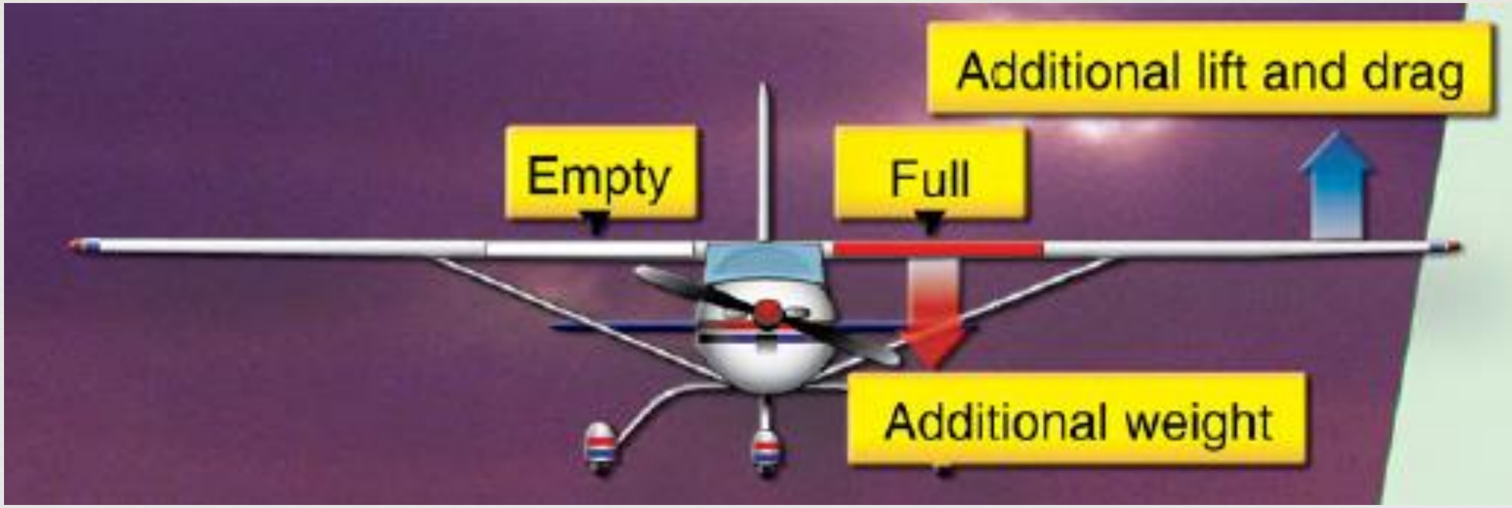
Aircraft general engineering and maintenance practices

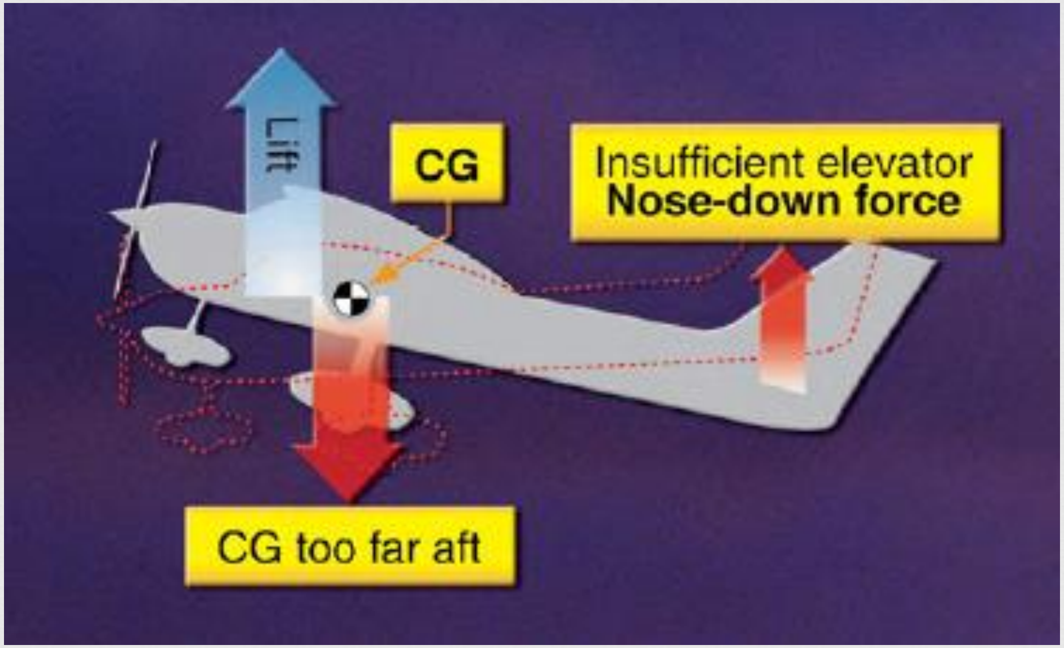
COURSE CODE : **Ao307**

R.BALAJI,
Department of Aeronautical Engineering,
Jawaharlal College of Engineering and Technology,
Kerala.

Weight and Balance Control

- There are many factors in the safe and efficient operation of aircraft, including proper weight and balance control.
- The weight and balance system commonly employed among aircraft consists of three equally important elements
  - The weighing of the aircraft,
  - The maintaining of the weight and balance records,
  - The proper loading of the aircraft.


Additional lift and drag
Empty
Full
Additional weight


Lift
CG
Insufficient elevator
Nose-down force
CG too far aft

Introduction

- Improper loading decreases the efficiency and performance of an aircraft from the standpoint of altitude, maneuverability, rate of climb, and speed.
- It may even be the cause of failure to complete the flight or, for that matter, failure to start the flight. Because of abnormal stresses placed upon the structure of an improperly loaded aircraft

Responsibility for Weight and Balance Control

- The designers of an aircraft set the maximum weight based on the amount of lift the wings or rotors can provide under the operational conditions for which the aircraft is designed. (CG)
- The manufacturer provides the aircraft operator with the empty weight of the aircraft and the location of its empty weight center of gravity (EWCG) at the time the certified aircraft leaves the factory.

Responsibility for Weight and Balance Control

- The FAA-certificated mechanic or repairman who maintains the aircraft keeps the weight and balance records current, recording any changes that have been made because of repairs or alterations.
- The pilot in command (PIC) has the responsibility prior to every flight to know the maximum allowable weight of the aircraft and its CG limits.

Weight Control

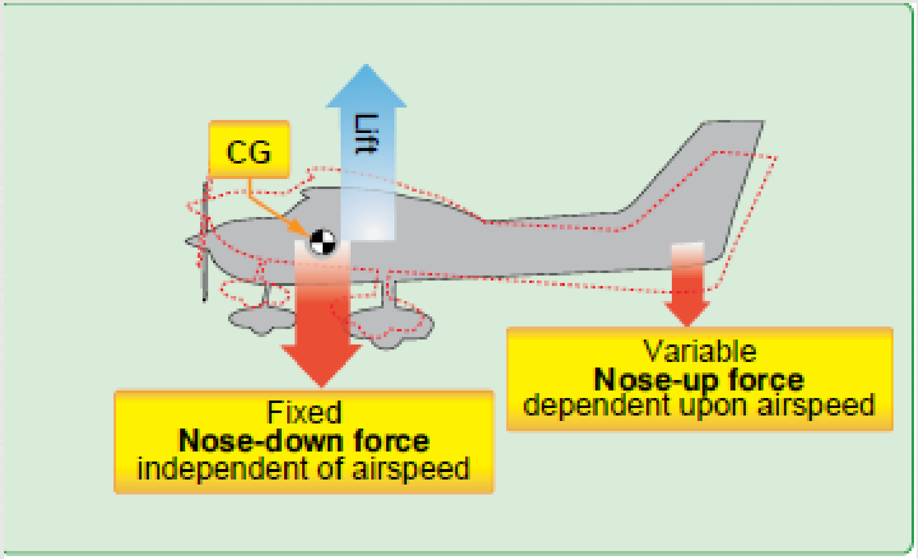
- The wings of a 3,000-pound airplane must support 3,000 pounds in level flight, but when the airplane is turned smoothly and sharply using a bank angle of 60°, the dynamic load requires the wings to support twice this or 6,000 pounds.
- An aircraft operated in the utility category must sustain a load factor of 4.4 times its weight, and acrobatic category aircraft must be strong enough to withstand 6.0 times their weight.

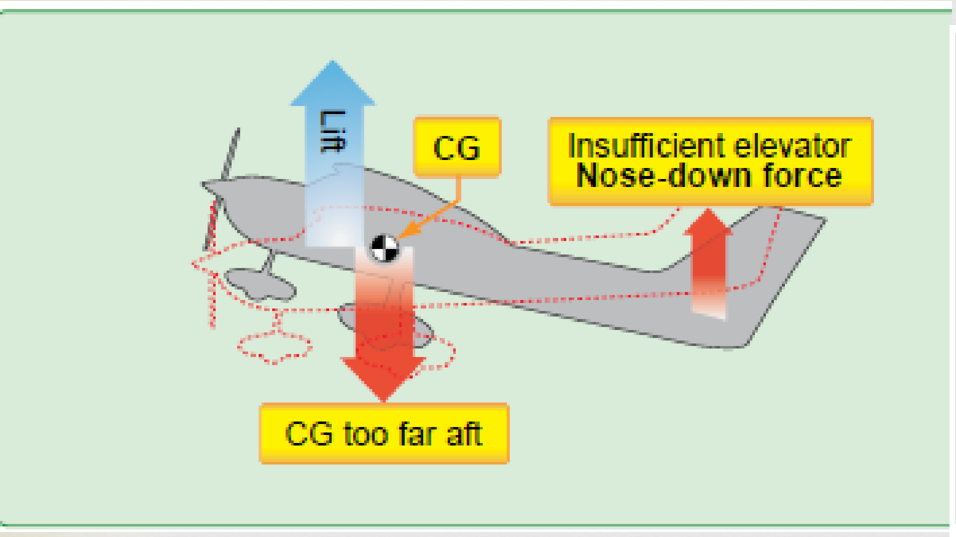
Effects of Weight

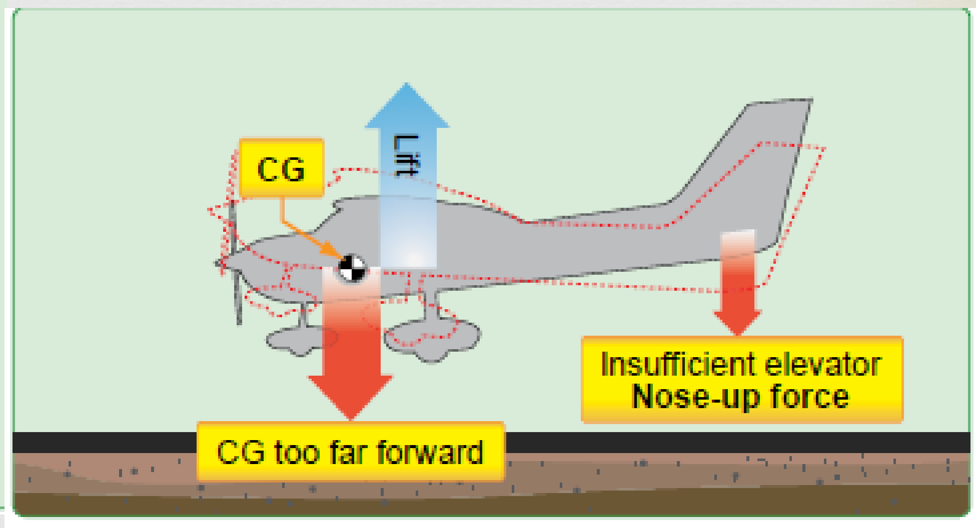
- The aircraft needs a higher takeoff speed, which results in a longer takeoff run.
- Both the rate and angle of climb are reduced.
- The service ceiling is lowered.
- The cruising speed is reduced.
- The cruising range is shortened.
- Maneuverability is decreased.
- A longer landing roll is required because the landing speed is higher.
- Excessive loads are imposed on the structure, especially the landing gear.

Stability and Balance Control

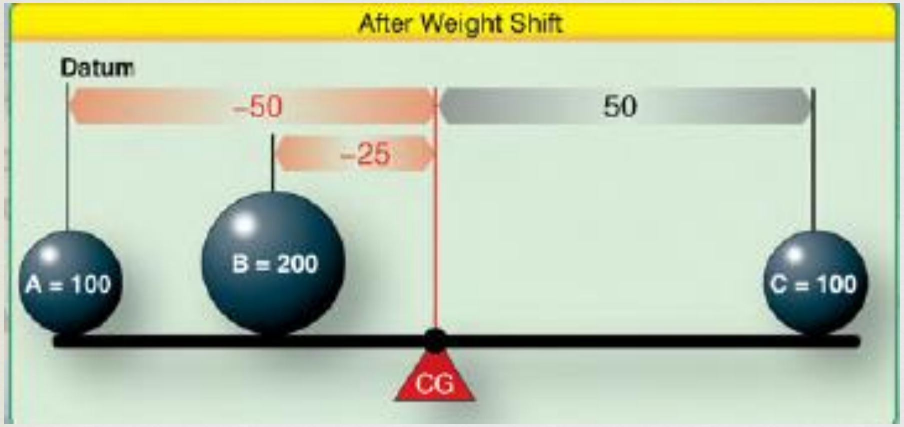
- An airplane is designed to have stability that allows it to be trimmed to maintain straight-and-level flight with hands off the controls.
- Both lateral and longitudinal balance are important, but the prime concern is longitudinal balance; that is, the location of the CG along the longitudinal or lengthwise axis.


CG
Lift
Variable
Nose-up force
dependent upon airspeed
Fixed
Nose-down force
independent of airspeed


Lift
CG
Insufficient elevator
Nose-down force
CG too far aft


CG
Lift
Insufficient elevator
Nose-up force
CG too far forward

Weight and Balance Theory



- Weight and balance in aircraft is based on the law of the lever. This chapter discusses the application of the law of the lever and its applications relative to locating the balance point of a beam or lever on which various weights are located or shifted.

Weight and Balance Theory

Two elements are vital in the weight and balance considerations of an aircraft.

- The total weight of the aircraft must be no greater than the maximum weight allowed by the FAA for the make and model of the aircraft.
- The center of gravity (CG), or the point at which all of the weight of the aircraft is considered to be concentrated, must be maintained within the allowable range for the operational weight of the aircraft.

Arm

- The arm is usually measured and expressed in inches and refers to the horizontal distance between the CG of an item or object and the datum, a point from where all measurements are taken.
- Arms to the left of the datum are negative (–) and those to the right of the datum are positive (+).
- The datum is an imaginary vertical plane from which all horizontal distances are measured for balance purposes.
- The position of the reference datum varies by aircraft design and manufacturer.

Moment

- A moment is a force that tries to cause rotation and is the product of the arm, in inches, and the weight, in pounds. Moments are generally expressed in pound-inches (lb-in) and may be either positive or negative.

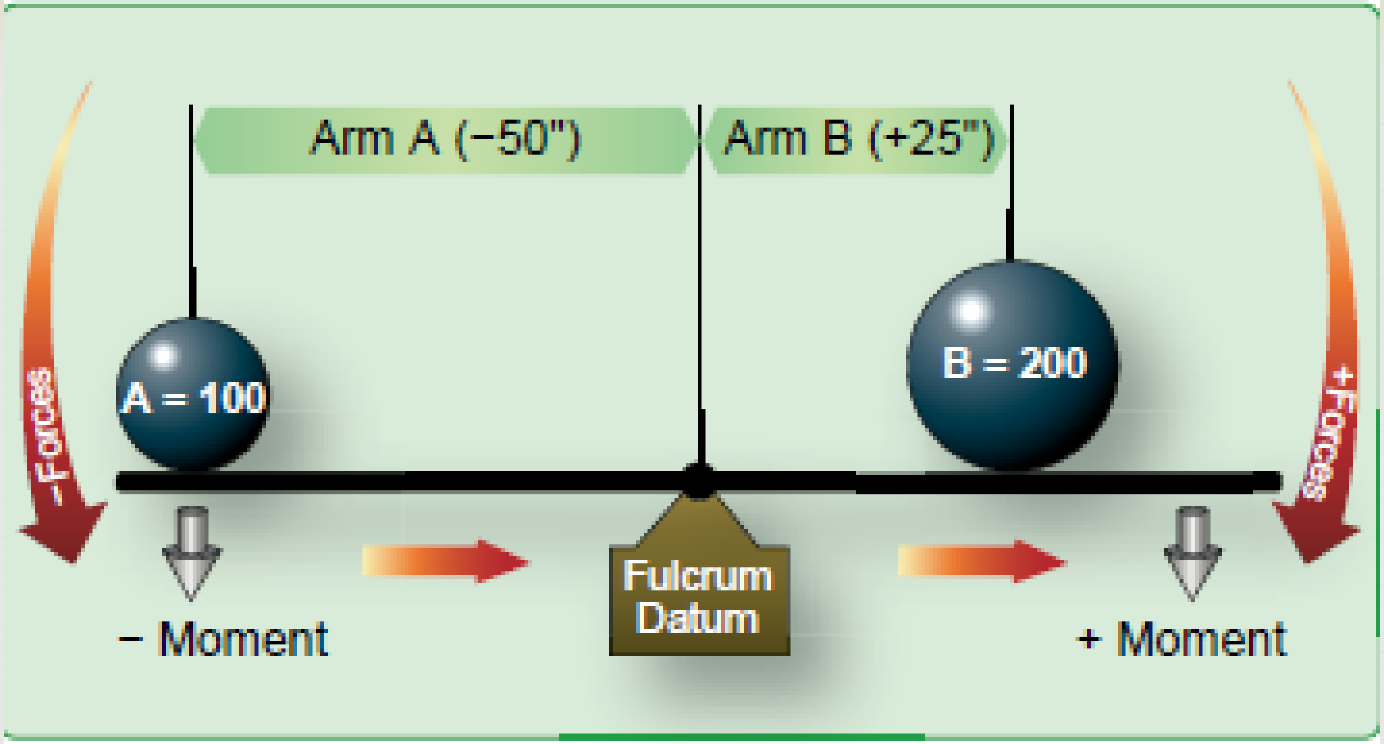


Figure 2-1. *Balance lever.*

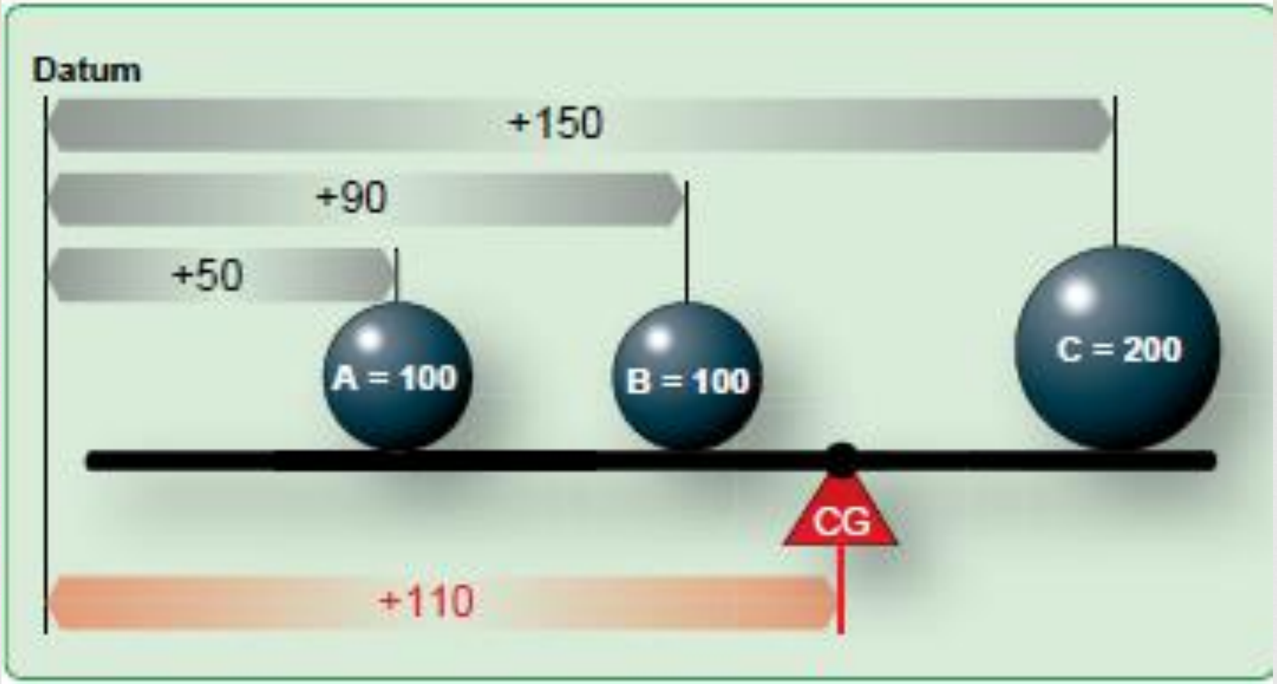
Item	Weight (lb)	Arm (in)	Moment (lb-in)
Weight A	100	−50	−5,000
Weight B	200	+25	+5,000
	300		0

The Law of the Lever

- Weight and balance problems are based on the physical law of the lever. This law states that a lever is balanced when the weight on one side of the fulcrum (a pivot point for the lever) multiplied by its arm is equal to the weight on the opposite side multiplied by its arm.
- In other words, the lever is balanced when the sum of the moments about the fulcrum is zero

Determining CG point

- Measure the arm of each weight in inches from the datum.
- Multiply each arm by its weight in pounds to determine the moment in pound-inches of each weight.
- Determine the total of all weights and of all the moments. (Disregard the weight of the lever).
- Divide the total moment by the total weight to determine the balance point.

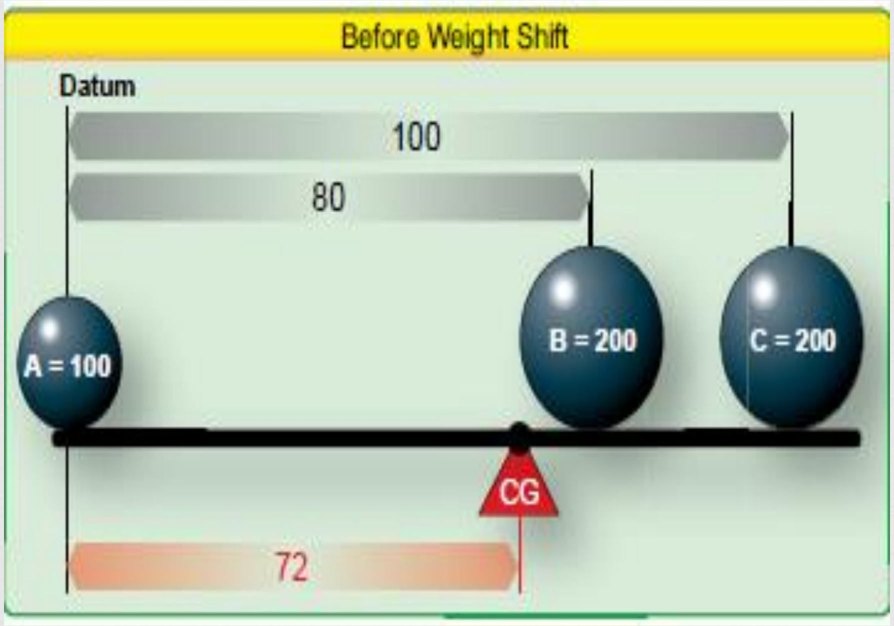


Item	Weight (lb)	Arm (in)	Moment	CG
Weight A	100	50	5,000	
Weight B	100	90	9,000	
Weight C	200	150	30,000	
	400		44,000	110

Shifting the Balance Point or CG

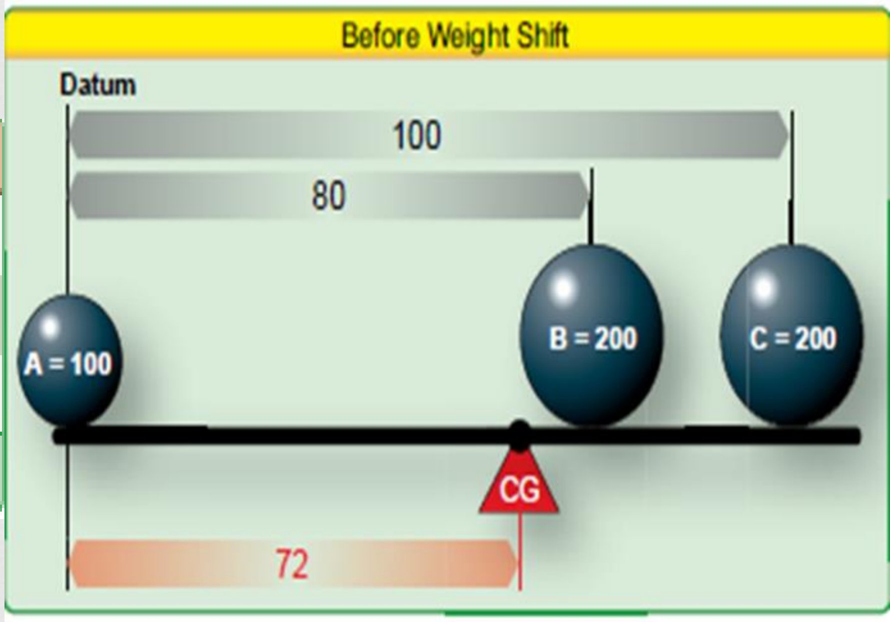
- One common weight and balance problem involves moving or shifting weight from one point to another in order to move the balance point or CG to a desired location.
- This can be demonstrated by using a lever with three weights to work out the problem.

Shifting the Balance Point or CG



Shifting the Balance Point or CG

Item	Weight (lb)	Arm (in)	Moment (lb-in)
Weight A	100	−50	−5,000
Weight B			
Weight C	200	+50	+10,000
			+5,000



Shifting the Balance Point or CG

Item	Weight (lb)	Arm (in)	Moment (lb-in)
Weight A	100	-50	-5,000
Weight B	200	-25	-5,000
Weight C	200	+50	+10,000
			0

Basic Weight and Balance Equation

- The following formulas can be used to determine the distance weight must be shifted to obtain a desired change in the CG location.
- The equation can also be rearranged to find the amount of weight required to be shifted to move the CG to a desired location, to find the distance the CG is moved when a specified amount of weight is shifted, or to find the total weight that would allow shifting a specified amount of weight to move the CG a given distance.

Basic Weight and Balance Equation

$$\frac{\text{Weight to be shifted}}{\text{Total weight}} = \frac{\Delta\ \text{CG}}{\text{Distance weight is shifted}}$$

$$\text{Total weight} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\Delta\ \text{CG}}$$

$$\text{Weight shifted} = \frac{\text{Total weight shifted} \times \Delta\ \text{CG}}{\text{Distance weight is shifted}}$$

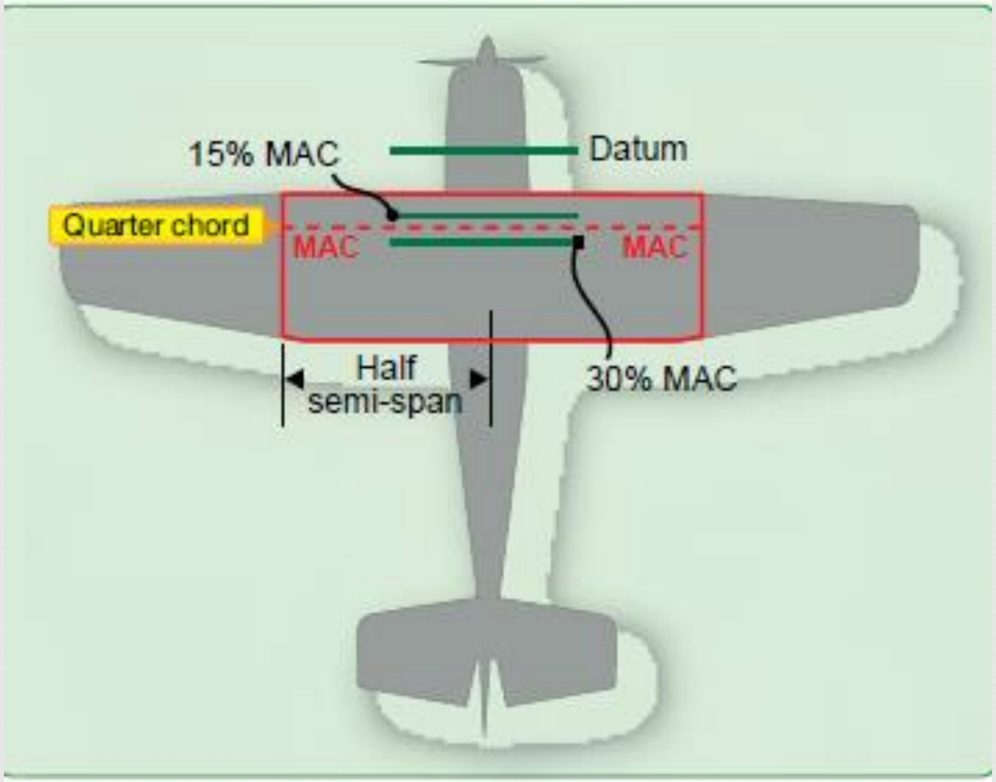
$$\Delta\ \text{CG} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\text{Total weight}}$$

$$\text{Distance weight is shifted} = \frac{\text{Total weight} \times \Delta\ \text{CG}}{\text{Weight shifted}}$$

Mean Aerodynamic Chord

- The CG point affects the stability of the aircraft. To ensure the aircraft is safe to fly, the CG must fall within specified limits established by the manufacturer.
- On some aircraft, the CG is expressed as a percentage of the length of the mean aerodynamic chord (MAC) or "percent MAC."

Mean Aerodynamic Chord



FAA-Furnished Weight and Balance Information

- Before an aircraft CG can be computed, certain information must be known. This information, furnished by the FAA for every certificated aircraft in the Type Certificate Data Sheets (TCDS).
- The TCDS includes all of the pertinent specification for the aircraft; at each annual or 100-hour inspection, it is the responsibility of the inspecting mechanic or repairman to ensure that the aircraft adheres to them

Aircraft Serial No. 18259080 FAA Registration No. N42565 Date: 4-22-09

Item	Weight (lb) ×	C.G. Arm (in)	Moment (lb-in/1,000)
Standard empty weight	1,876.0	36.1	67,798.6
Optional equipment	1.2	13.9	16.7
Special installation	6.2	41.5	257.3
Paint	—	—	—
Unusable fuel	30.0	46.0	1,380.0
Basic empty weight	1,913.4		69,452.6

Figure 2-16. *Weight and balance report.*

Item No	Equipment List Description	Ref Drawing	Wt (lbs.)	Arm (ins.)
24-04-S	Basic Avionics Kit Installation		4.3*	55.5*
	- Support Straps Installation		0.1	10.0
	- Avionics Cooling Fan Installation		1.6	3.0
	- Avionics Ground Installations		0.1	41.0
	- Circuit Breaker Panel Installation		1.5	16.5
	- Microphone Installation		0.2	18.5
	- Omni Antenna Installation		0.5	252.1
	- Omni Antenna Cable Assembly Installation		0.3	248.0
	Chapter 25 – Equipment/Furnishings			
25-01-R	Seat, Pilot, Adjustable		33.8	41.5
25-02-S	Seat, Copilot, Adjustable		33.8	41.5
25-03-S	Seat, Rear, Two Piece Back Cushion		50.0	82.0
25-04-R	Seat Belt and Shoulder Harness, Inertia Reel, Pilot and Copilot		5.2	50.3
25-05-S	Seat Belt and Shoulder Harness, Inertia Reel, Rear Seat		5.2	87.8
25-06-S	Sun Visors (Set of 2)		1.2	33.0
25-07-S	Baggage Retaining Net		0.5	108.0
25-08-S	Cargo Tie Down Rings (10 Tie Downs)		0.4	108.0
25-09-S	Pilot's Operating Checklist (Stowed in Instrument Panel Map Case)		0.3	15.0
25-10-R	Pilot's Operating Handbook and FAA Approved Airplane Flight Manual (Stowed in Pilot's Seat Back)		1.2	61.5
25-11-S	Fuel Sampling Cup		0.1	14.3
25-12-S	Tow Bar, Nose Gear (Stowed)		1.7	108.0
25-13-S	Emergency Locator Transmitter Installation		2.2*	134.8*
	- ELT Transmitter		1.7	135.0
	- Antenna and Cable Assembly		0.4	133.0
	- Hardware		0.1	138.0
	Chapter 26 – Fire Protection			
26-01-S	Fire Extinguisher Installation		5.3*	29.0*
	- Fire Extinguisher		4.8	29.0
	- Mounting Clamp & Hardware		0.5	29.0
	Chapter 27 – Flight Controls			
27-01-S	Dual Controls Installation, Right Seat		6.3*	12.9*
	- Control Wheel, Copilot		2.0	26.0
	- Rudder and Brake Pedal Installation Copilot		4.3	6.8

Weight Control for Aircraft Other Than Fixed and Rotor-wing

- Some light aircraft utilize different methods of determining weight and balance from the traditional fixed and rotor-wing aircraft.
- Most notable of these are weight-shift control (WSC) aircraft (also known as trikes), powered parachutes, and balloons
- These aircraft typically do not specify either an EWCG or a CG range. They require only a certified or approved maximum weight.

Weight Control for Aircraft Other Than Fixed and Rotor-wing

- Airplanes and WSC aircraft control flight under the influence of the same four forces (lift, gravity, thrust, and drag), and around the same three axes (pitch, yaw, and roll). However, each aircraft accomplishes this control in a very different manner.
- The fixed-wing airplane has movable controls that alter lift on various airfoil surfaces to vary pitch, roll, and yaw. In turn, these changes in lift affect the characteristics of the flight parameters. Weight normally decreases in flight due to fuel consumption, and the airplane CG changes with this weight reduction.

Weight-Shift Control Aircraft

- The WSC aircraft has a relatively set platform wing without a tail. The pilot achieves control by shifting weight.
- In the design of this aircraft, the weight of the airframe and its payload is attached to the wing at a single point in a pendulous arrangement.
- The pilot, through the flight controls, controls the arm of this pendulum and thereby controls the aircraft.

Weight-Shift Control Aircraft

- The flight controls primarily affect the pitch-and-roll axes. Since there is no vertical tail plane, there is minimal or no yaw control.
- the CG experienced by the WSC aircraft wing remains constant.

Powered Parachutes

- The powered parachute is also a pendulum-style aircraft. Its airframe CG is fixed at the pendulum attach point. It is more limited in controllability than the WSC aircraft because it lacks an aerodynamic pitch control. Pitch (and lift) control is primarily a function of the power control.
- Increased power results in increased lift; cruise power amounts to level flight; decreased power causes a descent

Balloons

- The balloon is controlled by the pilot only in the vertical dimension; this is in contrast to all other aircraft. He or she achieves this control through the use of lift and weight. Wind provides all other movement.

Terminology

- Pilots and FAA-certificated mechanics or repairmen must ensure they understand the terms as they relate to the aircraft in question.
- For small aircraft terminology, use the information found in sources associated with Civil Air Regulation (CAR) 3 certification or General Aviation Manufacturers Association (GAMA) Specification No. 1 for part 23 aircraft or part 27 for rotorcraft

ABBREVIATIONS

BCF	BromoChlorodiFluoromethane (Halon- Fire Extinguisher)	
BRT	Bright	
C°	Celsius	C
CAA	Civil Aviation Authority	
CAT	Clear Air Turbulence	
CAO	Cargo Aircraft Only	
CBT	Computer Based Training	
CCM	Cabin Crew Member	
CDL	Configuration Deviation List	
CO_2	Carbon Dioxide	
CN	Company Notice	
CPL	Commercial Pilot Licence	
CPR	Cardio Pulmonary Resuscitation	
CPT	Captain	
CRM	Crew Resource Management	
CTOT	Calculated Take-Off Time (Slot)	
CFMD	Confirmed	
CSPM	Cabin Safety Procedures Manual	

FAA-Furnished Weight and Balance Information

- The information discussed to this point can be readily applied to any aircraft weight and balance problem.
- To apply the techniques, certain elements of information are required.
- This information is obtained from both FAA documents and manufacturer provided data.
- When the design of an aircraft is approved by the FAA, an Approved Type Certificate and TCDS are issued

FAA-Furnished Weight and Balance Information

- The TCDS includes all of the pertinent specification for the aircraft; at each annual or 100-hour inspection, it is the responsibility of the inspecting mechanic or repairman to ensure that the aircraft adheres to them.
- The weight and balance information on a TCDS includes CG range, empty weight CG range (EWCG), maximum weights, number of seats, maximum baggage, fuel capacity, oil capacity, and datum location.

CG Range

- Forward Limits: 138.7 inches at 2,110 lb with a straight line taper to 141.0 in at 2,694 lb and 143.0 in at 2,900 lb.
- Aft Limits: 144.6 in at 2,110 lb, with straight line taper to 147.4 in at 2,570 lb, and to 147.9 in at 2,745 lb, and 148.2 in at 2,900 lb

Empty Weight CG Range (EWCG)

- When all of the seats and baggage compartments are located close together, it is not possible (as long as the EWCG is located within the EWCG range) to legally load the aircraft so that its operational CG falls outside this allowable range.
- If the seats and baggage areas extend over a wide range, the EWCG range is listed as “None.”

Maximum Weights

- The maximum allowable takeoff and landing weights and the maximum allowable ramp weight are given. This basic information may be altered by a note. Notes are found in data pertinent to all models.

Number of Seats

- The number of seats and their arms are given in such terms as: 4 (2 at 143.5 aft of datum, 2 at 180 aft of datum).

Maximum Baggage

Maximum baggage for this model is 130 pounds at 208 inches.

Fuel Capacity

This important information is given in such terms as: 60.5 gal at 153.75 in. Usable: 56 gal (See Note 1). Notes can be found in data pertinent to all models.

Oil Capacity (Wet Sump)

The quantity of the full oil supply and its arm are given: 8 quarts at 76.2 in.

Weighing the Aircraft and Determining the Empty Weight Center of Gravity

The practical aspects of weighing an airplane and locating its CG are discussed. Formulas are introduced that allow the CG location to be measured in inches from various datum locations and in percentage of the mean aerodynamic chord (MAC).

Weighing the Aircraft and Determining the Empty Weight Center of Gravity

- The primary purpose of aircraft weight and balance control is safety.
- Manufacturers conduct extensive flight tests to establish loading limits for their aircraft because limit information is critical for safe flight.
- A secondary purpose is to aid efficiency during flight.
- Overloading of the aircraft is not the only concern; the distribution of the weight is important also.
- The aircraft has CG limits, and any loading that places the CG outside the established limits seriously impairs controllability of the aircraft.

Weighing the Aircraft and Determining the Empty Weight Center of Gravity

1. Establish by computation that the authorized weight and CG limits as shown in the type certificate data sheet (TCDS) and aircraft specifications are not exceeded, and

2. Record the new empty weight center of gravity (EWCG) data in the current approved aircraft flight manual or issued operating limitations.

Equipment for Weighing

Weighing aircraft with accurately calibrated scales is the only sure method of obtaining an accurate empty weight and CG location.

The two basic types of scales used to weigh aircraft are

- platform
- load cell

Platform scales or ramp wheel scales

- Modified version of the platform scale are low profile, easy to handle, safe, and reliable
- Tow or push the aircraft wheels or skids onto the scale pad at ground level.
- With one scale per wheel, each device should be capable of measuring up to at least 60,000 pounds since the weight on each wheel rarely exceeds


WEIGHING SERVICE

Load cell scales

- Load cell scales are also a reliable means to weigh aircraft and are typically cheaper than the platform type.
- With this method, the aircraft is placed on jacks with electronic load cells placed between the jack and the jack pad on the aircraft.
- The aircraft is raised on the jacks until the wheels or skids are off the floor and the aircraft is in a level flight attitude. The weight measured by each load cell is indicated on the control panel.
- The maximum recognized period between calibration checks is 12 months

Preparation for Weighing

- In general, weight procedures may vary with the aircraft and types of weight equipment employed.
- The weighing procedure contained in the manufacturer's maintenance manual should be followed for each particular aircraft.
  - Scale Preparation
  - Weigh Clean Aircraft Inside Hangar
  - Equipment List
  - Ballast
  - Standard Weights

Scale Preparation

- Mechanical and electronic scales shall be inspected prior to use and set to zero. This is done by adding and removing a weight, then rechecking for zero.
- The scales should be located in the same environment in which they are to be used and allowed to come up to temperature at least 2 hours prior to use.
- Scales should not be used in temperature extremes below 40 °F or above 100 °F unless the scale is specifically designed for use in those temperatures

Weigh Clean Aircraft Inside Hangar

- The aircraft should be weighed inside a hangar where wind cannot blow over the surface and cause fluctuating or false scale readings.
- The aircraft should be clean inside and out, with special attention paid to the bilge area to ensure that no water or debris is trapped there.
- The outside of the aircraft should be as free as possible of all mud and dirt.

Equipment List

- All of the required equipment must be properly installed, and there should be no equipment installed that is not included in the equipment list.
- If such equipment is installed, the weight and balance record must be corrected to indicate it.

Ballast

- All required permanent ballasts must be properly secured in place. All temporary ballasts must be removed.

Standard Weights

- Standard weights are established weights for numerous items involved in weight and balance computations. These weights should not be used if actual weights are available.

Weighing Point	Pounds per U.S. Gallon	
	32 °F	59 °F
AVGAS (Aviation Gasoline)	6.14	6.01
JET A & A-1	6.75	6.68
Water	8.35	8.33
Oil	7.50	7.43

Figure 3-4. *Standard fuels and weights with temperatures of 32 °F and 59 °F.*

Draining the Fuel

- Drain fuel from the tanks in the manner specified by the aircraft manufacturer.
- If there are no specific instructions, drain the fuel until the fuel quantity gauges read empty when the aircraft is in level-flight attitude
- Any fuel remaining in the system is considered residual or unusable fuel and is part of the aircraft empty weight.

Draining the Fuel

- If it is not feasible to drain the fuel, the tanks can be topped off to be sure of the quantity they contain and the aircraft weighed with full fuel.
- After weighing is complete, the weight of the fuel and its moment are subtracted from those of the aircraft as weighed. To correct the empty weight for the residual fuel, add its weight and moment.
- When computing the weight of the fuel (e.g., a tank full of jet fuel), measure its specific gravity (sg) with a hydrometer and multiply it by 8.345 (the nominal weight of 1 gallon of pure water whose sg is 1.0).

Oil

- The empty weight for aircraft certificated under the Civilian Air Regulations (CAR) part 3 does not include the engine lubricating oil.
- The oil must either be drained before the aircraft is weighed, or its weight must be subtracted from the scale readings to determine the empty weight.

Other Fluids

- The hydraulic fluid reservoir and all other reservoirs containing fluids required for normal operation of the aircraft should be full.
- Fluids not considered to be part of the empty weight of the aircraft are potable (drinkable) water, lavatory pre charge water, and water for injection into the engines.

Configuration of the Aircraft

- Consult the aircraft service manual regarding position of the landing gear shock struts and the control surfaces for weighing.
- When weighing a helicopter, the main rotor must be in its correct position

Jacking the Aircraft

- Aircraft are often weighed by rolling them onto ramps in which load cells are embedded.
- This eliminates the problems associated with jacking the aircraft off the ground.
- However, many aircraft are weighed by jacking the aircraft up and then lowering them onto scales or load cells.

Leveling the Aircraft

- When an aircraft is weighed, it must be in its level flight attitude so that all of the components are at their correct distance from the datum. This attitude is determined by information in the TCDS.
- Some aircraft require a plumb line to be dropped from a specified location so that the point of the weight (the bob) hangs directly above an identifiable point.

Safety Considerations

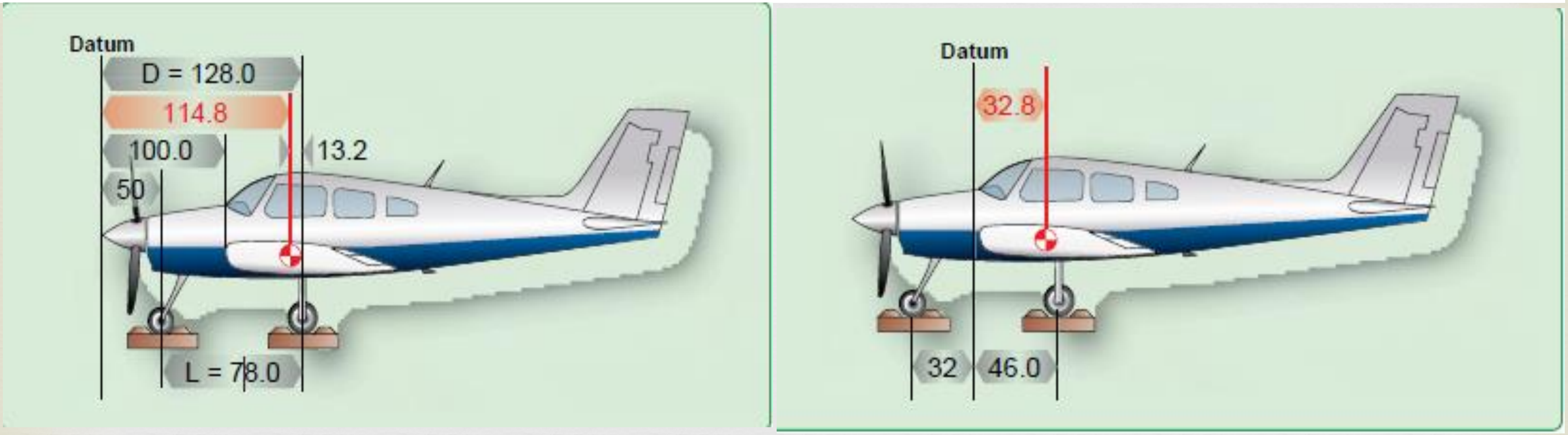
- Stress plates must be installed under the jack pads if the manufacturer specifies them
- If anyone is required to be in the aircraft while it is being jacked, there must be no movement.
- The jacks must be straight under the jack pads before beginning to raise the aircraft.
- All jacks must be raised simultaneously and the safety devices are against the jack cylinder to prevent the aircraft tipping if any jack should lose pressure. Not all jacks have screw down collars, some use drop pins or friction locks.

Determining the CG

- When the aircraft is in its level flight attitude, drop a plumb line from the datum and make a mark on the hangar floor below the tip of the bob. Draw a chalk line through this point parallel to the longitudinal axis of the aircraft.
- Determine the CG by adding the weight and moment of each weighing point to determine the total weight and total moment. Then, divide the total moment by the total weight to determine the CG relative to the datum

Weighing point	Scale reading (lb)	TARE weight (lb)	Net weight (lb)	Arm (in)	Moment (lb-in)	CG
Right side	846	16	830	46.0	38,180	
Left side	852	16	836	46.0	38,456	
Nose	348	8	340	-32.0	-10,880	
Total			2,006		65,756	32.8

Figure 3-5. *Locating the CG of an airplane relative to the datum.*

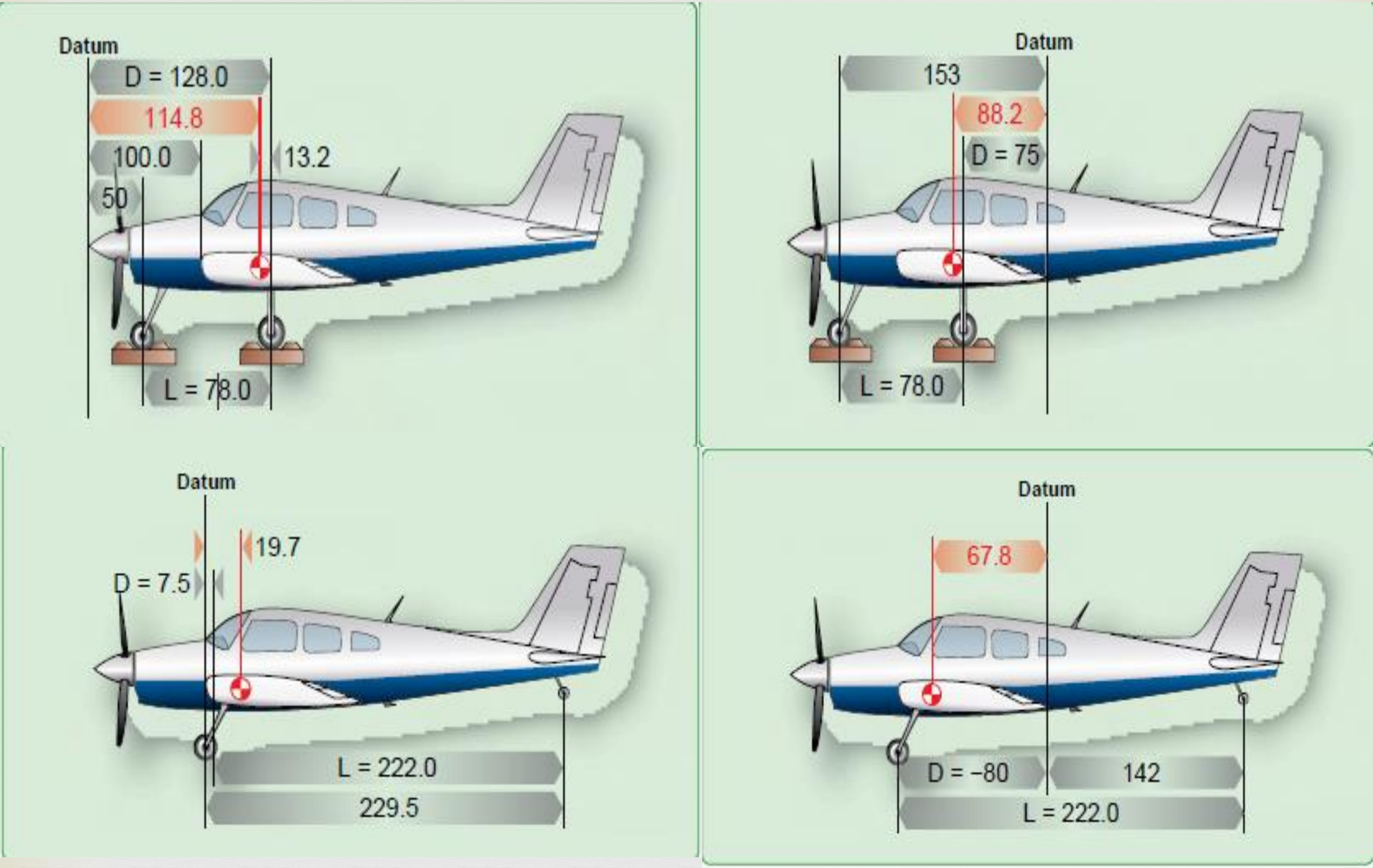


EWCG Formulas

- A chart such as the one in *Figure 3-5* helps the pilot visualize the weights, arms, and moments when solving an EWCG problem, but it is quicker to determine the EWCG by using formulas and an electronic calculator.

EWCG Formulas

- Datum Forward of the Airplane—Nosewheel Landing Gear
- Datum Aft of the Main Wheels—Nosewheel Landing Gear
- Datum Forward of the Main Wheels—Tailwheel Landing Gear
- Datum Aft of the Main Wheels—Tailwheel Landing Gear



Datum
D = 128.0
114.8
100.0
13.2
50
L = 78.0
Datum
153
88.2
D = 75
L = 78.0
Datum
19.7
D = 7.5
L = 222.0
229.5
Datum
67.8
D = −80
142
L = 222.0

Datum Forward of the Airplane Nosewheel Landing Gear

- The datum of the airplane in *Figure 3-8* is 100 inches forward of the leading edge of the wing root or 128 inches forward of the main-wheel weighing points. This is distance (D).
- The weight of the nosewheel (F) is 340 pounds, and the distance between main wheels and nosewheel (L) is 78 inches. The total weight of the airplane (W) is 2,006 pounds

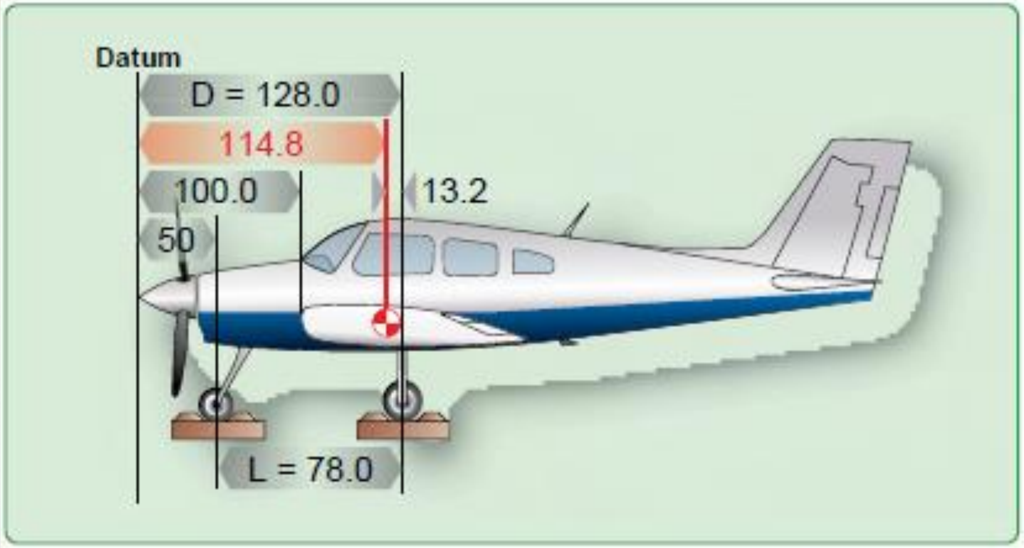


Figure 3-8. *The datum is 100 inches forward of the wing root leading edge.*

$$CG = D - \left(\frac{F \times L}{W}\right)$$

$$= 128 - \left(\frac{340 \times 78}{2{,}006}\right)$$

$$= 114.8$$

Datum Aft of the Main Wheels Nosewheel Landing Gear

- The datum of some aircraft may be located aft of the main wheels. The airplane in this example is the same one just discussed, but the datum is at the intersection of the trailing edge of the wing with the fuselage.
- The distance (D) between the datum of the airplane in *Figure 3-10* and the main-wheel weighing points is 75 inches, the weight of the nosewheel (F) is 340 pounds, and the distance between main wheels and nosewheel (L) is 78 inches. The total net weight of the airplane (W) is 2,006 pounds

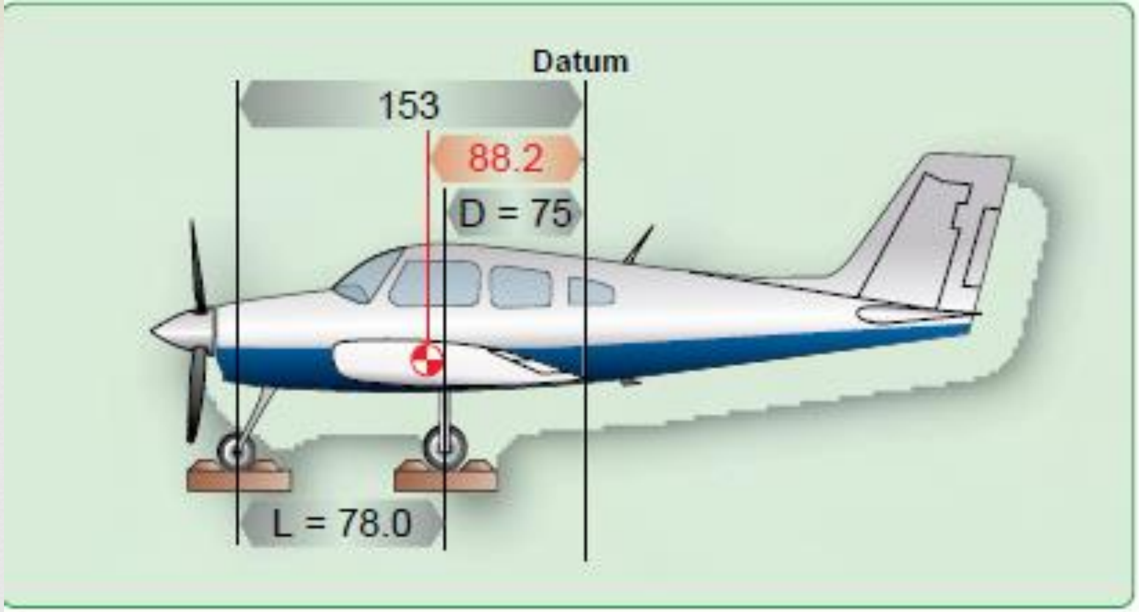


Figure 3-10. *The datum is aft of the main wheels at the wing trailing edge.*

$$CG = -\left(D + \frac{F \times L}{W}\right)$$

$$= -\left(75 + \frac{340 \times 78}{2{,}006}\right)$$

$$= -88.2$$

Figure 3-11. *Determining the CG with datum aft of the main wheels of an airplane with nosewheel landing gear.*

Datum Forward of the Main Wheels—Tailwheel Landing Gear

The distance (D) between the datum of the airplane in Figure 3-12 and the main-gear weighing points is 7.5 inches, the weight of the tailwheel (R) is 67 pounds, and the distance (L) between the main-wheel and the tailwheel weighing points is 222 inches. The total weight of the airplane (W) is 1,218 pounds. Determine the CG by using the formula in Figure 3-13.

Locating the CG of a tailwheel airplane is done in the same way as locating it for a nosewheel airplane except the formula is $\left(\frac{R \times L}{W}\right)$

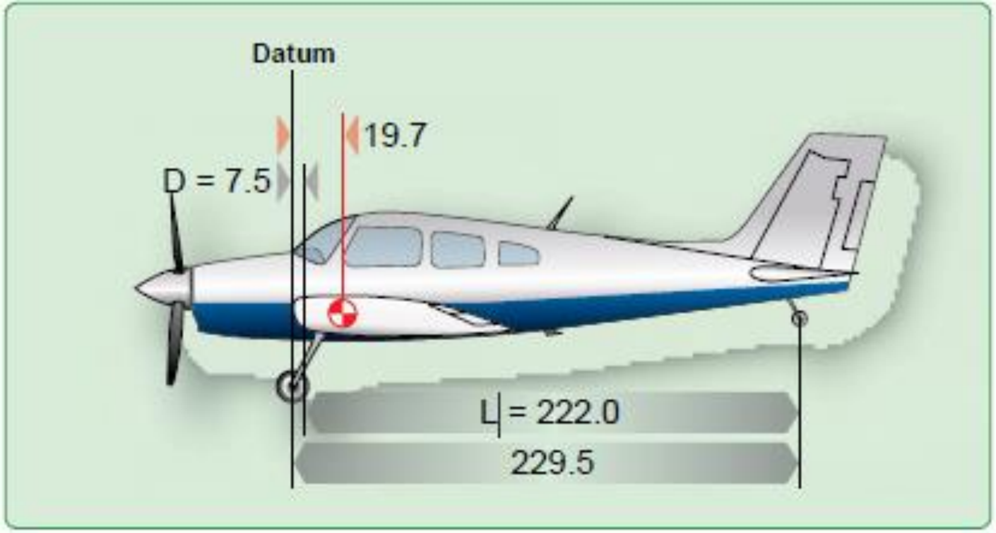


Figure 3-12. *The datum of this tailwheel airplane is the wing root leading edge.*

$$CG = D + \left(\frac{R \times L}{W}\right)$$

$$= 7.5 + \left(\frac{67 \times 222}{1{,}218}\right)$$

$$= 19.7$$

Figure 3-13. *Determining the CG with datum forward of the main wheels in an airplane with tailwheel landing gear.*

Datum Aft of the Main Wheel Tailwheel Landing Gear

- The datum of the airplane in *Figure 3-14* is located at the intersection of the wing root trailing edge and the fuselage.
- This places the arm of the main gear (D) at –80 inches. The net weight of the tailwheel (R) is 67 pounds, the distance between the main wheels and the tailwheel (L) is 222 inches, and the total net weight (W) of the airplane is 1,218 pounds.
- Since the datum is aft of the main wheels, use the formula

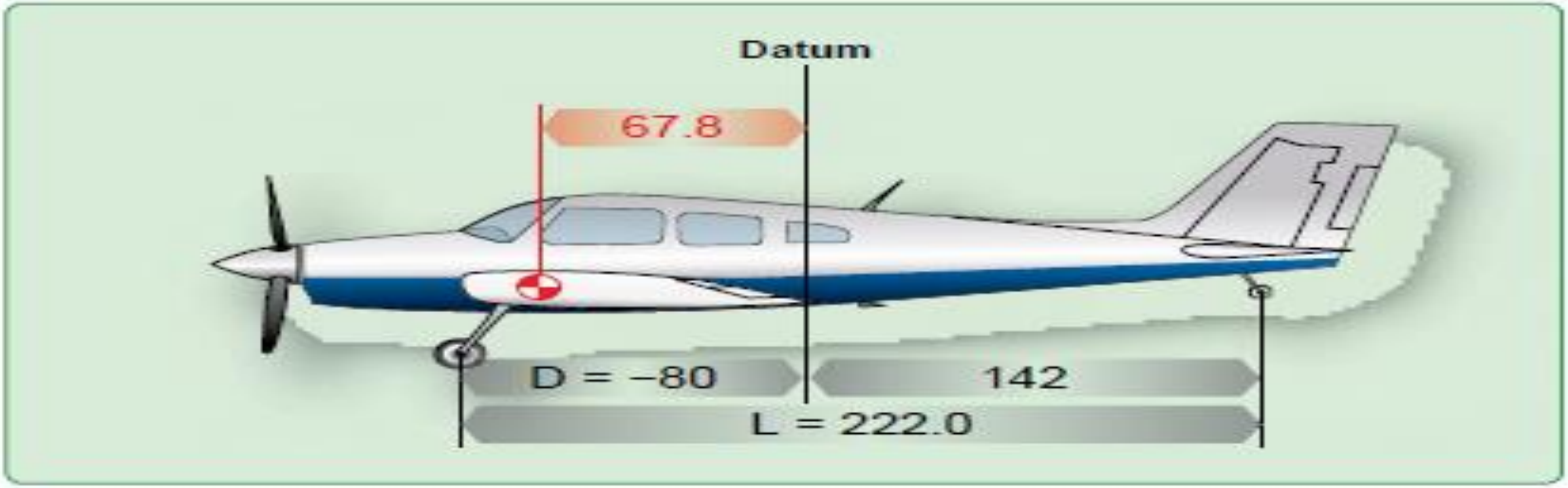


Figure 3-14. *The datum is aft of the main wheels, at the intersection of the wing trailing edge and the fuselage.*

$$CG = -D + \left(\frac{R \times L}{W}\right)$$

$$= -80 + \left(\frac{67 \times 222}{1{,}218}\right)$$

$$= -67.8$$

Figure 3-16. *Determining the CG with datum aft of the main wheels in an airplane with tailwheel landing gear.*

Aircraft Rigging

- Aircraft rigging involves the adjustment and travel of movable flight controls which are attached to aircraft major surfaces, such as wings and vertical and horizontal stabilizers.
- Ailerons are attached to the wings, elevators are attached to the horizontal stabilizer, and the rudder is attached to the vertical stabilizer.
- Rigging involves setting cable tension, adjusting travel limits of flight controls, and setting travel stops.

Rigging Specifications

- Type Certificate Data Sheet
- Maintenance Manual
- Structural Repair Manual (SRM
- Manufacturer’s Service Information

Airplane Assembly

- **Aileron Installation**
- **Flap Installation**
- **Empennage Installation**

Control Operating Systems

Cable Systems

- Material
- Cable construction
- Cable designations

Material

aircraft control cables are fabricated from carbon steel or stainless (corrosion resistant) steel. Additionally, some manufacturers use a nylon coated cable that is produced by extruding a flexible nylon coating over corrosion-resistant steel (CRES) cable.

By adding the nylon coating to the corrosion resistant steel cable, it increases the service life by protecting the cable strands from friction wear, keeping dirt and grit out, and dampening vibration which can work harden the wires in long runs of cable.

Cable construction

The basic component of a cable is a wire. The diameter of the wire determines the total diameter of the cable.

A number of wires are preformed into a helical or spiral shape and then formed into a strand.

These preformed strands are laid around a straight center strand to form a cable.

Cable designations

Based on the number of strands and wires in each strand. The 7 × 19 cable is made up of seven strands of 19 wires each. Six of these strands are laid around the center strand.

This cable is very flexible and is used in primary control systems and in other locations where operation over pulleys is frequent. The 7 × 7 cable consists of seven strands of seven wires each.

Six of these strands are laid around the center strand. This cable is of medium flexibility and is used for trim tab controls, engine controls, and indicator controls.

Rigging Checks

The purpose of this section is to explain the methods of checking the relative alignment and adjustment of an aircraft’s main structural components. It is not intended to imply that the procedures are exactly as they may be in a particular aircraft. When rigging an aircraft, always follow the procedures and methods specified by the aircraft manufacturer.

Rigging Checks

Structural Alignment

- Checking Dihedral
- Checking Incidence
- Checking Fin Verticality
- Checking Engine Alignment
- Symmetry Check

Rigging Checks

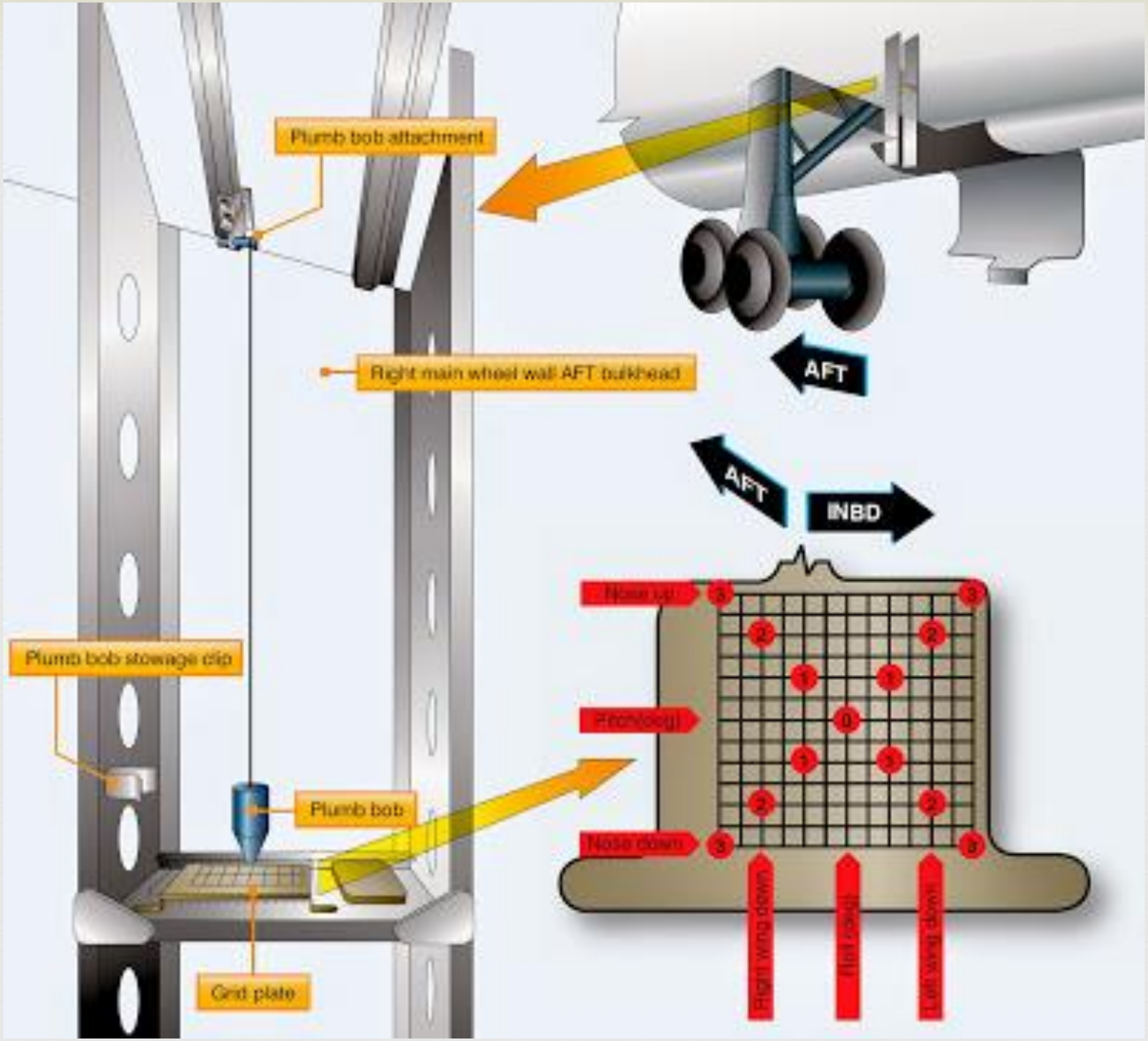
- **Cable Tension**
- **Control Surface Travel**
- **Checking and Safe tying the System**

Structural Alignment

The position or angle of the main structural components is related to a longitudinal datum line parallel to the aircraft center line and a lateral datum line parallel to a line joining the wing tips. Before checking the position or angle of the main components, the aircraft must be jacked and leveled.

Structural Alignment

- Small aircraft usually have fixed pegs or blocks attached to the fuselage parallel to or coincident with the datum lines.
- A spirit level and a straight edge are rested across the pegs or blocks to check the level of the aircraft.
- This method of checking aircraft level also applies to many of the larger types of aircraft.
- However, the grid method is sometimes used on large aircraft. The grid plate is a permanent fixture installed on the aircraft floor or supporting structure


Plumb bob attachment
Right main wheel wall AFT bulkhead
AFT
AFT
INBD
Plumb bob stowage clip
Plumb bob
Grid plate
Nose up
Nose down
Right wing down
Left wing down

Structural Alignment

- Some manufacturers permit adjusting the wing angle of incidence to correct for a wing-heavy condition.
- The dihedral and incidence angles should be checked after hard landings or after experiencing abnormal flight loads to ensure that the components are not distorted and that the angles are within the specified limits

Structural Alignment

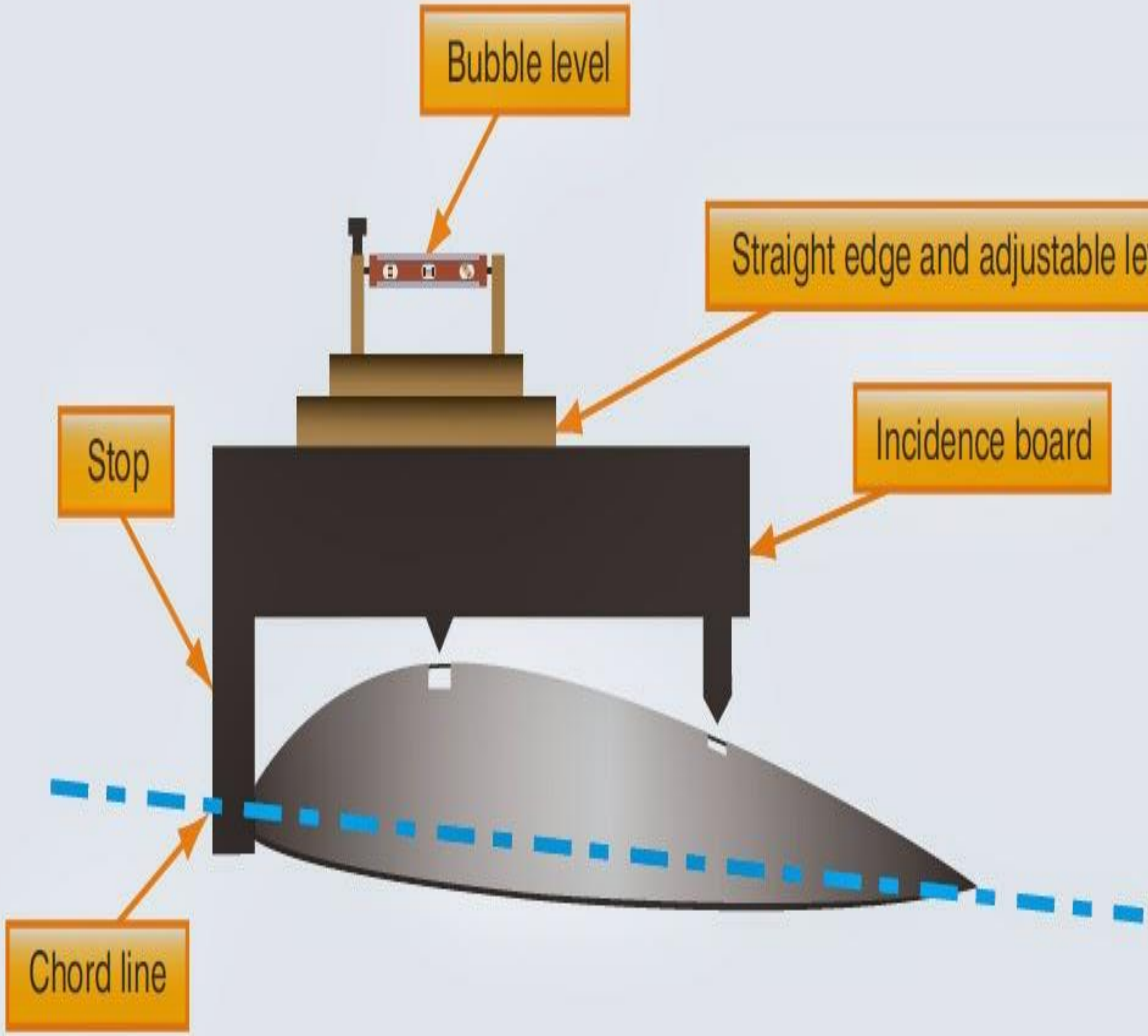
- Wing dihedral angle
- Wing incidence angle
- Verticality of the fin
- Engine alignment
- A symmetry check
- Horizontal stabilizer incidence
- Horizontal stabilizer dihedral

Checking Dihedral

The dihedral angle should be checked in the specified positions using the special boards provided by the aircraft manufacturer. If no such boards are available, a straight edge and a inclinometer can be used.

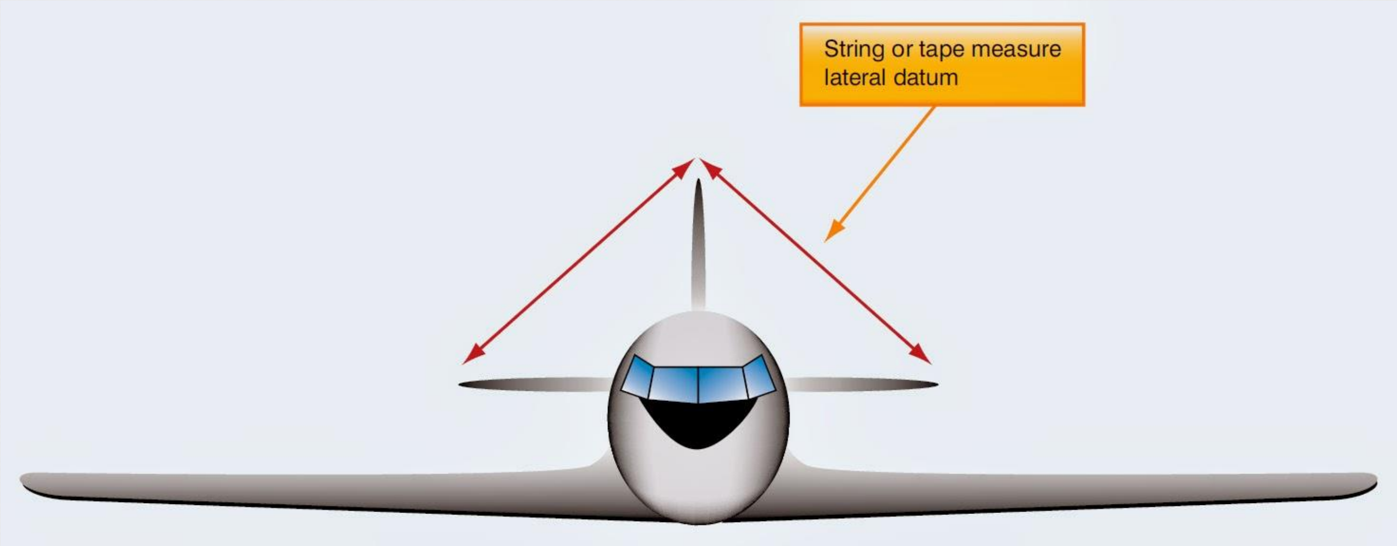
Checking Incidence

- Incidence is usually checked in at least two specified positions on the surface of the wing to ensure that the wing is free from twist.
- A variety of incidence boards are used to check the incidence angle. Some have stops at the forward edge, which must be placed in contact with the leading edge of the wing.
- Others are equipped with location pegs which fit into some specified part of the structure


Bubble level
Straight edge and adjustable level
Incidence board
Stop
Chord line

Checking Fin Verticality

After the rigging of the horizontal stabilizer has been checked, the verticality of the vertical stabilizer relative to the lateral datum can be checked. The measurements are taken from a given point on either side of the top of the fin to a given point on the left and right horizontal stabilizers



Checking Engine Alignment

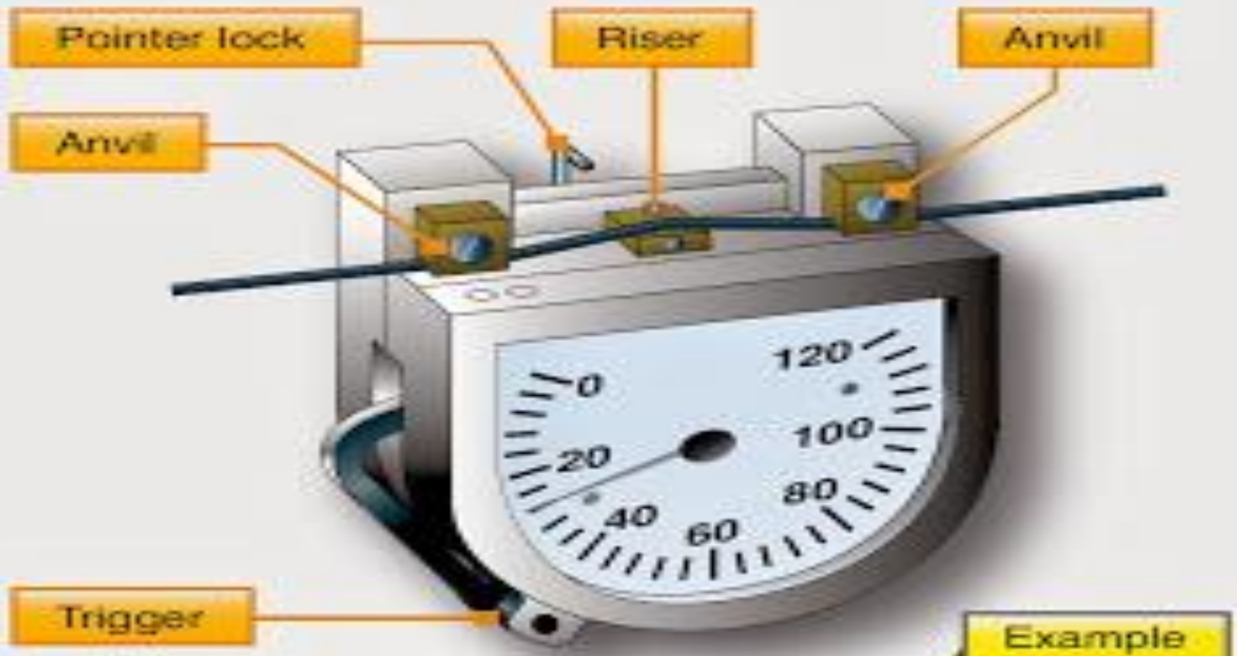
- Engines are usually mounted with the thrust line parallel to the horizontal longitudinal plane of symmetry.
- However, this is not always true when the engines are mounted on the wings.
- Checking to ensure that the position of the engines, including any degree of offset is correct, depends largely on the type of mounting.
- Generally, the check entails a measurement from the center line of the mounting to the longitudinal center line of the fuselage at the point specified in the applicable manual

Symmetry Check

- On small aircraft, the measurements between points are usually taken using a steel tape.
- When measuring long distances, it is suggested that a spring scale be used with the tape to obtain equal tension. A five-pound pull is usually sufficient.

Cable Tension

- To determine the amount of tension on a cable, a tensiometer is used.
- When properly maintained, a tensiometer is 98 percent accurate.
- Cable tension is determined by measuring the amount of force needed to make an offset in the cable between two hardened steel blocks called anvils



Example

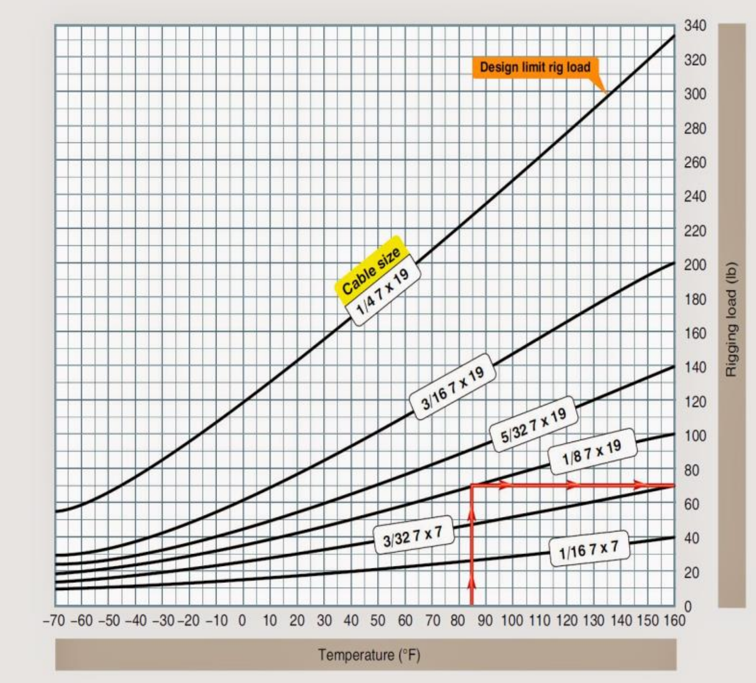
No. 1			Riser	No. 2		No. 3	
Diameter			Tension (lb)				
1/16	3/32	1/8		5/32	3/16	7/32	1/4
12	16	21	30	12	20		
19	23	29	40	17	26		
25	30	36	50	22	32		
31	36	43	60	26	37		
36	42	50	70	30	42		
41	48	57	80	34	47		
46	54	63	90	38	52		
51	60	69	100	42	56		
			110	46	60		
			120	50	64		

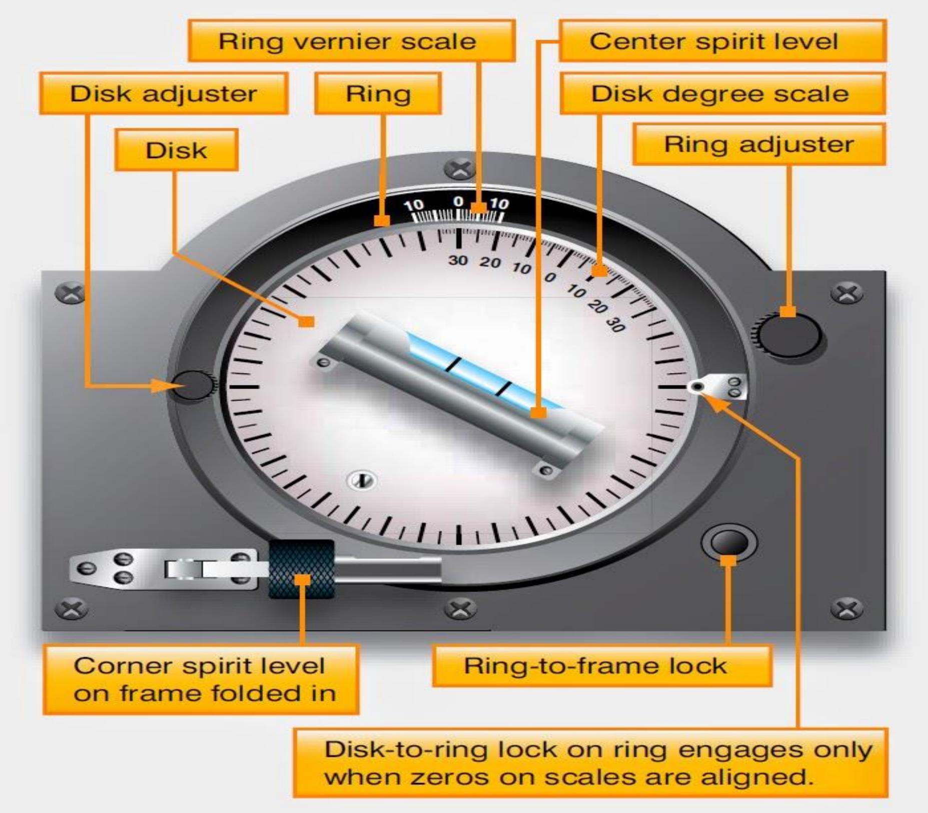
Cable Tension

- Included with each tensiometer is a conversion chart, which is used to convert the dial reading to pounds.
- The dial reading is converted to pounds of tension as follows. Using a No. 2 riser to measure the tension of a 5/32" diameter cable, a reading of 30 is obtained.
- The actual tension (see chart) of the cable is 70 lbs

Cable Tension

Another variable that must be taken into account when adjusting cable tension is the ambient temperature of cable and the aircraft. To compensate for temperature variations, cable rigging charts are used when establishing cable tensions in flight control, landing gear, and other cable-operated systems





Ring vernier scale
Center spirit level
Disk adjuster
Ring
Disk degree scale
Disk
Ring adjuster
10 0 10
30 20 10 0 10 20 30
Corner spirit level
on frame folded in
Ring-to-frame lock
Disk-to-ring lock on ring engages only
when zeros on scales are aligned.

Control Surface Travel

- Lock the flight deck control, bell cranks, and the control surfaces in the neutral position.
- Adjust the cable tension, maintaining the rudder, elevators, or ailerons in the neutral position.
- Adjust the control stops to limit the control surface travel to the dimensions given for the aircraft being rigged.

Control Surface Travel

- The range of movement of the controls and control surfaces should be checked in both directions from neutral.
- There are various tools used for measuring surface travel, including protractors, rigging fixtures, contour templates, and rulers.
- These tools are used when rigging flight control systems to ensure that the aircraft is properly rigged and the manufacturer's specifications have been complied with.

Checking and Safe tying the System

- Whenever rigging is performed on any aircraft, it is good practice to have a second set of eyes inspect the control system to make certain that all turnbuckles, rod ends, and attaching nuts and bolts are correctly safetied.

Small screw in closely spaced closed geometrical pattern • Single-twist method

Cable Inspection

- Aircraft cable systems are subject to a variety of environmental conditions and deterioration. Wire or strand breakage is easy to recognize visually. Other kinds of deterioration, such as wear, corrosion, and distortion, are not easily seen. Special attention should be given to areas where cables pass through battery compartments, lavatories, and wheel wells. These are prime areas for corrosion. Special attention should be given to critical fatigue areas

Cable Inspection

- Hose areas are defined as anywhere the cable runs over, under, or around a pulley, sleeve, or through a fairlead; or any section where the cable is flexed, rubbed, or within 1 foot of a swaged-on fitting. Close inspection in these critical fatigue areas can be performed by rubbing a rag along the cable

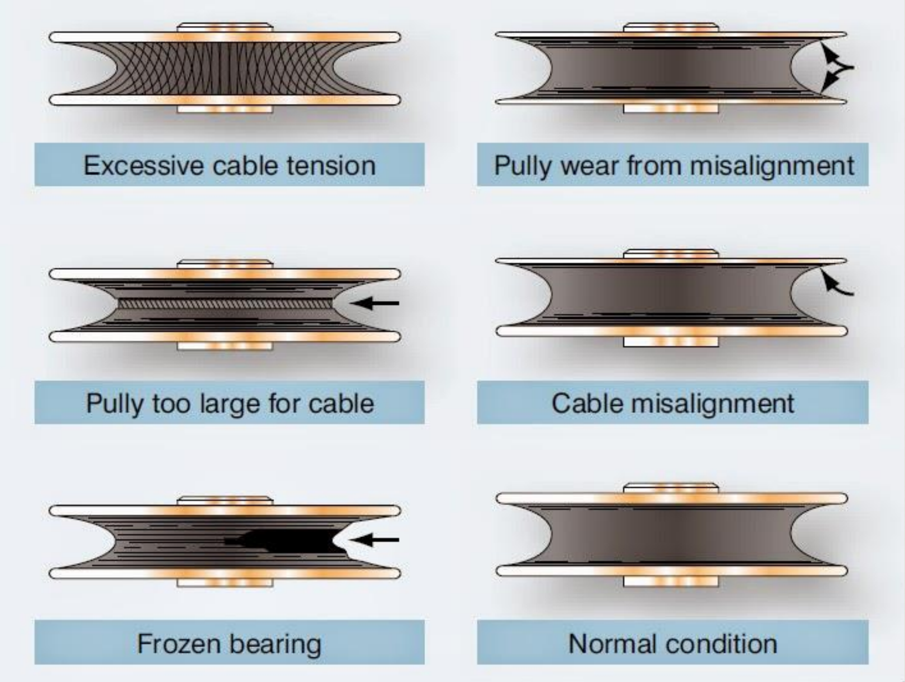
Cable System Installation

Cable Guides

- Pulleys are used to guide cables and also to change the direction of cable movement.
- Pulley bearings are sealed and need no lubrication other than the lubrication done at the factory.
- Brackets fastened to the structure of the aircraft support the pulleys. Cables passing over pulleys are kept in place by guards.
- The guards are close fitting to prevent jamming or to prevent the cables from slipping off when they slacken due to temperature variations

Cable System Installation

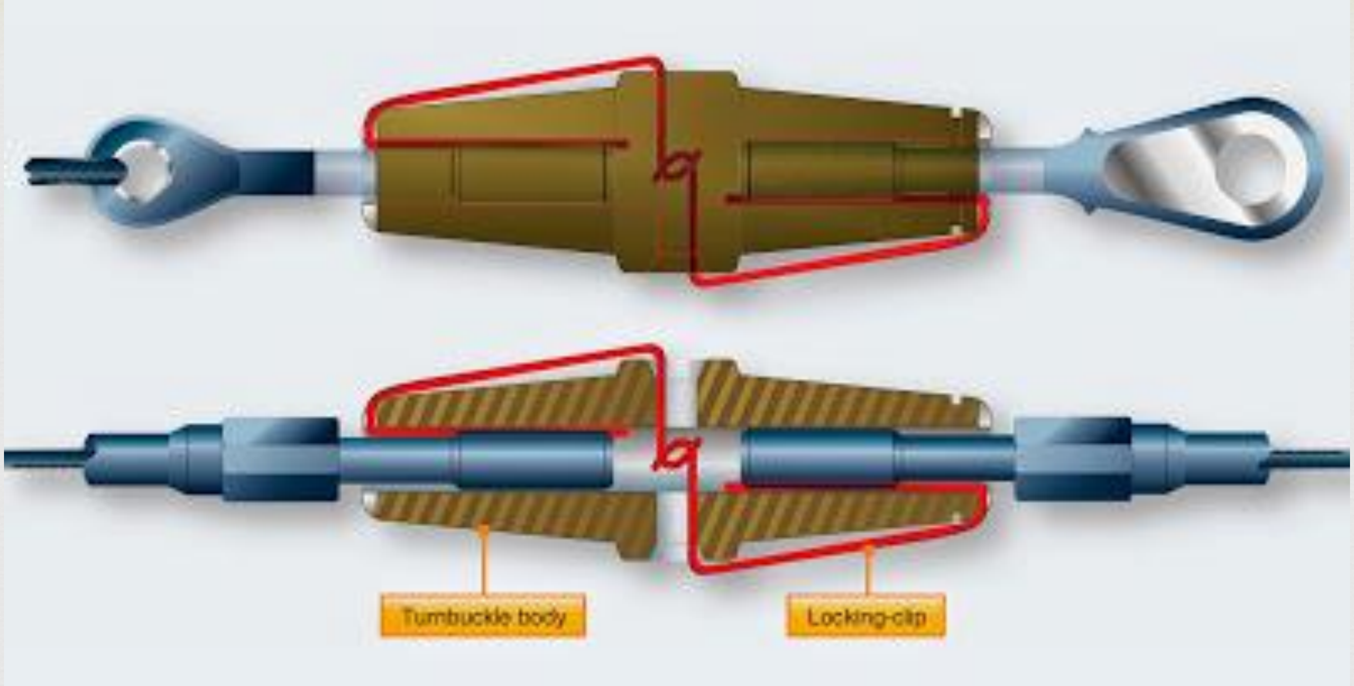
Pulleys should be examined to ensure proper lubrication; smooth rotation and freedom from abnormal cable wear patterns which can provide an indication of other problems in the cable system



Rigging Fixtures

Rigging fixtures and templates are special tools (gauges) designed by the manufacturer to measure control surface travel. Markings on the fixture or template indicate desired control surface travel.

- ✓ **Tension Regulators**
- ✓ **Turnbuckles**
- ✓ **Cable Connectors**
- ✓ **Spring-Back**

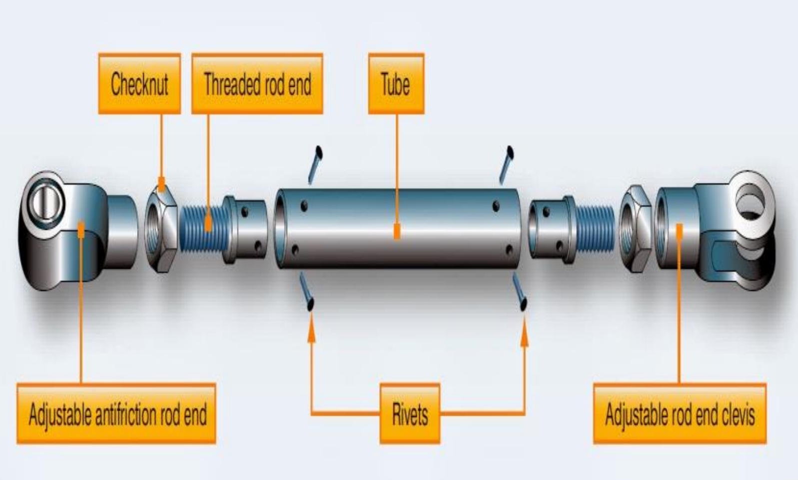

Turnbuckle body
Locking-clip

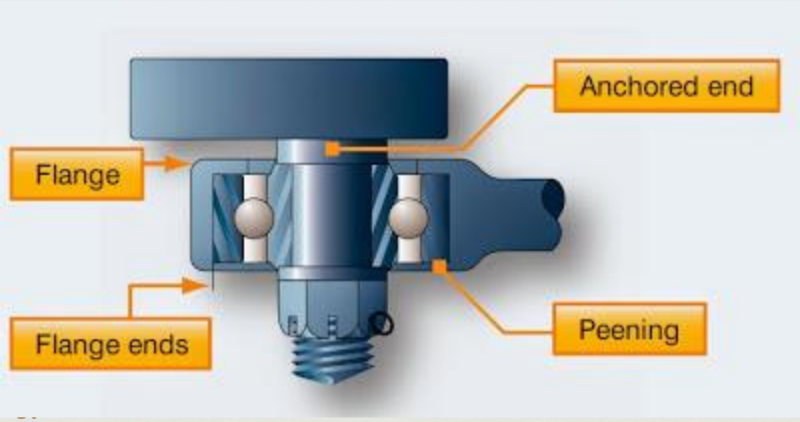

Spring connector

Push Rods (Control Rods)

Push rods are used as links in the flight control system to give push-pull motion. They may be adjusted at one or both ends

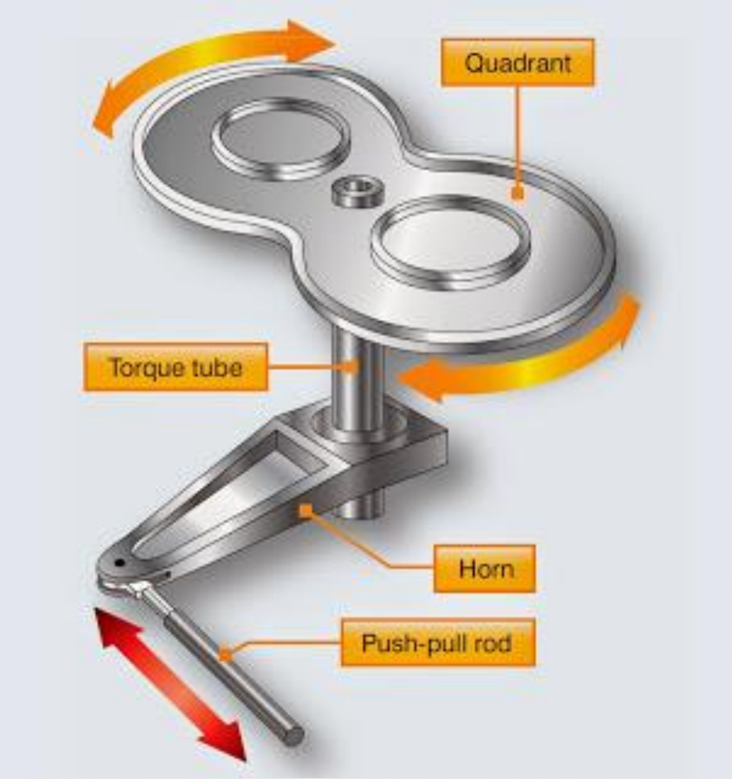
Notice that it consists of a tube with threaded rod ends. An adjustable antifriction rod end, or rod end clevis, attaches at each end of the tube





Torque Tubes

Where an angular or twisting motion is needed in a control system, a torque tube is installed. shows how a torque tube is used to transmit motion in opposite directions



THANK YOU