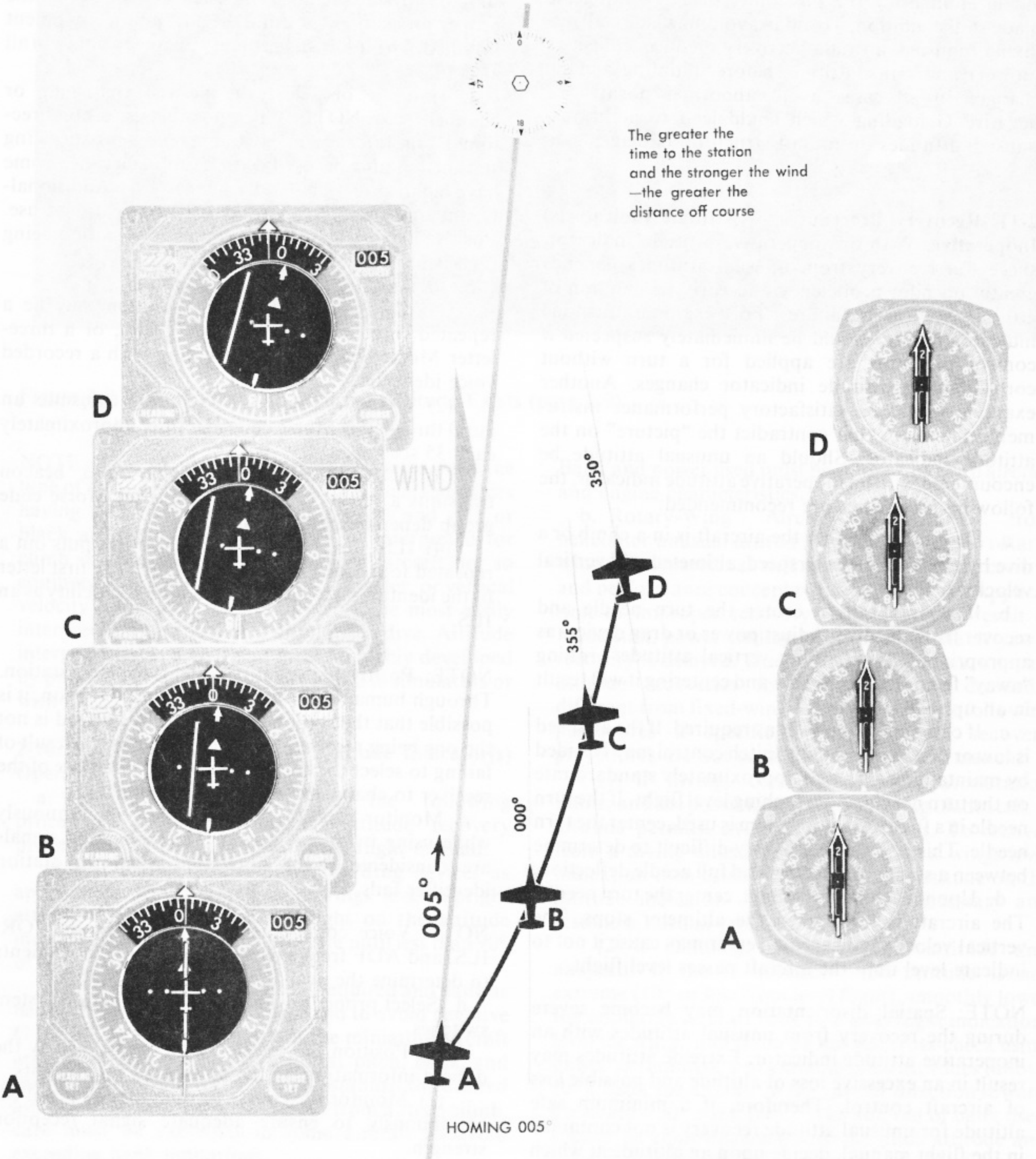


Figure 2-10. Curved Flight Path as a Result of Homing With a Crosswind (para 2-13).

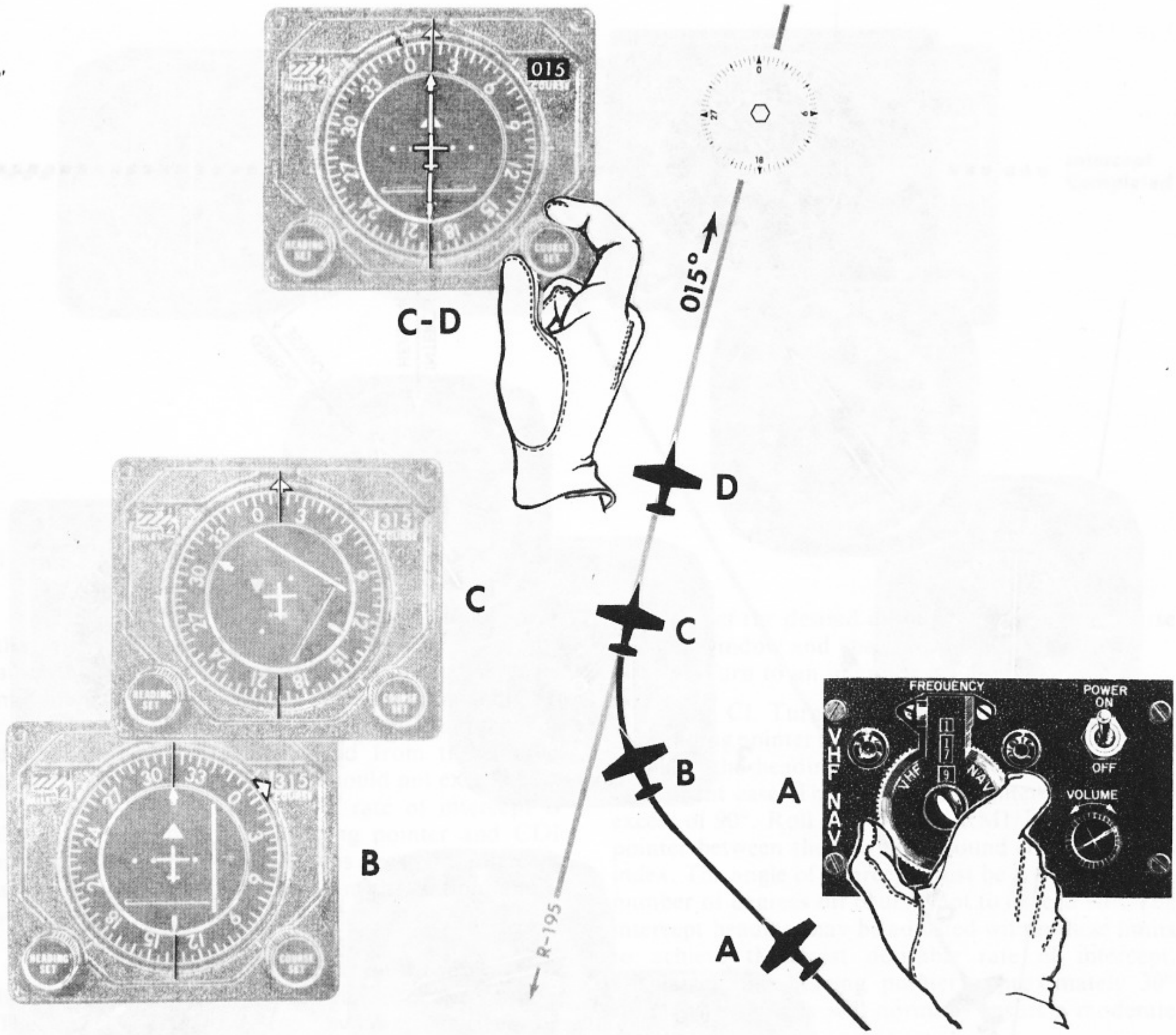


Figure 2-11. Proceeding Direct to Station (para 2-14).

2-14. Proceeding Direct to a Station (figure 2-11):

a. When proceeding direct to a station, the following applies:

(1) Tune and identify the station.

(2) Turn the aircraft in the shorter direction to place the head of the bearing pointer under the top index or upper lubber line.

(3) Center the CDI with a TO indication (does not apply to ADF).

(4) Maintain this course to the station.

b. If either the compass card or the bearing pointer is inoperative, a course indicator or HSI may be used to determine the bearing to the station by rotating the course set knob until the CDI centers and TO is read in the TO-FROM indicator. The magnetic bearing from the aircraft to the station then appears in the course selector window. Until verified by radar or other navigation equipment, consider this bearing information unreliable.

2-15. Course Interceptions:

a. General. Course interceptions are performed in many phases of instrument navigation. To ensure successful course interception, an intercept heading must be used that results in an angle or rate of intercept sufficient to complete a particular intercept problem.

(1) Intercept Heading. The intercept heading (aircraft heading) is the heading determined to solve an intercept problem. When selecting an intercept heading, the essential factor is the relationship between distance from the station and the number of degrees the aircraft is displaced from course. Adjustments to the intercept heading may be necessary to achieve a more desirable rate of intercept.

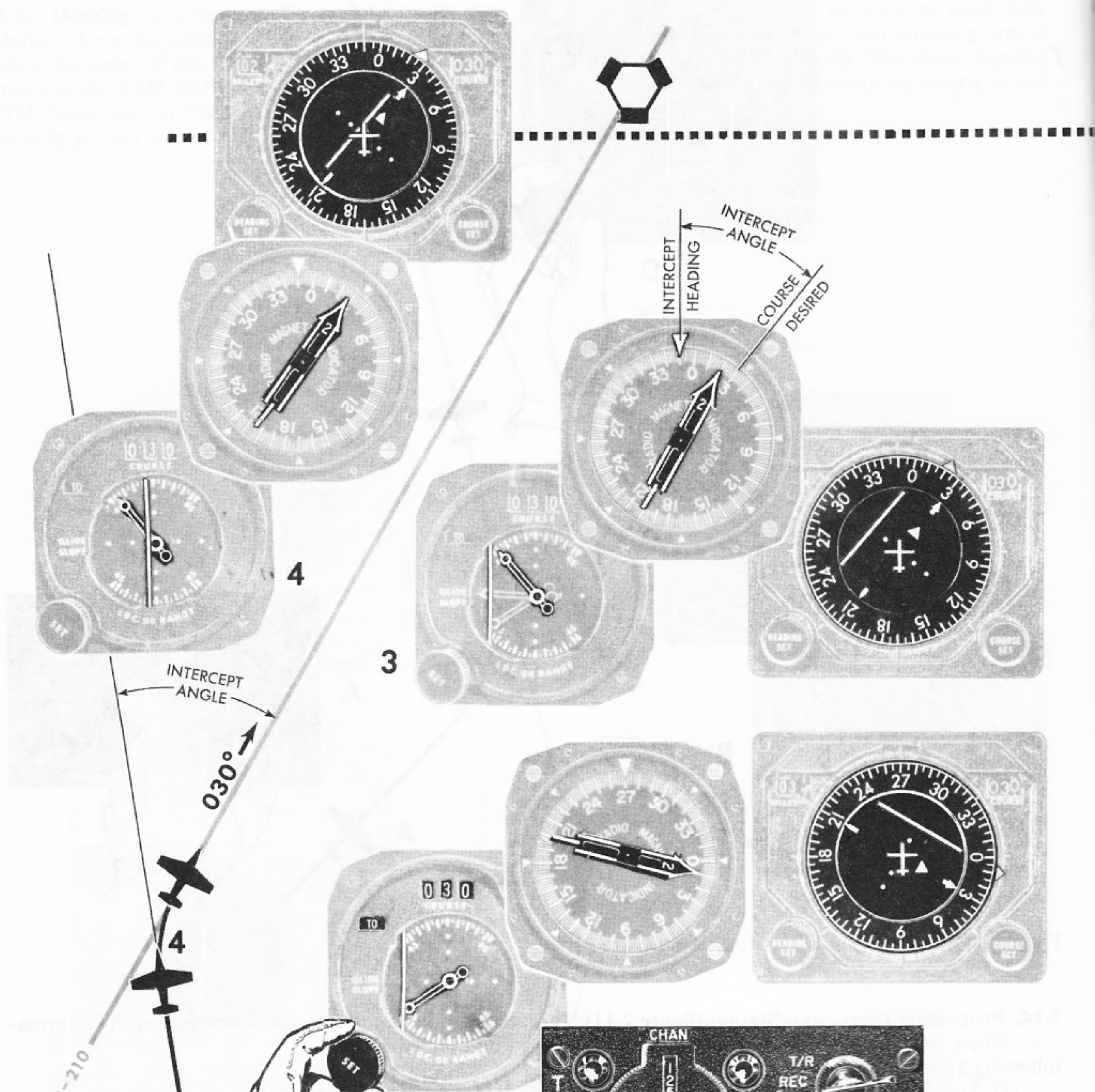


Figure 2-12. Inbound Course Interceptions (Course Indicator and RMI; HSI) (para 2-15b)

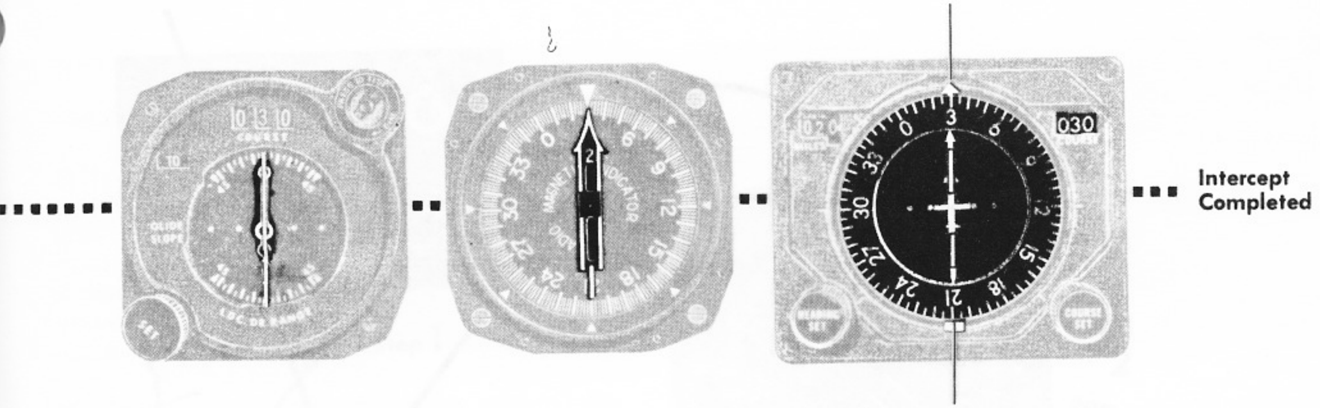


Figure 2-12. Continued.

(2) Angle of Intercept. The angle of intercept is the angular difference between the heading of the aircraft (intercept heading) and the desired course. The minimum acceptable angle of intercept for an inbound course interception must be greater than the number of degrees the aircraft is displaced from the desired course. The angle of intercept should not exceed 90°.

(3) Rate of Intercept. The rate of intercept is determined by observing bearing pointer and CDI movement. The rate of intercept is a result of intercept angle, groundspeed, distance from the station, and if you are proceeding to or from the station.

(4) Completing the Intercept:

(a) A lead point to roll out on the course must be determined because of turn radius of the aircraft. The lead point is determined by comparing bearing pointer or CDI movement with the time required to turn to course.

(b) To determine the rate of intercept, monitor the bearing pointer or CDI movement.

(c) The time required to make the turn to course is determined by the intercept angle and the aircraft turn rate.

(d) Use the CDI, when available, for completing the course intercept.

(e) If it is obvious that the selected lead point will result in undershooting the desired course, either reduce the angle of bank or roll out of the turn and resume the intercept. If the selected lead point results in an overshoot, continue the turn and roll out with a correction back to the course.

(f) The aircraft is on course when the CDI is centered or the bearing pointer points to the desired course. A correction for known winds should be applied when completing the turn to course.

b. Inbound (CI and HSI) (figure 2-12):

(1) Tune and identify the station.

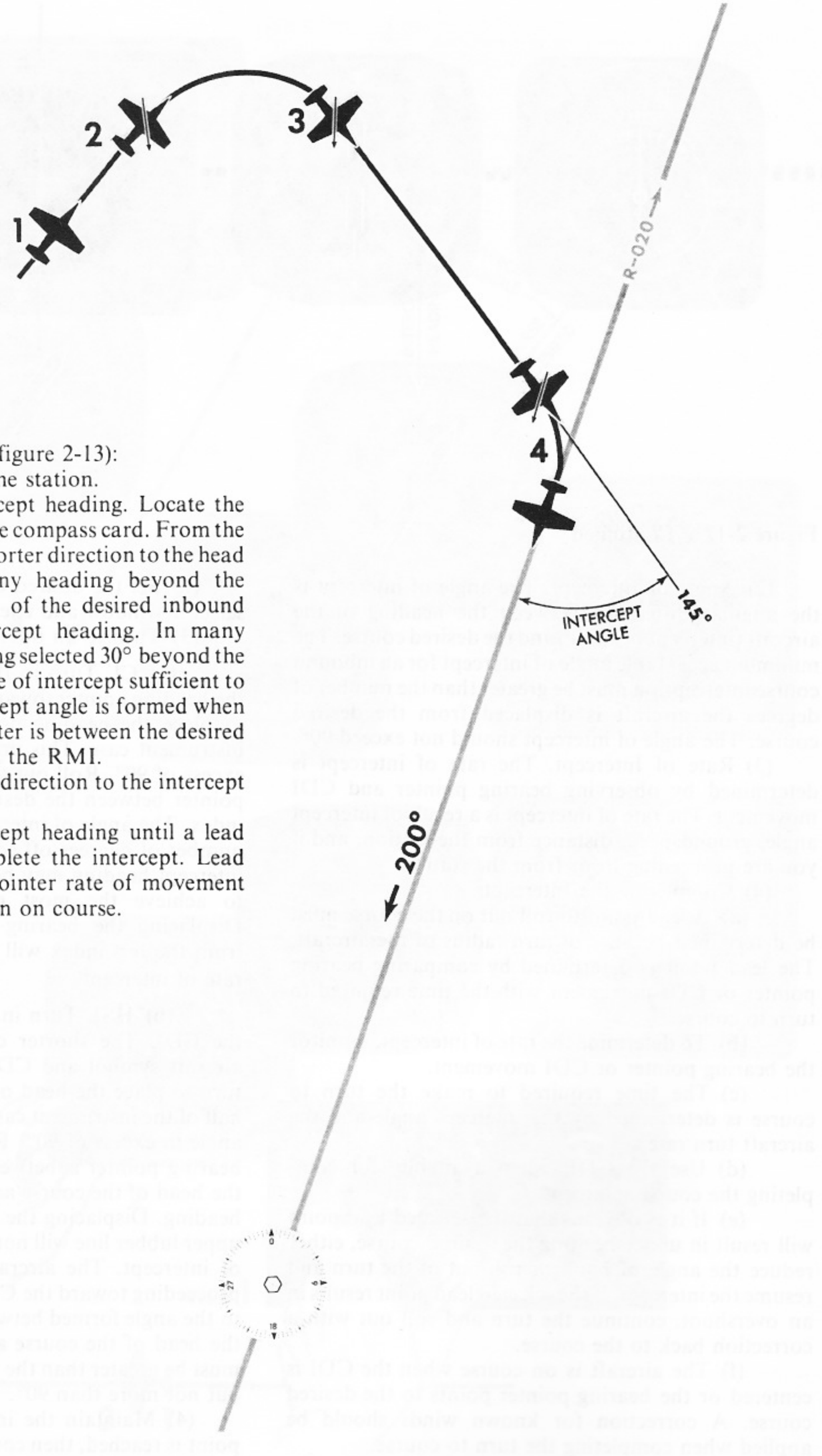
(2) Set the desired inbound course in the course selector window and check for a TO indication.

(3) Turn to an intercept heading:

(a) CI. Turn in the shorter direction to place the heading pointer toward the CDI. Continue the turn to place the heading pointer in the top half of the instrument case. This precludes an intercept angle in excess of 90°. Roll out with the RMI/BDHI bearing pointer between the desired inbound course and top index. The angle of intercept must be greater than the number of degrees off course, not to exceed 90°. The intercept heading may be adjusted within these limits to achieve the most desirable rate of intercept. Displacing the bearing pointer approximately 30° from the top index will normally ensure a moderate rate of intercept.

(b) HSI. Turn in the shorter direction toward the CDI. The shorter direction is displayed by the aircraft symbol and CDI relationship. Continue the turn to place the head of the course arrow in the top half of the instrument case. This precludes an intercept angle in excess of 90°. Roll out of the turn when the bearing pointer is between the upper lubber line and the head of the course arrow to establish an intercept heading. Displacing the bearing pointer 30° from the upper lubber line will normally ensure a moderate rate of intercept. The aircraft symbol will appear to be proceeding toward the CDI at an intercept angle equal to the angle formed between the upper lubber line and the head of the course arrow. The angle of intercept must be greater than the number of degrees off course, but not more than 90°.

(4) Maintain the intercept heading until a lead point is reached, then complete the intercept. The lead point depends on bearing pointer or CDI rate of movement and the time required to turn on course.



c. Inbound (RMI Only) (figure 2-13):

(1) Tune and identify the station.

(2) Determine an intercept heading. Locate the desired inbound course on the compass card. From the desired course, look in the shorter direction to the head of the bearing pointer. Any heading beyond the bearing pointer, within 90° of the desired inbound course, is a no-wind intercept heading. In many instances, an intercept heading selected 30° beyond the bearing pointer ensures a rate of intercept sufficient to solve the problem. An intercept angle is formed when the head of the bearing pointer is between the desired course and the top index on the RMI.

(3) Turn in the shorter direction to the intercept heading.

(4) Maintain the intercept heading until a lead point is reached, then complete the intercept. Lead point depends on bearing pointer rate of movement and the time required to turn on course.

Figure 2-13. Inbound Course Interceptions (RMI Only) (para 2-15c).

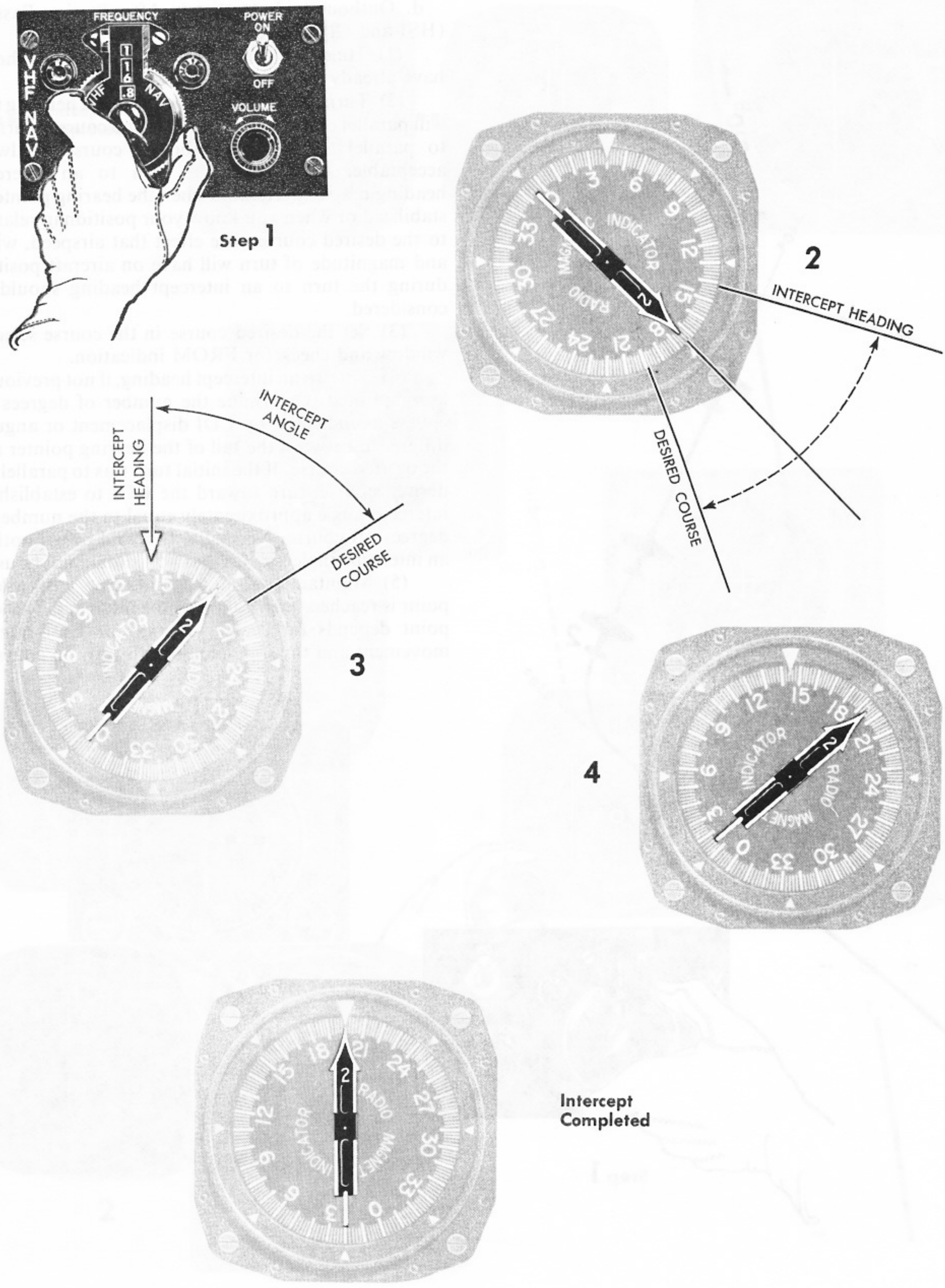


Figure 2-13. Continued.

d. Outbound - Immediately After Station Passage (HSI and CI) (figure 2-14):

(1) Tune and identify the station. This should have already been accomplished.

(2) Turn in the shorter direction to a heading that will parallel or intercept the outbound course. Turning to parallel the desired outbound course is always acceptable. Continuing the turn to an intercept heading may be preferable when the bearing pointer is stabilized or when you know your position in relation to the desired course. The effect that airspeed, wind, and magnitude of turn will have on aircraft position during the turn to an intercept heading should be considered.

(3) Set the desired course in the course selector window and check for FROM indication.

(4) Turn to an intercept heading, if not previously accomplished. Determine the number of degrees off course as indicated by CDI displacement or angular difference between the tail of the bearing pointer and the desired course. If the initial turn was to parallel the desired course, turn toward the CDI to establish an intercept angle approximately equal to the number of degrees off course. Normally, to avoid overshooting, an intercept angle greater than 45° should not be used.

(5) Maintain the intercept heading until a lead point is reached, then complete the intercept. The lead point depends on bearing pointer or CDI rate of movement and the time required to turn on course.

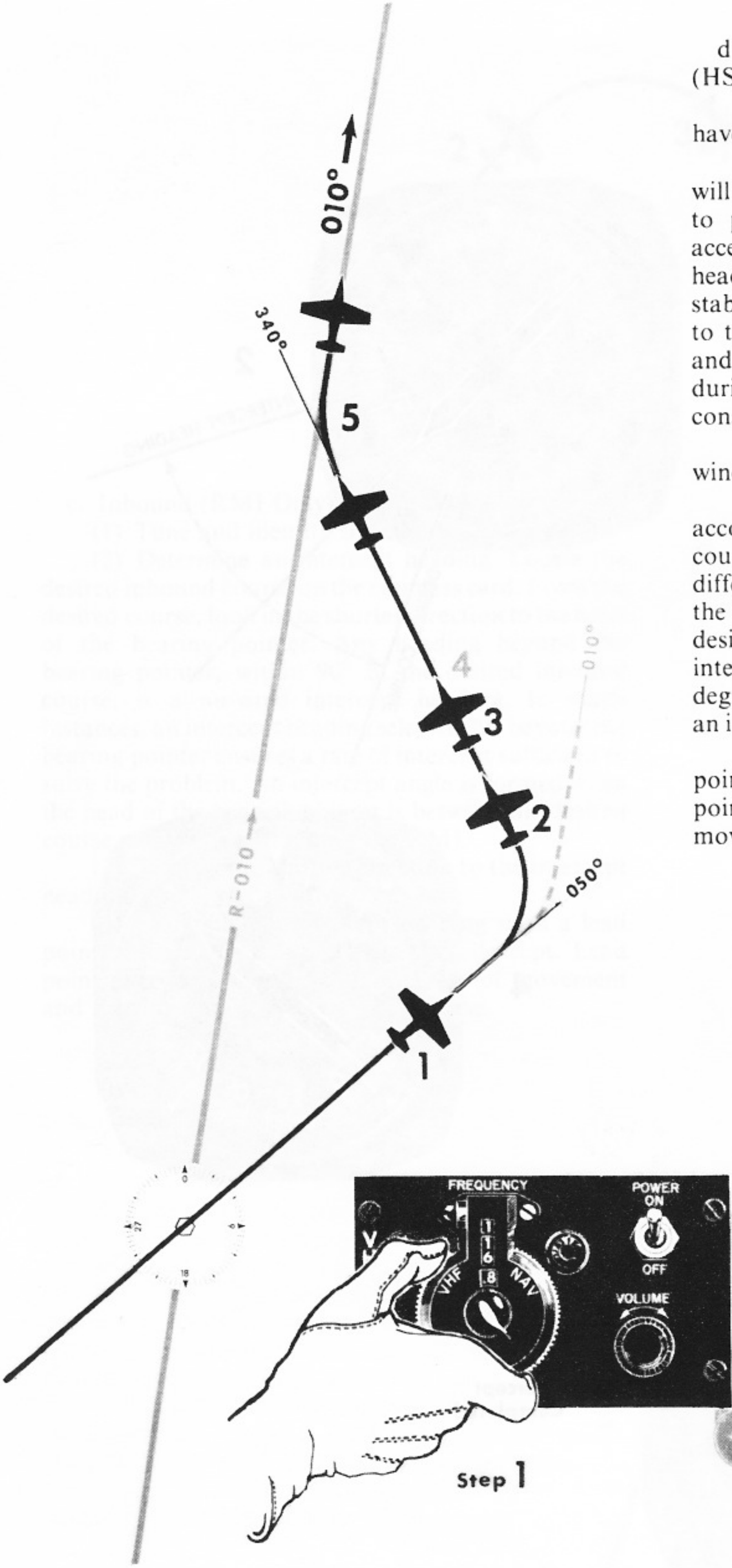


Figure 2-14. Outbound Course Interceptions — Immediately After Station Passage (Course Indicator and RMI; HSI) (para 2-15d).

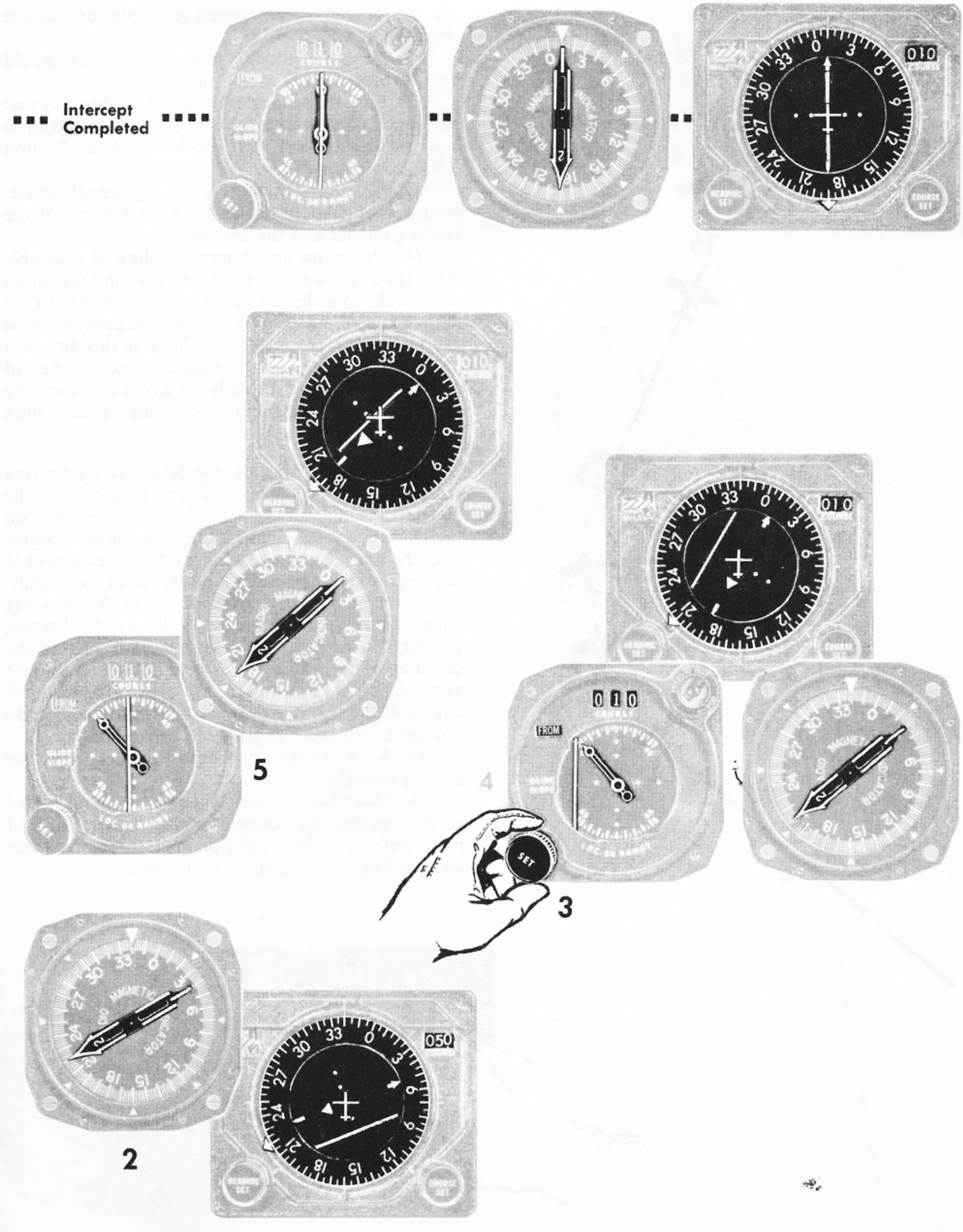
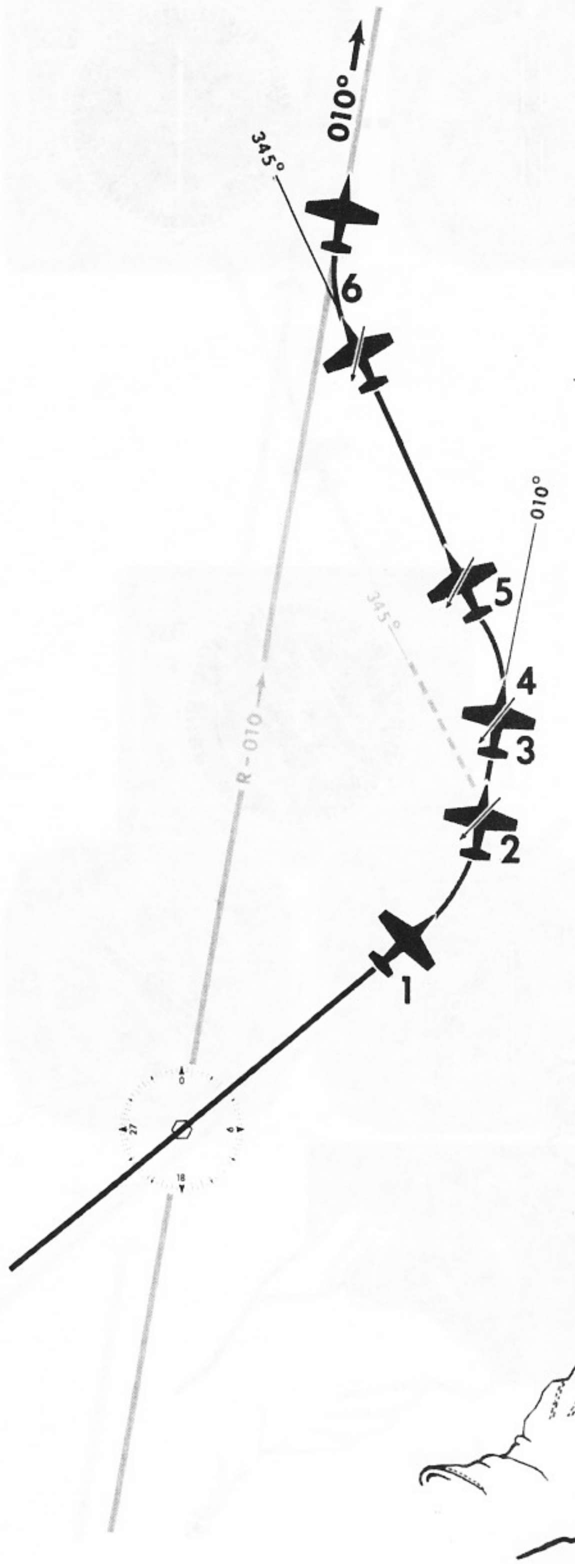


Figure 2-14. Continued.



e. Outbound — Immediately After Station Passage (RMI Only) (figure 2-15):

(1) Tune and identify the station. This should have already been accomplished.

(2) Turn in the shorter direction to a heading that will parallel or intercept the outbound course. Refer to d above (Outbound - Immediately After Station Passage (HSI and CI)).

(3) Determine the number of degrees off course. Note the angular difference between the tail of the bearing pointer and the desired course.

(4) Determine an intercept heading. If a suitable intercept angle was not established during the initial turn, look from the tail of the bearing pointer to the desired course. Any heading beyond the desired course is a no-wind intercept heading. Turn in this direction an amount approximately equal to the number of degrees off course. Normally, to avoid overshooting the course, do not use an intercept angle greater than 45°.

NOTE: On some aircraft, the RMI/BDHI bearing pointer does not have a tail. In this case, turn to the magnetic heading of the desired course. Continue on the outbound magnetic heading of the desired course until the bearing pointer stabilizes. Note the number of degrees the bearing pointer is off the tail of the aircraft. This is the number of degrees off course. Any heading change in the direction toward the head of the bearing pointer is a no-wind intercept heading. Turn in the direction of the head of the bearing pointer an amount approximately equal to the number of degrees off course. Normally, to avoid overshooting the course, do not use an intercept angle greater than 45°.

(5) Turn to an intercept heading, if not previously accomplished.

(6) Maintain the intercept heading until a lead point is reached, then complete the intercept. The lead point depends on the bearing pointer rate of movement and the time required to turn on course.

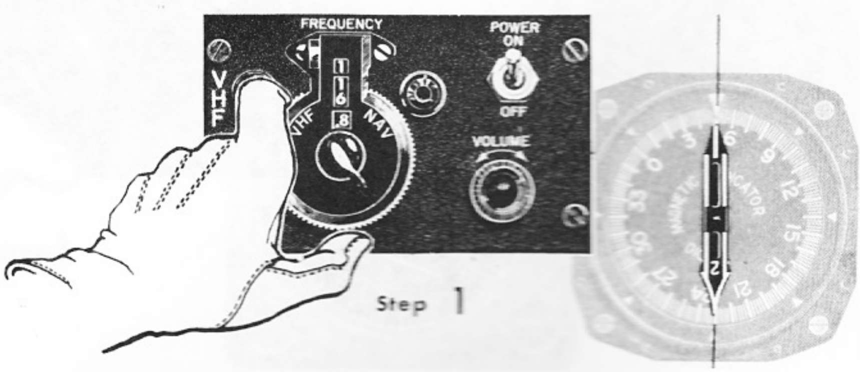


Figure 2-15. Outbound Course Interceptions — Immediately After Station Passage (RMI Only) (para 2-15e).

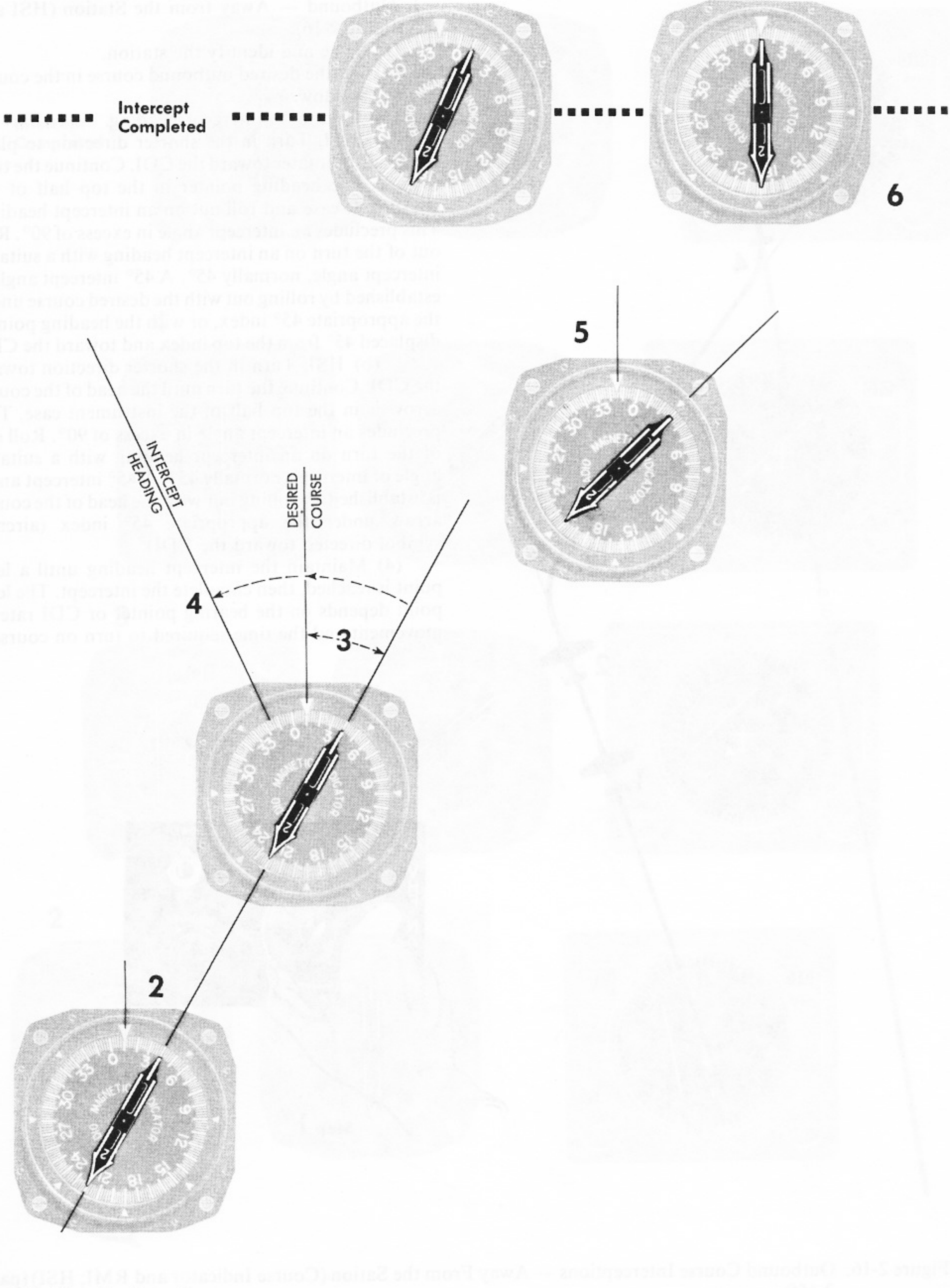


Figure 2-15. Continued.

f. Outbound — Away from the Station (HSI and CI) (figure 2-16):

(1) Tune and identify the station.

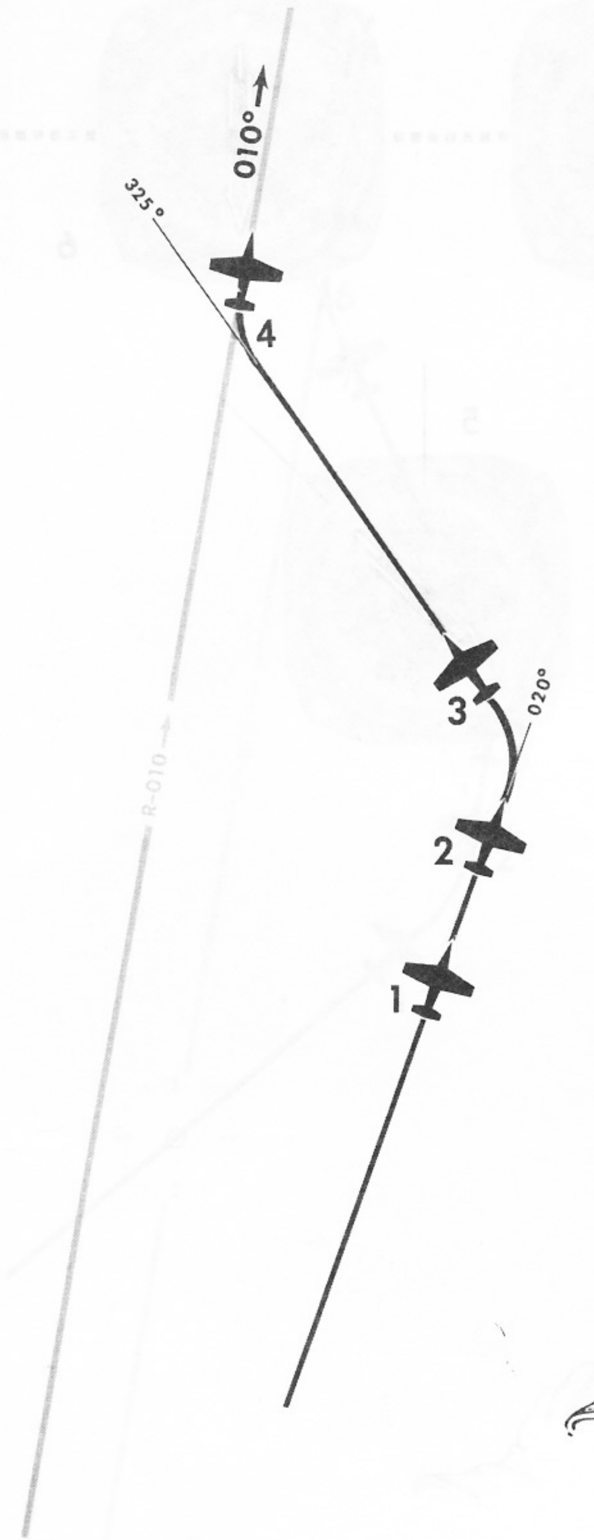
(2) Set the desired outbound course in the course selector window.

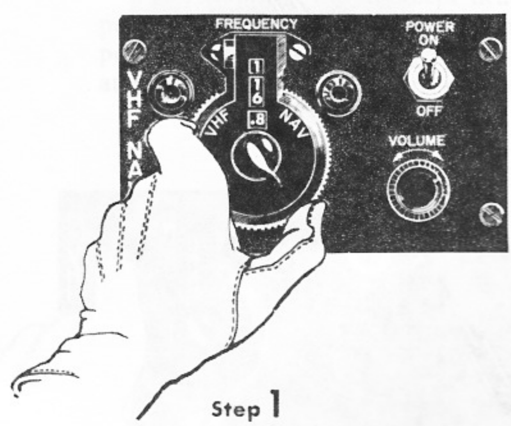
(3) Turn to an intercept heading.

(a) CI. Turn in the shorter direction to place the heading pointer toward the CDI. Continue the turn to place the heading pointer in the top half of the instrument case and roll out on an intercept heading. This precludes an intercept angle in excess of 90°. Roll out of the turn on an intercept heading with a suitable intercept angle, normally 45°. A 45° intercept angle is established by rolling out with the desired course under the appropriate 45° index, or with the heading pointer displaced 45° from the top index and toward the CDI.

(b) HSI. Turn in the shorter direction toward the CDI. Continue the turn until the head of the course arrow is in the top half of the instrument case. This precludes an intercept angle in excess of 90°. Roll out of the turn on an intercept heading with a suitable angle of intercept, normally 45°. A 45° intercept angle is established by rolling out with the head of the course arrow under the appropriate 45° index (aircraft symbol directed toward the CDI).

(4) Maintain the intercept heading until a lead point is reached, then complete the intercept. The lead point depends on the bearing pointer or CDI rate of movement and the time required to turn on course.





Step 1

Figure 2-16. Outbound Course Interceptions — Away From the Sation (Course Indicator and RMI; HSI) (para 2-15f).

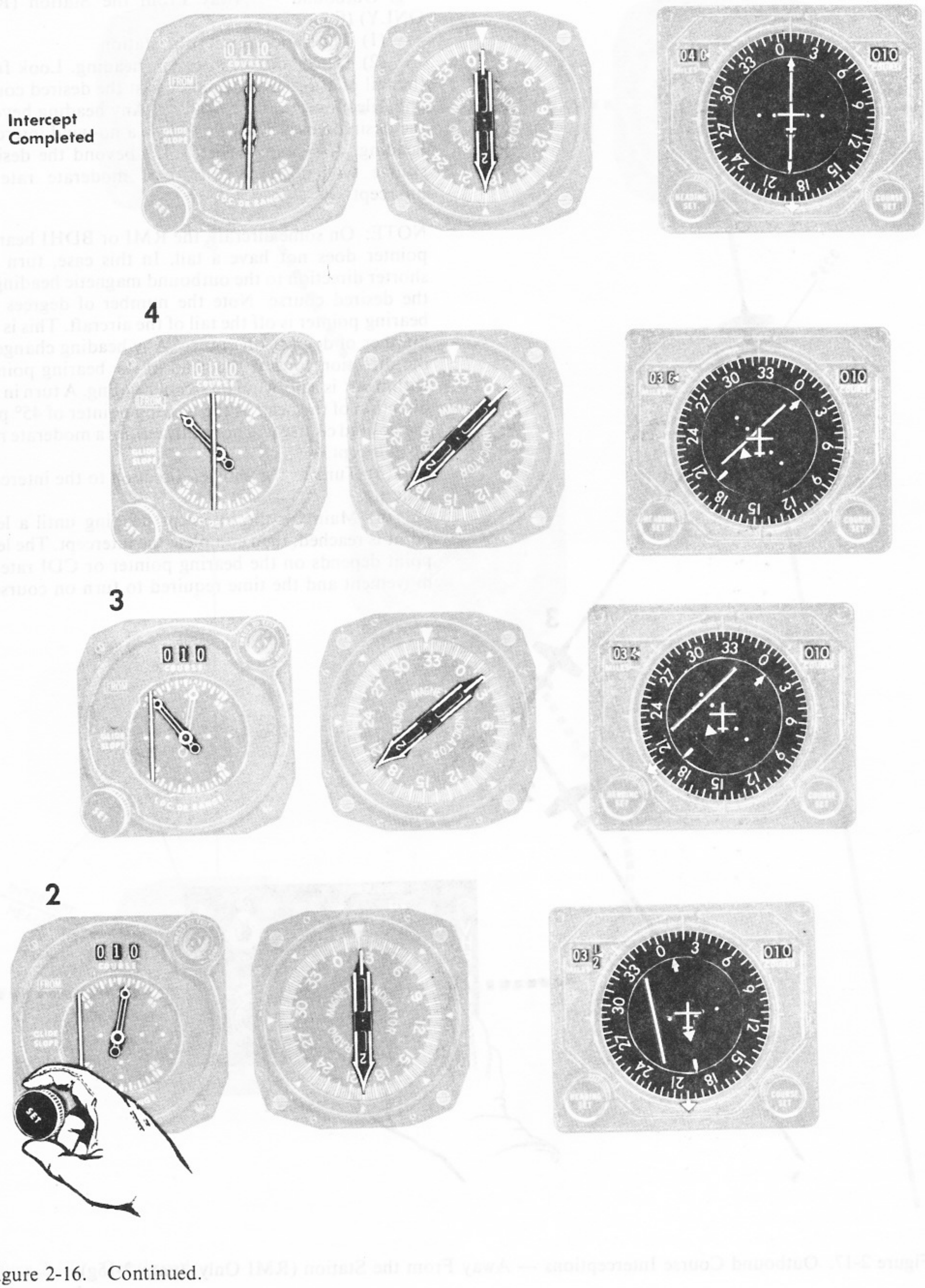


Figure 2-16. Continued.

g. Outbound — Away From the Station (RMI ONLY) (figure 2-17):

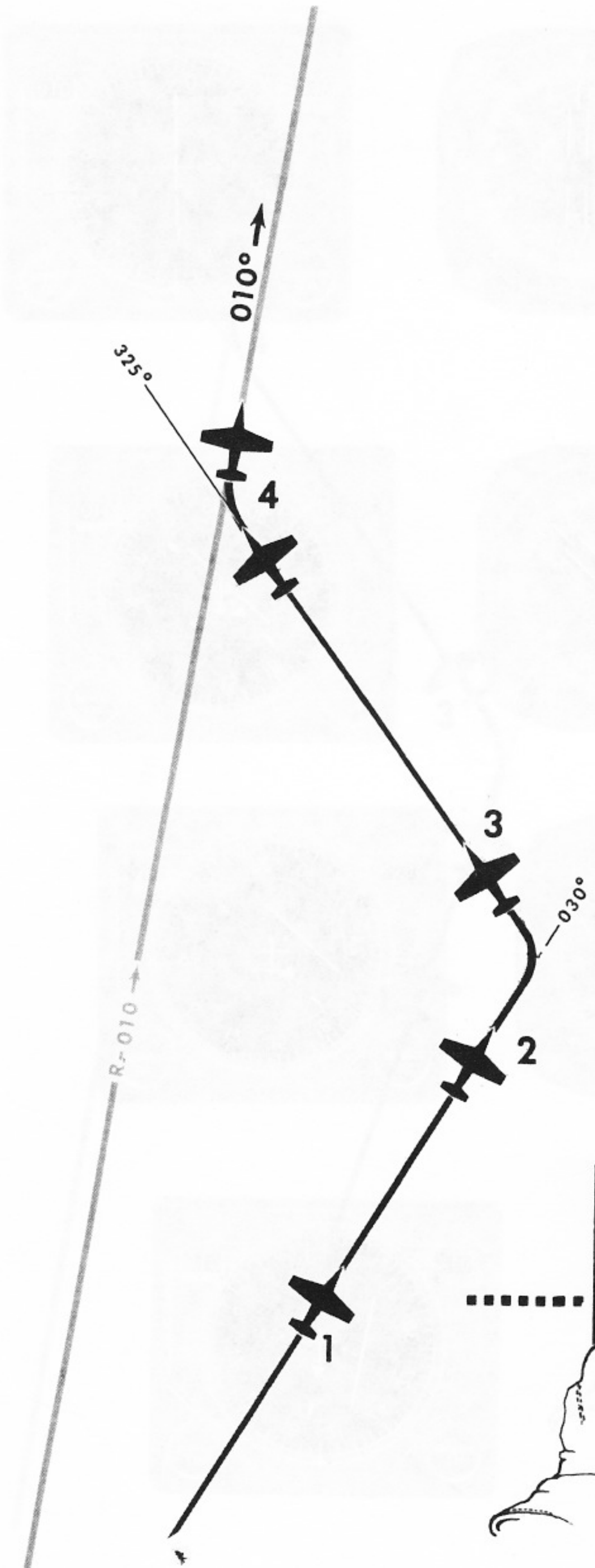
(1) Tune and identify the station.

(2) Determine an intercept heading. Look from the tail of the bearing pointer past the desired course and select an intercept heading. Any heading beyond the desired course, within 90°, is a no-wind intercept heading. A heading selected 45° beyond the desired course will normally ensure a moderate rate of intercept.

NOTE: On some aircraft, the RMI or BDHI bearing pointer does not have a tail. In this case, turn the shorter direction to the outbound magnetic heading of the desired course. Note the number of degrees the bearing pointer is off the tail of the aircraft. This is the number of degrees off course. Any heading change in the direction toward the head of the bearing pointer within 90° is a no-wind intercept heading. A turn in the direction of the head of the bearing pointer of 45° past the desired course will normally ensure a moderate rate of intercept.

(3) Turn in the shorter direction to the intercept heading.

(4) Maintain the intercept heading until a lead point is reached, then complete the intercept. The lead point depends on the bearing pointer or CDI rate of movement and the time required to turn on course.



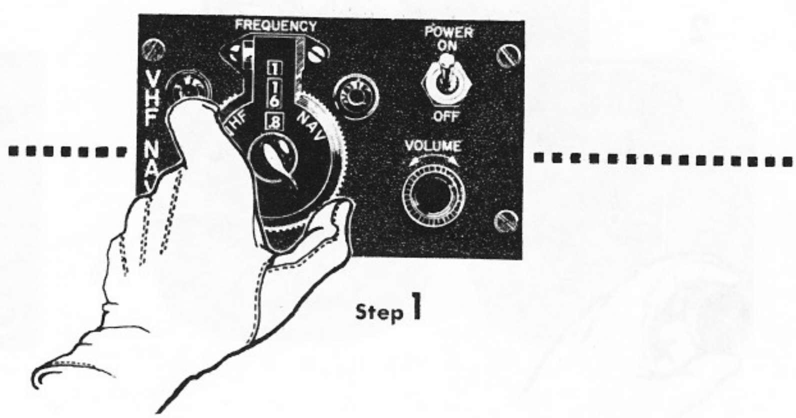


Figure 2-17. Outbound Course Interceptions — Away From the Station (RMI Only) (para 2-15g).

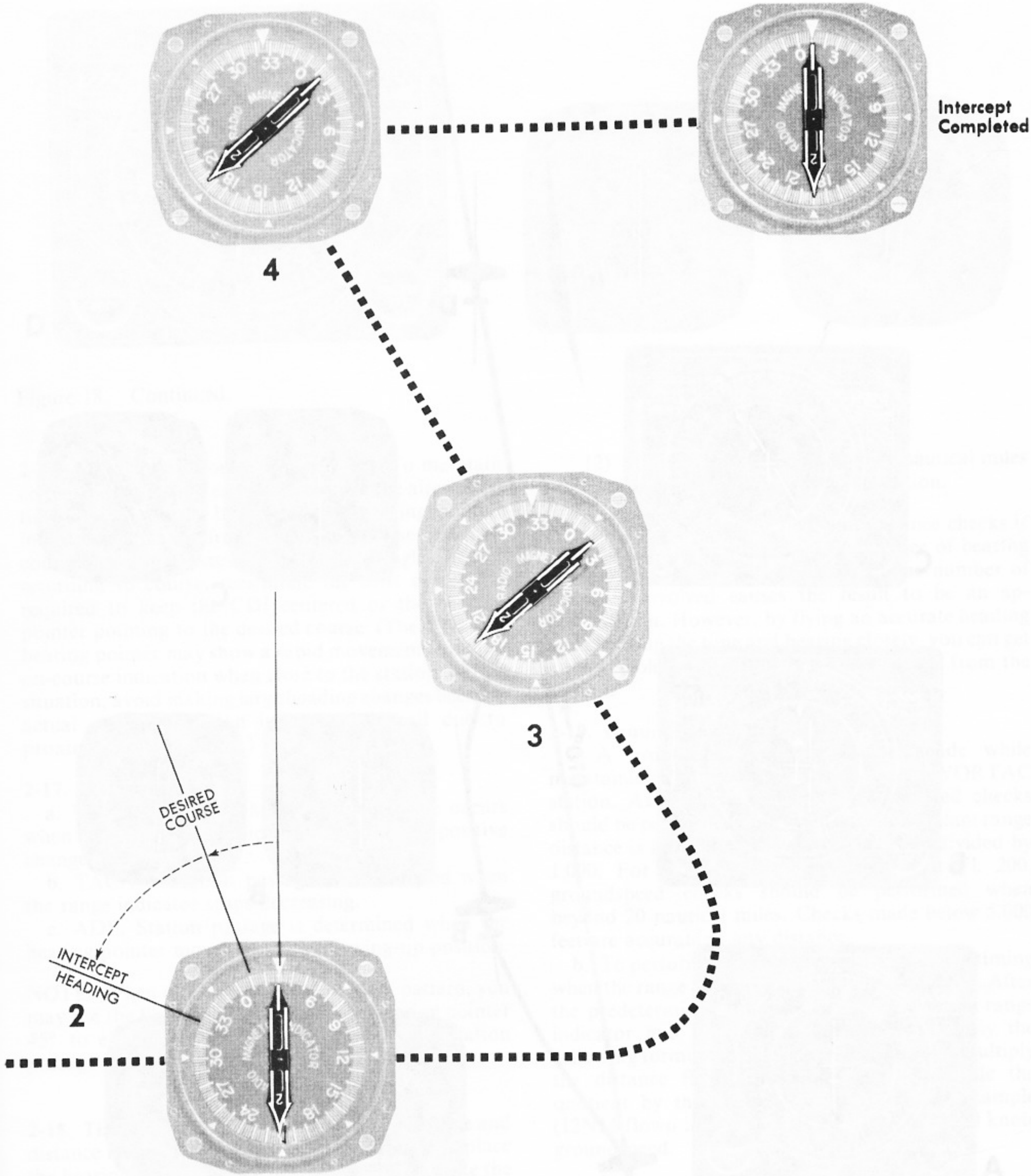


Figure 2-17. Continued.

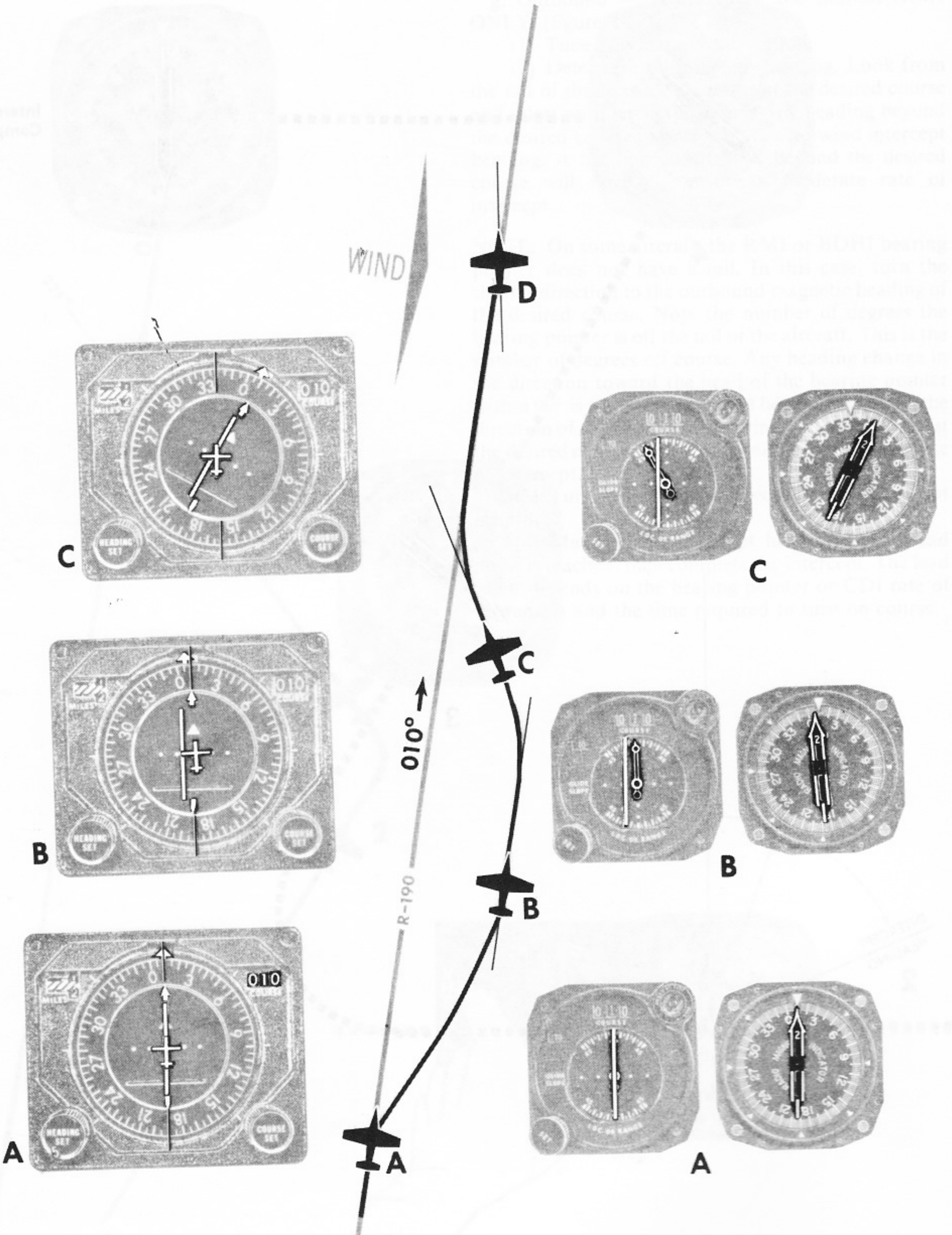
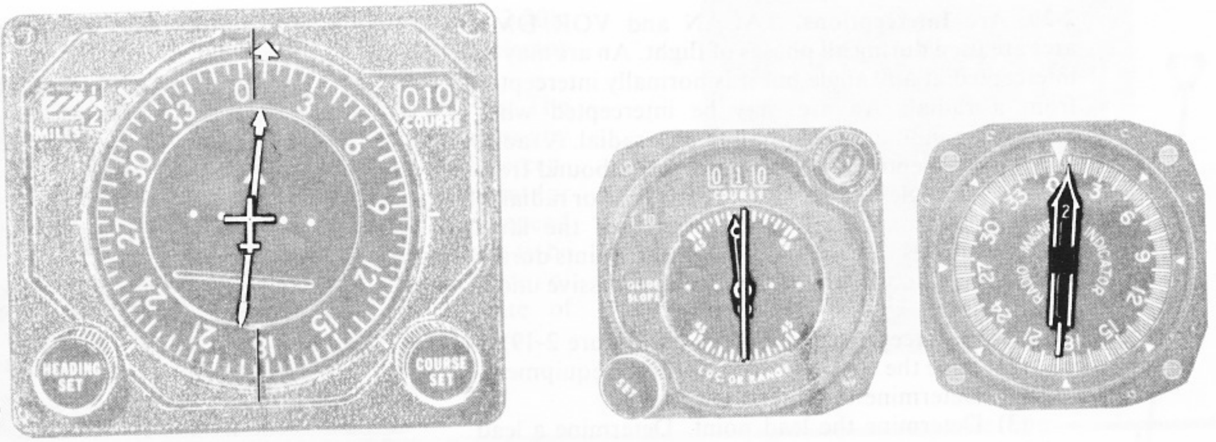


Figure 2-18. Maintaining Course (para 2-16).



D

Figure 18. Continued.

2-16. Maintaining Course (figure 2-18). To maintain course, fly a heading estimated to keep the aircraft on the selected course. If the CDI or bearing pointer indicates a deviation from the desired course, return to course avoiding excessive intercept angles. After returning to course, reestimate the drift correction required to keep the CDI centered or the bearing pointer pointing to the desired course. (The CDI and bearing pointer may show a rapid movement from the on-course indication when close to the station. In this situation, avoid making large heading changes because actual course deviation is probably small due to proximity to the station.)

2-17. Station Passage:

a. VOR and VOR/DME. Station passage occurs when the TO-FROM indicator makes the first positive change to FROM.

b. TACAN. Station passage is determined when the range indicator stops decreasing.

c. ADF. Station passage is determined when the bearing pointer moves through the wing-tip position.

NOTE: When established in the holding pattern, you may use the first definite move by the bearing pointer 45° to either side of the holding course as station passage indication for holding pattern timing.

2-18. Time and Distance Check. To compute time and distance from a station, first turn the aircraft to place the bearing pointer on the nearest 90° index. Note the time and maintain heading. When the bearing pointer has moved 10°, note the elapsed time in seconds and apply the following formulas to determine time and distance:

(1) Divide the elapsed time in seconds by the degrees of bearing change to obtain minutes from the bearing change): 120 ÷ 10 = 12 minutes from the station.

(2) Multiply your groundspeed in nautical miles per minute by the minutes from the station.

NOTE: The accuracy of time and distance checks is governed by the existing wind, the degree of bearing change, and the accuracy of timing. The number of variables involved causes the result to be an approximation. However, by flying an accurate heading and checking the time and bearing closely, you can get a reasonable estimate of time and distance from the station.

2-19. Groundspeed Check:

a. A groundspeed check can be made while maintaining a course to or from a TACAN/VORTAC station. As a guide, however, groundspeed checks should be performed only when the aircraft slant range distance is more than the aircraft altitude divided by 1,000. For example, if the aircraft is at FL 200, groundspeed checks should be performed when beyond 20 nautical miles. Checks made below 5,000 feet are accurate at any distance.

b. To perform the groundspeed check, begin timing when the range indicator shows a whole number. After the predetermined time has elapsed, check the range indicator and note the distance flown. Apply the following formula to determine groundspeed: multiply the distance flown times 60 and then divide the quotient by the elapsed time in minutes. Example (12NM flown in 2 minutes): 12 x 60 ÷ 2 = 360 knots groundspeed.

NOTE: For precise computation, time for longer periods and solve the problems on a computer. To simplify computations, use a 2-minute time check and multiply the distance traveled by 30; a 3-minute time check, distance times 20; or a 6-minute time check, distance times 10. A rapid groundspeed check can be accomplished by timing the range indicator for 36 seconds and multiplying the distance traveled by 100.

2-20. Arc Interceptions. TACAN and VOR/DME arcs are used during all phases of flight. An arc may be intercepted at any angle but it is normally intercepted from a radial. An arc may be intercepted when proceeding inbound or outbound on a radial. A radial may be intercepted either inbound or outbound from an arc. The angles of intercept (arc to radial or radial to arc) are approximately 90°. Because of the large intercept angles the use of accurate lead points during the interception will aid in preventing excessive under or overshoots.

a. Arc Interception From a Radial (figure 2-19):

(1) Tune the TACAN or VOR/DME equipment.

(2) Determine the direction of turn.

(3) Determine the lead point. Determine a lead point that will result in positioning the aircraft on or near the arc at the completion of the initial turn.

(4) When the lead point is reached, turn to intercept the arc.

(a) Monitor the bearing pointer and range indicator during the turn and roll out with the bearing pointer on or near the 90° index (wing-tip position).

(b) If the aircraft is positioned outside the arc, roll out with the bearing pointer above the 90° index; if inside the arc, roll out with the bearing pointer below the 90° index.

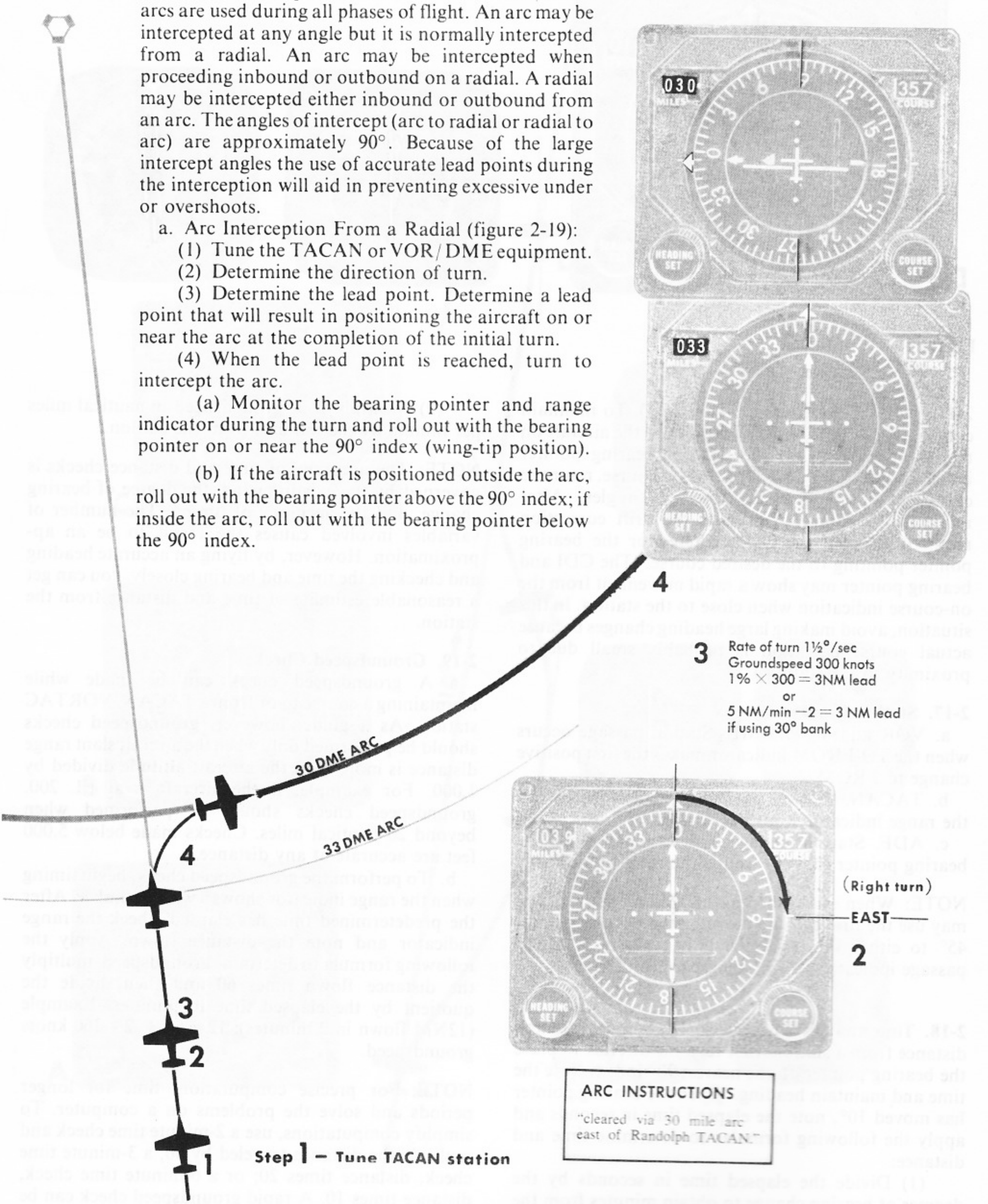


Figure 2-19. Arc Interception From a Radial (para 2-20a).

b. Radial Interception From an Arc (figure 2-20):

(1) Set the desired course in the course selector window.

(2) Determine the lead required in degrees. The interception of a radial from an arc is similar to any course interception, except that the angle of interception will usually approximate 90°. The lead point for starting the turn to intercept the course will depend upon several variables. These are the rate of turn to be used, the angle of interception, and the rate of movement of the bearing pointer. The rate of movement of the bearing pointer is governed by the size of the arc being flown, aircraft true airspeed, wind direction, and velocity.

(3) When the lead point is reached, turn to intercept the selected course. Monitor the course deviation indicator or bearing pointer during the turn and roll out on course or with a suitable correction to course.

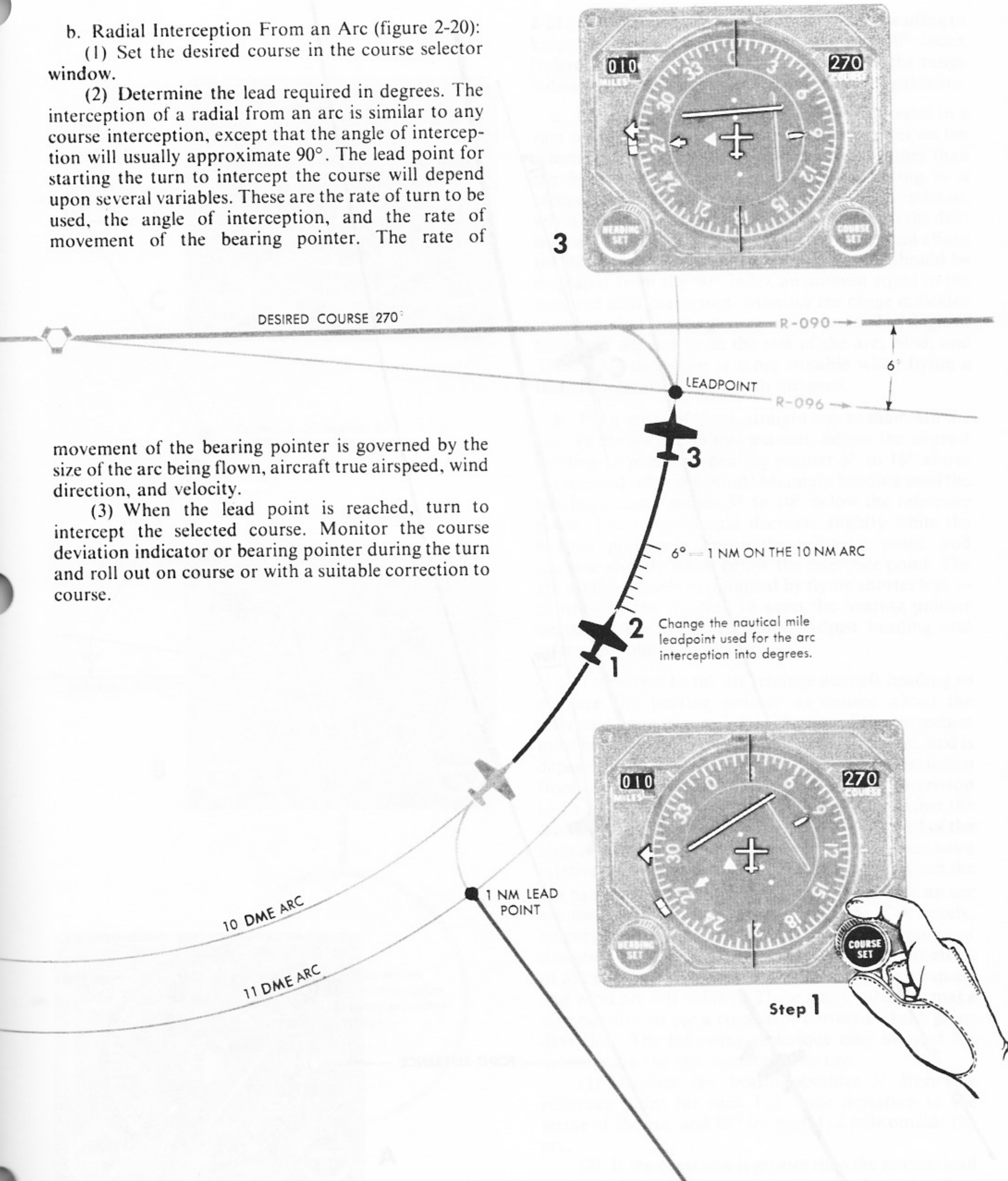


Figure 2-20. Radial Interception From an Arc (para 2-20b).

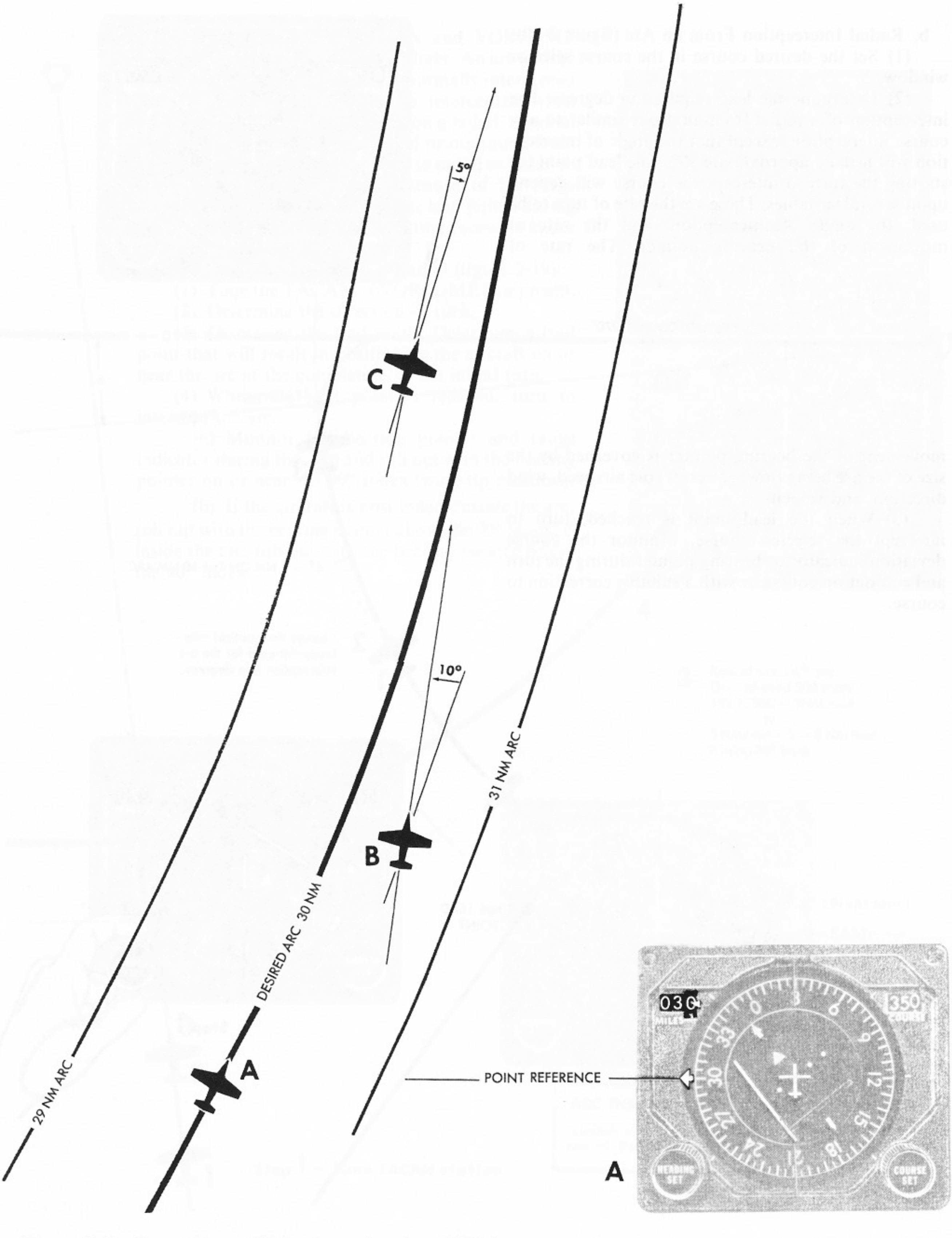


Figure 2-21. Correcting to Maintain an Arc (para 2-21c).

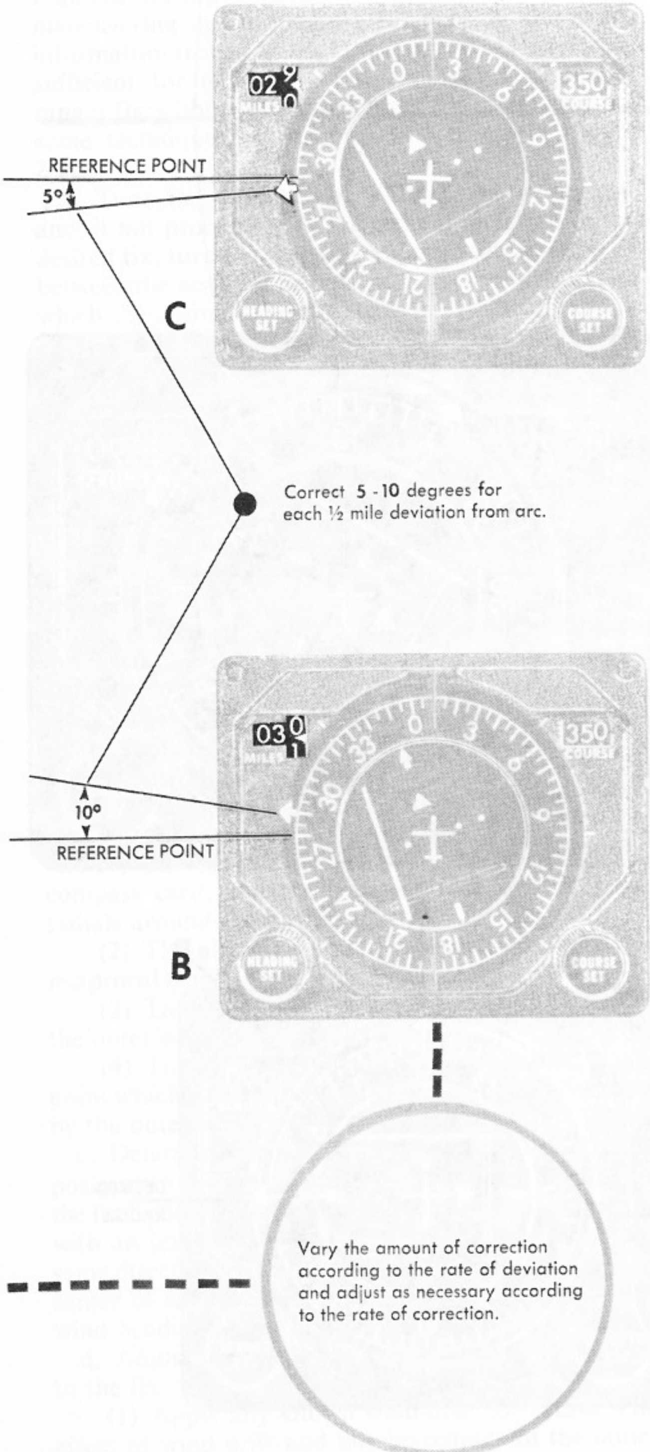


Figure 21. Continued.

2-21. Maintaining an Arc. Control aircraft heading to keep the bearing pointer on or near the 90° index (reference point), and the desired range in the range indicator. Some techniques for accomplishing this are:

a. Establish a small bank angle that will result in a rate of turn that will keep the bearing pointer on the selected reference point. A reference point other than the 90° index must be used when operating in a crosswind. If the aircraft drifts toward the station, select a reference point below the 90° index. If the drift is away from the station, select a reference point above the 90° index. The selected reference point should be displaced from the 90° index an amount equal to the required drift correction. Monitor the range indicator to ensure that the range remains constant. The angle of bank will depend upon the size of the arc, wind, and TAS. This technique is more suitable when flying a relatively small arc at a high airspeed.

b. Fly a series of short, straight legs to maintain the arc. To fly an arc in this manner, adjust the aircraft heading to place the bearing pointer 5° to 10° above the selected reference point. Maintain heading until the bearing pointer moves 5° to 10° below the reference point. The range should decrease slightly while the bearing pointer is above the reference point, and increase slightly when below the reference point. The arc is more closely maintained by flying shorter legs -- controlling the heading to keep the bearing pointer nearer to the reference point. Adjust heading and reference point as necessary.

c. To correct to the arc, change aircraft heading to displace the bearing pointer as desired about the reference point (figure 2-21). The size of the correction must be adequate to return the aircraft to the arc, and is dependent upon the magnitude and rate of deviation from the arc. The rate of deviation from or correction to an arc will vary with the size of the arc, whether the aircraft is inside or outside the arc, true airspeed of the aircraft, wind direction, and velocity. A small arc has a relatively sharp curvature, and deviation to or from the arc can occur rapidly. Corrections from inside an arc are assisted by the curvature of the arc. Conversely, corrections from outside the arc for a like amount of deviation must necessarily be larger to offset the effect of arc curvature. The effects of aircraft true airspeed and wind are self-evident. These many variables make it impossible to use a consistent correction for a given deviation. The following technique may be used for determining the size correction to use:

(1) Displace the bearing pointer 5° from the reference point for each 1/2 mile deviation to the inside of the arc, and 10° for each 1/2 mile outside the arc.

(2) If the deviation is greater than the normal lead required for a 90° interception, consider using "arc interception" procedures rather than "correcting to the arc."

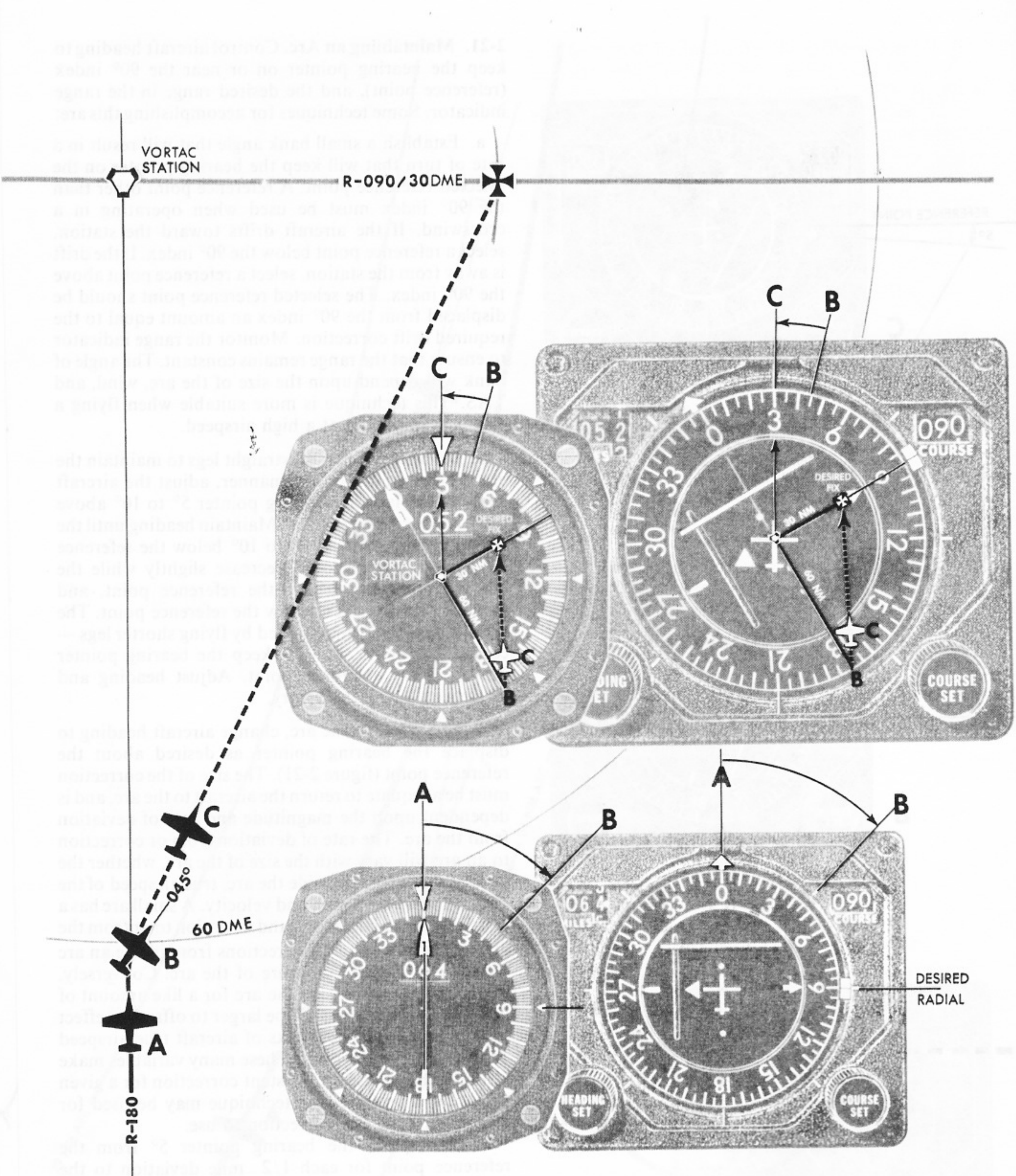


Figure 2-22. Proceeding Direct to a DME Fix (para 2-22).

2-22. Proceeding Direct to a VOR/DME or TACAN Fix. To proceed direct from one fix to another is often required during departures, approaches, or when maneuvering in a terminal area. Bearing and range information from a VOR/DME or TACAN facility is sufficient for navigating direct to any (radial and range) fix within reception range. The following are some techniques to accomplish a fix-to-fix (figure 2-22):

a. Tune the TACAN or VOR/DME equipment and, if not proceeding in the general direction of the desired fix, turn to a heading approximately half-way between the head of the bearing pointer and radial on which the desired fix is located.

(1) The objective is to turn in the general direction of the desired fix rather than fly away from the fix while attempting to determine a precise heading.

(2) When using an HSI, the desired radial may be set in the course selector window and the aircraft turned to a heading between the head of the bearing pointer and the head of the course arrow.

(3) The initial turn may be adjusted to roll out on a heading other than halfway between the bearing pointer and the desired fix and present location. If the range must be decreased, roll out on a heading closer to the bearing pointer. To increase the range, roll out on a heading closer to the desired radial.

b. Visualize the aircraft position and the desired fix on the compass card of an RMI or similar instrument. The following factors must be understood when visually establishing the aircraft position and the desired fix on the compass card.

(1) The station is located at the center of the compass card, and the compass rose simulates the radials around the station.

(2) The aircraft position is visualized along the reciprocal (radial) of the bearing pointer.

(3) The fix with the greater range is established at the outer edge of the compass card.

(4) The fix with the lesser range is visualized at a point which is proportional to the distance represented by the outer edge of the compass card.

c. Determine a precise heading from the aircraft position to the desired fix. Determine the heading to the fix by connecting the aircraft position to desired fix with an imaginary line. Establish another line in the same direction, parallel to the original line through the center of the compass card. This will establish a no-wind heading to the desired fix.

d. Adjust aircraft heading as necessary and proceed to the fix.

(1) Apply any known wind drift correction. The effect of wind drift and any inaccuracy of the initial solution may be compensated for by repeating the previous steps while en route. As the aircraft approaches the desired fix, adjust the heading as necessary to intercept the arc or radial, or to comply with route clearance beyond the fix.

(2) The distance to the desired fix can be estimated since the distance between the aircraft position and the desired fix is proportionate to the distance established from the center to outer edge of the compass card.

NOTE: The same problem can be easily and more accurately solved on the CPU/26A computer. This is done on the wind face by imagining that the center grommet is the station, and applying the same basic techniques as in b, c, and d above.

2-23. Lead Points:

a. Lead points for turns onto course are used in all phases of flight and are valuable aids to precise navigation. Determining a lead point that will result in positioning the aircraft on or very near the selected course is highly desirable.

b. The lead point can be determined by comparing CDI or bearing pointer movement (rate of intercept) to the time required to turn to course. The rate of movement of the bearing pointer is affected by angle of intercept, groundspeed, and distance from the station.

c. Many lead point computation techniques exist. Two of them are as follows:

(1) One technique is to compute the turn radius of the aircraft and adjust it for distance from the station and the angle of intercept to determine the required lead point. This technique can be used effectively in all situations, but does require multiple computations in some instances. The formulas become easy with practice.

(a) An approximate radius of turn in NM can be quickly determined as follows:

1. For 30° of bank, subtract 2 from the indicated mach number times 10; or subtract 2 from miles per minute. Examples: (.6 indicated mach minus 2) .6 x 10 — 2 = 4 NM turn radius; (4 NM per minute -2) 4-2 = 2 NM turn radius.

2. Use 1 percent of the groundspeed for a one-half standard rate turn or one-half of 1 percent for a standard rate turn. Examples: (240 knots GS) 240 x 1% (.01) = 2.4 NM turn radius for one-half standard rate turn; 240 x ½% (.005) = 1.2 NM turn radius for a standard rate turn.

3. For speeds below 150 knots, 1/2 NM turn radius is usually satisfactory for a standard rate turn.

(b) If intercepting an arc from a radial, further computation is not necessary since, for all practical purposes, it will be a 90° intercept and the computed lead point can be easily seen in DME on the range indicator. If intercepting a radial or course from an arc, further computation is necessary to convert the turn radius to degrees. This can be done in the following manner:

1. Divide the DME (at which the radial or course will be intercepted) into 60. This will be the number of degrees per nautical mile at that point.

Example (30 DME estimated intercept point): 60 ÷ 30 = 2° per nautical mile (figure 2-23). (The most convenient values to use are 10, 15, 20, 30, 40, and 60 NM values because they result in easy to use numbers. Additionally, the accuracy available in lead point computation does not demand more exact values.)

2. Multiply the degrees per nautical mile times the turn radius in nautical miles to obtain the lead point in degrees for a 90° intercept to a radial or course. Example (2NM turn radius and 2° per NM): 2 x 2 = 4° lead point.

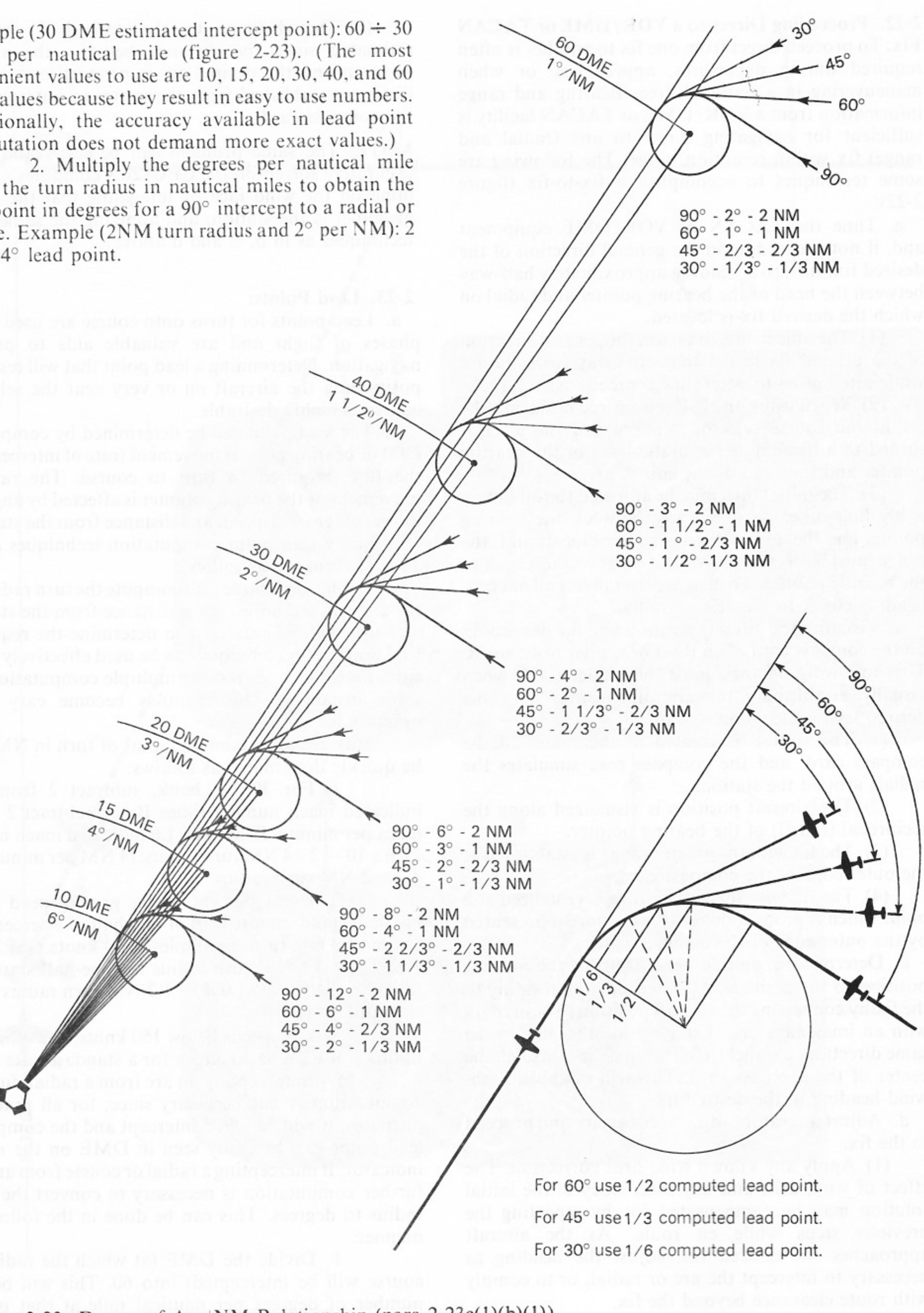
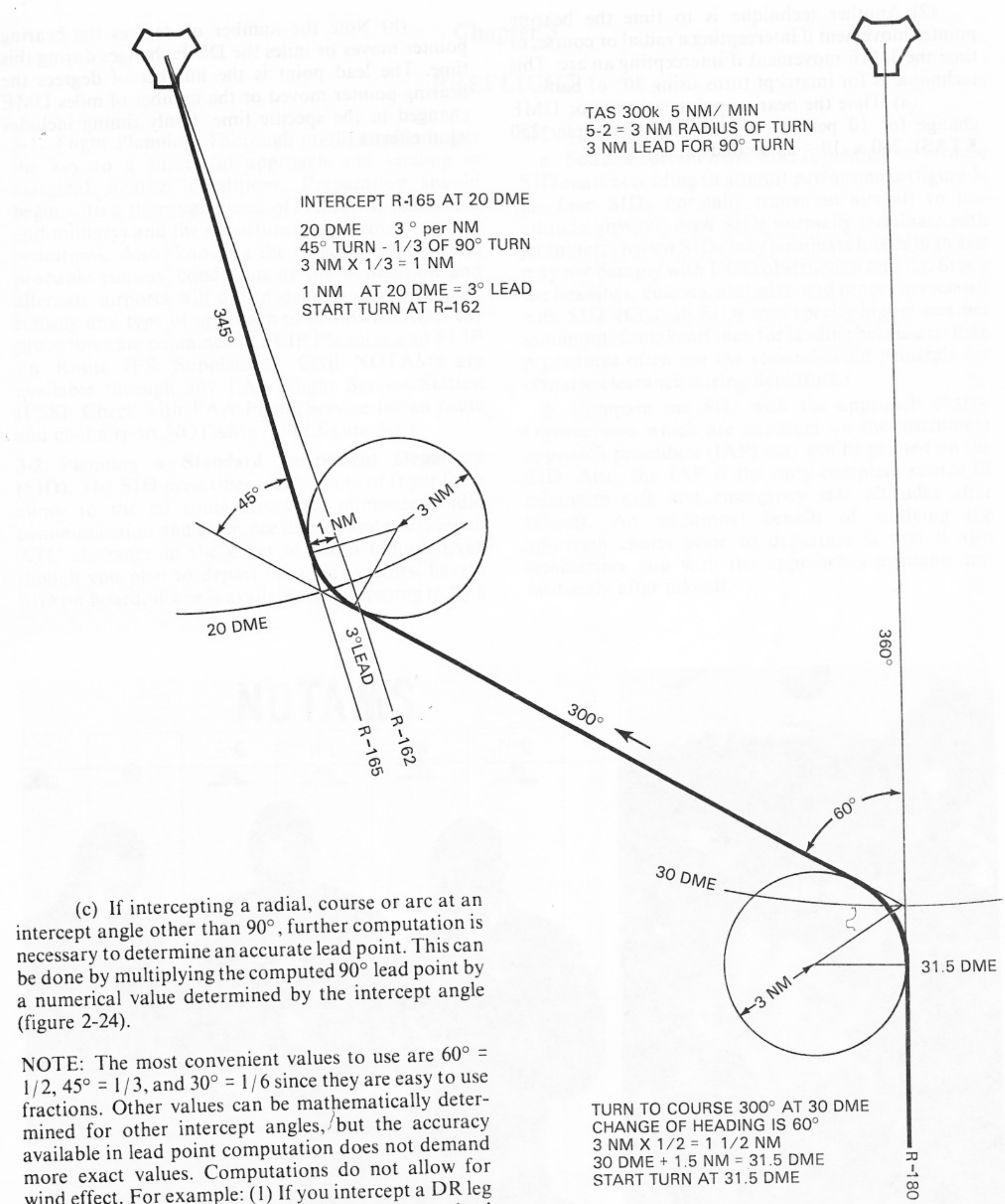


Figure 2-23. Degree of Arc/NM Relationship (para 2-23c(1)(b)(1)).



(c) If intercepting a radial, course or arc at an intercept angle other than 90°, further computation is necessary to determine an accurate lead point. This can be done by multiplying the computed 90° lead point by a numerical value determined by the intercept angle (figure 2-24).

NOTE: The most convenient values to use are 60° = 1/2, 45° = 1/3, and 30° = 1/6 since they are easy to use fractions. Other values can be mathematically determined for other intercept angles, but the accuracy available in lead point computation does not demand more exact values. Computations do not allow for wind effect. For example: (1) If you intercept a DR leg from a radial that requires a 60° turn and your lead point for a 90° turn is 3NM, then the lead point for a 60° turn is 1½ NM (3NM x ½ = 1½ NM). (2) If you intercept a radial from a DR leg with an intercept angle of 45° and the lead point for a 90° turn is 9°, then the lead point for 45° of turn is 3° (9° x 1/3 = 3°).

Figure 2-24. Lead Points for Turns of Less than 90 Degrees (para 2-23c(1)(c)).

(2) Another technique is to time the bearing pointer movement if intercepting a radial or course, or time the DME movement if intercepting an arc. This technique is for intercept turns using 30° of bank.

(a) Time the bearing pointer change or DME change for 10 percent of the TAS. Example (250 KTAS): 250 x .10 = 25 seconds.

(b) Note the number of degrees the bearing pointer moves or miles the DME changes during this time. The lead point is the number of degrees the bearing pointer moved or the number of miles DME changed in the specific time. (Only timing includes wind effect.)

Chapter 3

PREFLIGHT

3-1. Flight Planning. Thorough preflight planning is the key to a successful approach and landing in marginal weather conditions. Preparation should begin with a thorough check of NOTAMs (both civil and military) and the departure and en route weather conditions. Also, knowing the forecast weather and probable runway conditions at the destination and alternate airports will aid in determining the active runway and type of approach to be flown. (NOTAM procedures are contained in FLIP Planning and FLIP En Route IFR Supplement. Civil NOTAMs are available through any FAA Flight Service Station (FSS). Check with FAA Flight Service for en route and civil airport NOTAMs.) (See figure 3-1.)

3-2. Planning a Standard Instrument Departure (SID). The SID prescribes a safe route of flight for a climb to the en route structure, minimizes radio communication and clearance delays, and provides an ATC clearance in the event of radio failure. Even though you plan to depart via radar vectors, have a SID on board, if one is available. In preparing to fly a SID, you should:

a. Select a current *high, low, combined,* or *civilian* SID chart according to aircraft performance (figure 3-2). *Low* SIDs normally transition aircraft to low altitude airways; *high* SIDs normally terminate with jet routes; *civilian* SIDs may terminate low or high and may not comply with DOD obstruction criteria. Study the headings, courses, altitudes, and ranges associated with SID. (Civilian SIDs may specify higher weather minimums for takeoff than for landing because civilian procedures often use the see-and-avoid principle for obstacle clearance during departure.)

b. Compare the SID with the approach charts. Obstructions which are apparent on the instrument approach procedure (IAP) may not be printed on the SID. Also, the IAP is the only complete source of minimum safe and emergency safe altitudes after takeoff. An additional benefit of studying the approach charts prior to departure is that it also familiarizes you with the approaches available immediately after takeoff.

Figure 3-1. Planning the Approach and Landing Begins Here. . . . . .Not Here (para 3-1).

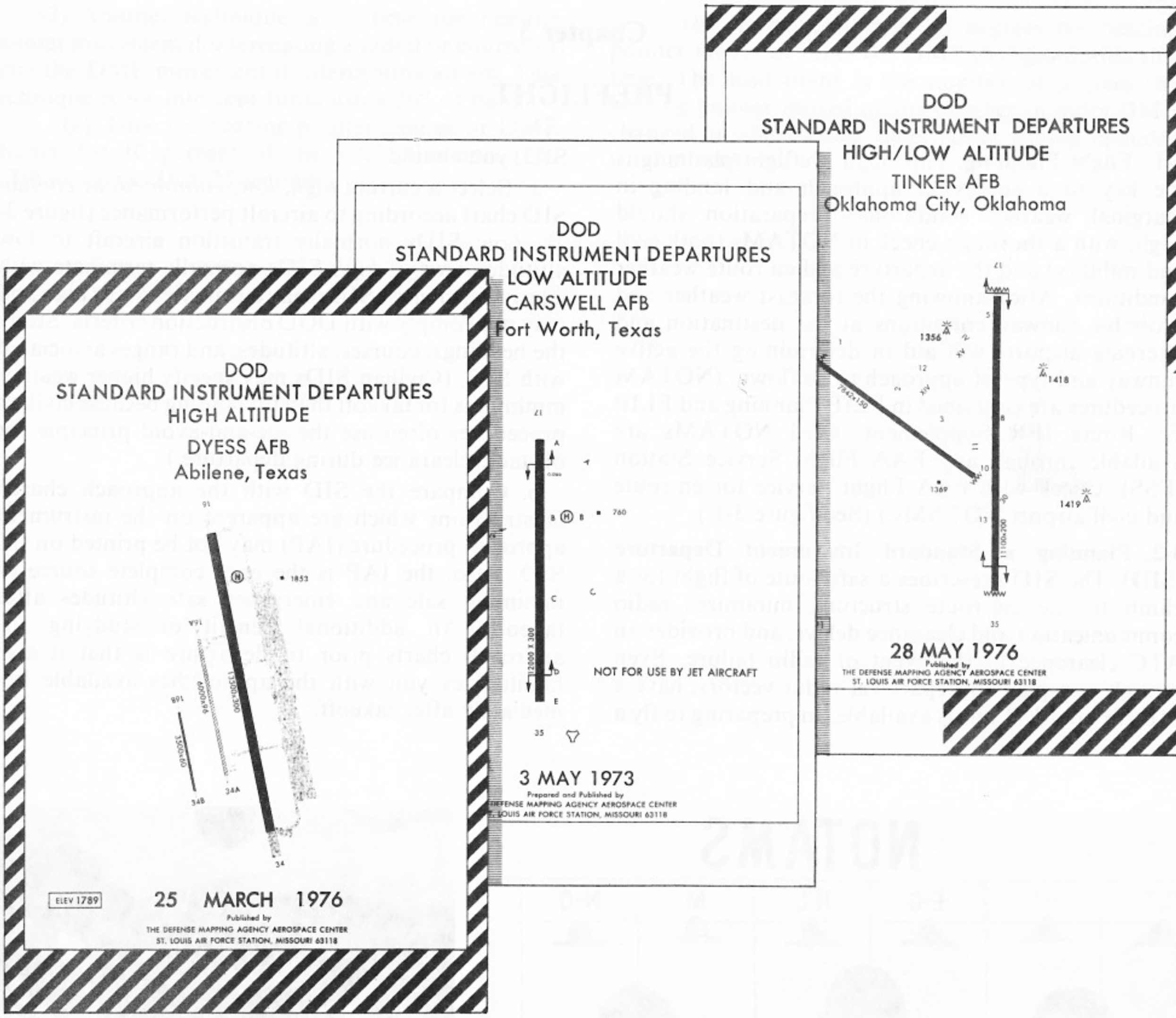


Figure 3-2. High, Low, and Combined High and Low SID (para 3-2a).

c. Study the climb rate/gradient (figure 3-3). In the absence of climb gradient information, an aircraft is expected to climb a rate of at least 150 feet per nautical mile. If the gradient exceeds this rate, the SID will provide a chart to depict the required vertical velocity. If the aircraft's capability to meet the climb gradient is doubtful, you should either select a SID with an acceptable gradient, reduce aircraft weight, or request a VFR climb, if necessary. Requesting a radar departure in lieu of a SID may not necessarily solve a climb gradient problem since the controller has no way of knowing the aircraft's climb capability. If you choose this departure option, coordinate your requirements with the controlling agency prior to takeoff.

3-3. Planning for En Route. Preflight planning of the en route portion should be adequate to ensure a safe and efficient flight. As a minimum, aircrews should review:

a. The intended route of flight using current flight publications.

b. En route NOTAMs. (Check FAA NOTAMs through an FAA Flight Service Station.)

c. En route weather.

d. The appropriate FLIP products to ensure compliance with any special procedures which may apply.

e. Emergency diversion fields and approaches.

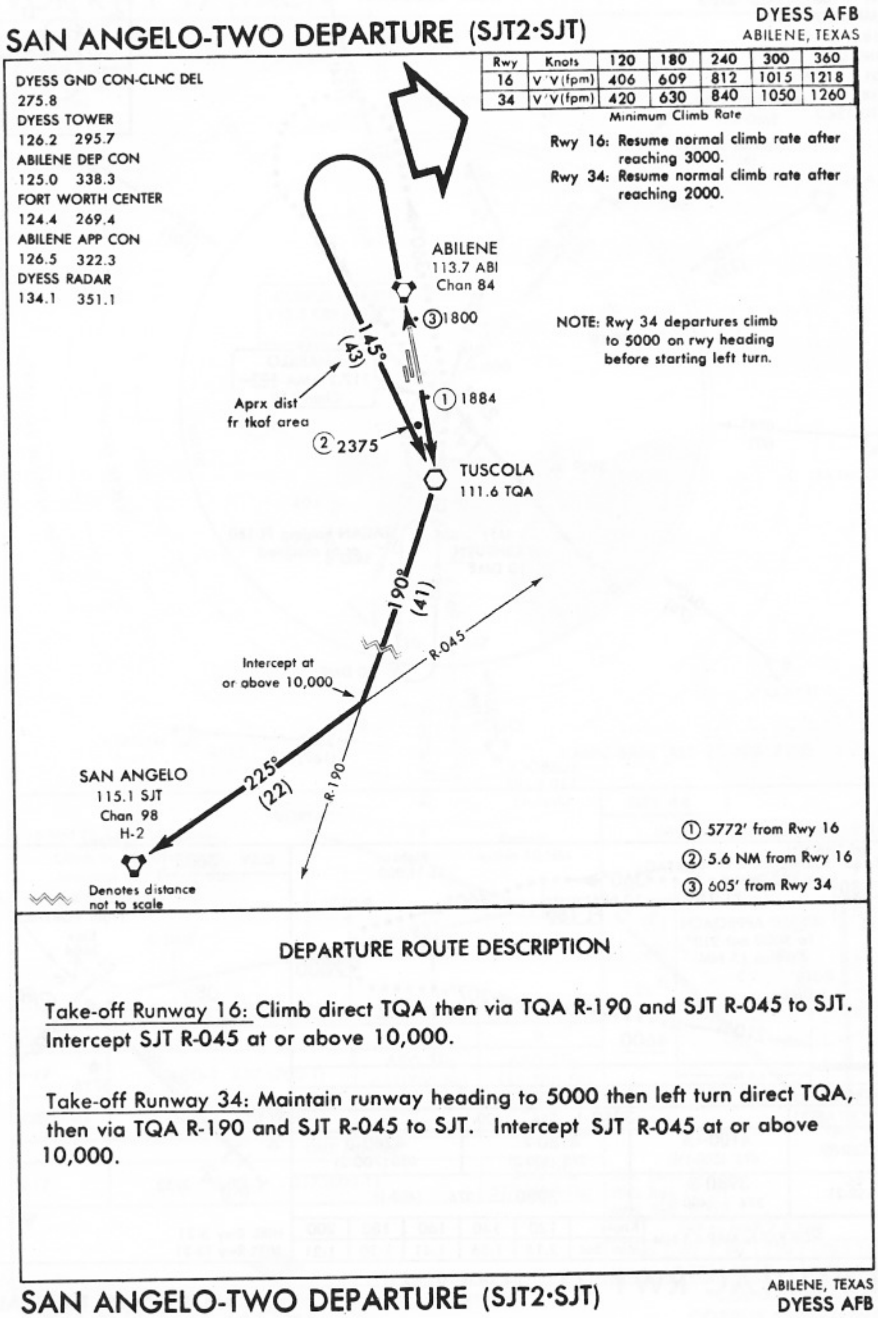
3-4. Planning the Approach. Preparation for flying an instrument approach begins with a study of the approach depiction during preflight planning. The end result of an approach - a landing or a missed approach - can be directly dependent upon the pilot's familiarity with the approach depiction.

a. Aircraft Categories and Instrument Approach Procedures Selection:

(1) Aircraft are assigned categories as designated in FLIP General Planning. An aircraft can fly an IAP only for its own category or higher (for example, a category B aircraft may fly an approach using category C minimums).

(2) A current copy of the appropriate IAP chart must be available in the aircraft. Low altitude IAP charts depict instrument approaches for categories A, B, C, and D aircraft. High altitude IAP charts depict instrument approaches for category C, D, and E aircraft. When an operational requirement exists, the low altitude IAP charts may depict category E procedures.

NOTE: Consult the Military Aviation Notice (MAN) to ensure the approach selected is current.



Rwy	Knots	120	180	240	300	360
16	V'V(fpm)	406	609	812	1015	1218
34	V'V(fpm)	420	630	840	1050	1260

Minimum Climb Rate

DEPARTURE ROUTE DESCRIPTION

Take-off Runway 16: Climb direct TQA then via TQA R-190 and SJT R-045 to SJT. Intercept SJT R-045 at or above 10,000.

Take-off Runway 34: Maintain runway heading to 5000 then left turn direct TQA, then via TQA R-190 and SJT R-045 to SJT. Intercept SJT R-045 at or above 10,000.

Figure 3-3. SID Minimum Climb Gradient (para 3-2c).

(3) Ensure that the approach you select is compatible with the navigation equipment installed in your aircraft.

(a) If the IAP is annotated VORTAC, a VOR/DME or TACAN equipped aircraft may fly the approach (figure 3-4). An example would be VORTAC-RWY 26. However, some VORTAC approaches are designed so that VOR only equipped aircraft may also fly the approach. If you have VOR only, study the approach to determine if DME is required.

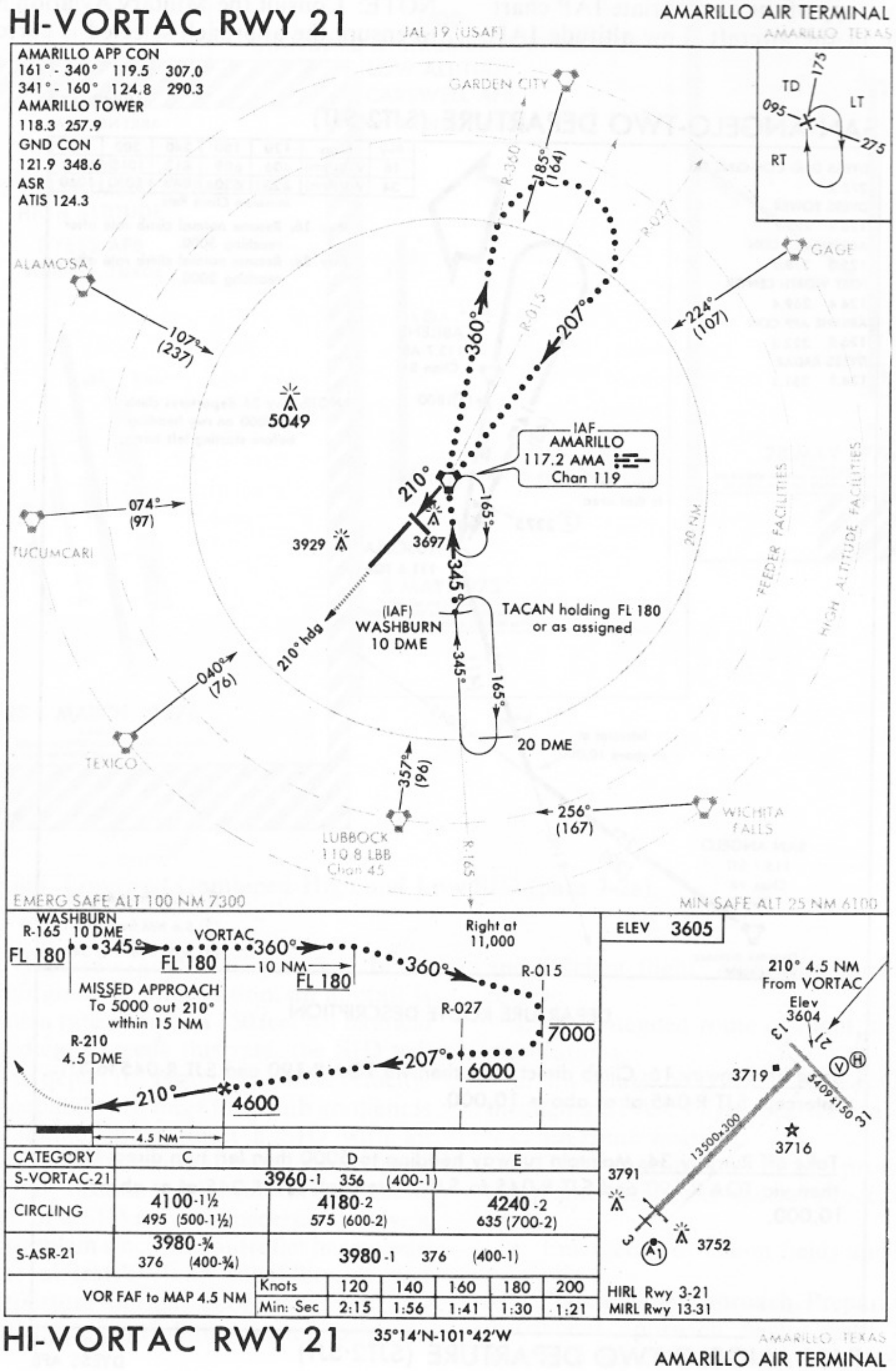


Figure 3-4. VORTAC Approach (para 3-4a(3)(a)).

(b) Some VOR approaches are approved for use by TACAN equipped aircraft. These will be designated by the term "(TAC)" printed adjacent to the name of the procedure; for example, VOR-A(TAC) (figure 3-5).

(c) VOR/DME approaches without the term (TAC) are not authorized for TACAN only aircraft.

(d) When the name of the approach is followed by a letter such as A, B, C, etc., the approach is designed for circling minimums only. They would be listed VOR-A, TACAN-B, NDB-C, etc.

(4) Radar minimums by aircraft category are depicted in the IFR supplement and may also be printed on the IAP chart.

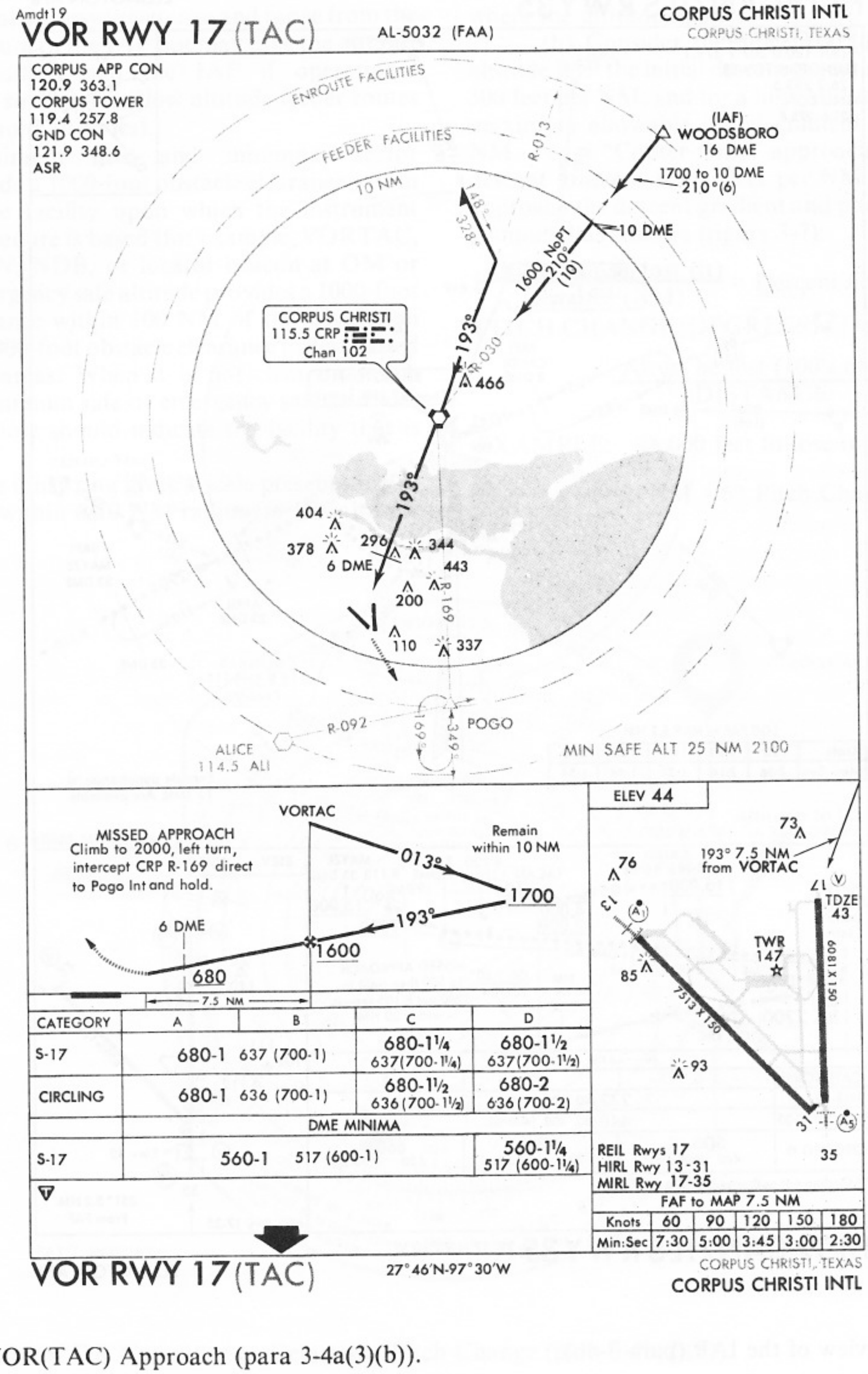


Figure 3-5. VOR(TAC) Approach (para 3-4a(3)(b)).

b. Reviewing an IAP (figure 3-6). Prior to departure, you should become familiar with all aspects of the IAP so that during the recovery you can concentrate on flying the maneuver rather than trying to fly and interpret it simultaneously. Here are some important areas to consider and techniques to use:

(1) Plan View:

(a) Note the general ground track of the approach, the NAVAIDs that provide the course guidance, and the NAVAID location. (The NAVAID(s) which appear in the name of an IAP are the NAVAID(s) which provide the final approach guidance. Other types of NAVAIDs *may* be required to accomplish the approach.)

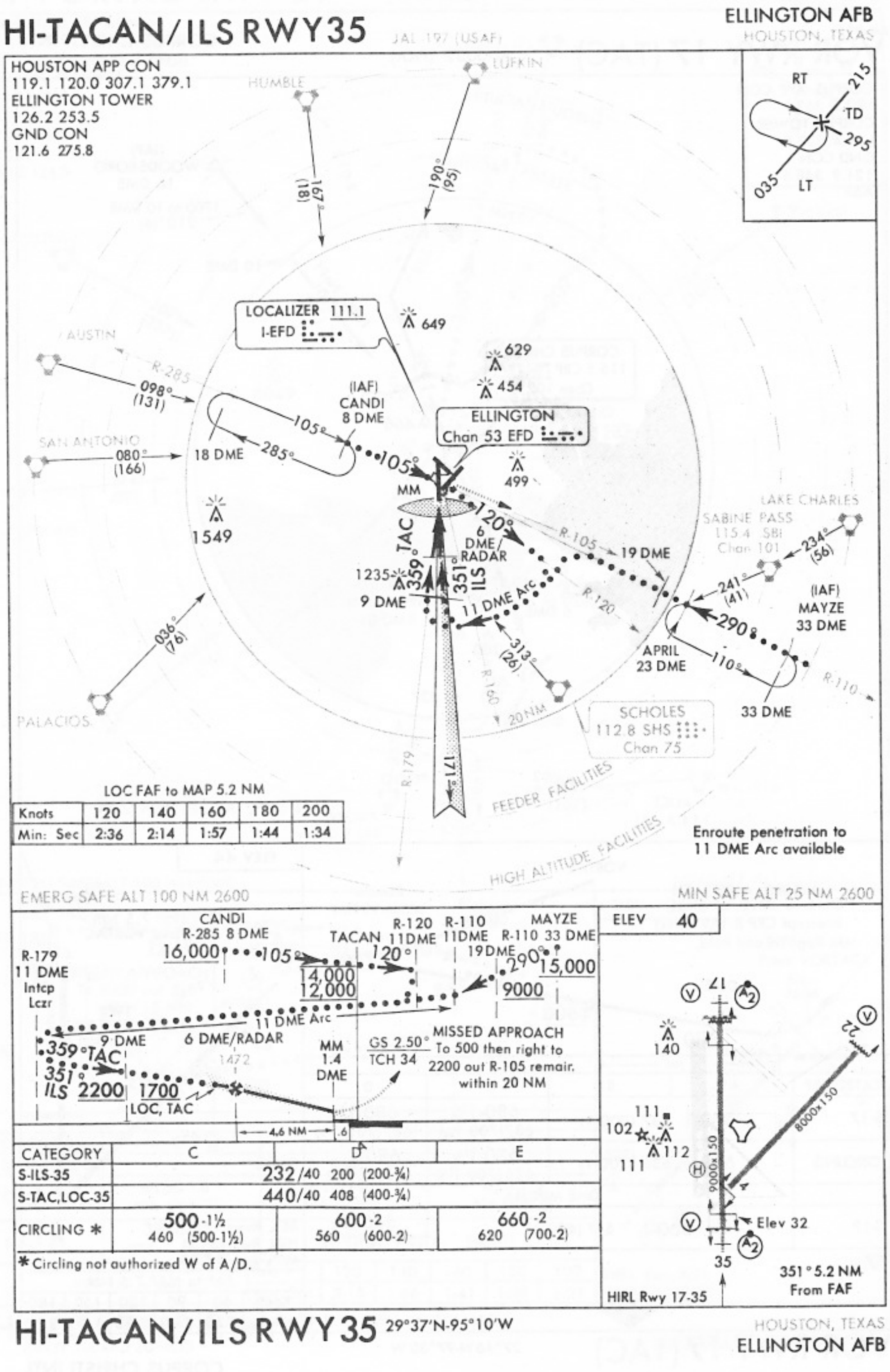


Figure 3-6. Review of the IAP (para 3-4b).

(b) Note the location of the holding pattern and its relation to the IAF.

(c) Mentally fly the approach from the initial approach fix (IAF) to the missed approach point (MAP) and determine the lead points for radial, course, or arc interceptions.

(d) Identify the point where the aircraft should be configured for landing.

(e) Terminal routings from en route or feeder facilities normally provide a course and range from the en route structure to the IAF but may take the aircraft to a point other than the IAF if operational circumstances so require. (Low altitude feeder routes provide minimum altitudes).

(f) Minimum safe and minimum sector altitudes provide a 1000-foot obstacle clearance within 25 NM of the facility upon which the instrument approach procedure is based (for example, VORTAC, VOR, TACAN, NDB, or locator beacon at OM or MM). An emergency safe altitude provides a 1000-foot obstacle clearance within 100 NM of the navigation facility, or a 2000-foot obstacle clearance in designated mountainous areas. When it is not clear on which facility the minimum safe or emergency safe altitudes are based, a note should indicate the facility that is used.

(g) The inner ring gives a scale presentation of the approach within a 10 NM radius for low altitude approaches and a 20 NM radius for high altitude approaches. Some, but not necessarily all, obstacles are depicted. This inner ring is normally necessary for better portrayal of the IAP.

(2) Profile View:

(a) Note the altitude restrictions. Minimum, maximum, mandatory, and recommended altitudes normally precede the fix or facility to which they apply. If this is not feasible, an arrow will indicate exactly where the altitude applies.

(b) Consider the descent gradient. For a low altitude IAP the initial descent gradient will not exceed 500 feet per NM; and for a high altitude approach, the maximum allowable initial gradient is 1000 feet per NM. For a "Copter Only" approach, the maximum descent gradient is 800 feet per NM. For a TACAN approach the descent gradient and pitch change can be computed as follows (figure 3-7):

$$\frac{\text{Altitude to be lost (ft)}}{\text{Distance (NM)}} = \text{Descent Gradient ft/NM}$$

$$\text{PITCH CHANGE (DEGREES)} = \text{Descent Gradient} = \frac{\text{Alt to be lost (100's of ft)}}{\text{DISTANCE}}$$

EXAMPLE: 18,000 feet to lose in 30 NM

$$\frac{18{,}000}{30} = 600 \text{ ft/NM} = 6^\circ \text{ Pitch Change}$$

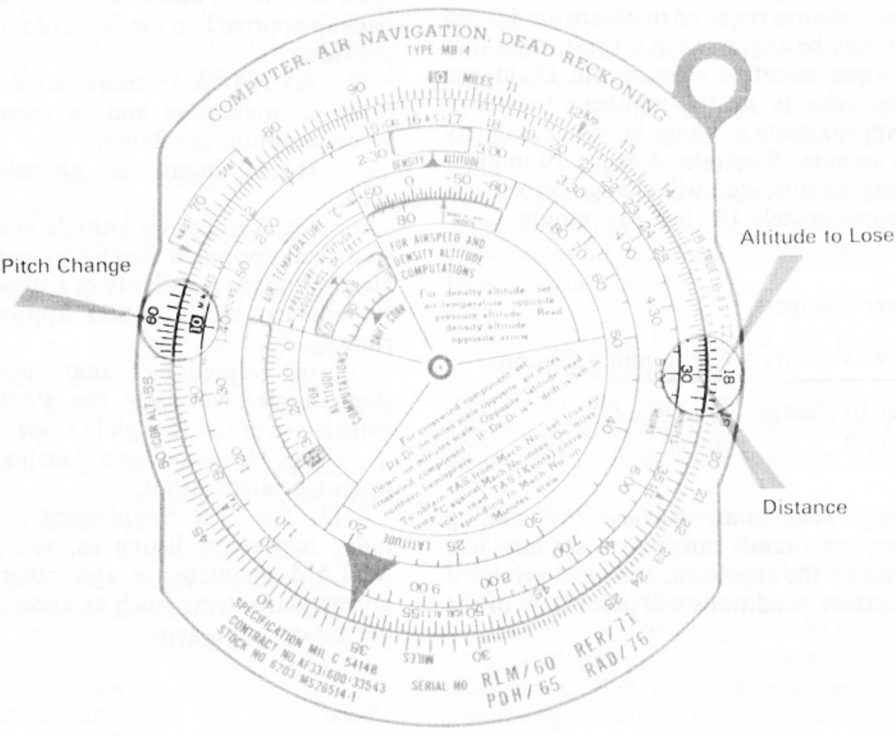


Figure 3-7. Use of DR Computer to Determine Pitch Change (para 3-4b(2)(b)).

With this information and knowing the approximate TAS in nautical miles per minute (NM/min), you can figure the required vertical velocity (VV). TAS in NM/min is obtained by dividing TAS in knots by 60. Use whole numbers for ease of computation. If a mach indicator is available, use indicated mach times 10.

DESCENT GRADIENT (ft/NM) X TAS (NM/min) = VV (ft/min)

$$NM/min = \frac{TAS\ knots}{60} = MI \times 10$$

EXAMPLE: Descent Gradient 600 ft/NM

300 Knots TAS or .5 Mach

$$NM = \frac{300}{60} = .5\ Mach \times 10 = 5\ NM/min$$

600 ft/NM X 5 NM/min = 3000 ft/min

Remember that with a constant IAS, TAS decreases as altitude decreases. Therefore, the required VV will also decrease as the approach progresses. Also, this technique does not consider wind. However, when flying a straight-in TACAN approach you can stay current on your actual descent gradient by noting the altitude lost each nautical mile and comparing it to the desired descent gradient.

(c) For Helicopters: In addition to the above techniques, the following may be used to determine the amount of power change required to obtain the desired results. Power may be expressed in several ways; that is, fuel flow, torque, manifold pressure, etc. Divide the desired vertical velocity by the number of units of power which approximate a change in vertical velocity of 10 feet per minute. Example: Assume 10 units of power (fuel flow, torque, etc.) will change the vertical velocity by approximately 100 feet per minute.

Required power change =

$$\frac{\text{Desired Vertical Velocity}}{\text{Units of power to change VV by 100 ft/min}} = \frac{\text{500 ft/min}}{\text{10 units of power}} = \text{50 units}$$

(3) Landing Minimums. Review the landing minimums for your aircraft category to see how low you can descend on the approach, and to determine if the forecast weather conditions will permit use of the IAP.

NOTE: The minimums published in FLIP must be the lowest possible minimums, in accordance with AFM 55-9 (TERPs) criteria; however, major commands may establish higher minimums for their pilots. The visibility values determine whether a straight-in approach may be flown. If a circling approach is to be flown, the weather must be at or above both the published ceiling and visibility.

(4) Aerodrome Sketch:

(a) Check the field elevation which is the highest point on any usable landing surface.

(b) Note the touchdown zone elevation which is the highest point in the first 3000 feet of the landing runway.

(c) Observe the runway dimensions and layout.

(d) Check the types of approach lighting systems available.

(e) Note the direction and distance of the runways from the navigation facility.

(f) Check the location of prominent obstructions.

(5) Additional Information. Review carefully for notes on the IAP. Notes are used to identify either nonstandard IAP criteria or to emphasize areas essential for the safe completion of the approach.

c. Reviewing a Radar Approach. Although depictions of radar approaches are not included in flight publications, some important aspects of the approach are available.

(1) It is helpful to review a published IAP for the same airfield. In addition to helping you prepare for a backup approach in the event of radio failure, the IAP provides:

(a) NAVAID frequencies and locations for position orientation and in some cases, additional voice reception capability.

(b) Minimum safe altitudes in the terminal area.

(c) A stepdown altitude between the nonprecision final approach fix (FAF) and MAP which may alert you to the possibility of a stepdown on an airport surveillance radar (ASR) approach to the same runway.

(d) Depiction of radar minimums and the glide slope angle. Normally the PAR glide slope will coincide with the ILS glide slope.

(e) The aerodrome sketch and all the information associated with it.

(2) The IFR Supplement contains a complete radar minimums listing as well as periods of no-NOTAM maintenance and other notes identifying nonstandard items (such as excessive climb gradients for missed approach).

Chapter 4

DEPARTURE

SECTION A — INSTRUMENT COCKPIT CHECK

4-1. Cockpit Check. Before flight, accomplish a thorough instrument cockpit check. You should check the items listed below if applicable:

a. Publications. Ensure that appropriate, up-to-date publications are in the aircraft.

b. Pitot Heat. Check for proper operation.

c. Attitude Indicators:

(1) Ensure that it is erect and that the bank pointer is aligned vertically with the zero bank index. Check your flight manual for tolerance limits.

(2) Ensure that the warning flag(s) is not visible.

(3) Check the pitch trim knob alignment and ensure that it is within limits; then set the miniature aircraft or horizon bar for takeoff.

d. Magnetic Compass. Check the accuracy of heading information.

e. Clock. Ensure that the clock is running and the correct time is set.

f. Vertical Velocity Indicator. Ensure that the pointer is at zero. If it is not, tap the case gently. If indicator does not return to zero, adjust it with a small screwdriver or use the ground indication as the zero position in flight.

g. Altimeters:

(1) Set current altimeter setting on barometric scale. Tap the altimeter case gently.

(2) Check the altimeter at a known elevation and note any error in feet.

(3) If the error exceeds 75 feet, do not accept the instrument for flight.

(4) Ensure that the 10,000/1,000/100 counter-drum-pointers indicate approximate field elevation. Check and ensure that the low altitude warning symbol is in view.

(5) Check both reset and standby modes on AIMS altimeter and set in accordance with the flight manual or command directives.

(6) Helicopter rotor operation may affect altimeter indications. Check individual helicopter flight manual for altimeter limitations, if published. (Refer to chapter 1, Altimeter Setting Procedure.)

h. Turn and Slip Indicator:

(1) Check and ensure that the turn needle indicates proper direction of turn.

(2) Check the ball for freedom of movement in the glass tube.

i. Heading Indicators:

(1) Check the accuracy of heading information.

(2) Ensure that heading indicators indicate correct movement in turns.

(3) Set the desired heading under the adjustable indicators.

(4) For flight director systems, check the bank steering bar for proper commands in the heading mode.

j. Airspeed and Mach Indicators:

(1) Set the airspeed or command mach markers as desired.

(2) Check the pointers or rotating airspeed scale for proper indications.

k. Airspeed Mach Indicator (AMI):

(1) Airspeed Warning Flag. Ensure it is out of view.

(2) Command Airspeed Marker. Set the marker as desired; that is, decision, rotation, climb speed, etc.

l. Altitude Vertical Velocity Indicator (AVVI):

(1) Vertical Velocity. Check for a zero indication.

(2) Altimeter. Make the same check as for conventional altimeter. Ensure the altimeter warning flag is out of view.

(3) Command Altitude Marker. Set the marker to first anticipated leveloff altitude or, if in IFR conditions, set DH/MDA for an emergency return.

WARNING: The command airspeed or altitude slewing switches should not be placed in the side detent position for takeoff due to the possibility of misreading those instruments.

m. Navigation Equipment and Instruments:

(1) Tune and identify.

(2) Ensure the bearing pointers point to the station. When checking the VOR/TACAN at a designated ground check point, the allowable error is ± 4°.

(3) Check and ensure that the range warning flag on the range indicator is out of view and the distance indicated is within ½ mile or 3 percent of the distance to the facility, whichever is greater.

(4) When checking the VOR/TACAN at a designated ground check point, ensure that the allowable CDI error is ± 4° and the CDI and bearing pointer agree within the tolerances specified for the aircraft.

(5) Rotate the course set knob and check for proper CDI displacement.

(6) Rotate the course set knob and check that the TO-FROM indication changes when the selected course is approximately 90° to the bearing point.

SECTION B — AIR TRAFFIC CONTROL (ATC) CLEARANCES

4-2. Clearances. Ensure that a complete clearance is received in accordance with FLIP. If an incomplete clearance is accepted, the planned flight may not be possible in the event of two-way radio failure. For example, if the clearance specifies an intermediate leveloff but does not include a time or place to expect a higher altitude as filed on the flight plan, then the higher fuel consumption at the lower altitude could prevent you from reaching your destination with the required fuel remaining.

4-3. Clearance Readback. There is no USAF requirement for an ATC clearance to be read back; however, you should read back the clearance if you feel the need for confirmation. You are also expected to request that the clearance be repeated or clarified if you do not understand it.

SECTION C — INSTRUMENT TAKEOFF (ITO)

4-4. General:

a. The ITO is accomplished by referring to outside visual references and the flight instruments. The amount of attention given to each reference varies with the individual, the type of aircraft, and existing weather. The ITO is a composite visual or instrument takeoff and should not be confused with "hooded takeoffs."

b. The ITO procedures and techniques are invaluable aids during takeoffs at night, toward and over water or deserted areas, and during periods of reduced visibility. It is important to immediately transition to instrument references any time you become disoriented or when outside visual references become unreliable.

NOTE (FOR HELICOPTER PILOTS): Helicopter ITOs may have to be accomplished entirely on instruments due to restrictions to visibility induced by rotor downwash on dust, sand or snow.

4-5. Preparing for the ITO;

a. Before performing an ITO, you should perform an adequate before takeoff check of all flight and navigation instruments to include publications, select the appropriate navigational aids to be used for the departure, and set the navigation instruments and switches as required.

b. The air traffic control clearance and departure procedures must be thoroughly understood before takeoff. It is a good operating practice to have the appropriate instrument approach procedures charts available in the event an instrument approach is necessary immediately after takeoff. Review of the approach for an emergency return should include frequencies, final approach course, DH or MDA, and minimum safe, sector, or emergency safe altitudes. Brief all crew members on specific duties during an emergency return.

4-6. Performing the ITO:

a. Fixed Wing:

(1) The ITO procedure for your aircraft is discussed in the flight manual. The procedures are aligned as nearly as possible to the normal VFR takeoff. Operate pitot heat and other anti-ice equipment as required. When cleared into position for takeoff, align the aircraft with the runway centerline and complete the before takeoff checklist. Recheck the heading indicators and attitude indicators for possible precession errors. When cleared, select the assigned departure frequency and monitor "Guard" frequency during takeoff.

(2) When cleared for takeoff, release wheel brakes simultaneously to minimize initial directional control difficulties. Directional control immediately following brake release should be accomplished predominantly with the aid of outside visual references. As the takeoff progresses, the cross-check should transition from outside references to the heading indicator, airspeed indicator, and attitude indicator. The rate of transition is directly proportional to the rate at which the outside references deteriorate. It is extermely important for this cross-check to be "in progress" before losing complete outside visual references during the takeoff roll or subsequent departure. Takeoffs at night or into poor visibilities are especially conducive to spatial disorientation. As you lift off be committed to attitude instrument flying so you can disregard erroneous sensory inputs.

(3) The takeoff attitude should be established on the attitude indicator at the appropriate point during the takeoff roll. This is normally at rotation or just prior to reaching takeoff airspeeds. Know the specific takeoff attitude required for your aircraft. This pitch attitude and a wings level attitude should be held constant as the aircraft becomes airborne. Cross-check the vertical velocity indicator and altimeter for positive climb indications before retracting the gear and wing flaps. While the gear and flaps are being retracted, maintain or adjust the pitch attitude as necessary to ensure the desired climb.

WARNING: Some attitude indicators are susceptible to precession errors caused by aircraft acceleration. This causes the horizon bar to lower slightly and appear at a higher than actual pitch attitude. To avoid lowering the nose prematurely, you must cross-check the vertical velocity and altimeter throughout this phase of flight to ensure proper climb performance.

(4) After the gear and flaps are retracted, adjust the pitch attitude to provide a reasonable increase in both airspeed and altitude until the desired climb schedule is reached. Control the bank attitude to maintain the desired heading. Cross-check the turn needle and standby attitude indicator (if available) against the attitude indicator.

b. Helicopter:

(1) In helicopters, an ITO may be accomplished from a hover or from the ground as visibility restrictions permit. Normally, a composite takeoff is accomplished using normal VMC procedures and combining reference to the flight instruments with outside visual reference to provide a smooth transition from VMC to IMC flight. However, when rotor downwash causes a restriction to visibility, the takeoff must be accomplished by complete reference to instruments. Prior to takeoff, the attitude indicators should be adjusted by aligning the adjustment knobs with the zero trim dots (the J-8 attitude indicator is adjusted by aligning the miniature aircraft with the 90° bank indexes). These settings will provide a constant attitude reference for the ITO regardless of the aircraft attitude at the time of adjustment.

(2) As power is applied for takeoff and positive climb indication is obtained, the pitch attitude should be adjusted as specified in the flight manual. As soon as the takeoff attitude is established, the vertical velocity indicator and altimeter should be cross-checked to ensure that you are still climbing. While the aircraft is below airspeeds required for accurate altitude or VVI readings, predetermined power settings and pitch attitudes will provide the most reliable source of climb path information. As climb airspeed is obtained, power and attitude should be adjusted as necessary for the desired rate of climb. The attitude indicators may be readjusted during climb and cruise as desired.

SECTION D — PERFORMING DEPARTURES

4-7. Standard Instrument Departures (SIDs). Adhere to the published SID route and altitude unless specifically instructed otherwise by the controlling agency. Apply known wind corrections to depicted DR legs. If an amended clearance is accepted (including radar vectors), ensure that the route, altitude, and clearance limit fix are understood. If there is any question regarding the intent of a clearance received, query the controller. After establishing initial contact with departure control, some controllers will issue a clearance to climb to specific altitude via a particular SID, usually the original clearance altitude and SID; however, this does not mean to disregard altitude restrictions published on the SID. To preclude misinterpretation, ensure that the controller intends for you to climb unrestricted to your assigned altitude. (Refer to FLIP for additional SID guidance and two-way radio failure procedures.)

4-8. Radar Departures:

a. Adhere to the vector headings and altitudes assigned by the controller. Since the controller does not know the climb capabilities of the aircraft, inform him if you cannot meet an altitude assigned at a fix or point. Be sure you understand the point to which you are being radar vectored. If at any time during the departure you are uncertain of your instructions or clearance, query the controller.

b. The use of IFR departures without a SID or radar service is discouraged. This is especially true when high terrain is in the vicinity of the airport. If under these conditions and a SID is not practicable you should climb out VFR until radar or published routing is available. If mission requirements dictate an IFR departure without a SID or radar service, preplan the route in compliance with AFR 60-16. Use a suitable terrain map for the route and comply with the service volume area of the navigation facilities. Refer to FLIP for two-way radio failure procedures.

Chapter 5

EN ROUTE

SECTION A — HIGH AND LOW ALTITUDES

5-1. General. Comply with the jet route or airway system as published on the FLIP enroute charts and air traffic clearances.

5-2. Minimum Altitudes:

a. Ensure that altitude clearances received en route do not conflict with minimum en route altitudes (MEAs), minimum obstruction clearance altitudes (MOCAs), minimum reception altitudes (MRAs), or minimum crossing altitudes (MCAs) shown on en route charts.

b. In controlled airspace, the air traffic controller will assign altitudes that provide obstacle clearance. You should use all available navigational aids to remain position-oriented and immediately query the controller if there is any uncertainty of the obstacle clearance provided by the assigned altitude. When a new altitude is assigned by ATC, include the newly assigned altitude when you report vacating the previously assigned altitude. When flying via published routing (a route with minimum altitudes depicted), compliance with the minimum altitude published on the routing ensures obstacle clearance. If a published minimum altitude is not available, aircrews must determine minimum altitudes in accordance with AFR 60-16.

c. In uncontrolled airspace, you must ensure that the altitudes flown will provide obstacle clearance during all phases of flight.

d. In case of radio failure, you are responsible for minimum altitude selection. Comply with published radio failure procedures in FLIP.

SECTION B— HOLDING

5-3. General. Holding is maneuvering an aircraft in relation to a navigational fix while awaiting further clearance. The standard no-wind holding pattern is flown by following a specified holding course inbound to the holding fix, making a 180° turn to the right, flying a heading outbound to parallel the holding course, and making another 180° turn to the right to intercept and follow the holding course to the fix (figure 5-1). The holding pattern is nonstandard when the turns are made to the left. Unless otherwise instructed by ATC, pilots are expected to hold in a standard pattern. The standard no-wind length of the inbound legs of the holding pattern is 1 minute when holding at or below 14,000 feet MSL and 1½ minutes when holding above 14,000 feet MSL. DME holding patterns specify the maximum outbound leg length. If holding at a DME fix without specified outbound leg length, use timing procedures listed above.

5-4. Holding Instructions:

a. ATC clearances requiring holding where holding patterns are charted, include the following instructions:

(1) Direction of holding from the fix.

(2) Holding fix.

b. ATC clearances requiring holding where holding

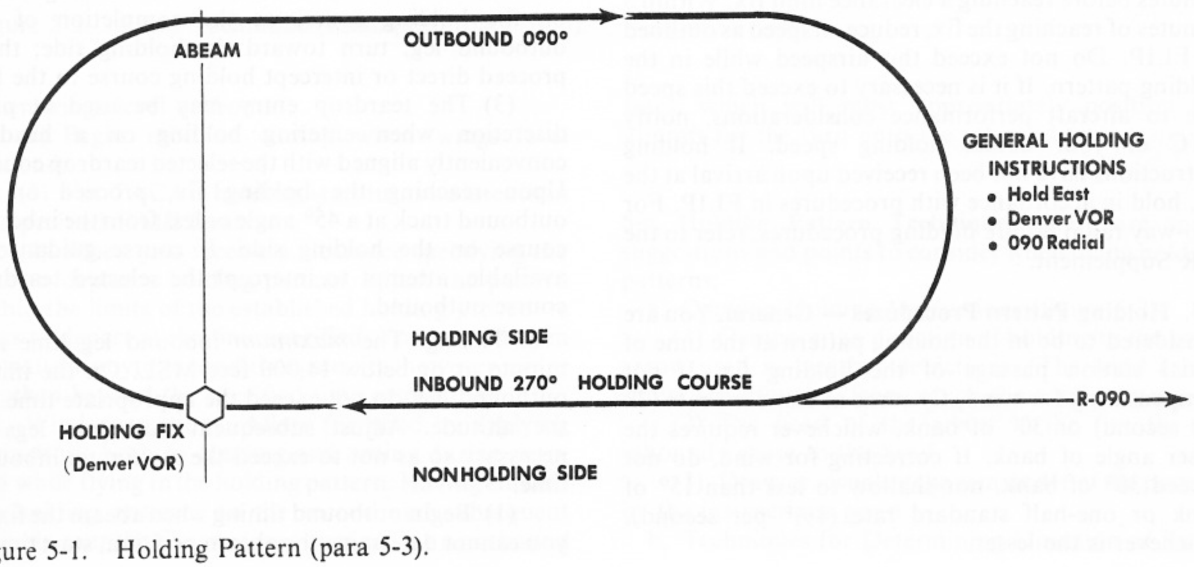


Figure 5-1. Holding Pattern (para 5-3).

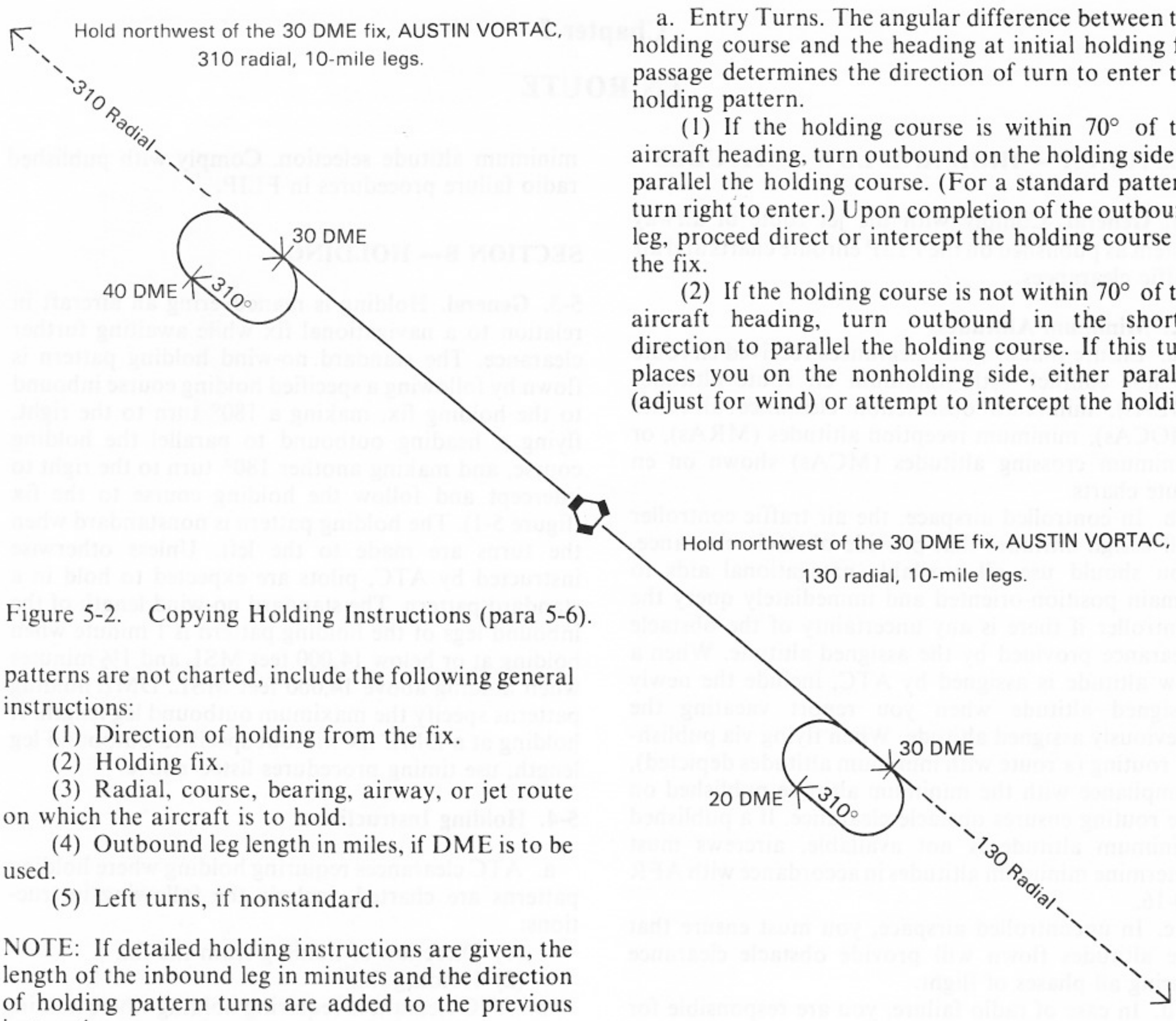


Figure 5-2. Copying Holding Instructions (para 5-6).

patterns are not charted, include the following general instructions:

(1) Direction of holding from the fix.

(2) Holding fix.

(3) Radial, course, bearing, airway, or jet route on which the aircraft is to hold.

(4) Outbound leg length in miles, if DME is to be used.

(5) Left turns, if nonstandard.

NOTE: If detailed holding instructions are given, the length of the inbound leg in minutes and the direction of holding pattern turns are added to the previous instructions.

c. ATC should issue holding instructions at least 5 minutes before reaching a clearance limit fix. Within 3 minutes of reaching the fix, reduce airspeed as outlined in FLIP. Do not exceed this airspeed while in the holding pattern. If it is necessary to exceed this speed due to aircraft performance considerations, notify ATC of your actual holding speed. If holding instructions have not been received upon arrival at the fix, hold in accordance with procedures in FLIP. For two-way radio failure holding procedures, refer to the IFR Supplement.

5-5. Holding Pattern Procedures — General. You are considered to be in the holding pattern at the time of initial station passage of the holding fix. If not compensating for wind, fly turns at standard rate (3° per second) or 30° of bank, whichever requires the lesser angle of bank. If correcting for wind, do not exceed 30° of bank, nor shallow to less than 15° of bank or one-half standard rate (1½° per second), whichever is the lesser.

a. Entry Turns. The angular difference between the holding course and the heading at initial holding fix passage determines the direction of turn to enter the holding pattern.

(1) If the holding course is within 70° of the aircraft heading, turn outbound on the holding side to parallel the holding course. (For a standard pattern, turn right to enter.) Upon completion of the outbound leg, proceed direct or intercept the holding course to the fix.

(2) If the holding course is not within 70° of the aircraft heading, turn outbound in the shorter direction to parallel the holding course. If this turn places you on the nonholding side, either parallel (adjust for wind) or attempt to intercept the holding course outbound. If you are on the nonholding side or on the holding course at the completion of the outbound leg, turn toward the holding side; then, proceed direct or intercept holding course to the fix.

(3) The teardrop entry may be used at pilot discretion when entering holding on a heading conveniently aligned with the selected teardrop course. Upon reaching the holding fix, proceed on an outbound track at a 45° angle or less from the inbound course on the holding side. If course guidance is available, attempt to intercept the selected teardrop course outbound.

b. Timing. The *maximum* inbound leg time is 1 minute at or below 14,000 feet MSL. On the initial outbound leg, do not exceed the appropriate time for the altitude. Adjust subsequent outbound legs as necessary so as not to exceed the maximum inbound time.

(1) Begin outbound timing when abeam the fix. If you cannot determine the abeam position, start timing

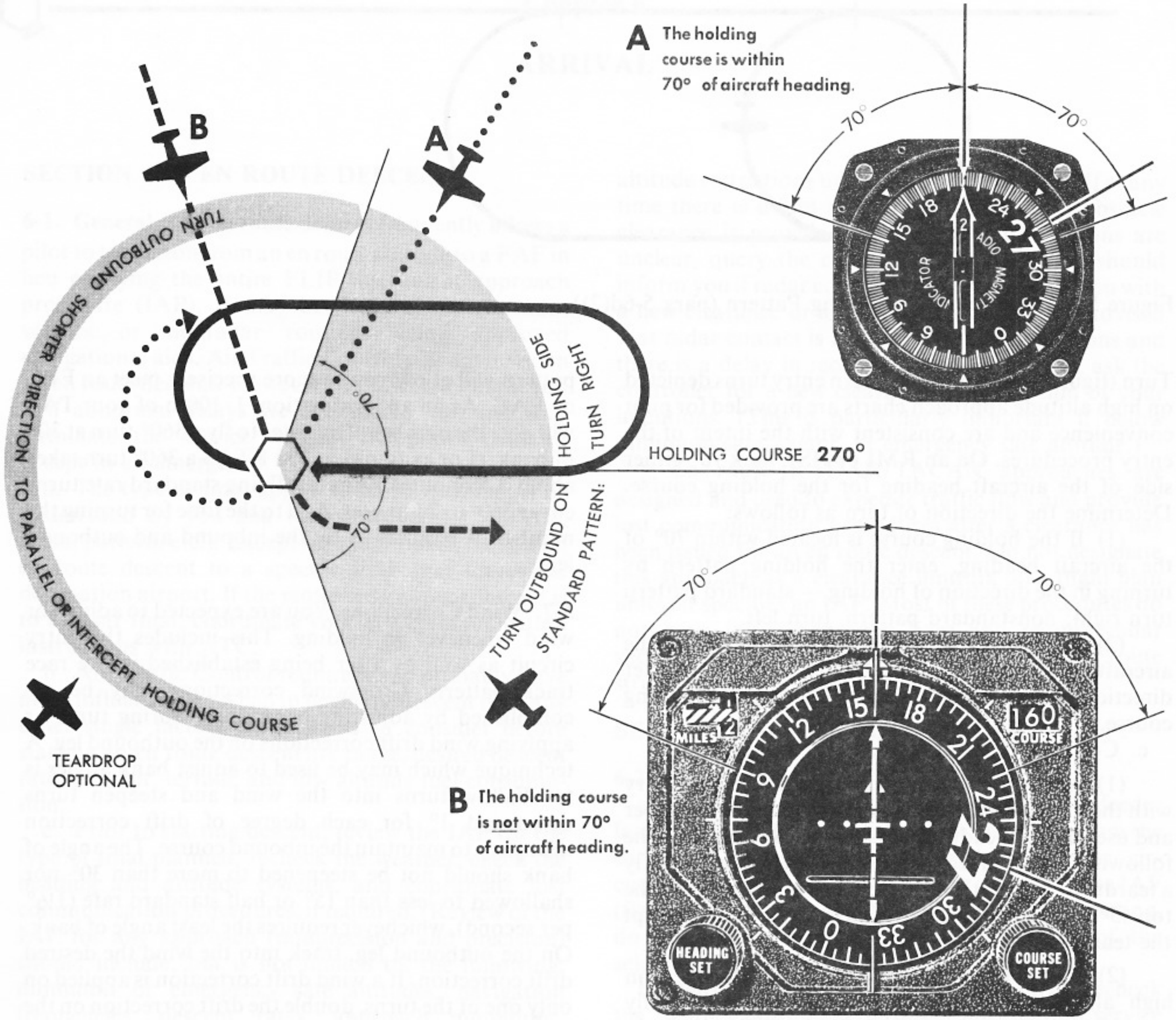


Figure 5-3. Entry Technique (Examples) (para 5-6b).

when wings level outbound.

(2) Begin inbound timing when wings level inbound.

(3) For TACAN holding, start turns no later than the specified DME limits.

(4) When you receive a clearance specifying the time to depart a holding pattern, adjust the pattern within the limits of the established holding procedure so as to depart at the time specified. You may shorten the pattern anytime conditions require; however, never lengthen beyond the specified time or distance.

c. Wind corrections. Allow for wind by applying corrections both to heading and timing during entry and while flying in the holding pattern. Having entered the holding pattern, on the second and subsequent arrivals over the fix, execute a turn to fly an outbound track which will most appropriately position the aircraft for the turn onto the inbound track.

5-6. Holding Pattern Techniques. Here are some suggestions and points to consider when flying holding patterns:

a. Copying Holding Instructions (figure 5-2):

(1) Compare the direction of holding to the wind arrow used in weather depictions. (The wind arrow shows the direction from which the wind comes.)

(2) The head of the arrow is the fix; fly the inbound course to the head.

(3) Draw or visualize the remainder of the pattern by the instructions given.

b. Techniques for Determining Direction of Entry

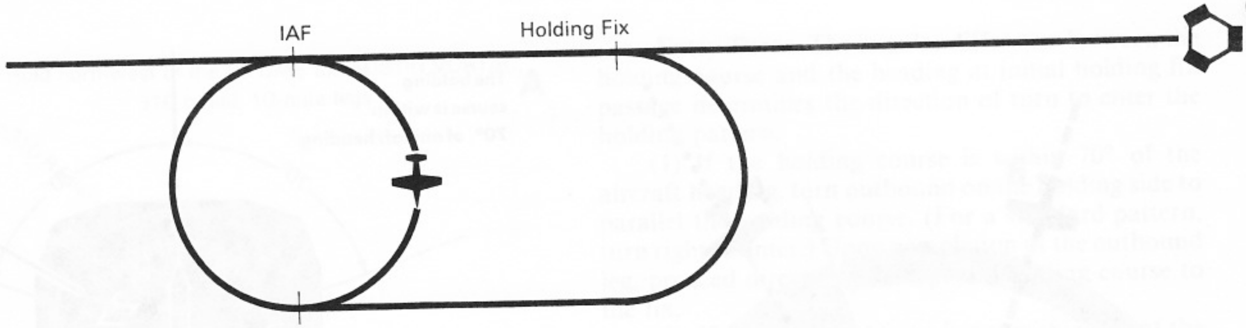


Figure 5-4. Shortening a Holding Pattern (para 5-6d(2)).

Turn (figure 5-3). Holding pattern entry turns depicted on high altitude approach charts are provided for pilot convenience and are consistent with the intent of the entry procedures. On an RMI or HSI, look 70° either side of the aircraft heading for the holding course. Determine the direction of turn as follows:

(1) If the holding course is located within 70° of the aircraft heading, enter the holding pattern by turning in the direction of holding — standard pattern turn right; nonstandard pattern, turn left.

(2) If the holding course is not within 70° of the aircraft heading, turn outbound in the shorter direction to parallel or attempt to intercept the holding course.

c. Conveniently Aligned for a Teardrop:

(1) Although "conveniently aligned" may vary with the aircraft and situation, 45° is easy to remember and use. If your heading indicator has 45° indexes, the following is a good technique to use if you choose to fly a teardrop entry. If the teardrop course lies between the top 45⁰ indexes, at holding fix passage turn to intercept the teardrop course.

(2) The holding pattern entry turns depicted on high altitude approach chart plan views generally specify a teardrop entry if the aircraft heading is within 40° of a 30° teardrop course at holding fix passage.

d. Timing:

(1) After completing the first circuit of the holding pattern, adjust the time outbound as necessary to provide the desired inbound times within the maximum limits allowed. In extreme wind conditions, even though the turn inbound is initiated when abeam the station, the inbound leg may exceed the 1- or 1½-minute limit. In this case, you are authorized to exceed the time limit inbound.

(2) Timing procedures dictate maximum leg lengths. When adjusting the holding pattern, you may choose to shorten the inbound leg. TACAN holding allows the flexibility of shortening the pattern at the opposite end from the holding fix as shown in figure 5-4.

(3) Knowing the time it takes you to fly a holding pattern will allow you to more precisely meet an EFC or EAC. As an approximation, 1/100th of your TAS will give the number of minutes to fly a 360° turn at 30° of bank. (For example, at 350 KTAS a 360° turn takes about 3.5 minutes.) Aircraft flying standard rate turns cover 360⁰ in 2 minutes. Add to the time for turning the number of minutes to fly the inbound and outbound legs.

5-7. Wind Corrections. You are expected to adjust for wind whenever in holding. This includes the entry circuit as well as after being established in the race track pattern. Crosswind corrections may be accomplished by adjusting bank angle during turns or applying wind drift corrections on the outbound leg. A technique which may be used to adjust bank angles is to shallow turns into the wind and steepen turns downwind 1° for each degree of drift correction necessary to maintain the inbound course. The angle of bank should not be steepened to more than 30° nor shallowed to less than 15° or half standard rate (1½° per second), whichever requires the least angle of bank. On the outbound leg, track into the wind the desired drift correction. If a wind drift correction is applied on only one of the turns, double the drift correction on the outbound leg. If you do not apply bank correction to either of the turns, triple the drift correction on the outbound leg.

5-8. Drift Corrections. Knowledge of drift correction and true airspeed relationship can be very useful, especially in those instances where course guidance is not available; for example, outbound leg of holding pattern or procedure turn. The following techniques may be used to determine approximate drift correction when the crosswind component is known:

a. Divide the crosswind component by the mach times 10. Example: 50 knots crosswind and 300 KTAS (.5M) = 10° drift correction; or

b. Divide the crosswind component by the aircraft speed in nautical miles per minute. Example: 30 knots crosswind and 180 knots TAS (3 NM per minute) 30 ÷ 3 = 10° drift correction.

Chapter 6

ARRIVAL

SECTION A — EN ROUTE DESCENT

6-1. General. The en route descent frequently allows a pilot to transition from an en route altitude to a FAF in lieu of flying the entire FLIP instrument approach procedure (IAP). It may be flown either via radar vectors or nonradar routings using approved navigational aids. Air Traffic Control will not insist on an en route descent. However, ATC will not authorize it if abnormal delays are anticipated, nor will they terminate the service without the pilot's consent, except in an emergency.

a. The type of final approach to be flown must be understood by you and the controller (ILS, PAR, visual pattern, etc.). Except for radar finals, request an en route descent to a specific FAF that serves the destination airport. If the requested en route descent is to a radar final, coordinate your lost communication instructions with ATC.

b. Air Traffic Control requirements probably have more influence over when to begin the descent than any other single factor. Other items to consider before starting an en route descent are range, desired descent rate, weather, terrain, and low altitude fuel consumption.

c. Prior to starting descent, review the IAP for the type of final planned, recheck the weather, check the heading and attitude systems, and coordinate lost communication procedures, if required. (Review of the IAP for any approach (nonprecision and precision) should include, but is not limited to, the following: minimum or emergency safe altitudes, navigation frequencies, descent rates, approach minimums, missed approach procedures and aerodrome sketch.)

d. During the descent, control descent rate and airspeed to comply with any altitude or range restriction imposed by ATC.

e. Reduce airspeed to 250 KIAS or less when below 10,000 feet MSL, unless aircraft or military operating procedures require a higher airspeed.

f. When descending via radar vectors, remain oriented in relation to the final approach fix by using all available navigational aids. Have the IAP available for the approach to be flown along with an alternate or backup procedure to be used if available. Note the minimum safe, sector, or emergency safe altitudes. Be prepared to fly the approach when cleared by the controller. Once cleared for the approach, maintain the last assigned altitude and heading until established on a segment of the published routing or IAP. Use normal lead points to roll out on course. Do not climb above last assigned altitude to comply with published altitude restrictions unless instructed to do so. If at any time there is doubt as to whether adequate obstacle clearance is provided, or controller instructions are unclear, query the controller. The controller should inform you if radar contact is lost and provide you with a new clearance or additional instructions. If advised that radar contact is lost while in IFR conditions and there is a delay in receiving new instructions, ask the controller for a new clearance or advise him of your intentions. (This is particularly important if below minimum safe, sector, or emergency safe altitude.)

g. En route RADAR/TACAN approaches are designed and used to expedite traffic flow and provide lost communication procedures after a clearance has been issued for an en route descent. Do not designate this approach as a clearance limit fix on a flight plan unless it specifies an IAF. Most of these procedures do not have initial approach fixes and require radar vectors for transition from the high altitude en route structure to final appraoch.

SECTION B — EN ROUTE TO THE IAF

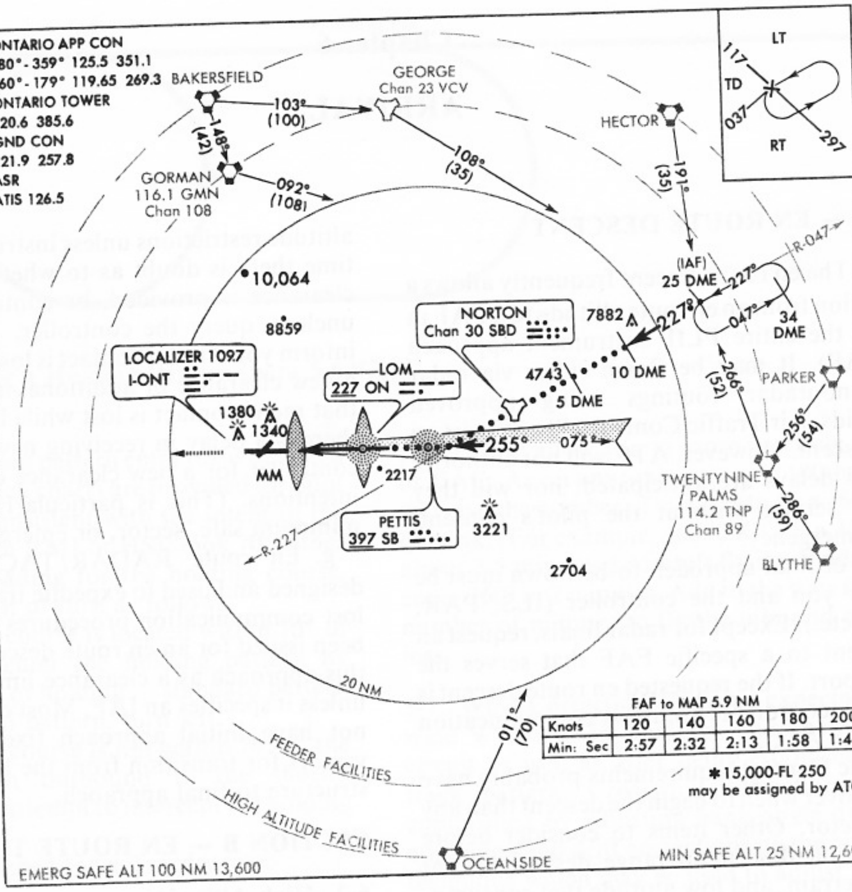
6-2. High Altitude:

a. Terminal routings from en route or feeder facilities normally provide a course and range from the en route structure to the IAF but in some circumstances may take you to a point other than the IAF (figure 6-1). If you use other than a published routing, do not exceed the operational limitations of the selected NAVAIDs.

b. Before reaching the IAF, review the IAP, recheck the weather (automatic terminal information service (ATIS) if appropriate), check the heading and attitude systems, and obtain clearance for the approach. If holding is not required, reduce to penetration airspeed or below before reaching the IAF. Accomplish the descent check in accordance with the aircraft flight manual. Set the altimeter in accordance with AFR 60-16 and FLIP instructions.

c. If cleared for an approach while en route to a holding fix which is not collocated with the IAF, you are expected to proceed to the IAF via the holding fix. However, if the IAF is located along the route of flight to the holding fix, you are expected to begin the approach at the IAF. If in doubt as to the clearance, query the controller (figure 6-2).

d. When ATC issues an approach clearance, you are expected to turn immediately to intercept the penetration course upon reaching the IAF. Clearance for the approach does not include clearance to use holding airspace. However, if your heading is within 90° of the



Knots	120	140	160	180	200
Min: Sec	2:57	2:32	2:13	1:58	1:46

Figure 6-1.
Feeder Routes
(High Altitude)
(para 6-2a).

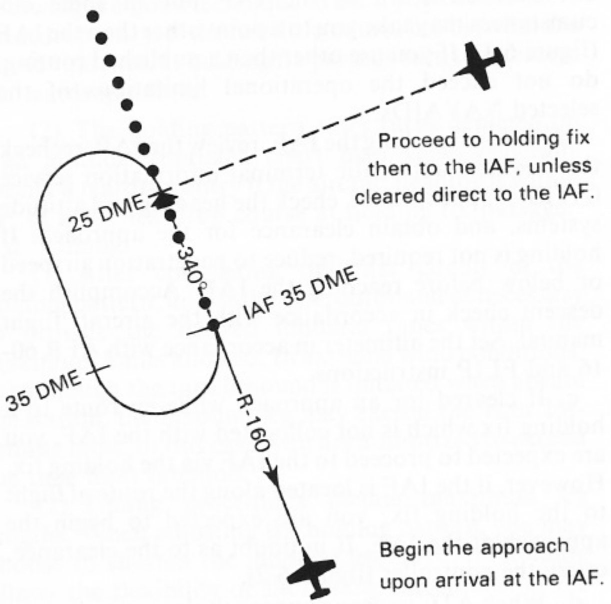


Figure 6-2. Cleared for the Approach While En Route to the Holding Fix (para 6-2c, 6-3d).

penetration course you may use normal lead points to intercept the course. If your heading is not within 90° of the penetration course, you may need to maneuver the aircraft into a more favorable alignment prior to starting the penetration. If maneuvering is desired, obtain clearance from ATC since clearance for the approach does not include clearance for the use of holding or maneuvering airspace (figure 6-3).

c. When cleared for the approach, maintain the last assigned altitude until established on a segment of the published routing or instrument approach procedure. Penetration descent may be initiated when abeam or past the IAF with a parallel or intercept heading to the course. The controller should assign you the depicted IAF altitude. If you are not assigned the IAF altitude and can not make the descent gradient by starting the penetration from your last assigned altitude, request a lower altitude. If maneuvering, such as a holding pattern, is necessary to lose excess altitude, obtain clearance to do so. Remember that you must be able to comply with subsequent mandatory and maximum altitudes.

6-3. Low Altitude:

a. Terminal routings from en route or feeder facilities normally provide a course, range, and minimum altitude from the en route structure to the

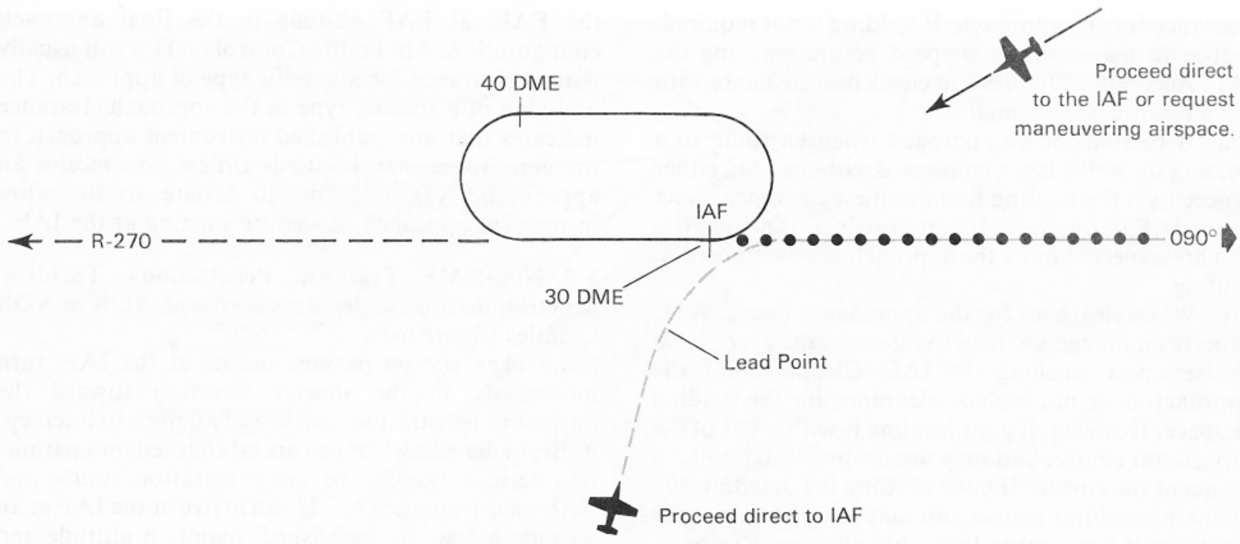


Figure 6-3. Leading the Turn at the IAF (para 6-2d, 6-3e).

IAF, but may take the aircraft to a point other than the IAF if it is operationally advantageous to do so (figure 6-4). If you use other than a published routing, do not exceed the operational limitations of the selected NAVAIDs.

b. An altitude published on a terminal route provides the same protection as an airway minimum en route altitude (MEA).

c. Before reaching the IAF, review the IAP chart, recheck the weather (ATIS if appropriate), and obtain

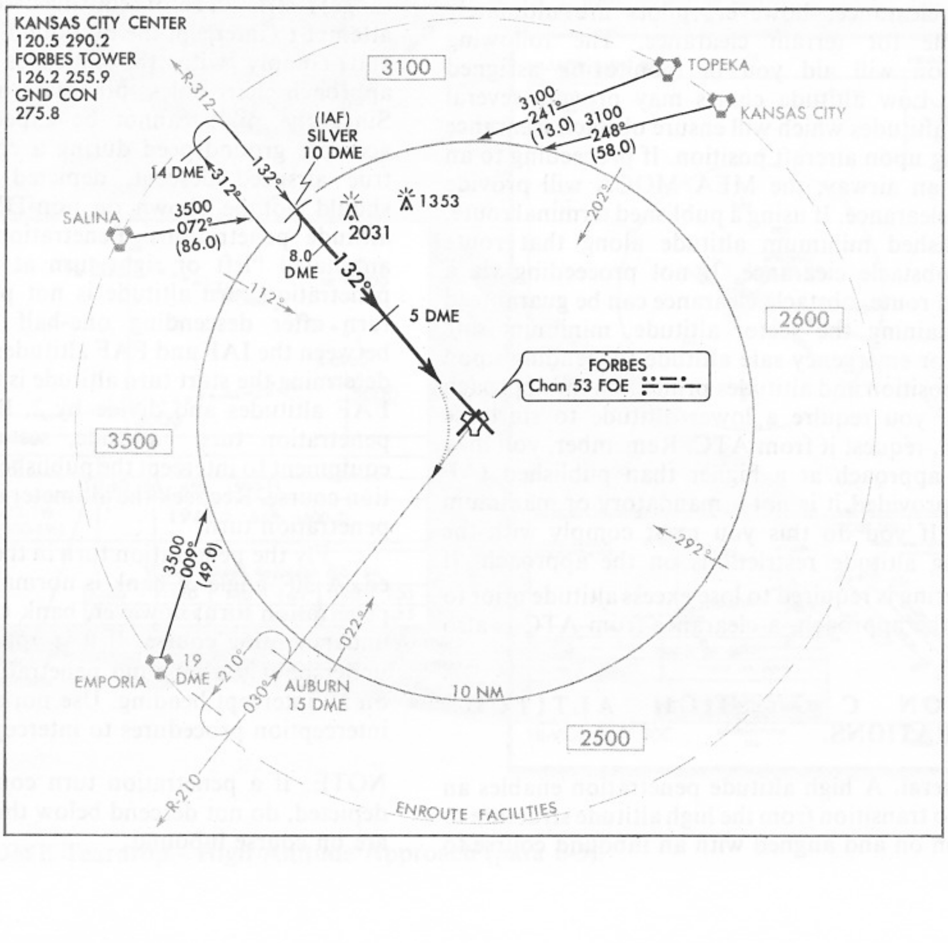


Figure 6-4.
Feeder Routes
(Low Altitude)
(para 6-3a).

clearance for the approach. If holding is not required, reduce to maneuvering airspeed before reaching the IAF. Accomplish the descent check in accordance with the aircraft flight manual.

d. If cleared for an approach when en route to a holding fix which is not collocated with the IAF, either proceed via the holding fix or request clearance direct to the IAF (figure 6-2). If you overfly a transition fix, you are expected to fly the approach via the transition routing.

e. When clearance for the approach is issued, ATC expects an immediate turn to intercept the procedural course upon reaching the IAF. Clearance for the approach does not include clearance for the holding airspace. However, if your heading is within 90° of the procedural course, you may use normal lead points to intercept the course. If your heading is not within 90° of the procedural course you may need to maneuver the aircraft for a more favorable alignment prior to starting the approach. If maneuvering is desired, obtain an amended clearance from ATC since clearance for the approach does not include clearance for the use of holding or maneuvering airspace (figure 6-3).

f. When cleared for the approach, maintain the last assigned altitude until established on a segment of the published routing or instrument approach procedure. ATC will not assign an altitude that does not provide obstacle clearance; however, pilots are ultimately responsible for terrain clearance. The following information will aid you in monitoring assigned altitudes. Low altitude charts may provide several different altitudes which will ensure obstacle clearance depending upon aircraft position. If proceeding to an IAF via an airway, the MEA/MOCA will provide obstacle clearance. If using a published terminal route, the published minimum altitude along that route ensures obstacle clearance. If not proceeding via a published route, obstacle clearance can be guaranteed by maintaining the sector altitude, minimum safe altitude, or emergency safe altitude (depending upon aircraft position and altitudes printed on the approach chart). If you require a lower altitude to start the approach, request it from ATC. Remember, you may start an approach at a higher than published IAF altitude provided it is not a mandatory or maximum altitude. If you do this you must comply with the remaining altitude restrictions on the approach. If maneuvering is required to lose excess altitude prior to starting the approach, a clearance from ATC is also required.

SECTION C — HIGH ALTITUDE PENETRATIONS.

6-4. General. A high altitude penetration enables an aircraft to transition from the high altitude structure to a position on and aligned with an inbound course to the FAF, at FAF altitude in the final approach configuration. Air Traffic Control (ATC) will usually issue a clearance for a specific type of approach. The omission of a specific type in the approach clearance indicates that any published instrument approach to the aerodrome may be used. Unless you receive an appropriate ATC clearance to deviate, fly the entire instrument approach procedure starting at the IAF.

6-5. Non-DME Teardrop Penetrations. Teardrop penetrations are usually associated with VOR or NDB facilities (figure 6-5).

a. When station passage occurs at the IAF, turn immediatly in the shorter direction toward the outbound penetration course and attempt to intercept it. Begin descent when you are established on a parallel or intercept heading to the penetration course and outbound from the IAF. If you arrive at the IAF at an altitude below that published, maintain altitude and proceed outbound 15 seconds for each 1000 feet the aircraft is below the published altitude before starting descent. If you arrive at the IAF at an altitude above that published, a descent to the published IAF altitude should be accomplished prior to starting the penetration. If descent is required at the IAF, obtain clearance to descend in a holding pattern. Set the altimeter in accordance with AFR 60-16 and FLIP.

b. Some penetrations use a fly-off (altitude or range) restricton before starting descent. In these cases, attempt to intercept the outbound penetration course and comply with the altitudes depicted on the approach chart unless otherwise instructed by ATC. Since the pilot cannot be expected to determine accurate groundspeed during a constantly changing true airspeed descent, depicted range restrictions should not be shown on non-DME teardrop high altitude penetrations. Penetration turns should be annotated "left or right turn at altitude." When a penetration turn altitude is not published, start the turn after descending one-half the total altitude between the IAF and FAF altitudes. One technique to determine the start turn altitude is to add the IAF and FAF altitudes and divide by 2. Before reaching the penetration turn altitude, set up the navigation equipment to intercept the published inbound penetration course. Recheck the altimeter and the direction of penetration turn.

c. Fly the penetration turn in the direction published. A 30° angle of bank is normally used during the penetration turn; however, bank may be shallowed if undershooting course. If it is apparent that you will undershoot the inbound penetration course, roll out on an intercept heading. Use normal inbound course interception procedures to intercept the course.

NOTE: If a penetration turn completion altitude is depicted, do not descend below this altitude until you are on course inbound.

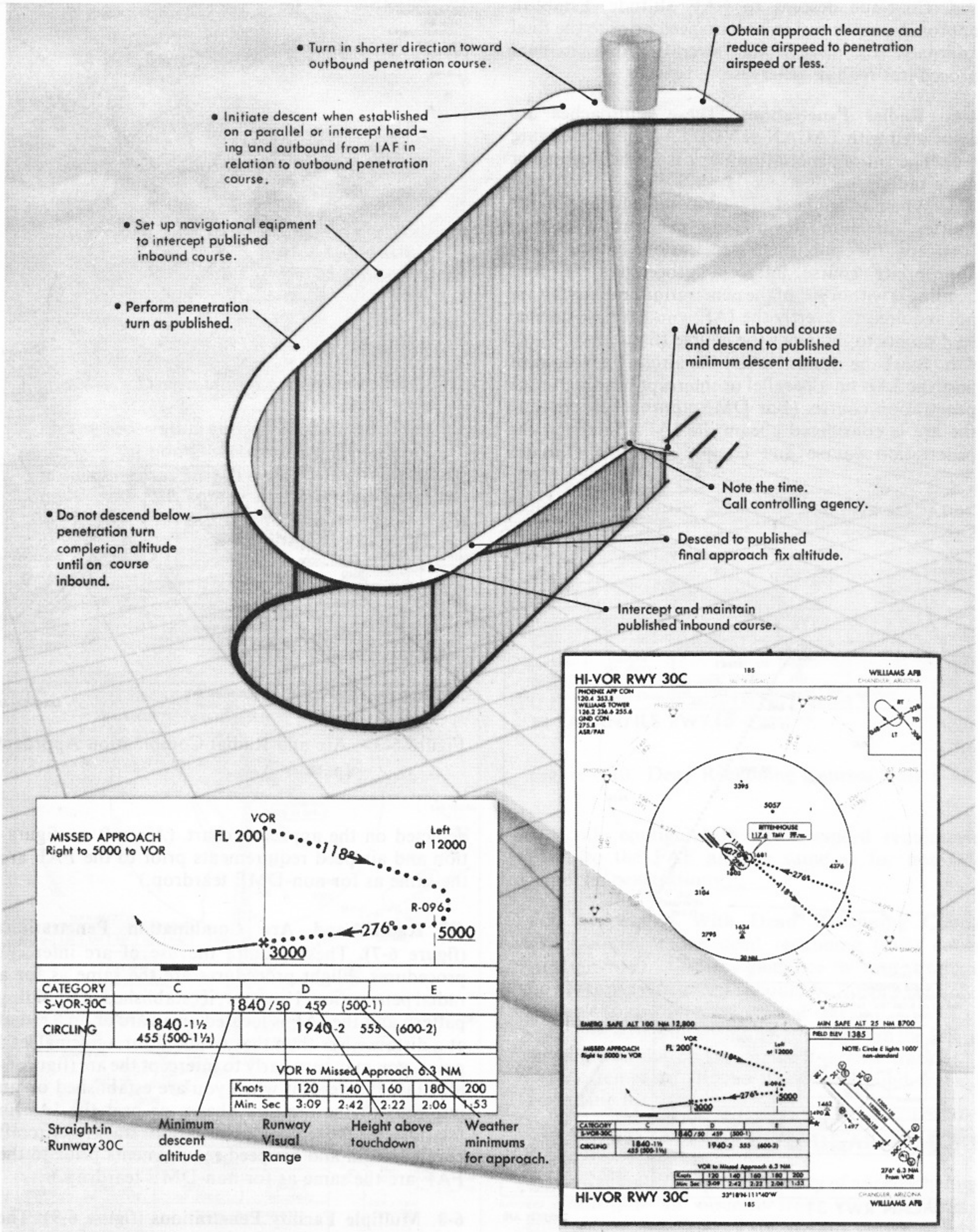


Figure 6-5. Non-DME Teardrop - High Altitude Approach (para 6-5).

d. Continue descent to FAF altitude. Establish approach configuration and airspeed prior to the final approach fix unless the aircraft flight manual procedures require otherwise.

6-6. Radial Penetrations. These approaches are associated with TACAN or VORTAC facilities (figure 6-6). The entire penetration track is formed by one or more radials.

a. When over the IAF, turn immediately in the shorter direction toward the penetration course. Intercept the published penetration course using appropriate course intercept procedures. If your heading is within 90° of the penetration course, you are not required to overfly the IAF; you may use normal lead points to intercept the course (figure 6-3).

b. Start the descent when the aircraft is abeam or past the IAF on a parallel or intercept heading to the penetration course. (For DME approaches, crossing the arc is considered abeam the IAF.) Intercept the penetration course and comply with the altitudes

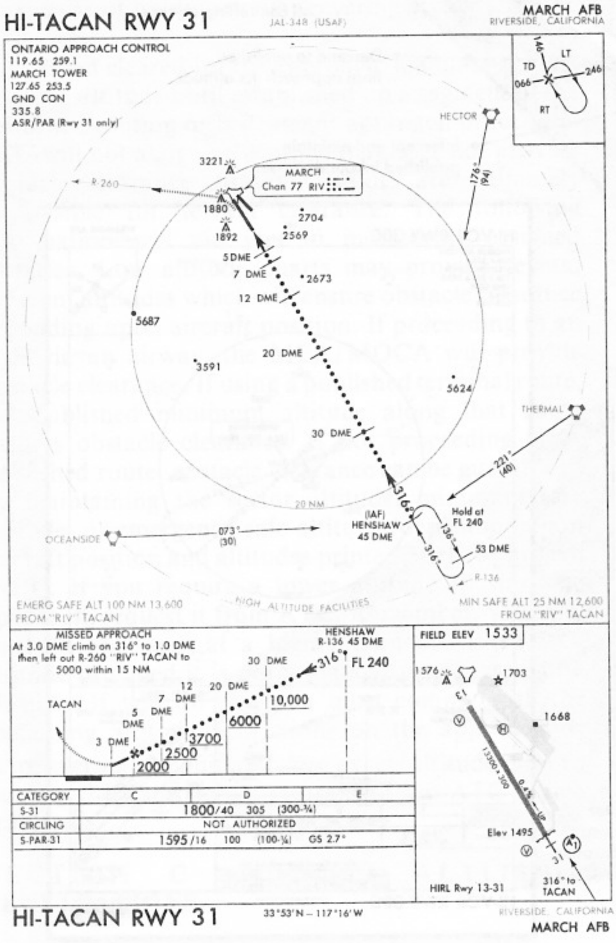


Figure 6-6. Radial - High Altitude Approach (para 6-6).

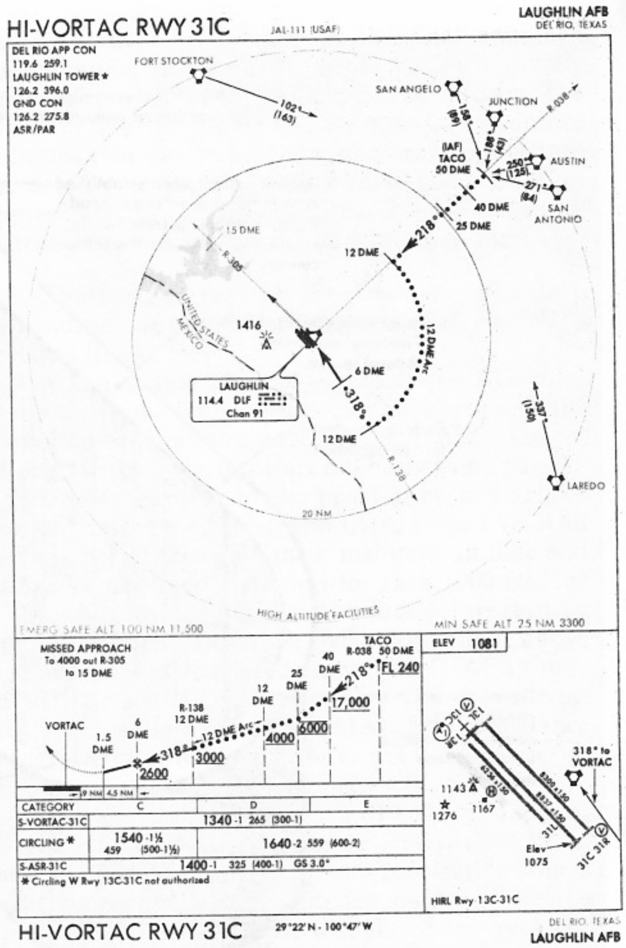


Figure 6-7. Arc and Radial Combination Approach (para 6-7).

depicted on the approach chart. (Aircraft configuration and airspeed requirements prior to the FAF are the same as for non-DME teardrop.)

6-7. Radial and Arc Combination Penetrations (figure 6-7). These require the use of arc intercept procedures. Flight procedures are the same as for a radial penetration. However, if established in a holding pattern and the IAF is located on an arc or on a radial at a distance less than that required for a normal lead point, you may turn early to intercept the arc (figure 6-8). Start the descent when you are established on an intercept to the arc and abeam or past the IAF in relation to the initial penetration track. (Aircraft configuration and airspeed requirements prior to the FAF are the same as for non-DME teardrop.)

6-8. Multiple Facility Penetrations (figure 6-9). The multiple facility type approach normally uses a combination of two or more VORs, NDBs, TACANs, etc., to provide the penetration track.

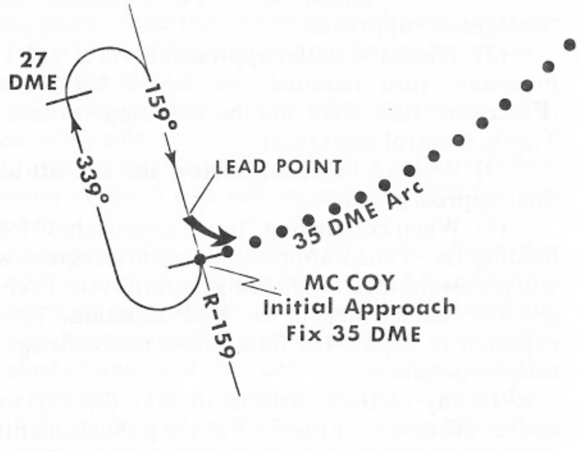


Figure 6-8. Determining Lead Point (para 6-7).

a. The penetration entry procedures are the same as prescribed for non-DME teardrop penetration.

b. The entire approach must be flown as depicted to comply with all course and altitude restrictions.

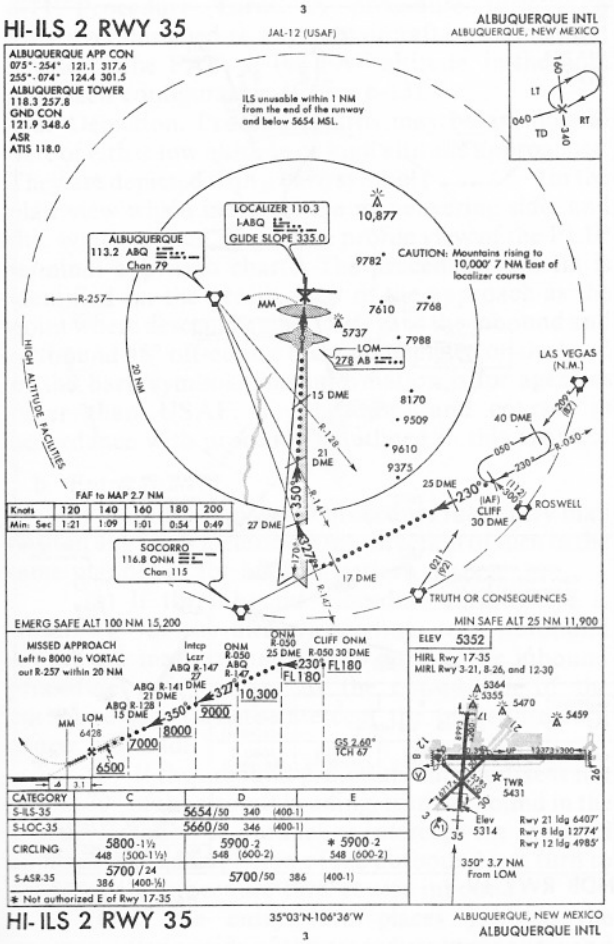


Figure 6-9. Multiple Facility Approach (para 6-8).

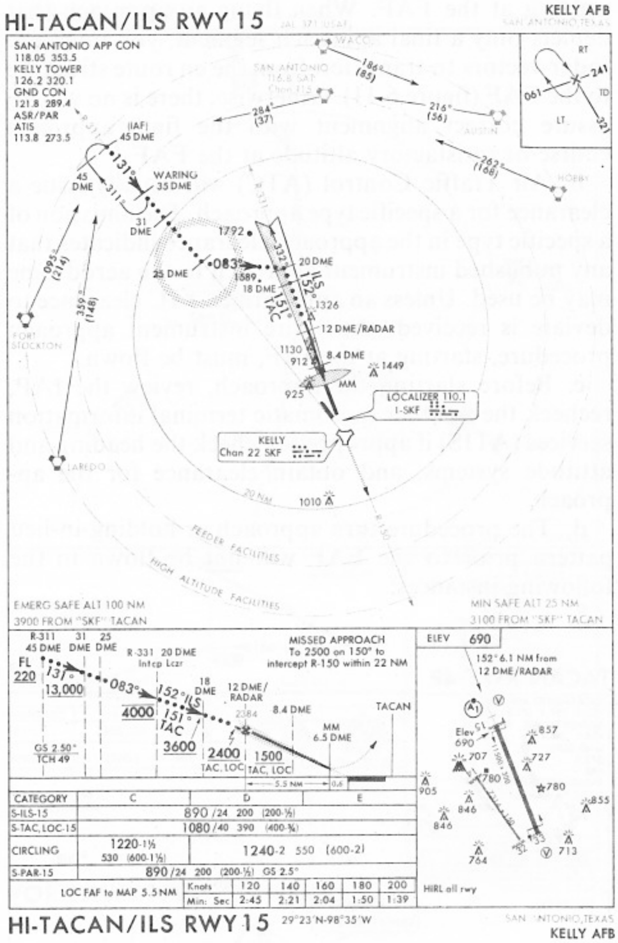


Figure 6-10. Dead Reckoning Courses (para 6-9).

(Aircraft configuration and airspeed requirements prior to the FAF are the same as for non-DME teardrop penetrations.)

6-9. Penetration With Dead Reckoning Courses. Many IAPs utilize dead reckoning (DR) courses (figure 6-10). Course guidance is not available; however, the DR course should be flown as closely as possible to the depicted ground track.

a. Use lead points for turns to and from the DR legs so as to roll out on the depicted ground track.

b. Attempt to fly the depicted ground track by correcting for wind.

SECTION D — LOW ALTITUDE APPROACHES

6-10. General. There are a variety of approaches used to transition an aircraft from the low altitude environment to final. This section covers a cross-section of available low altitude approaches.

a. Some low altitude instrument procedures depict only a final approach segment with the approach

6-10

starting at the FAF. When flying an approach that depicts only a final approach segment, you must use radar vectors to transition from the en route structure to the FAF (figure 6-11). Otherwise, there is no way to assure correct alignment with the final approach course or satisfactory altitude at the FAF.

b. Air Traffic Control (ATC) will usually issue a clearance for a specific type approach. The omission of a specific type in the approach clearance indicates that any published instrument approach to the aerodrome may be used. Unless an appropriate ATC clearance to deviate is received, the entire instrument approach procedure, starting at the IAF, must be flown.

c. Before starting the approach, review the IAP, recheck the weather (automatic terminal information services (ATIS) if appropriate), check the heading and attitude systems, and obtain clearance for the approach.

d. The procedure turn approach or holding-in-lieu pattern prior to the FAF will not be flown in the following instances:

(1) When issued an ATC clearance for a "straight-in" approach.

(2) When the initial approach is via a NoPT (no procedure turn required, see figure 6-12) course. (Procedure turn shall not be executed without Air Traffic Control clearance).

(3) When ATC radar vectors the aircraft to the final approach course.

(4) When conducting "timed approaches" from a holding fix. Timed approaches are in progress when you are established in a holding pattern at the FAF and given a time to depart the FAF inbound. You are expected to depart the fix as close to the designated time as possible.

e. In any of the situations in d(1), (2), (3), or (4) above, proceed over the FAF at the published altitude and continue inbound on the final approach course without making a procedure turn, holding pattern, or any other aligning maneuver prior to the FAF, unless otherwise cleared by ATC.

f. Two instances when the portion of the procedure turn approach prior to the FAF is not required, are:

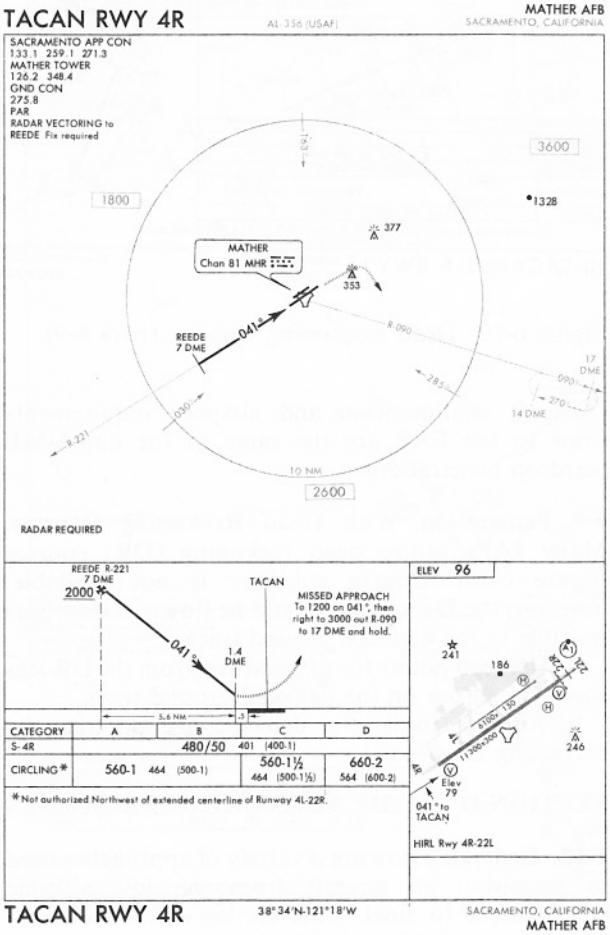


Figure 6-11. Approach With Final Segment Only (RADAR Required) (para 6-10a).

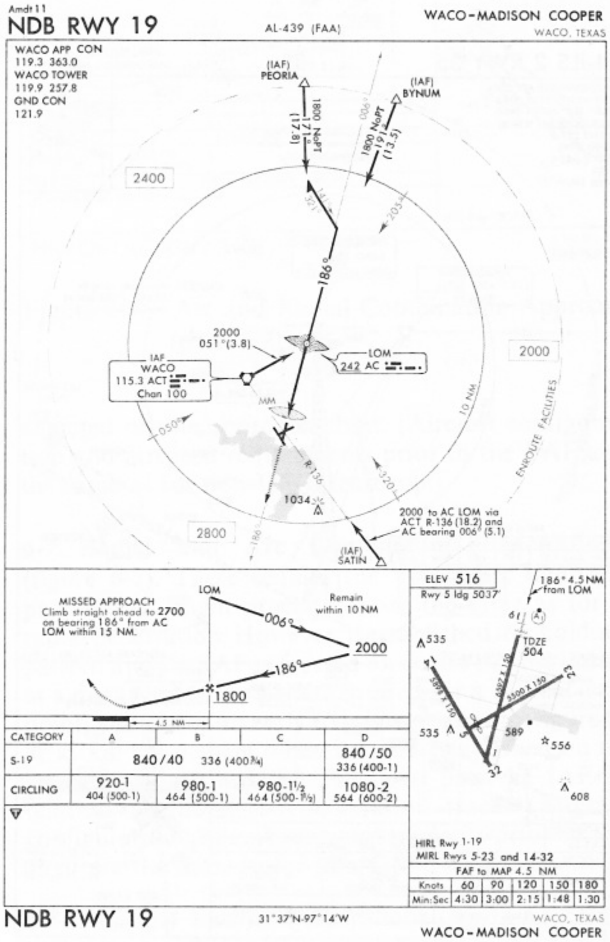


Figure 6-12. NoPT Routing (para 6-10d(2)).

(1) When established in a published or assigned holding pattern and the following conditions are met:

(a) The holding course and the procedure turn course are the same.

(b) The aircraft is on the procedure turn maneuvering side.

(2) When established in a holding pattern (in lieu of procedure turn) and subsequently cleared for the approach.

g. In either of the situations in f(1) or (2) above, the pilot has the option of returning to the IAF and flying the approach as depicted; or proceeding inbound via the published approach course to cross the FAF at the published altitude and then continuing inbound on the final approach course (without making a procedure turn, holding pattern, or any other aligning maneuver prior to the FAF). The decision to return to the IAF and complete the entire approach or to execute the approach from a holding pattern should be based upon such factors as your position in the holding pattern, altitude to be lost, aircraft capabilities, etc. In either case, advise ATC of your intentions.

6-11. Procedure Turns. A procedure turn is a maneuver designed to align an aircraft on an inbound course to the FAF, at the FAF altitude, in the final approach configuration (figure 6-13).

a. Depiction. Procedure turns may be an integral part of either low altitude or high altitude approaches. They are depicted with a barb symbol ( ) in the plan view which indicates the maneuvering side, and this symbol ( ) in the profile view of the FLIP terminal approach charts. The procedure turn fix is identified on the profile view of the approach as the point where descent begins. Disregard the inbound and outbound 45° off-course bearings depicted on the head of the barb symbol. This information is for agencies other than USAF. Fly headings and courses in accordance with procedures outlined in this chapter.

b. Entry:

(1) Parallel. A parallel procedure turn entry may be used any time. Determine the direction of turn in the same manner as for holding pattern entry.

(a) If the inbound procedure turn course is within 70° of the aircraft heading, turn outbound toward the maneuvering side to parallel the inbound procedure turn course. At the completion of the outbound leg, turn to intercept the procedure turn course inbound.

(b) If the inbound procedure turn course is not within 70° of the aircraft heading, turn outbound in the shorter direction to parallel or intercept the inbound course. At the completion of the outbound leg, turn to intercept the procedure turn course inbound.

(c) If the entry turn places you on the nonmaneuvering side of the procedure turn course and you are flying in excess of 180 KTAS, you must correct

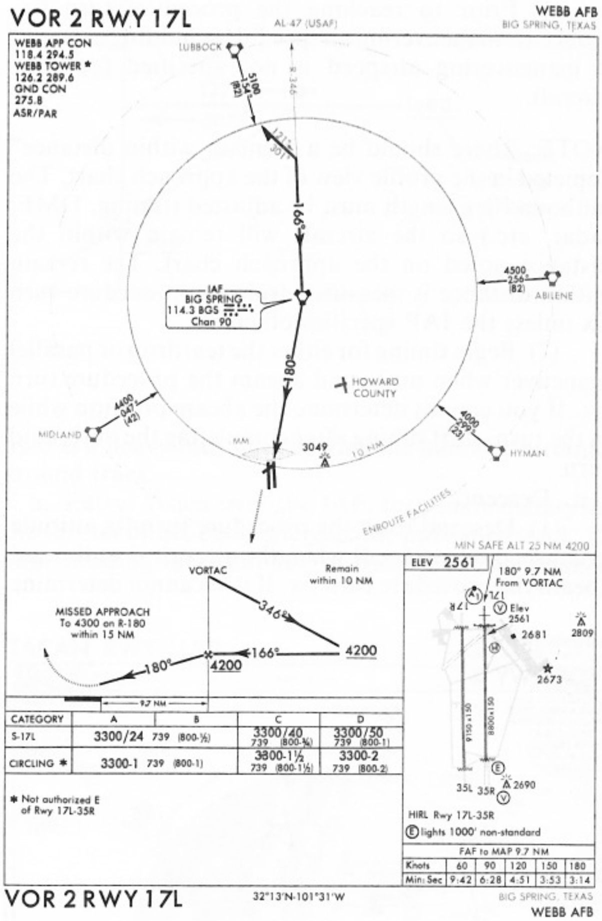


Figure 6-13. Procedure Turn (para 6-11).

toward the procedure turn course using an intercept angle of at least 20 degrees.

(d) If the procedure turn course is intercepted outbound, maintain course for the remainder of the outbound leg, then turn toward the maneuvering side to reverse course.

(2) Teardrop. The teardrop procedure turn maneuver may be used if, upon arrival at the procedure turn fix, the aircraft heading is conveniently aligned with the teardrop course. The teardrop course will be displaced 30° or less from the published inbound course and on the maneuvering side. When over the procedure turn fix, turn to parallel or intercept the selected outbound teardrop course. When outbound course guidance is available from the procedure turn fix, attempt to intercept and maintain the selected teardrop course before starting the inbound turn. If course guidance is not available, fly a heading which will allow the aircraft to parallel the teardrop course. At the completion of the outbound leg, turn to intercept the procedure turn course inbound.

c. Proceeding Outbound:

(1) Prior to reaching the procedure turn fix, reduce to maneuvering airspeed. Use holding airspeed if maneuvering airspeed is not specified for your aircraft.

NOTE: There should be a "remain within distance" depicted in the profile view of the approach chart. The outbound leg length must be adjusted (timing, DME, radar, etc.) so the aircraft will remain within the distance noted on the approach chart. The remain within distance is measured from the procedure turn fix unless the IAP specifies otherwise.

(2) Begin timing for either the teardrop or parallel maneuver when outbound abeam the procedure turn fix. If you cannot determine the abeam position while in the turn, start timing after completing the outbound turn.

d. Descent:

(1) Descend from the procedure turn fix altitude (published or assigned) when the aircraft is outbound abeam the procedure turn fix. If you cannot determine the abeam position while in the turn, start descent after completing the outbound turn. Descend from the procedure turn altitude when the aircraft is on course inbound. Continue descent to FAF altitude. Establish approach configuration and airspeed prior to the final approach fix unless your aircraft flight manual procedures require otherwise.

(2) When the portion of a procedure turn prior to the FAF is not flown (when established in a published or assigned holding pattern, the holding course and the procedure turn course are the same, the aircraft is on the maneuvering side, and subsequently cleared for the approach), the descent procedures in the preceding paragraph apply.

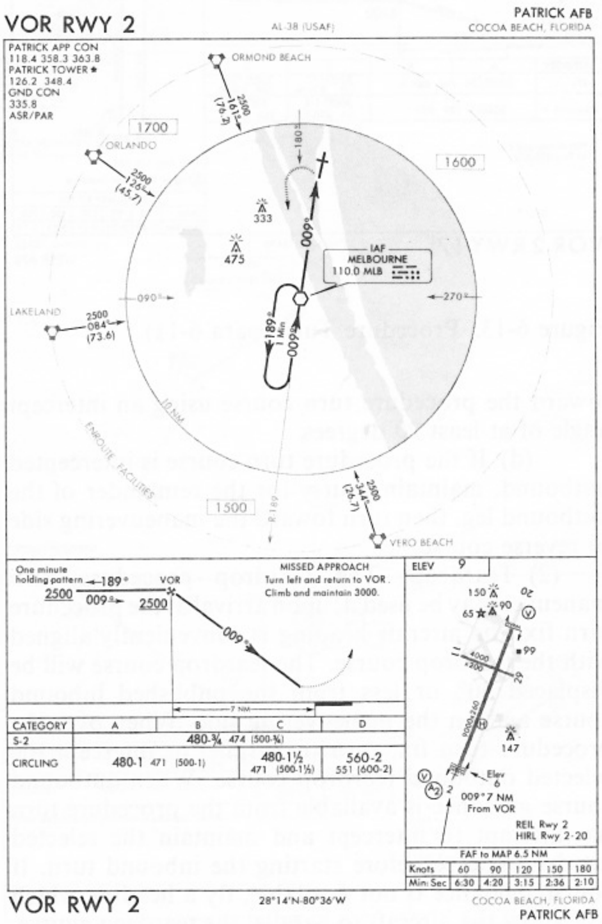


Figure 6-14. Holding Pattern (In Lieu of Procedure Turn) (para 6-12).

6-12. Holding Pattern (In Lieu of Procedure Turn) (figure 6-14). A holding pattern serves the same purpose as a procedure turn. They are used to align an aircraft on an inbound course to the FAF, at FAF altitude in the final approach configuration.

a. Depiction. The depiction used is the normal holding pattern track printed with a heavy blue line (▭) in the plan view. The profile view may vary since the descent may occur at different points for different approaches.

b. Entry. The entry maneuvering is the same as for any other holding pattern.

c. Pattern. Fly the holding pattern using the normal holding procedures for timing and corrections.

NOTE: If entry places you on the nonholding side of the holding course and you are maneuvering in excess of 180 KTAS you must correct toward the holding course using an intercept angle of at least 20 degrees.

d. Descent (figure 6-15). Descent from the minimum holding altitude may be depicted in two ways — descent at the holding fix, or descent on the inbound leg. When descent is depicted on the inbound leg, the aircraft must be on course prior to beginning descent.

(1) When cleared for the approach en route to the holding fix, proceed to the holding fix, turn and proceed outbound in the holding pattern for the applicable time. (If cleared for the approach after established in the holding pattern, you may fly the remainder of the approach as depicted from your present position, or fly direct to holding fix and execute the holding pattern approach. In either case, notify ATC of your intentions.)

(2) Continue descent to the FAF altitude and establish the approach configuration and airspeed prior to reaching the FAF or in accordance with the aircraft flight manual.

6-13. Procedural Tracks. These alternate maneuvers to a procedure turn are designed to align the aircraft on an inbound course to the FAF, and at FAF altitude in the final approach configuration (figures 6-16, 6-17, and 6-18).

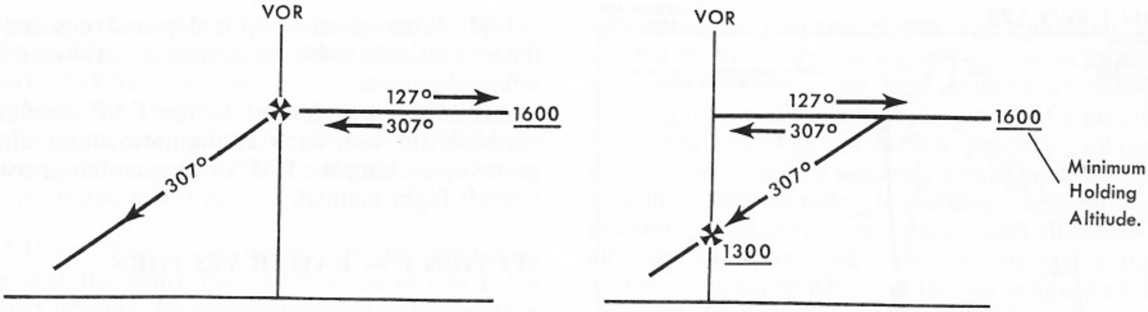


Figure 6-15. Descent from Holding Pattern (para 6-12d).

a. Depiction. There is no specific depiction for a procedural track. It may employ arcs, radials, courses, turns, etc. When a specific flightpath is required, procedural track symbology is used to depict the flightpath between the IAF and FAF. The depiction used is a heavy blue line showing the intended aircraft ground track.

b. Entry. When over the IAF, turn immediately in the shorter direction to intercept the published track. If your heading is within 90° of the procedural course

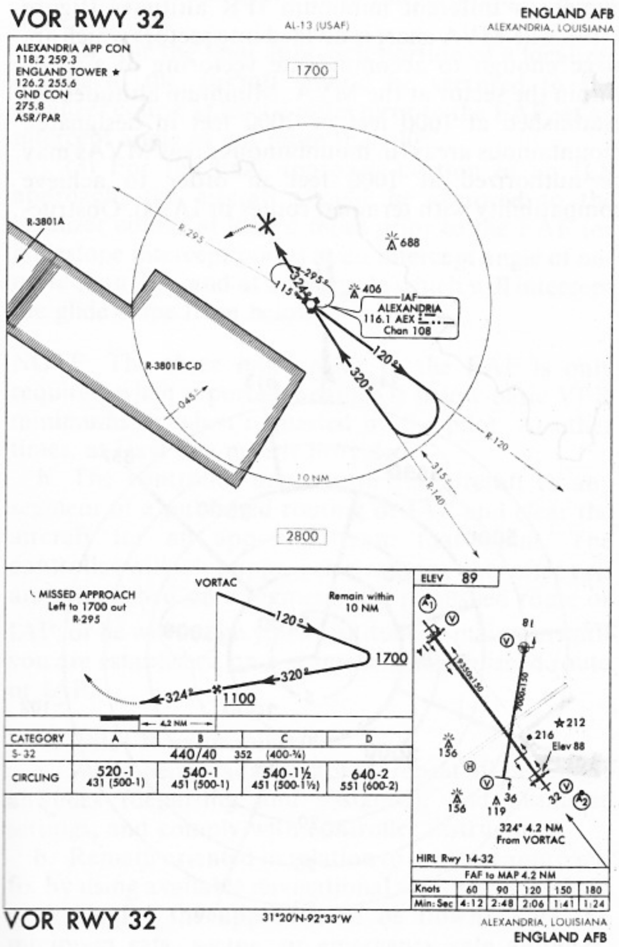


Figure 6-16. Procedural Track (Teardrop) (para 6-13).

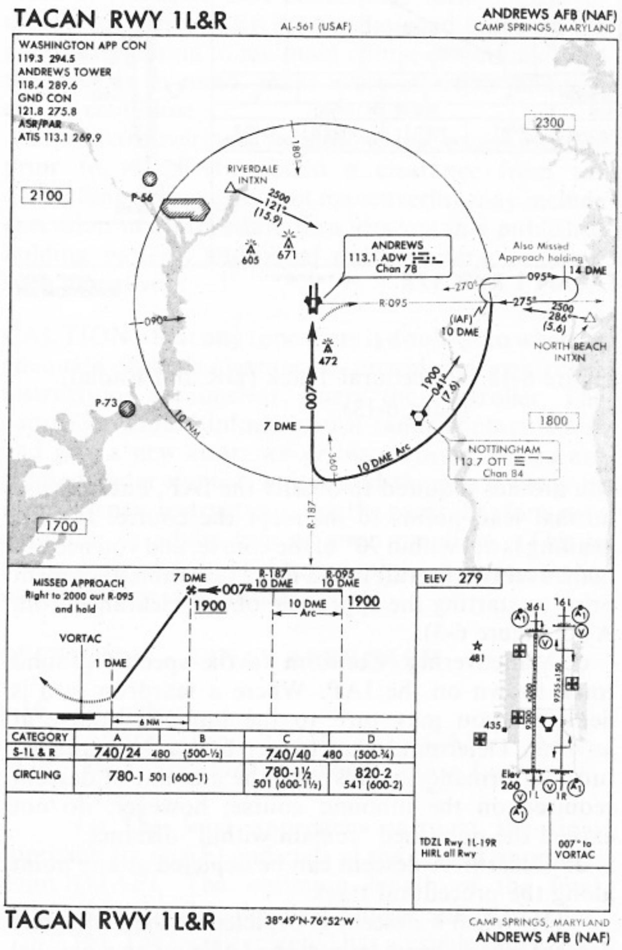


Figure 6-17. Procedural Track (Arc and Radial) (para 6-13).

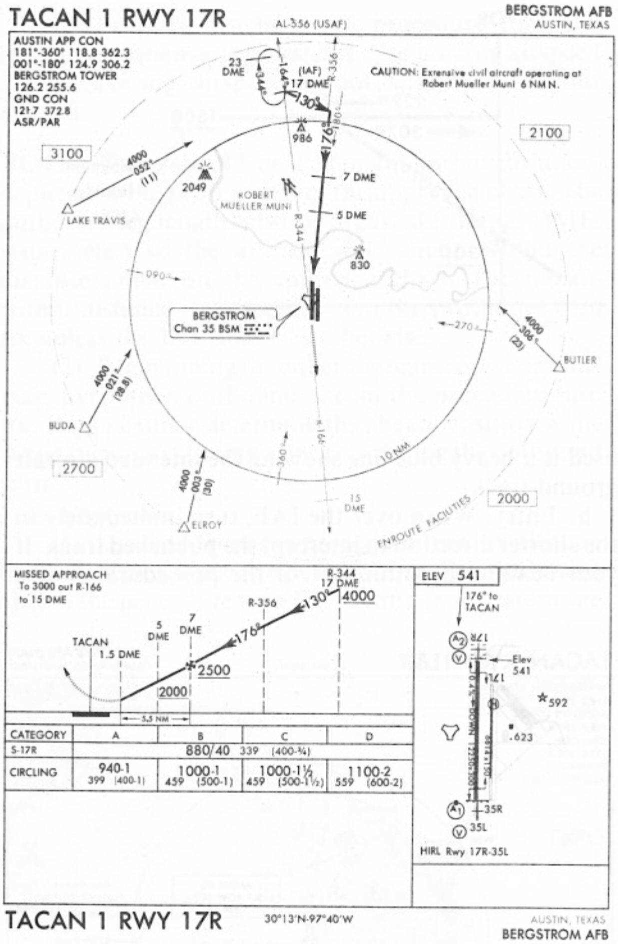


Figure 6-18. Procedural Track (DR and Radial) (para 6-13).

you are not required to overfly the IAF, but may use normal lead points to intercept the course. If your heading is not within 90° of the course, and you need to maneuver the aircraft into a more favorable alignment prior to starting the approach, obtain clearance from ATC (figure 6-3).

c. Maneuvering. Conform to the specific ground track shown on the IAP. Where a teardrop turn is depicted, you may turn to the inbound course at anytime. Determine when to turn by using the aircraft turn performance, winds, and the amount of descent required on the inbound course; however, do not exceed the published "remain within" distance.

d. Descent. A descent can be depicted at any point along the procedural track.

(1) When a descent is depicted at the IAF, start descent when abeam or past the IAF and on a parallel or intercept heading to the procedural track course. Be on the procedural track course prior to descending to the next appropriate altitude shown on the IAP.

(2) Where a teardrop is depicted, descend from the turn altitude when the aircraft is established on the inbound course.

(3) Continue descent to the FAF altitude and establish the approach configuration and airspeed prior to reaching the FAF or in accordance with the aircraft flight manual.

SECTION E — RADAR VECTORS

6-14. General. The use of radar vectors is the simplest and most convenient way to position an aircraft for an approach. Using radar, air traffic controllers can position an aircraft at almost any desired point, provide obstacle clearance by the use of minimum vectoring altitudes, and ensure traffic separation. This flexibility allows an aircraft to be vectored to any segment of a published routing shown on the IAP or to a radar final. Radar controllers use minimum vectoring altitude (MVA) charts which are prepared by the air traffic facilities at locations where there are numerous different minimum IFR altitudes (figure 6-19). The MVA chart is divided into sectors which are large enough to accommodate vectoring of aircraft within the sector at the MVA. Minimum altitudes are established at 1000 feet or 2000 feet in designated mountainous areas (in mountainous areas MVAs may be authorized at 1000 feet in order to achieve compatibility with terminal routes or IAPs). Obstruc-

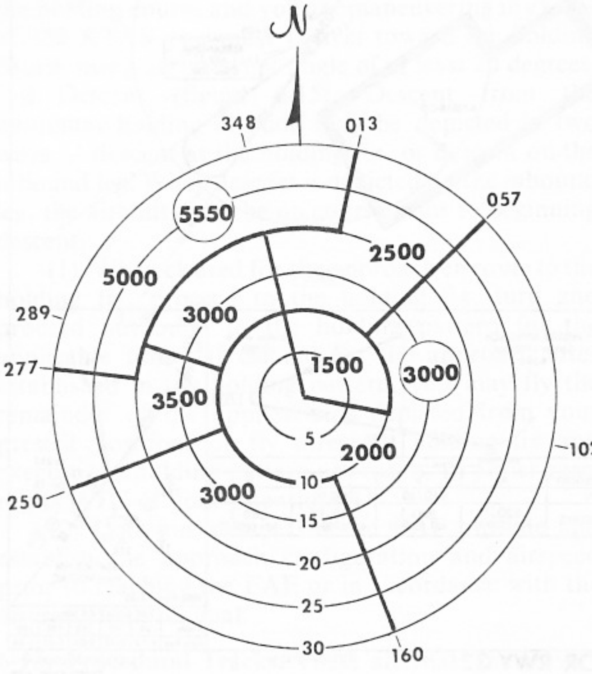


Figure 6-19. Minimum Vector Altitude (MVA) Chart (para 6-14).

tions may be enclosed in a 3 NM buffer area (5 NM if the obstruction is beyond 40 NM from the radar antenna). MVAs may be lower than nonradar MEAs/MOCAs. They may also be below emergency safe, minimum safe, or sector altitudes. However, when being radar vectored, IFR altitude assignments will be at or above MVA.

WARNING: "Traffic advisories" is an additional service that the controller will provide to you if his workload permits. Be aware that traffic information while on a PAR final is almost nil due to the narrow azimuth scan of the PAR equipment.

a. Radar vectors are often given to enable an aircraft to complete a nonradar final approach without accomplishing the entire IAP. The following general guidance applies to the radar controller when positioning an aircraft for a final approach:

(1) For the final approach portion of a nonprecision approach (other than localizer), the aircraft should be vectored to the final approach course at least 1 mile prior to the FAF, at an intercept angle of not more than 30°.

(2) For the final approach portion of a localizer approach, the aircraft should be vectored to the localizer course at least 3 miles piror to the FAF, at an intercept angle of not more than 30°.

(3) For the final approach portion of an ILS approach, the aircraft should be vectored to the localizer course at least 3 miles prior to the FAF (or glideslope intercept point) at an intercept angle of not more than 30°, and at an altitude which will intercept the glide slope from below.

NOTE: The three miles prior to the FAF is only required when reported weather is below basic VFR minimums or when requested by the pilot. At other times, at least one mile is provided.

b. The controller may vector the aircraft to any segment of a published routing or IAP and clear the aircraft for an approach from that point. The controller will issue approach clearance only after you are established on a segment of a published route or IAP; or he will assign you an altitude to maintain until you are established on a segment of a published route or IAP.

6-15. Pilot Responsibilities:

a. While being radar vectored, repeat all headings, altitudes (departing and assigned), and altimeter settings; and comply with controller instructions.

b. Remain oriented in relation to the final approach fix by using available navigational aids. Have the IAP available for the approach to be flown. Note the minimum safe, sector, or emergency safe altitudes. Start the Before Landing Checklist (landing check), review approach minimums, and determine the approximate initial rate of descent required on final approach. Be prepared to fly the approach when cleared by the controller. Once you receive approach clearance, maintain the last assigned altitude and heading until established on a segment of a published routing or IAP. Use normal lead points to roll out on course. Then use any available means (such as DME, crossing radials, or radar) to accurately determine your position. From that point, comply with all course and altitude restrictions at or below the last assigned altitude. Do not climb above the last assigned altitude to comply with published altitude restrictions unless so instructed by the controlling agency. Establish final approach configuration and airspeed prior to the FAF (unless flight manual procedures require otherwise).

c. For descent purposes (for all approaches) you are considered on course when you have an intercept heading to the course and are within, and will remain within, 2½° of the course. Momentary deviations outside the 2½° do not require you to discontinue descent nor do they require you to climb back to the previously assigned or published altitude (except localizer full scale CDI deflection). Terminal Instrument Procedures (TERPs) are designed based on the pilot's attempting to maintain course centerline. With this criteria in mind, make every effort to maintain course centerline.

d. If maneuvering is required to lose excess altitude prior to the FAF, obtain a clearance from the controlling agency. Descent maneuvering may include execution of a procedure turn, descent in a published holding pattern, additional radar vectors, or other such maneuver.

CAUTION: If at any time there is doubt as to whether adequate obstacle clearance is provided or controller instructions are unclear, query the controller. The controller should inform you if radar contact is lost and give a new clearance or instructions. If you are advised radar contact is lost and there is a delay in receiving new instructions, ask the controller for a new clearance or advise him of your intentions. (This is particularly important if below minimum safe, sector, or emergency safe altitude.)

SECTION F — FINAL APPROACH

6-16. Nonradar:

a. Nonprecision (VOR, TACAN, ADF, VOR/DME, Localizer and Back Course Localizer):

(1) General:

(a) The final approach starts at the final approach fix (FAF) and ends at the missed approach point (MAP). The optimum length of the final approach is 5 miles; the maximum length is 10 miles.

(b) The localizer signal has a usable range of at least 18 miles within 10° of the course centerline unless the instrument approach procedure depicts a greater distance or radar service is provided. For back course localizer approaches, set the published front course in the course selector window.

(2) Flying the approach:

(a) Avoid rapid descent requirements on final by crossing the FAF at the published altitude.

(b) Timing is required when the final approach does not terminate at a published fix, as is usually the case with VOR, ADF, and localizer. Start timing when passing the FAF. Time and distance tables in the approach charts are based on groundspeed; therefore, the existing wind and TAS must be considered to accurately time the final approach. (Timing can also be valuable as a backup in the event of DME loss or other problems which might preclude determination of the MAP.)

(c) When a turn is required over the FAF, turn immediately and intercept the final approach course to ensure that obstruction clearance airspace is not exceeded.

(d) When passing the FAF, start descent to minimum descent altitude (MDA) or stepdown fix altitude.

(e) Arrive at MDA with enough time and distance remaining to identify runway environment and depart MDA from a normal visual descent point to touchdown at a rate normally used for a visual approach in your aircraft.

(f) Descent below MDA is not authorized until sufficient visual reference with the runway environment has been established and the aircraft is in a position to execute a safe landing. Thorough preflight planning will aid you in locating the runway environment (lighting, final approach displacement from runway, etc.).

(g) Be aware that the final approach course on a nonradar final may vary from the runway heading as much as 30° (except localizer) and still be published as a straight-in approach.

(h) A step down fix between the FAF and the missed approach point is sometimes used. Descent below stepdown fix altitude is limited to aircraft capable of simultaneous reception of final approach course guidance and the stepdown fix. Regardless of the type or number of navigational facilities used to form the stepdown fix, one navigational receiver must remain tuned to and display the navigational facility that provides final approach course guidance. For example, aircraft equipped with a single VOR receiver will not descend below a stepdown fix altitude when that fix is formed by two VOR radials. The VOR receiver must remain tuned to and display the facility that provides the final approach course.

(i) (HELICOPTER PILOTS ONLY) Helicopter only approaches are identified by the term "copter," the type of facility producing final approach course guidance, and a numerical identification of the final approach course; for example, copter VOR 090, copter TACAN 293 (figure 6-20). The criteria for

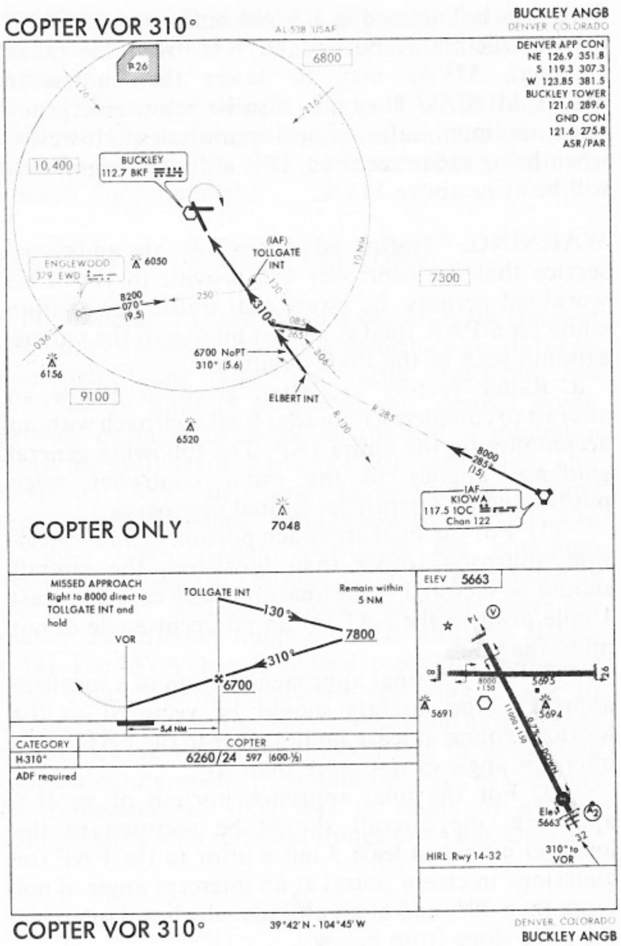


Figure 6-20. Copter Only Approach (para 6-16a(2)(i)).

copter approaches are based on the premise that helicopters are approach category A aircraft with special maneuvering characteristics. The approach is based on an airspeed not exceeding 90 knots. Copter approaches are generally shorter in length and the descent gradient on the approach can be steeper than on a fixed wing approach.

b. Precision (ILS and Back Course ILS):

(1) Transition to the ILS Localizer Course. This is performed by using either radar vectors or a published approach procedure.

(a) Tune the ILS as soon as practicable during the transition and monitor the identifier during the entire approach.

(b) Set the published localizer front course in the course selector window prior to attempting localizer interception.

NOTE: If using a flight director system, the switches should be positioned in accordance with instructions in the aircraft flight manual for intercept and final approach modes of operation. Normally, manual selection of the final approach mode would be delayed until the aircraft heading is within 15° of the localizer course and the CDI is within one dot of center.

(c) Use any available navigation facility (for example, TACAN) to aid in remaining position oriented in relation to the localizer course and glide slope intercept point. (The glide slope has a usable range of 10 miles.)

(2) Accomplish the Approach.

(a) Once the localizer course is intercepted, reduce heading corrections as the aircraft continues inbound. Heading changes of approximately 5° increments will usually result in more precise course control.

(b) Maintain glide slope interception altitude (published or assigned) until reaching the glide slope intercept point. (Do not descend below glide slope interception altitude if the CDI indicates full scale deflection.)

(c) Prepare to intercept the glide slope as the glide slope indicator (GSI) moves downward from its upper limits. Determine the approximate rate of descent required to maintain the glide slope. Slightly before the GSI reaches the center position, coordinate pitch and power control adjustments to establish a rate of descent on the VVI. The pitch change required will depend upon aircraft groundspeed and glideslope angle.

1. Pitch adjustments made in increments of 2° or less will usually result in more precise glide path control. As the approach progresses, smaller pitch and bank corrections are required for a given CDI/GSI deviation.

2. During the latter part of the approach, pitch changes of 1° and heading corrections of 5° or less will prevent overcontrolling.

(d) If using pitch and bank steering commands supplied by a flight director system, monitor flightpath and aircraft performance instruments to ensure that the desired flightpath is being flown and aircraft performance is within acceptable limits. A common and dangerous error when flying an ILS on the flight director is to concentrate on the steering bars and ignore flightpath and aircraft performance instruments. Failure of the flight director computer (steering bars) may NOT always be accompanied by the appearance of warning flags. Steering commands must be correlated with flightpath (CDI and GSI) and aircraft performance instruments.

(e). Maintain a complete instrument cross-check throughout the approach, with increased emphasis on the altimeter during the latter part (DH is determined by the barometric altimeter). Establish a systematic scan for the runway environment prior to reaching DH. At DH, if visual reference with the runway environment is established, continue the approach to landing using flight instruments to complement the visual reference.

CAUTION: The ILS/LOC approach must be discontinued if the localizer course becomes unreliable, or any time full scale deflection of the CDI occurs on final approach. Do not descend below localizer minimums if the aircraft is more than one dot (half scale) below or two dots (full scale) above the glide slope. If localizer minimums are not published, transition may be made to another straight-in approach if published in conjunction with the ILS approach. If the glide slope is recaptured to within the above tolerance, descent may be continued to DH.

6-17. Radar:

a. General. There are two basic types of approaches — the precision and the surveillance. The precision approach provides the pilot with precise course, glide slope, and range information; the surveillance approach provides course and range information and is classified as a nonprecision approach. Upon request, the controller will provide recommended altitudes on final to the last mile which is at or above the published MDA. Recommended altitudes are computed from the start descent point to the runway threshold. (At the MAP, the straight-in surveillance system approach error may be as much as 500 feet from the runway edges.)

b. Voice Procedures. The radar approach is predicated entirely upon voice instructions from the approach control or radar controller. Repeat all headings, altitudes (departing and assigned), and altimeter settings until the final controller advises "do not acknowledge further transmissions." During high density radar operations, a limiting factor is the communication time available. Keep transmissions brief and specific, commensurate with safety of flight. Never sacrifice aircraft control to acknowledge receipt of instructions.

c. Transitioning to Final:

(1) The transition to final segment of the approach includes all maneuvering up to a point where the aircraft is inbound and approximately 8 nautical miles from touchdown. A dogleg to final is considered to be part of the "transition to final" segment.

(2) During the transition to final, the radar controller directs heading and altitude changes as required to position the aircraft on final approach. Turns and descents should be initiated immediately after instructed. Perform turns by establishing an angle of bank, on the attitude indicator, which will approximate a standard rate turn for the TAS flown but not to exceed 30° of bank. When the aircraft or mission characteristics dictate very low turn rates, it is advisable to inform the controller. The controller uses this information to assist in determining lead points for turns or corrections.

(3) The radar controller will issue lost communication procedures as soon as possible after establishing radar contact and radio communication if weather reports indicate that IFR conditions are likely to be encountered. Lost communication procedures must be understood and remembered — written down if necessary.

(4) Weather information issued by the radar controller will include altimeter setting, ceiling, and visibility. The controller is required to issue ceiling and visibility only when the ceiling is below 1000 feet or below the highest circling minimum, whichever is greater, or if the visibility is less than 3 miles.

(5) The controller will furnish pertinent information on known field conditions which he considers necessary to the safe operation of the aircraft concerned. You should request additional information, as necessary, to make a safe approach.

(6) Use available navigational aids to remain position oriented in relation to the landing runway and the glide slope intercept point. The controller will advise you of the aircraft position at least once before starting final approach.

(7) Start the Before Landing Checklist (landing check), review approach minimums, and tune navigation equipment to comply with lost communication instructions when practical. Determine the approximate initial descent rate required on final approach. Establish the aircraft configuration and airspeed in accordance with the aircraft flight manual. If final approach configuration is established prior to turning onto final, avoid using excessive bank angles that could make precise aircraft control difficult.

d. Accomplishing the Approach:

(1) Nonprecision - Airport Surveillance Radar (ASR):

(a) The controller will inform the pilot of the runway to which the approach will be made, the straight-in MDA (if a straight-in approach is being made), and MAP location, and will issue advance notice of where the descent to MDA will begin. When the approach will terminate in a circling approach, furnish the controller with your aircraft category. He will then issue the circling MDA. Circling MDA for radar approaches are found in the IFR Enroute Supplement. (The circling MDA found on the IAP does not refer to radar.)

(b) When the aircraft reaches the descent point, the controller will advise you to descend to MDA. If a descent restriction exists, the controller will specify the prescribed restriction altitude. When the aircraft is past the altitude limiting point, the controller will advise you to continue descent to MDA.

(c) Arrive at the MDA with enough time and distance remaining to identify runway environment and descend from MDA to touchdown at a rate normally used for a visual approach in your aircraft.

NOTE: Upon request, all controllers will provide recommended altitudes each mile on final approach down to the last mile that is at or above the published MDA. Due to the possible different locations of the MAP, recommended altitudes may position you at MDA at or slightly prior to the MAP. Consider this in relation to the normal visual descent point required for your aircraft.

(d) The controller will issue course guidance when required and he will give range information each mile while on final approach. You may be instructed to report the runway in sight. Approach guidance will be provided until the aircraft is over the missed approach point unless you request discontinuation of guidance. The controller will inform you when you are at the MAP.

(e) Fly the aircraft at MDA until arrival at the missed approach point or until establishing visual contact with the runway environment. If you do not report the runway environment in sight, missed approach instructions will be given.

(2) Precision Approach Radar (PAR):

(a) The precision final approach starts when the aircraft is within range of the precision radar and contact is established with the final controller. Normally this occurs at approximately 8 miles from touchdown.

(b) Approximately 10 to 30 seconds before final descent, the controller will advise that the aircraft is approaching the glide path. When the aircraft reaches the point where final descent is to start, the controller will state "begin descent." At that point, establish the predetermined rate of descent. Adjust power or use drag devices as required to maintain desired airspeed or angle of attack. When the airspeed or angle of attack and glide path are stabilized note the power, attitude, and vertical velocity. Use these values as guides during the remainder of the approach.

(c) The controller issues course and glide path guidance, and frequently informs you of any deviation from course or glide path. The controller's terminology will be: on course, on glide path; slight/well above/below glide path; or slightly/well left/right of course. Controllers may also issue trend information to assist you in conducting a PAR approach. Examples of trend information phraseologies which may be used are: going above/below glide path; holding above/below glide path; holding left/right of course, etc. Trend information may be modified by the use of the terms rapidly or slowly as appropriate. The terms slightly or well are used in conjunction with the trend information.

(d) Corrections should be made immediately after instructions are given, or when deviation from established attitude or desired performance is noted. Avoid excessive throttle, pitch, or bank changes. Normally pitch changes of one degree will be sufficient to correct back to glide path.

(e) Accurate heading control is important for runway alignment during the final approach phase. When instructed to make heading changes, make them immediately. Heading instructions are preceded by the phrase "turn right" or "turn left." To prevent overshooting, the angle of bank should approximate the number of degrees to be turned, not to exceed a one-half standard rate turn. At high final approach speeds, a larger angle of bank may be required to prevent a prolonged correction. In any case, do not exceed the one-half standard rate turn. After a new heading is directed, the controller assumes it is being maintained. Additional heading corrections will be based on the last assigned heading.

(f) Decision Height (DH) is the altitude at which a missed approach will be initiated when either visual reference with the runway environment has not been established or the aircraft is not in a position to execute a safe landing. The controller will advise the pilot when the aircraft is passing the published DH. DH is determined in the cockpit either as read on the altimeter or when advised by the controller, whichever occurs first. The controller will continue to provide advisory course and glide path information until the aircraft passes over the landing threshold at which time he will advise "over landing threshold." (To provide a smooth transition from instrument to visual conditions, a systematic scan for runway environment should be integrated into the cross-check prior to reaching DH.)

(3) No-Gyro Approach (Heading Indicator Inoperative):

(a) If the heading indicator should fail during flight, advise the radar controller and request a no-gyro approach. The final approach may be either precision or surveillance.

(b) Perform turns during the transition to final by establishing an angle of bank on the attitude indicator which will approximate a standard rate turn (not to exceed 30° of bank). Perform turns on final by establishing an angle of bank on the attitude indicator which will approximate a half-standard rate turn. If unable to comply with these turn rates, advise the controller so that he may determine lead points for turns and heading corrections. Initiate turns immediately upon hearing the words "turn right" or "turn left." Stop the turn on receipt of the words "stop turn." Acknowledge the controller's commands to start and stop turns until advised not to acknowledge further transmissions.

SECTION G — LANDING FROM INSTRUMENT APPROACHES

6-18. Planning the Approach and Landing:

a. A successful approach and landing in marginal weather conditions requires considerable planning, which should begin before the flight. Checking the forecast weather, winds, NOTAMs, and runway conditions at your destination and alternate will normally help you determine the runway and type of approach that is likely to be used. A study of the instrument approach procedure for the destination airport will show the approach as well as the runway layout, obstructions, type of lighting installed, and minimum data.

b. When planning, try to form a mental picture of the airfield layout as well as the location of prominent landmarks. Be familiar with the types of lighting installed on the landing runway. Note the distance to the airfield from available NAVAIDS in the immediate area. There is no substitute for proper and thorough planning as this will help prepare you for the transition from instrument to visual conditions.

6-19. Transitioning From Instrument to Visual Flight Conditions. The transition from instrument to contact flight conditions varies with each approach. Pilots seldom experience a distinct transition from instrument to visual conditions during an approach in obscured weather. Obscured conditions present you with a number of problems not encountered during an approach that is either hooded or has a cloud base ceiling. At the point where the hood is pulled or the aircraft breaks out below the ceiling, the visual cues used to control the aircraft are usually clear and distinct and there is instantaneous recognition of the position of the aircraft in relation to the runway. With obscured ceilings or partially obscured conditions, the reverse is usually true; visual cues are indistinct and easily lost, and it is difficult to discern aircraft position laterally and vertically in relation to the runway. Consider every factor which might have a bearing on the final stages of an approach and landing. The visibility, type of weather, expected visual cues, and even crew procedures and coordination are some of the tangibles requiring careful consideration. Preparation and understanding are the keys which will make the transition smooth and precise. Only through a thorough understanding of the weather environment and how it affects the availability and use of visual cues will you be prepared to transition safely and routinely. The following information deals with some of the conditions you may encounter during this phase of flight.

a. Restrictions to Visibility. There are many phenomena, such as rain, smoke, snow, and haze which restrict visibility; however, one of the most common restrictive elements is fog, which may be encountered in a number of different forms, each with its own particular properties. When visibility restricitons do exist and the sky or clouds are totally hidden from the observer, it is reported as a total obscuration and the reported ceiling is the vertical visibility from the ground. If you are executing an approach in an obscured condition, you will not normally see the approach lights or runway environment as you pass the level of the obscured ceiling. You should be able to see the ground directly below; however, the transition from instrument to visual flight will occur at an altitude considerably lower than the reported vertical visibility. In partially obscured conditions, vertical visibility is not reported since the ground observer can see the sky through the obscuration. When clouds are visible with a partial obscuration, their heights and amounts are reported. The amounts (in 10ths) of the sky or clouds obscured by a partial obscuration is included in the remarks section of weather reports. Although this may help clarify the reported conditions in many cases, it still does not provide an idea of the height at which visual cues will be sighted or the slant range visibility. In some cases the partial obscuration can be associated with shallow patchy fog so you can expect to lose visual references once the fog condition is entered. Also of concern is the visual range at which you will be able to discern visual cues for runway alignment and flare. Be aware that the runway visibility or runway visual range (RVR) may not be representative of the range at which you will sight the runway. In fact, slant range visibility may be considerably less than the reported RVR. Another factor to consider is the decrease in the visual segment due to an aircraft downward vision angle. This also may be several hundred feet. Knowledge of these various factors will aid you in making a safe, smooth transition from instrument to visual flight.

(1) Shallow Fog. Fog that extends no more than 200 feet in height is considered shallow fog and is normally reported as a partial obscuration. Since the fog may be patchy, it is possible that the visual segment may vary considerably during the approach and rollout. Also, you may be misinformed if RVR is measured by transmissometer located in an area of good visibility. One of the most serious problems with this type of fog stems from the abundance of cues available at the start of the approach. You may see the approach lighting system and possibly even some of the runway during the early stages of the approach. However as the fog level is entered, most or all the cues may be lost. If you are not flying instruments, you may become confused and disoriented. In these conditions, you should not rely entirely on visual cues for guidance. They can be brought into the cross-check to confirm position, but instrument flight must be maintained until visual cues can be kept in view and the runway environment can provide sufficient references for alignment and flare.

(2) Deep Fog. Fog that extends to a height of several hundred feet usually forms a total obscuration. You will not normally see cues during the early portion of an approach. Most likely, you will pick up cues from only the last one thousand feet of the approach lighting system. From a US Standard approach lighting system, in rapid succession you will probably see cues from the 1000-foot bar, the last 1000 feet of the centerline approach lights, red terminating bar, red wing lights, green threshold lights, and the high intensity runway edge lights. If operating at night and the strobe lights are on, these may produce a blinding effect. Care should be taken with the use of landing lights as they also may cause a blinding effect at night. The transition from an approach in a total obscuration involves the integration of visual cues within the cross-check during the latter portion of the approach. Again, be thoroughly familiar with the approach lighting system to develop the proper perspective between these cues and the runway environment.

(3) Fog Below Clouds. This fog is usually reported as a partial obscuration below a cloud ceiling. Visibility usually increases when you descend below the cloud ceiling. Therefore, the transition from instrument to visual flight is sharper, with more pronounced use of visual cues after passing the ceiling. Night approaches may produce the sensation that the aircraft is high once the cloud base is passed. You should continue on instruments, cross-checking visual cues to confirm runway alignment. During the flare you may experience a sensation of descending below the surface of the runway. This will be especially pronounced at facilities with 300-foot wide runways. In either case, avoid abrupt or large attitude changes.

(4) Advection Fog. In most types of fog you may be expecting almost calm wind conditions and not be too concerned with side slip or decrab procedures. Advection fog, however, can present wind and turbulence problems not normally associated with other types of fog. Advection fog may possess characteristics similar to shallow, deep, or cloud base fog. It may be more difficult to maintain precise instrument flight because of turbulence. The characteristics of advection fog will be related to the wind speed increases. Wind greater than 15 knots usually lifts the fog and it forms a cloud base. The best procedure is to be aware of the conditions which might be encountered and to integrate visual cues within the cross-check during the latter portion of the approach. Since crosswinds may exist, be prepared to decrab while avoiding large attitude changes which might produce an undesirable touchdown attitude. Also closely monitor airspeed because of the effects of turbulence and the decrab.

(5) Ice Fog. This type of fog is most common to the arctic region; however, it can occur in other areas if the air temperature is below approximately −25° F. It consists of a suspension of ice crystals in the air and is more common around airports and cities. Condensation nuclei caused by human activity often cause the fog to form. When there is little or no wind, it is possible for an aircraft to generate enough fog during landing or takeoff to cover the runway and a portion of the field. Depending on the atmospheric conditions, ice fogs may last for several minutes or days. The

piloting hazards and procedures are basically the same as with other fogs but careful preflight planning must be made if the conditions exist for the formation of ice fog.

(6) Rain. Approaches and the ensuing transition to visual flight can be very hazardous since moderate to heavy rain conditions can seriously affect the use of visual cues. Night approaches in these conditions can be even more critical as you may be distracted by flashing strobes or runway end identifier lights. Transition to visual flight can be severely hampered by the inability to adequately maintain aircraft control and interpret the instruments as a result of gusty or turbulent conditions. The moderate or heavy rain conditions can also render the rain removal equipment ineffective, causing obscuration of visual cues at a critical time during the transition. In these conditions be prepared for an alternate course of action and act without hesitation to prevent the development of an unsafe situation.

(7) Snow. Blowing snow is accompanied by many of the same hazards as rain, such as turbulence, difficulties in reading the flight instruments, obscured visual cues, and aircraft control problems. Of special interest will be a lack of visual cues for runway identification for the visual portion of the approach. The approach and runway lights will provide some identification; however, runway markings and the contrast with relation to its surroundings may be lost in the whiteness. Therefore, depth perception may be difficult, requiring more emphasis on instruments for attitude control. It is extremely important to avoid large attitude changes during approaches in snow.

b. Visual Cues:

(1) Approach lights, runway markings, lights, and contrast are the primary sources of visual cues. At some facilities, touchdown zone and centerline lights may also be available. Become familiar with the lighting and marking patterns at your destination and correlate them with the weather so you will be prepared to transition to visual flight. In minimum visibility conditions, the visual cues and references for flare and runway alignment are extremely limited compared to the normal references used during a visual approach. Therefore, the aircraft's projected runway contact point may not be within your visual segment until considerably below published minimums.

WARNING: Any abrupt attitude changes to attempt to bring the projected touchdown point into your visual segment may produce high sink rates and thrust/lift problems at a critical time. Those so-called duck-under maneuvers must be avoided during the low visibility approach.

(2) Another potential duck-under situation occurs when you attempt to land within the first 500 to 1000 feet of the runway after breaking out of an overcast. In this case you may attempt to establish a visual profile similar to the one you use most often. Establishing the visual profile usually involves reducing power and changing attitude to aim the aircraft at some spot short of the end of the runway. In this maneuver you may attempt to use as much of the available runway as possible because of a short runway or due to poor braking conditions. The duck-under is not recommended since high sink rates and poor thrust/lift relationships can develop which may cause undershoots or hard landings. Base your landing decision upon the normal touchdown point from the instrument approach and if stopping distances are insufficient, proceed to an alternate.

c. Downward Vision Angle (figure 6-21). There is an area hidden by the nose of an aircraft which cannot be seen from the cockpit. The downward vision line from the pilot's eye projected under the nose of the aircraft forms an angle with the horizontal vision line. This angle is called the "downward vision angle." The area hidden from the pilot's view can then be determined from a trigonometric relationship based on aircraft elevation and downward vision angle. An aircraft with a 14° downward vision angle 100 feet above the surface will conceal about 400 feet beneath its nose. Consider an approach in 1600-foot visibility. This means your visual segment at 100-foot elevation with a 14° downward vision will be reduced to about 1200 feet. Other factors, such as a nose-high pitch attitude and a slant range visibility less than the RVR, can further reduce your visual segment.

d. Pilot Reaction Time. At 100-foot elevation and a 3° glide slope, an aircraft is approximately 1900 feet from the runway point of intercept (RPI). If your aircraft final approach speed is 130 knots (215 feet per second), you have about 9 seconds to bring visual cues into the cross-check, ascertain lateral and vertical position, determine a visual flightpath, and establish appropriate corrections. More than likely, 3 to 4 seconds will be spent integrating visual cues before making a necessary control input. By this time, the aircraft will be 600 to 800 feet closer to the RPI, 40 to 60 feet lower, and possibly well into the flare. Therefore, it is absolutely essential to be prepared to use visual cues properly and with discretion during the final stages of a low visibility approach. Prior to total reliance on visual information, confirm that the instrument indications support the visual perspective.

e. Crew Procedures:

(1) A copilot can assist the aircraft commander in a number of ways. He can fly the approach, control airspeed, be responsible for communications, direct the checklist, perform the missed approach, establish aircraft configurations, or perform any other duties assigned by the aircraft commander. However, the copilot must understand exactly what his duties and responsibilities are before the approach.

(2) One technique which has proven quite successful has been to allow highly qualified copilots to

fly the approach, while the aircraft commander makes the decision to land or go-around at decision height. At decision height the aircraft commander states either "go-around" or "I have the aircraft." He assumes control if a landing is to be made; if not, the copilot executes the go-around. This procedure has unburdened the aircraft commander, allowing him more time to obtain information from the visual cues for landing. If the approach is unsatisfactory or insufficient visual references are available to execute a landing at decision height, the copilot, since he is on instruments, is prepared to execute a missed approach on command. If the aircraft commander executes the approach, he may allow the copilot to control power or airspeed until decision height where the aircraft commander assumes control for the landing or missed approach.

6-20. Approach Lighting Systems:

a. General:

(1) Approach lighting systems are visual aids used during instrument conditions to supplement the guidance information of electronic aids such as VOR, TACAN, PAR, and ILS. Lighting systems are intended to improve operational safety during the final approach and landing phase of flight. The approach lights are designated high intensity (the basic type of installation) and medium intensity, according to candle power output.

(2) Most runway and approach light systems allow the tower controller to adjust the lamp brightness for different visibility conditions, or at a pilot's request. The extreme brilliance of high intensity lights penetrate fog, smoke, precipitation, etc., but may cause excessive glare under some conditions.

(3) The approach lighting systems now in use, along with their standard lengths, appear on a legend sheet in the Terminal FLIP (figure 6-22). Each IAP chart indicates the type of approach lighting system by a circled letter on the airport diagram. Actual length is shown on the airport diagram for any system, or portion thereof, not of standard length. The IFR Supplement indicates availability of airfield, runway, approach, sequenced flashing, threshold strobe, runway centerline lights, and visual approach slope indicator (VASI).

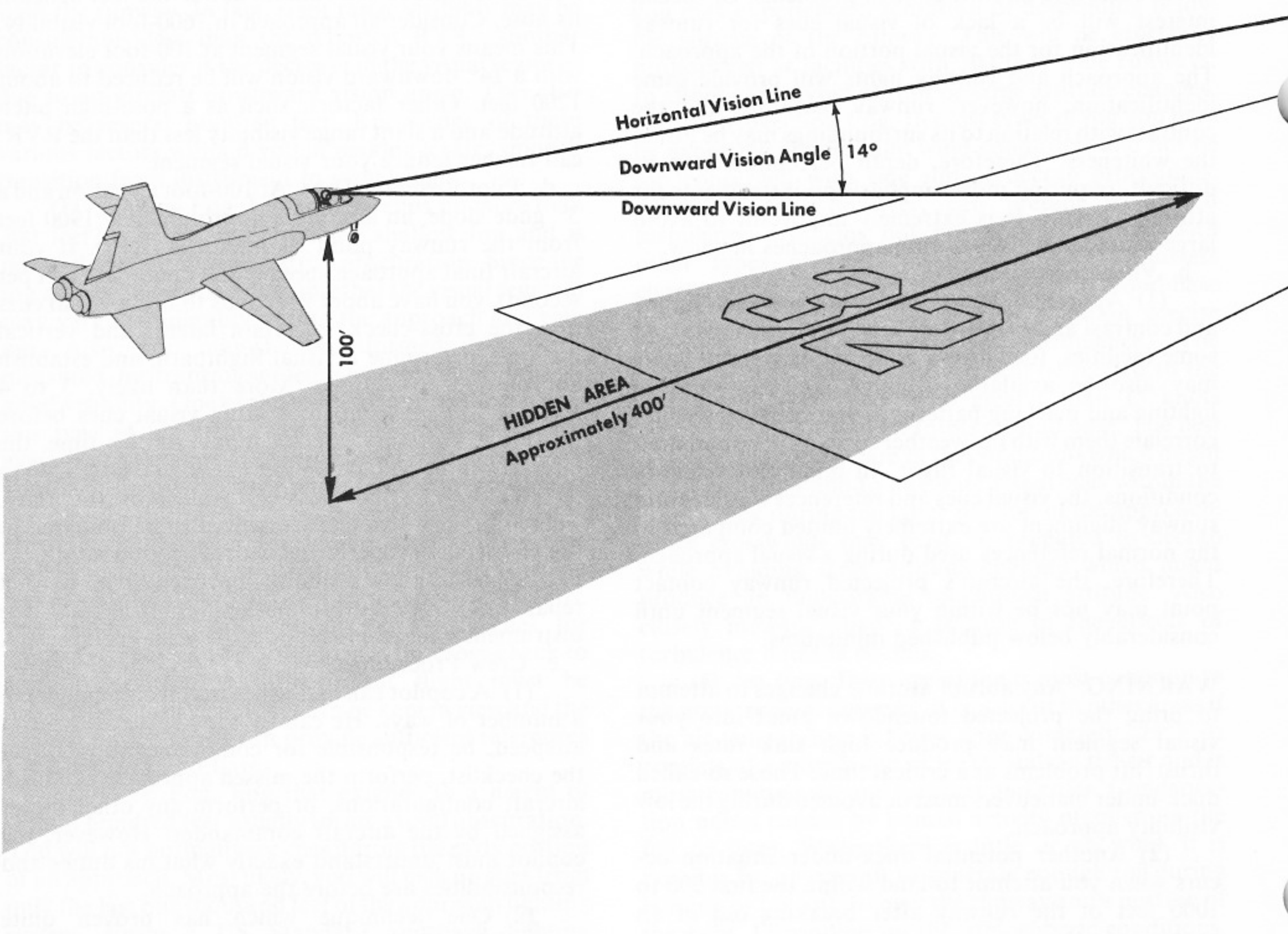


Figure 6-21. Downward Vision Angle (para 6-19c).

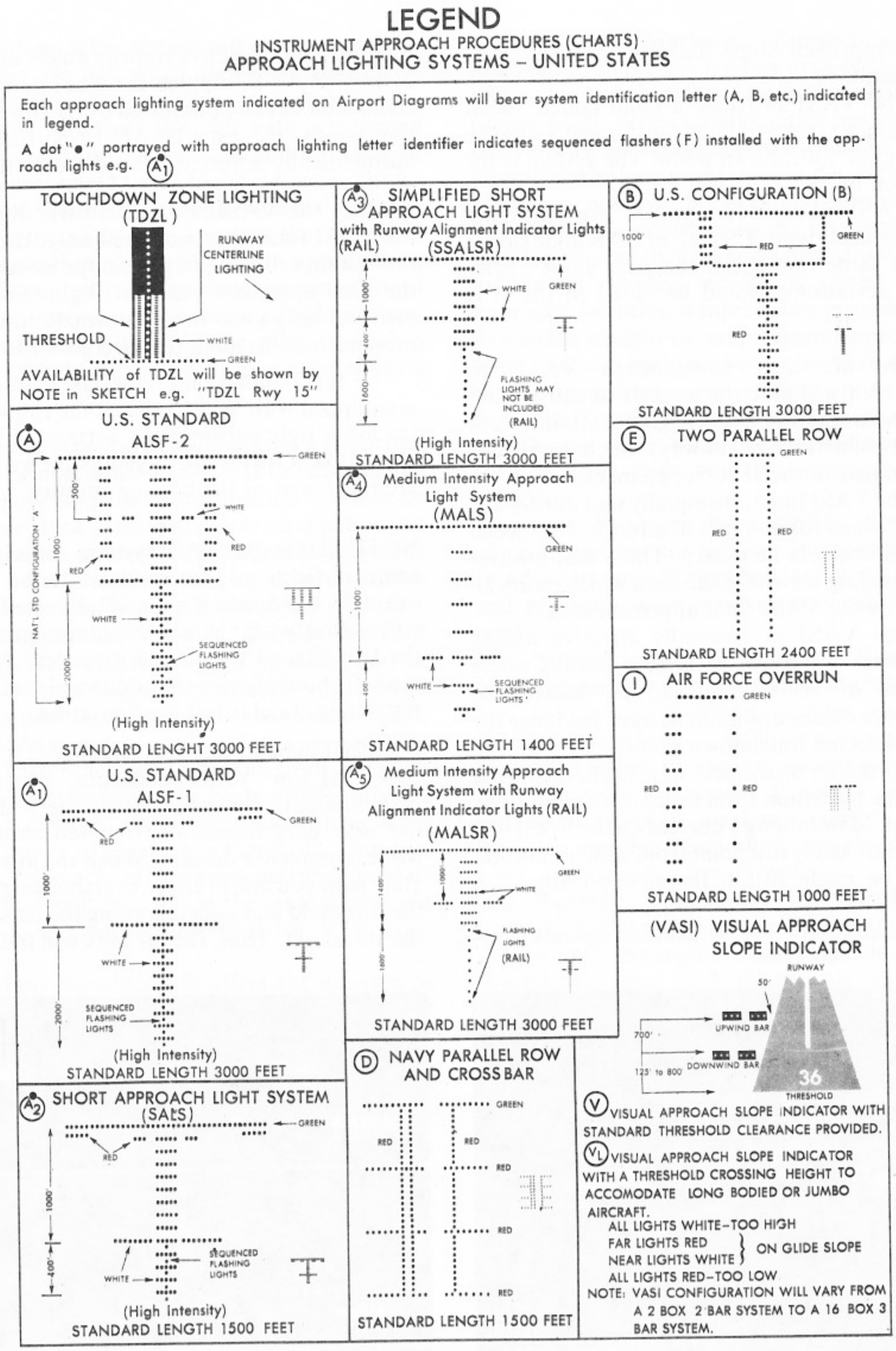


Figure 6-22. Approach Lighting Systems Legend Sheet (para 6-20a(3)).

b. Runway End Identifier Lights (REIL). Runway end identifier lights are installed at many airfields to help identify the approach end of the runway. The system consists of two synchronized flashing lights, one of which is located laterally on each side of the runway threshold facing the approach area. They are effective for identifying a runway which lacks contrast with the surrounding terrain or which is surrounded by other lighting, and for approaches during reduced visibility.

c. Visual Approach Slope Indicator (VASI):

(1) General:

(a) The VASI provides a color-coded visual glide path using a system of lights positioned along the runway, near the touchdown point. The system is for final approach only.

(b) VASI glide slope angles are normally adjusted to coincide with ILS and/or PAR glide slopes servicing the same runway. If the glide slope angles differ, such deviations should be noted in the IFR Supplement.

NOTE: There are also nonstandard VASI installations which will take the aircraft to some point other than the normal ILS/PAR glide path intercept point (usually short of the runway). Such deviations will also be noted in the IFR Supplement.

(c) The VASI functions equally well during day or night conditions for all types of aircraft. No special airborne equipment is necessary. The VASI ensures safety by providing a visual glide path which clears all obstructions in the VASI final approach area.

(d) The VASI is especially effective during approaches over water or featureless terrain where other sources of visual reference are lacking or misleading. It provides optimum descent guidance for landing to a selected touchdown point.

(e) During an instrument approach, the VASI can assist in the transition from instrument conditions to visual flight. Maintaining a descent on the VASI will bring the aircraft safely to a point from which a normal landing can be made within the first poriton of a runway.

(f) USAF/USN VASI facilities operate continuously on the active runway unless noted otherwise in the IFR/VFR Supplement. The intensity of VASI at civil facilities can be adjusted by the tower controller at the pilot's request. USAF/USN installations are automatically adjusted by a photoelectric cell.

NOTE: The VASI provides obstruction clearance in the VASI final approach area only; therefore, use of the system is limited to glide slope information during the final approach phase of flight. Since the VASI provides only glide slope information, other facilities must be used to align the aircraft with the runway.

(g) To determine if the base of intended landing is equipped with VASI, consult the runway diagram in the lower right corner of the Terminal FLIP approach chart. The VASI is portrayed by the symbol Ⓥ at the approach end of the landing runway.

NOTE: Three-Bar VASI systems are being installed at some airfields to accomodate jumbo aircraft; for example, C-5A, and Boeing 747. Pilots of these aircraft will use the two far bars in the same manner as pilots fly the two bars of the standard system. Pilots of other aircraft should ignore the additional far bar and fly the remaining standard of configuration.

(2) Flight Procedures (figure 6-23):

(a) For VFR conditions, proceed inbound maintaining the normal traffic pattern altitude. When the near bars transition from red through pink to white, commence descent. When the aircraft is on the glide path you are, in effect, overshooting the bars near the threshold and undershooting the bars farther from the threshold. Thus, the far bars will indicate red and

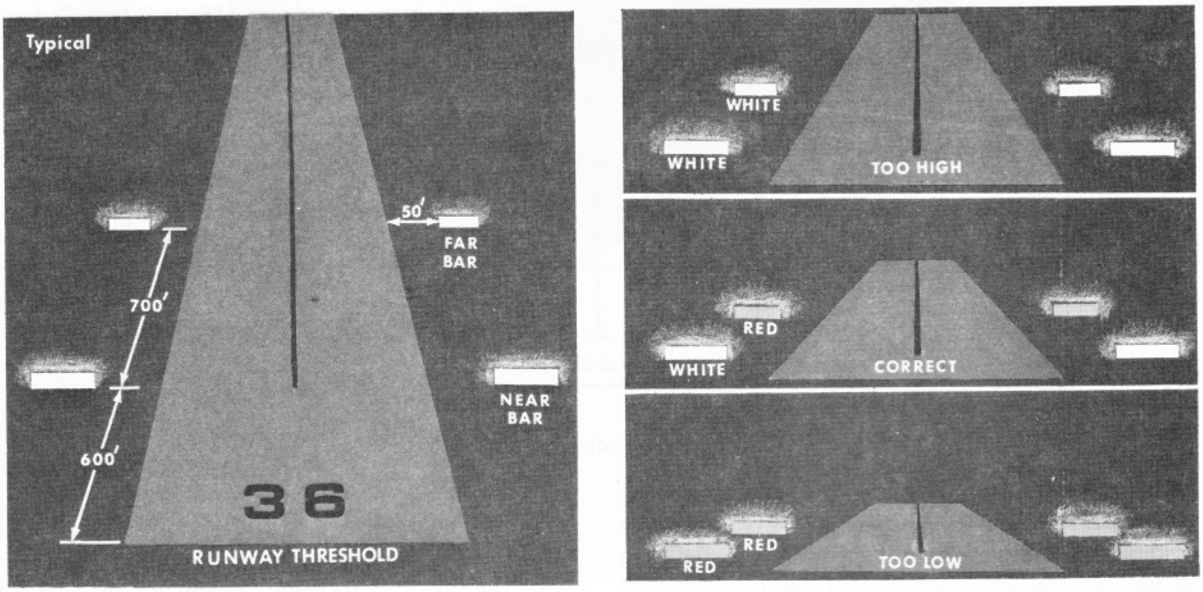


Figure 6-23. Visual Approach Slope Indicator (VASI) (para 6-20c(2)).

the near bars white. When the aircraft is below the glide path, both bars are red; when above the glide path, both are white.

(b) Departure from the glide path is indicated by color changes from red through pink to white or vice versa. (A movement to the high side causes the far bars to change from red through pink to white. A descent below the glide path changes the near bars from white through pink to red.) When approaching the threshold, you may notice some deterioration of system guidance because of the spread of light sources. However, the VASI will bring the pilot through a "gate" at the threshold where you may accomplish a normal flare and landing.

NOTE: Although the VASI will indicate a departure from the glide slope, white-over-white or red-over-red indications show only that your position is above or below the glide slope. The system has no capability to indicate how far the aircraft is above or below the glide slope. Pilots must, therefore, employ other available references to ensure a positive position.

(c) Although the VASI is basically for VFR only, it blends well with instrument approaches. For example, when on a precision glide slope it permits a smooth transition from instrument to visual flight. Since the VASI and precision glide slopes are normally aligned with each other, the transition from one glide slope reference to another can be made without aircraft power or pitch changes; merely continue with the same attitude and power to the runway threshold. During a nonprecision approach, after having descended out of the instrument conditions, follow the same glide slope interception as previously described for VFR conditions.

(d) Many variables will affect the decision to initiate a missed approach while using VASI. Some of the variables to be considered are: terrain, obstacles, weather, distance from the runway, runway lighting, approach lighting, aircraft or pilot capabilities, and the runway glide path intercept point. Other available references may include ILS glide slope, PAR glide slope, altimeter, vertical velocity indicator, and DME. Since each approach may provide any or all of these factors, consider the individual situation and make your decisions based upon all of the available information. However, once transition has been made to the VASI for a visual approach to landing, you must confirm your exact position above or below the glide slope by reference to the runway environment.

(e) Some caution should be exercised when using VASI facilities that are associated with runway threshold bar lights. Further, some erroneous glide slope observations may occur during low visibility periods from reflection of the light beams. Therefore, remember that VASI is an approach aid and should be used in conjunction with, and cross-checked against, all other available aids.

6-21. Runway Markings. Runway markings are designed to make the landing area more conspicuous and to add a third dimension for night operations (figure 6-24). When visual contact has been established, runway markings aid the pilot in aligning the aircraft with the runway and in determining if a safe landing is possible. Serviceable runways are marked and classified according to the instrument approach facilities serving them. The classifications are precision instrument runways which are served by precision approach facilities, nonprecision instrument runways to which a straight-in nonprecision approach has been approved, and basic runways which are used for visual flight operations and circling nonprecision approaches. Standard runway markings in most cases are in reflective white, while markings of nontraffic areas, such as blast pads and overruns, are in reflective yellow.

a. Basic Runways. Basic runway markings consist of a runway direction number and centerline marking. In addition, any of the elements of the nonprecision and precision instrument runway markings may be used.

b. Nonprecision Instrument Runways. The markings used on nonprecision instrument runways are the runway direction number, centerline, and threshold markings. Additional elements of the precision instrument runway markings may be added.

c. Precision Instrument Runways. The precision instrument runway markings consist of a runway direction number, centerline, threshold, touchdown zone, and side stripe markings.

d. Runway Touchdown Zone Marking. The runway touchdown zone marking pattern consists of groups of rectangular markings to outline the touchdown zone and to provide distance coded information by means of the "3-3-2-2-1-1" marking pattern. Groups of rectangular markings begin 500 feet from the threshold and are spaced at 500-foot intervals up to 3000 feet from the threshold. Fixed distance markings are found on precision instrument runways. These markings begin 1000 feet from the threshold and provide an aiming point for touchdown.

e. Runway Direction Numbers. All runways are marked with a runway direction number. This number is the number nearest the 10° increment of the magnetic azimuth of the centerline of the runway. Single numbers are not preceded by a zero. To differentiate between two parallel runways, the runway direction number has a letter "L" or "R" following it. With three parallel runways, the center runway has the letter "C" added to the runway direction number.

f. Associated Runway Area Markings:

(1) Overrun or blast pad areas at the approach end of Air Force runways not intended for use by aircraft are marked by a series of equally spaced yellow chevrons. The apex of the chevrons is on the centerline extension of the runway and points to and terminates

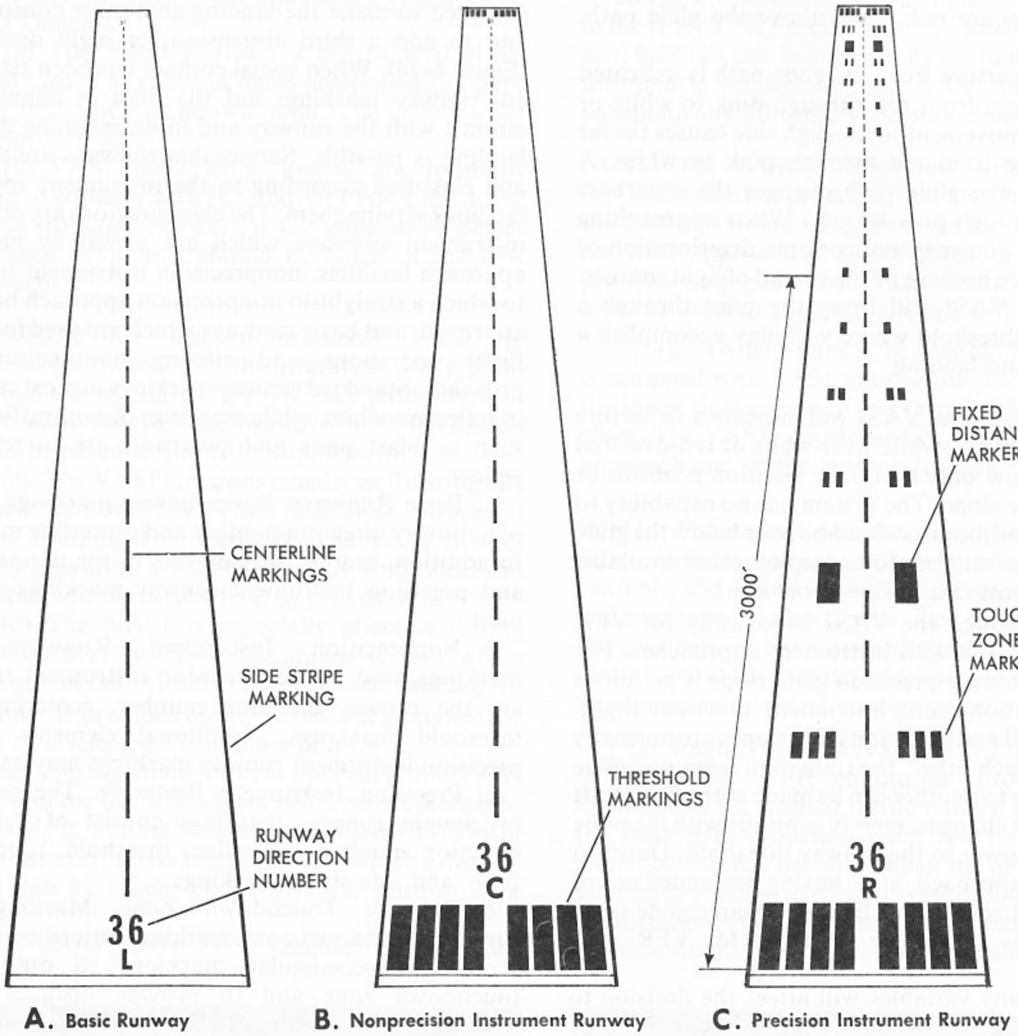


Figure 6-24. Runway Markings (para 6-21).

at the threshold of the usable runway.

(2) Where it has been necessary to position the landing threshold up the runway from the end of the paving, it is known as a displaced threshold. Two methods of marking this area are used (figure 6-25). When the paved area on the approach side of the displaced threshold can be used for taxiing and takeoff, it will be marked with a series of large white arrows. The arrows are placed along the centerline on the approach side of the displaced threshold and point to the landing area. Where the paved area on the approach side of the displaced threshold is not to be used for taxiing or takeoff, the area is marked in the same manner as the overrun or blast pad areas previously discussed. In all cases a white stripe across the width of the full strength runway precedes the threshold markings.

(3) Runway shoulders which have been stabilized with materials that give the appearance of paving but are not intended for use by aircraft are marked with a series of partial yellow chevrons. When a center section of a runway has been strengthened, the unstrengthened sections on either side are marked in the same manner as stabilized runway shoulders.

6-22. Circling Approaches:

a. General. Circling to land is a visual flight maneuver. When the instrument approach is completed, it is used to align the aircraft with the landing runway. Each landing situation is different because of the variables of ceiling, visibility, wind direction and velocity, obstructions, final approach course alignment, aircraft performance, cockpit visibility, and controller instructions. The circling minimum descent altitude (MDA) and weather minima to be used are those for the runway to which the instrument approach is flown (this is not always the landing runway).

b. Instructions. If the controller has a requirement to specify the direction of the circling maneuver in relation to the airport or runway, he will issue instructions in the following manner: "Circle (direction given as one of eight cardinal compass points) of the airport/runway for a right/left base/downwind to runway (number). For example, "circle west of the airport for a right base to runway 18."

NOTE: Obstruction clearance areas are determined by aircraft category. Maneuver the aircraft to remain within the circling area for your aircraft category (see figure 7-13 for radii of circling approaches). If it is necessary to maneuver at speeds in excess of the upper limit of the speed range authorized for your aircraft's category use the landing minima for the category appropriate to the maneuvering speed. When you request circling MDA from the controller for a circling ASR approach, tell him your aircraft category.

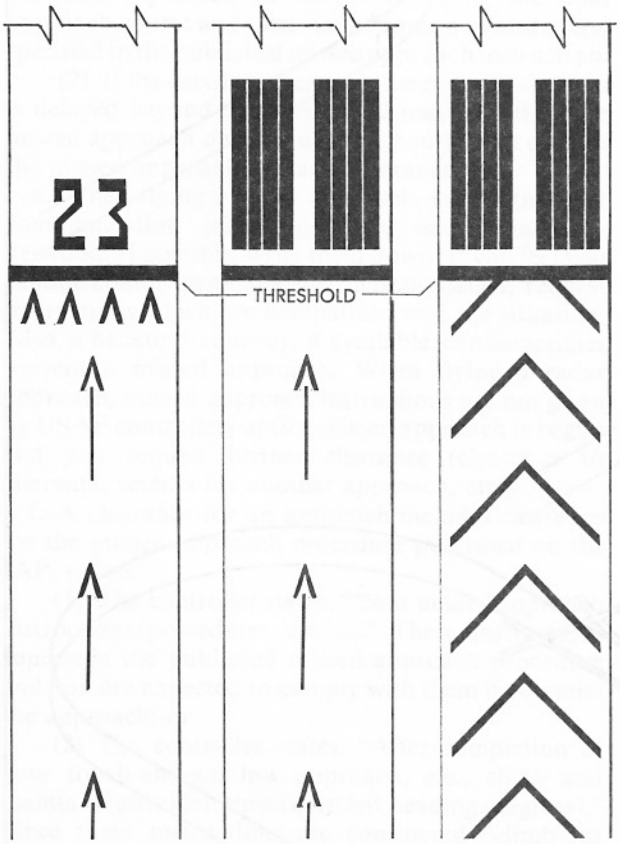


Figure 6-25. Displaced Threshold Markings (para 6-21f(2)).

c. Accomplishing the Approach (figure 6-26):

(1) After descending to circling minimum descent altitude and when the airport environment is in sight, determine if the ceiling and visibility are sufficient for performing the circling maneuver. The airport environment is considered the runway(s), its lights and markings, taxiways, hangars, and other buildings associated with the airport. (Since the MDA is a minimum altitude, a higher altitude may be maintained throughout the maneuver.)

(2) Choose a pattern that best suits the situation. Maneuver the aircraft to a position which allows you to keep as much of the airport environment in sight as possible. Consider making your turn to final into the wind, if this maneuvering allows you to also keep the airport environment in sight. You may make either left or right turns to final unless you are:

(a) Directed by the controlling agency to do otherwise.

(b) Required to do otherwise by restrictions on the approach chart or IFR Supplement.

(3) If weather permits, fly the circling approach at your normal VFR traffic pattern altitude. (This allows the maneuver to be flown with more familiar perspective and visual cues.) Descend when in position to place the aircraft on a normal glide path to the landing runway.

(4) If weather does not permit circling above the MDA, do not descend below circling MDA until the aircraft is in a position to execute a normal landing. Then descend from the MDA as necessary to place the aircraft on a normal glide path to the landing runway.

(5) If there is any doubt whether the aircraft can be safely maneuvered to touchdown, execute the missed approach.

WARNING: Be aware of the common tendency to maneuver too close to the runway at altitudes lower than your normal VFR pattern altitude. This is caused by using the same visual cues that you use from normal VFR pattern altitudes. Select a pattern that displaces you far enough from the runway that will allow you to turn to final without over banking or overshooting final.

SECTION H — MISSED APPROACH

6-23. General. Performing a missed approach successfully is the result of thorough planning. Familiarize yourself with the missed approach procedure during the preflight planning. The missed approach path is designed to return the aircraft to the

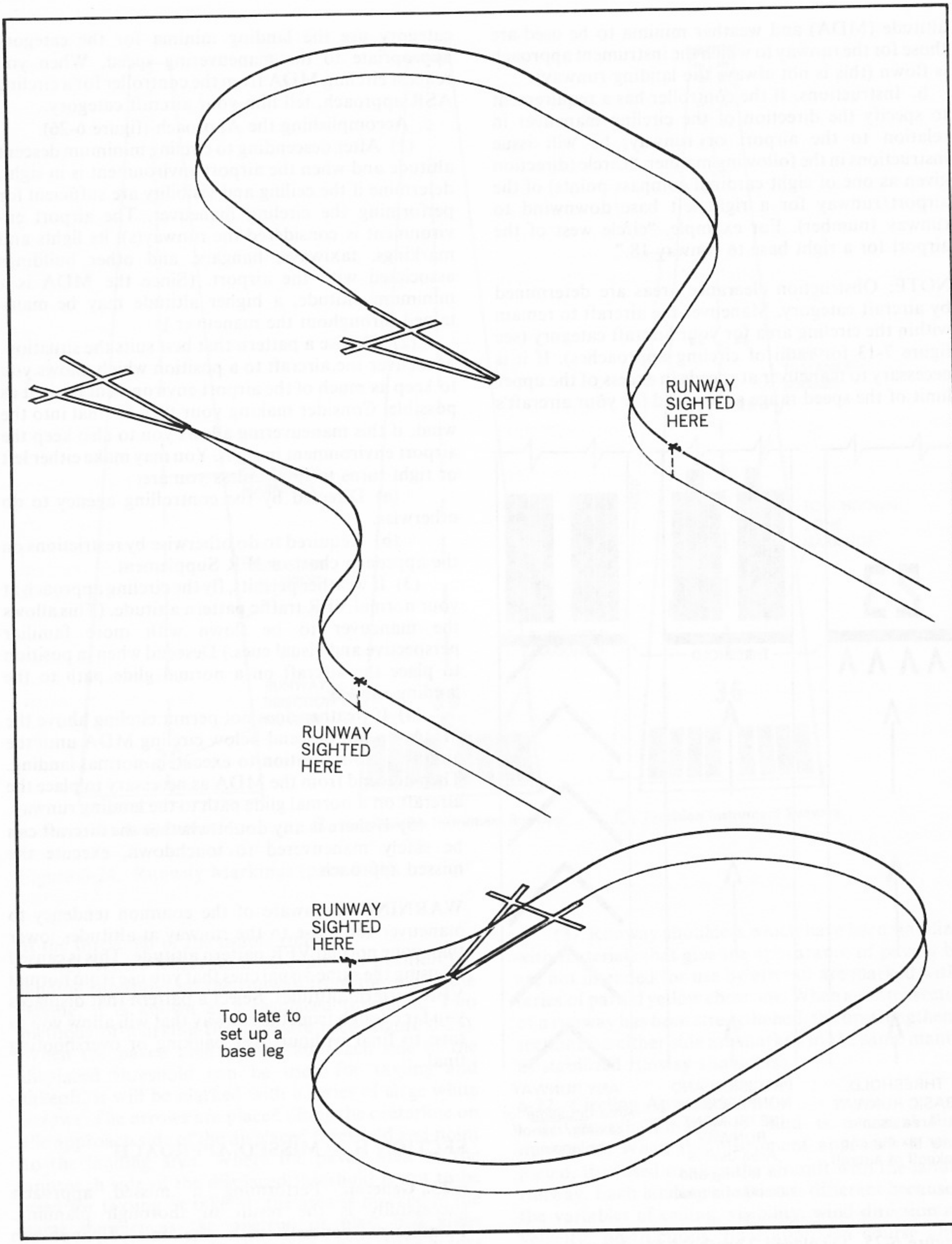


Figure 6-26. The Circling Approach (para 6-22c).

initial segment of the approach being flown or to the en route structure.

a. The missed approach point (MAP) for a nonprecision straight-in approach is located along the final approach course, at MDA, and not farther from the FAF than the runway threshold (or over an on-airport navigational facility for a NoFAF procedure).

b. The missed approach point for a circling approach is also located along the final approach course, at MDA, but not farther from the FAF than the first portion of the usable landing surface.

c. The missed approach point for any precision approach is the point at which the decision height is reached.

d. The obstacle clearance area provided for the missed approach is predicated upon the missed approach being started at the MAP.

(1) When the missed approach is initiated prior to the MAP, proceed to the MAP along the final approach course and then via the route and altitude(s) specified in the published missed approach instruction.

(2) If the decision to execute the missed approach is delayed beyond the MAP, you may be below the missed approach obstacle clearance surface or outside the missed approach obstacle clearance area.

e. When flying a radar approach, ensure that lost communication instructions are issued and understood. If possible, write them down. If you feel you cannot comply with the instructions issued, request instructions which are compatible with the situation. Also, a backup frequency, if available, can sometimes prevent a missed approach. When flying a radar approach, missed approach instructions are not given by USAF controllers until a missed approach is begun and you request further clearance (clearance to alternate, vectors for another approach, etc.).

f. A clearance for an approach includes clearance for the missed approach procedure published on the IAP, unless:

(1) The controller states, "Your missed approach instructions/procedures are ...." These instructions supersede the published missed approach procedure and you are expected to comply with them if you miss the approach; or

(2) The controller states, "After completion of your touch-and-go, low approach, etc., climb and maintain (altitude), turn right/left heading (degrees)." Since these instructions are considered "climb-out instructions" comply with them only after completing the requested maneuver (touch-and-go, low approach, etc.). If, however, you miss the approach due to weather (low ceilings or visibility), follow the published missed approach procedure and notify ATC you are "missed approach;" or

(3) Following either (1) or (2) above, the controller issues radar vectors (heading and altitude), those instructions take precedence over the published or assigned missed approach procedure.

g. There are various terms in the missed approach procedure written on the IAP which have specific meanings with respect to climbing to altitude, to execute a turn for obstruction avoidance, and other reasons. Examples:

(1) "Climb to" means a normal climb along the prescribed course.

(2) "Climbing right turn" means climbing right turn as soon as safety permits, normally to avoid obstructions straight ahead.

(3) "Climb to 2400 turn right" means climb to 2400 feet prior to making the right turn, normally to clear obstructions.

6-24. Accomplishing the Missed Approach:

a. Perform the missed approach when the missed approach point or decision height (DH) is reached and if:

(1) The runway environment is not in sight (the runway threshold or approved lighting aids or other markings identifiable with the runway).

(2) You are unable to make a safe landing.

(3) You are so directed by the controlling agency.

b. When you decide to execute the missed approach, fly the aircraft in accordance with the flight manual missed approach procedures. They are normally similar to those used for the instrument takeoff.

c. Transition from the approach to the missed approach in a positive manner using precise attitude and power control changes. Establish the missed approach attitude, power setting, and configuration prescribed in the flight manual. Cross-check the vertical velocity indicator and altimeter for positive climb indications before retracting the gear and wing flaps. Since aircraft control will require almost total attention, you should have the first heading, course and altitude in mind before reaching the missed approach point.

d. If you lose visual reference while circling to land, follow the missed approach specified for the approach procedure just flown, unless otherwise directed. An initial climbing turn toward the landing runway will assure that the aircraft remains within the circling obstruction clearance area. Continue to turn until established on the published missed approach course (figure 6-27).

e. Ensure that your aircraft can achieve the published climb gradient. If the gradient exceeds 150 feet per nautical mile, the approach chart will depict the vertical velocity required. When the gradient is not published, climb at least 150 feet per mile in order to clear obstructions. (FOR HELICOPTER PILOTS ONLY: The missed approach criteria for copter only approaches is based on a climb gradient of at least 300 feet per nautical mile.)

f. As soon as practical after initiating the missed approach, advise Air Traffic Control and request

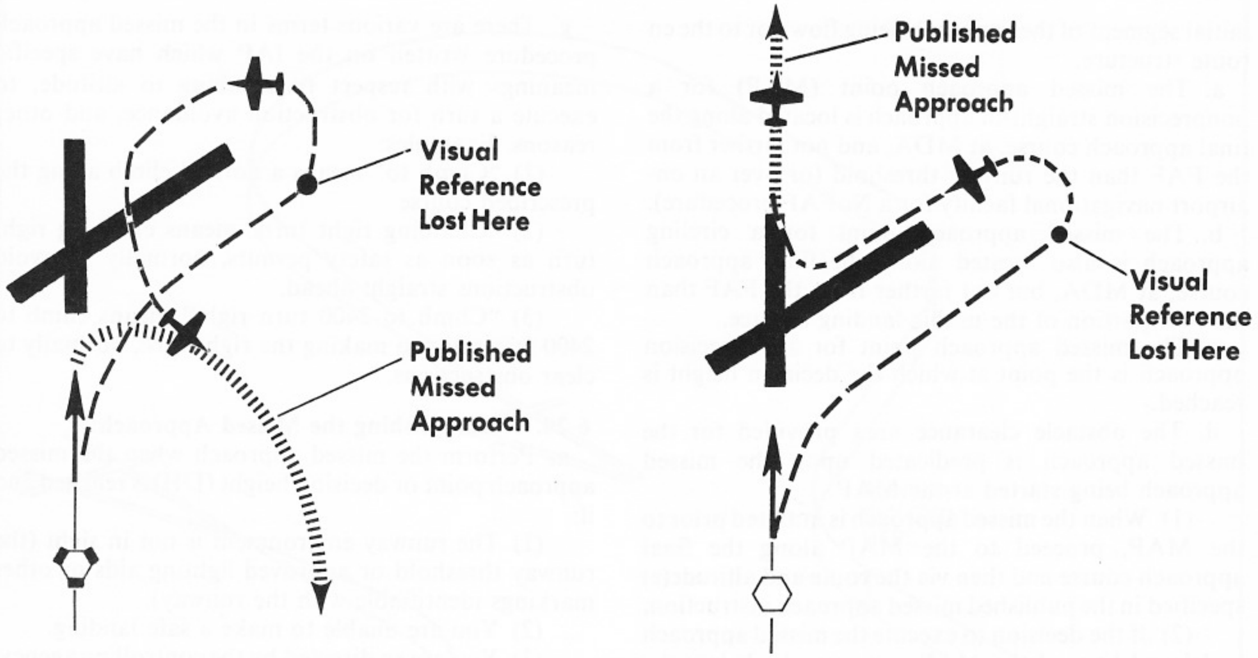


Figure 6-27. Missed Approach From the Circling Approach (para 6-24d).

additional ATC clearance. Do not sacrifice aircraft control for the sake of voice transmission.

g. Terrain clearance is provided within established boundaries of the approach course and the missed approach path. It is essential that you follow the procedure depicted on the IAP chart or the instructions issued by the controller. Be aware of the minimum safe altitudes found on the IAP charts. Remember that the missed approach climb gradient begins at the published missed approach point.

Chapter 7

ADDITIONAL INFORMATION AND GUIDANCE

SECTION A — ILLUSIONS IN FLIGHT

7-1. General. During flight, illusions result from false or misinterpreted sensory impressions created by in-flight forces acting upon the organs of equilibrium and balance. All pilots are susceptible to sensory illusions which may suddenly and markedly affect their ability to accurately determine their flight attitude. During visual flight, the sense of sight is used to determine the relationship between aircraft attitude and the earth's surface. During instrument flight, when aircraft attitude must be controlled by reference to the flight instruments, conflicts may evolve which cause the supporting senses to disagree with the sense of sight. When you cannot accurately determine the location of the surface of the earth, you are said to be suffering from spatial disorientation, also commonly called pilot's vertigo. It is important to remember that sensory conflicts will occur regardless of your instrument experience or proficiency. However, the influence and result of the illusion will depend partly on your experience and training. By recognizing that the inputs from the supporting senses are false or not reliable, you may suppress or ultimately learn to disregard these inputs to prevent conflict with what you see on the aircraft instruments.

7-2. Organs of Equilibrium (figure 7-1). Three of our sensory systems are especially important for maintaining equilibrium and balance. These sensory systems function adequately for the normal earth-bound activities such as walking, running, jumping, falling, etc., but when a person is subjected to the environment of air and space, the organs of equilibrium induce errors. Such errors cause illusions which may result in spatial disorientation or vertigo. These three sensory systems are:

a. Vestibular System (figure 7-2):

(1) Semicircular Canals. The semicircular canals are filled with a fulid which moves relative to the canal walls when angular accelerations are applied to the head. The movement of the fluid causes bending of hair filaments in the canals, resulting in nerve impulses being sent to the brain. The pilot interpretation is that rotary motion is occurring. The three semicircular canals on each side are positioned at right angles to each other so that angular accelerations in any spatial plane can be detected; that is, yaw, pitch, or roll. Since the response characteristics of the semicircular canal system are specific for ground-based operations, perceptual errors may be induced in flight because:

(a) A very small or very short-lived angular acceleration may not be perceived.

(b) The patterns of acceleration experienced in flight are quite different from those experienced on the ground, thus the response of the canals gives erroneous information.

(2) Otolith Organs. If these organs are subjected to linear acceleration or gravity force, the hair cell filaments penetrating the otolithic membrane bend. When the filaments are bent, nerve impulses travel along the vestibular nerve to the brain, providing information relating head position to true vertical (the direction of the pull of gravity). During flight, inertial forces are combined with the force of gravity. The direction of this combined or resultant force, which acts upon the otolith membrane, is almost never the direction of the true vertical. In fact, if the brain monitors the positions of the otolithic membranes and determines from them which way is "down," the brain

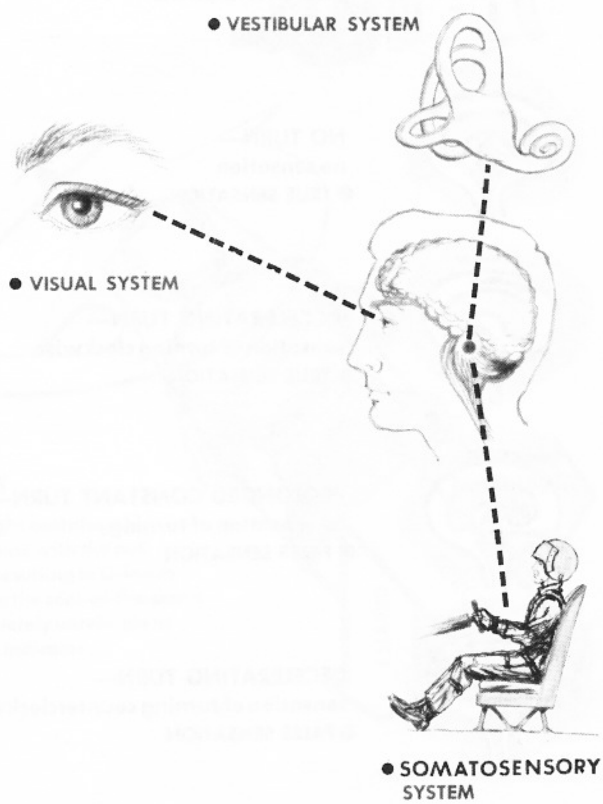


Figure 7-1. Organs of Equilibrium (para 7-2).

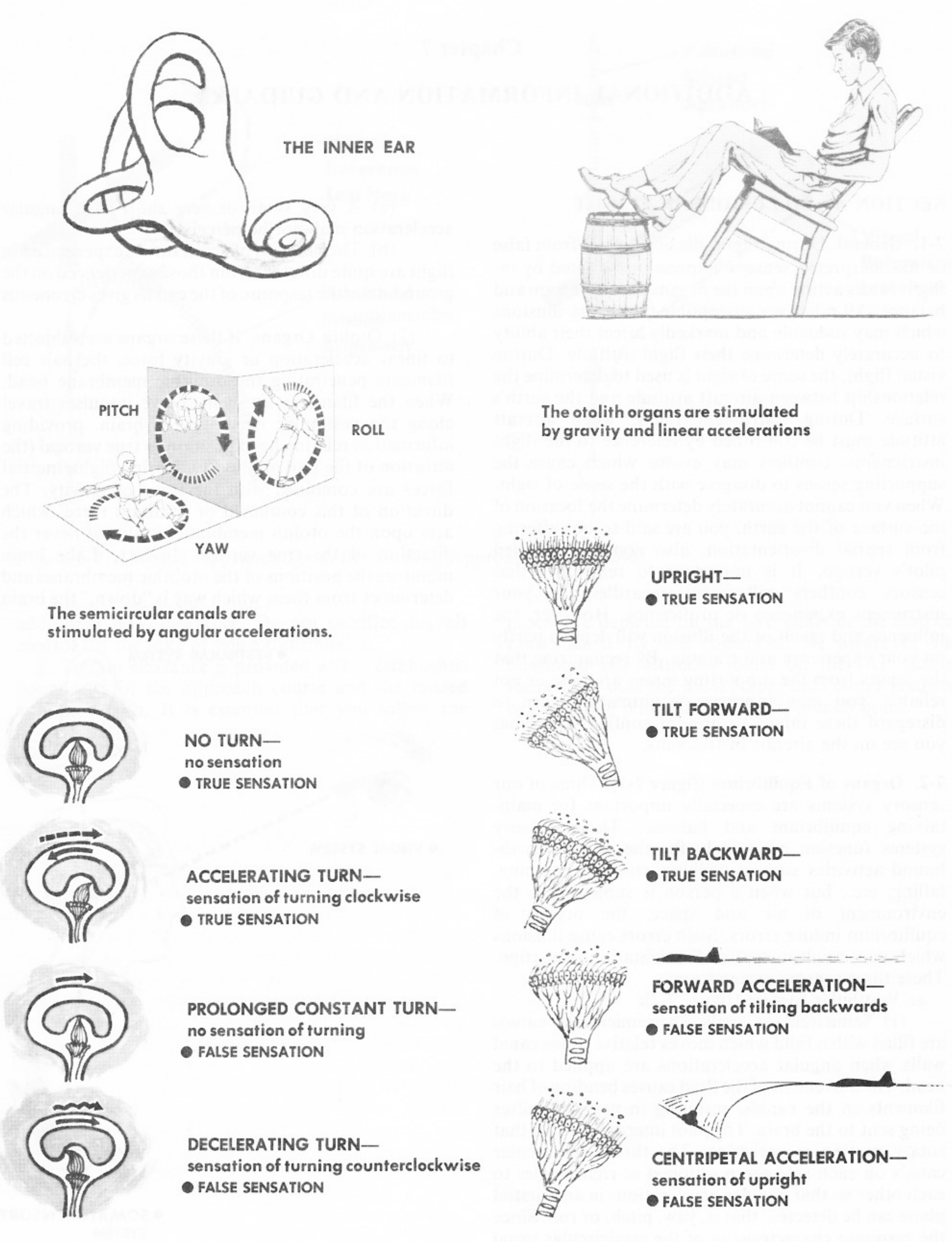


Figure 7-2. Vestibular (Inner Ear) System (para 7-2a).

will be deceived a large portion of the time in flight.

b. Somatosensory System (figure 7-3). The somatosensory sensors, which are of major importance in equilibrium, are those that respond to pressure and stretch. They are buried in many body structures, including the skin, joints, and muscles; and the sensations they elicit when stimulated are the pressing feelings that you experience when you sit, or the sensations which enable you to know the position of your arms, legs, and body. This system is the so-called seat-of-the-pants sense referred to in flying because

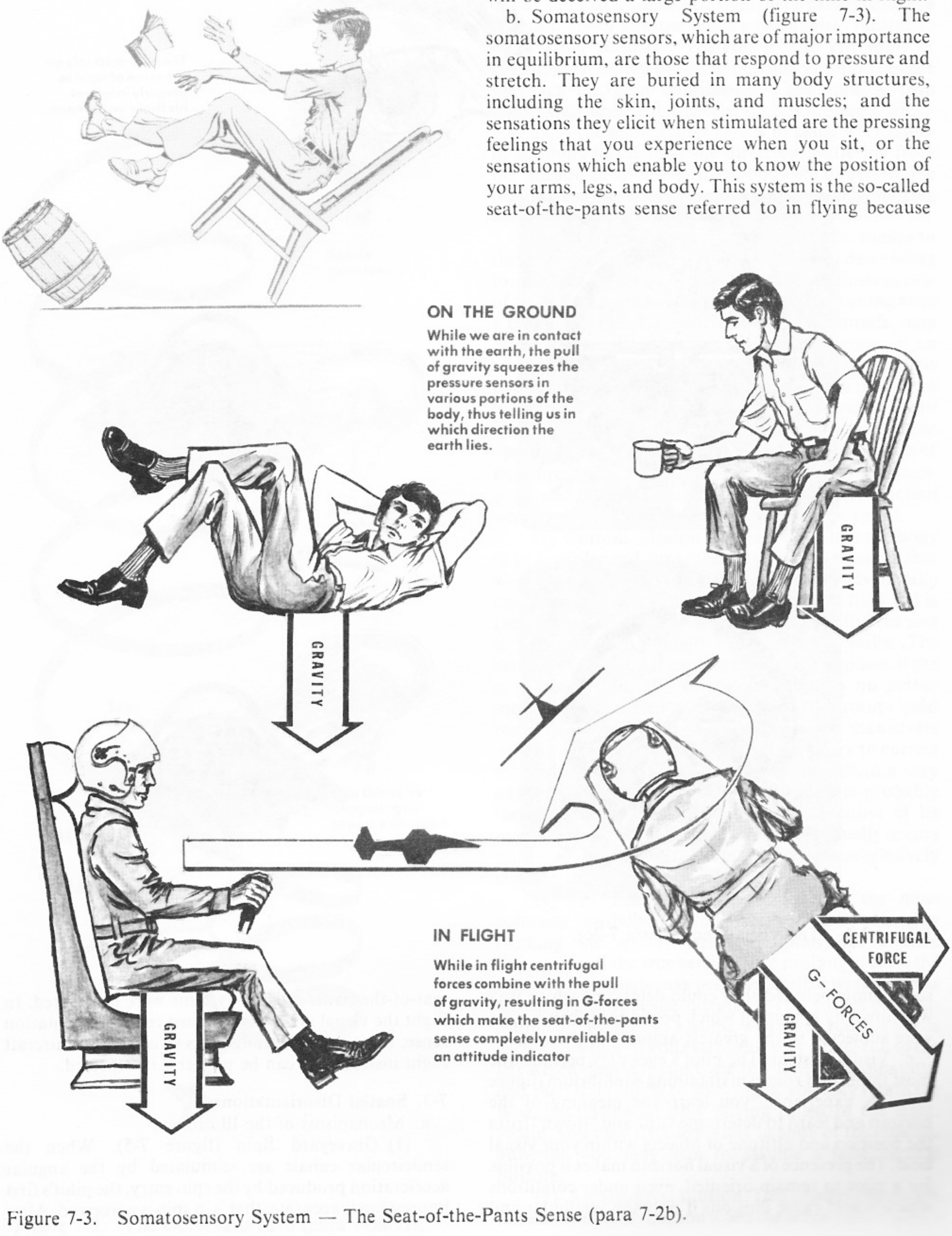


Figure 7-3. Somatosensory System — The Seat-of-the-Pants Sense (para 7-2b).

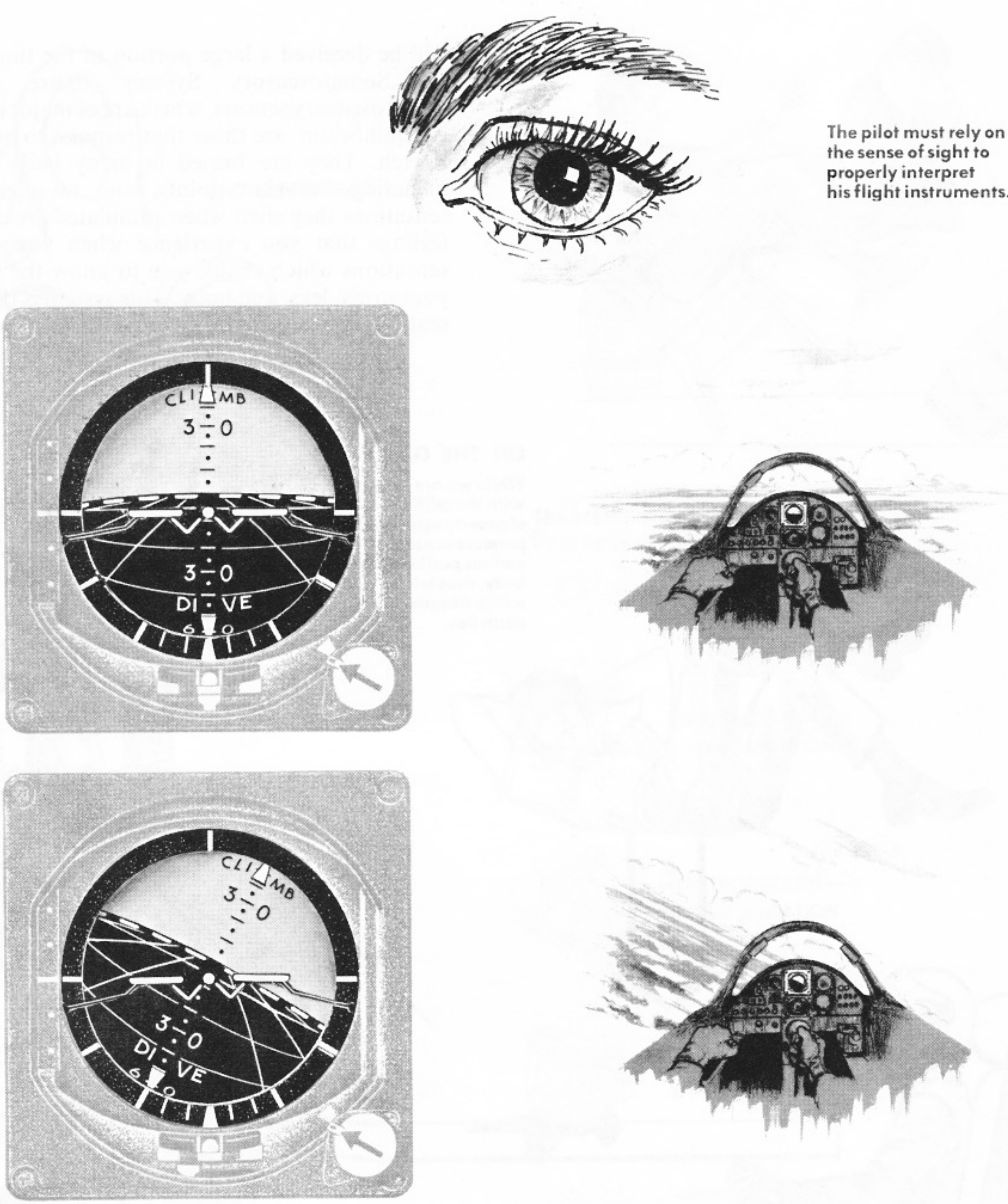


Figure 7-4. The Visual Sense (para 7-2c).

some pilots believed they could determine which way was down by analyzing which portions of their bodies were subjected to the greatest amount of pressure.

c. Visual System. The pilot's eyes play perhaps the most important role in maintaining equilibrium (figure 7-4). By experience, you learn the meaning of the horizon and learn to determine "up" and "down" from the position and attitude of objects within your visual field. The presence of a visual horizon makes it possible for a pilot to remain oriented, even under conditions which would cause illusions if only the vestibular and seat-of-the-pants sensory systems were monitored. In flight the visual system is the most reliable orientation sense, for it is only through this sense that the aircraft flight instruments can be properly interpreted.

7-3. Spatial Disorientation:

a. Mechanisms of the Illusions:

(1) Graveyard Spin (figure 7-5). When the semicircular canals are stimulated by the angular acceleration produced by the spin entry, the pilot's first impression is accurate; that is, a spin is perceived. After

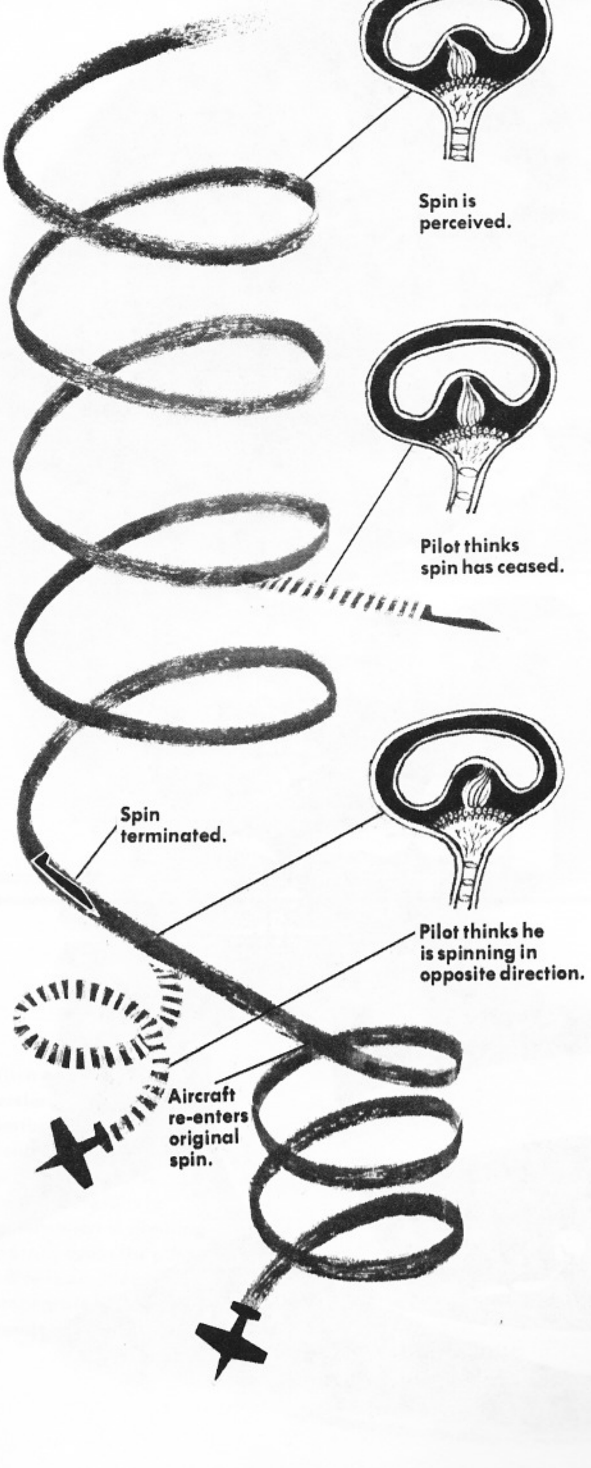


Figure 7-5. The Graveyard Spin (para 7-3a(1)).

about 10 to 20 seconds, the fluid in the canals reaches a constant speed and the sensing mechanism returns to the resting position. Thereupon, the sensation of spinning is replaced by one of no-rotary motion despite the fact the spin continues. If the spin is then terminated, an angular deceleration is produced which acts upon the semicircular canals to cause a sensation of spinning in the opposite direction. Suffering from the illusion of spinning in the opposite direction, the pilot may try to correct for false impression by putting the aircraft back into the original spin.

(2) Graveyard Spiral. This maneuver is similar to the graveyard spin except the aircraft is in a descending turn rather than a stalled condition. The constant rate of turn causes you to lose the sensation of turning after a period of time. You, noting the loss of altitude, may pull back on the stick or perhaps add power in an attempt to gain the lost altitude. Unless you have first corrected the bank attitude, such actions can only serve to tighten a downward spiral. Once the spiral has been established, you will suffer the illusion of turning in the opposite direction after you stop the turning motion of the aircraft. Under these circumstances, an inexperienced pilot may take the wrong corrective action which will result in reestablishment of the spiral.

(3) Coriolis Illusion (figure 7-6). When the body is in a prolonged turn, the fluid in those canals that were stimulated by the onset of the turn eventually come up to speed with the canal walls. If the head is then tipped, the angular momentum of the fluid causes it to move again relative to the canal walls. The resulting sensation is one of rotation in the plane of the new position of the canal even though no actual motion has occurred in that plane. Thus, abrupt head movements may cause you to perceive maneuvers which you are not actually doing. If you try to correct for your illusion, you may put the aircraft in a very dangerous attitude. The coriolis illusion is probably the most deadly of all the illusions because of its overwhelming sensations and because it usually occurs during maneuvers that normally take place relatively close to the ground.

(4) The Leans (figure 7-6). This is the most common vestibular illusion and is caused by rolling or banking the aircraft after the pilot has a false impression of the true vertical. In a prolonged turn, the semicircular canals may perceive a roll to wings level as a turn in the opposite direction. This causes pilots to lean in an attempt to assume what they think is a true vertical posture. If you establish a very subtle roll to the left which does not stimulate the vestibular apparatus and then roll rapidly to level flight, you may retain the false impression of only having rolled to the right. Again, you may fly adequately in spite of this illusion, although you may lean to assume a false vertical posture.

(5) Somatogyral Illusion. This illusion creates the false sensation of rotation when the semicircular canals

are abnormally stimulated by angular acceleration. Such an illusion occurs during the graveyard spin, the graveyard spiral, and other turning maneuvers. A somatogyral illusion may be associated with the coriolis illusion. Under similar conditions of semicircular canal stimulation by angular acceleration, uncontrollable eye movement (nystagmus) may occur resulting in loss of effective vision due to inability to focus. Under these conditions, the duration of the nystagmus is normally between 30 and 40 seconds after the stimulation stops.

(6) Somatogravic Illusion (figure 7-7). This illusion creates the sensation of change of attitude when the otolith organs are abnormally stimulated by linear acceleration. Such an illusion can occur when an aircraft accelerates forward while in level flight and gives the pilot the sensation of being in a nose-up attitude. A similar illusion of nose-high pitch may occur as a result of takeoff or missed approach acceleration. If you were to correct for this illusion during climb-out, you might dive the aircraft into the ground. The opposite illusion of nose-down attitude may occur as a result of deceleration. If you were to correct for the illusion of nose-low pitch caused by deceleration on final approach, your corrective action might result in a low altitude stall. Although the somatogravic illusion is of greatest magnitude in high-performance aircraft, it may occur in all aircraft. The maximum effect of the illusion normally occurs 30 to 60 seconds after onset of the linear acceleration (stimulus), but a substantial part of the illusion may occur within a few seconds after the stimulus. The illusion remains constant during constant stimulus, and ceases immediately on cessation of the stimulus. You can readily overcome the illusion by giving

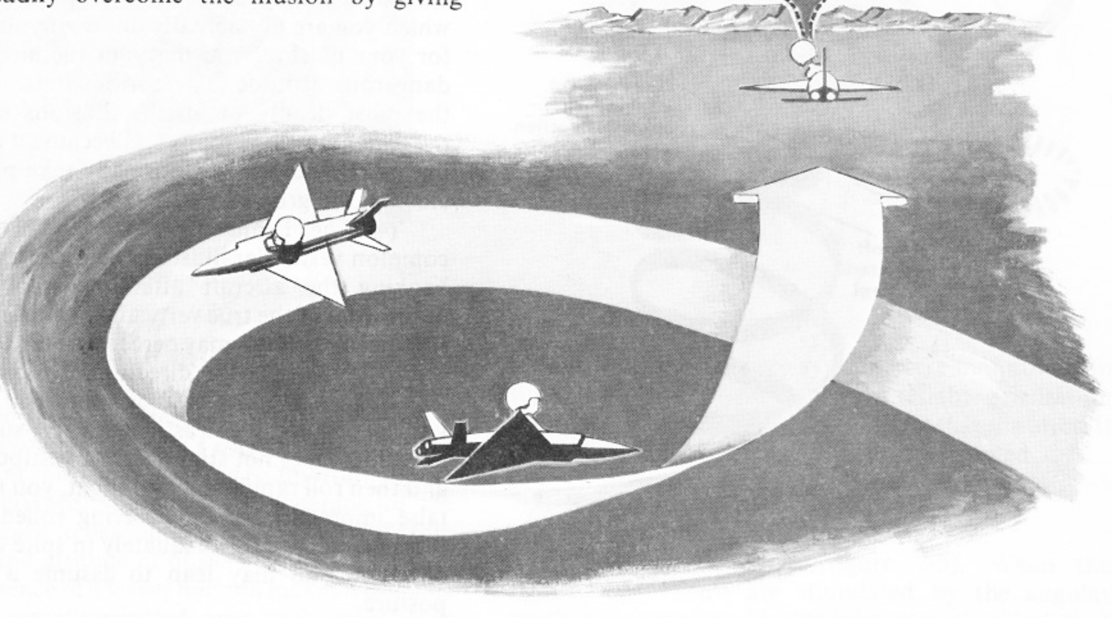
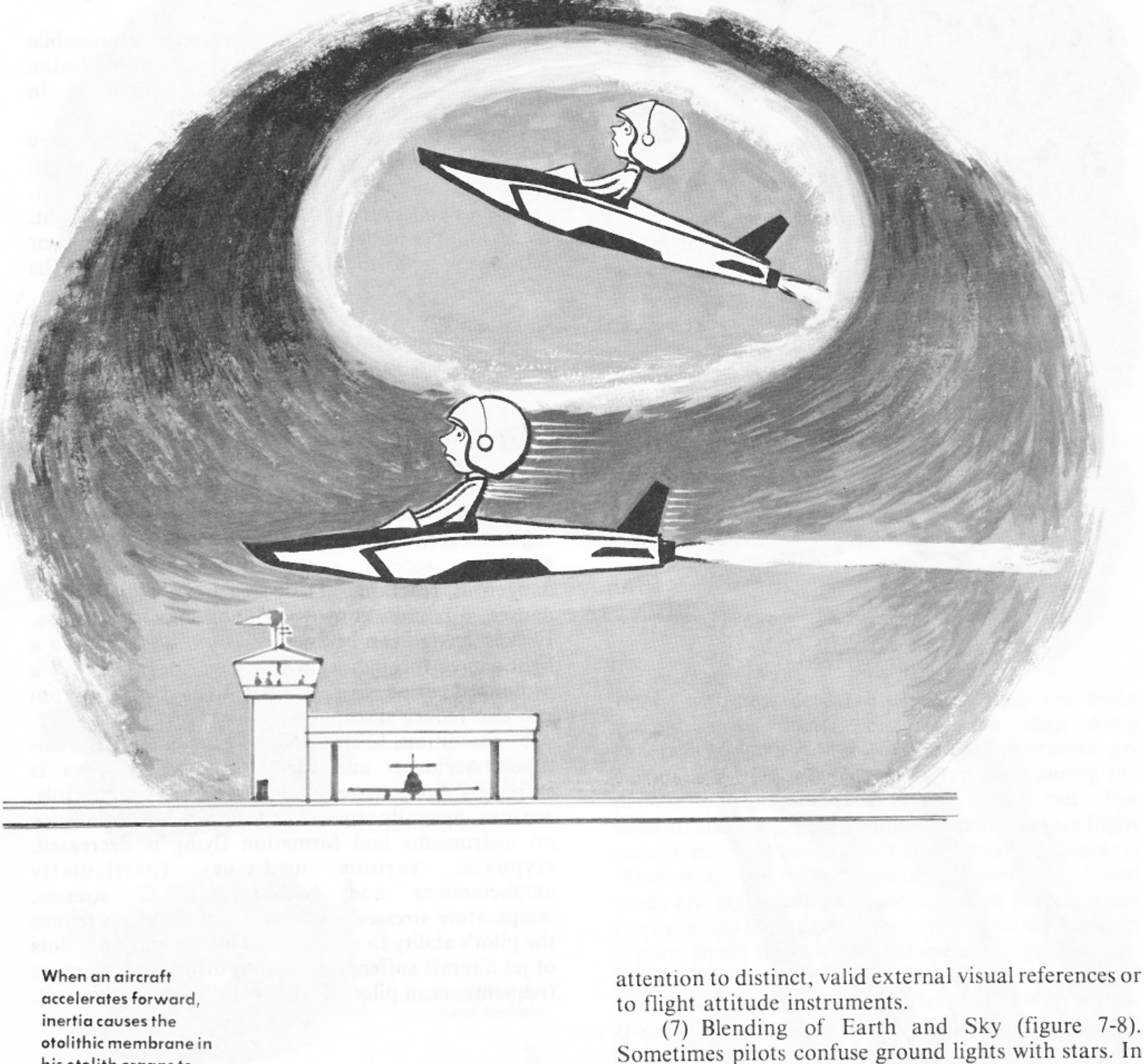


Figure 7-6. The Coriolis Illusion and the Leans (para 7-3a(3), (4)).



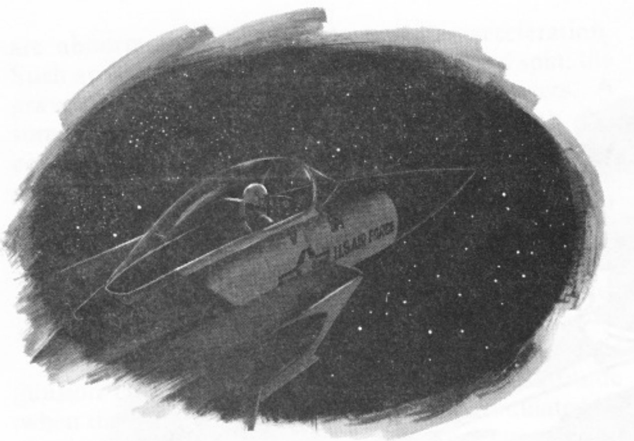
When an aircraft accelerates forward, inertia causes the otolithic membrane in his otolith organs to move. This results in the sensation of climbing, and may cause the pilot to dive in an attempt to compensate for illusory change of attitude.

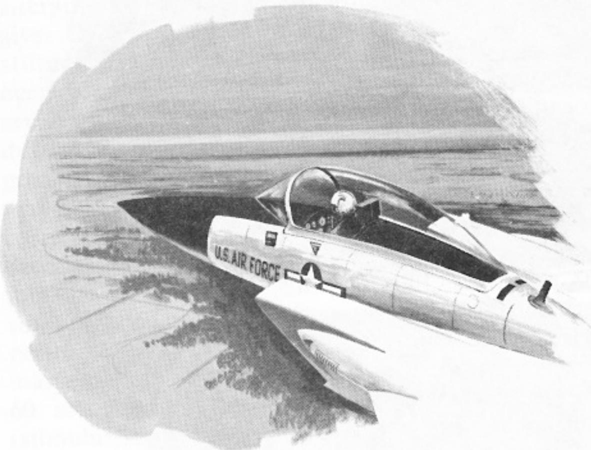
Figure 7-7. The Somatogravic Illusion (para 7-3a(6)).

attention to distinct, valid external visual references or to flight attitude instruments.

(7) Blending of Earth and Sky (figure 7-8). Sometimes pilots confuse ground lights with stars. In doing so, the possibility exists of flying into the ground because the perceived horizon is below the actual one. Sometimes pilots confuse unlighted areas of the earth with an overcast night sky. They are likely to perceive certain ground features such as a seashore as the horizon, and fly into the unlighted water or terrain above it.

(8) False Vertical and Horizontal Cues (figure 7-8). Flying over sloping cloud decks or land that slopes gradually upward into mountainous terrain often compels pilots to fly with their wings parallel to the slope rather than straight and level. A related





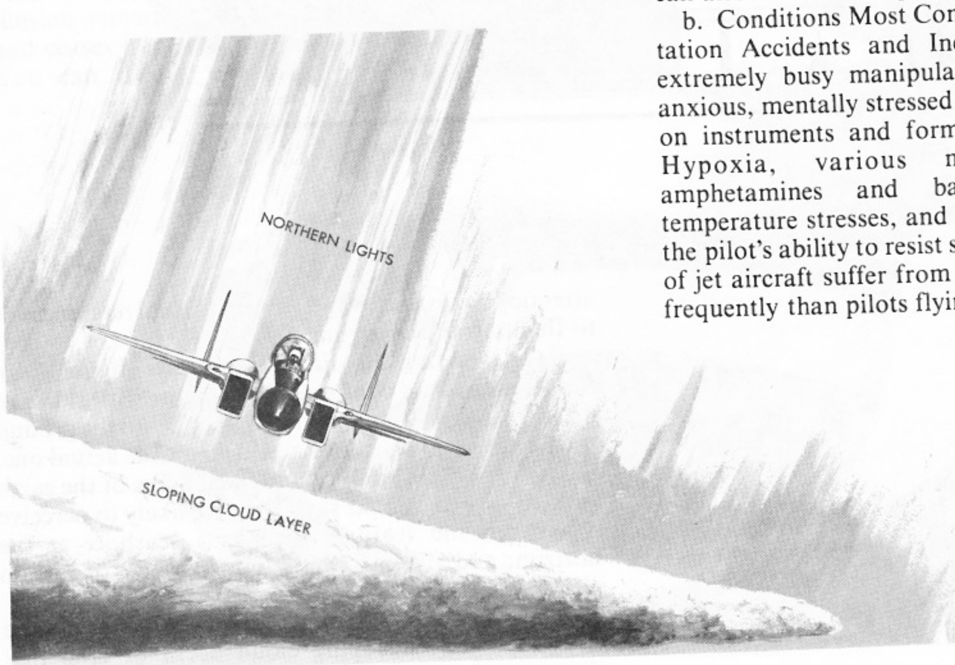


Figure 7-8. Visual Illusions (para 7-3a(7), (8)).

phenomenon is the disorientation caused by the aurora borealis, in which false vertical and horizontal cues generated by the aurora result in attitude confusion in pilots trying to fly formation or refuel at night in northern regions.

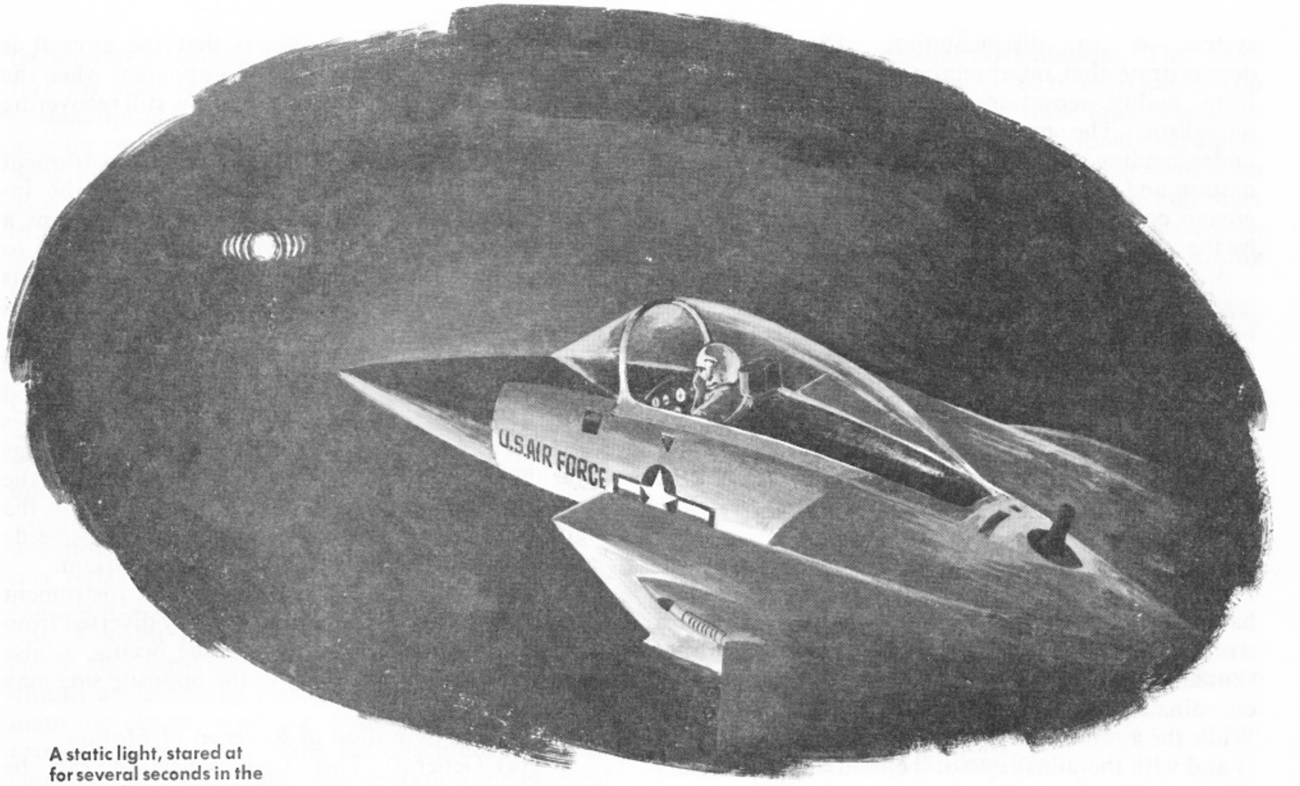
(9) Relative Motion. An adjacent automobile creeping forward at a stop light can create the illusion that your own vehicle is creeping backwards. In formation flying, such illusions are common.

(10) Visual Autokinesis (figure 7-9). A stationary light stared at for several seconds in the dark will appear to move. This phenomenon can cause considerable confusion in pilots flying formation at night. Increasing the brilliance, size, or number of lights, or causing the lights to flash on and off will diminish the effect of the autokinetic phenomenon.

(11) The Seat-of-the-Pants Sense. This is a misleading sense because during coordinated flight the forces resulting from centrifugal force and gravity are always toward the floor of the aircraft. Thus, pilots can never tell through their pressure sensors which direction is the true vertical.

(12) Flicker Vertigo. This can be caused by the passage of light through propellers or rotor blades, and by rotating beacons flickering against an overcast sky. Light flickering at certain frequencies from 4 to 20 times per second, can produce unpleasant and dangerous reactions. These reactions may include nausea, dizziness, convulsions, and unconsciousness. Flicker vertigo can be avoided by not looking into a light source through a propeller or rotor blade for a prolonged period. Frequent but small changes in rpm can also reduce susceptability.

b. Conditions Most Conducive to Spatial Disorientation Accidents and Incidents. When a pilot is extremely busy manipulating the cockpit controls, anxious, mentally stressed or fatigued, his proficiency on instruments and formation flying is decreased. Hypoxia, various medicines (particularly amphetamines and barbiturates), G stresses, temperature stresses, and emotional problems reduce the pilot's ability to resist spatial disorientation. Pilots of jet aircraft suffer from spatial disorientation more frequently than pilots flying propeller-driven aircraft.



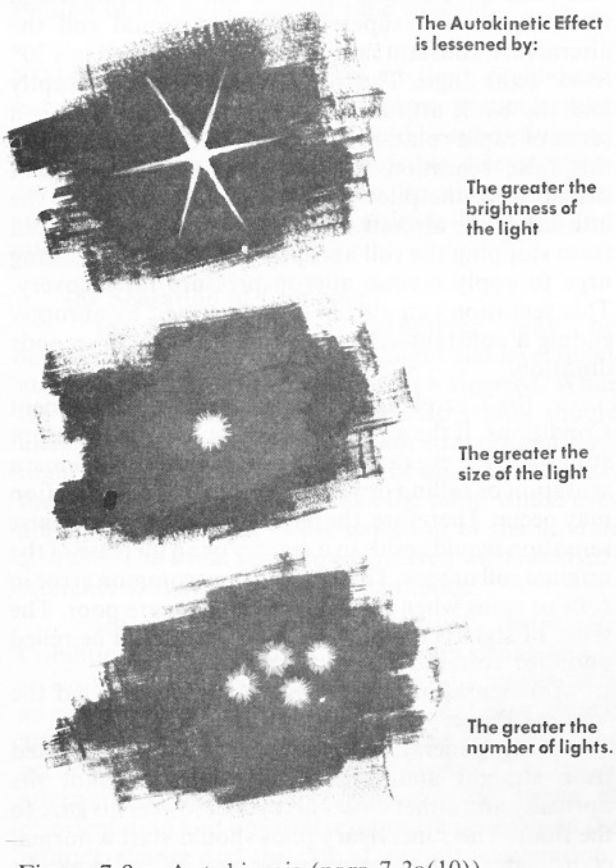


Figure 7-9. Autokinesis (para 7-3a(10)).

Pilots with less actual instrument time are more susceptible to spatial disorientation than more experienced pilots. Many spatial disorientation accidents and incidents have been reported during the penetration turn, final approach, climb out after takeoff, and while performing high performance flight maneuvers. This is when the coriolis and somatogravic illusions are the most devastating. Other very critical times are night and weather formation flights, when the wingman loses sight of the lead in weather, or when a pilot flying in VMC (visual meteorological condition) suddenly enters IMC (instrument meteorological condition). The maneuvering associated with air-to-ground ordnance deliveries, especially at night or periods of reduced visibility, is highly susceptible to disorientation accidents. Flying in the vicinity of thunderstorms may also contribute to spatial disorientation due to turbulence, flash blindness, electrical shock, and equipment loss from lightning strikes. (Spatial disorientation may be accompanied by hyperventilation.)

c. Inducing Spatial Disorientation. A number of maneuvers can be used to induce spatial disorientation. Each maneuver normally creates a specific reaction; however, any reaction resulting in a false sensation is effective. The purpose of these maneuvers is to help pilots understand how susceptible the human system is to disorientation. The maneuvers demonstrate that interpretations of aircraft attitudes from bodily sensations are frequently false and unrealistic. The maneuvers also provide a better understanding of how disorientation relates to aircraft motion and head movement. They instill in the pilots greater confidence in flight instrument interpretation by the sense of sight to determine the aircraft attitude.

d. Spatial Disorientation Maneuvers. The following spatial disorientation maneuvers are selected because of their relation to normal instrument or turbulent flight. These maneuvers should be simulated and practiced only under direct supervision. They should not be accomplished in a single-place aircraft. Other maneuvers, more violent and prolonged, may have a disorienting effect; however, they are not the type of maneuver or situation likely to be inadvertently encountered.

(1) Sensation of Climbing While Turning:

(a) General. This sensation can be induced by having the pilot close his eyes while the aircraft is in a straight and level attitude. The supervisory pilot should execute, with a relatively slow entry, a well-coordinated 90° turn using about 1½ positive Gs. While the aircraft is turning under the effect of positive G and with the pilot's eyes still closed, the supervisory pilot should ask the pilot his impression of the aircraft attitude. The usual sensation is that of a climb. If the pilot so responds, have him open his eyes. He can then see that a slowly established coordinated turn produces a climb sensation from the action of centrifugal force (+G) on the equilibrium organs.

(b) Correlation Under Actual Instrument Conditions. If the aircraft enters a slight, coordinated turn in either direction while the eyes are diverted away from the instruments, the sensation of a nose-up attitude may occur. The instantaneous application of similar forces may create this same illusion without the aircraft actually turning because when a change of direction in any one of the three planes of motion occurs and the rate of angular acceleration in the turn is too little to stimulate the inner ear, the change in G forces caused by the turn is the only sensation perceived. Positive G is usually associated with a climb; negative G with a dive or nose over. This association is an unconscious habit developed through experience with G forces, as well as a conscious feeling of climbing or diving due to the effect of gravity on the inner mechanisms of the ear.

(2) Sensation of Diving During Recovery From a Turn:

(a) General. This sensation can be created by repeating the turning procedure described above, except that the pilot keeps his eyes closed until the recovery from the turn is approximately one-half completed. While the recovery is being executed and with the pilot's eyes still closed, the supervisory pilot should observe the pilot's impression of the aircraft attitude. The usual response is that the aircraft is descending. This false sensation is apparent when the pilot opens his eyes while the aircraft is still recovering from the turn.

(b) Correlation Under Actual Instrument Conditions. If the eyes are diverted from the instruments during a turn under instrument conditions, a slow inadvertent recovery will cause the body to perceive only the decrease in positive G force. This sensation causes the pilot to believe he has entered a descent.

(3) False Sensations of Tilting to Right or Left:

(a) General. This sensation may be induced from a straight and level attitude with pilot's eyes closed. The supervisory pilot should maintain wings level and use right rudder to produce a slight skid to the left. The usual sensation is that of being tilted to the right. This false sensation is the effect of side-to-side accelerative forces on the organs of equilibrium.

(b) Correlation Under Actual Instrument Conditions. If the eyes are momentarily diverted from the instruments as a skid to one side occurs, a false sensation of tilting the body to the opposite side may occur.

(4) False Sensation of Reversal of Motion:

(a) General. This false sensation can be demonstrated in any one of the three planes of motion. The pilot should close his eyes while in straight and level flight. The supervisory pilot should roll the aircraft at a constant rate of 1° to 2° per second to a 30° to 45° bank angle. The roll should be stopped abruptly and the bank attitude held. The usual reaction is a sense of rapid rotation in the opposite direction. After this false sensation is noted, the supervisory pilot should have the pilot open his eyes and observe the attitude of the aircraft. The false sensations produced from stopping the roll abruptly may result in a strong urge to apply reverse aileron pressure for recovery. This sensation can also be demonstrated by abruptly ending a constant velocity yaw after 20 to 30 seconds duration.

(b) Correlation Under Actual Instrument Conditions. If the aircraft rolls or yaws with an abrupt stop while the eyes are diverted from the instruments, a sensation of rolling or yawing to the opposite direction may occur. Therefore, the natural response to this false sensation would result in a reentry or an increase of the original roll or yaw. This response is a common error in rolls or spins when the visual references are poor. The sense of sight is the only sense which should be relied upon for correct recovery techniques.

(5) Sensation of Diving or Rolling Beyond the Vertical Plane:

(a) General. This maneuver should be started from straight and level flight while the pilot sits normally and either closes his eyes or lowers his gaze to the floor. The supervisory pilot should start a normal coordinated turn to between 30° and 45° of bank. As the aircraft is turning, have the pilot lean forward and turn his head to either side, then rapidly resume the normal upright position. The supervisory pilot should time the maneuver so that the turn is stopped just as the pilot resumes his normal position. This maneuver usually produces disorientation by giving the sensation of falling in the direction of roll and downward. The sensation may result in a quick and forcible movement upward and backward in the opposite direction. The physical response associated with this type of sensation can be very dangerous if it occurs at low altitude.

(b) Correlation Under Actual Instrument Conditions. Severe spatial disorientation may result when the aircraft enters a turn while the pilot's head is moved down and sideways and then returned to the upright position. The usual reflex and almost uncontrollable urge to move physically in the opposite direction may be transferred to the aircraft controls. If this reflex is not controlled, it could easily cause exaggerated aircraft attitudes and further disorientation. Cockpit duties or distractions most likely to create this sensation under actual instrument conditions are changing radio frequencies, reaching for maps or charts, studying terminal instrument approach procedures, looking for obscure switches or controls, etc. The degree of disorientation and physical response depends upon the motion of the aircraft, the motion of the head, and the time element.

NOTE: Exercise extreme care to limit rapid head movements during descents and turns, particularly at low altitudes. Cockpit duties should be subordinate to maintaining aircraft control. If possible, delegate these duties to other crew members so that sufficient attention can be given to the attitude indicator and other flight instruments.

(6) Sensation of Climbing:

(a) General. This maneuver may be demonstrated by starting from straight and level flight at the aircraft's normal final approach airspeed. While the pilot closes his eyes, the supervisory pilot should increase the airspeed and maintain straight and level flight. During the latter part of the airspeed increase, the supervisory pilot should ask the pilot, whose eyes are still closed, what is his sensation of the aircraft attitude. The usual sensation perceived without visual reference is that the aircraft is climbing.

(b) Correlation Under Actual Instrument Conditions. This sensation may be very strong during an instrument missed approach. The false sensation of an excessive climb is produced by the change in aircraft attitude and aircraft acceleration. This sensation may occur prior to the climb and after leveloff. The use of afterburners increases this illusion. The degree of disorientation and physical response depends upon the attitude change and the rate of aircraft acceleration.

7-4. Maintaining Spatial Orientation. The false sensations of flight are experienced by most pilots. You will become less susceptible to these false sensations and their effects as you acquire additional instrument experience (figure 7-10). Although these sensations cannot be completely prevented, you can and must suppress them by self-discipline, conscientious instrument practice, and experience. The keys to preventing or suppressing spatial disorientation are:

a. Learning to control the aircraft by relying on the sense of sight and the flight instruments.

b. Learning to rapidly transition to flight instruments when outside visual references become unreliable.

c. Learning to ignore or control the urge to believe any false sensations perceived from the supporting sense.

SECTION B — AIMS

7-5. General. AIMS is an acronym for:

A — Air Traffic Control Radar Beacon System
I — Identification Friend or Foe
M — Mark XII Identification
S — System

Basically, AIMS is a system which provides altitude reporting and several selective identification features. The equipment is capable of automatically reporting a coded altitude and aircraft identification signal to ground stations upon interrogation. This information provides selective identification and altitude readout for control of air traffic. Two types of AIMS systems presently being used in Air Force aircraft are the servo/pneumatic system and the altitude encoder system.

a. Servo/Pneumatic AIMS System:

(1) The servo/pneumatic type system generally consists of an IFF/SIF transponder, precision pressure altimeter, servomechanism, altitude computer, controls, and other associated equipment. In this system, pitot and static pressures are provided to an altitude computer which is designed to apply a correction for installation error. The computer supplies calibrated altitude information to the transponder for altitude reporting and to the servoed altimeter for display to the pilot.

(2) The AAU-19 servo/pneumatic counter-drum-pointer altimeter has two modes of operation: the primary or servoed mode (reset) and the secondary or nonservoed mode (standby). In the primary (servoed) mode, the altimeter displays calibrated altitude. The installation error correction is applied to the barometric altitude by a servo-mechanism using electrical signals supplied by the altitude computer. A secondary (nonservoed) mode is provided in the event

Figure 7-10. Believe What the Flight Instruments are Telling You About the Aircraft Attitude (para 7-4).

of malfunction. The altimeter display then operates directly from static air pressure, and the appropriate altimeter installation error correction must be applied to ensure the aircraft is at the proper altitude. (As long as the altitude computer is operating properly, it will supply an altitude reporting signal regardless of the mode displayed on the pilot's altimeter.)

b. Altitude Encoder AIMS System. The altitude encoder type system is found in aircraft with small or negligible installation error. It generally consists of an IFF/SIF transponder, precision pressure altimeter, and an altitude encoder. In this system, the altimeter and altitude encoder are a single unit. The encoder portion of the unit simply takes the barometric altitude measured by the altimeter and converts it to signals for altitude reporting. (The appropriate altimeter installation error correction must be applied at all times to ensure that the aircraft is at the proper altitude.)

7-6. Altitude Reporting. AIMS systems report altitude based on the standard datum plane (29.92" Hg), regardless of the value set in the altimeter barometric scale. When aircraft are flying below the lowest usable flight level, ground station computers automatically apply the local altimeter setting to display accurate altitude to the air traffic controller. In order for cockpit altimeters to reflect the correct altitude as displayed to the controller, the proper value must be set in the altimeter barometric scale.

NOTE: "Code off" and "standby" flags on AIMS altimeters do not always mean that altitude reporting has been lost. If a warning flag appears, verify that your altitude is being reported to the air traffic controller.

7-7. Altimeter Tolerances. Refer to your aircraft flight manual for specific operating guidance and altimeter tolerances.

SECTION C — AUTOMATED RADAR TERMINAL SYSTEMS

7-8. Purpose and Advantages of Automated Radar Terminal Systems (ARTS):

a. Purpose. ARTS is designed to provide controllers with an alphanumeric display of aircraft identification and groundspeed on aircraft equipped with transponders, along with altitude readout on those aircraft capable of automatic altitude reporting (Mode C). This information is displayed on the controller's radar display as a data block and automatically tracks those as aircraft. ARTS is installed in many, but not all, terminal areas.

b. Advantages. ARTS equipment has simplified coordination within the terminal ATC facilities and significantly reduced the pilot/controller radio calls. This reduction in communications allows the controller to concentrate more of his attention on control decisions and planning.

7-9. Flight Considerations. While the Federal Aviation Administration (FAA) has provided automated ground equipment, the benefit to individual aircraft operation is dependent on the status of the airborne transponder equipment. The following are recommendations to assist pilots in obtaining optimum use of transponder equipment.

a. Aircraft with transponders having altitude reporting capability should have them turned on prior to takeoff and contacting approach control.

b. When you are assigned a discrete code (4 digits) and you are not sure of the number, ask for a repeat. It is important to dial the correct code as it is a discrete code specified for your aircraft alone. If you dial the wrong code, there is a chance that it has already been assigned to another aircraft. The computer cannot distinguish between two aircraft on the same code in the same radar coverage area.

NOTE: Squawking a 4-digit code does not supply the ground equipment with altitude readout. Altitude reporting is a separate function and must be specifically selected on the transponder.

c. When dialing in the assigned beacon code, delay in the selection of each digit of the assigned beacon code can result in the transmission and recognition by the computer of a code assigned to a different aircraft. As noted above, the computer cannot distinguish between two aircraft on the same code in the same radar coverage area. Consistent with safe aircraft control, avoid hesitating between selection of each digit.

d. For controllers to use your automatic altitude report, they must first verify your altitude. In order to use the automatic altitude data, it must not have an error of 300 feet or more of the pilot's reported altitude. Actual altitude reports will permit the controller to verify the automated altitude report transmitted by your transponder. (There are several ways the controller can verify altitude without directly asking you; therefore, you are not always aware that your altitude has been verified.)

SECTION D — TERMINAL INSTRUMENT PROCEDURES (TERPS)

7-10. General. AFM 55-9, United States Standard for Terminal Procedures (TERPS), prescribed standardized instrument procedures.

a. Purpose. The primary purpose of TERPS is to provide safe terminal procedures for aircraft operating to and from military and civil airports. The main considerations include criteria for obstacle clearance, descent gradients, and landing minimums.

b. Application. TERPS criteria applies to the design of Instrument Approach Procedures (IAPs) at any location over which a United States agency exercises jurisdiction.

(1) Outside of the United States, IAPs may not have been designed by a US agency. Therefore, the designing country or agency is noted in parentheses at the top of the IAP page.

(2) If the IAP is published in FLIP, it has been

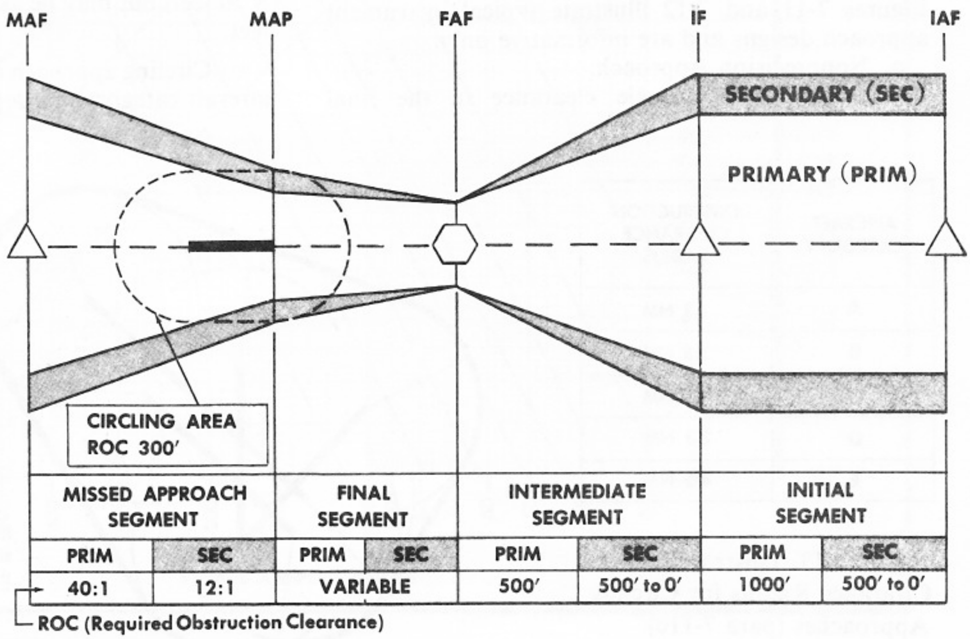
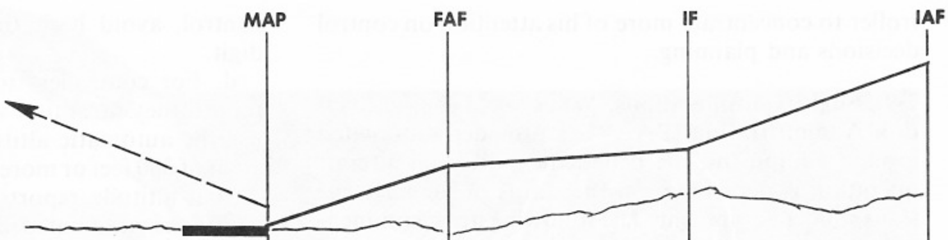


Figure 7-11. Segments of Typical Straight-In Instrument Approach With Required Obstacle Clearance (ROC) (para 7-11).



MISSED APPROACH	FINAL		INTERMEDIATE		INITIAL	
	OPT	MAX	OPT	MAX	OPT	MAX
Gradient/NM	300′	400′	150′	300′	(HI) 800′	1000′
					(LO) 250′	500′

Figure 7-12. Descent Gradients by Segment for Typical Straight-In Instrument Approach (para 7-11).

★ *NOTE: The final segment descent gradient is computed using the distance from the FAF to the runway threshold and the altitude between the FAF altitude and the touchdown zone elevation.*

reviewed by an appropriate US agency and is safe to use.

7-11. Typical Approach Designs. An instrument approach is comprised of up to four segments. They are initial, intermediate, final, and missed approach segments. All segments may not be identifiable to the pilot since some begin or end at points where no navigational fixes are available. The purpose of the segments is to provide adequate maneuvering area and obstacle clearance altitude, proper alignment, and optimum descent gradients. The flight procedures prescribed for instrument approaches are predicted upon the specifications stated in TERPs and, if used, should keep the aircraft within the allocated airspace. Figures 7-11 and 7-12 illustrate typical instrument approach designs and are informative only.

a. Nonprecision Approach:

(1) Required obstacle clearance in the final segment must be provided throughout the entire segment.

(2) The final segment descent gradient on straight-in procedures is computed using the distance from the FAF to the runway threshold and the altitude between the FAF altitude and the touchdown zone elevation. The descent gradient will normally not exceed 400 feet per nautical mile.

b. Precision Approach:

(1) Normally, the glide slope angle is 2½° to 3°.

(2) Required obstacle clearance in the final segment constantly reduced as the aircraft approaches the runway.

(3) Optimum Threshold Crossing Height (TCH) is 50 feet, but may be as high as 60 feet or as low as 32 feet.

c. Circling approach obstruction clearance areas by aircraft category are depicted in figure 7-13.

AIRCRAFT CATEGORY	OBSTRUCTION CLEARANCE RADIUS
A	1.3 NM
B	1.5 NM
C	1.7 NM
D	2.3 NM
E	4.5 NM

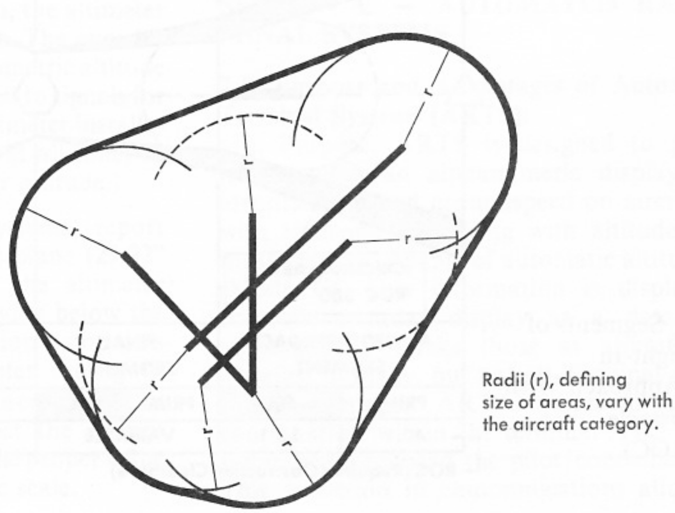


Figure 7-13. Obstruction Clearance Radius for Circling Approaches (para 7-11c).

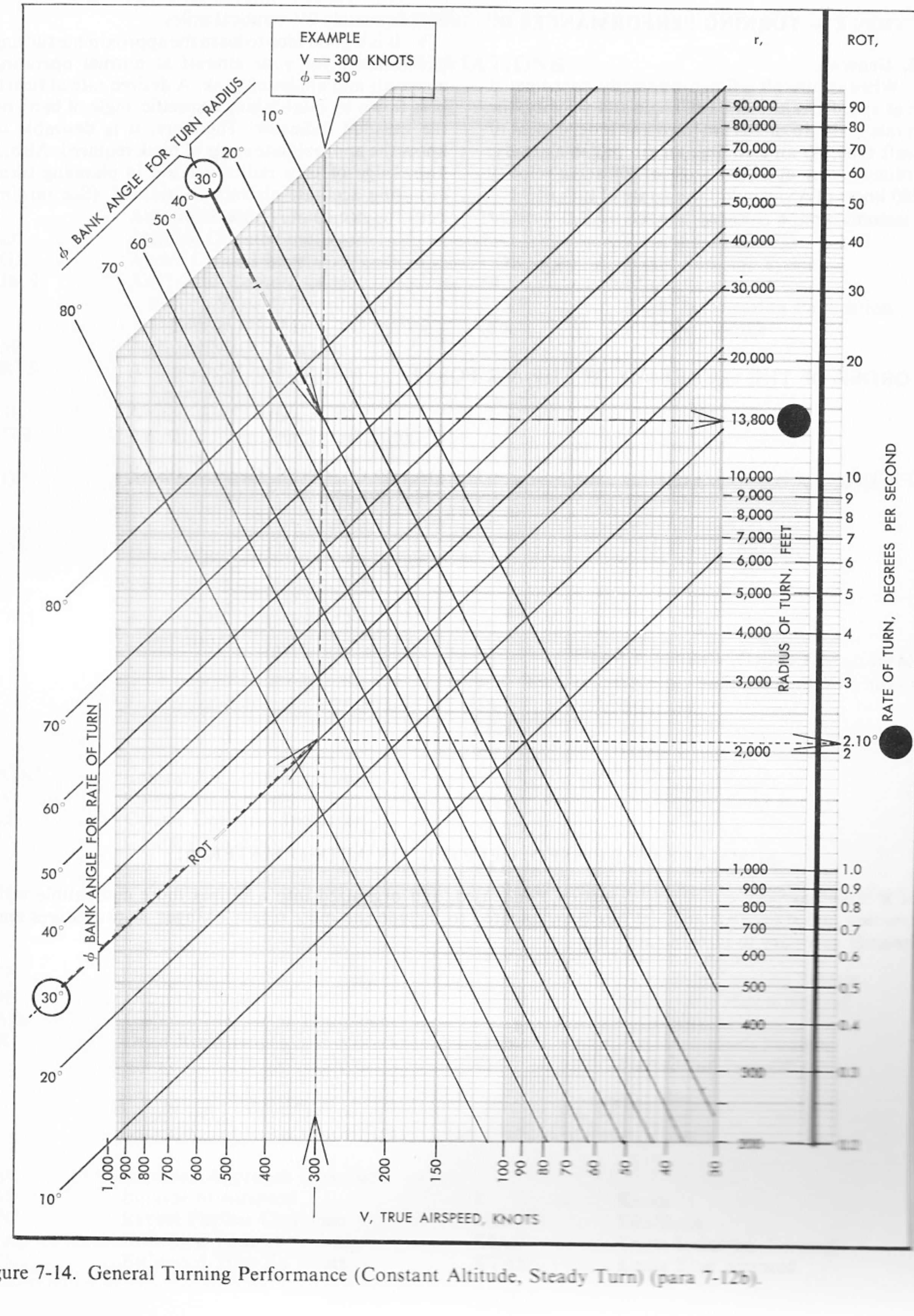


Figure 7-14. General Turning Performance (Constant Altitude, Steady Turn) (para 7-12b).

SECTION E — TURNING PERFORMANCES

7-12. General:

a. When an aircraft is flown in a steady, coordinated turn at specific values of bank angle and velocity, the turn rate and turn radius are fixed and independent of aircraft type. As an example, an aircraft in a steady, coordinated turn at a bank angle of 30° and a velocity of 300 knots (TAS) would have a rate of turn of 2.10° per second and a turn radius of 13,800 feet or approximately 2¼ nautical miles.

b. It is a good idea to learn the approximate turning performance for your aircraft at normal operating airspeeds and angles of bank. A desired rate of turn is best flown by establishing a specific angle of bank on the attitude indicator. Therefore, it is desirable to know the approximate angle of bank required. Also, a knowledge of turn radius will aid in planning turns requiring accurate aircraft positioning. (See turning performance chart, figure 7-14.)

BY ORDER OF THE SECRETARY OF THE AIR FORCE

OFFICIAL

DAVID C. JONES, General, USAF
Chief of Staff

JAMES J. SHEPARD, Colonel, USAF
Director of Administration

SUMMARY OF REVISED, DELETED, OR ADDED MATERIAL

This manual has been completely rewritten, condensed, and organized into a format more compatible with instruction and study. All material has been updated to include the most recent changes in procedures and techniques necessary to instrument flying.

Attachment 1

ABBREVIATIONS

A

ADF Automatic Direction Finding
ADI Attitude Director Indicator
AGL Above Ground Level
AIMS Air Traffic Control Radar Beacon System/Identification Friend or Foe/Mark XII System
AMI Airspeed Mach Indicator
ARTS Automated Radar Terminal Systems
ASR Airport Surveillance Radar
ATIS Automatic Terminal Information Service
ATC Air Traffic Control

B

BDHI Bearing Distance Heading Indicator

C

CADC Central Air Data Computer
CAS Calibrated Airspeed
CDI Course Deviation Indicator
CI Course Indicator

D

DG Directional Gyro
DH Decision Height
DME Distance Measuring Equipment
DR Dead Reckoning

E

EAC Expected Approach Clearance
EAS Equivalent Airspeed
EFC Expect Further Clearance
ETA Estimated Time of Arrival
ETE Estimated Time En Route

F

FAA Federal Aviation Administration
FAF Final Approach Fix
FDS Flight Director System
FL Flight Level
FLIP Flight Information Publication
fpm Feet Per Minute

G

GCA Ground Controlled Approach
GPI Glide Path Intercept Point
GS Groundspeed
GSI Glide Slope Indicator

H

HF Holding Fix
Hg Mercury
HSI Horizontal Situation Indicator
Hz Hertz (cycles per second)

I-J

IAF Initial Approach Fix
IAP Instrument Approach Procedure
IAS Indicated Airspeed
IFF Identification, Friend or Foe
IFR Instrument Flight Rules
ILS Instrument Landing System
IMC Instrument Meteorological Conditions
IMN Indicated Mach Number
ITO Instrument Take Off

K-L

k Knots
kHz KiloHertz
KIAS Knots Indicated Airspeed
KTAS Knots True Airspeed

M

MAP	Missed Approach Point
MCA	Minimum Crossing Altitude
MDA	Minimum Descent Altitude
MEA	Minimum En Route Alitude
mHz	MilliHertz
MHz	MegaHertz
MM	Middle Marker
MOCA	Minimum Obstruction Clearance Altitude
MRA	Minimum Reception Altitude
MSL	Meal Sea Level

N

NAVAID	Navigational Aid
NDB	Nondirectional Beacon
NM	Nautical Miles
NoPT	No Procedure Turn Required
NOTAM	Notices to Airmen

O

OM	Outer Marker

P-Q

PAR	Precision Approach Radar

R

RADAR	Radio Detecting and Ranging
RDF	Radio Direction Finding
REIL	Runway End Identifier Lights
RMI	Radio Magnetic Indicator
RNAV	Area Navigation
RPI	Runway Point of Intercept
rpm	Revolutions per minute
RVR	Runway Visual Range

S

SID	Standard Instrument Departure
SIF	Selective Identification Feature

T

TACAN	Tactical Air Navigation
TAS	True Airspeed
TCH	Threshold Crossing Height
TERPs	Terminal Instrument Procedures
TMN	True Mach Number

U

UHF	Ultra High Frequency

V

VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
VORTAC	VHF Omnidirectional Range Tactical

ATTACHMENT 2

INDEX

M

N

O

P

R

S