NAVAL AIR TRAINING COMMAND

NAS CORPUS CHRISTI, TEXAS **CNATRA P-1287 (Rev. 08-09) PAT**

FLIGHT SUPPORT LECTURE GUIDE

AERODYNAMICS

T-45TS, TAILHOOK, AND IUT

2009

DEPARTMENT OF THE NAVY
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CNATRA P-1287 (REV. 08-09)

Subj: FLIGHT SUPPORT LECTURE GUIDE, AERODYNAMICS, T-45TS, TAILHOOK, AND IUT

1. CNATRA P-1287 (Rev. 08-09) PAT, "Flight Support Lecture Guide Aerodynamics, T-45TS, Tailhook, and IUT" is issued for information, standardization of instruction, and guidance for all flight instructors and student aviators within the Naval Air Training Command.

2. This publication shall be used as an explanatory aid to support the T-45A/C Advanced Strike Flight Training Curriculum. It will be the authority for the execution of all flight procedures and maneuvers herein contained.

3. Recommendations for changes shall be submitted via CNATRA TCR form 1550/19 in accordance with CNATRAINST 1550.6E.

4. CNATRA P-1287 (09-99) PAT is hereby cancelled and superseded.

JAMES A. CRABBE
Chief of Staff

Distribution:
CNATRA N7 (5) Plus Original
COMTRAWING ONE (200)
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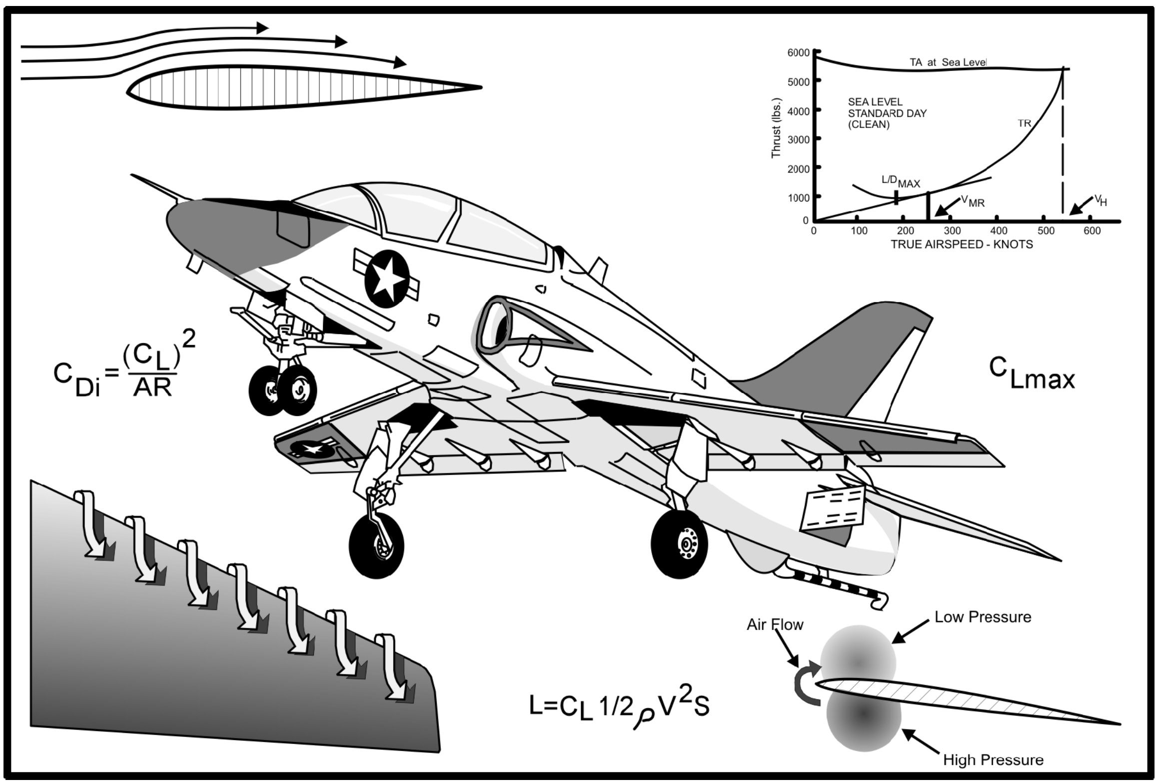
FLIGHT SUPPORT LECTURE GUIDE

FOR

AERODYNAMICS

P-1287



LIST OF EFFECTIVE PAGES

Dates of issue for original and changed pages are:
Original...0...15 Sep 99 (this will be the date issued)
Revision1…0…07 Oct 09

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 134 CONSISTING OF THE FOLLOWING:

Page No.	Change No.	Page No.	Change No
COVER	0		
LETTER	0		
iii - x	0		
1-1 – 1-27	0		
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A-1 – A-2	0		

INTERIM CHANGE SUMMARY

The following Changes have been previously incorporated in this manual:

CHANGE NUMBER	REMARKS/PURPOSE

The following interim Changes have been incorporated in this Change/Revision:

INTERIM CHANGE NUMBER	REMARKS/PURPOSE	ENTERED BY	DATE

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TABLE OF FIGURES

CHAPTER ONE
HIGH-SPEED FLIGHT

100. INTRODUCTION – N/A

COURSE/STAGE:

- T-45TS, TAILHOOK, AND IUT/Aerodynamics

LESSON TITLE:

- High-Speed Flight

LESSON IDENTIFIER:

- T-45A/C TS, TAILHOOK, AND IUT Aero 02

LEARNING ENVIRONMENT:

- Classroom

ALLOTTED LESSON TIME:

- 1.0 hr

TRAINING AIDS:

1. T-45 Scale Model
2. Figures
    - Figure 1: Flow About an Airfoil
    - Figure 2: Compression Wave Formation
    - Figure 3: T-45 Midspan Vortex
    - Figure 4: Transonic Lift Distribution
    - Figure 5: Cause of Reduced T-45 Stability in Transonic Flight
    - Figure 6: Effect of Wing Sweep on High-Speed Airflow
    - Figure 7: Area Rule
    - Figure 8: Transonic/Supersonic Flight Controls

- Figure 9: Transonic/Supersonic Flight Controls
- Figure 10 Supersonic Flow in an Engine Inlet
- Figure 11: Vortex Generators on the T-45

STUDY RESOURCES:

1. T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

LESSON PREPARATION:

- Read:

  a. Part IV, Section 11.3, "General Flight Characteristics," T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

  b. Aero-02 Lesson Guide

REINFORCEMENT:

- N/A

EXAMINATION:

The objectives in this lesson will be tested in Aerodynamics 07X.

101. LESSON OBJECTIVES

1. Identify effects of high-speed flight on aircraft
2. Recall T-45 high-speed flight characteristics
3. State methods utilized to overcome the effects and permit high-speed flight

102. MOTIVATION

Flight at high Mach numbers affects an aircraft differently than at low Mach numbers. Understanding the effect of compressibility at high Mach numbers is important to you because of the effects on stability, lift, and drag. Knowing the flight characteristics of the T-45 during high-speed flight will help you, as a pilot, realize the maximum potential of the aircraft.

103. OVERVIEW

Aircraft that are capable of high-speed flight look different from those developed for low-speed flight. Many significant differences exist between high-speed and low-speed aerodynamics. The nature and cause of these differences and their application to the T-45 will be discussed in this lecture.

In this lesson, we will be discussing:

1. The effects of high-speed flight on aircraft

2. Methods used to overcome effects and permit high-speed flight

104. PRESENTATION

Effects of High-speed Flight on Aircraft

1. Flight Regimes

    a. Compressibility

        i. Normally ignored in study of subsonic flight

        ii. Not limited to flight greater than speed of sound

        iii. Progressive and effect may be experienced well below the speed of sound

    b. Flight Regimes

        i. Subsonic -- all airflow about the aircraft is subsonic

        ii. Transonic -- there is a mixed airflow about the aircraft, that is part subsonic and part supersonic

        iii. Supersonic -- all airflow about the aircraft is supersonic

2. Velocity and Pressure Changes

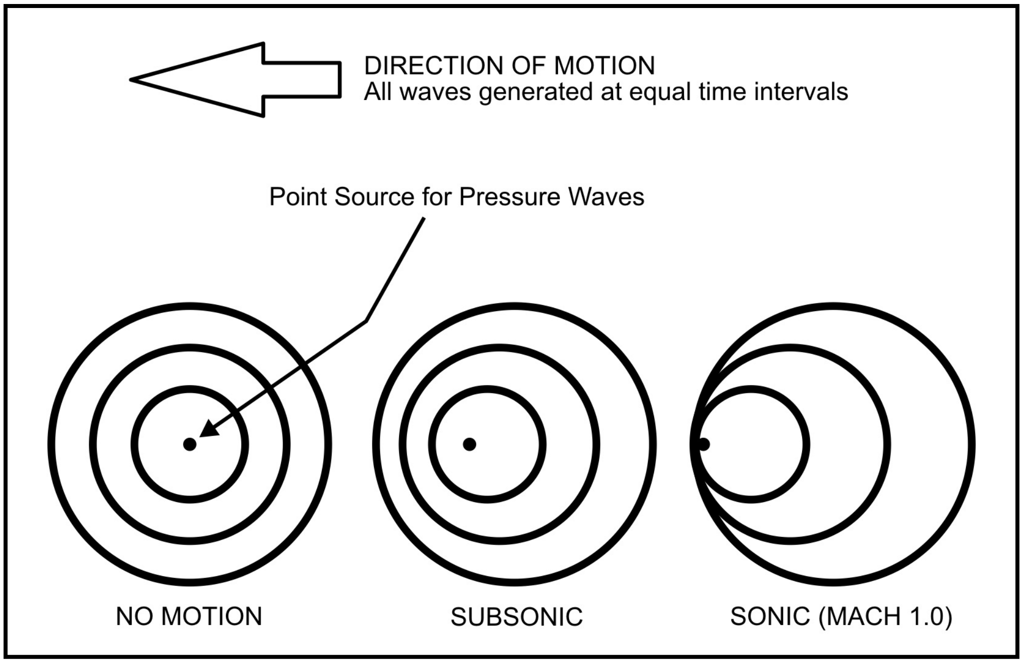

Figure 1-1 Pressure Wave Formation

a. Occur as an object moves through an airmass

b. Create pressure disturbances in the airflow surrounding the object

i. Series of pressure waves transmitted from one molecule to another

(a). Extend in all directions

(b). Spread well ahead of the object when object is traveling at a slow speed

(c). Warn the air ahead and help the airflow around the object

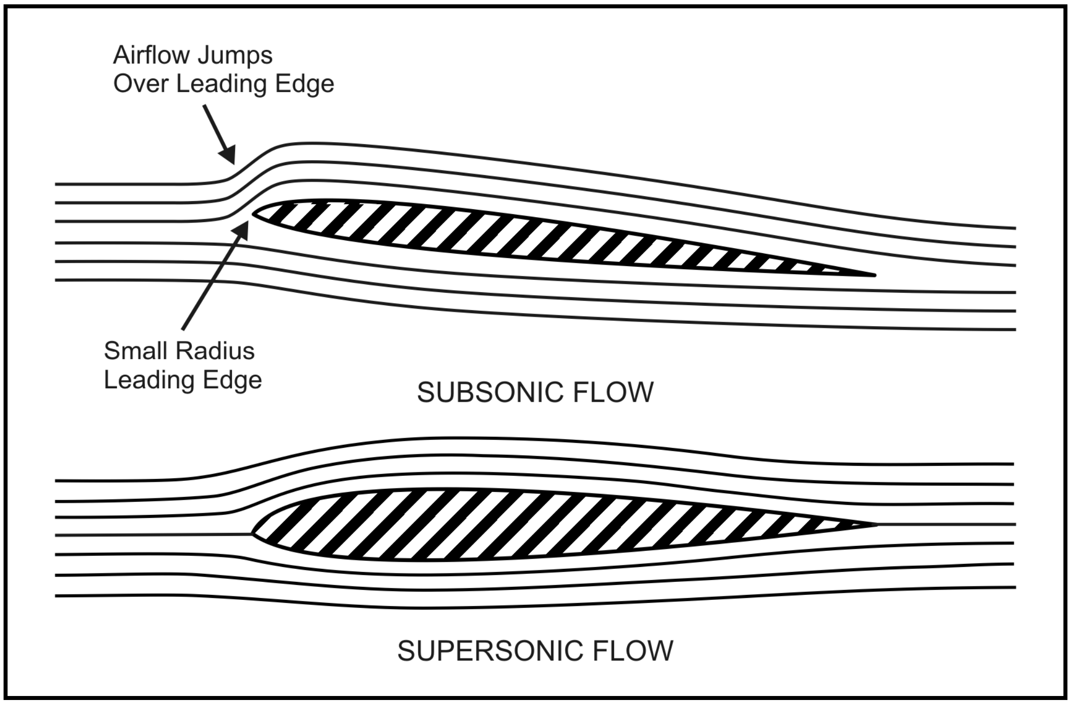

Figure 1-2 Flow About an Airfoil

(d). Spread at the speed of sound

(1). Speed of sound depends on air temperature, i.e., at 59 degrees F, the sea level speed of sound is 662 knots; at 90 degrees, it is 687 knots; at 32 degrees, it is 643 knots

(2). Speed of sound decreases with altitude

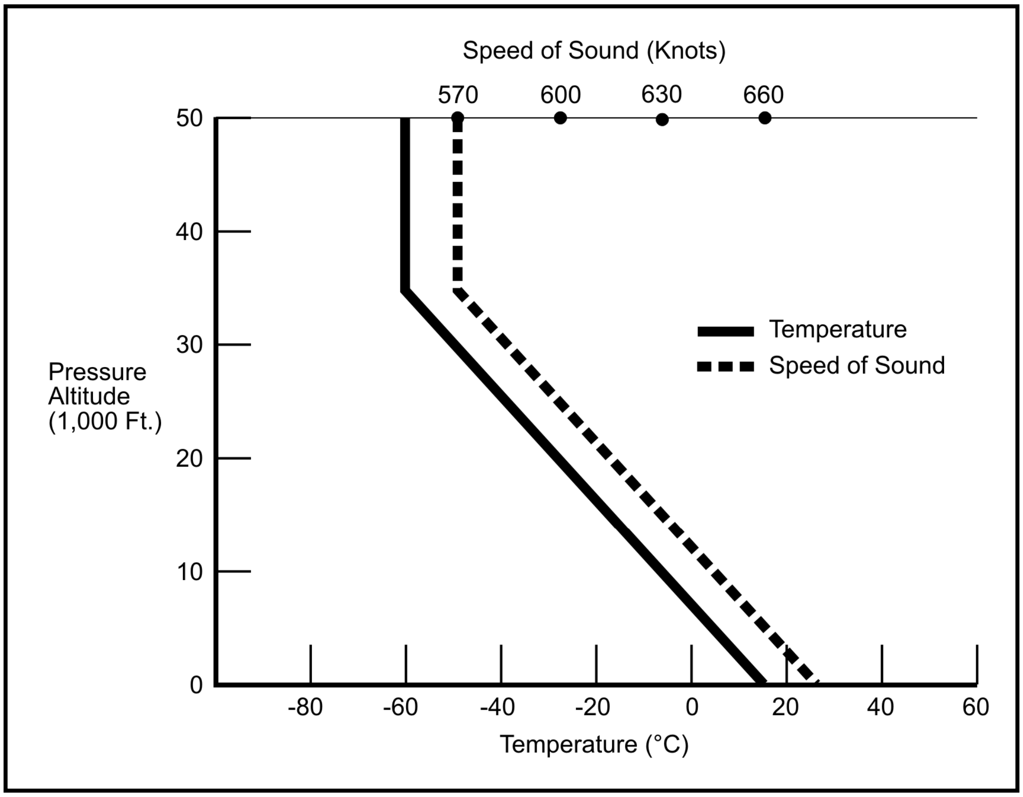

Figure 1-3 Temperature and Speed of Sound Relationship

c. Compressibility effects occur at lower IAS as altitude increases

d. Relationship described by Mach number (the ratio of true airspeed to the speed of sound)

  i. Compressibility effects (assume high thickness-to-chord ratio and rounded large radius leading edge)

  ii. Local sonic flow on airfoil at speed less than Mach 1

  iii. Critical Mach number

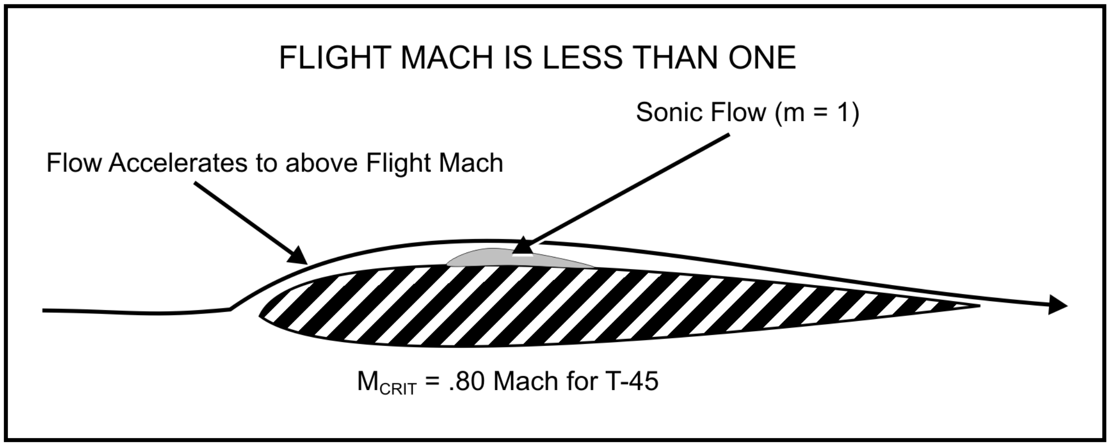

Figure 1-4 Critical Mach Number

(a). Flight Mach number at which the first sonic flow on the aircraft occurs

(b). Important reference point because it is the beginning of the transonic flight regime

(1). Airflow is mixed--part subsonic, part supersonic

(2). 0.8 Mach in T-45

i) Occurs on wingtips

ii) Occurs on landing gear door blister

iv. Force divergent Mach number

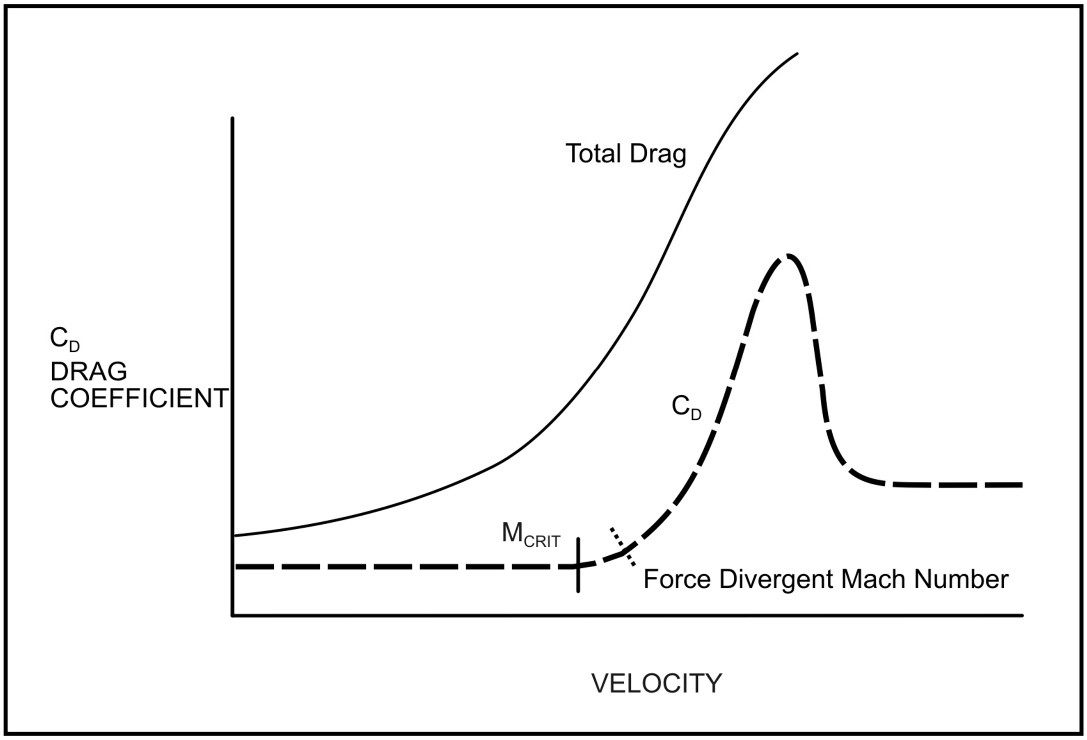

Figure 1-5 Force Divergence Mach Number

(a). Approximately 5% above critical Mach number (0.85 Mach in T-45)

(b). Pressure waves pile up to form normal compression wave, and flow is slowed to subsonic.

(c). Rapid rise in drag

(1). Due to heating of air being compressed

(2). Boundary layer separation

(d). Airflow just in front of compression wave has highest speed and lowest pressure.

NOTE

The following does not occur in the T-45.

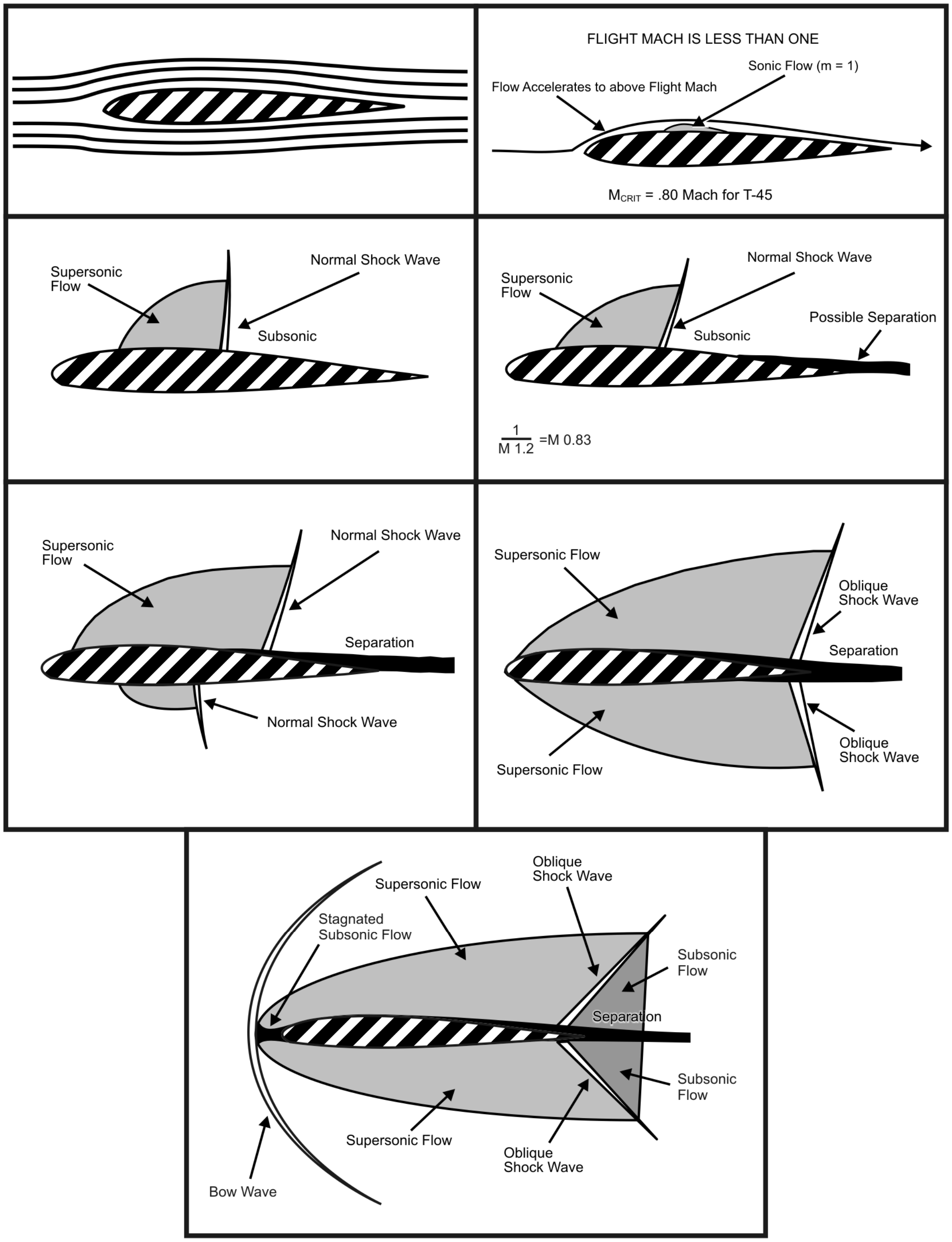

Figure 1-6 Compression Wave Formation

e. Waves continue to move aft and attach to the trailing edge as aircraft speed increases.

f. Area in front of waves continues to send out pressure warnings.

g. As aircraft speed increases, waves pile up and form a bow wave which leading edge catches up to.

  i. If leading edge radius is small enough or sharp, the bow wave will attach.

  ii. If bow wave does not attach, an area of stagnation and large drag values will occur.

  iii. Until bow wave attaches, part of flow is subsonic and aircraft remains in the transonic flight regime; aircraft is not in supersonic flight regime until all airflow about it is supersonic.

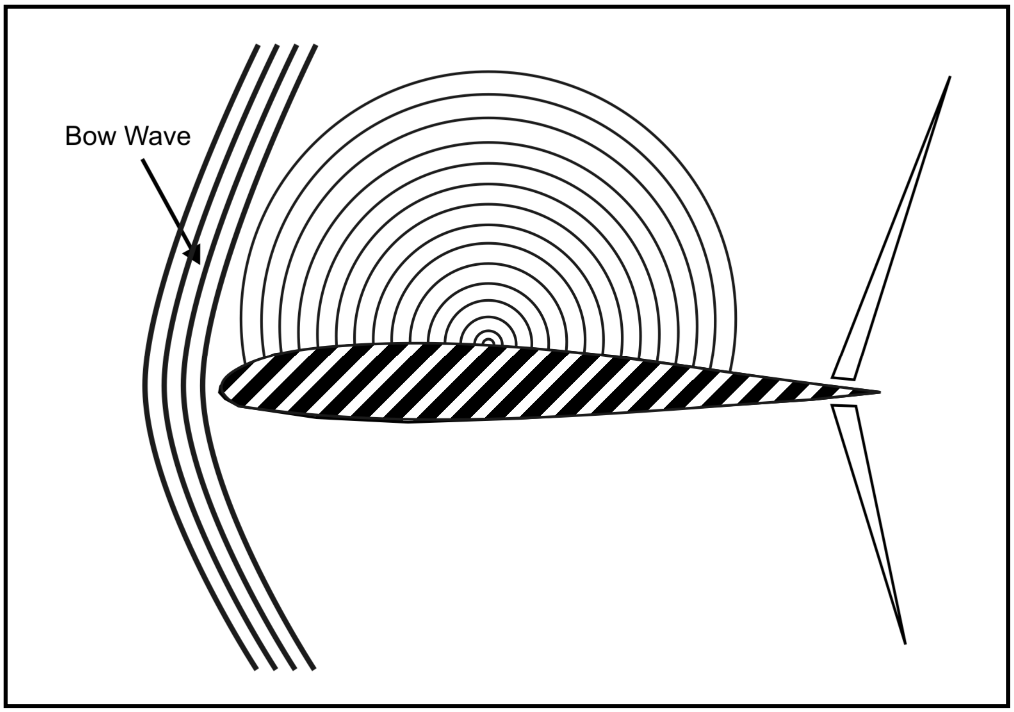

Figure 1-7 Detail of Bow Wave

h. Increased by transonic and supersonic flight

  i. Occurs at the force divergent Mach number and continues to build

  ii. Rate of total aircraft drag rise decreases as the bow wave attaches

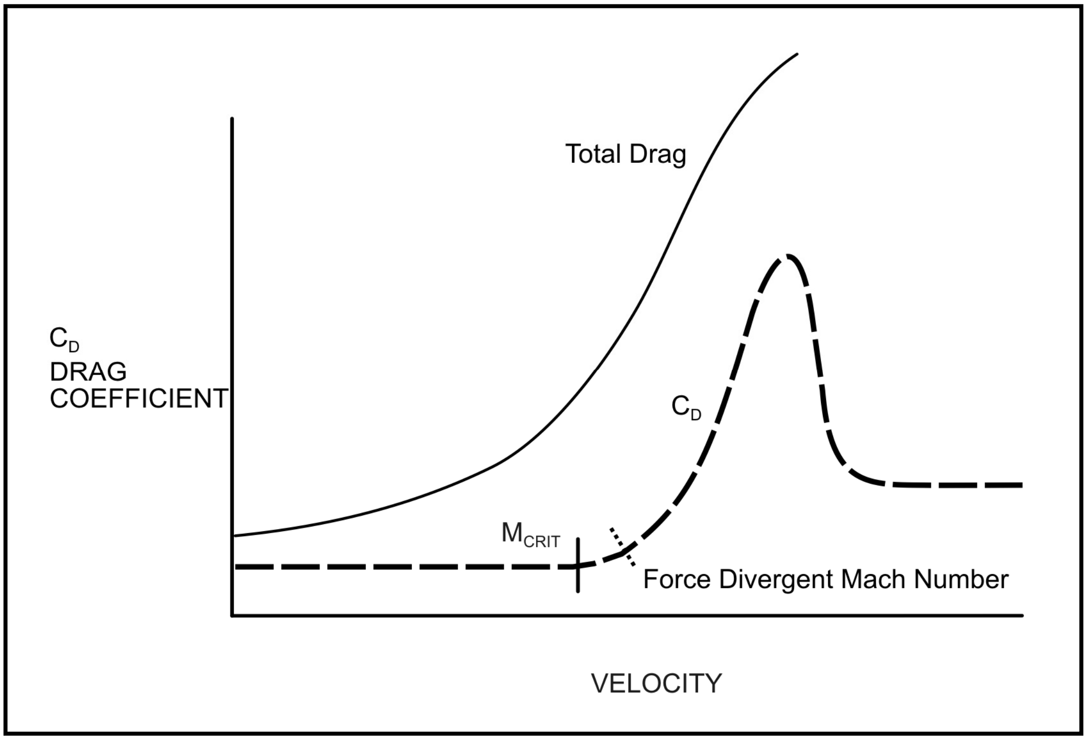

Figure 1-8 High-Speed Drag Characteristics

3. Transonic and Supersonic Affects on Stability

a. Buffeting -- caused by turbulence associated with separation of boundary layers as normal compression waves form

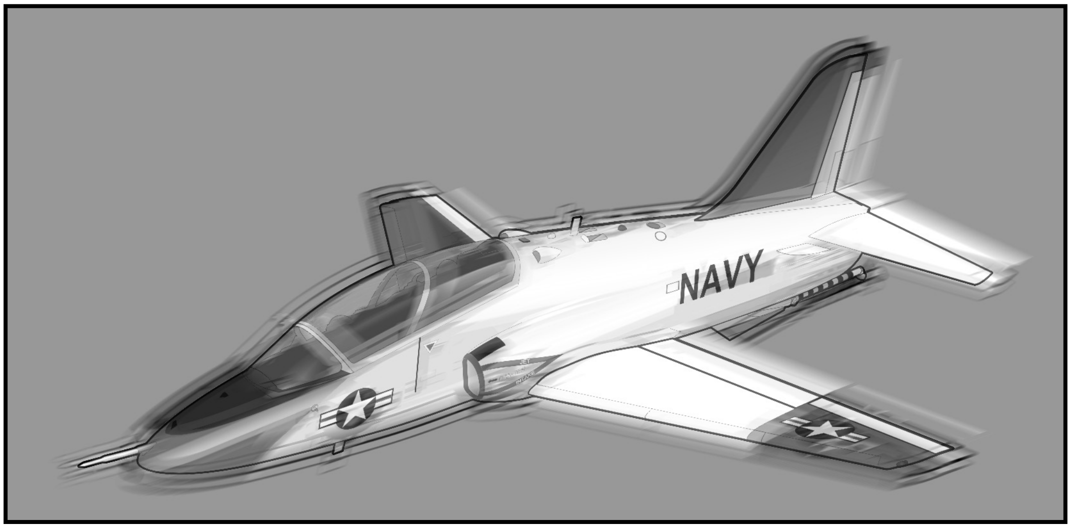

Figure 1-9 Airframe Buffeting

b. Tuck under

i. Aerodynamic center moves aft, causing a nose down pitch or "tuck under"

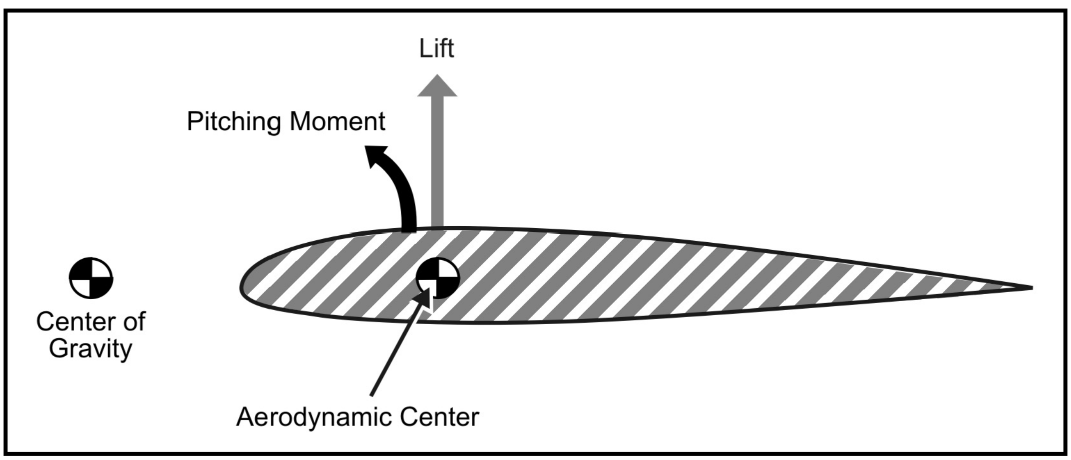

Figure 1-10 Tuck Under

ii. Further increase in flight speed causes a bottom shock

iii. Transonic pitch characteristics

(a). Dive recovery: 0.85-0.90 Mach

(b). Nose-up pitch attributed to an increase in the downwash angle at the horizontal tail

(c). Increased downwash attributed to spanwise lift distribution

(1). Strongest lift gradient normally near wingtip, resulting in wingtip vortexing

(2). Midspan shock-induced separation results in reduction in lift over outer 40% of wing, resulting in large lift gradient at midspan

(3). Caused by midspan vortex

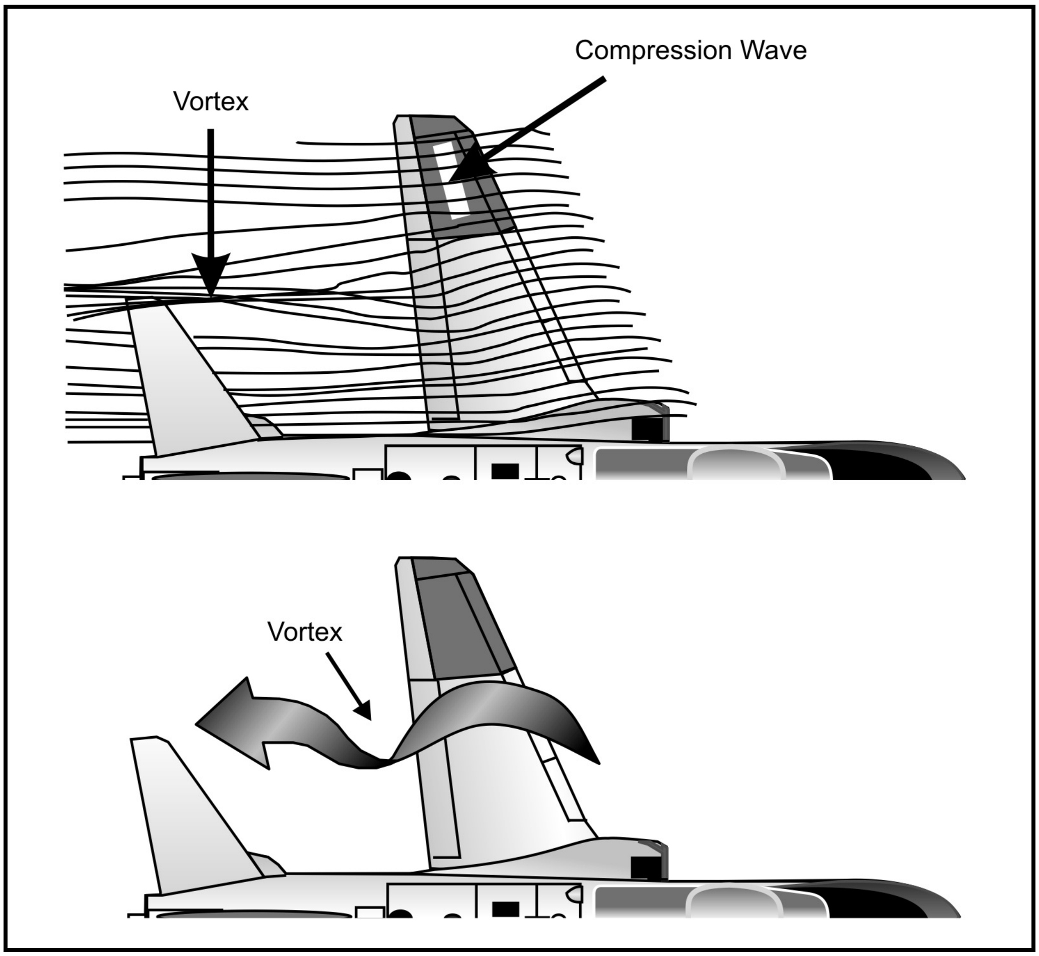

Figure 1-11 Midspan Vortex

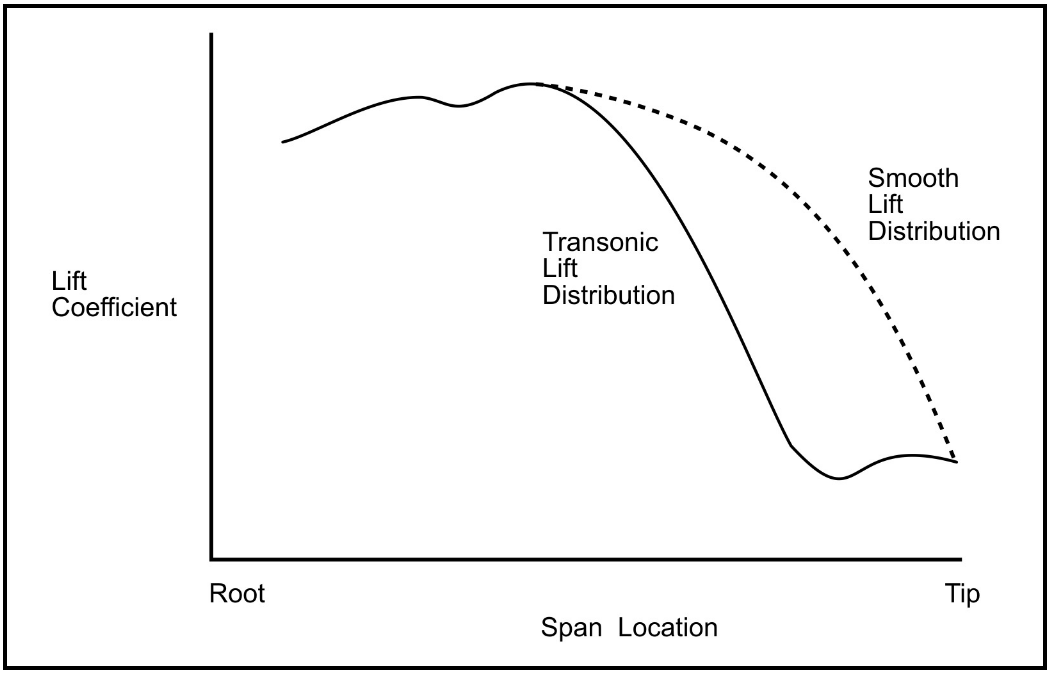

Figure 1-12 Transonic Lift Distribution

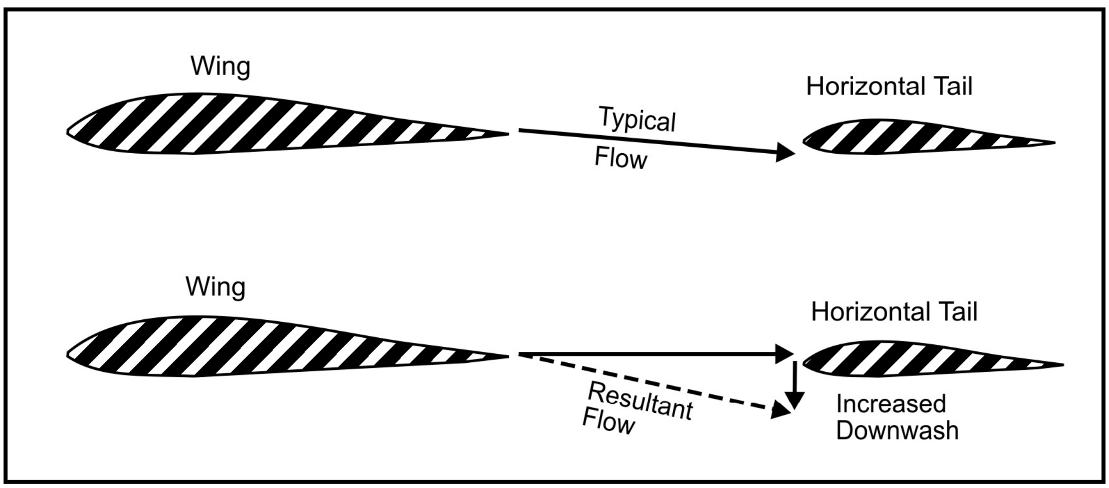

Figure 1-13 Cause of Reduced T-45 Stability in Transonic Flight

Methods Used to Overcome Effects and Permit High-speed Flight

1. High-speed aircraft design

NOTE

Aircraft designed to fly at near transonic or supersonic speeds all have features incorporated in their design to delay onset of critical Mach number, reduce wave drag, reduce or eliminate “tuck under”, reduce flow separation, and maintain engine performance.

a. Thin airfoil sections of low thickness-to-chord ratio

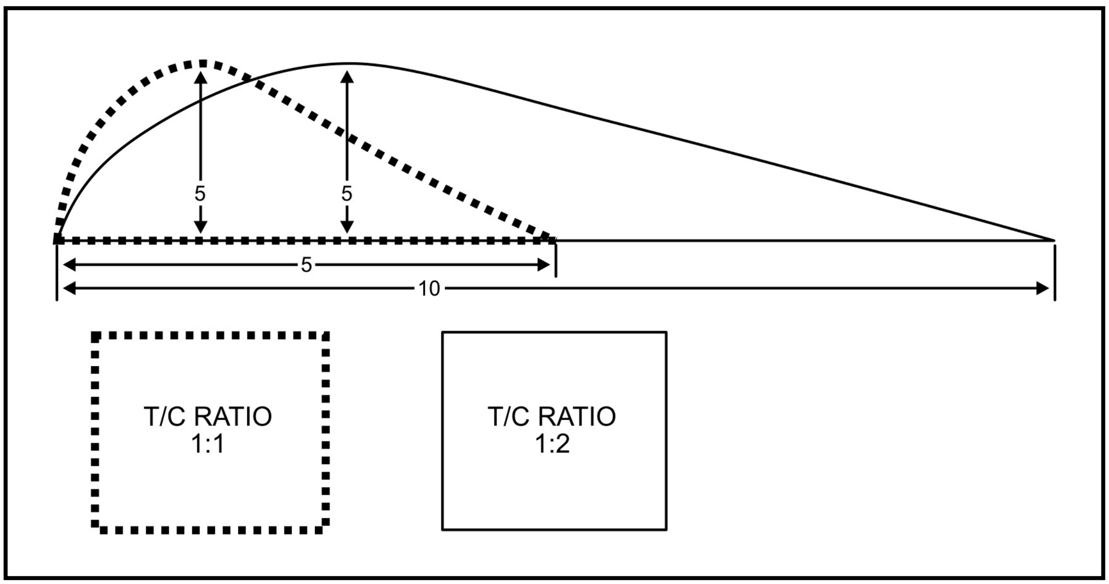

Figure 1-14 Thickness-to-Chord Ratio

i. Do not accelerate the air to the extent that a thick airfoil does

ii. Compression wave is not as strong, once formed

iii. Lack structural strength and volume for landing gear and fuel

iv. Sweepback (thin wing with thick section) “fools” air into thinking wing is a thin airfoil section

(a). Airflow broken into vector components

(1). A component perpendicular to the leading edge contributes to lift; this component is less than the free stream component

(2). A spanwise component does not contribute to lift; this component at high AOAs/low IAS's causes tip stalling

(3). Airflow "sees" an airfoil section of lower thickness-to-chord ratio and smaller leading edge radius

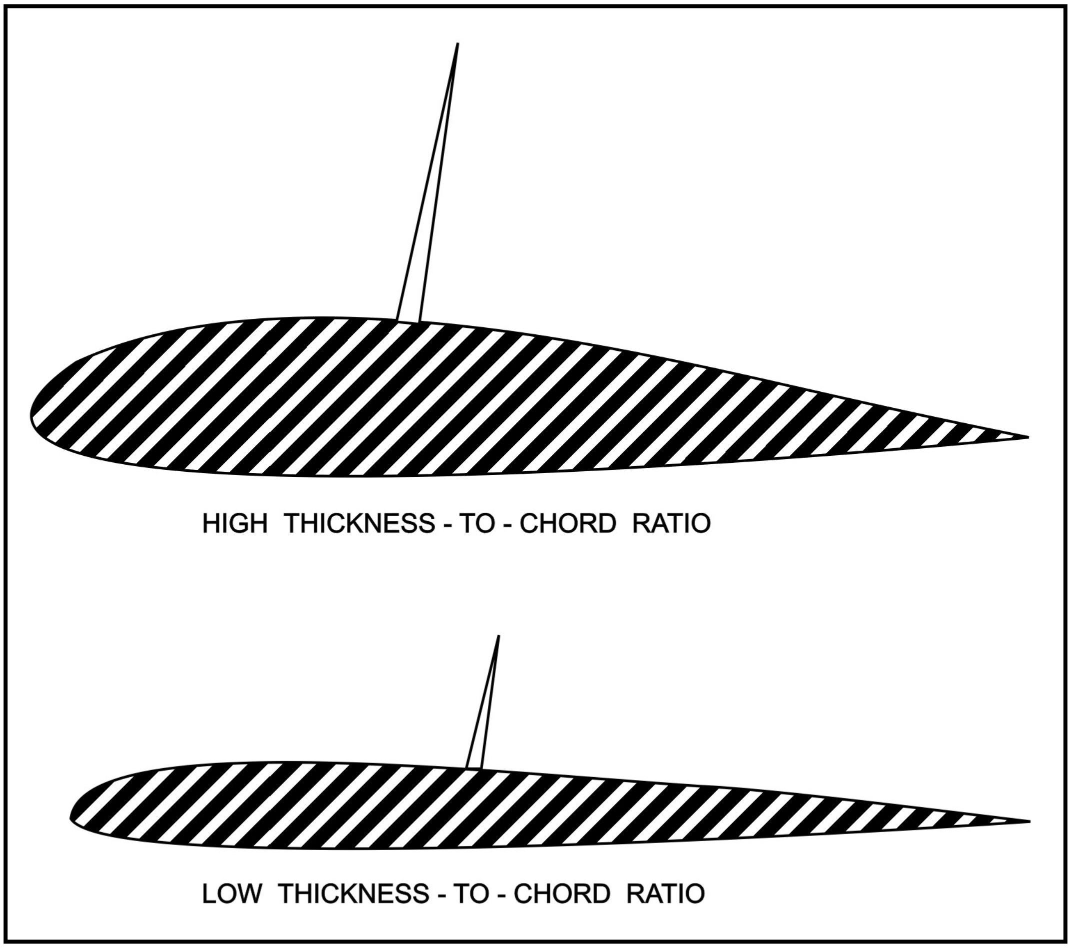

Figure 1-15 Effect of Low Thickness-to-Chord Ratio Airfoil on Shock Wave Formation

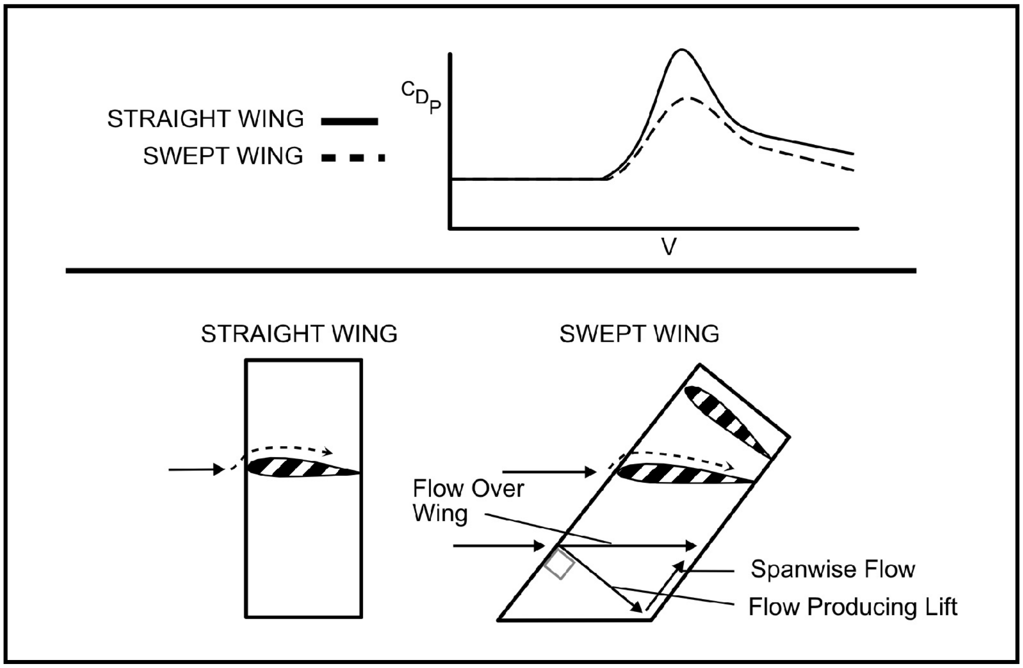

Figure 1-16 Effect of Wing Sweep on High-Speed Airflow

(b). Sweepback effect on drag

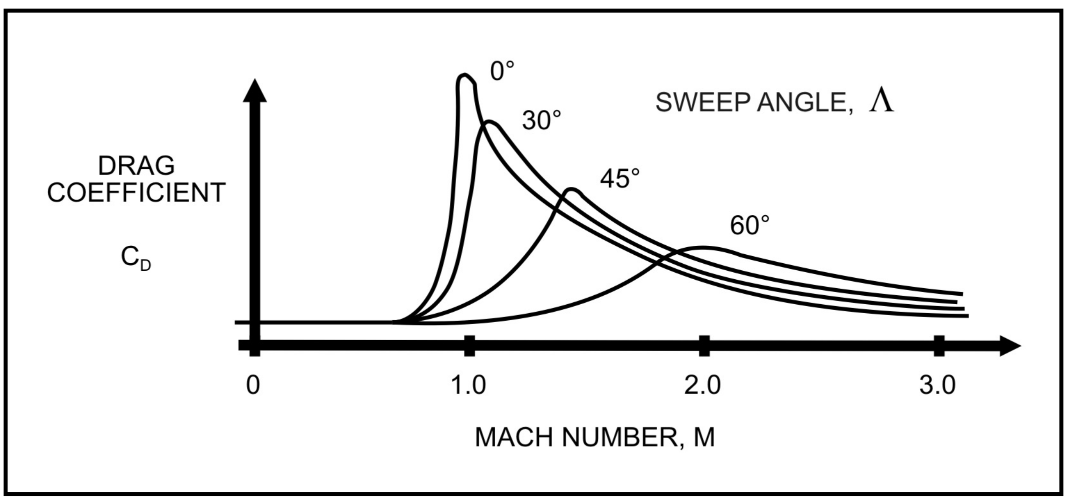

Figure 1-17 Effect of Wing Sweep on Drag

(1). Reduces peak drag rise

(2). Higher critical Mach number than straight wing of same planform

v. Reduce wave drag and help reduce tuck-under tendencies

vi. Small leading edge radius

(a). Allows bow wave to move in closer to leading edge or become attached to it

(b). Deflects airstream less than a large radius leading edge, resulting in a weaker oblique compression wave; this reduces drag of bow wave

vii. Point of maximum thickness is at 35-40% or more of the chord length instead of 25% on a conventional airfoil

- Helps reduce the pitching moment associated with shock wave formation and tuck under tendencies

b. Area rule

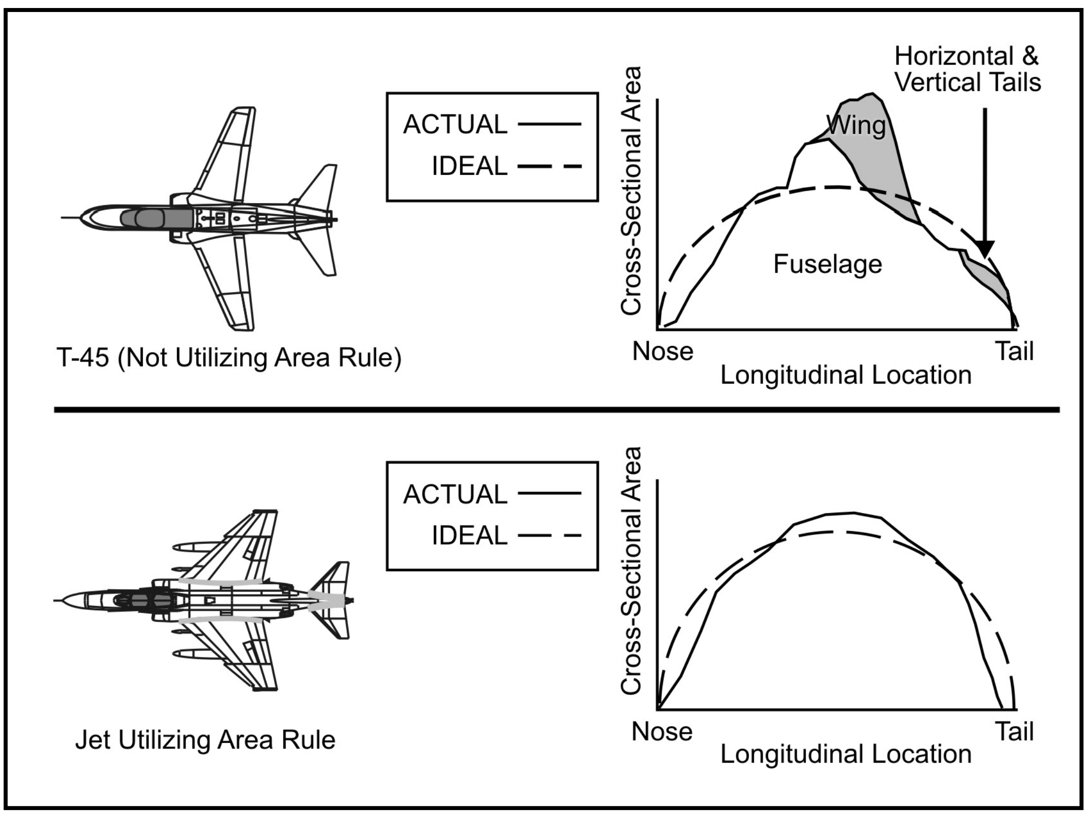

Figure 1-18 Area Rule

i. Minimizes drag of airplane if the distribution of its cross-sectional area (wings, fuselage, etc.) is made as smooth as possible

ii. Dictates reduction of cross-sectional area of the fuselage in the region of the wing and tail to compensate for the additional cross-sectional area of these surfaces

iii. At supersonic speeds, continues to provide benefits

c. Horizontal stabilizer configuration with a movable leading edge

i. Slab-type tail (stabilator), i.e., T-45, or trimmable horizontal stabilizer with elevators

ii. Effective as counter to "tuck under," even when aft portion is behind a compression wave; portion forward of compression wave remains effective

iii. Differential stabilizer, i.e., F-14 and F-18, provide not only pitch moments, but also rolling moments

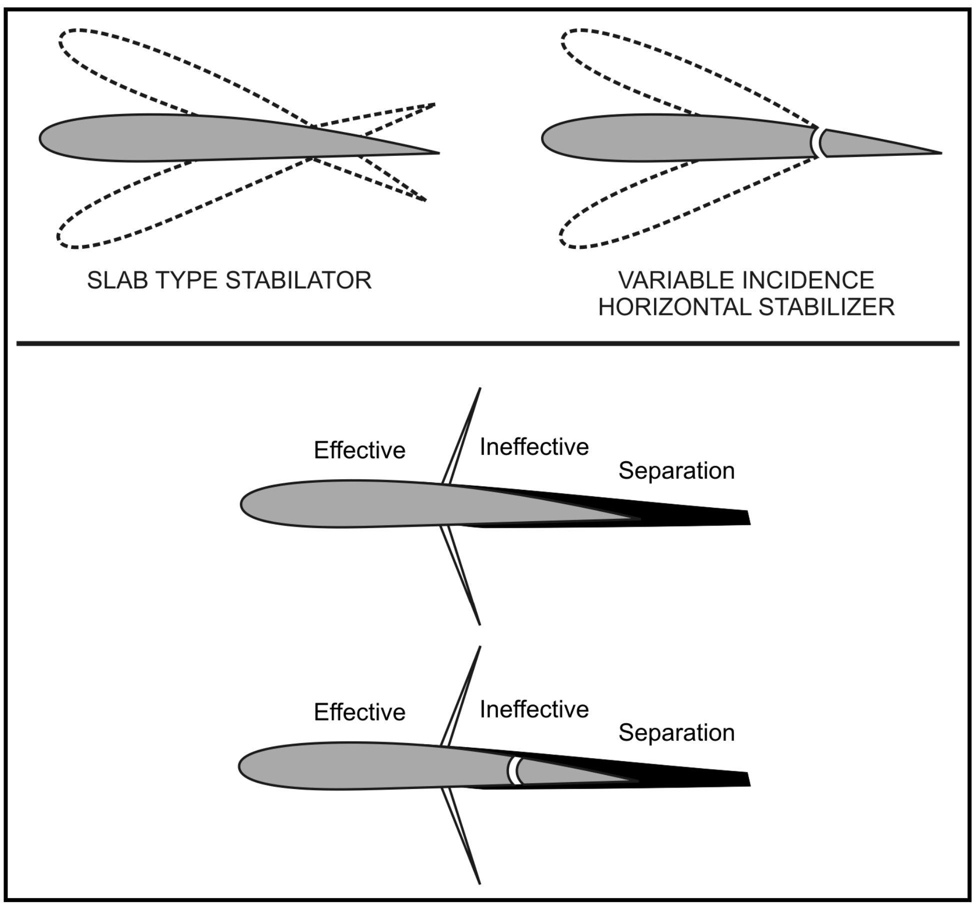

Figure 1-19 Transonic/Supersonic Flight Controls

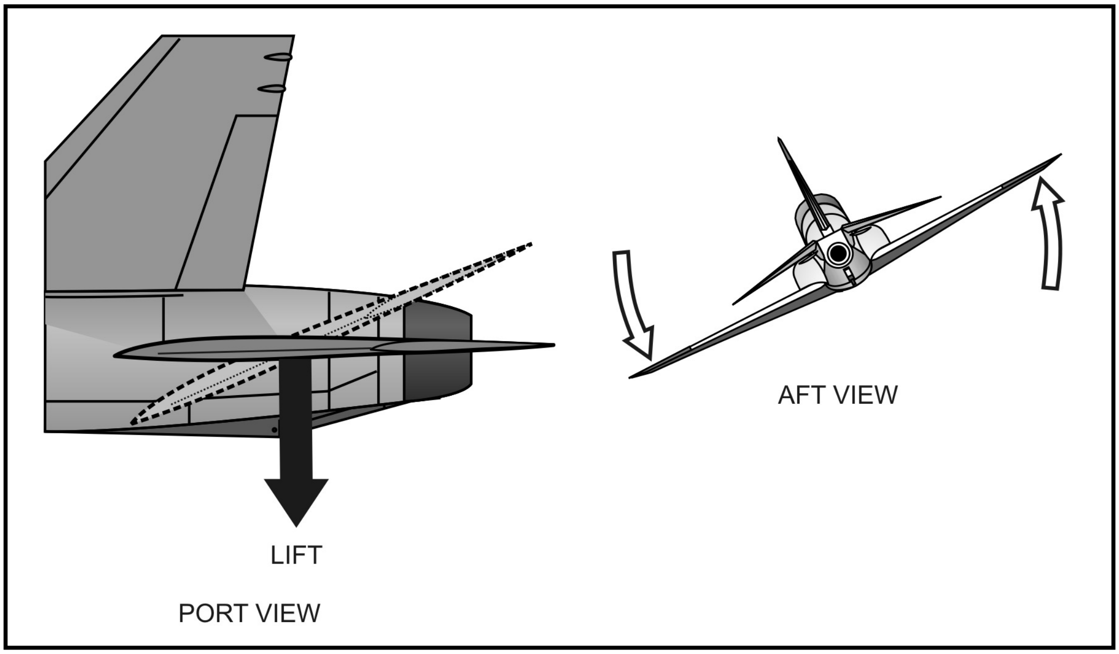

Figure 1-20 Transonic/Supersonic Flight Controls

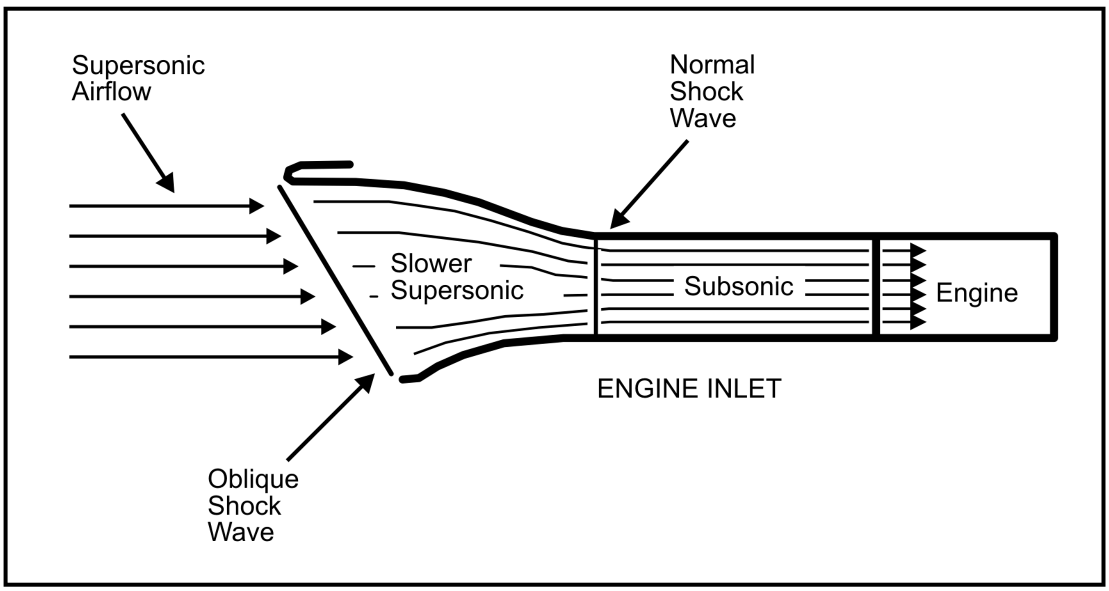

Figure 1-21 Supersonic Flow in an Engine Inlet

d. Fully powered, irreversible control systems

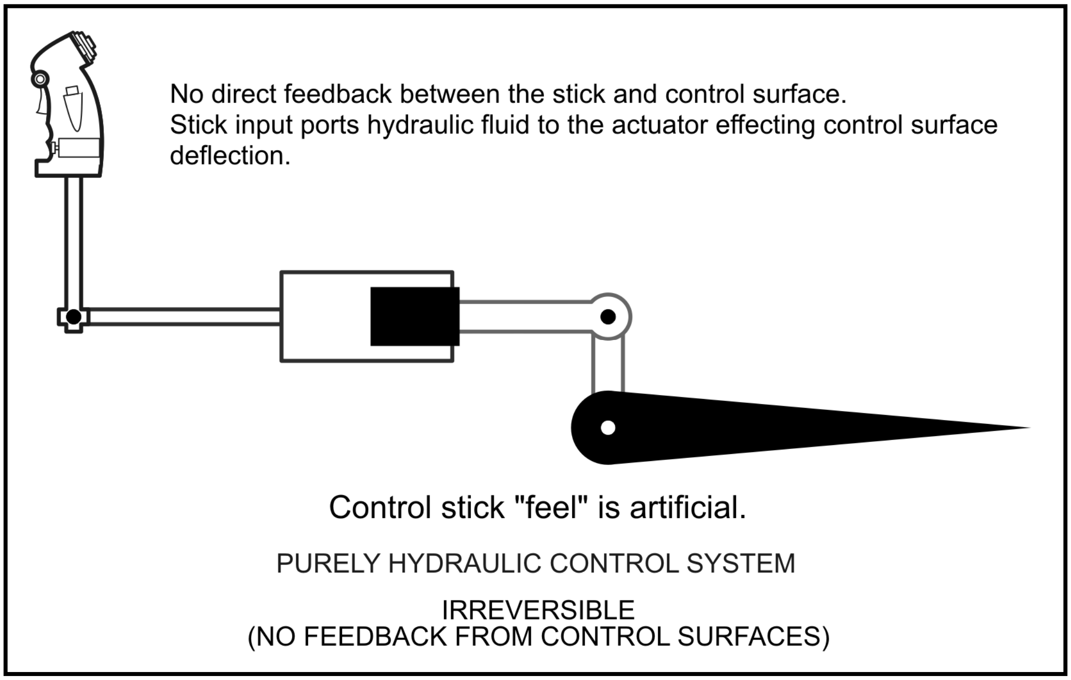

Figure 1-22 Fully Powered Control System

i. Overcome large control forces encountered at high speeds

ii. Prevent unwanted aerodynamic feedback often described as control “buzz”

e. Engine installation

- No present operational turbojet/fan engines can ingest supersonic flow

(a). All intake air must be decelerated to subsonic through a series of compression waves

(b). Exhaust gases must be accelerated above supersonic if aircraft is to achieve supersonic flight; generally achieved through the use of a convergent-divergent duct

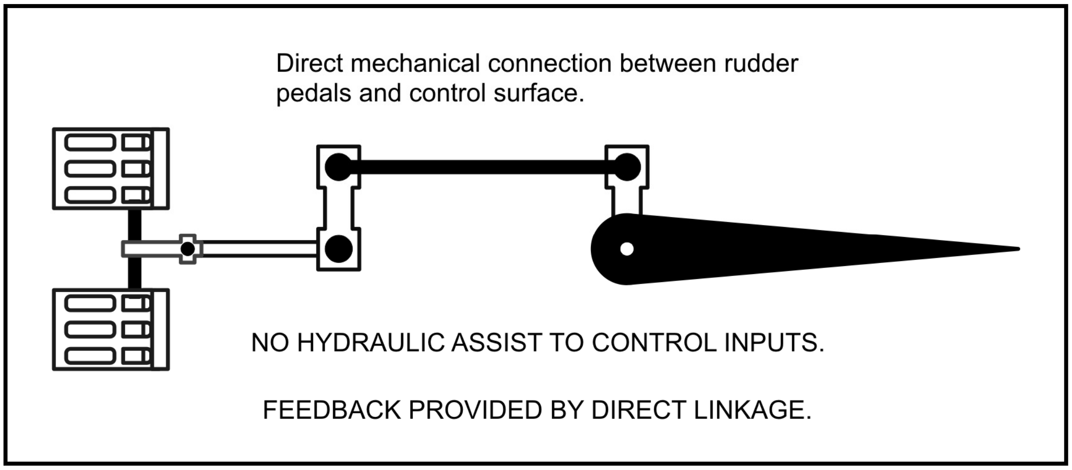

Figure 1-23 Conventional Control System

2. T-45 aircraft design

   a. Swept wings (low thickness-to-chord ratio/small radius leading edge)

   b. Stabilator

   c. Vortex generators (VGs)

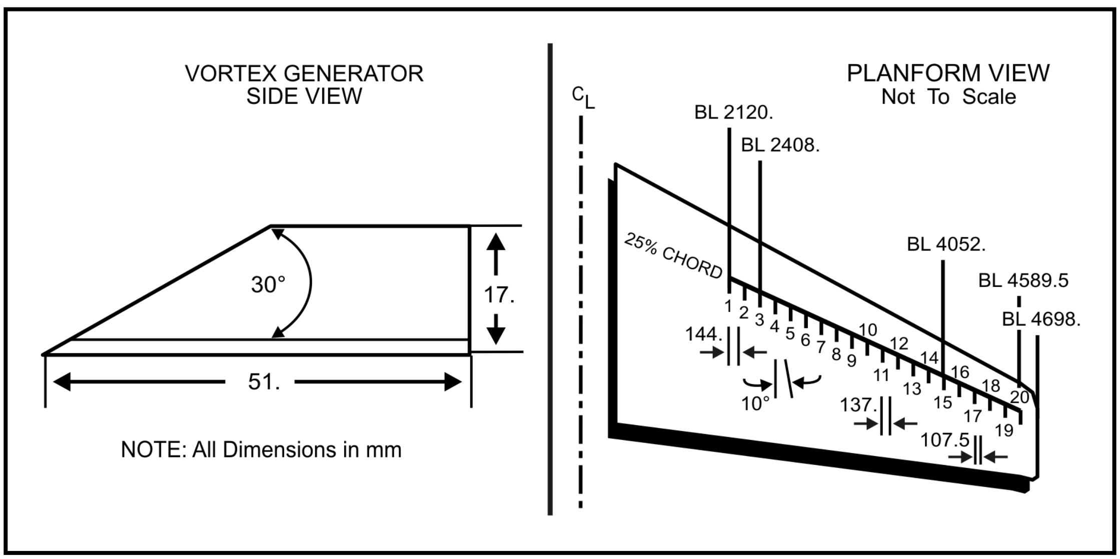

Figure 1-24 Vortex Generators on the T-45

i. Single row of 20 installed on each wing at 25% of wing chord

ii. Reduce boundary layer growth and delay forward migration of the shock and shock-induced separation

iii. Primary purpose to improve longitudinal stability at speeds above Mach 0.80 Rudder Shock Stabilization Strips

d. Rudder shock stabilization strips

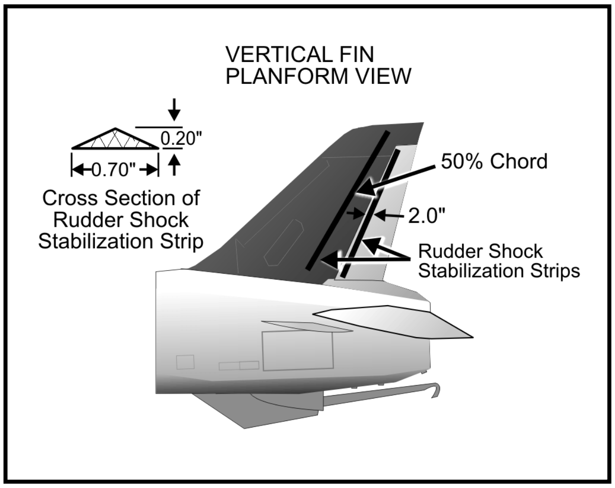

Figure 1-25 Rudder Shock Stabilization Strips

i. Two located on each side of vertical tail, one at 50% of tail chord and one just aft of rudder hinge line

ii. Installed after uncontrollable rudder oscillation (rudder buzz) occurred at high speed, Mach 0.9-0.95

(a). Rudder buzz results from unstable shock wave motion and shock-induced separation

(b). Strips stabilize the shock wave motion

iii. Developed after computational flowfield analysis and flight tests

3. T-45 high-speed flight characteristics (found in NATOPS)

a. Capable of transonic flight ONLY in a dive and in a clean configuration

b. Speeds up to Mach 1.04 have been achieved

i. No pronounced nose-down pitch transient during acceleration

ii. High-speed acceleration is moderate and Mach effect is gradual

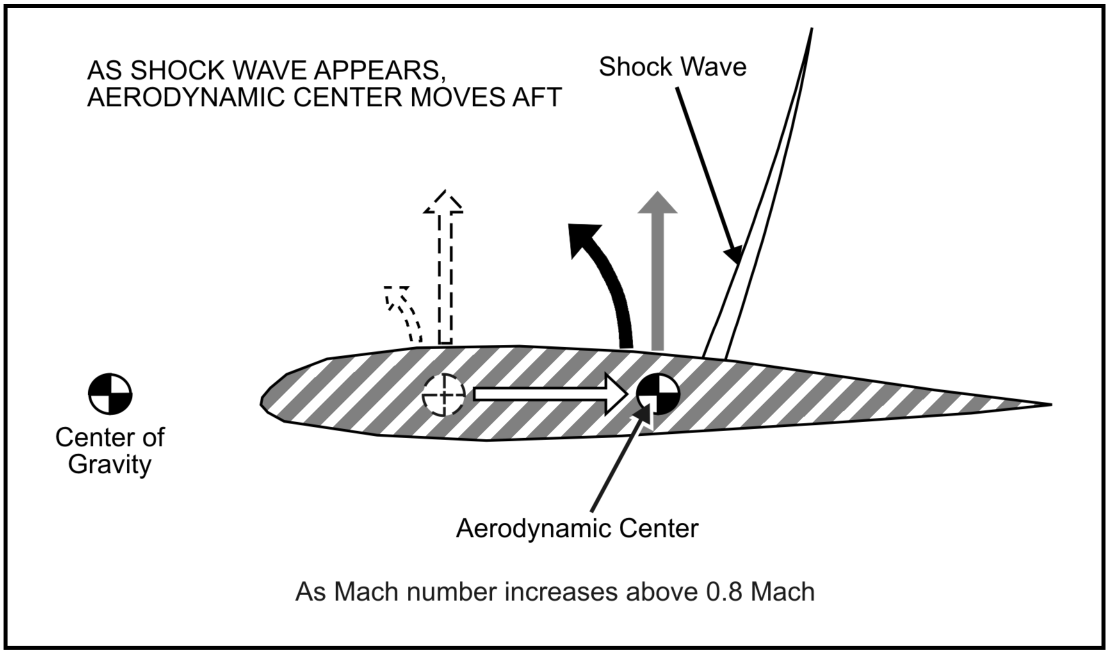

Figure 1-26 Aft Movement of the Center of Pressure

iii. Very stable above Mach 1.0

c. High-speed dives

i. Slight buffeting above Mach 0.9

ii. Some pitch oscillations as center of pressure shifts aft

iii. Recovery

(a). Pitch-up at about Mach 0.99 due to wing shock movement

(b). Second pitch-up occurs at Mach 0.85 (same as described in VG section)

(c). Should be initiated by pulling no more than 4 g's because of the second pitchup (this second pitchup could occur prior to Mach 0.85)

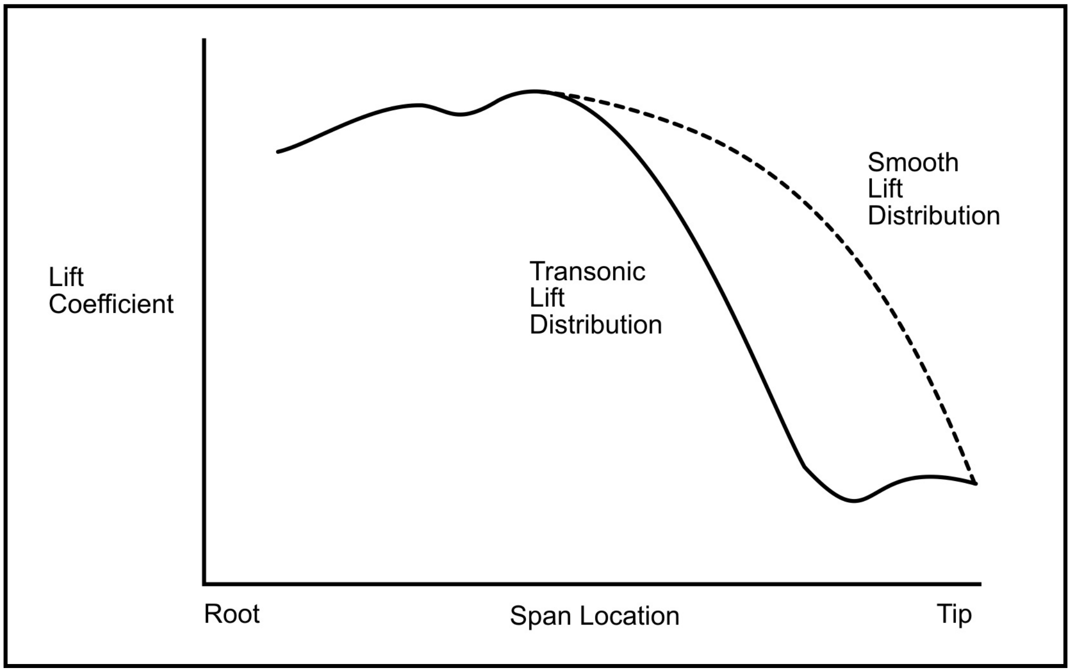

Figure 1-27 Transonic Lift Distribution

iv. “Heavy wing” experienced starting at about Mach 0.92

(a). May take up to 3/4 lateral stick to maintain wings level due to reduced aileron effectiveness from Mach 0.92 to Mach 0.95

(b). Heavy wing and reduced aileron effectiveness caused by shock-induced separation on the outer 40% of the wing

v. Wing heaviness disappears and aileron effectiveness returns above Mach 0.95

NOTE

Refer to NATOPS for applicable restrictions in regard to high-speed flight maneuvering.

105. SUMMARY

This lesson has focused on:

1. The effects of high-speed flight on aircraft

2. Methods used to overcome effects and permit high-speed flight

106. CONCLUSION

Changing the geometry of the airfoil to a low aspect ratio, low camber, swept back configuration provides not only more speed but also greater maneuverability. After you get your wings, you will experience other aircraft with different characteristics and designs. Understanding the aerodynamics associated with these different designs will help you adapt to the unique characteristics of these aircraft.

NOTES

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CHAPTER TWO
SLOW-SPEED FLIGHT, STALL AND SPIN, AND AOA SYSTEM

200. INTRODUCTION – N/A

COURSE/STAGE:

- TS, E2-C2, TAILHOOK AND IUT/AERODYNAMICS

LESSON TITLE:

- Slow-Speed Flight, Stall and Spin, and AOA System

LESSON IDENTIFIER:

- T-45A/C TS, E2-C2, TAILHOOK & IUT Aero-03

LEARNING ENVIRONMENT:

- Classroom

ALLOTTED LESSON TIME:

- 1.5 hr

TRAINING AIDS:

1. T-45 Scale Model

2. Figures

    - Figure 1: Leading Edge Vortexing
    - Figure 2: Tip Stall
    - Figure 3: Effect of Geometric Twist, Flaps, and Slats
    - Figure 4: Slats
    - Figure 5: Stall Strips
    - Figure 6: T-45 Stall Characteristics
    - Figure 7: Stall Progression Diagram
    - Figure 8: Cross-Control Departure
    - Figure 9: Nose High Departure

- Figure 10: Spin Characteristics
- Figure 11: Upright Spin Indications
- Figure 12: Inverted Spins (Steady State Indications)
- Figure 13: AOA System Theory
- Figure 14: T-45 Navigation Approach HUD Display

STUDY RESOURCES:

1. Flight Training Instruction, Out of Control Flight Procedures, Intermediate & Advanced Strike

2. T-45A NATOPS Flight Manual, A1-T45AB-NFM-000

3. T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

LESSON PREPARATION:

- Read:

  a. Aero-03 Lesson Guide

  b. Part IV, sections 11.6, "High Angle of Attack Characteristics," T-45A NATOPS Flight Manual, A1-T45AB-NFM-000 or T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

REINFORCEMENT:

- N/A

EXAMINATION:

- The objectives in this lesson will be tested in Aerodynamics 07X for TS, E2-C2 and Advanced.

201. LESSON OBJECTIVES

1. Identify high AOA characteristics of a swept wing

2. State factors which affect T-45 high AOA characteristics

3. Identify T-45 stall characteristics

4. Recognize causes and indications of out-of-control flight

5. State recovery techniques for out-of-control flight

6. State principles and indications of the AOA system

202. MOTIVATION

The margin for error in a high performance aircraft flying straight and level at 500 KIAS and 25,000 ft is much larger than the margin for error as you approach the carrier all dirtied up at 120 KIAS with 500 ft of altitude. Most pilot-induced accidents occur during takeoff, approach, and landing; so it is critical that you understand the aerodynamics of slow-speed flight maneuvering.

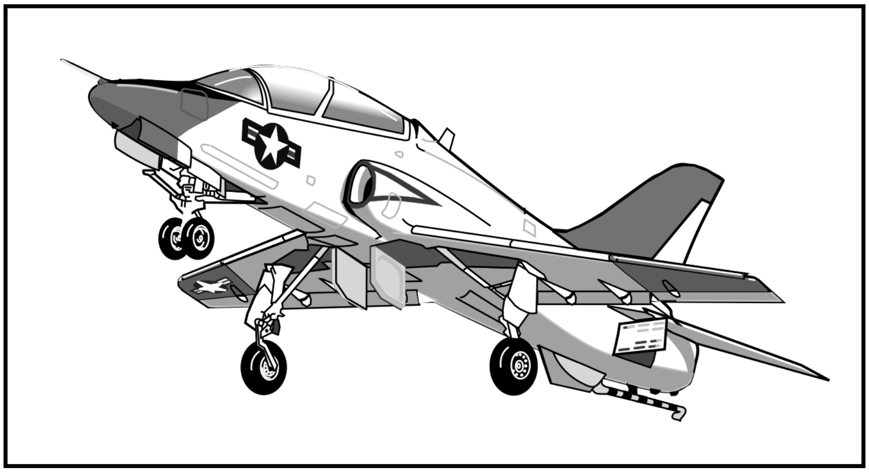


Figure 2-1 Slow Flight

203. OVERVIEW

This lesson is designed to prepare you for slow-speed flight in a high performance aircraft.

In this lesson we will be studying:

1. Slow-speed flight

2. Stalls and spins

3. Angle-of-attack (AOA) system

204. REFRESHER

Recall that:

- Changing the wing's geometry to a lower camber, a lower thickness-to-chord ratio, and a lower aspect ratio and adding sweepback will lower the total drag of the wing, but the wing will require a higher AOA to produce the same amount of lift as a wing of higher aspect ratio. At high speeds, we benefit from these changes with better performance and maneuverability; however, the high AOA and slow-speed flight characteristics will be degraded.

205. PRESENTATION

Slow-speed flight

1. Planform of T-45 aircraft

    a. Two-place, lightweight aircraft with tapered (in both chord and airfoil section), swept wing

    b. Advantages:

        i. Increase in aspect ratio compared to a rectangular, swept wing design, resulting in reduction of induced drag

        ii. Lift load decreases toward the tips, reducing need for structure

        iii. Structural efficiency is increased while maintaining a constant thickness ratio

    c. Disadvantages:

        i. Tip stall tendencies

        ii. Loss of ailerons at stall

        iii. Negative longitudinal stability at high angles of attack

2. Wing design

    - Swept wings normally exhibit tip stall tendencies because of the lower energy level of the boundary level at the tip

        i. Lower energy level due to shorter tip chord compared to root chord

ii. Flow separation at tip aggravated by spanwise flow due to wing sweep; further aggravated by leading-edge vortexing

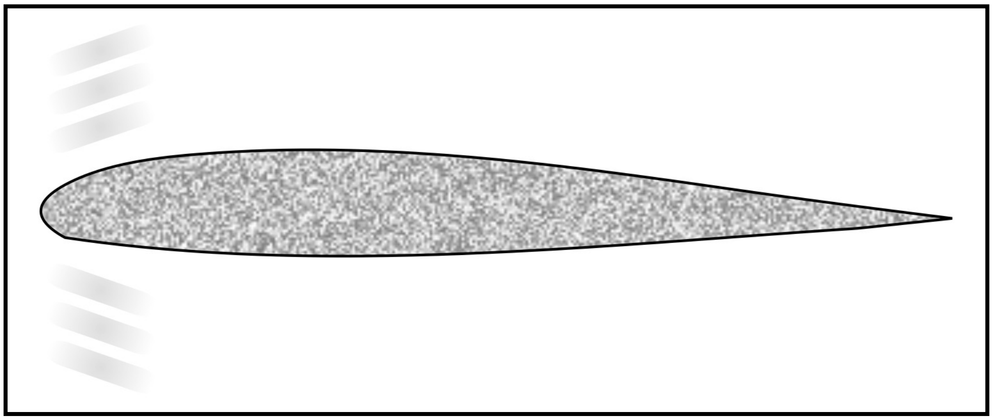


Figure 2-2 Flow Separation

(a). On a leading edge of large radius, the flow is smooth

(b). On an airfoil with a small radius leading edge (T-45), the air flow tends to “jump” around the leading edge due to the discontinuity

(1). An area of low pressure forms on the leading upper surface of the small radius leading edge

(2). High pressure air from under the wing comes around the leading edge creating a leading edge vortex

(3). Joins with spanwise flow to give tip stall

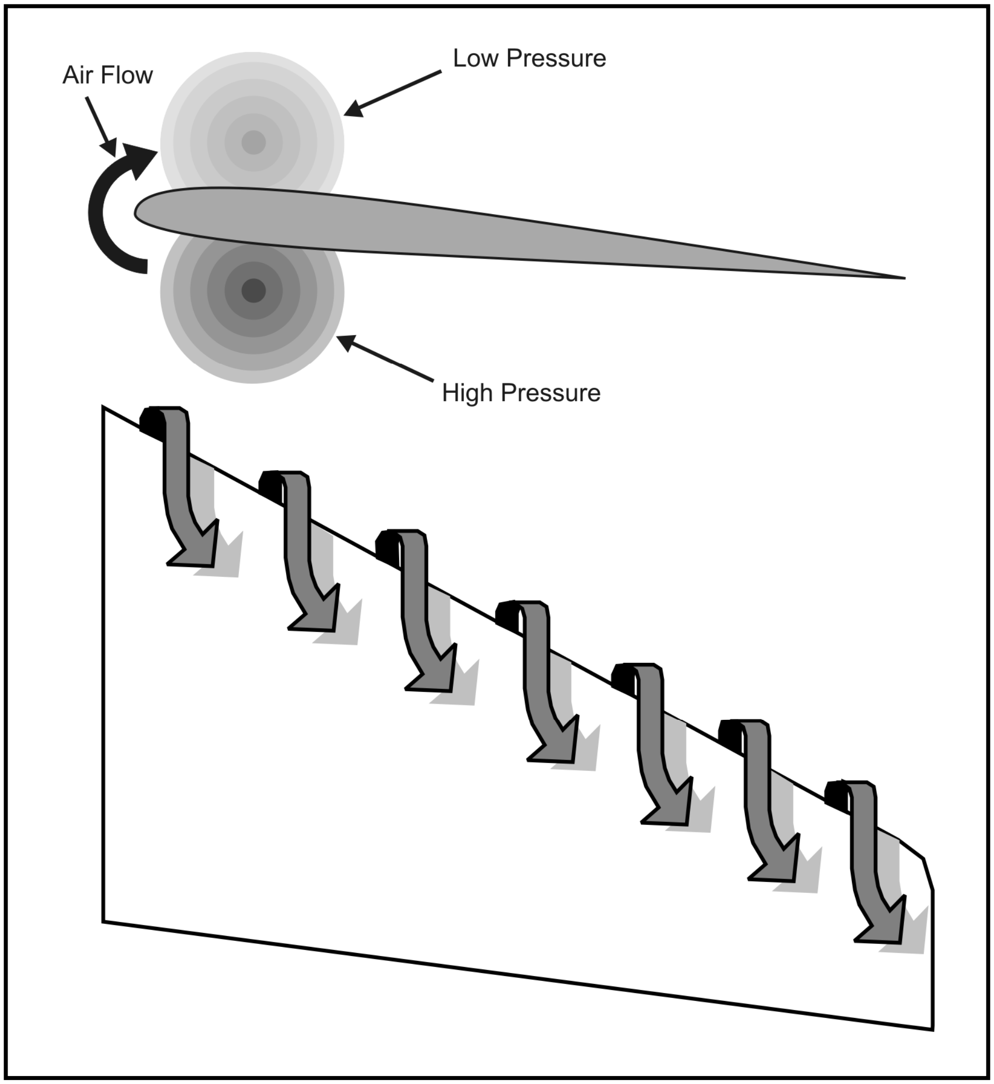


Figure 2-3 Leading Edge Vortexing

iii. As tip stalls

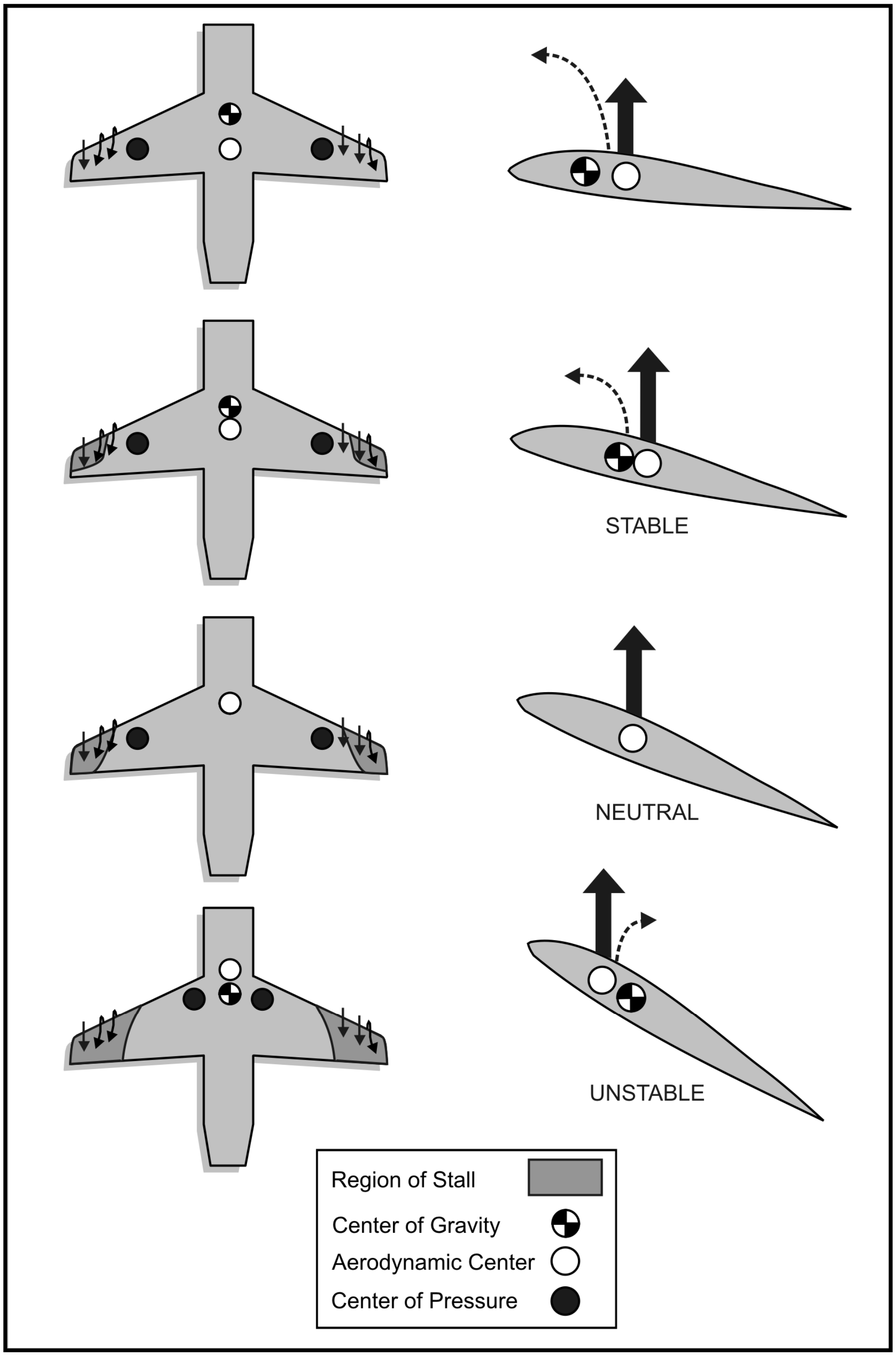


Figure 2-4 Tip Stall

(a). Ailerons become ineffective

(b). A loss of lateral stability occurs as center of pressure of each wing moves inboard

(c). No stall warning occurs

iv. As centers of pressure move inboard on each wing, they also move forward, shifting the aerodynamic center of the aircraft forward

- If aerodynamic center shifts forward of center of gravity, aircraft will have negative longitudinal stability, and nose will pitch up

3. High-lift devices in T-45 provide excellent slow flight characteristics

a. Geometric twist (3-1/2 degrees)

i. Reduces angle of attack of tip compared to root

ii. Accomplished by reducing angle of incidence used at tip compared to root

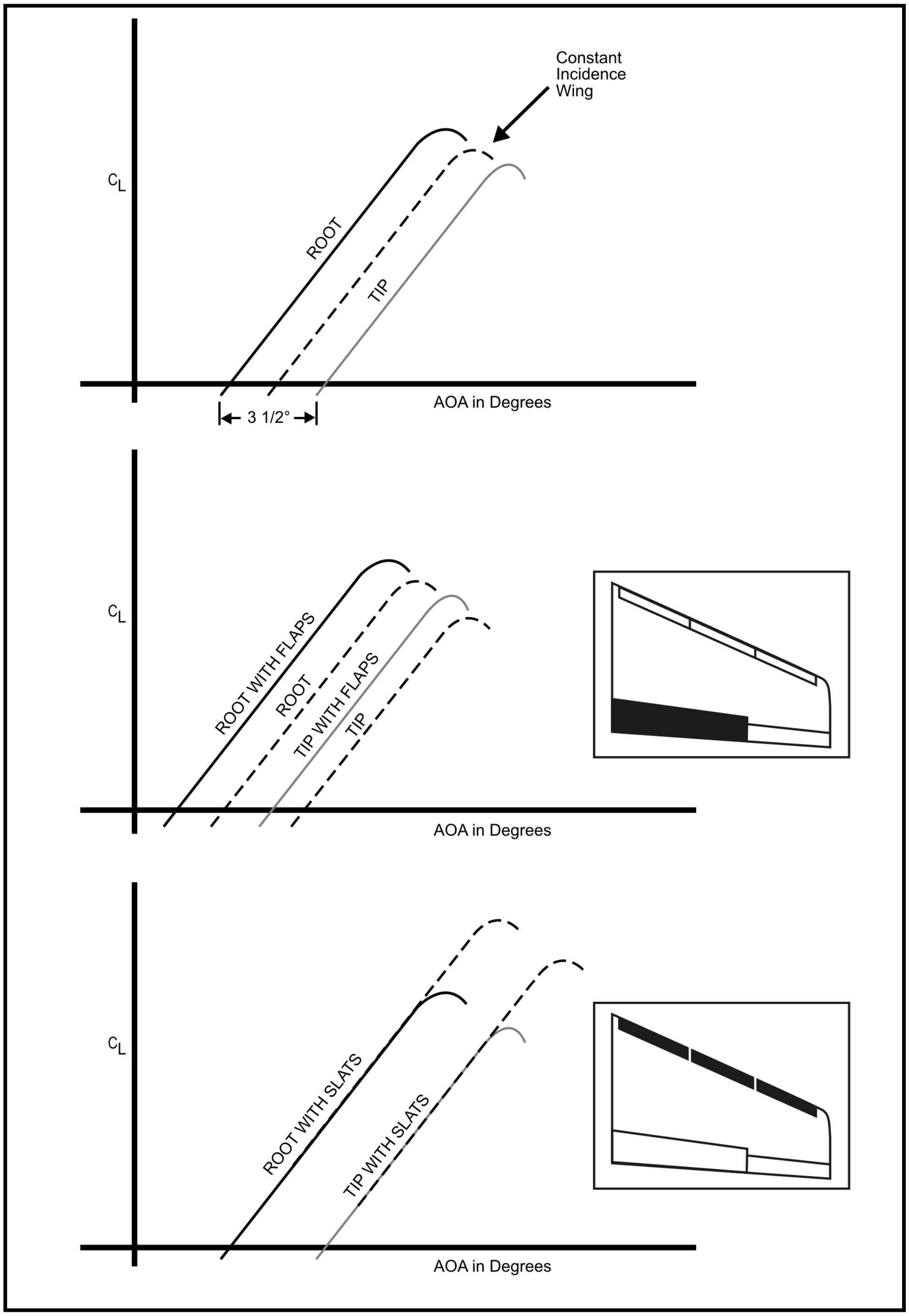


Figure 2-5 Effect of Geometric Twist, Flaps, and Slats

b. Slotted flaps

i. Increase maximum lift coefficient attainable, but at lower AOA

ii. Extension affects inboard portion of wing more than outboard portion, causing root to operate at higher AOA (in degrees) than tip

c. Leading edge slats

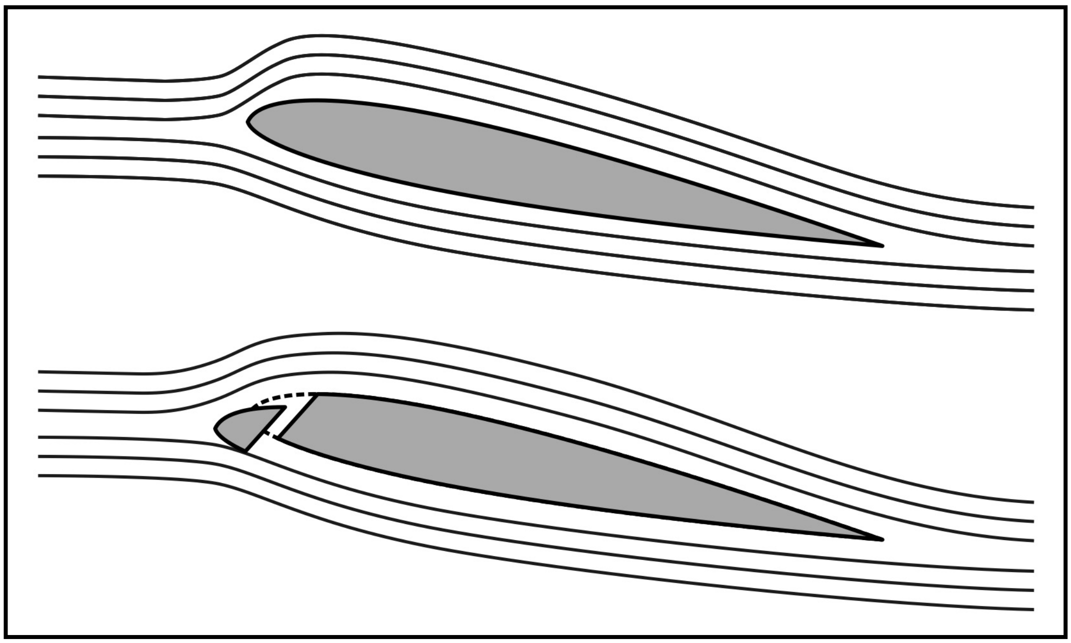


Figure 2-6 Slats

i. Reduce leading edge vortexing by increasing leading edge radius

ii. Increase lift coefficient over the wing at very high AOA

NOTE

In conjunction with a slat, an automatic slot is opened which allows the high pressure, high energy air from below the wing to flow into the low pressure area above the wing. This airflow is directed along the upper surface in such a manner that it increases the energy and delays boundary layer separation. See the NATOPS flight manual for further discussion of slat operation and malfunctions.

d. Row of vortex generators on leading edge of each wing

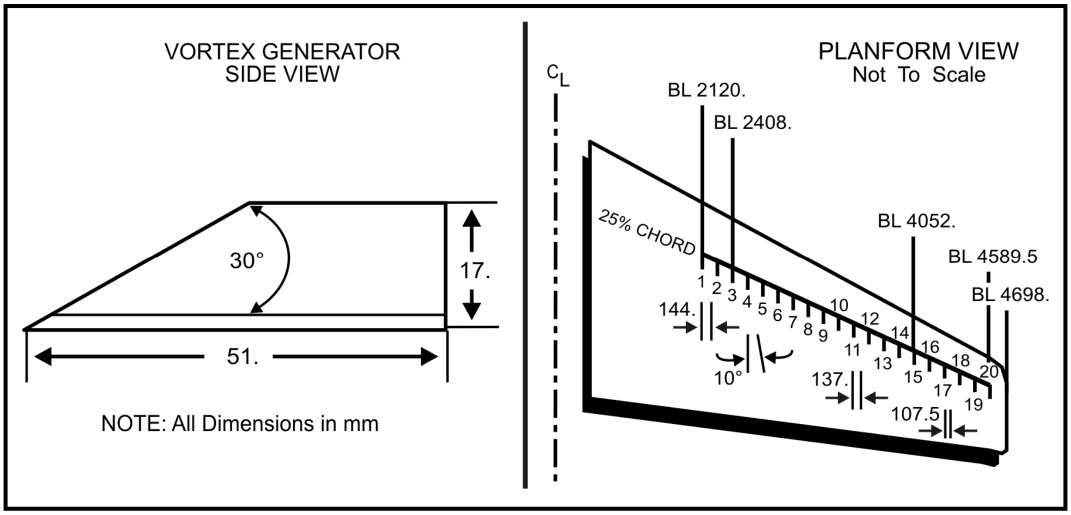


Figure 2-7 Vortex Generators

i. Small, low aspect ratio airfoils set perpendicular to wing surface with a large AOA

ii. Vortices cause high energy free-stream air to be mixed with low velocity boundary layer air, reenergizing the boundary layer and delaying separation

iii. Reduce boundary layer growth by reenergizing boundary layer

NOTE

The vortex generators were installed on the T-45 to help airflow characteristics during high-speed (high Mach) flight. However, they also improve slow-speed airflow characteristics.

e. Stall strips

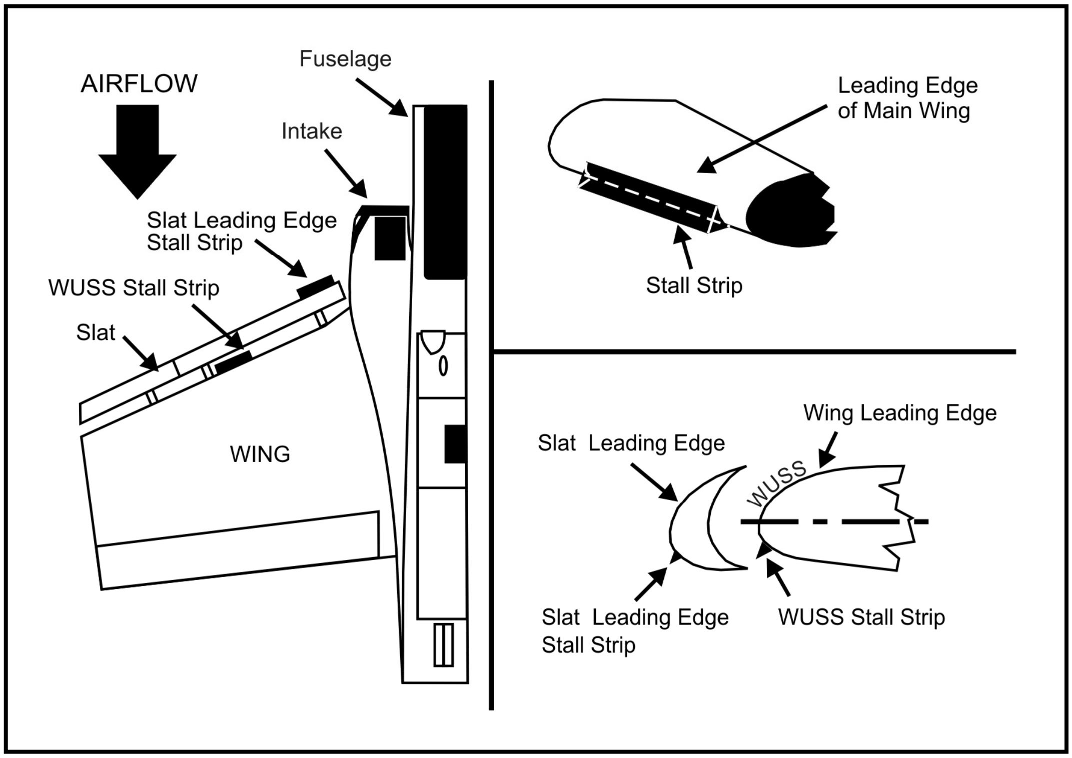


Figure 2-8 Stall Strips

i. Located on inboard slat and wing leading edges to improve stall characteristics of the aircraft

ii. Cause a premature flow separation at the wing root, contributing to a root stall.

iii. Slow the outward progression of stall

iv. Contribute to more consistent root stall at all flap/slat settings

v. Improve handling qualities at stall by controlling roll-off

vi. Do not reduce maximum lift coefficient

f. Stabilator vanes

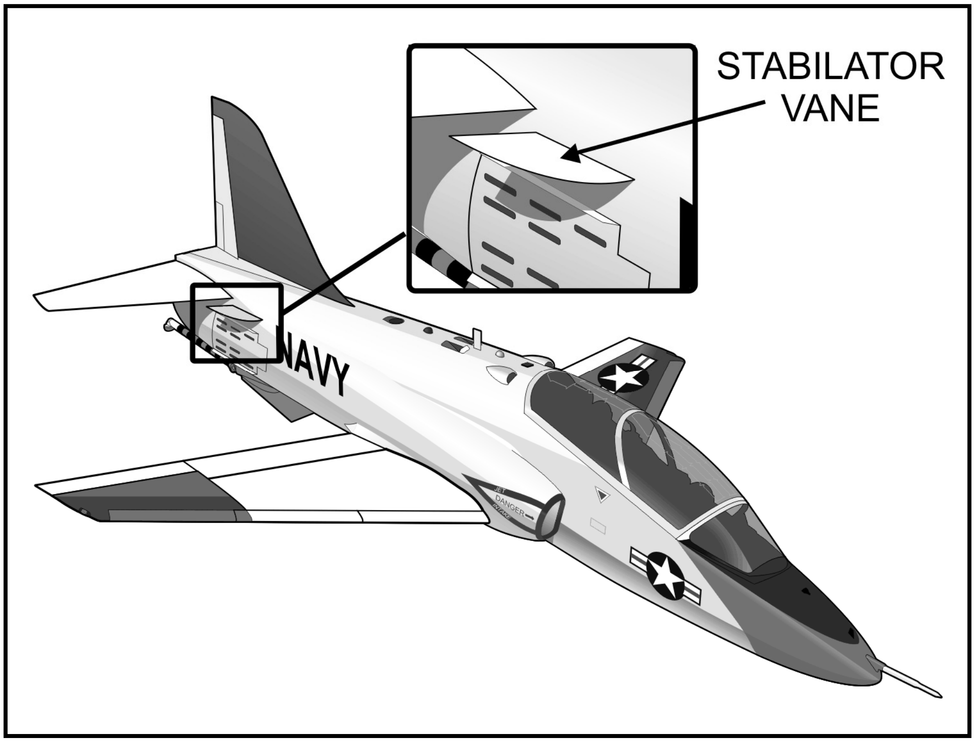


Figure 2-9 Stabilator Vanes

i. Located on both sides of fuselage, just forward of stabilator and above speed brakes

ii. Generate a vortex which passes below the stabilator

iii. Vortex energizes flow over stabilator lower surface, keeping it effective, particularly at maximum leading-edge-down stabilator deflection

NOTE

The overall effect of high-lift devices is to cause the root to stall at a lower AOA than the tip, thus giving the T-45 root stall characteristics.

Stall and Spin

1. Stall defined: when an increase in AOA produces a reduction in C_L

2. T-45 stall characteristics

	ARTIFICIAL STALL WARNING	STALL BUFFET	STALL
CLEAN	21.5 Units / 10	25 Units / 1-2	26 Units / 0
APPROACH	21.5 Units / 10	28 Units / 1	29-30 Units / 0

Note: All speeds are KIAS above stall speed.

Figure 2-10 T-45 Stall Characteristics

a. Predictable, consistent

   i. Nose-high 20-degree pitch

   ii. Artificial stall warning

   iii. Airframe buffet

   iv. Wing drops 25-30 degrees AOB

   v. Nose falls through

b. Recovery neutral controls

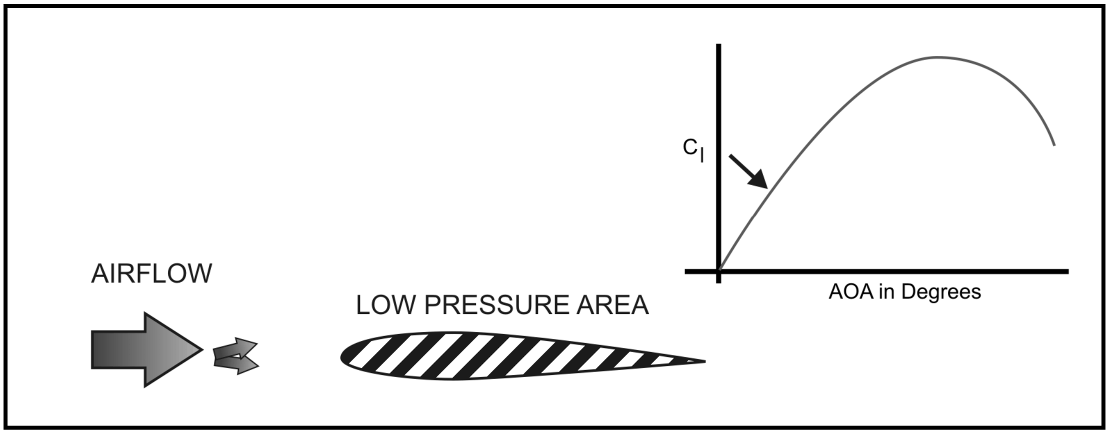


Figure 2-11 Aerodynamics of a Stall

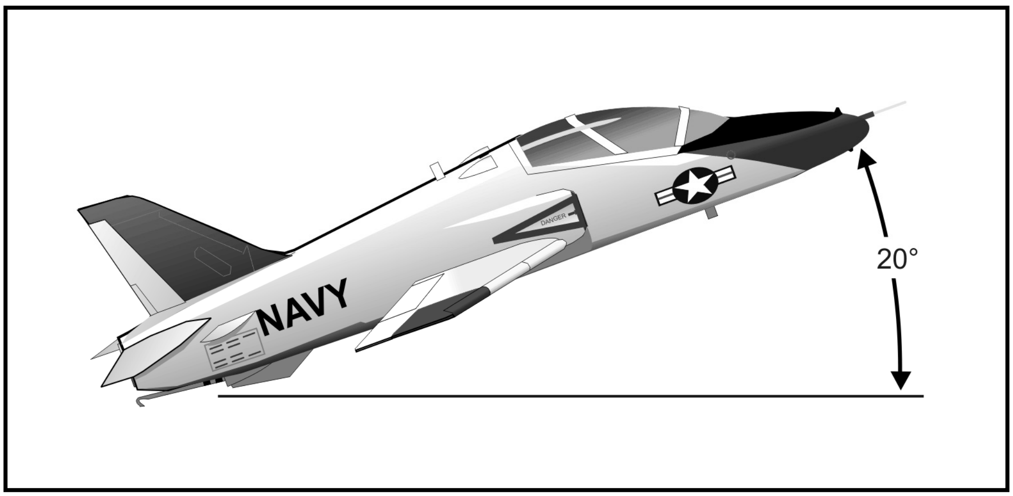


Figure 2-12 T-45 Stall

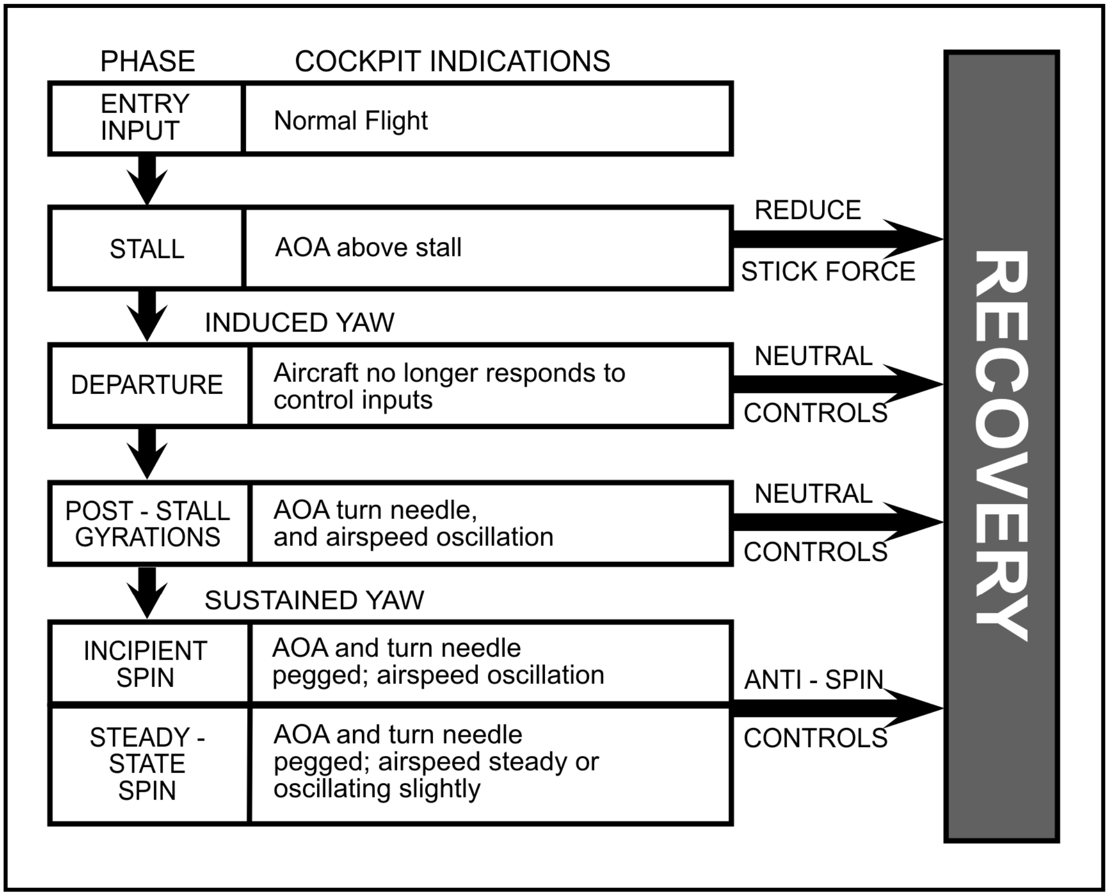


Figure 2-13 Stall Progression Diagram

3. Departures

a. Definition--One wing is producing much more lift than the other, causing abrupt pitch, roll, and yaw

i. Aggravated by control inputs

ii. Typically followed by post-stall gyrations

b. Types

NOTE

Asterisked (*) maneuvers are not authorized in the T-45 syllabus.

i. Adverse yaw departure*

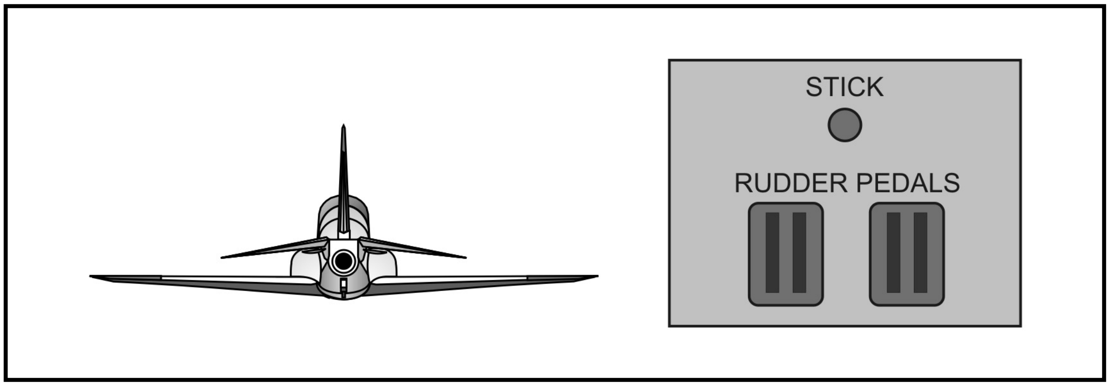


Figure 2-14 Adverse Yaw Departure

(a). Entry example:

(1). Simultaneously displace the aileron to roll the aircraft left while increasing back stick pressure to maximum available

(2). Once the plane has achieved approximately 60 degrees left AOB and full AFT elevator, abruptly position the flight controls to full right aileron while maintaining aft elevator

(b). Result:

(1). The aircraft will initially roll right, and then the upgoing (left) wing will achieve such a high AOA that it will stall

(2). A snap roll to the left is initially the result, followed by random post-stall gyrations and then, finally, an extremely nose-low dive recovery

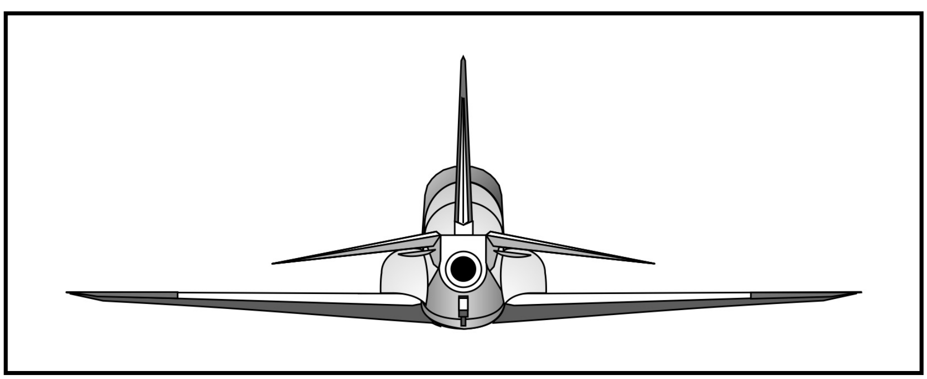


Figure 2-15 Adverse Yaw Departure

ii. Cross-controlled departure*

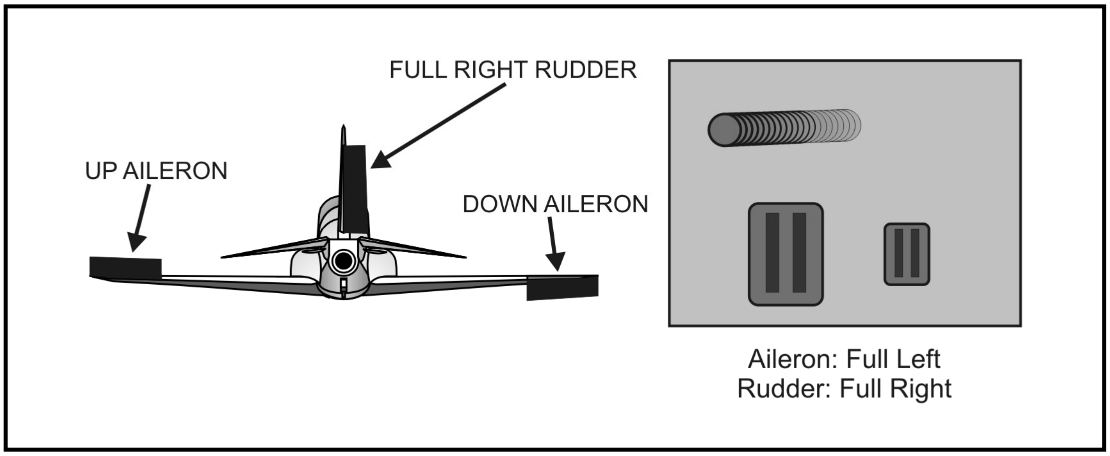


Figure 2-16 Cross-controlled Departure

(a). Entry example:

(1). Simultaneously displace the aileron to the full left position while pushing the rudder to the full right position

(2). Reduce power until AOA rises and stall occurs

(b). Result:

(1). The aircraft will maintain its left-wing-down (LWD) attitude while the AOA increases and, finally, stall occurs over the right (trailing) wing

(2). When the aircraft departs, it will snap roll to the right (in the direction of the rudder), followed by random post-stall gyrations and then, finally, an extremely nose-low dive recovery

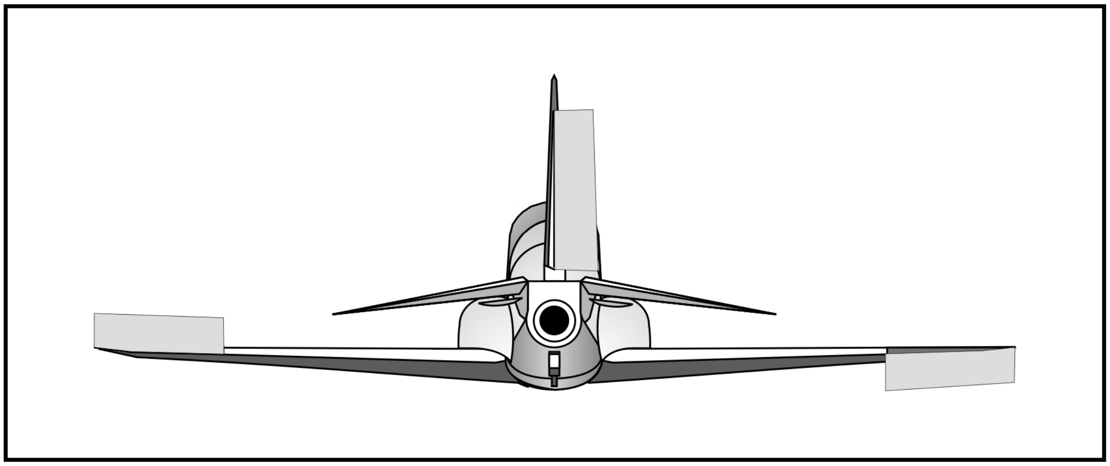


Figure 2-17 Cross-controlled Departure

iii. Nose-high, 60-70 degree departure (low airspeed recovery)

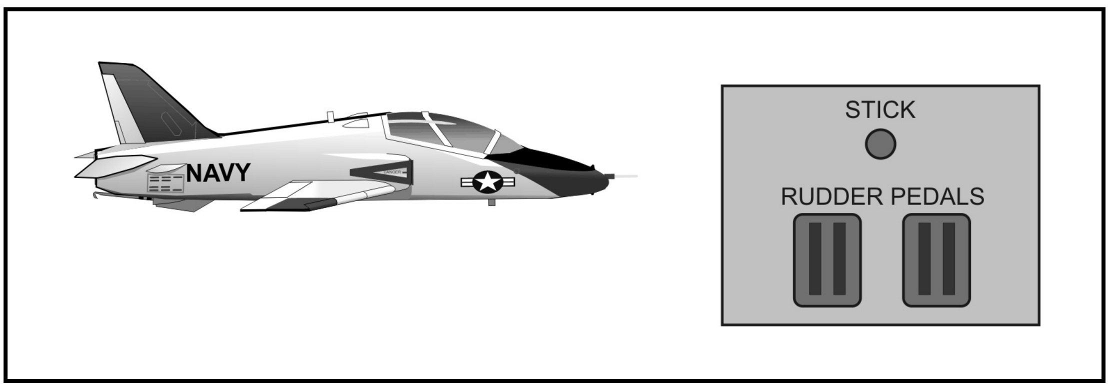


Figure 2-18 60-70 Degree Departure

(a). Entry example:

- From medium airspeed, smoothly raise the nose to a wings-level, 60-70 degree attitude

(b). Result:

(1). At approximately 100 KIAS, the nose will smoothly drop below the horizon despite full aft elevator input

(2). Neutral flight controls should be set at this time; the nose will continue to fall forward, through the horizon, to the vertical

(3). No unusual roll or yaw deviations should be expected; airspeed will steadily increase until the controls become effective again

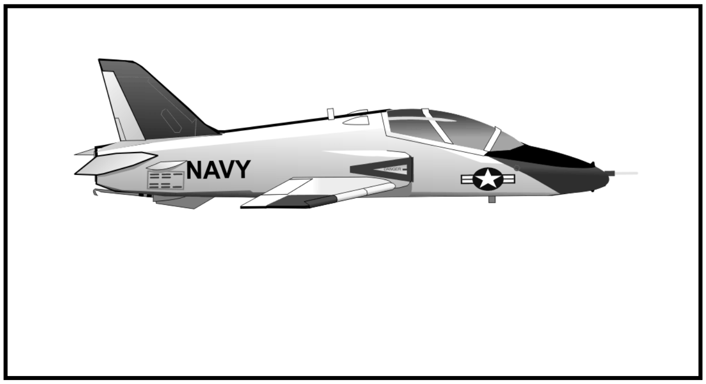


Figure 2-19 60-70 Degree Departure

iv. Pitchdown departure*

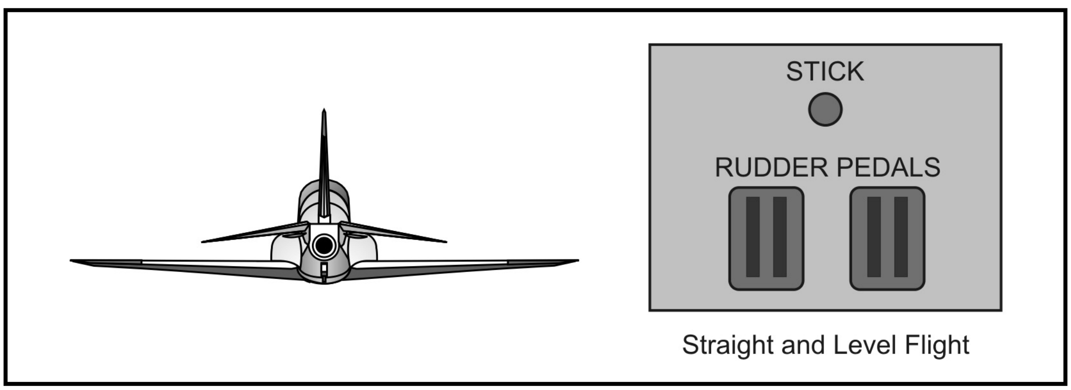


Figure 2-20 Pitchdown Departure

(a). Entry example:

(1). From medium airspeed, smoothly raise the nose to a wings-level, 30-40 degree, noseup attitude

(2). Simultaneously displace the aileron to the full left position while pushing the rudder to the full right position

(3). Reduce power until AOA rises and stall occurs, then force the elevator to a full nosedown position (b). Result:

(1). A violent nosedown, rolling departure occurs to the left (in the direction of the aileron) with no significant warning to the pilot

(2). Negative g and roll rates in excess of 500 degrees per second are likely

(3). Rudder blowout is common due to high aerodynamic loading

(4). If any yaw rate is sustained after the initial departure, an inverted spin is likely to develop

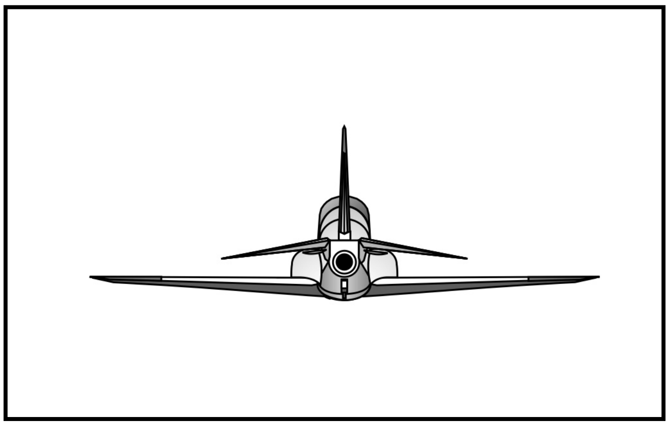


Figure 2-21 Pitchdown Departure

v. Nose-high, 80-90/90-100 degree departure*

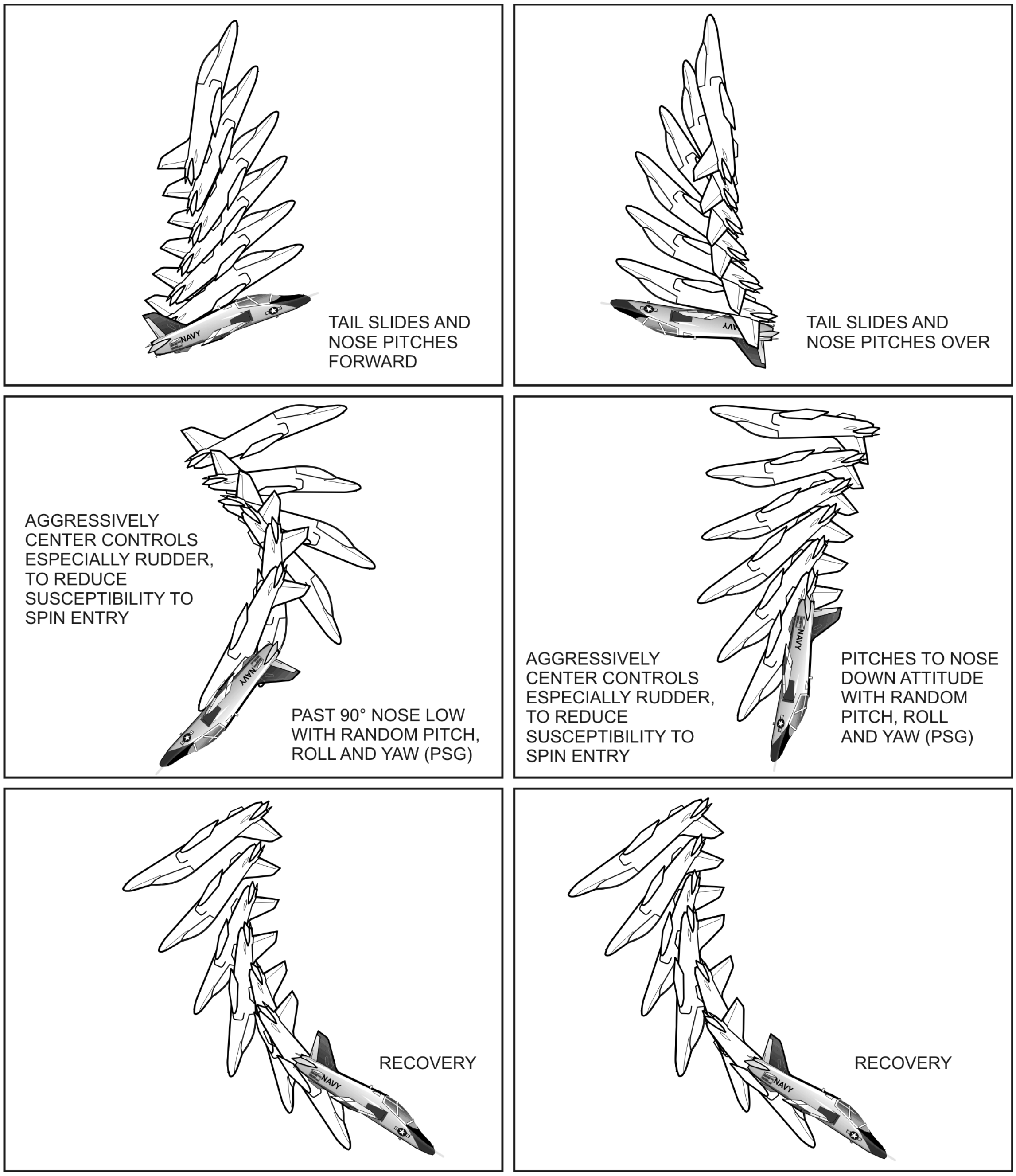


Figure 2-22 Nose High Departures

(a). Entry example:

(1). From medium airspeed, smoothly raise the nose to a wings-level, 80-100 degree, noseup attitude

(2). Allow the aircraft to slow to zero airspeed

(b). Result:

(1). After achieving zero airspeed, the aircraft will begin a tailslide until control surfaces become effective again at approximately 60-100 KIAS (negative airspeed)

(2). At this point, the aircraft will swap ends abruptly and may overshoot the vertical by as much as 90 degrees in the pitch axis.

i) From the 80-90 degree departure, the aircraft pitches forward

ii) From the 90-100 degree departure, the aircraft will “topple” backward (Figure 2-22)

iii) Ten percent of the nose-high departures flight-tested resulted in pitchdown departures. A substantial number of tailslides will produce inverted spins due to inadvertent displacement of flight controls from the neutral position

(3). The engine may have its airflow interrupted causing a compressor stall

NOTE

Nearly all of the flight-tested aircraft developed some type of engine stall under these conditions.

(4). After one or two nose-low oscillations, the airspeed will increase to a nose-low dive recovery

(5). Adverse roll and yaw oscillations are to be expected if the pilot fails to maintain neutral controls throughout the departure

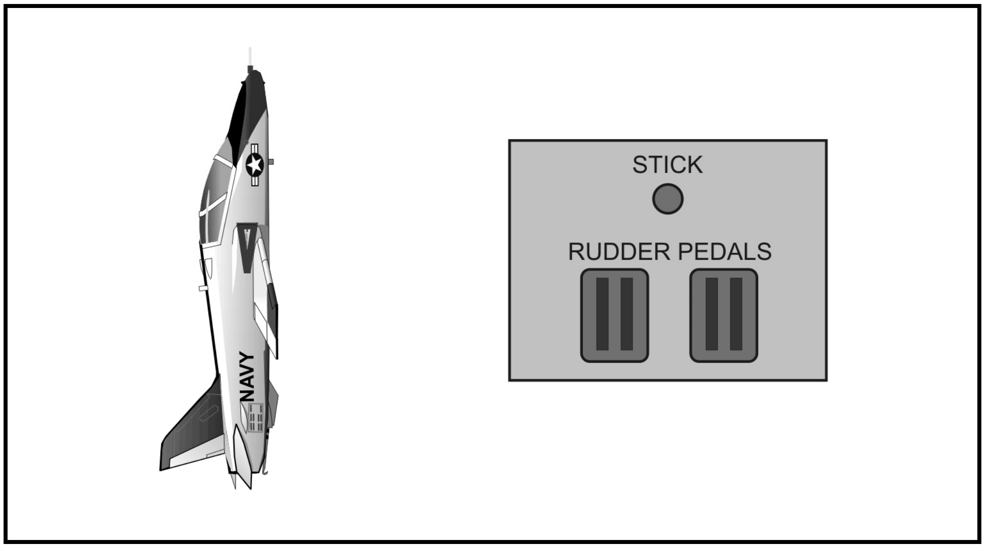


Figure 2-23 80-100 Degree Departure

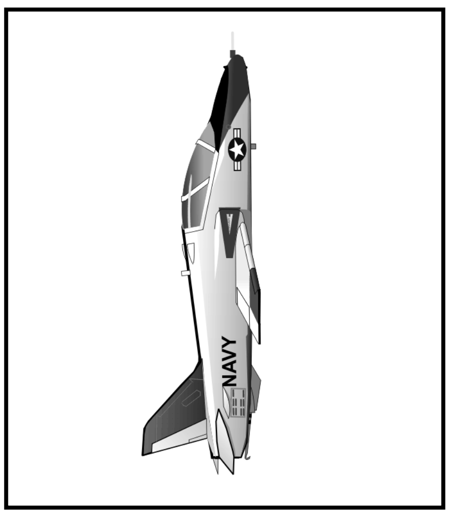


Figure 2-24 80-100 Degree Departure

4. Post-stall gyration

    a. Defined--Random pitch, roll, and yaw

    b. Problems

        i. Control input, especially lateral aggravate

ii. Sideslip

(a). Can cause rudder blowout

(b). Need in excess of 300 pounds force to neutralize

(c). Excessive sideslip can cause yaw and roll, resulting in inverted spin

iii. To recover, neutralize (squadron will teach specific procedures)

5. Spins—general

a. Defined

i. Aggravate stall condition with autorotation, describing helical path

ii. Aircraft is in a steady-state, self-sustained mode which is a combination of roll and yaw

(a). If nose down, pure roll

(b). If flat, pure yaw

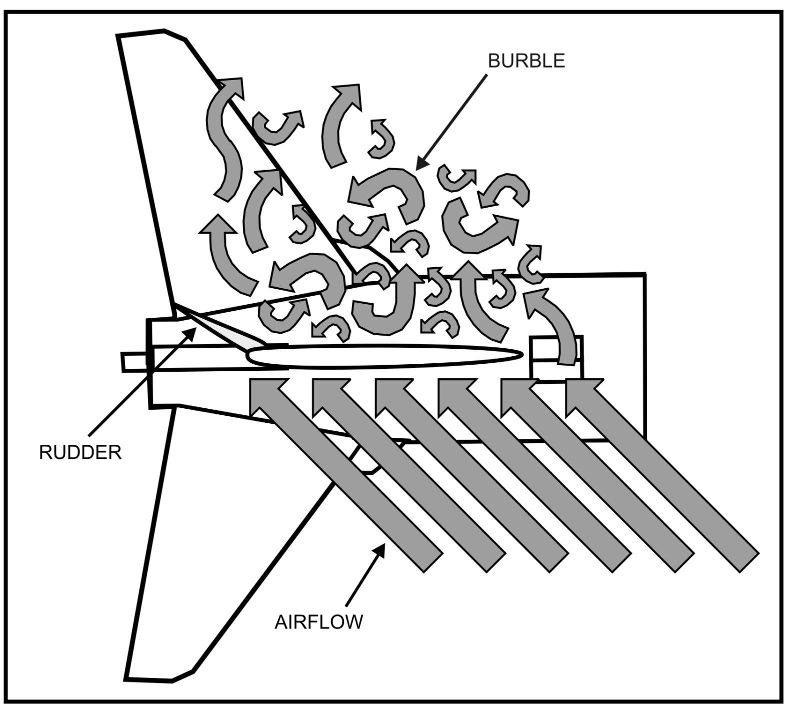


Figure 2-25 Rudder Blowout

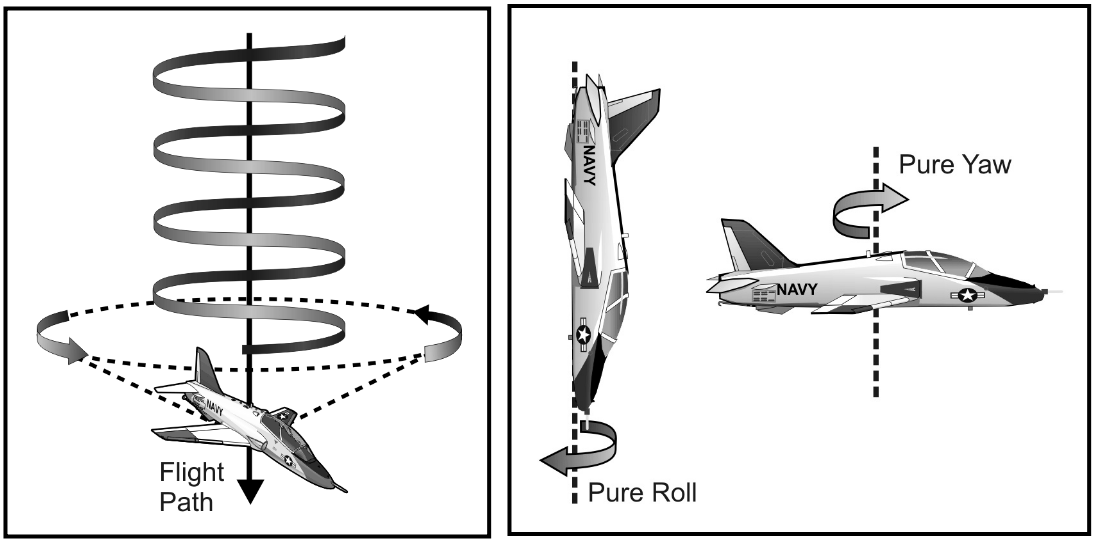


Figure 2-26 Spin Characteristics

b. Upright spin*

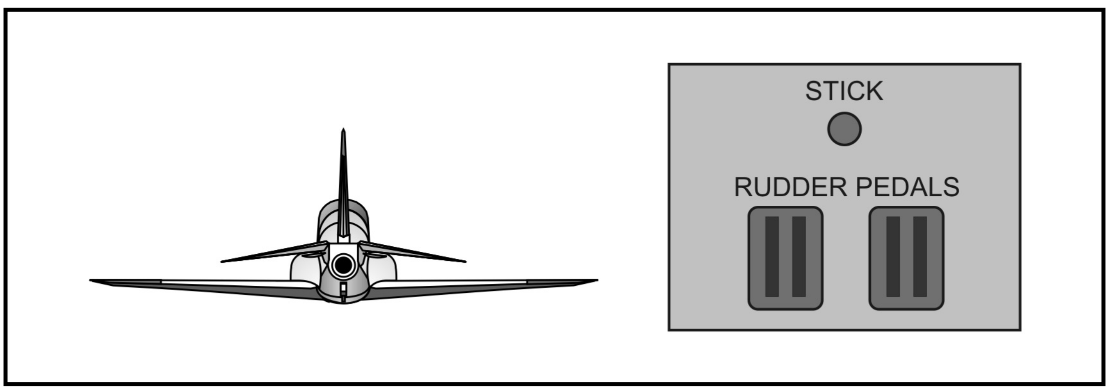


Figure 2-27 Upright Spins

i. Entry example:

(a). Smoothly raise the nose to a wings-level, noseup attitude

(b). Reduce power to IDLE and, as the aircraft slows, program in full left rudder and full aft stick

(c). Hold the control inputs through the post-stall gyration phase until the aircraft has developed a significant yaw rate

ii. Result:

(a). Classically, an aircraft will initially enter some short post-stall gyrations, to be immediately followed by a nearly wings-level, slightly nosedown, steady-state rotation about the center of gravity

(b). To date, the T-45 has demonstrated no tendency to spin in an upright mode with symmetrical loading

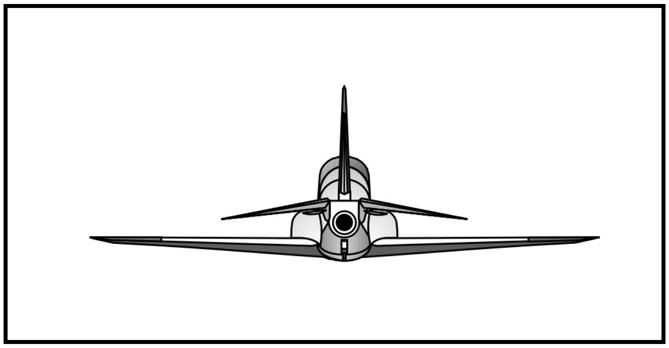


Figure 2-28 Upright Spin

iii. Modes

(a). 30-degree true AOA

AOA above 28 units; airspeed about 180 kts; 1,200 ft per turn (10 turns per minute); transitions either to 45-degree true AOA mode or inverted spin mode

(b). 45-degree true AOA

AOA at 30 units; airspeed 100-110 kts; 1,000 ft per turn (15 turns per minute)

iv. Steady-state indications

(a). Positive g

(b). Pegged turn needle (in direction of spin)

(c). 30 units AOA

c. Inverted spin*

i. Entry example:

(a). See “Nose-high, 80-90/90-100 degree” or “Pitchdown departure” entries

(b). At first indication of stall, hold the elevator in a position somewhere forward of neutral

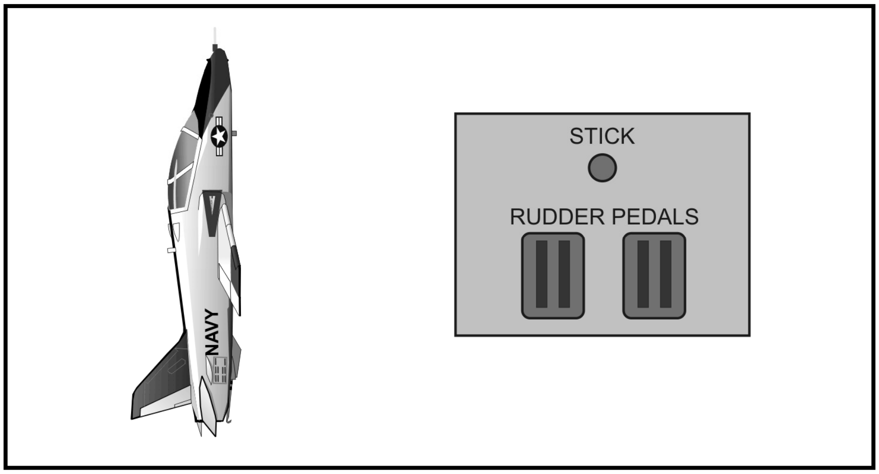


Figure 2-29 Inverted Spin

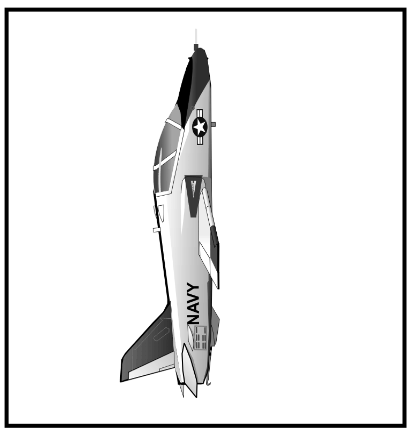


Figure 2-30 Inverted Spin

ii. Result:

(a). The T-45 has demonstrated some tendency to enter inverted spins after post-stall gyrations where FWD stick and yaw are introduced

(b). The aircraft will rotate about the center of gravity from an inverted, slightly nose-low and wings-level attitude

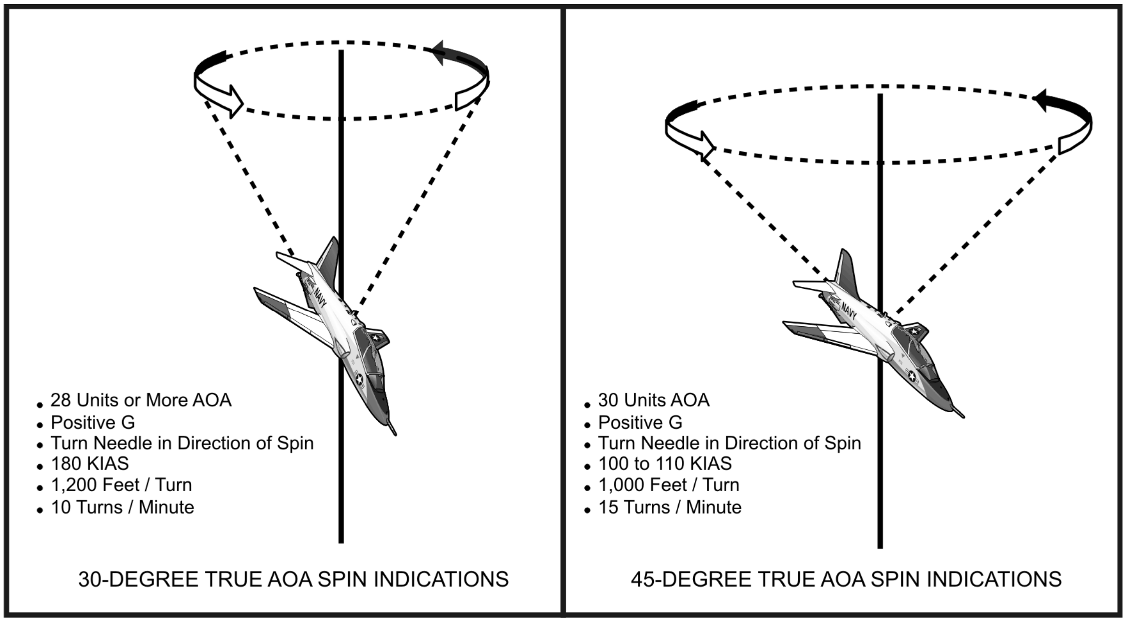


Figure 2-31 Upright Spin Indications

iii. Modes

(a). Low speed

(1). -60-degree true AOA

Nose 30 to 50 degrees below horizon; may see horizon; 3-4 seconds per turn or 15-20 turns per minute; altitude loss of 1,000 ft per turn or 15-20,000 fpm, airspeed of 50-120 KIAS (Figure 2-32)

(2). -40-degree true AOA

Nose 30 to 50 degrees below horizon; probably will not see horizon; 3-4 seconds per turn or 15-20 turns per minute; altitude loss of 1,000 ft per turn or 15-20,000 fpm airspeed of 100-160 KIAS (Figure 2-32)

(b). High speed

(1). -25-degree true AOA

Nose 65 degrees below horizon; will not see horizon; 6 seconds per turn or 10 turns per minute; altitude loss of 1,100 ft per turn or 11,000 fpm airspeed of 140-200 KIAS (Figure 2-32)

iv. Steady-state indications

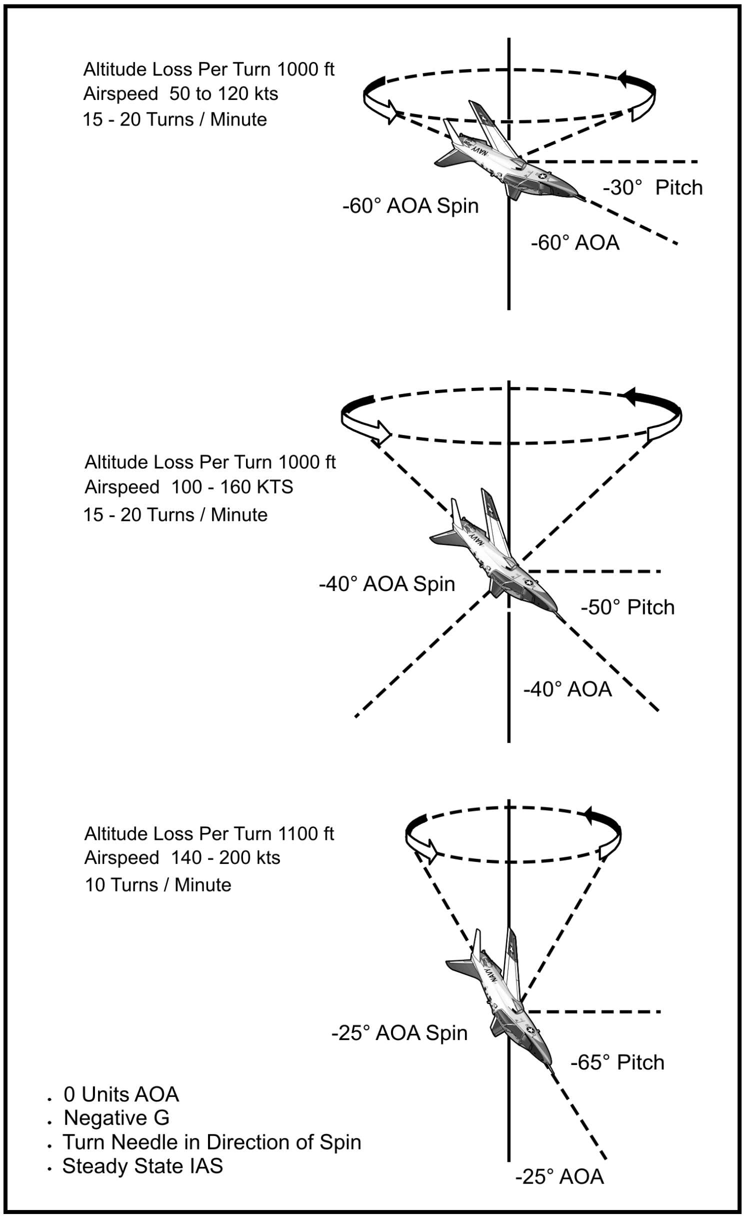


Figure 2-32 Inverted Spins (Steady-State Indications)

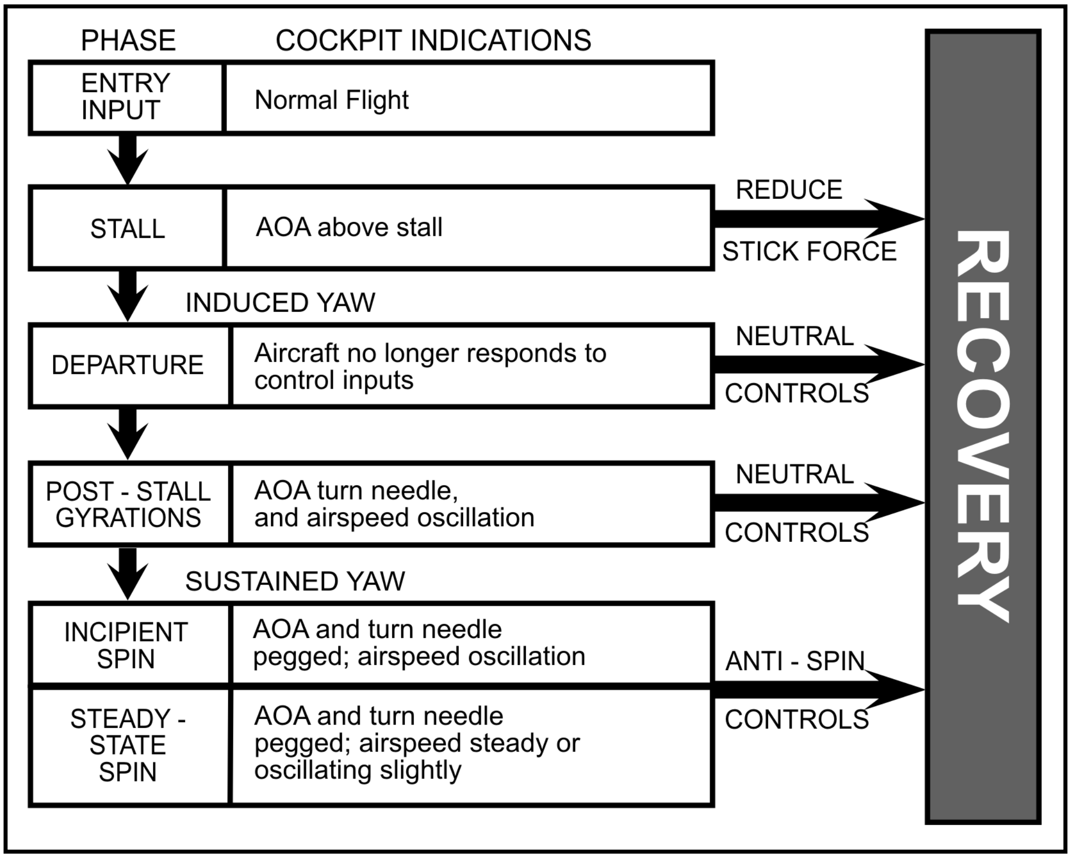


Figure 2-33 Stall Progression Diagram

(a). Negative g

(b). Pegged turn needle (in direction of spin)

(c). Zero units AOA

Angle of Attack (AOA) System

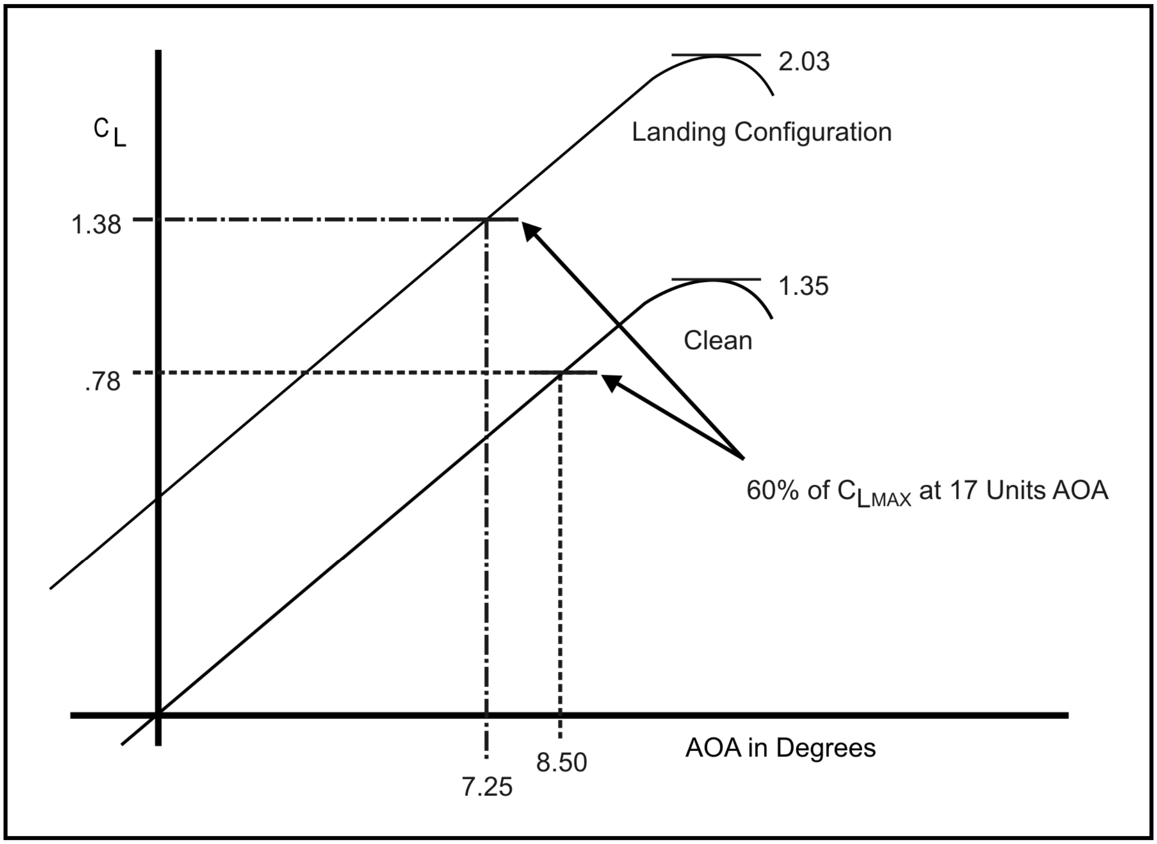


Figure 2-34 AOA System Theory

1. Provides the pilot with information necessary to obtain optimum aircraft performance, particularly at low airspeeds and high AOAs

2. Used primarily during the approach and landing phases of flight

NOTE

Aerodynamically, AOA is indicated airspeed (IAS). By controlling the AOA, the pilot controls IAS.

3. Indicates for each AOA a percentage of the maximum lift coefficient available for the flap configuration being used

   a. During flight at a constant AOA (approach and landings), a constant coefficient of lift is maintained

NOTE

Recall that as aircraft weight decreases, so must lift (basic lift formula). This is accomplished in the T-45 by holding AOA constant and reducing IAS as weight is reduced.

b. Flying correct AOA and maintaining proper glideslope (using power) will obtain optimum landing speed, landing attitude, and sink rate

i. Reduces possibility of in-flight engagements

ii. Reduces overstressing of the aircraft

4. Use during landings is more desirable than use of the pitot-static system

a. AOA more accurately measures aircraft performance than pitot-static system at low speeds; as speed decreases, position error increases

b. Optimum landing AOA is not affected by weight, bank angle, g load, or density altitude; IAS is affected

c. A change in AOA is easier to detect than a change in airspeed; in landing configuration, 1 unit AOA is equal to 3 KIAS

d. Changes in flap settings are compensated for

e. Instrument scan is reduced

f. Pilot workload is reduced by eliminating the need for weight and speed calculations

5. AOA components

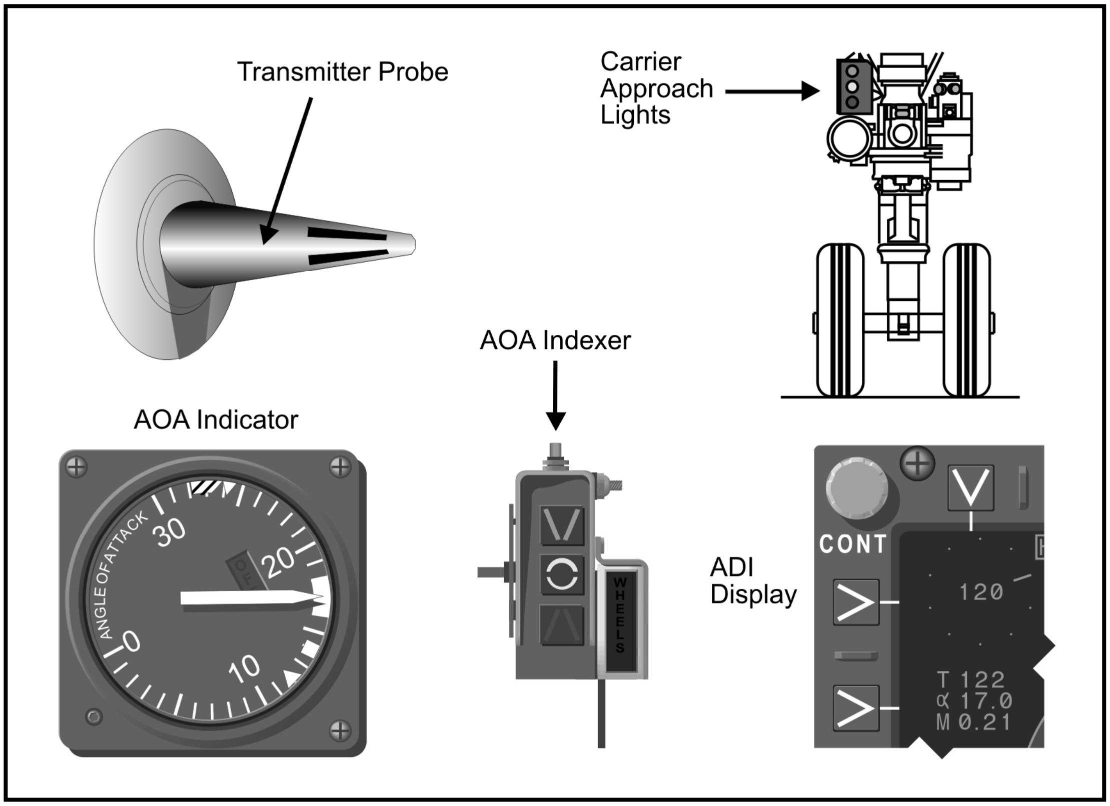


Figure 2-35 AOA Components

a. Probe transmitter

i. Probe aligns itself with the relative wind and sends out electrical signal

ii. Transmitter amplifies signal and sends it to other system components

b. Carrier approach lights

i. Located on nose landing gear strut

ii. Used to aid LSO in determining if T-45 is being flown at optimum AOA

iii. Controlled by AOA indicator; red, amber, and green lights show if AOA is low, optimum, or high

c. Rudder pedal shaker

i. Controlled by forward cockpit AOA indicator

ii. Provides an artificial stall warning through the left rudder pedal

d. AOA indicator

i. Indicates AOA in nondimensional units; a specific unit is used as a reference for each phase of flight

ii. Conventional round dial displays AOA information (pointer read against fixed dial)

iii. AOA for approach and landing in Navy aircraft is always at the 3 o'clock position (17 units AOA for the T-45)

NOTE

Stall warning (pedal shaker and aural tone) and stall AOA are indexed on the T-45.

e. AOA indexer

i. Presents AOA information by use of three lights

ii. Operates only when landing gear down and locked

iii. Receives information from forward cockpit AOA indicator

iv. Display consists of low-speed symbol (upper chevron), high-speed symbol (lower chevron), and on-speed symbol (donut)

v. Mounted on glare shield for easy scanning while looking forward through windshield

vi. Displays AOA and indicates airspeed relative to an optimum approach AOA and speed

vii. Cannot be used as a rate instrument (unlike the indicator) or to maintain an airspeed in event of a pitot-static system failure

f. ADI Display (T-45C)

i. Digital AOA in tenths of units

ii. AOA units prefix is the "alpha" symbol

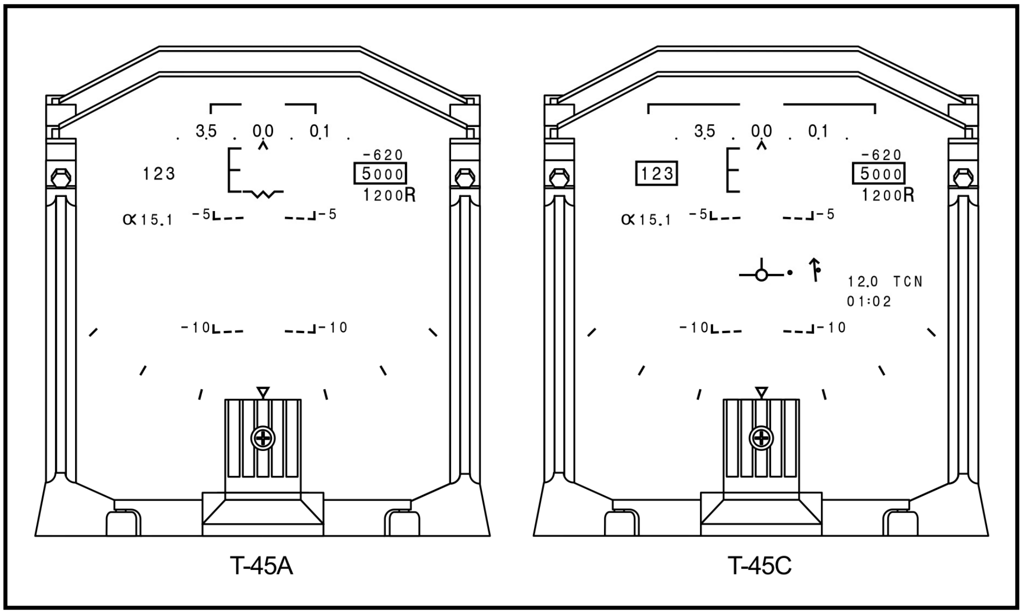


Figure 2-36 T-45 Navigation Approach HUD Display

g. HUD indications

i. Uses AOA information from AOA probe to present AOA information in with digital and graphical symbols

ii. AOA bracket "E" shows AOA in relationship to waterline (T-45A) or velocity vector (T-45C)

6. Actual flight path of T-45 at particular AOA depends on thrust selected by pilot

a. Example: A particular thrust setting will maintain level flight at 17 units AOA, a higher thrust setting will result in a climb, and a lower thrust setting will cause the aircraft to descend; a pilot would thus use AOA to control airspeed and thrust to control altitude

7. AOA system is subject to failure

a. Perform an AOA check prior to landings

b. If system fails, IAS is then used to fly the approach and landing

i. Proper speed for T-45 in landing configuration is approximately 117 KIAS with 1,000 pounds of fuel; this speed is increased 5 knots per 1,000 pounds of fuel

ii. Stall, glide, and other speeds vary approximately 5 knots per 1,000 pounds of weight

206. SUMMARY

In this lesson we have studied:

1. Slow-speed flight

2. Stalls and spins

3. Angle of attack system

207. CONCLUSION

Although slow-speed flight does not represent a difficult or dangerous condition, it can amplify errors of basic flying technique; therefore, slow-speed flight requires precise control of power and pitch to ensure a safe approach and landing.

NOTES

CHAPTER THREE
STABILITY

300. INTRODUCTION – N/A

COURSE/STAGE:

- TS, E2-C2, TAILHOOK & IUT/Aerodynamics

LESSON TITLE:

- Stability

LESSON IDENTIFIER:

- T-45A/C TS, E2-C2, TAILHOOK & IUT Aero-04

LEARNING ENVIRONMENT:

- Classroom

ALLOTTED LESSON TIME:

- .5 hr

TRAINING AIDS:

1. T-45 Scale Model

2. Figures

    - Figure 1: Fully Powered Control System
    - Figure 2: Coefficient of Lift Curve, Straight vs Swept Wing
    - Figure 3: Aspect Ratio
    - Figure 4: Swept Wing (Tip Stall)
    - Figure 5: Center of Gravity Travel
    - Figure 6: Landing Gear Door Effect on Directional Stability
    - Figure 7: Spiral Divergence
    - Figure 8: Crosswind Handling

STUDY RESOURCES:

1. T-45A NATOPS Flight Manual, A1-T45AB-NFM-000

2. T-45C NATOPS Flight Manual, A1-T45AC-NFM-000

LESSON PREPARATION:

1. Review:

   - Aero-01 Lesson Guide

2. Read:

   - Aero-04 Lesson Guide

REINFORCEMENT:

- N/A

EXAMINATION:

- The objectives in this lesson will be tested in Aerodynamics 07X for TS, E2-C2 and Advanced.

301. LESSON OBJECTIVES

1. Identify stability characteristics of the T-45 aircraft

2. State the factors which affect T-45 stability and flight characteristics

302. MOTIVATION

Knowing what to expect from the T-45 and understanding why the T-45 possesses certain flight characteristics will help you to obtain the maximum performance from the aircraft.

Figure 3-1 T-45

303. OVERVIEW

This lesson will discuss the flight and stability characteristics of the T-45 as follows:

1. T-45 Flight Controls

2. Stability (Generic)

3. T-45 Stability (General)

4. Factors Affecting T-45 Stability

304. REFRESHER

Recall that:

1. As aircraft become more maneuverable, they become less stable

2. The relationship between the center of gravity and the aerodynamic center affects both the stability and controllability of an aircraft

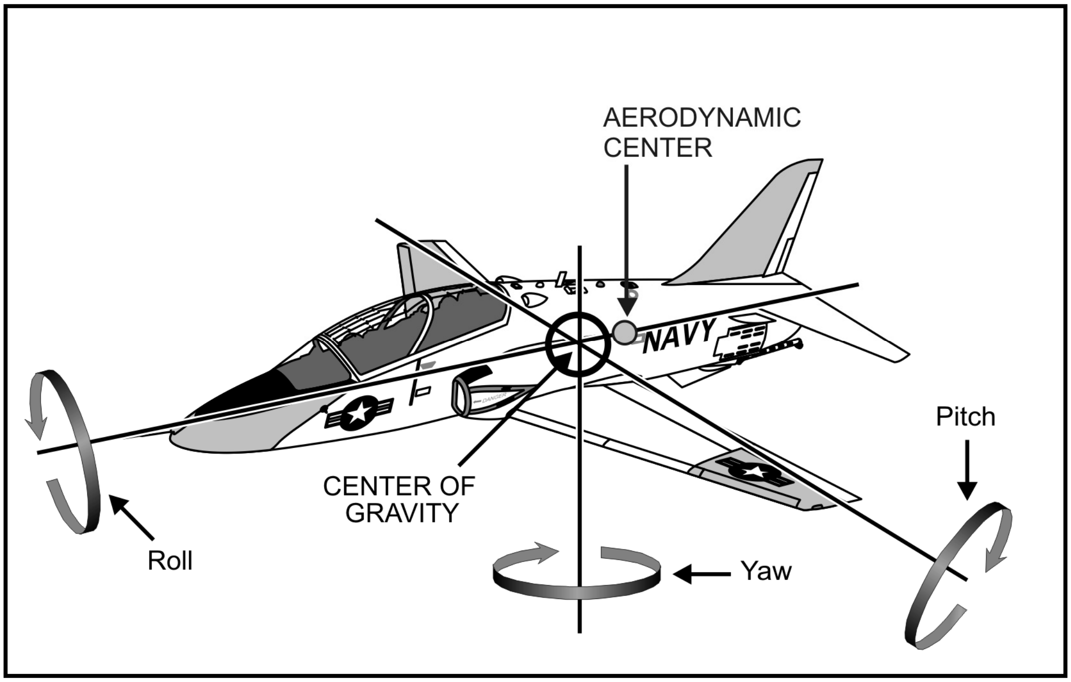


Figure 3-2 Center of Gravity/Aerodynamic Center Relationship to Stability

305. PRESENTATION

T-45 Flight Controls

1. T-45 has irreversible flight control system

   a. Elevator

   b. Stabilator

   c. Aerodynamic pressures are not fed back to pilot from control surface

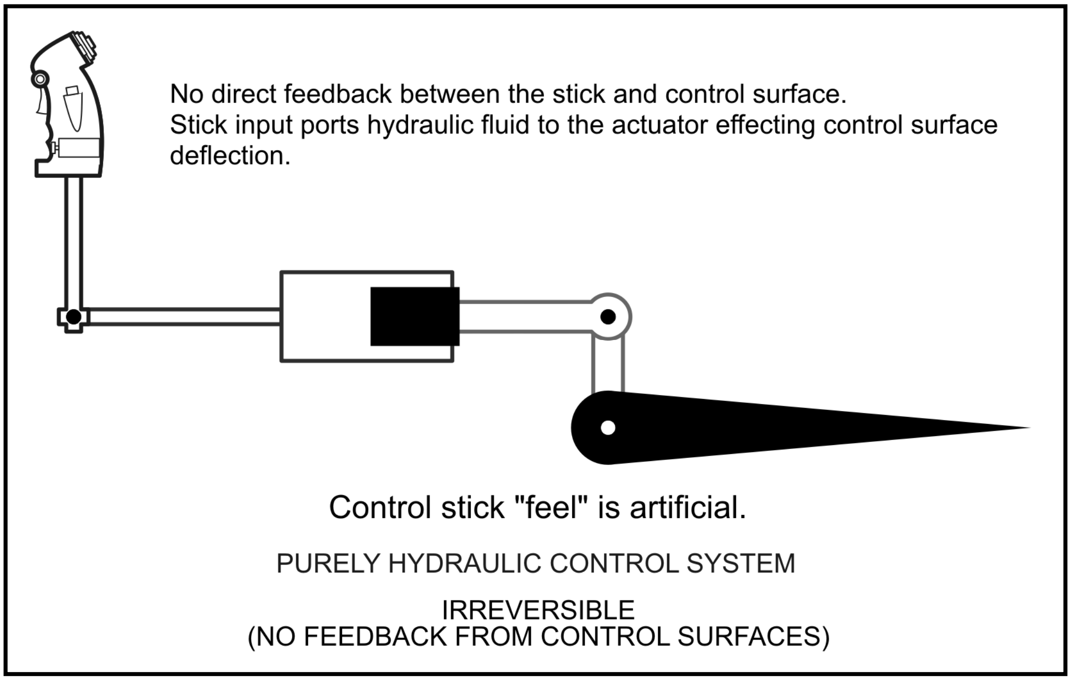


Figure 3-3 Fully Powered Control System

2. T-45 has conventional rudder

   a. Aerodynamic forces may feed back to rudder pedals

   b. Rudder pedals will be displaced due to side loads during post-stall gyration or spin

   c. Up to 300 pounds of pressure may be required to counter air loads on rudder during post-stall gyration or spin

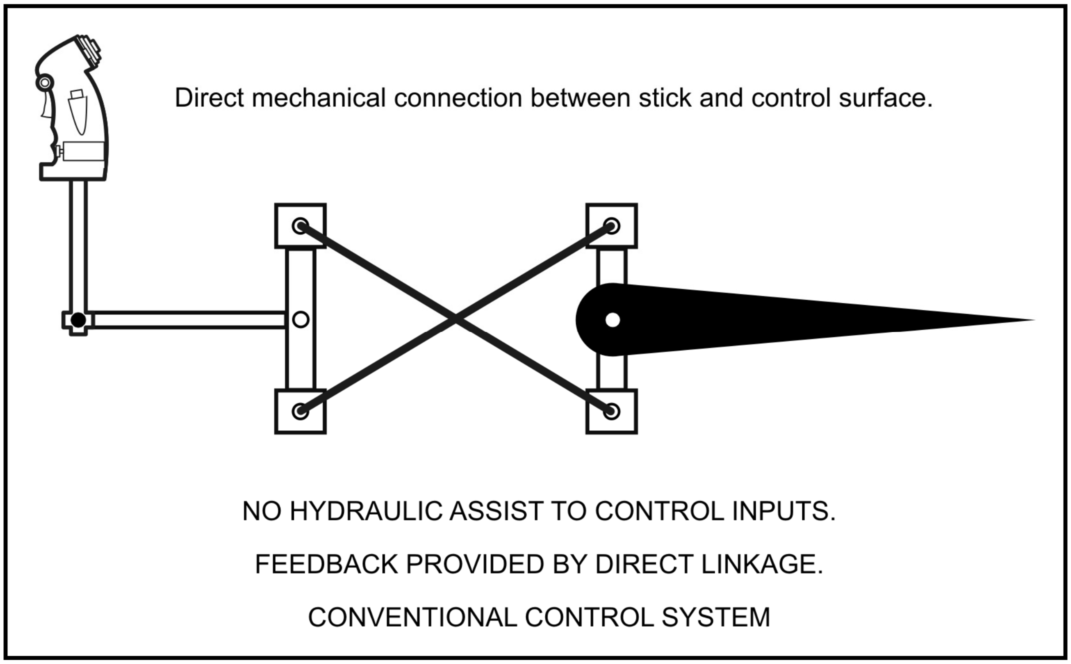


Figure 3-4 Conventional Control System

Stability (General)

1. Stall

   a. Condition when any increase in angle of attack (AOA) results in decrease in coefficient of lift (C_L)

   b. Stalling AOA is AOA that stall commences or coefficient of lift max $(C_L)_{max}$

   c. Swept wing aircraft generate less C_L

      i. stall at higher AOA than straight wing aircraft

      ii. stall less dramatic, flatter C_L curve

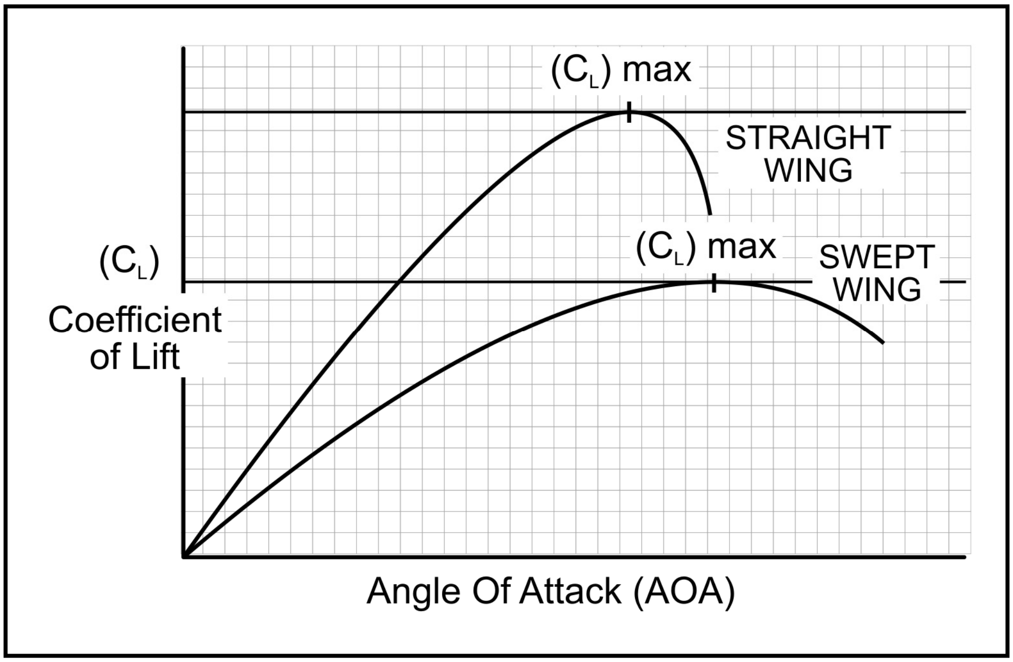


Figure 3-5 Coefficient of Lift Curve: Straight vs Swept Wing

2. Induced Drag

   a. Product of generating lift

   b. Greater at low airspeeds

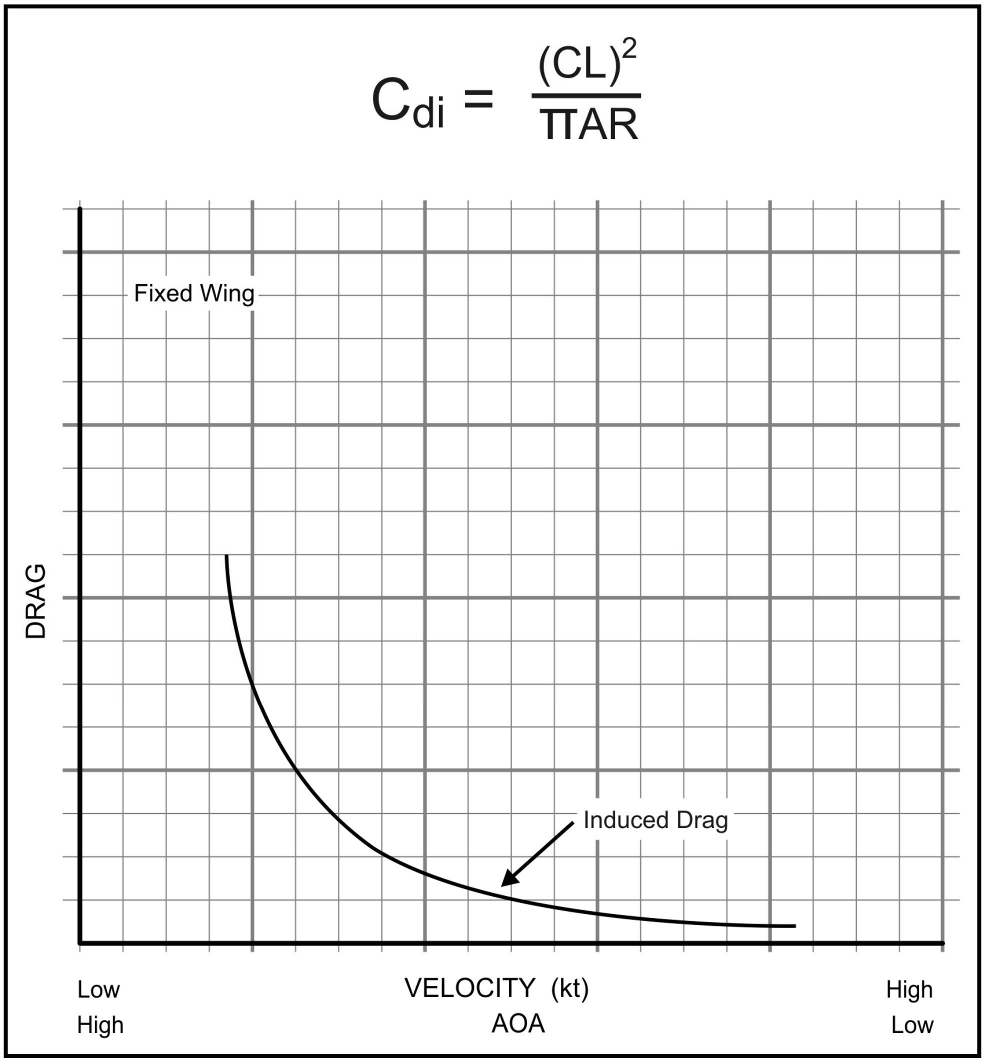


Figure 3-6 Induced Drag

3. Mean Aerodynamic Chord (MAC)

a. Center of pressure (CP)

i. Located along sweep angle of wing

ii. Determined overall aerodynamic center (AC) of aircraft; AC hard to determine for swept wing aircraft, as are overall pitch

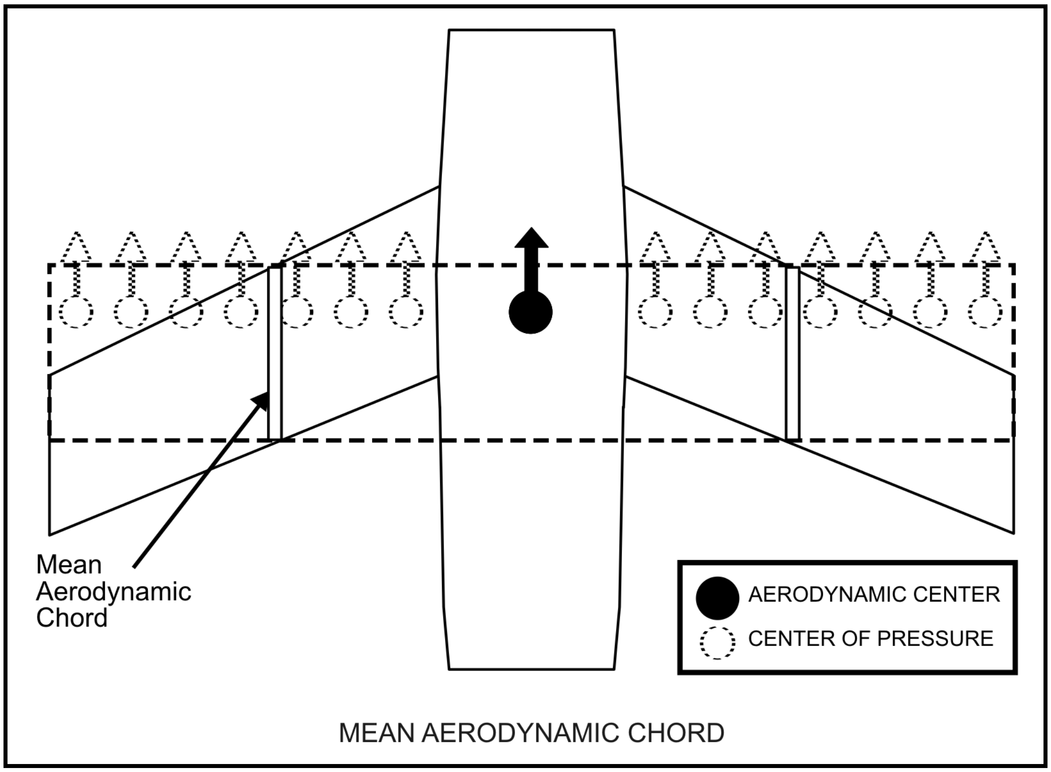


Figure 3-7 Mean Aerodynamic Chord

b. Concept

- Treats wing as if it were rectangular in planform, which makes pitching moments easy to determine

c. Precisely determined as to both location and length

i. MAC for T-45 is 69.96 inches

ii. Leading edge of MAC (LEMAC) is 240.9 inches aft of datum, which is the tip of the nose boom

d. Center of gravity (CG) computations and limits normally expressed as % MAC; CG range of T-45 is 14-22% of MAC

e. Used as primary reference for longitudinal stability considerations by aerodynamic engineers

4. Aspect Ratio (AR)

a. Ratio of span of the wing divided by average chord

b. Fineness ration of the wing that affects aerodynamic characteristics and structural weight

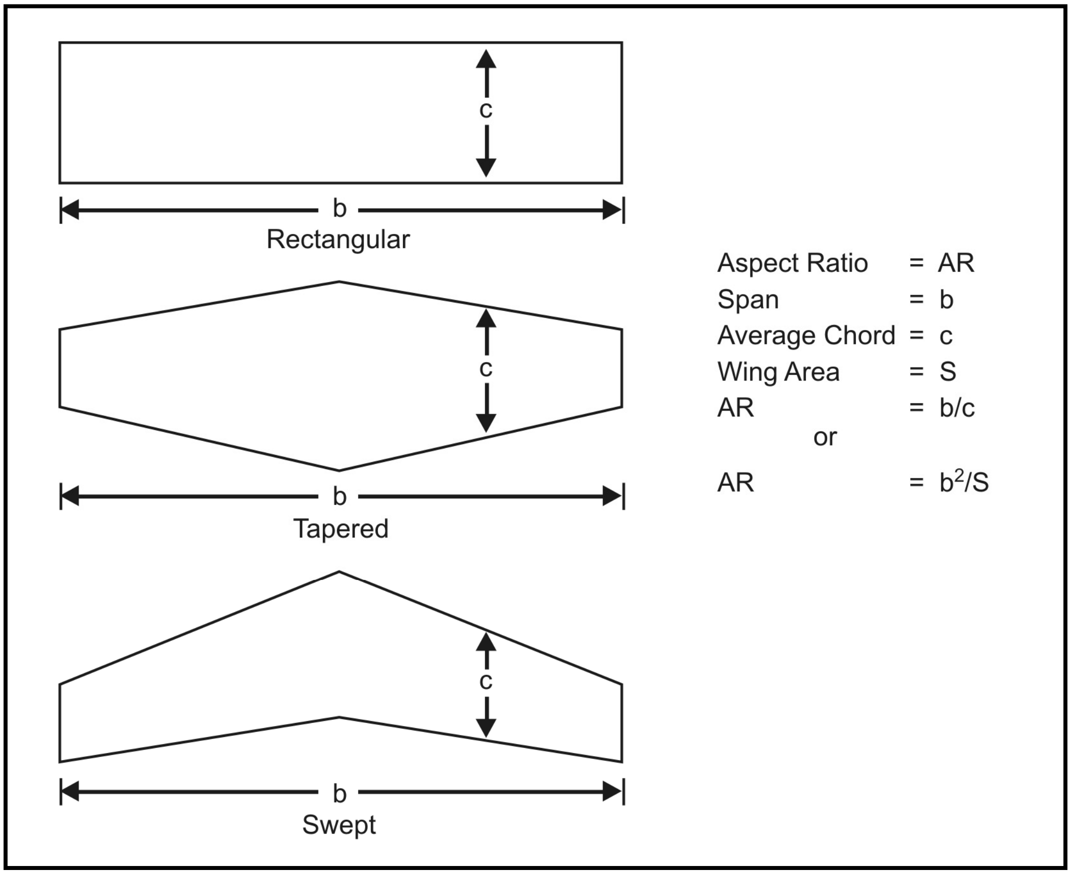


Figure 3-8 Aspect Ratio

5. Taper

a. Gradual reduction in chord length from root to tip

b. Affects lift distribution and structural weight of wing

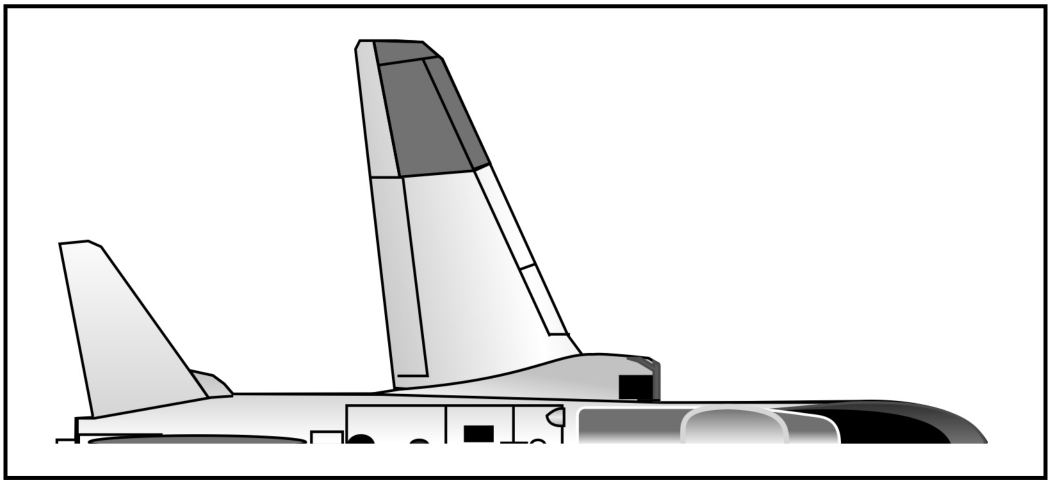


Figure 3-9 Taper

6. Thickness is the cross sectional height of airfoil measured perpendicular to chordline

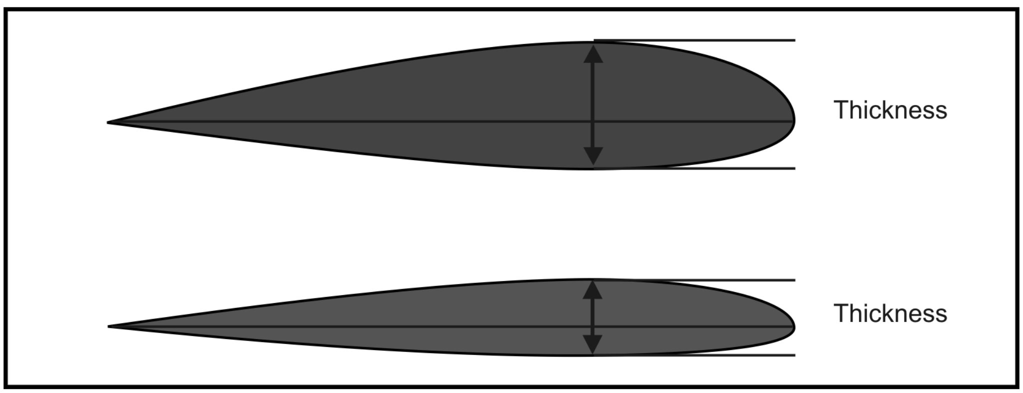


Figure 3-10 Thickness

7. Swept Wings

   a. Advantage over straight wing

      i. Delays onset of all compressibility effect

      ii. Delays critical Mach (M_{crit}) and force divergence Mach number

      iii. Lower aspect ratio results in higher speed capability less parasite drag

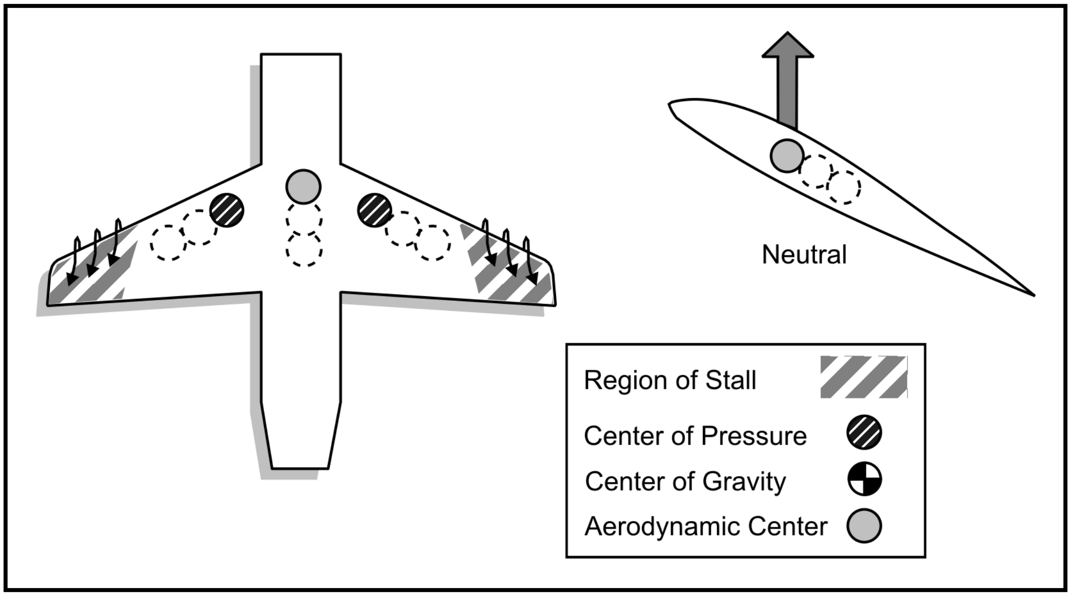


Figure 3-11 Swept Wing Tip Stall

b. Disadvantage over straight wing

i. Tip stall from wing sweep and taper

ii. Loss of ailerons at stall (some aircraft)

iii. Negative longitudinal stability or pitch up at high AOA

8. Tip Stall

a. Stall of the outer portion of wing

b. May cause loss of ailerons

c. Cause center of pressure to move forward

d. Aircraft could pitch up if aerodynamic center moves forward of the center of gravity

9. Leading Edge Vortexing

a. At high angle of attack, high-pressure air from the bottom of wing jumps past leading edge to lower pressure area on top of wing

b. Results in loss of lift and possibly loss of control

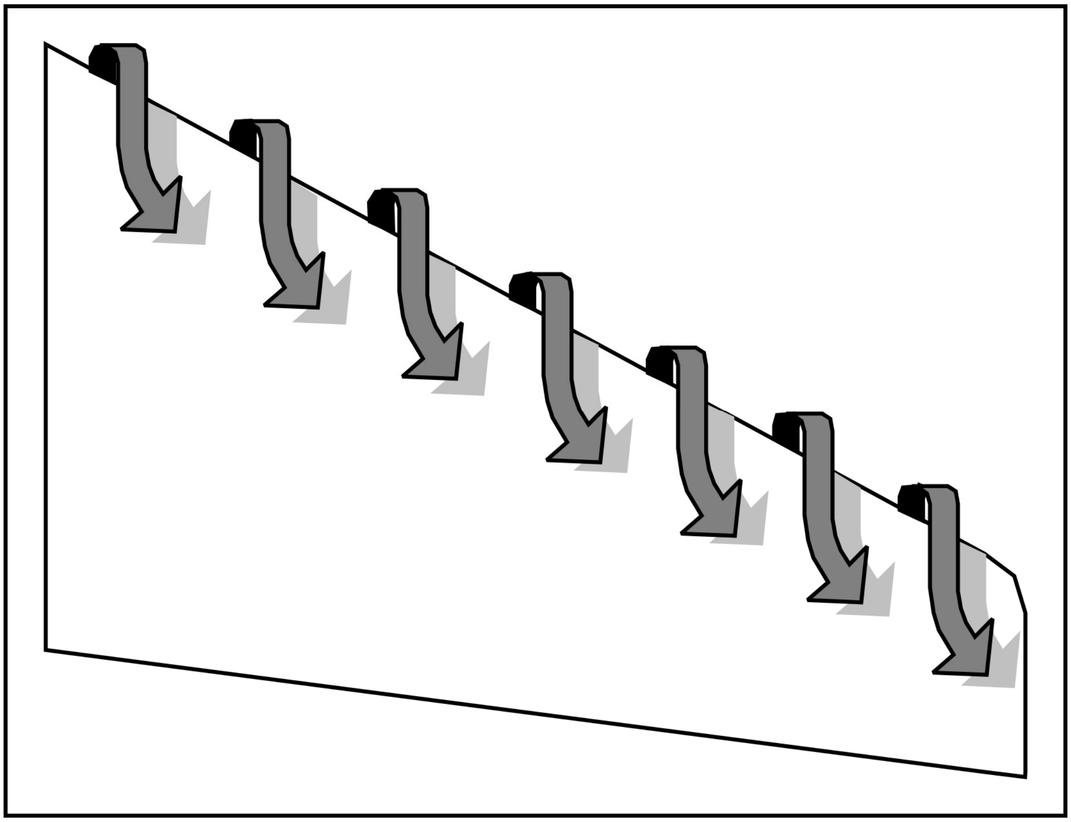


Figure 3-12 Leading Edge Vortexing

10. Geometric Twist

   a. The wing is designed with a twist that reduces the angle of incidence at the tip

   b. Wing tip less prone to stall, compared to the root

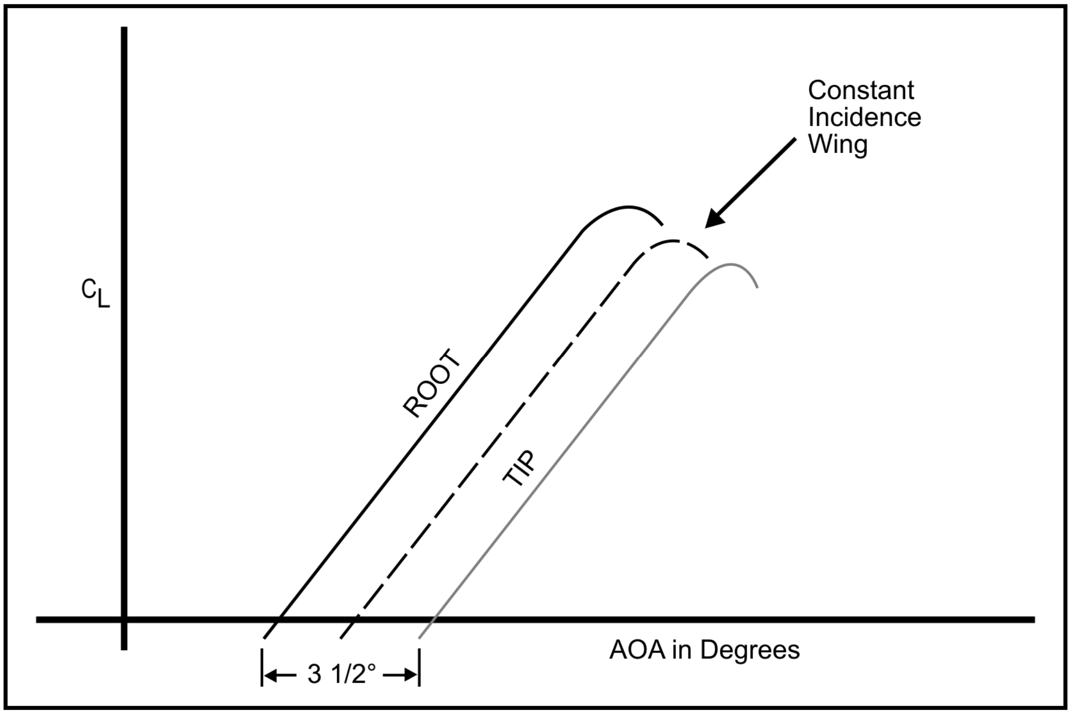


Figure 3-13 Effect of Geometric Twist

11. Stall Strips

   a. Short triangular strips on leading edge of slat and on wing leading edge, under the slat

   b. Cause root to stall earlier

   c. Works in conjunction with geometric twist to cause root and tip to stall at about same AOA

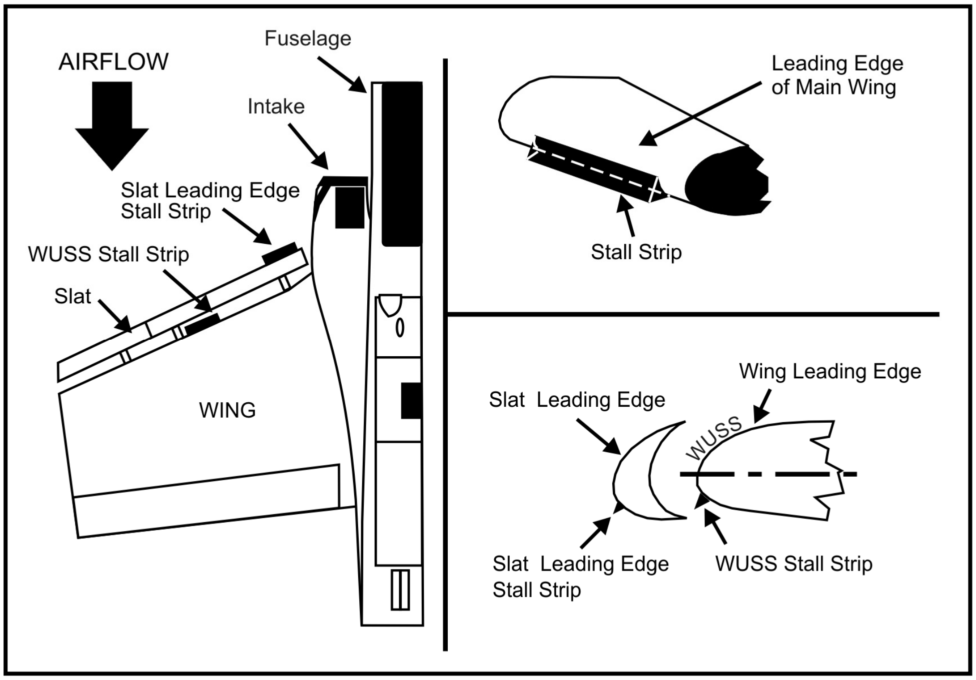


Figure 3-14 Stall Strips

12. Tip versus Root Stall

a. Undesirable traits of tip stall with a swept wing design

i. Little stall warning

ii. Serious reduction in lateral control

iii. Forward shift of center of pressure causing pitch up

b. Aerodynamic modifications to T-45 changed tip to root stall characteristics

i. 3.5 degrees of geometric twist delays outboard leading edge stall

ii. Stall strips enhance root stall to point that wing tip stalls only slightly before root

iii. Stall strips induce airframe buffeting prior to stall (1-2 knots clean, 1 knot dirty)

13. Center of Gravity (CG) Limitations

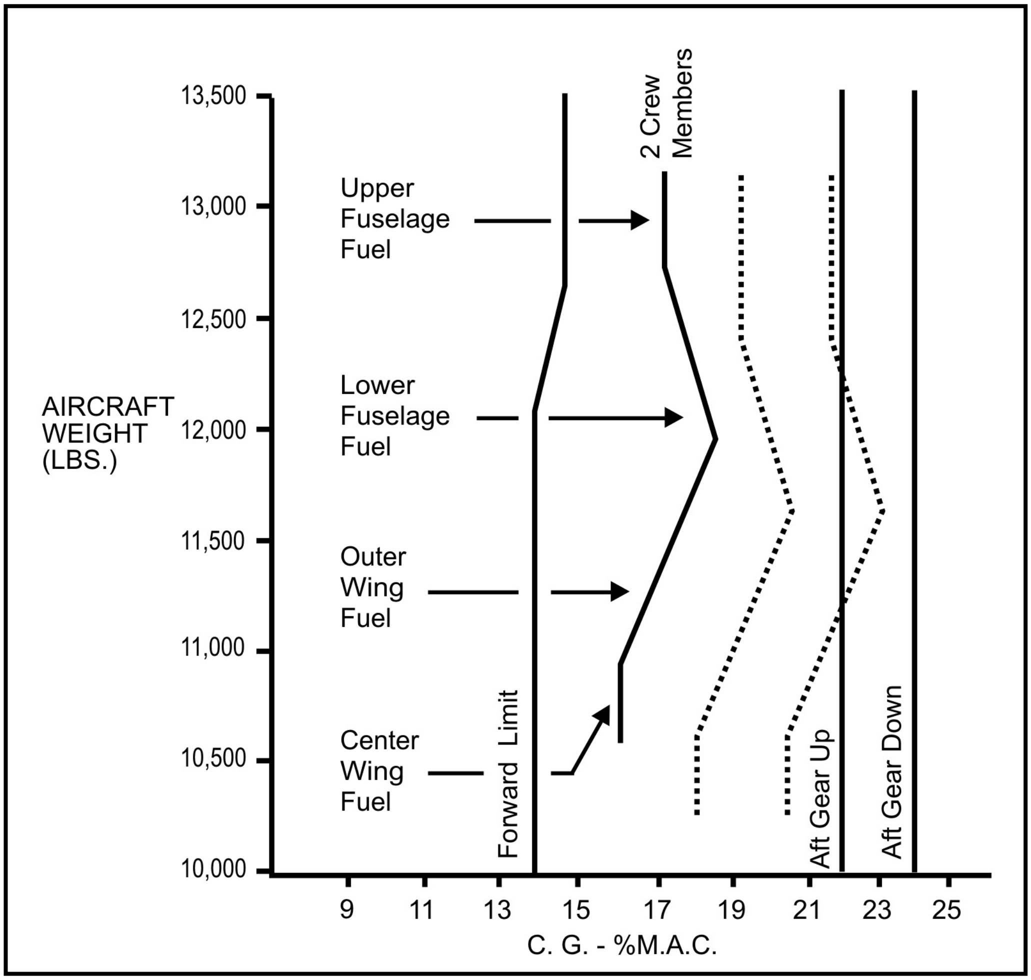


Figure 3-15 Center of Gravity Travel

a. Point at which weight of an object can be considered concentrated

b. Aircraft designed for certain range of CG movement

c. Factors affecting CG location in a tactical aircraft

   i. landing gear position

   ii. fuel burned

   iii. wing sweep

   iv. ordnance

   v. ejection of aft seat

14. Aerodynamic Center (AC)

    a. Point along chord where all changes in lift effectively take place

    b. Aerodynamic Center forms moment arm with CG that affects aircraft performance

        i. When AC is far aft of CG the aircraft is very stable but less maneuverable

        ii. When AC moves forward, closer to the CG, the aircraft becomes less stable but more maneuverable

    c. When an aircraft is very slow, the AC may move forward of the CG creating a very unstable pitch up situation that can not be stopped by full nose down stabilator

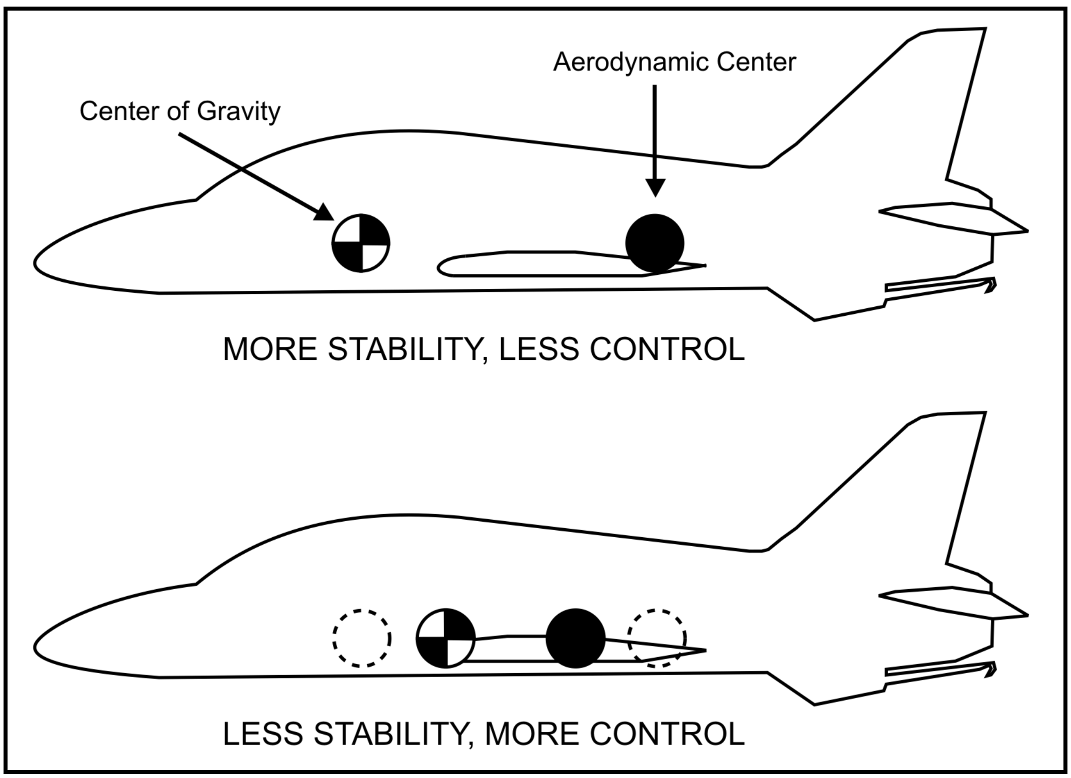


Figure 3-16 Center of Gravity/Aerodynamic Center Relationship to Stability

    d. Flap/Slat Extension

        i. Moves AC forward 3.49 inches (extending landing gear moves CG aft)

        ii. Aircraft less stable but more maneuverable

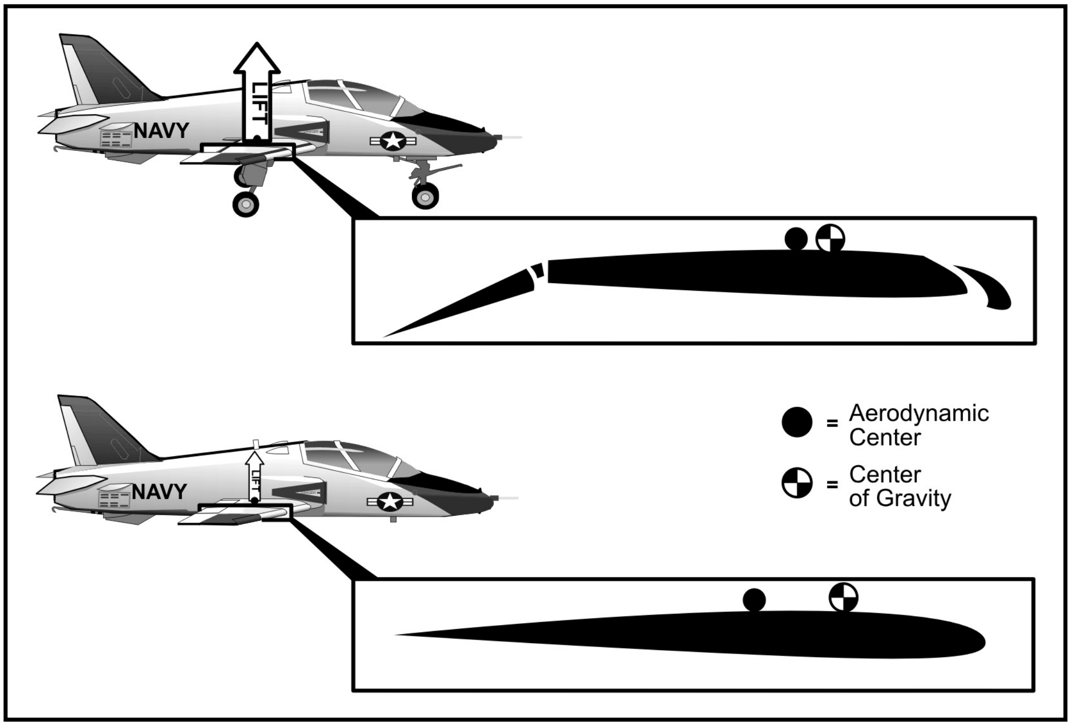


Figure 3-17 Longitudinal Stability -- Gear, Flap/Slat Extension

15. Speed Brakes

a. Extending the speed brakes is destabilizing

b. Turbulent flow on lower surface of horizontal stabilizer reduces pressure causing aircraft to pitch up

c. Speed Brake to stabilator Interconnect (SBI) is one of Control Augmentation System functions that reduces pitch transients during speed brake extension and retraction

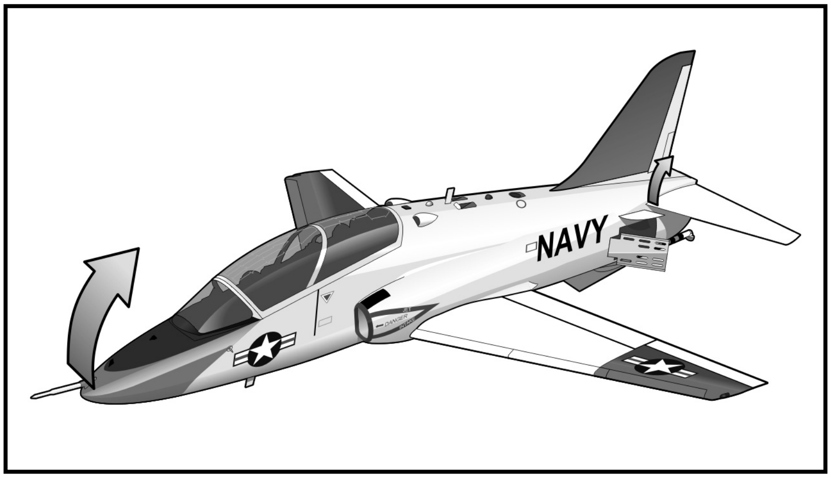


Figure 3-18 Longitudinal Stability -- Speed Brake Effect

i. Reduces positive pitch transients (speed brake extension) from 0.2 to 0.7 Mach

ii. Reduces negative pitch transients (speed brake extension) above 0.7 Mach during speed brake

iii. Control stick does not move

16. Stabilator Vanes

a. Located on both sides of fuselage above the speed brakes, forward of the stabilator

b. Generates vortex to energize flow over lower surface of stabilator to keep it effective

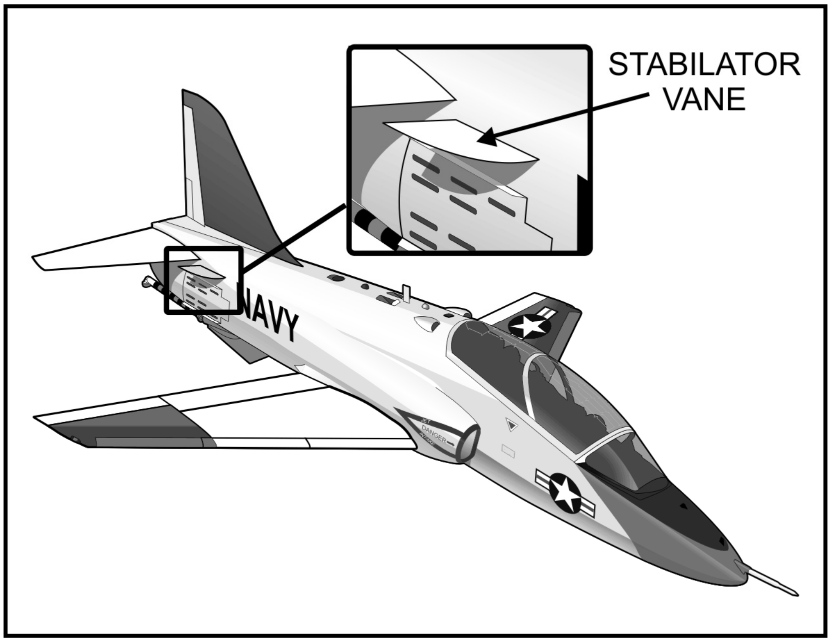


Figure 3-19 Stabilator Vane

17. Landing Gear Doors

    a. Directional stability is reduced during landing gear extension

        i. inner main landing gear (MLG) doors open

        ii. forward nose landing gear (NLG) doors open

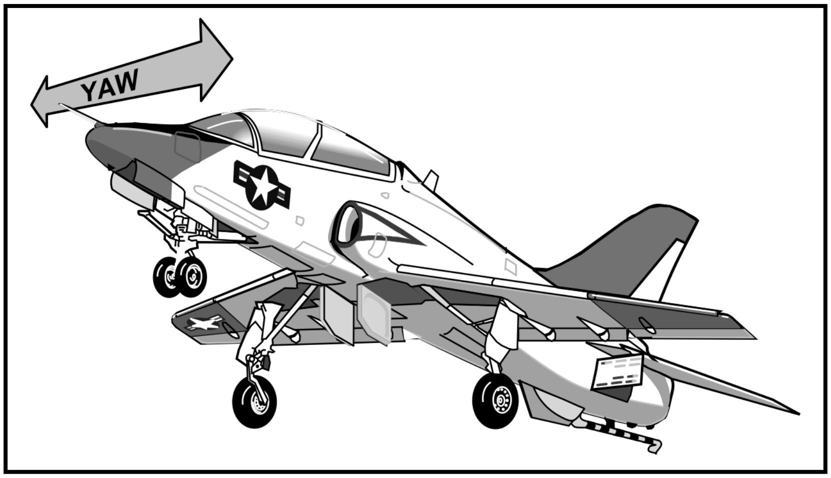


Figure 3-20 Landing Gear Doors Effect on Directional Stability

b. Yawing tendency caused by the increased sail area of the opened MLG doors and the forward NLG doors that are forward of the CG

c. MLG and forward NLG doors close when the landing gear is fully extended

d. During emergency gear extension

i. Inner MLG doors remain open

ii. Forward nose landing gear doors partially closed by an electric motor

e. In emergency gear extension configuration

i. Aircraft is less stable directionally

ii. Controlling the slight yaw excursions that may occur requires coordinated stick and rudder

18. Stability versus Maneuverability

a. Aircraft design is tradeoff between many variables including stability and maneuverability

b. The balance determined based on many factors but primarily dictated by aircraft mission

c. Maneuverability implies a responsive aircraft that may be less stable

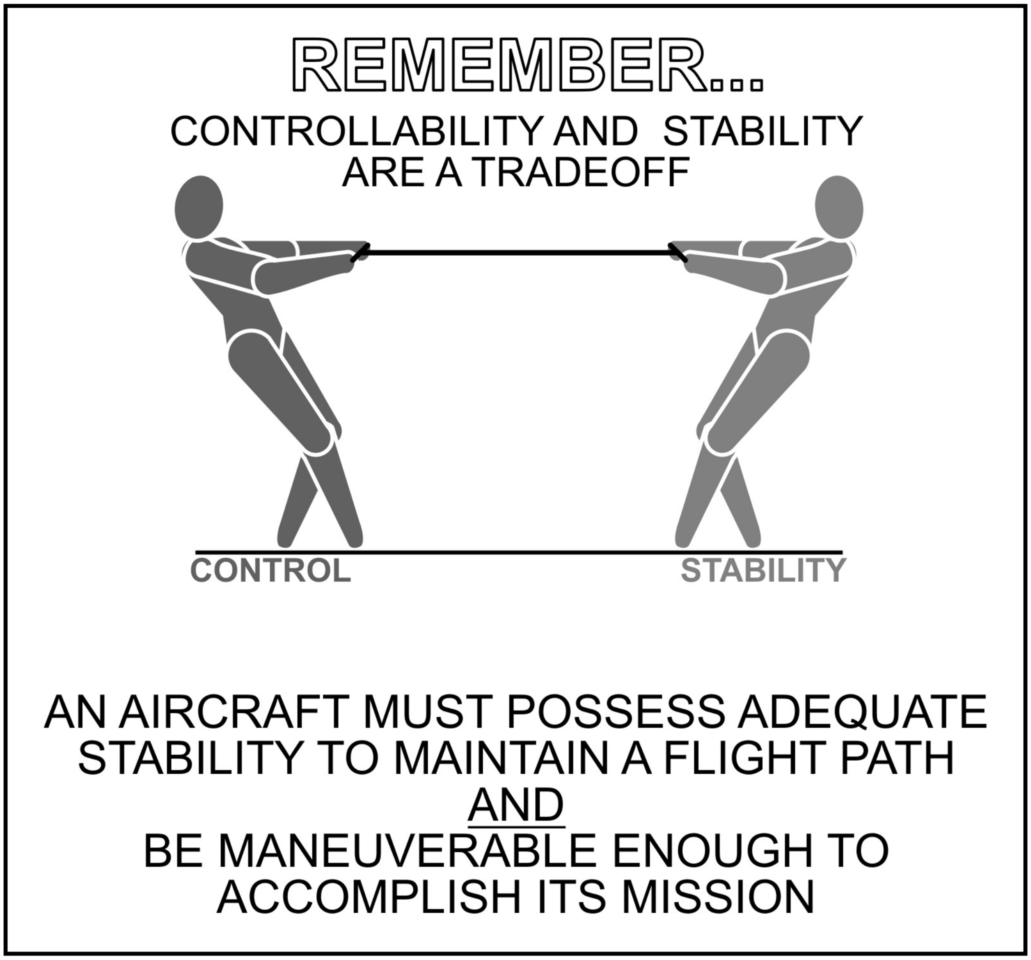


Figure 3-21 Stability vs Maneuverability

i. Transports mission dictates a very stable, and therefore a less responsive design

ii. The fighter mission demands maximum maneuverability, and therefore stability is less important

iii. T-45 is between the fighter and transport extremes

(a). Student training dictates a stable platform

(b). Lead in training for tactical fleet missions require more maneuverability

d. The relationship of longitudinal stability to maneuverability is inverse

e. The relative location of the CG and AC determine the degree of longitudinal stability to maneuverability that exists

f. Displacement of the AC from the CG creates a moment arm with the CG as the fulcrum

i. The longer the moment arm, assuming the force remains constant, the more stable and less maneuverable the aircraft

ii. The shorter the moment arm the aircraft is more controllable but less stable

T-45 Stability (General)

1. T-45 Roll Rate

a. Depends on airspeed

b. 180 degrees per second can be achieved between 0.7 and 0.9 Mach

2. Longitudinal Control

a. Below 0.85 Mach the T-45

i. is highly maneuverable

ii. has predictable flying qualities

iii. Stick forces are moderate and provide good feedback

b. Above 0.84 Mach

i. stick forces become noticeably more sensitive

ii. A region of reduced longitudinal stability exists within trim AOA band at approximately 0.87 true Mach number

(a). pilot perceives this as stick force lightening or pitch up

(b). less than three pounds of stick force can result in g excursions from +1 to +3g

(c). Excursions are highest at aft CGs

c. Use caution in high speed dive recoveries to avoid overstress in the pitch up regions of 0.99 and 0.87 Mach

d. Pullout at no more than 4.0 g's and ease the back pressure in the pitch up regions to maintain a maximum of 4.0 g's

3. Directional Divergence

   a. Results from negative directional stability

   b. T-45 and other aircraft do not exhibit this condition

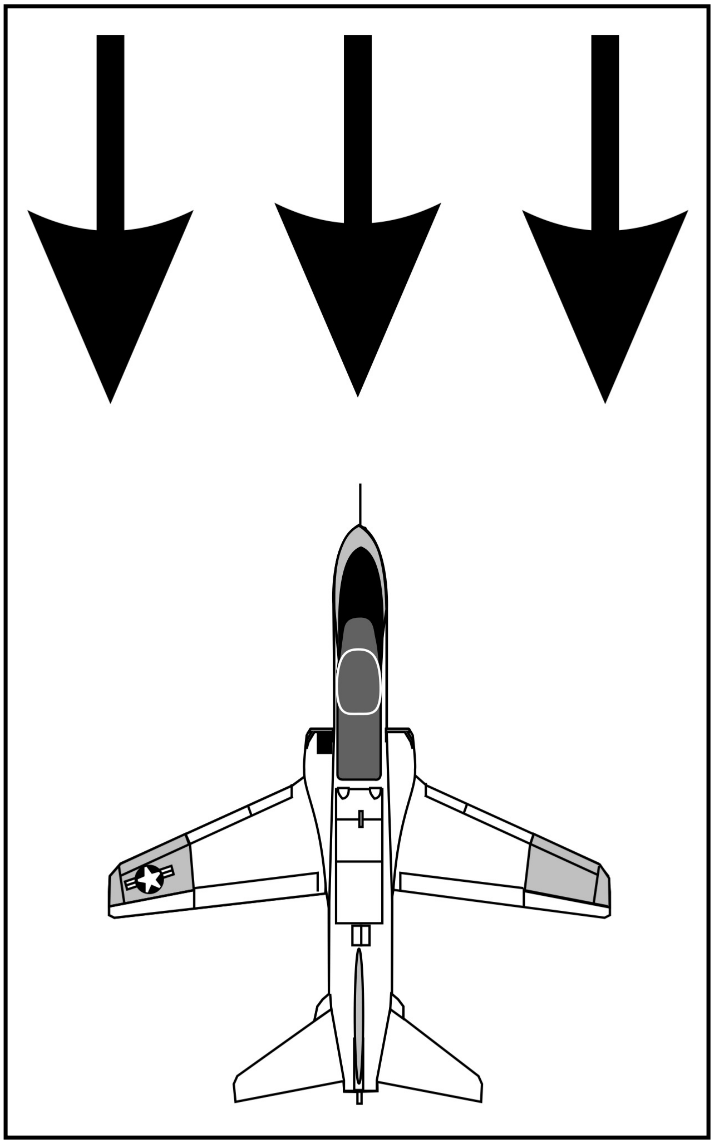


Figure 3-22 Directional Divergence

Factors Affecting T-45 Stability

1. Coupling

   a. Interaction of simultaneous roll and yaw movements

COUPLING

DEFINITION - THE INTERACTION OF SIMULTANEOUS ROLL AND YAW MOMENTS

COUPLING IN THE T-45
DUTCH ROLL AND SPIRAL DIVERGENCE

Figure 3-23 Coupling

b. T-45 may exhibit the following tendencies:

i. Dutch Roll

(a). Lateral stability stronger than directional stability

(b). Induced drag increases on wing into wind when aircraft yaws

(c). Weak directional stability allows adverse yaw, that causes roll and yaw in opposite direction

(d). Increase lateral stability at high AOA may produce Dutch roll tendency

(e). T-45 has dutch rolling tendency at slow speeds

(1). Countered by yaw damper system

(2). With yaw dampener/SBI inoperative, quite noticeable but controllable, resulting in an increased pilot workload

Figure 3-24 Dutch Roll

ii. Spiral Divergence

(a). strong directional stability relative to weak lateral stability

(b). bank angle keeps relative wind moving off nose

(c). aircraft continues to chase relative wind

(d). tight descending spiral develops

(e). stop spiral by raising wing with aileron

(f). directional stability usually design stronger than lateral stability in most aircraft

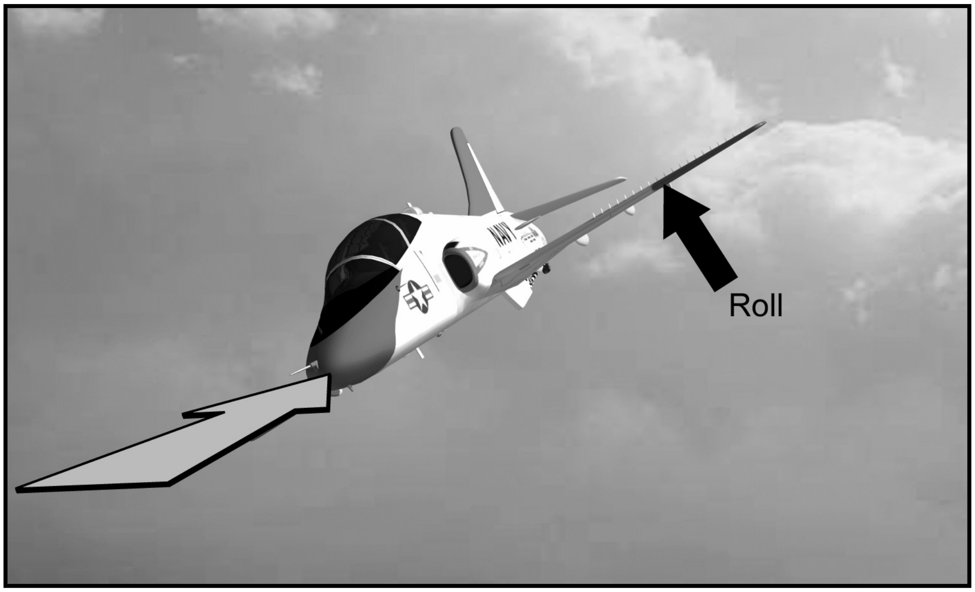


Figure 3-25 Spiral Divergence

(g). T-45 characteristics

(1). demonstrated a slowly divergent spiral mode with asymmetrical stores loadings

(2). Onset is slow, with bank angle doubling every 25 seconds

2. T-45 Landing in a Crosswind

a. T-45 will track away from a crosswind

i. Crosswind will cause the upwind wing to have more lift

ii. Upwind wing will come up

iii. Downwind wing will have more weight on its gear

iv. Downwind gear with more weight will have more drag, which produces a large turning moment away from the crosswind

NOTE

The squadron will brief you on proper crosswind flight procedures.

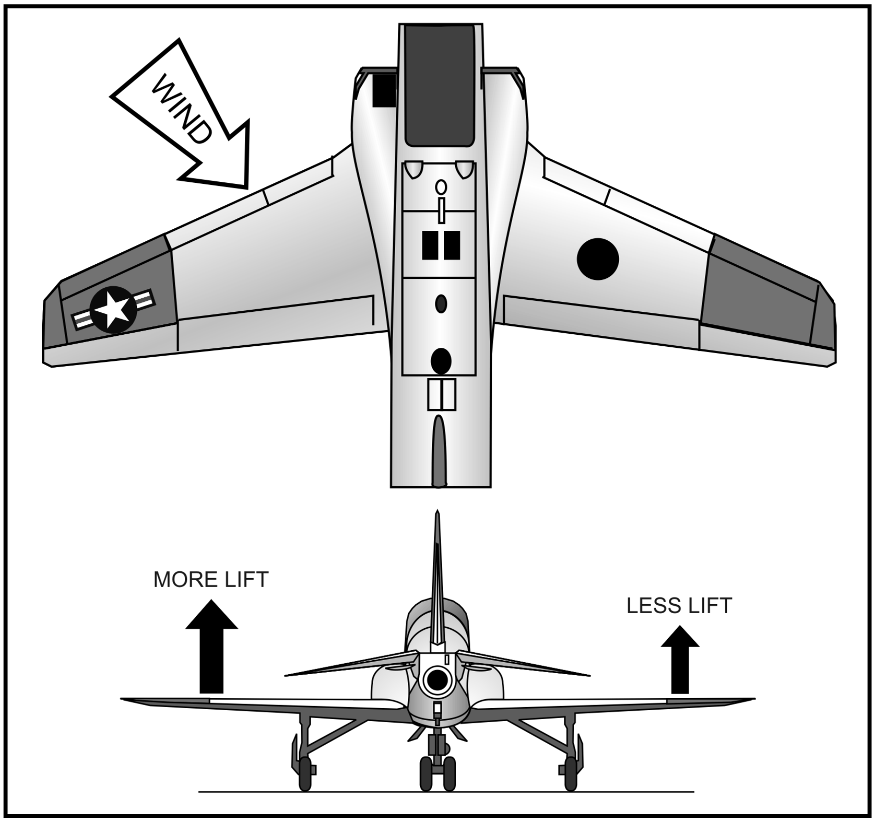


Figure 3-26 Crosswind Handling

306. SUMMARY

This lesson has focused on the following topics:

1. T-45 Flight Controls
2. Stability (Generic)
3. T-45 Stability (General)
4. Factors Affecting T-45 Stability

307. CONCLUSION

Knowing the factors that affect T-45 stability and the aircraft's stability characteristics will help you to obtain the maximum performance from the aircraft as you progress through your flight training.

CHAPTER FOUR
NATOPS PERFORMANCE CHARTS T-45C CHARTS AND EXAM REVIEW T-45A

400. INTRODUCTION – N/A

COURSE/STAGE:

- TS, E2-C2, TAILHOOK & IUT / Aerodynamics

LESSON TITLE:

- NATOPS Performance Charts T-45C Charts and Exam Review T-45A

LESSON IDENTIFIER:

1. T-45C TS, TAILHOOK & IUT Aero-06
2. T-45A TS & E2-C2 Aero-07, TAILHOOK & IUT Aero-06

LEARNING ENVIRONMENT:

- Classroom

ALLOTTED LESSON TIME:

- 2.5 hr T-45C and 1.5 hr T-45A

TRAINING AIDS:

- T-45 Scale Model

STUDY RESOURCES:

1. <u>T-45A NATOPS Flight Manual</u>, A1-T45AB-NFM-000
2. <u>T-45C NATOPS Flight Manual</u>, A1-T45AC-NFM-000
3. <u>T-45 NATOPS Flight Manual</u>, A1-T45AB-NFM-300

LESSON PREPARATION:

1. Review:
    - Aero-01

2. Bring to class:

   - T-45 NATOPS Flight Manual, A1-T45AB-NFM-300

REINFORCEMENT:

- N/A

EXAMINATION:

The objectives in this lesson will be tested in Aerodynamics 07X for TS, E2-C2 and Advanced.

401. LESSON OBJECTIVES

- Determine aircraft performance data

402. MOTIVATION

Charts published in the NATOPS Flight Manual provide the pilot with information which enables him to realize the maximum performance capabilities of the aircraft. Use of chart material for preflight planning and application of prescribed operating procedures will result in the optimum effectiveness of the aircraft.

403. OVERVIEW

In this lesson, instruction is provided on how to use T-45 aircraft performance charts.

404. PRESENTATION

NATOPS Performance Charts Section Layout

1. Presented in a standard order in all NATOPS manuals

   a. General

   b. Takeoff

   c. Climb

   d. Cruise

   e. Endurance

   f. Descent

   g. Landing

h. Flight Planning

i. Combat Performance

2. The introduction to each section has:

a. Definitions

b. Explanations

c. Conditions and assumptions used in charts

d. Sample problems

Techniques

1. Use the correct chart

a. Aircraft model

b. Configuration

2. Read all chart notes

3. Carefully work the chart

a. Lay the chart flat, if possible

b. Determine the values of each grid

c. Go from previous chart position to next “baseline”

d. Parallel “Guidelines” to next correction

e. Continue to next baseline

f. General Rule Baseline, correction, baseline correction

g. If correction is above baseline, the same procedure applies

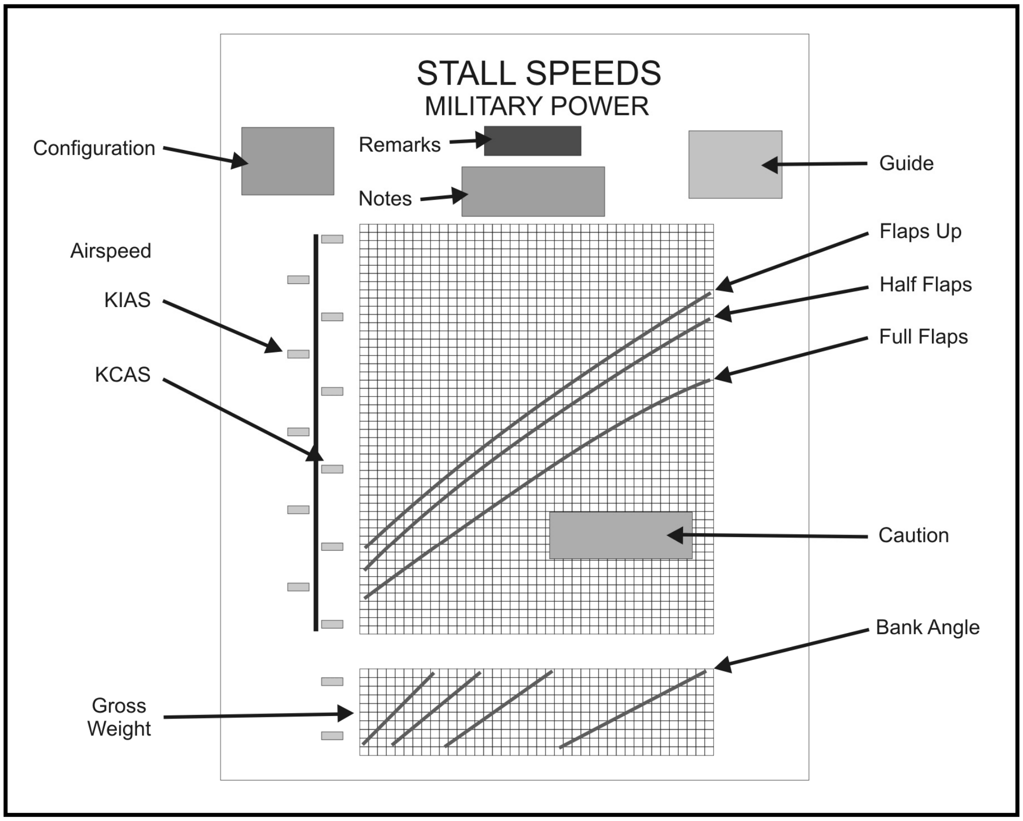


Figure 4-1 NATOPS Chart

4. Read all the notes, making any necessary corrections

5. Ask yourself, "Does this answer make sense?"

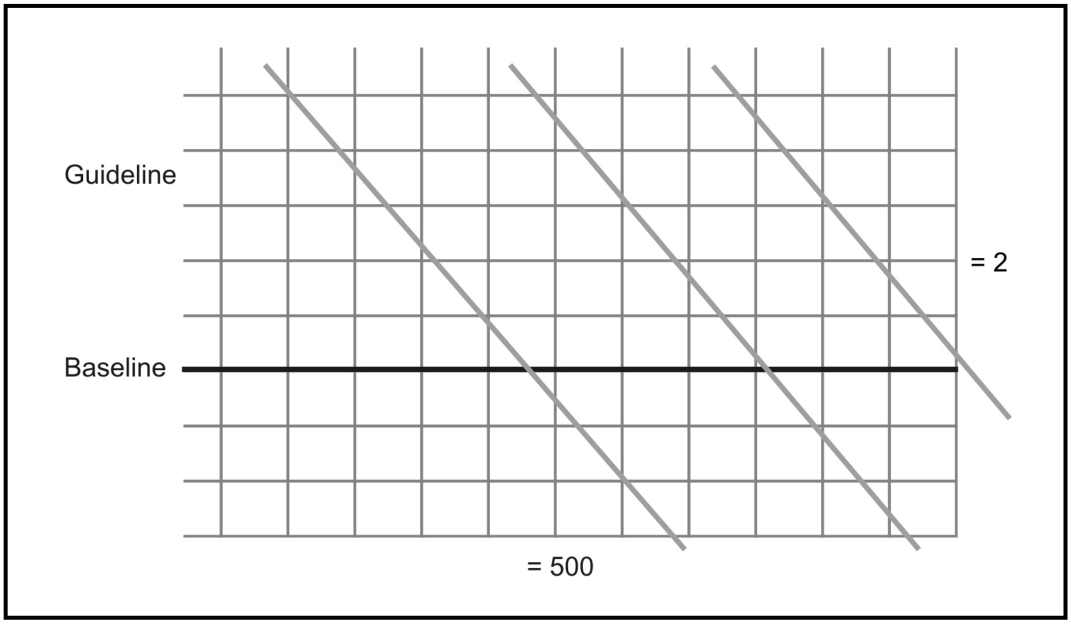


Figure 4-2 NATOPS Chartwork Techniques

INSTRUCTOR NOTE

The following material applies to T-45C Aero.

NATOPS Charts

1. Density Ratio Chart

   a. Combines effect of temperature and pressure altitude on engine performance

   b. Density ratio must be computed before using the takeoff and landing charts

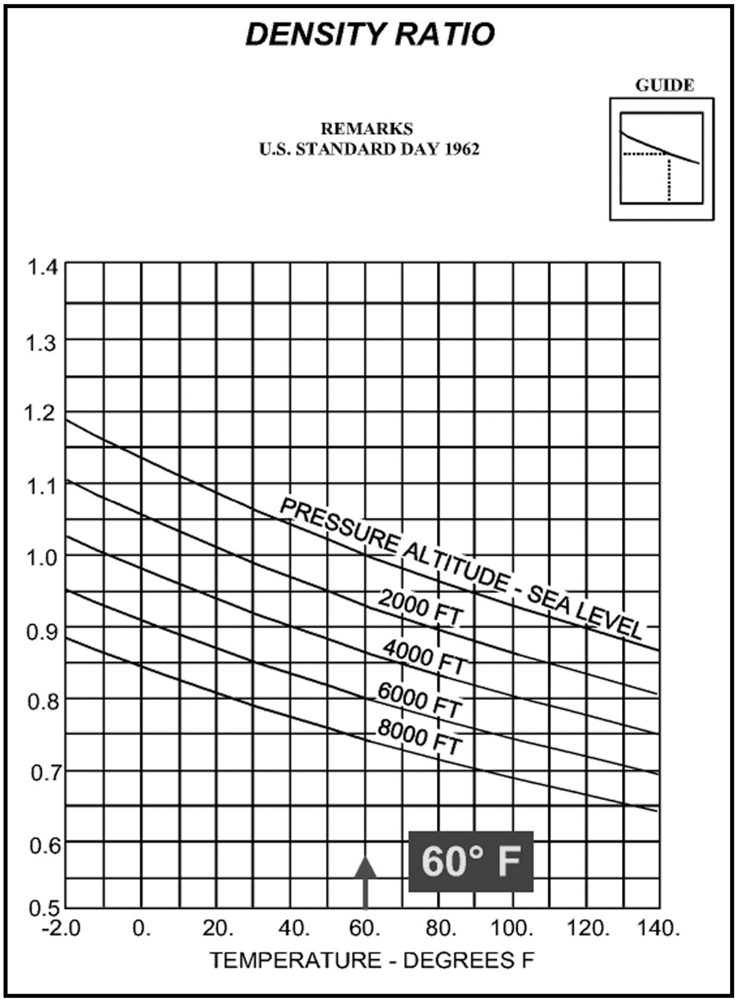


Figure 4-3 Density Ratio Chart

2. Takeoff Distance Chart

   a. Shows main wheel lift-off speed for various gross weights

   b. Used to compute no wind or a headwind or tailwind takeoff distance solution

   c. Also total distance from start of takeoff roll to clear a 50' obstacle

   d. Takeoff Distance Computation

      i. Gross Weight determines main wheel lift-off speed

      ii. Enter chart on density ratio scale

iii. Project a line from density ratio to takeoff gross weight reference line

iv. From intersection of density ration and gross weight, extend line vertically down to determine ground roll without wind

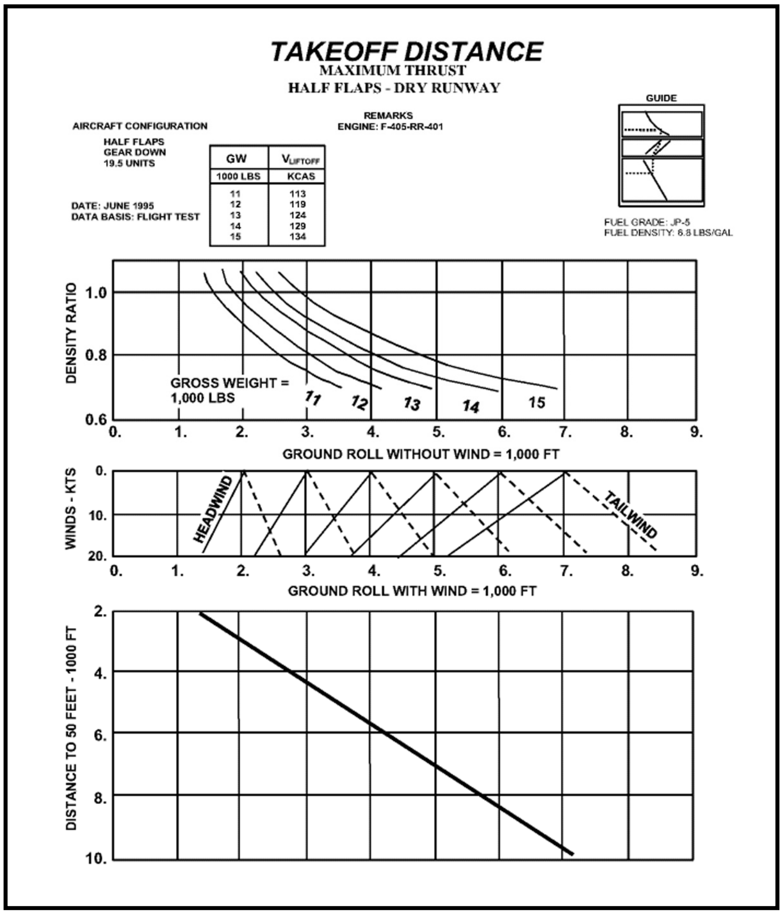


Figure 4-4 Takeoff Distance — Half Flaps

v. Extend no wind ground roll line down to headwind/tailwind graph

vi. Parallel headwind or tailwind guideline to takeoff wind velocity

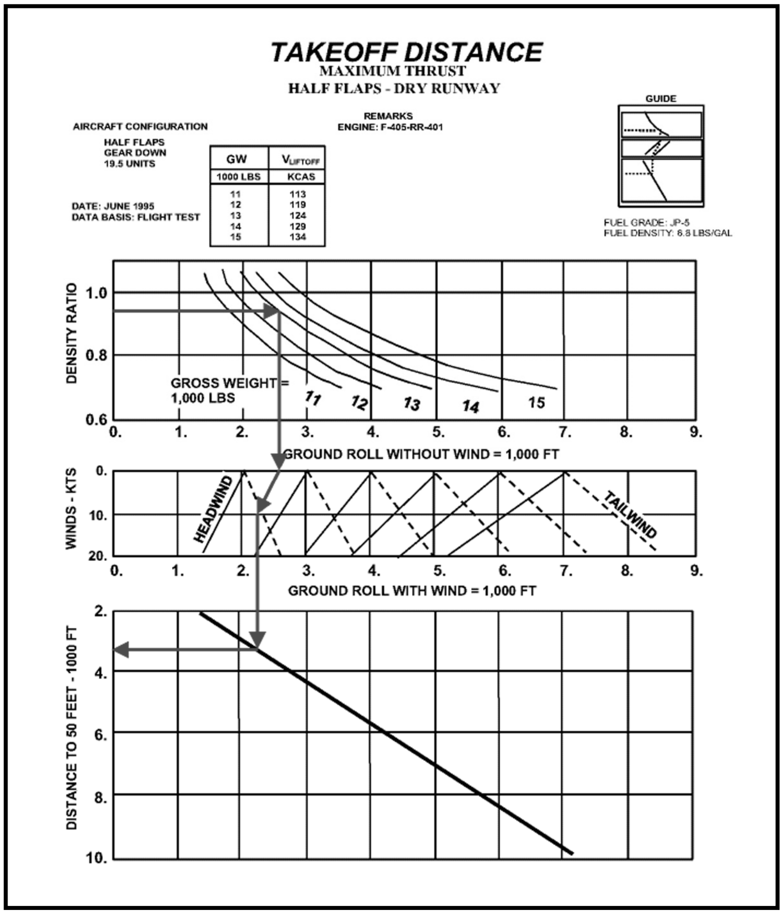
vii. From intersection of takeoff wind velocity and ground roll line, project line down vertically to determine ground roll with wind

viii. Extend ground roll with wind down to distance over 50-foot obstacle graph

ix. Continue ground roll with wind line down to reflector line

x. From intersection of ground roll with wind line and reflector line project a horizontal line to left to determine distance over a 50-foot obstacle

xi. Computing takeoff distance using NATOPS sample problem



GW 1000 LBS	$V_{LIFTOFF}$ KCAS
11	113
12	119
13	124
14	129
15	134

Figure 4-5 Takeoff Distance — Half Flaps, completed

3. Velocity during Takeoff Ground Run (Line Speed)

   a. Used to determine speed to which the aircraft should accelerate in a given distance during takeoff

   b. If aircraft does not achieve the calculated, abort Use the Velocity during Takeoff Ground Run chart to calculate the line check speed. Enter the chart with the distance from the commencement of takeoff roll to the selected object

   c. Line Speed Computation

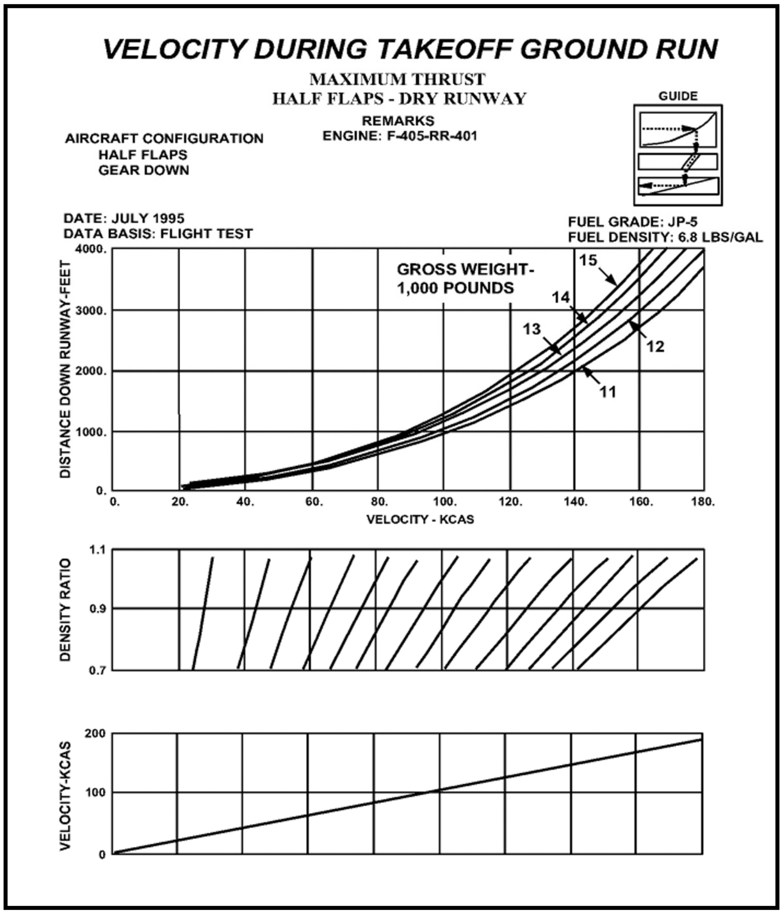


Figure 4-6 Velocity During Takeoff Ground Run

i. Enter chart at desired distance down runway

ii. Project horizontal line from desired distance down runway to gross takeoff weight reference line

iii. From intersection of desired distance down runway and gross takeoff weight reference line project vertically down to determine velocity in KCAS

iv. Extend the velocity line down to the density ration graph

v. Extend horizontal line from density scale on left

vi. Project the velocity line down parallel to the reference line to the horizontal density ratio line

vii. From intersection of velocity line and density ratio line extend line down vertically down to velocity graph

viii. Extend vertical line down to reflector line then to the left to determine ground velocity at desired distance down runway

ix. Computing takeoff distance using NATOPS sample problem

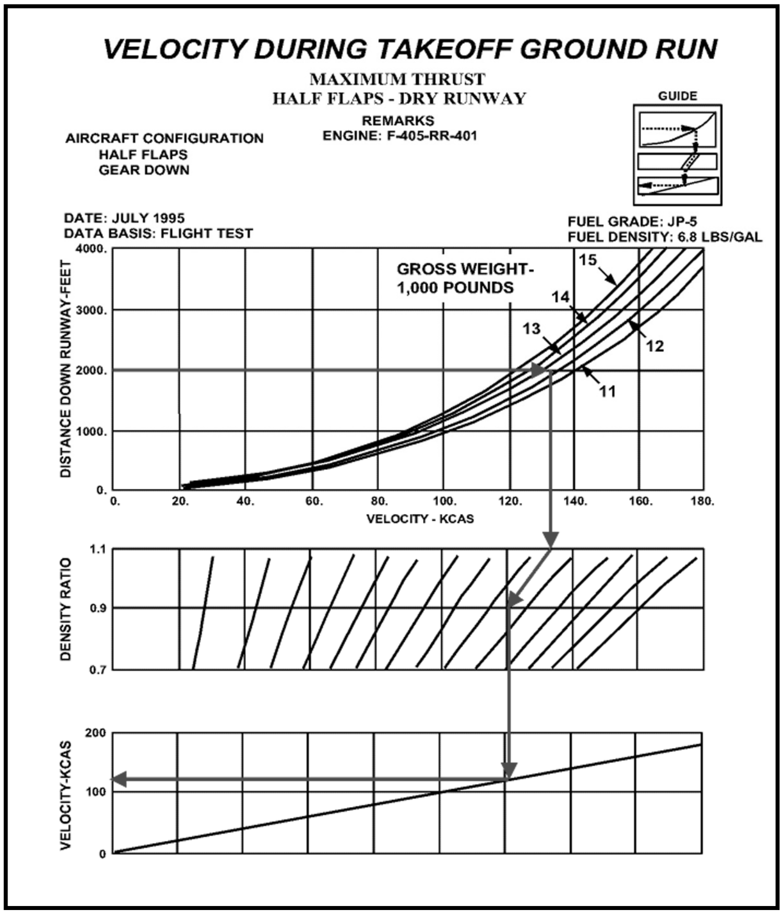


Figure 4-7 Velocity During Takeoff Ground Run

4. Maximum Abort Speed

a. Used to calculates the maximum speed to which an aircraft can accelerate and then abort on the remaining runway length

b. Individual charts for dry or wet runway

c. Maximum Abort Speed — Dry Runway Computation

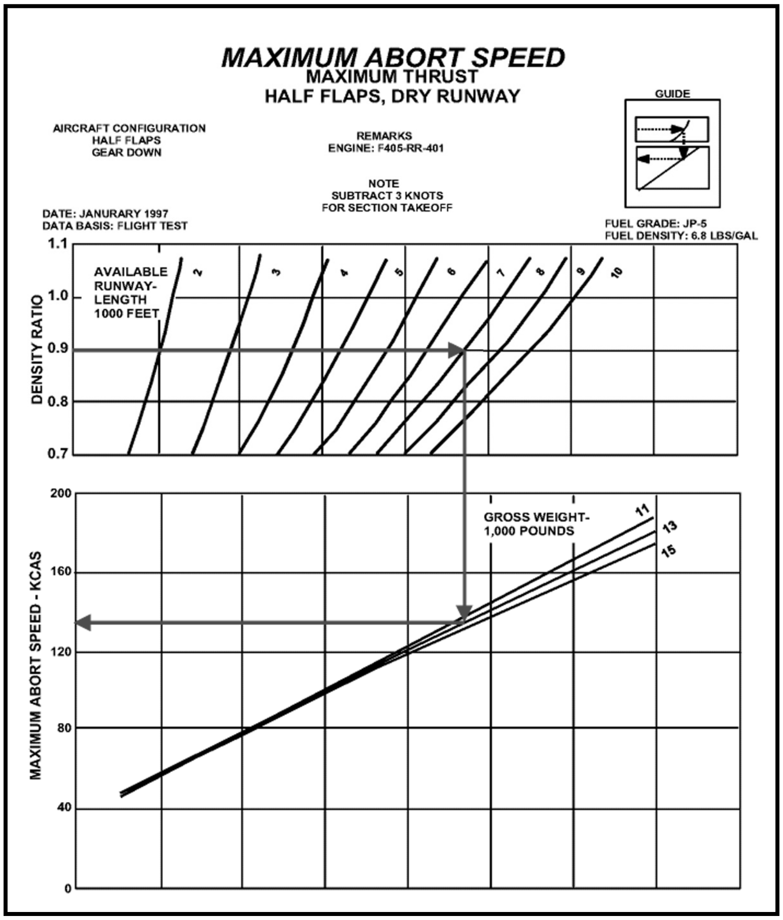


Figure 4-8 Maximum Abort Speed - DRY RUNWAY

i. Enter chart on density ratio scale

ii. From density ratio scale, project horizontal line the available runway length reference line

iii. From intersection of density ratio and available runway length reference line, extend a vertical line down to gross weight reference line on maximum abort speed chart

iv. Extend line down to gross takeoff weight line

v. From intersection of vertical reference line and gross weight reference line project a horizontal line to the left side of the graph to determine the maximum abort speed KCAS

d. Maximum Abort Speed — Wet Runway Computation

i. Enter chart on density ratio scale

ii. From density ratio scale, project horizontal line the available runway length reference line

iii. From intersection of density ratio and available runway length reference line, extend a vertical line down to gross weight reference line on maximum abort speed chart

iv. Extend line down to gross takeoff weight line

v. From intersection of vertical reference line and gross weight reference line project a horizontal line to the left side of the graph to determine the maximum abort speed KCAS

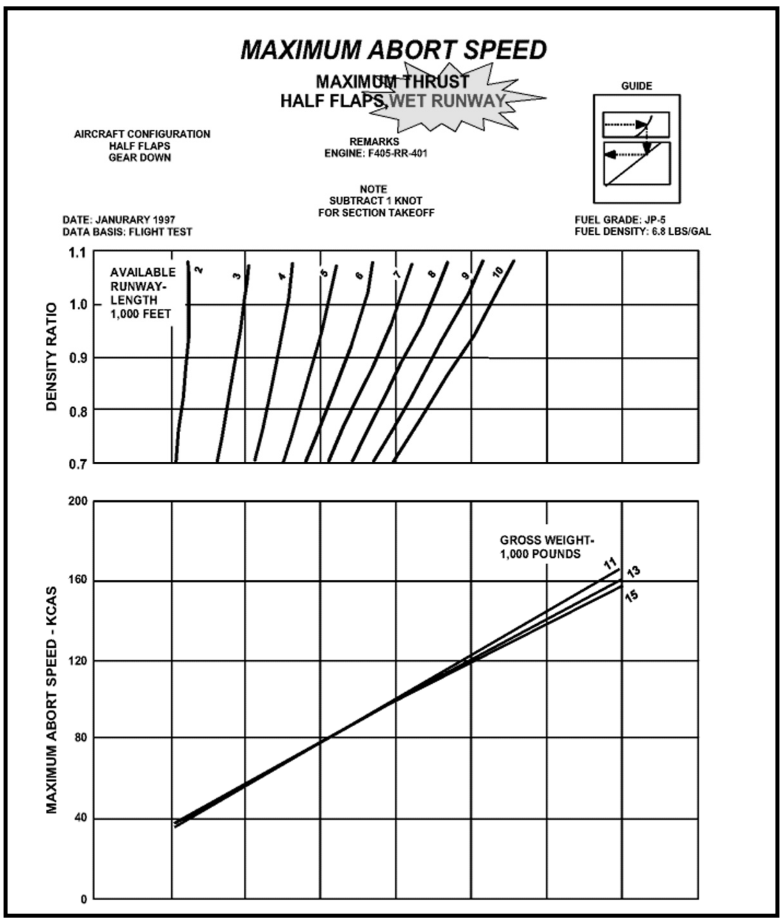


Figure 4-9 Maximum Abort Speed - WET RUNWAY

e. There is a significant decrease in maximum abort speed on a wet runway versus a dry runway

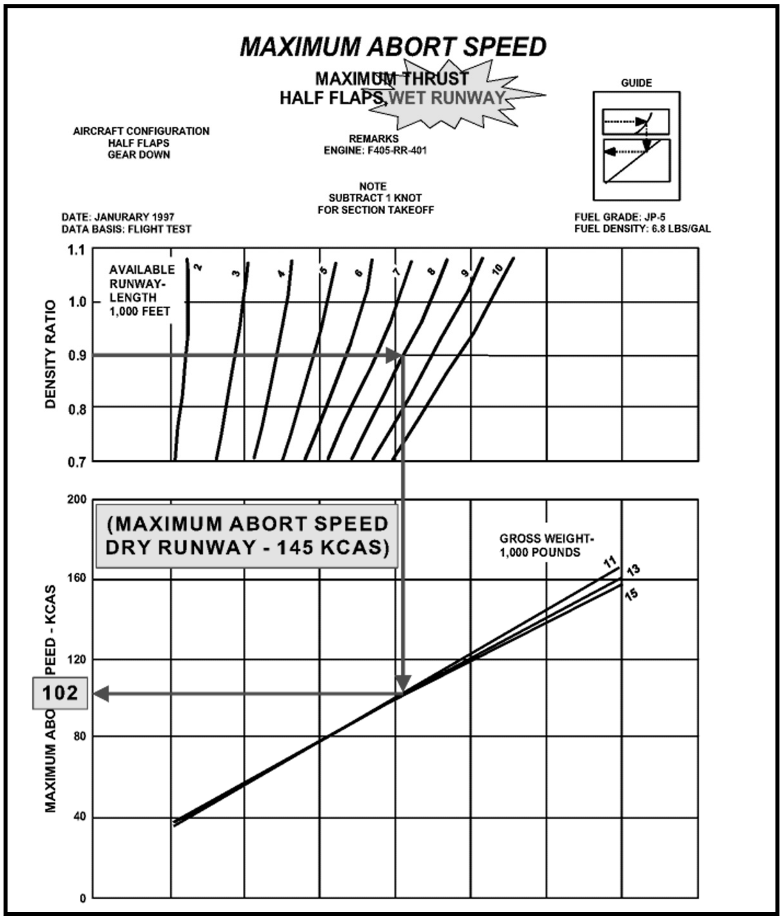


Figure 4-10 Maximum Abort Speed - WET RUNWAY

5. Compressibility Correction to Calibrated Airspeed

   a. Indicates subsonic air is compressible at higher speeds

   b. CAS and TAS gain over those computed in charts

   c. At the extreme limits of The T-45's envelope, 550 KCAS and 40,000', the compressibility correction would be 75 KCAS

   d. Under most circumstances, it will be less than half of compressibility correction at 550 KCAS

COMPRESSIBILITY CORRECTION TO CALIBRATED AIRSPEED

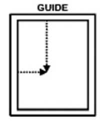
$V_{EQUIVALENT} = V_{CALIBRATED} - \Delta V_C$

AIRCRAFT CONFIGURATION
ALL

REMARKS
ENGINE: F-405-RR-400
U.S. STANDARD DAY, 1962

DATE: 15 APRIL 1990
DATA BASIS: ESTIMATED

GUIDE



CALIBRATED AIRSPEED - KNOTS

PRESSURE ALTITUDE - FEET	150	200	250	300	350	400	450	500	550	600	650	700	750	800
5,000	0	0	1	2	2	3	5	6	8	10	12	13	13	14
10,000	0	1	2	3	5	7	10	13	17	21	24	25	26	26
15,000	1	2	3	5	8	12	17	23	31	32	36	37	38	37
20,000	1	3	5	8	12	17	23	31	37	43	47	49	49	48
25,000	2	4	7	11	17	24	32	41	48	54	57	58	58	57
30,000	2	5	9	15	23	32	41	50	58	63	66	67	67	65
35,000	3	7	12	20	29	40	50	59	67	72	75	75	76	72
40,000	4	9	16	25	37	48	59	68	75	80	82	82	80	78
45,000	5	11	20	32	44	56	66	74	82	88	88	87	86	83
50,000	7	14	25	33	50	62	72	81	86	90	92	91	90	87
55,000	8	18	30	44	56	68	77	85	91	94	96	95	93	90
60,000	10	21	36	49	61	72	81	89	94	98	99	99	96	93

Figure 4-11 Compressibility Correction to Calibrated Airspeed

6. Climb Speed Schedule

   a. Determine climb speed for combination of drag index and pressure altitudes

   b. Simplified normal climb speed schedule, independent of weight, in constant indicated airspeed or Mach number

CLIMB SPEED SCHEDULE

AIRCRAFT CONFIGURATION
VARIOUS DRAG INDEXES
GEAR UP, FLAPS UP

MAXIMUM RATED THRUST
REMARKS

DATE: JANURARY 1997
DATA BASIS:**FLIGHT TEST**

ENGINE: F405-RR-401
U.S. STANDARD DAY, 1962

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LBS/GAL

PRESSURE ALTITUDE (Feet)	AIRCRAFT DRAG INDEX 0		50		100		150	
	KIAS	MACH	KIAS	MACH	KIAS	MACH	KIAS	MACH
SL	300	.45	265	.40	245	.37	235	.36
5,000	300	.49	265	.44	245	.40	235	.39
10,000	300	.54	265	.48	245	.44	235	.43
15,000	300	.59	265	.53	245	.49	235	.47
20,000	300	.65	265	.58	245	.54	235	.52
25,000	300	.72	265	.64	245	.59	227	.55
30,000	283	.75	263	.70	223	.60	203	.55
35,000	253	.75	235	.70	199	.60	181	.55
40,000	225	.75	209	.70	177	.60	161	.55

NOTE: Climb speed schedule is based on maximum rate of climb.

Figure 4-12 Climb Speed Schedule

7. Time, Fuel, and Distance to Climb

   a. Charts used to determine time, fuel, or distance required to climb to selected altitude at MRT and using Climb Speed Schedule

   b. All three charts presented in similar manner

   c. Time to climb computation

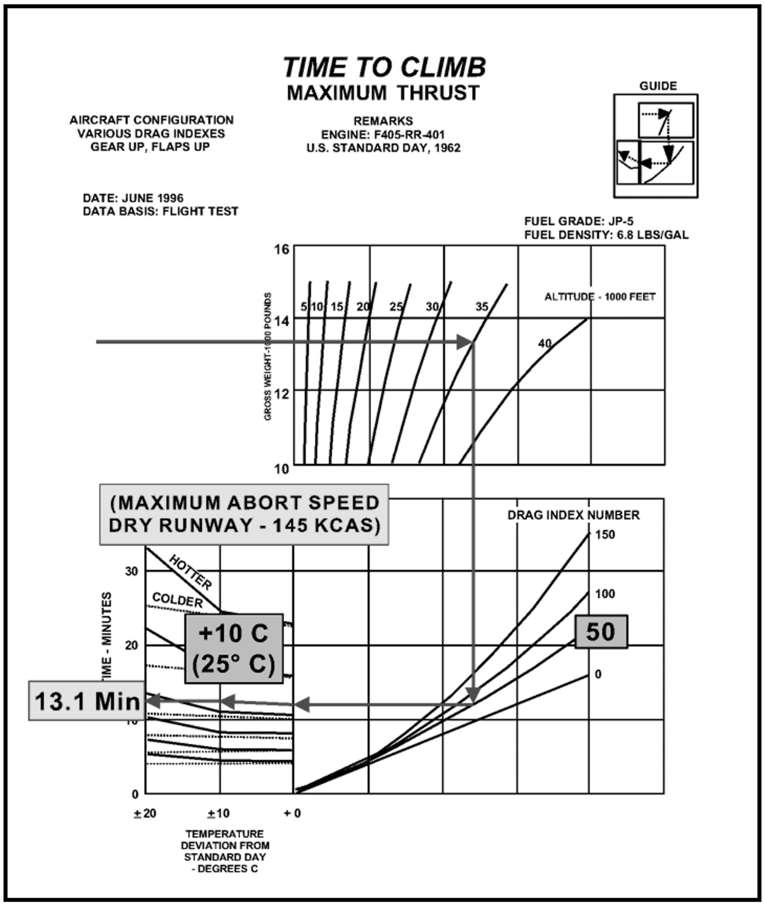


Figure 4-13 Time to Climb

i. Enter chart with initial gross weight

ii. Project horizontally from initial gross weight to desired pressure altitude reference line

iii. From intersection of initial gross weight and pressure altitude reference line project vertically down to drag index reference line

iv. From intersection of the vertical line and the drag index reference line project horizontally left to the zero temperature deviation from standard day line

v. From the zero temperature deviation from standard day line parallel the hotter or colder guide line to the temperature deviation from standard day line

vi. From the temperature deviation from standard day line project a line horizontally to the left of the graph to determine time, fuel or distance to climb as appropriate

d. The time, fuel and distance to climb charts take into account the kinetic energy corrections due to rate of climb

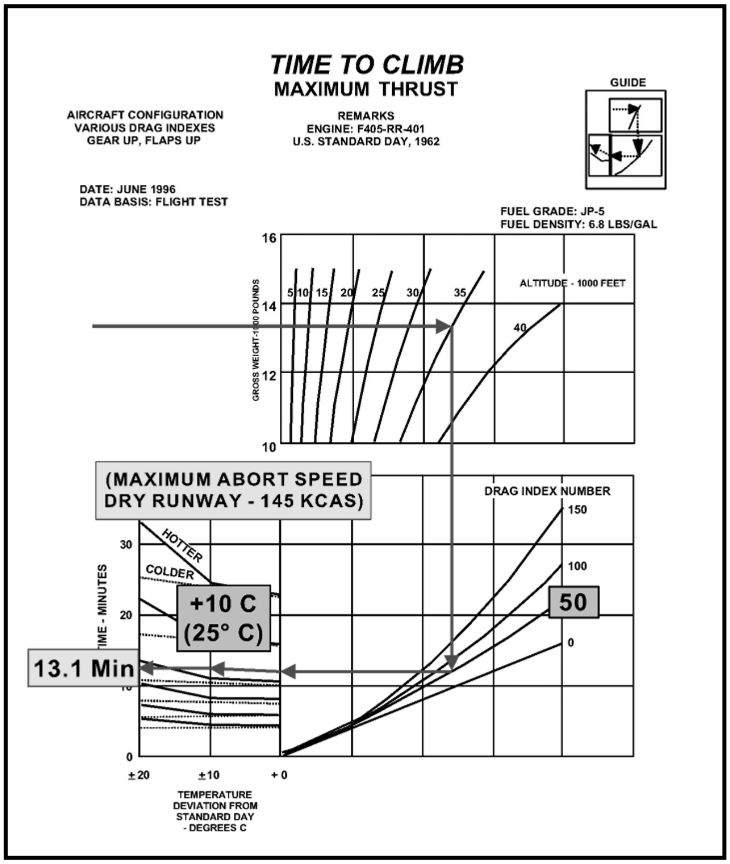


Figure 4-14 Time to Climb

6. Bingo

a. Bingo charts located in NATOPS manual and pocket checklist

b. T-45 bingo based on flying profile and landing with a fuel reserve of 300 pounds, no wind

c. Bingo used to go to divert airfield due to carrier deck not ready or runway closed

d. Used to determine fuel, time and speed for bingo profile or sea level divert for various zero fuel weights, configurations and drag indexes

e. BINGO computation

BINGO

GEAR UP - FLAPS UP

ZERO FUEL WEIGHT - 10,500 POUNDS

REMARKS

DATE: JUNE 1995
DATA BASIS: FLIGHT TEST

ENGINE: F-405-RR-401
U.S. STANDARD DAY, 1962

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LBS/GAL

	MAXIMUM RANGE CRUISE									SEA LEVEL CRUISE		
	DIST TO BASE	FUEL REQD	TIME REQD	CLIMB SPEED	CRUISE ALT	CRUISE SPEED		DESCEND SPEED	DESCEND DIST	FUEL REQD	TIME REQD	CRUISE SPEED
	NM	LB	MIN	KCAS	FEET	KCAS	IMN	KCAS	NM	LB	MIN	KCAS
DRAG INDEX = 0	25	421	7		5,000	217	.36		14	429	7	220
	50	529	13		10,000	219	.40		27	559	14	221
	75	626	19		15,000	217	.43		40	690	20	221
	100	714	24	300	20,000	217	.48		54	820	27	222
	125	796	29	Knots/	25,000	223	.54	180	67	952	34	222
	150	871	33	0.75	30,000	220	.59		80	1,083	40	223
	175	938	37	Mach	35,000	218	.65		93	1,216	47	224
	200	1,002	41		35,000	218	.65		93	1,349	53	224
	225	1,066	45		35,000	218	.65		93	1,482	60	225
	250	1,128	48		40,000	211	.71		107	1,616	66	226
DRAG INDEX = 50	25	434	7		5,000	212	.35		12	441	7	214
	50	553	14		10,000	211	.38		24	582	14	215
	75	658	20		15,000	212	.42		36	724	21	216
	100	753	25	265	20,000	212	.47		48	867	28	216
	125	841	30	Knots/	25,000	211	.51	170	60	1,010	35	216
	150	926	35	0.70	25,000	212	.51		60	1,153	42	217
	175	1,003	38	Mach	35,000	208	.63		83	1,297	48	217
	200	1,075	42		35,000	208	.63		83	1,442	55	218
	225	1,148	46		35,000	209	.63		83	1,587	62	218
	250	1,221	50		35,000	209	.63		83	1,733	69	219
DRAG INDEX = 100	25	445	8		5,000	207	.34		11	452	7	209
	50	574	14		10,000	205	.37		22	604	14	209
	75	687	20		15,000	207	.41		32	757	21	210
	100	789	26	245	20,000	206	.45		43	911	28	211
	125	883	30	Knots/	30,000	196	.53	165	64	1,066	36	211
	150	969	35	0.60	30,000	197	.53		64	1,221	43	212
	175	1,051	39	Mach	35,000	195	.59		75	1,377	49	212
	200	1,132	44		35,000	196	.59		75	1,533	56	213
	225	1,212	48		35,000	196	.59		75	1,690	63	213
	250	1,294	52		35,000	196	.59		75	1,848	70	214
DRAG INDEX = 150	25	455	8		5,000	203	.34		10	462	7	204
	50	592	15		10,000	201	.36		20	624	15	205
	75	712	21		20,000	199	.44		39	787	22	205
	100	820	26	235	25,000	197	.48		49	951	29	206
	125	917	31	Knots/	30,000	189	.51	160	59	1,116	36	207
	150	1,009	36	0.55	30,000	189	.51		59	1,281	43	207
	175	1,101	41	Mach	30,000	189	.51		59	1,447	51	208
	200	1,191	45		35,000	187	.56		68	1,615	58	208
	225	1,281	49		35,000	187	.57		68	1,783	65	209
	250	1,372	54		35,000	188	.57		68	1,952	72	210

NOTES:
1. FUEL REQUIRED INCLUDES 300 LBS RESERVE FUEL
2. INITIAL ALTITUDE IS SEA LEVEL
3. MAXIMUM THRUST CLIMB TO CRUISE ALTITUDE
4. IDLE THRUST MAXIMUM RANGE DESCENT TO SEA LEVEL (SPEEDBRAKES RETRACTED)

Figure 4-15 BINGO, Gear Up - Flaps Up, Zero Fuel Weight - 10, 500 Pounds

i. Enter with the distance to divert field and appropriate drag index

ii. In succeeding columns, read fuel required, time required, climb speeds, optimum range cruise, and maximum range descent

iii. Notes are important to flying proper profile

NOTE

Bingo charts fuel requirement includes 300 pounds fuel reserve. This reserve fuel is yours to burn if circumstances warrant. It will be on your fuel gauge but only should be used in an emergency. Anticipate that a runway might be closed suddenly and for a long period.

iv. Sea level divert data is included in last three columns

f. The NATOPS bingo charts have one deficiency. Winds are not considered

i. You must factor winds into chart data

ii. Use briefed or known winds

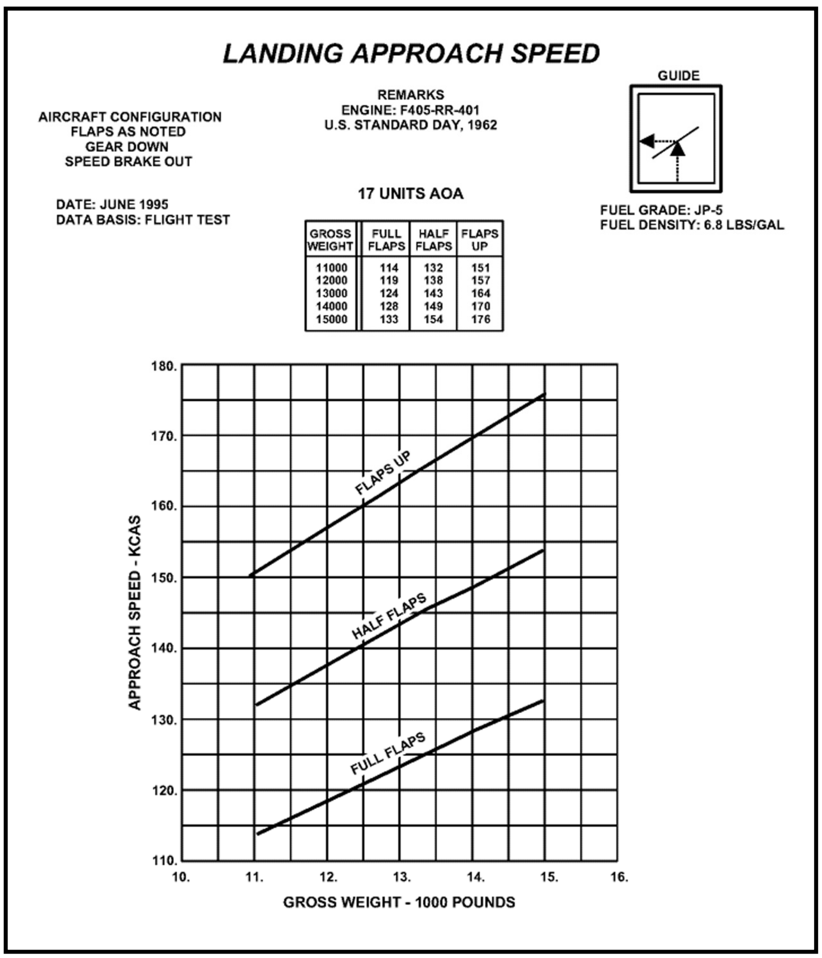
iii. Mentally or on the wheel (EGB computer) determine headwind component

iv. With significant headwind component, 60 knots for example, select higher mileage line on bingo chart and fly that profile

7. Landing Approach Speed

a. Calculates a steady 17 units angle of attack approach speed for a gross weight

b. Calculate the gross weight from



GROSS WEIGHT	FULL FLAPS	HALF FLAPS	FLAPS UP
11000	114	132	151
12000	119	138	157
13000	124	143	164
14000	128	149	170
15000	133	154	176

Figure 4-16 Landing Approach Speed

i. Zero fuel weight of particular bureau number aircraft

ii. Weight of external stores

iii. Fuel on board

c. Landing Approach Speed calculation

i. Approach speed matrix at top of chart

ii. Approach speed matrix in thousand of pound increments

iii. Enter approach speed graph with this total weight

iv. From total weight go up to the appropriate flap configuration line

v. From the flap reference line project a line to the left for the 17 units AOA approach speed in KCAS

vi. The weight to speed relation is a constant; each 200 pounds change in weight increases or decreased approach speed by 1 knot

vii. Each increment of flaps less than full flaps adds 18 knots to the approach speed

viii. 17 units angle of attack to airspeed calculation used to cross check these to indications

ix. If airspeed doesn’t correspond to calculation, fly 17 units or calculated airspeed whichever is the higher airspeed

NOTE

The LSO can verify approach speed from the aircraft attitude on approach.

8. Landing Distance

a. Used to determine landing ground roll distance for

i. Various flap configurations

ii. Gross weights

iii. Runway conditions dry, wet or icy

iv. Density ration (temperature and pressure altitude)

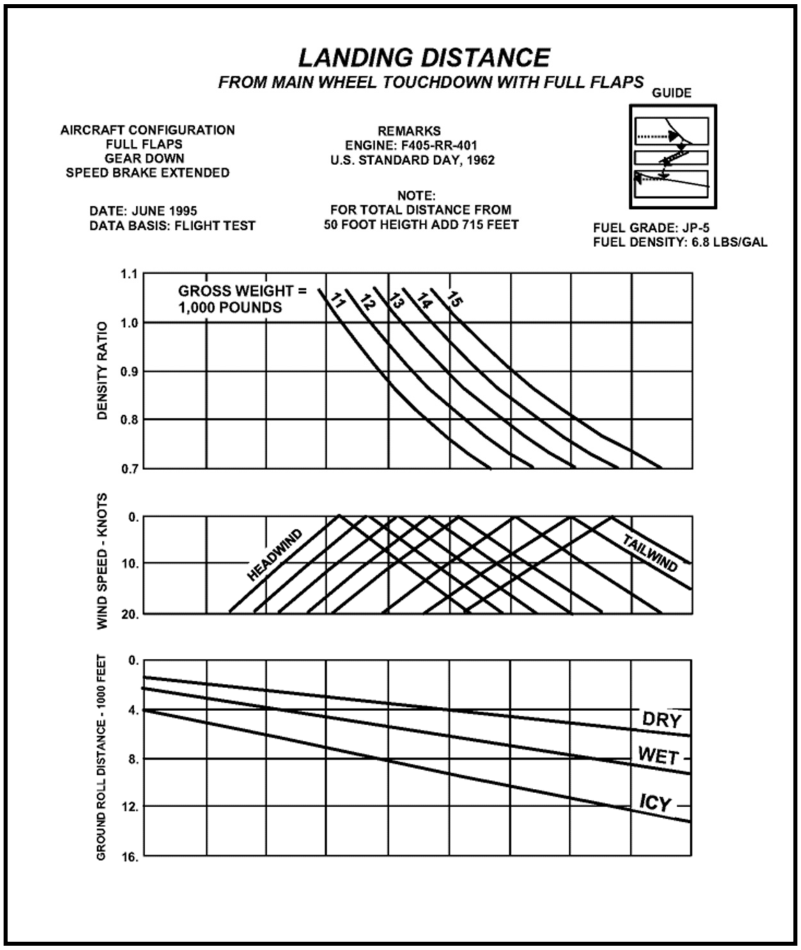


Figure 4-17 Landing Distance

b. Landing distance data is for a normal 17-unit AOA approach and landing using moderate braking coefficients

c. Landing Distance Computation

i. Enter chart with the density ratio

ii. Extend line horizontally from density ratio to approach gross weight line

iii. From the intersection of the density ratio line and approach gross weight line extend a line vertically down to the wind speed graph

iv. From the wind speed baseline, parallel the nearest headwind or tailwind guideline down to the appropriate headwind or tailwind component in knots

v. From the intersection of the line paralleling the guideline and the headwind or tailwind component project a line down vertically to the ground roll distance graph

vi. Continue the line down to the appropriate runway condition reference line

vii. From the intersection of the vertical line and runway condition reference line, project a horizontal line to the left to determine ground roll

d. For total landing distance from 50 feet over the runway, add 715 feet to computed ground roll distance, e.g. crossing approach end of runway at 50 feet

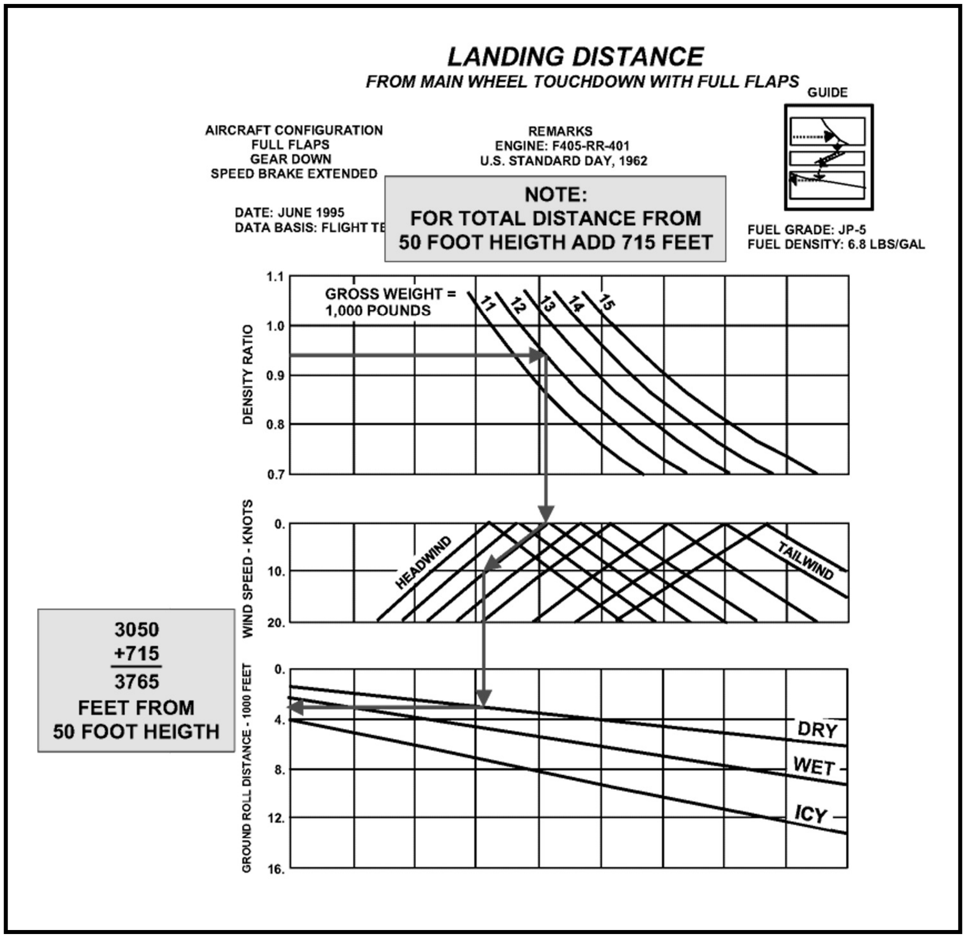


Figure 4-18 Landing Distance

9. Dive Recovery

a. This chart is used to compute the altitude loss during a dive recovery

b. Altitude loss based on a dive recovery with a 2 g per second buildup to a sustained 4-g's or maximum usable lift

c. Dive recovery computation

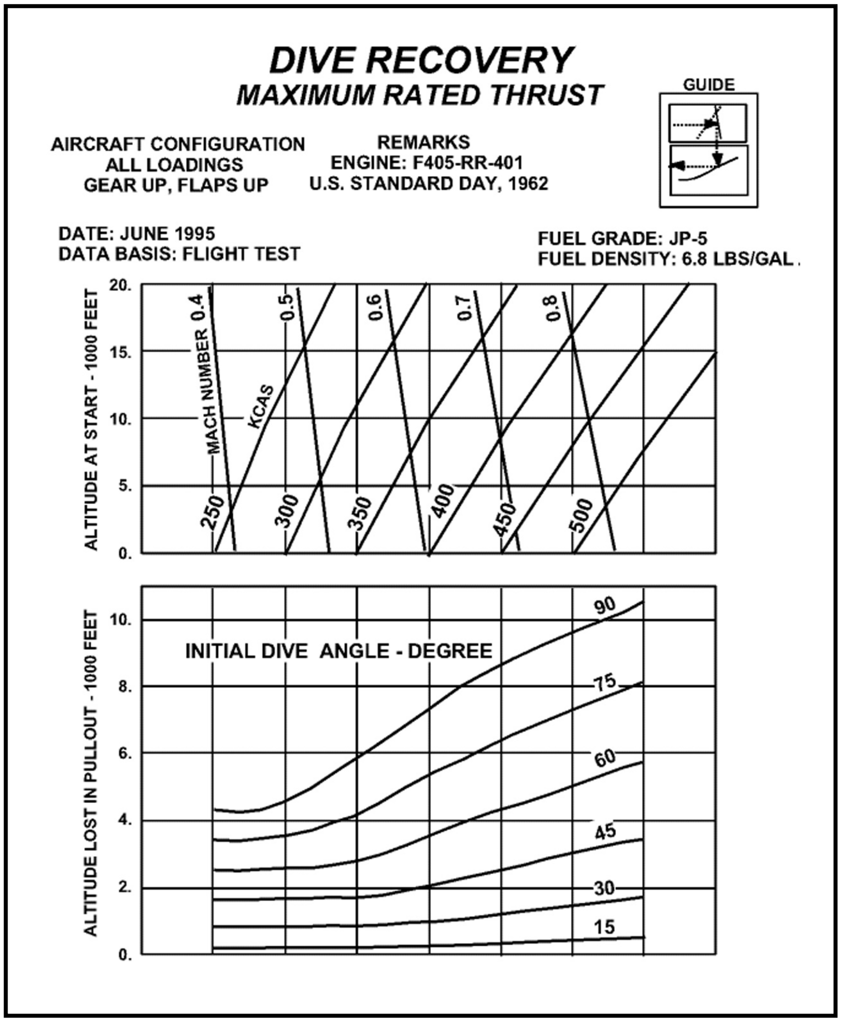


Figure 4-19 Dive Recovery

i. Enter chart at altitude at start of dive recovery

ii. Extend horizontal line from altitude at start of dive recovery to the Mach number or airspeed at start of dive recovery reference line

iii. From the intersection of the altitude line and Mach number or airspeed reference line extend a vertical line down to the initial dive-angle reference line

iv. From the intersection of the vertical line and the initial dive angle reference line extend a line horizontally to the left to determine altitude lost in the pullout

d. Subtract altitude lost during pullout from the altitude the pullout was initiated at to find the minimum altitude after pullout

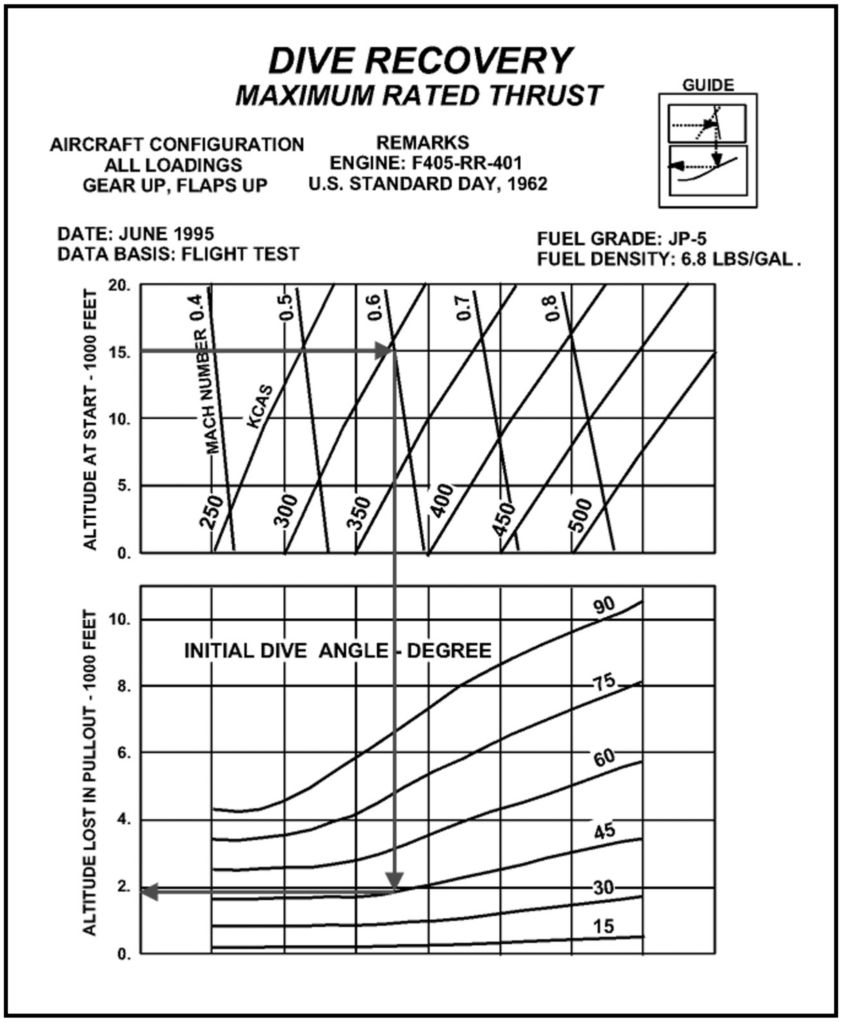


Figure 4-20 Dive Recovery

10. Operating Envelope

a. T-45 operating Envelope is a graphic representation of the airspeed and altitude limits

b. Portions of the envelope impose additional restrictions on throttle movement and position

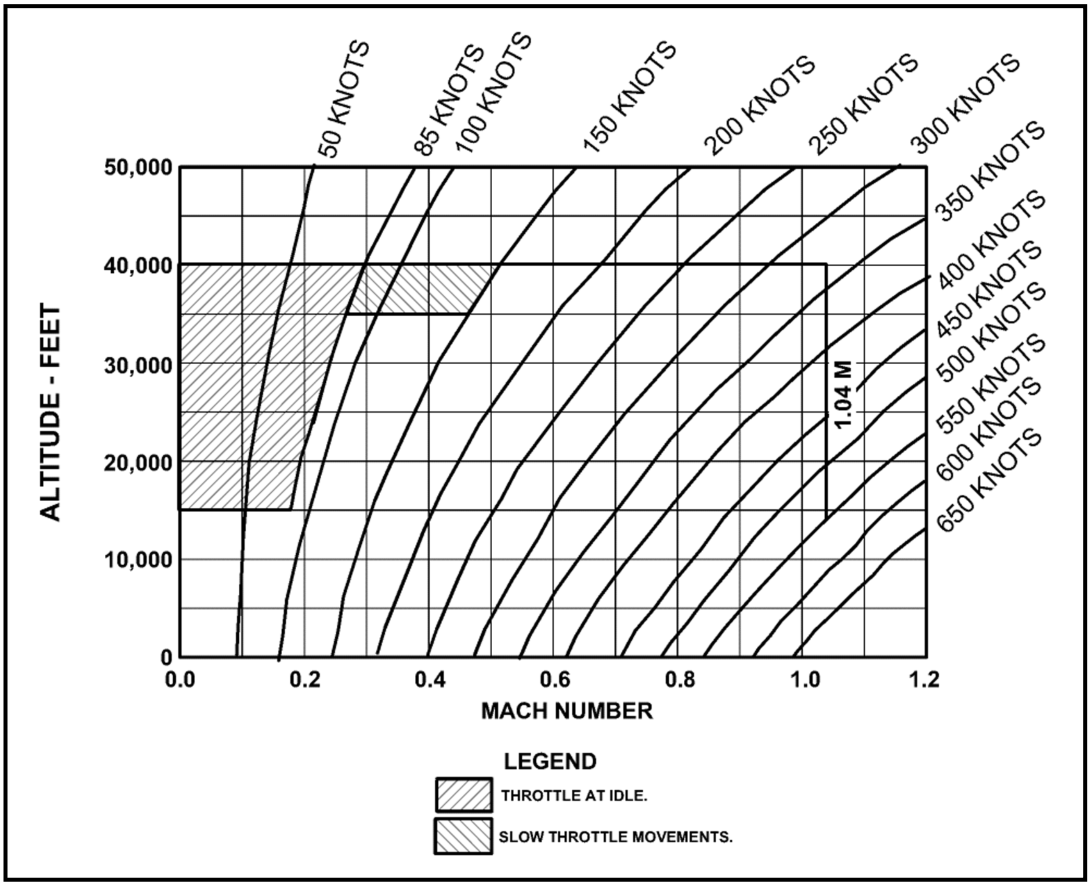


Figure 4-21 Operating Envelope

11. Acceleration Limits

a. Symmetrical and unsymmetrical maneuvering limits are shown graphically

b. Depicts the T-45 load limits under various conditions

i. Gross weight

ii. Altitude

iii. Airspeed

c. Unsymmetrical maneuvers are rolling maneuvers at other than 1-G flight

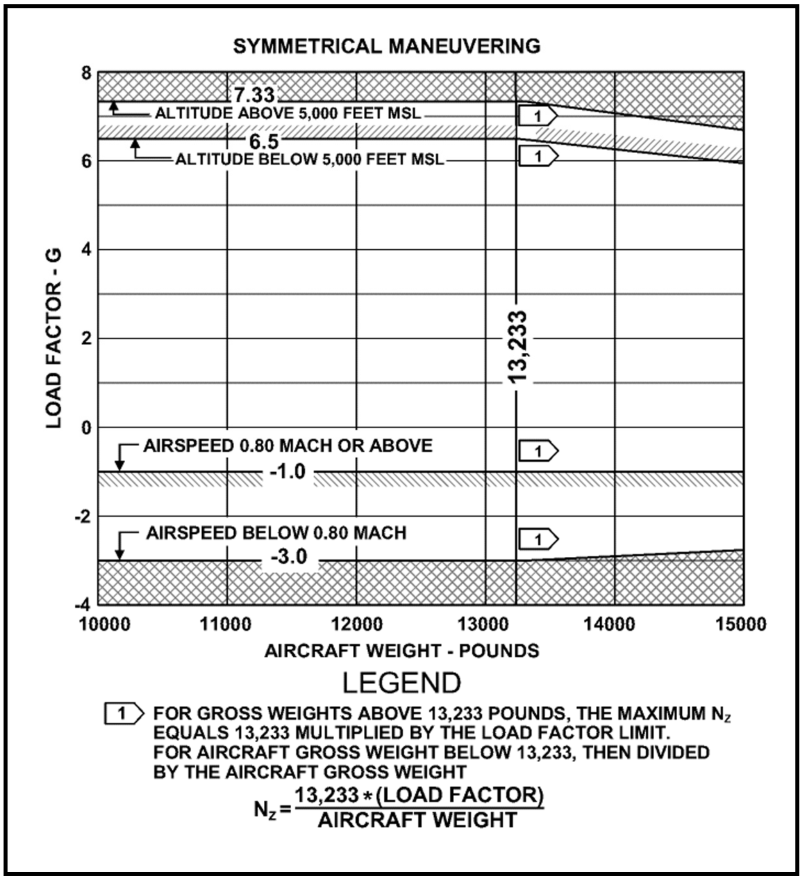


Figure 4-22 T-45 Acceleration Limits

12. External Stores Limitations

    a. Matrix shows specific external stores limitations for

        i. Station loading

        ii. Airspeed

        iii. Acceleration

        iv. Dive angle

        v. AOA

        vi. Center of gravity

LBA - LIMIT BASIC AIRCRAFT

STORE	DISTANCE FROM AIRCRAFT CENTERLINE - INCHES / STATION LOADING AND SUSPENSION			AIRSPEED - MAXIMUM KNOTS OR MACH WHICHEVER IS LESS			ACCELERATION - G				MAXIMUM DIVE ANGLE (DEGREES)	ANGLE OF ATTACK LIMITS (UNITS)	CG LIMITS % MAC	CONFIGURATION WEIGHTS (LBS)	APPLICABLE NOTES
							CARRIAGE		JETTISON						
	RIGHT	CENTER	LEFT	CARRIAGE	JETTISON	RELEASE	SYM	UNSYM	JETTISON	RELEASE					
PYLON				525/ 0.80	-	-	LBA	LBA	-	-	LBA	LBA	LBA	Wing/77	1. 2. 3.
PMBR WITH 0 TO 6 MK-76 BOMBS				525/ 0.80	300	450/ 0.80	LBA	LBA	1.0	0.7 to 1.0	45	LBA	LBA	PMBR/67 MK76/25 each	
LAU-68 WITH 0 TO 7 2.75" FFAR				525/ 0.80	200 TO 350	450/ 0.80 MIN A\S 350 MAX ALT 10,000 FTMSL	LBA	LBA	1.0	0.7 to 1.0	45	LBA	LBA	LAU-68/85 FFAR/21 each	
MIXED LOAD LAU-68 WITH 0 TO 7 2.75" FFAR AND PMBR WITH 0 TO 6 MK-76 BOMBS				525/ 0.80	300	450/ 0.80 FFAR MIN A\S 350 MAX ALT 10,000 FTMSL	LBA	LBA	1.0	0.7 to 1.0	45	LBA	LBA	PMBR/87 MK76/25 each LAU-68/85 FFAR/21 each	1. 2. 3.

NOTES

1. MIXED WING-MOUNTED STORES OR PYLONS CONFIGURATIONS ARE AUTHORIZED.
2. EITHER LEFT OR RIGHT WING STATION.
3. WING-MOUNTED STORES OR PYLONS MAY BE CARRIED SYMMETRICALLY OR ASYMMETRICALLY. MOST RESTRICTIVE LIMITATIONS APPLY.

Figure 4-23 External Stores Limitations

NOTE

Some limitations are listed as "LBA" or Limit Basic Aircraft. This means that limitations are the same as the basic aircraft limitations.

b. Also shown

i. Stores weight

ii. Applicable notes

LESSON NOTES

Remember to bring the T-45C NATOPS to the Aerodynamics exam (Aero-07X).

405. SUMMARY

This lesson has focused on the following topics:

1. NATOPS performance charts section layout

2. Techniques

3. NATOPS charts

406. CONCLUSION

Having practiced working the charts, you are now prepared to use the NATOPS charts for preflight planning and apply prescribed operating procedures for optimum effectiveness of your aircraft.

APPENDIX A
GLOSSARY

A100. INTRODUCTION – N/A

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