Complex / High-Performance Transition Training

April 2024

Ben Ndahi

Mission

- **Statement**
  - To provide an overview of complex and high-performance aircraft theory and provide the prerequisite ground training required to successfully achieve a complex and/or high-performance endorsement with minimum flight time required.

- **Overview**
  - 3 Sessions
  - 1.0 hrs duration

Definitions

- **High-Performance Airplane**
  - Airplane with engine capable of developing > 200 hp

- **Complex Airplane**
  - Airplane with retractable gear, flaps, and controllable pitch prop
  - In lieu of controllable pitch prop, could also have engine control system consisting of digital computer and associated accessories for controlling engine and prop, ie. FADEC

  - Note: Seaplane considered complex if it meets description above except has floats instead of a retractable landing gear

Airfoils

➢ Airfoil Types

- Straight
- Elliptical
- Tapered
- Delta
- Swept

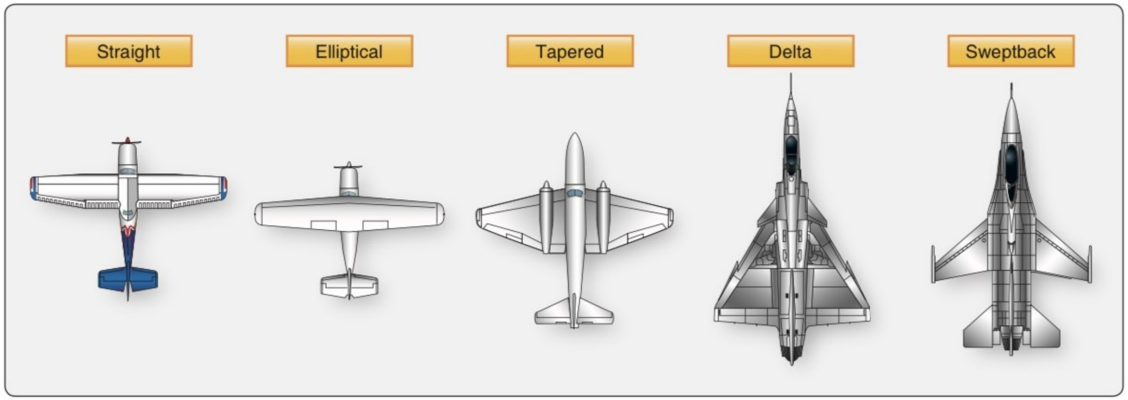


Figure 11-1. *Airfoil types.*

➢ Mission Specific Design

- High speed requires smaller wing areas and moderately cambered airfoils
- Low speed requires airfoils with greater camber and larger wing area.
- Design compromises made to balance high speed cruise and low speeds for landing

➢ Pilot Demands

- Increased performance requires additional planning, judgment, and skill

Airfoil Types

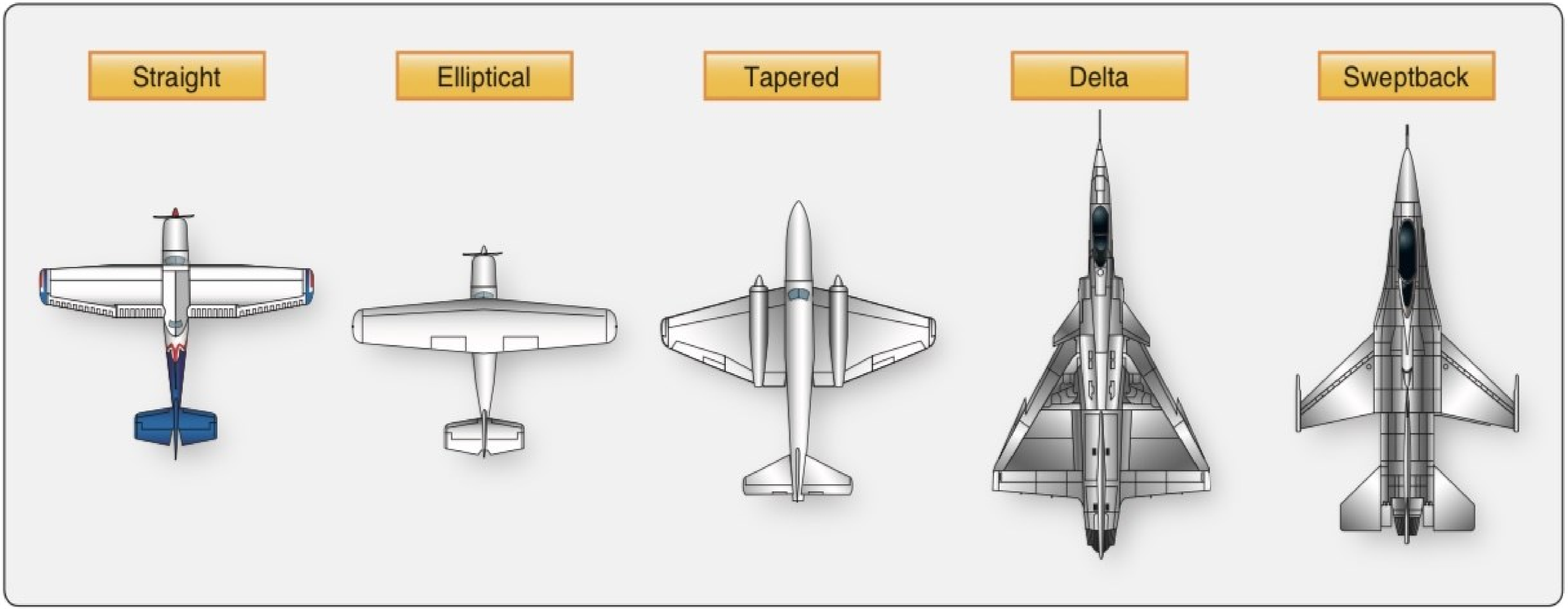
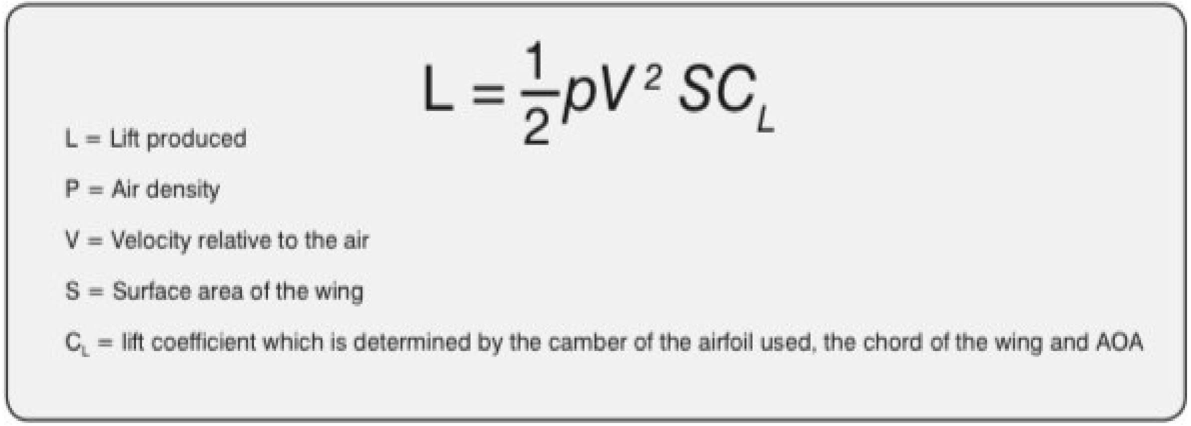


Figure 11-1. *Airfoil types.*

Flaps

➢Purpose

- Increase an airfoils camber and wing surface area
- Improve low speed flight characteristics



$$L = \frac{1}{2} pV^2 SC_L$$

L = Lift produced

P = Air density

V = Velocity relative to the air

S = Surface area of the wing

C_L = lift coefficient which is determined by the camber of the airfoil used, the chord of the wing and AOA

Figure 11-3. *Lift equation.*

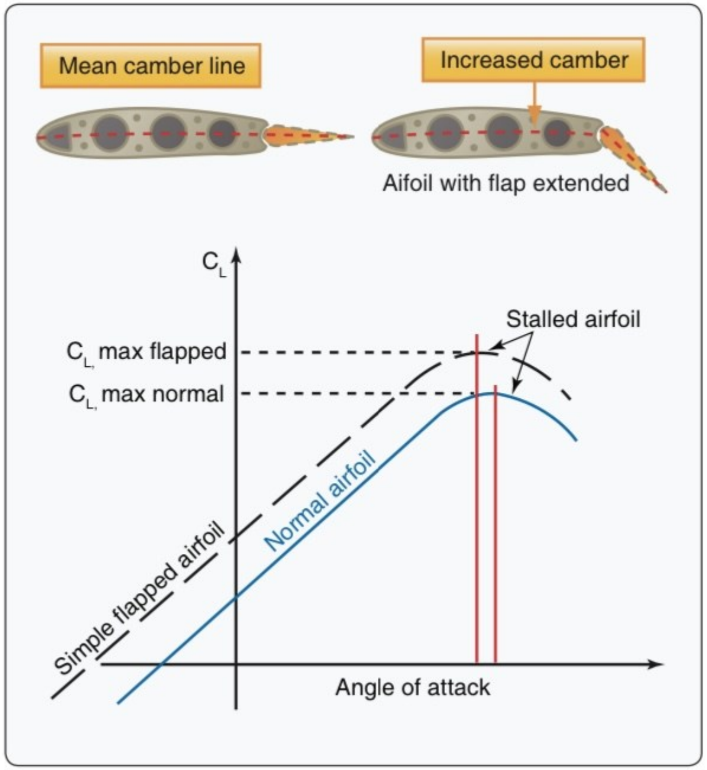


Figure 11-2. *Coefficient of lift comparison for flap extended and retracted positions.*

Flaps (cont)

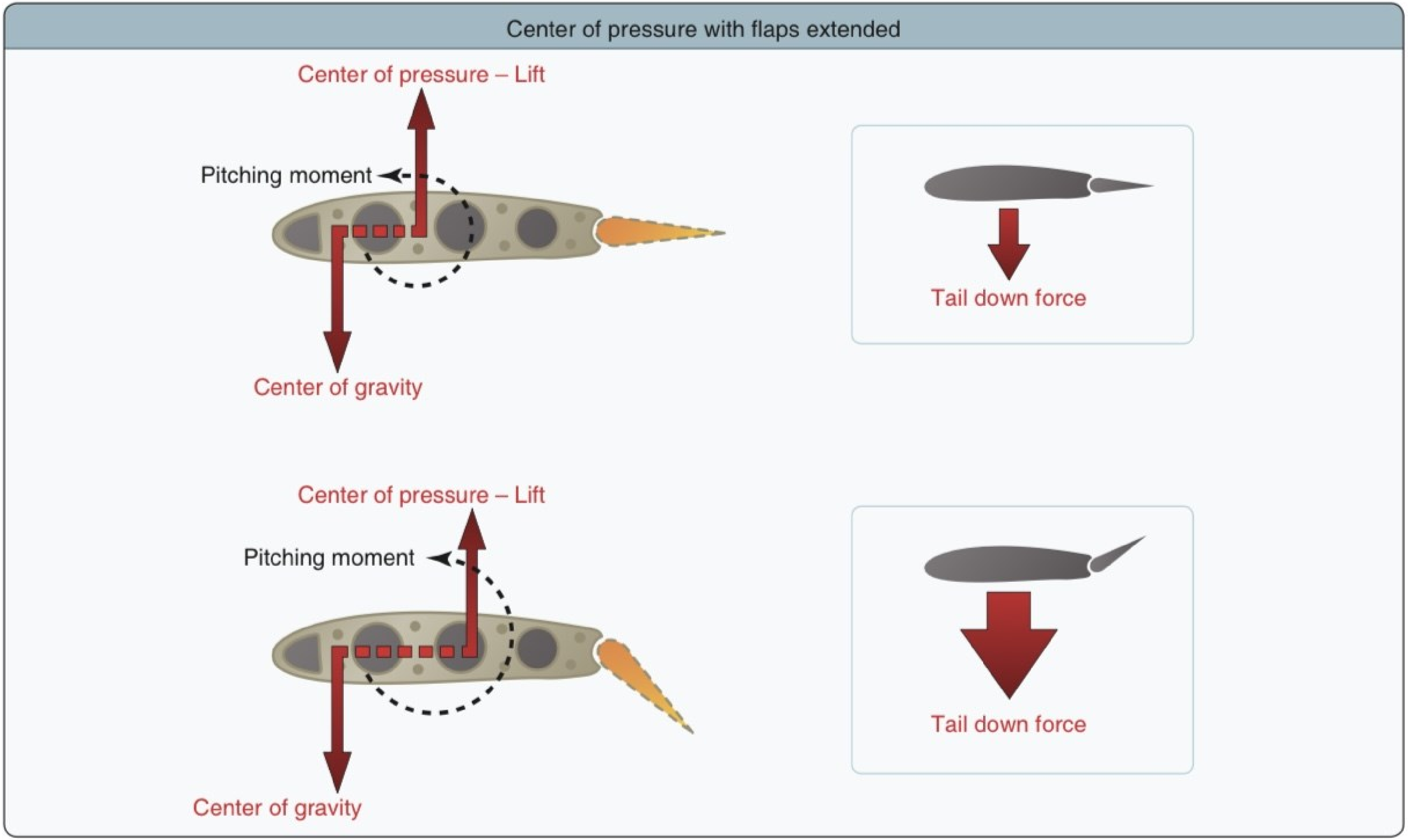


Figure 11-5. *Flaps extended pitching moment.*

Flap Types

➢Plain or Hinge Flap

- Hinged section of the wing
- Structure and function comparable to other controls

➢Split Flap

- More complex
- On lower or underside portion of wing
- Leaves upper trailing edge of wing undisturbed
- More effective than hinge flap because of greater lift and less pitching moment
- But creates more drag
- More useful for landing, but partially deflected hinge flaps have the advantage in takeoff
- Significant drag at small deflections, whereas the hinge flap does not because airflow remains “attached” to flap

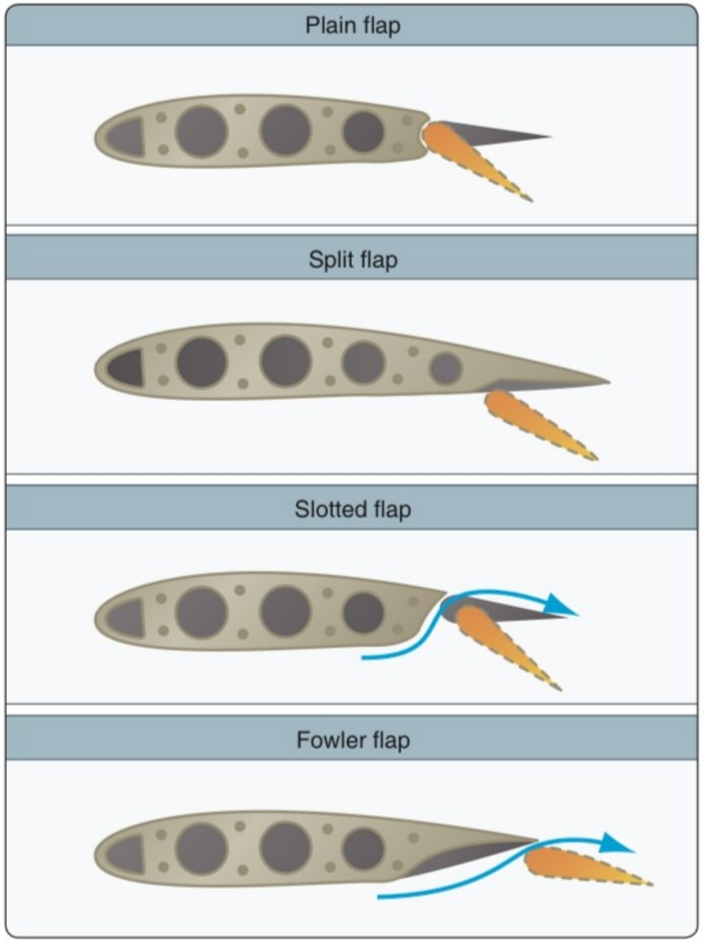


Figure 11-4. *Four basic types of flaps.*

Flaps Types (cont)

Slotted flap

- Has gap between wing and leading edge of flap
  - Allows high-pressure airflow on wing undersurface to energize lower pressure over top
  - Delays flow separation
- Greater lift than hinge flap but less than split flap
- Higher lift-drag ratio gives better takeoff and climb performance
- Small deflections give higher drag than hinge flap but less than split
  - Allows the slotted flap to be used for takeoff

Fowler flap

- Deflects down and aft to increase wing area.
  - Can be multi-slotted making it the most complex
  - Gives maximum lift coefficient.
  - Drag at small deflections like slotted flap.
  - Commonly used on larger airplanes because of their structural complexity and difficulty in sealing the slots

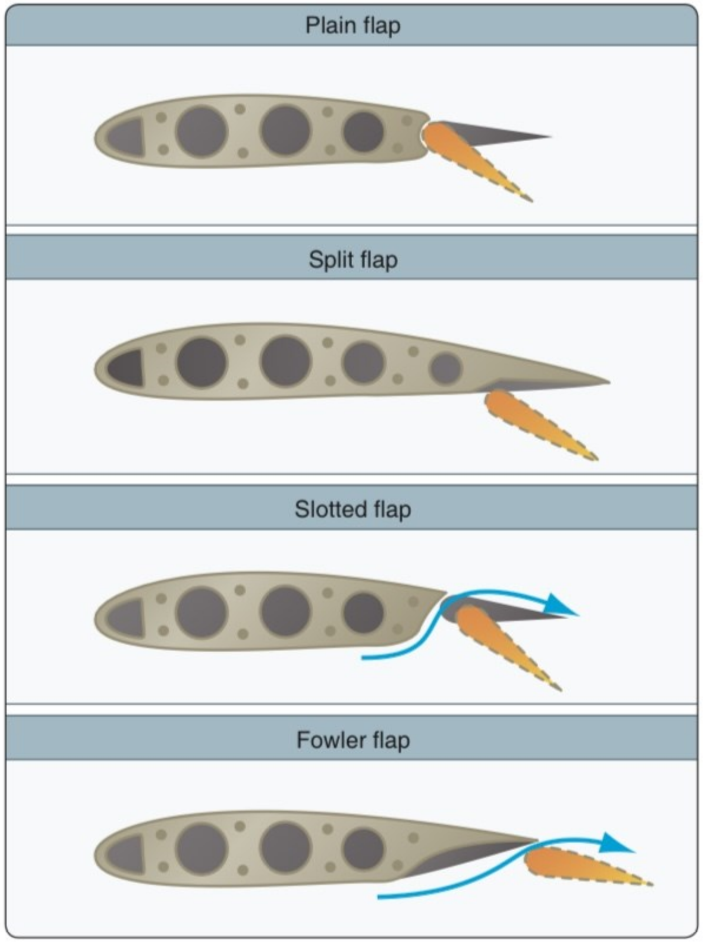


Figure 11-4. *Four basic types of flaps.*

Flap Use

➢ Operational Procedures

- Impossible to discuss all airplane flap combos
  - Refer to AFM/POH & use pilot discretion
  - Requires basic knowledge of flap aerodynamics and geometry
- Limitations
  - Speed & G's
- Variables
  - Extension and degree
  - Single point vs incremental deflections
  - Extension beyond 30°- creates significant levels of drag
  - Crosswind component
- Go-around
  - Retraction requires carefully monitoring of pitch and airspeed to minimize altitude loss
- Consistency
  - Extend same degree of flap deflection at same point in pattern
- No single formula to determine degree of flap deflection to be used
  - AFM/POH contains recommendations for some various landing situations
  - AFM/POH information on flap usage for takeoff is more precise
  - Requirements are based on the climb performance produced by a given flap design
  - Under no circumstances should flap setting given in the AFM/POH be exceeded for takeoff

Controllable-Pitch Props

- **Propeller purpose**
  - Fixed-pitch props
    - Designed for best efficiency at one speed of rotation & forward speed
    - Suitable performance in a narrow range of airspeeds
    - Efficiency suffers considerably outside this range

  - To provide high-propeller efficiency through a wide range of operation
    - Blade angle must be controllable
    - Most effective way of controlling blade angle is via a constant-speed governing system
    - Constant speed propeller is used

Constant-Speed Prop

- **What is a constant speed prop?**
  - The constant-speed propeller keeps the blade angle adjusted for maximum efficiency for most conditions of flight.
  - The pilot controls the engine revolutions per minute (rpm) indirectly by means of a propeller control in the flight-deck, which is connected to a propeller governor.
  - The way of controlling the propeller blade angle is by means of a constant-speed governing system

Constant-Speed Prop (cont.)

- **Takeoff**
  - For maximum takeoff power, the propeller control is moved all the way forward to the low pitch/ high rpm position,
  - Throttle is moved to the maximum manifold position
- **Climb**
  - To reduce engine wear, throttle is reduced in the climb
  - Throttle is reduced first to the desired value
  - Engine RPM is reduced by moving the propeller control toward the high pitch/low rpm position
  - Desired setting is observed on the tachometer
  - Power reduction change is done in this order to prevent a high load on the engine
- **Cruise**
  - Engine power is reduced by lowering the manifold pressure
  - Blade angle increases, by lowering propeller RPM
  - At high airspeeds and high blade angle the propeller is at or near maximum efficiency

Constant-Speed Prop (cont.)

Blade Angle Control

- Once the rpm settings for the propeller are selected, the propeller governor automatically adjusts the blade angle to maintain the selected rpm.
  - It does this by using **oil pressure.**
- the oil pressure used for pitch change comes directly from the engine lubricating system
- The rpm at which the propeller is to operate is adjusted in the governor head.
- he pilot changes this setting by changing the position of the governor rack through the flight-deck propeller control.

Twisting moment

- On some constant-speed propellers, changes in pitch are obtained by the use of an inherent **centrifugal twisting moment** of the blade.
  - this tends to **flatten** the blades toward **low pitch** and **oil pressure** applied to a hydraulic piston connected to the propeller blades which moves them toward **high pitch**
- Another type of constant-speed propeller uses counterweights attached to the blade shanks in the hub
  - **Governor oil pressure** and the **blade twisting** moment move the blades toward **the low pitch** position, and **centrifugal force** acting on the **counterweights** moves them (and the blades) toward the **high pitch** position.

Governor Range

- Blade angle range for CSP’s varies from 11.5° to 40°
- Higher speed of airplane = greater the blade angle range
- Governing Range
  - Range of possible blade angles
  - Defined by the limits between high and low blade angle pitch stops

Aircraft Type	Design Speed (mph)	Blade Angle Range	Pitch	
			Low	High
Fixed gear	160	11½°	10½°	22°
Retractable	180	15°	11°	26°
Turbo retractable	225/240	20°	14°	34°
Turbine retractable	250/300	30°	10°	40°
Transport retractable	325	40°	10/15°	50/55°

Figure 11-8. *Blade angle range (values are approximate).*

Constant-Speed Prop (cont)

Operation

- If blade angle is within the governing range and not against either pitch stop, a constant engine rpm is maintained.
- once the propeller blade reaches its pitch-stop limit, the engine rpm increases or decreases with changes in airspeed and propeller load similar to a fixed-pitch propeller.
- Example: once a specific rpm is selected, if the airspeed decreases enough, the propeller blades reduce pitch in an attempt to maintain the selected rpm until they contact their low pitch stops.
  - From that point, any further reduction in airspeed causes the engine rpm to decrease.
  - Conversely, if the airspeed increases, the propeller blade angle increases until the high pitch stop is reached. The engine rpm then begins to increase

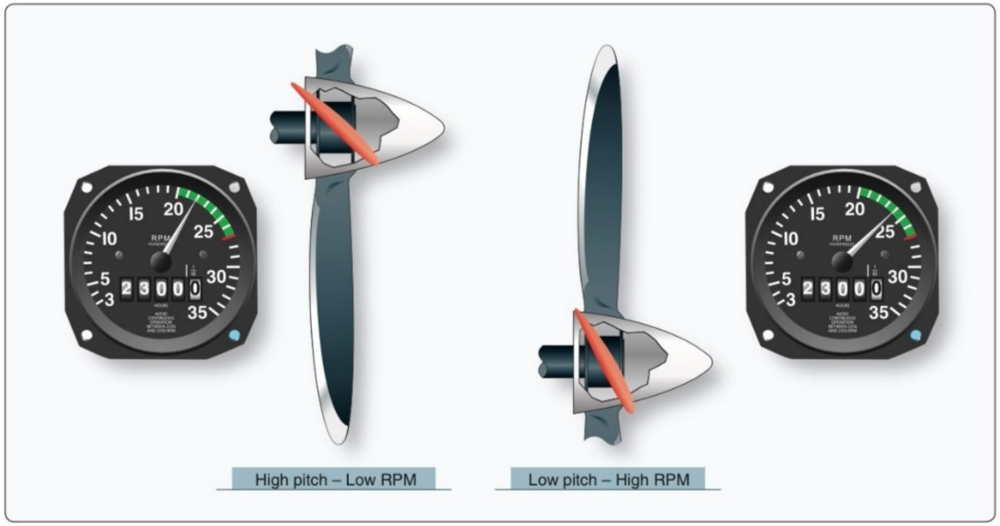


Figure 11-6. *Controllable pitch propeller pitch angles.*

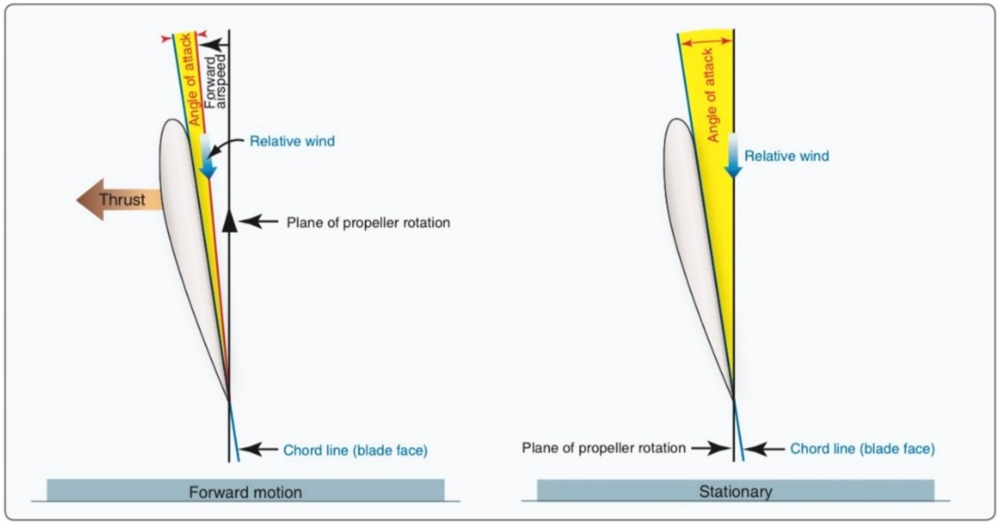


Figure 11-7. *Propeller blade angle.*

Turbocharging

➢ Purpose

- Maintains cruise power at high altitudes
  - less drag, means faster true airspeeds and increased range/fuel economy
- At low altitude gets better fuel consumption than turbine engine
- Does not take any horsepower from the engine to operate
  - Mechanically simple
- Can be used to pressurize the cabin

➢ Description

- The turbocharger is an exhaust-driven device that raises the pressure and density of the induction air delivered to the engine
- It consists of two separate components: a **compressor** and a **turbine**
  - The compressor supplies pressurized air to the engine for high-altitude operation
  - The turbine and its housing are part of the exhaust system and utilize the flow of exhaust gases to drive the compressor

Turbocharger operation

- **How a turbocharger works**
  - The turbine has the capability of producing manifold pressure ***in excess of*** the maximum allowable for the particular engine.
  - To prevent too much air from entering the intake manifold, a bypass or waste gate is used so that some of the exhaust is diverted overboard before it passes through the turbine
  - The position of the waste gate regulates the output of the turbine
    - When the waste gate is closed, **all** of the exhaust gases pass through and drive the turbine
    - As the waste gate opens, some of the exhaust gases are routed around the turbine, through the exhaust bypass, and overboard through the exhaust pipe.

Turbocharging (cont.)

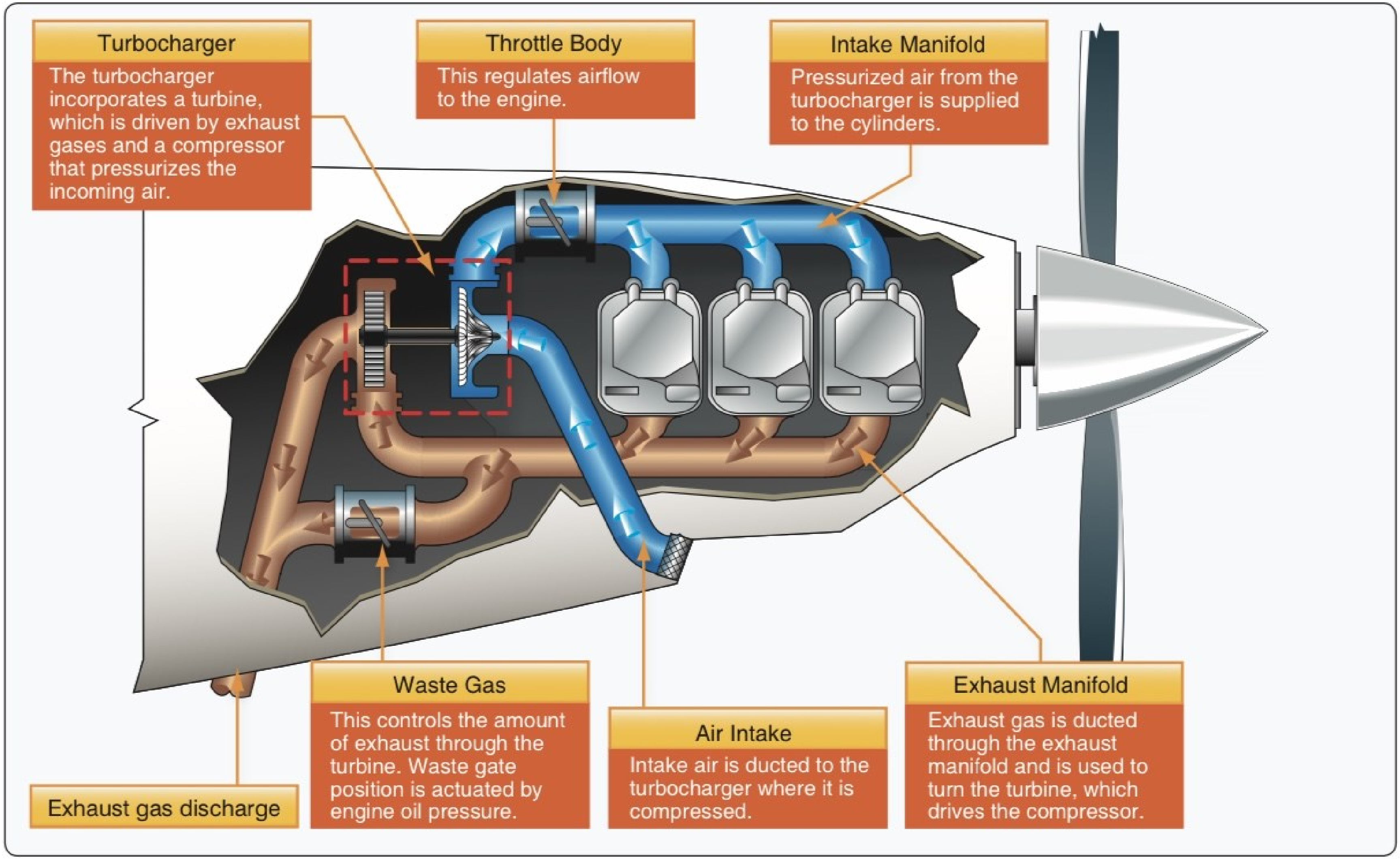


Figure 11-9. *Turbocharging system.*

Ground Boost vs altitude turbocharging

➢ **Altitude turbocharging**

- Altitude turbocharging (sometimes called “normalizing”) is accomplished by using a turbocharger that maintains maximum allowable sea level manifold pressure (normally 29–30 "Hg) up to a certain altitude
- Altitude is specified by the manufacturer and is called the critical altitude.
  - Above the critical altitude, the manifold pressure will decrease as altitude is gained

➢ **Ground boosting**

- Ground boosting, is an application of turbocharging, where more than the standard 29 inches of manifold pressure is used in flight.
  - takeoff manifold pressures may go as high as 45 "Hg

Turbocharging (cont)

Operating Characteristics

- No aggressive movements-slow and smooth (prevent over-boosting)
- When the waste gate is open, the turbocharged engine reacts the same as a normally aspirated engine
- when the rpm is varied. That is, when the rpm is increased, the manifold pressure decreases slightly. When the engine rpm is decreased, the manifold pressure increases slightly.
- However, when the waste gate is closed, manifold pressure variation with engine rpm is just the opposite of the normally aspirated engine
  - (An increase in engine rpm results in an increase in manifold pressure, and a decrease in engine rpm results in a decrease in manifold pressure

Heat Management

- Turbocharged engines must be thoughtfully and carefully operated with continuous monitoring of pressures and temperatures

- **There are two temperatures**
  - turbine inlet temperature (TIT)
  - exhaust gas temperature (EGT)

Turbocharging cont.

Turbocharger Failure

- High temperatures and pressures produced
  in the turbine exhaust systems, any malfunction of the
  turbocharger must be treated with extreme caution

- In all cases of turbocharger operation, the manufacturer’s
  recommended procedures should be followed

- If no recommended procedures exist, following procedures should be followed:

Turbocharging

Over-Boost Condition

- If an excessive rise in manifold pressure occurs during normal advancement of the throttle.
  - Faulty waste gate.

- **Immediately retard the throttle** smoothly to limit the manifold pressure below the maximum for the rpm and mixture setting

Low Manifold Pressure

- possible that a serious exhaust leak has occurred creating a potentially hazardous situation.

Retractable Landing Gear

- The primary benefits of being able to retract the landing gear are: **increased climb performance** and **higher cruise airspeeds** due to the resulting decrease in drag

- Retractable landing gear systems may be operated either **hydraulically** or **electrically** or may employ a **combination of the two systems**

- Warning indicators are provided in the flight deck to show the pilot when the wheels are down and locked and when they are up and locked or if they are in intermediate positions

- Systems for emergency operation are also provided.

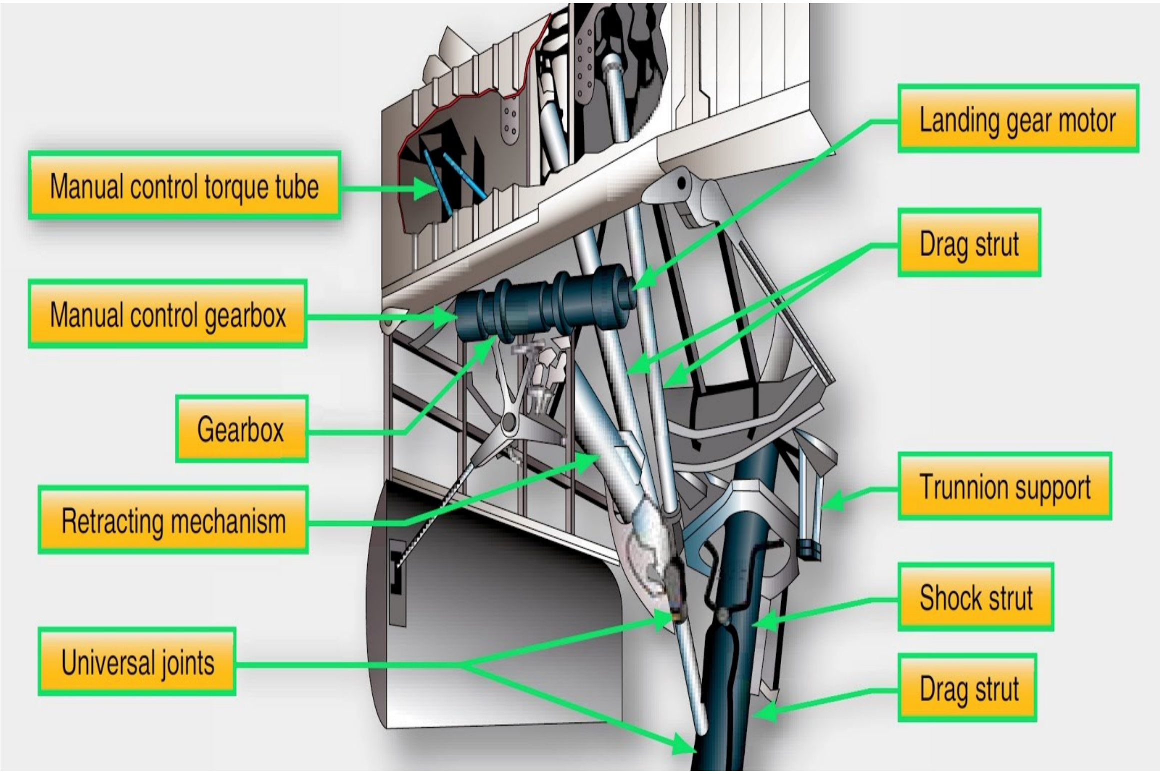
- The complexity of the retractable landing gear system requires that specific operating procedures be adhered to and that certain operating limitations not be exceeded.

Figure 11-10. *Typical landing gear switch with three light indicator.*

Landing Gear Systems

Electric

- An electrical landing gear retraction system utilizes an electrically-driven motor for gear operation
- The system is basically an electrically-driven jack for raising and lowering the gear.
- When a switch in the flight deck is moved to the **UP** position, the electric motor operates



Landing Gear Systems

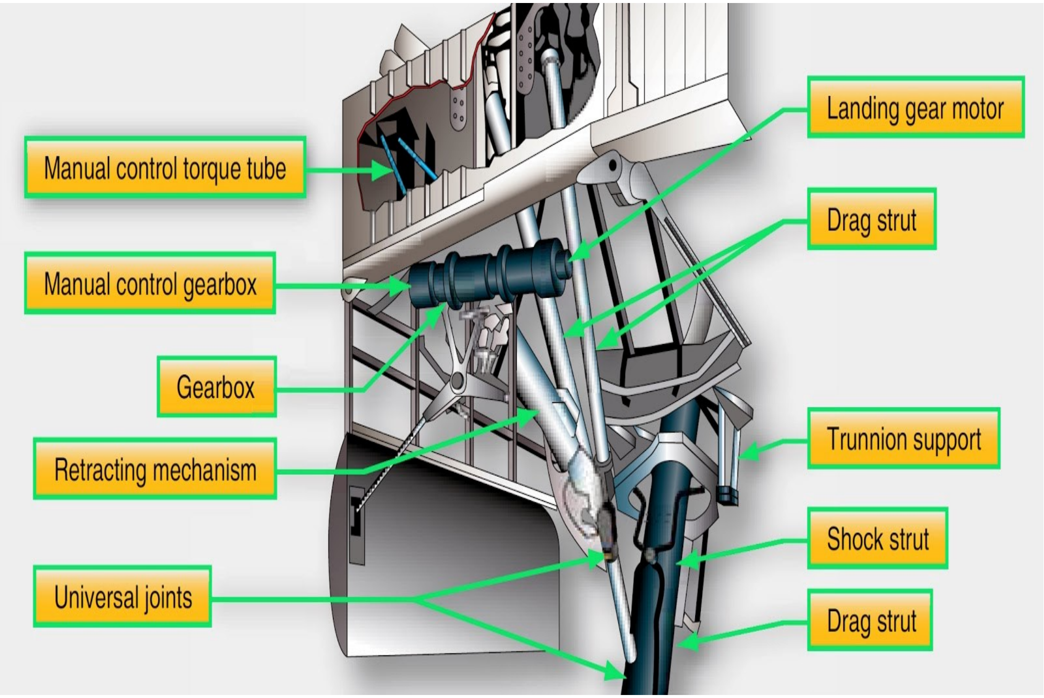
➢ Electric

- Through a system of shafts, gears, adapters, an actuator screw, and a torque tube, a force is transmitted to the drag strut linkages.

- Struts are also activated that open and close the gear doors

- If the switch is moved to the **DOWN** position, the motor reverses and the gear moves down and locks

- Once activated, the gear motor continues to operate until an up or down limit switch on the motor's gearbox is tripped.

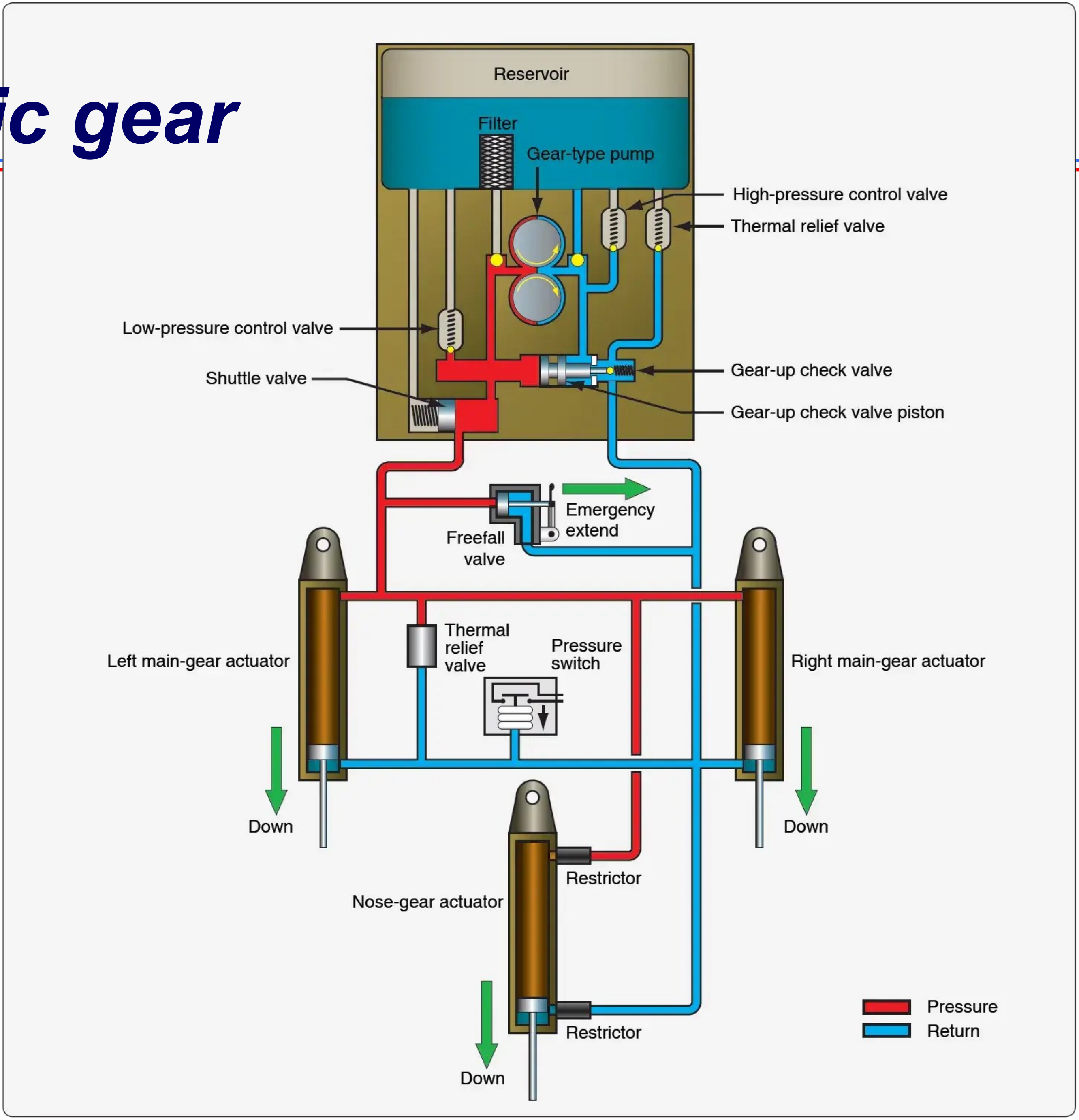


Landing Gear Systems

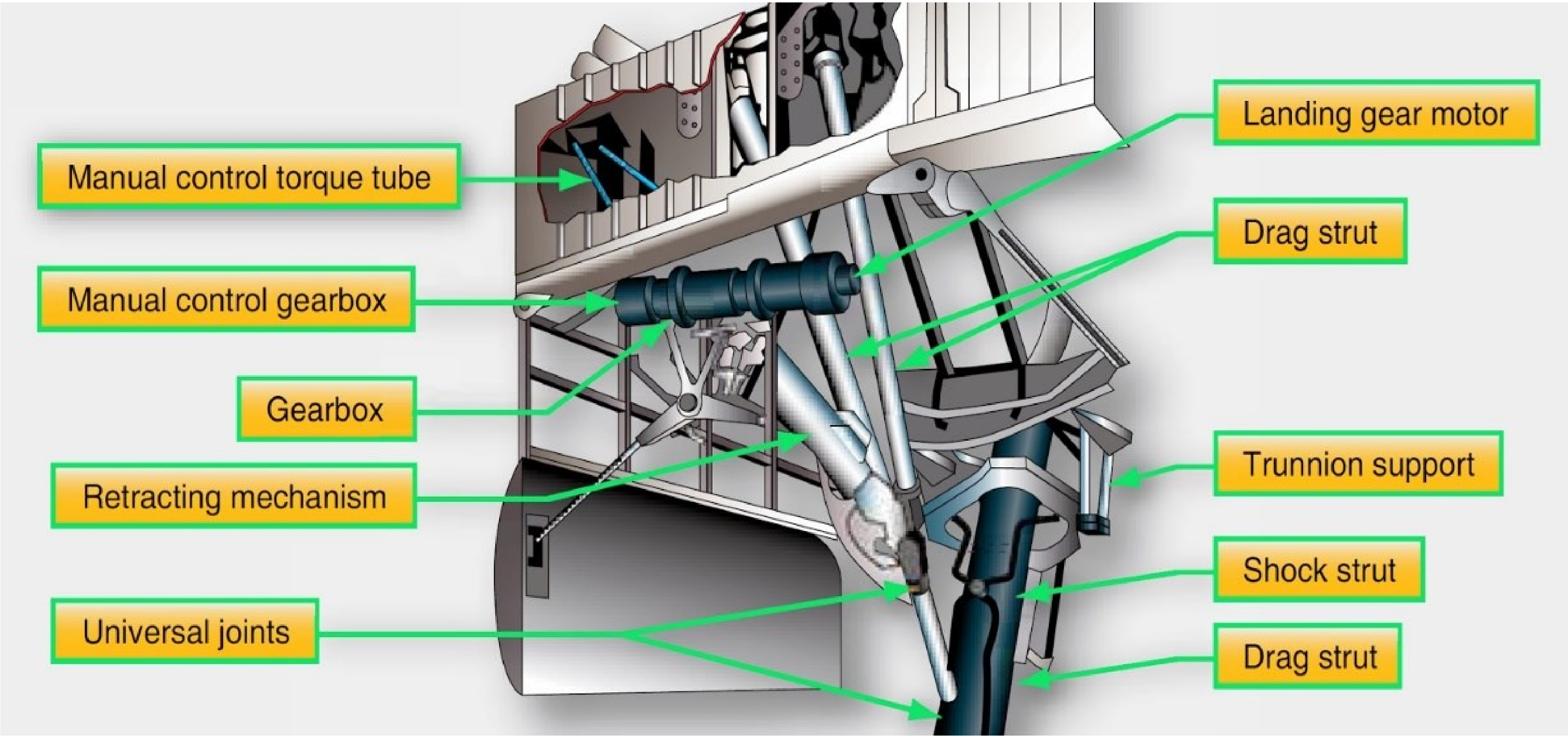
➢ Hydraulic

- A hydraulic landing gear retraction system utilizes pressurized hydraulic fluid to actuate linkages to raise and lower the gear
- When a switch in the flight deck is moved to the **UP** position, hydraulic fluid is directed into the gear up line
- The fluid flows through sequenced valves and down locks to the gear actuating cylinders.
- A similar process occurs during gear **extension** (**down**)
- The pump that pressurizes the fluid in the system can be either engine driven or electrically powered.
  - If an electrically-powered pump is used to pressurize the fluid, the system is referred to as an electrohydraulic system
  - The system also incorporates a hydraulic reservoir to contain excess fluid and to provide a means of determining system fluid level.

Hydraulic gear



Electric gear



Control & Position Indicators

- **Control**
  - Landing gear position is controlled by a switch on the flight deck panel.
    - gear switch is shaped like a wheel in order to facilitate positive identification and to differentiate it from other flight deck controls

- **Position**
  - the most common types of landing gear position indicators utilize a group of lights
  - One type consists of a group of three green lights, which illuminate when the landing gear is down and locked
  - Another type consists of one green light to indicate when the landing gear is down and an amber light to indicate when the gear is up

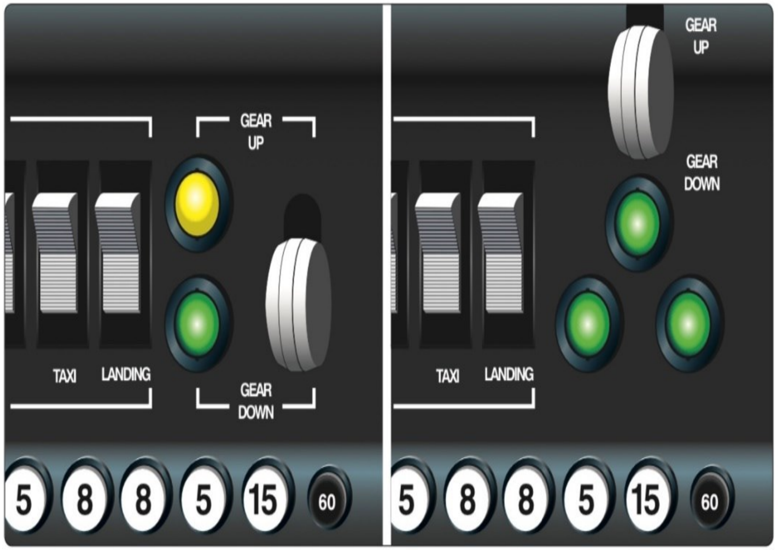


Figure 11-11. *Landing gear handles and single and multiple light indictor.*

Landing Gear Safety Devices

- **Horn**
  - sounds when the airplane is configured for landing and the landing gear is not down and locked
  - the horn is linked to the throttle or flap position and/or the airspeed indicator so that when the airplane is below a certain airspeed, configuration, or power setting with the gear retracted, the warning horn sounds

- **Ground locks**
  - One common type is a pin installed in aligned holes drilled in two or more units of the landing gear support structure
  - Another type is a spring-loaded clip designed to fit around and hold two or more units of the support structure together

- **Squat switch**
  - usually mounted in a bracket on one the main gear shock struts
  - When the strut is compressed by the weight of the airplane, the switch opens the electrical circuit to the mechanism that powers retraction.
  - if the landing gear switch in the flight deck is placed in the RETRACT position when weight is on the gear, the gear remains extended, and the warning horn may sound as an alert to the unsafe condition

Gear Safety Switch

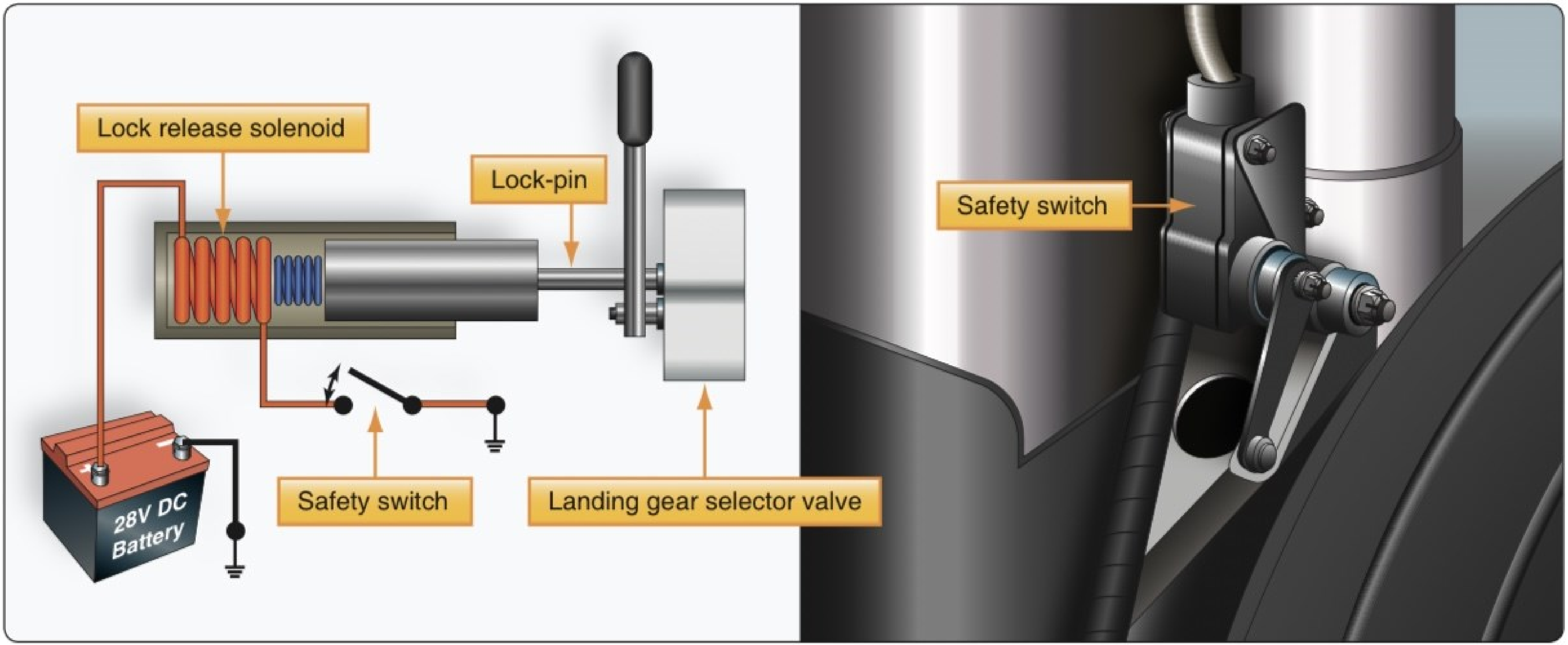


Figure 11-12. *Landing gear safety switch.*

Emergency Gear Extension

➢Overview

- The emergency extension system lowers the landing gear if the main power system fails.

- Some airplanes have an emergency release handle in the flight-deck, which is connected through a mechanical linkage to the gear up locks.
  - When the handle is operated, it releases the up locks and allows the gear to free fall or extend under their own weight

- On other airplanes, release of the up lock is accomplished using compressed gas, which is directed to up lock release cylinders.

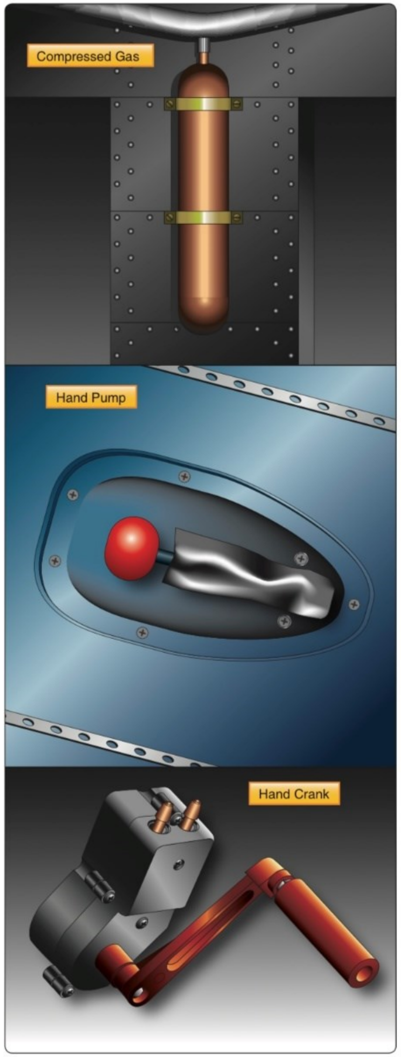


Figure 11-13. *Typical emergency gear extension systems.*

Operational Procedures

➢Preflight

- Because of their complexity, retractable landing gear demands a close inspection prior to every flight.
- Make certain that the landing gear selector switch is in the GEAR DOWN position.
  - turn on the battery master switch and ensure that the landing gear position indicators show that the gear is DOWN and locked
- The landing gear, wheel well, and adjacent areas should be clean and free of mud and debris
  - Dirty switches and valves may cause false safe light indications or interrupt the extension cycle before the landing gear is completely down and locked.

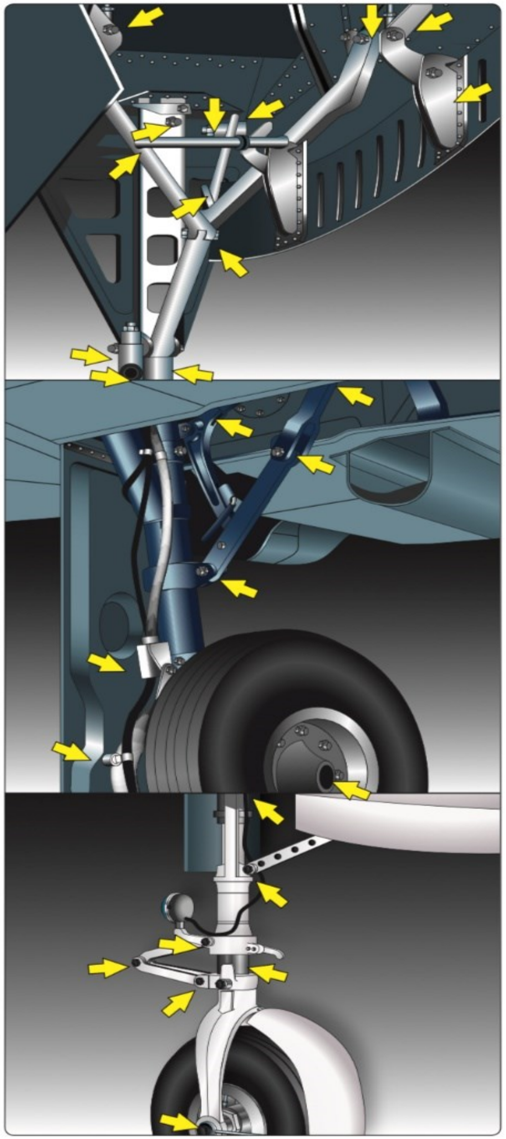


Figure 11-14. *Retractable landing gear inspection checkpoints.*

Operation procedures cont.

➢ Takeoff & Climb

- landing gear is retracted after lift-off when the airplane has reached an altitude where, in the event of an engine failure or other emergency requiring an aborted takeoff the airplane could no longer be landed on the runway.

- in some situations it may be preferable, in the event of an engine failure, to make an off airport forced landing with the gear extended in order to take advantage of the energy absorbing qualities of the terrain.

- Avoid premature landing gear retraction and do not retract the landing gear until a positive rate of climb is indicated on the flight instruments

- Gear retraction and locking (and gear extension and locking) is accompanied by sound and feel that are unique to the specific make and model airplane.

Operational Procedures cont.

Approach

- **The operating loads placed on the landing gear at higher airspeeds may cause structural damage due to the forces of the airstream.**
  - Limiting speeds, therefore, are established for gear operation to protect the gear components from becoming overstressed during flight

- **Lower gear by placing the lever in the gear down position **pause****
  - Speed will decrease
  - Pitch may change
- **Unless the landing gear has been previously extended to aid in a descent to traffic pattern altitude, the landing gear should be extended by the time the airplane reaches a point on the downwind leg**

Landing

- **Unless good operating practices dictate otherwise, the landing roll should be completed and the airplane should be clear of the runway before any levers or switches are operated.**
  - This technique greatly reduces the chance of inadvertently retracting the landing gear while on the ground.

Common Errors

➢Landing Gear Errors

- Neglected to extend landing gear
- Inadvertently retracted landing gear
- Activated gear but failed to check gear position
- Misused emergency gear system
- Retracted gear prematurely on takeoff
- Extended gear too late

➢ These mistakes are not only committed by pilots who recently transitioned to complex aircraft, but also by pilots who grew complacent over time

- Use an appropriate checklist.
- Be familiar with, and periodically review, the landing gear emergency extension procedures for the particular airplane.
- Be familiar with the landing gear warning horn and warning light systems for the particular airplane

Transition Training

➢ Overview

- Transition to a complex airplane or a high-performance airplane should be accomplished through a structured course of training administered by a competent and qualified flight instructor

➢ Transition

- The goal is to ensure proficiency standards are achieved.

- These standards are contained in the Practical Test Standards (PTS) or Airmen Certification Standard (ACS) as appropriate for the certificate that the transitioning pilot holds or is working towards.

- times must be based on the capabilities of the pilot. The time periods may be minimal for pilots with higher qualifications or increased for pilots who do not meet certification requirements or have had little recent flight experience

Piper Arrow Limitations

- **IO-360 C1C**
  - T/O 200HP @ 2700RPM
  - Caution (Yellow Zone) **1900-2350**
- **Fuel**

Total	50 gallons
Usable	48 gallons

- **Oil**

Capacity	8 quarts
Min	6 quarts
Pressure	25 min – 100 psi max

- **Weight (lbs)**

T/O	**2650**
Empty weight	1656.24
Baggage	200
Useful load	993.76

- **Xwind** 20 MPH (17kts)

- **Speeds (MPH)**

Vr	60-70
Vx	96
Vy	100 cruise climb
Vglide	105
Va	131
Vno	170
Vne	214
Vfe	125
Vlo	132
Vle	150
Vappch	90
Vfinal	85

Piper Saratoga Limitations (1 of 2)

- **IO-540**
  - Max Cont 294hp @ 2600rpm
  - T/O (5mins) 300hp @ 2700rpm
- **Fuel**
  - Total 107
  - Usable 102
  - Pressure 14 psi max
- **Oil**
  - Capacity 12
  - Min Safe Qty 2.75
  - Pressure 25 – 100 psi
- **Weight**
  - Ramp 3615
  - T/O **3600**
  - Empty 2240.1
  - Useful 1359.9
  - Baggage Fwd 100 / Aft 100
- **Xwind** 17kts

Piper Saratoga Limitations (2 of 2)

- **Speeds**
  - VR 75
  - VX 80
  - VY 91 / 105 (VCRUISE CLIMB)
  - VG 80 / 68 @ 2600 lbs
  - VA 134 / 114 @ 2600 lbs
  - VNO 154
  - VNE 197

VFE	**112**
VLO	**132**
VLE	**132**
VLR	**110**
VAPPCH	**95**
VFINAL	**79**

Cruise	Kts	M.P.	RPM	GPH	%HP
Econ	130	20.4”	2200	12.0	55%
Norm	145	22.0”	2300	13.8	65%
Max	158	23.8”	2400	16.0	75%

Admin

- **Complete Complex/High-Performance Endorsements**
  - Plan on 3-5 flights with normal progression
  - Additional flights as required

- **Timeline**
  - Tailored to your schedule

- **Scheduling and Billing**
  - Thru MyFBO
  - Will contact for CC info

- **Instructors**
  - Benjamin Ndahi et al (inquire within)

Questions ?

- **Contact Info:**
  - Ben.Ndahi@EpixAviation.com
    (Epix Aviation Chief Pilot)