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II.F. Airplane Weight and Balance

Objectives	The student should develop knowledge of the elements related to weight and balance, and be able to properly calculate an airplane's weight and balance for a given situation.
Key Elements	✈ Performance ✈ Calculating weight and balance ✈ Adding, removing, and shifting weight
Elements	✈ Terms ✈ Weight and flight performance ✈ Weight and balance control ✈ Determining weight and balance
Schedule	1. Discuss objectives 2. Review material 3. Development 4. Conclusion
Equipment	✈ White board ✈ Markers ✈ References
Instructor's Actions	1. Discuss lesson objectives 2. Present lecture 3. Questions 4. Homework
Student's Actions	Participate in discussion Take notes
Completion Standards	The student understands the factors related to weight and balance and the airplane's control, stability, and performance. The student can calculate the weight and balance for a given situation and make adjustments as necessary.

References

FAA-H-8083-1, *Weight and Balance Handbook*
FAA-H-8083-25B, *Pilot's Handbook of Aeronautical Knowledge* (Chapter 5, Chapter 9, **Chapter 10**)
POH/AFM

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Instructor Notes

Introduction

Overview—review objectives and key ideas.
Why—pilots need to keep weight within safe limits, and balance the loads carried to maintain control of the airplane.

Terms

Reference datum—an imaginary vertical plane from which all horizontal distances are measured for balance purposes. May be located anywhere the manufacturer chooses) nose, engine firewall, wing's leading edge, ahead of the nose,…)

Station—a location on the airplane fuselage usually given in terms of distance from the reference datum.

Arm—the horizontal distance (usually in inches) from reference datum to the CG of an item. Arms ahead of the reference datum are negative, arms behind the datum are positive. If the datum is ahead of the nose, all of the arms are positive.

Moment—force that causes (or tries to cause) an object to rotate.

Moment index—the moment divided by a reduction number (100 or 1000) to get it smaller and reduce errors.

Center of gravity—the point at which the airplane would balance if suspended. Distance of CG from reference datum = total moment/total weight.
Limits: extreme locations (forward/aft) at which the CG can be to be operated at a given weight.

Usable fuel—the fuel available for flight planning.
Unusable fuel—the fuel in the tanks that cannot be safely used in flight or drained on the ground.

Weights

Basic empty weight—the weight of the standard airplane, optional equipment, unusable fuel, and full operating fluids (including oil).
Payload—weight of occupants, cargo, and baggage.
Useful load—difference between takeoff (or ramp) weight and basic empty weight.
Maximum ramp weight—the maximum weight approved for ground maneuvers (including start, taxi, and runup fuel).
Maximum takeoff weight—maximum weight approved for the start of the takeoff roll.
Maximum landing weight—maximum weight approved for landing touchdown.

Maximum zero fuel weight—maximum weight excluding usable fuel.

Standard weights—
- Gas: 6lbs/gallon
- Jet fuel: 7lbs/gallon
- Oil: 7lbs/gallon
- Water: 8.35lbs/gallon

Weight and flight performance

Heavier gross weight—
- Longer takeoff/landing roll
- Shallower climb
- Faster touchdown speed
- Slower acceleration/deceleration
- Increased retarding forces (drag, ground friction)

Reduced climb/cruise performance can lead to—
- Overheating during climbs
- Added wear on engine
- Increased fuel consumption
- Slower cruise speed
- Reduced range

Structure

Overloading can result in catastrophic structural failures. However, often, structural failures affect the structure progressively, making it difficult to detect and repair.
Airplanes are certified to withstand structural loads based on category. Total load remains in limits if gross weight and load factor limits are observed. Exceeding the max gross weight can cause damage even if the load factors are within weight limits.
Cumulative results of routine overloading can result in failure later on during normal operations.

Stability

Airplane with forward loading
- Slower
- Nose-up trim required, requires tail surfaces to produce a greater down load, adding to wing loading/total lift required from wing to maintain altitude.
- Requires a higher AOA, resulting in more drag, producing a higher stalling speed.
- More controllability—longer arm makes elevator more effective.

Airplane with aft loading
- Faster cruise
- Reduced drag (smaller AOA, less down deflection on stabilizer)
- Tail surface produces less down load, relieving the wing of loading and lift.

- Lower stall speed.
- Recovery from stall becomes progressively more difficult as CG moves aft.

Controllability

Generally, aircraft becomes less controllable as CG moves aft.
The elevator arm is shorter, requires greater deflection for the same result.
Aft CG makes stall recovery harder—plane's tendency to pitch down is reduced. Moving the CG beyond the aft limit may make stall and spin recovery impossible.
Moving the CG forward makes the airplane more nose-heavy, and the elevator may be unable to hold up the nose, especially at low airspeeds.

Weight and balance control

The pilot is responsible for managing weight and balance, and determining weight and balance conditions via various methods:
- CG calculations
- CG graphs
- CG tables

Determining weight and balance

CG = total moment/total weight
1. Beginning with the empty weight, list everything that will be loaded in the airplane (people, items, fuel).
2. Make sure the loaded weight is within limits. If too high, remove items/people.
3. Calculate moments of each item—use graph, or multiply weight by arm.
4. Calculate CG.
5. Determine if CG is within limits.

Weight change, CG shift

$CG = (M+\Delta M)/(W+\Delta W)$
Weight added causes a positive moment change.
Weight shifted aft causes a positive moment change, weight shifted forward causes a negative moment change.

Conclusion	Brief review of the main points. Weight and balance affects flight—ensure the airplane is correctly balanced before each flight.

CFI PTS

Objective: To determine that the applicant exhibits instructional knowledge of the elements of runway incursion avoidance by describing:

1. Distinct challenges and requirements during taxi operations not found in other phases of flight operations.
2. Procedures for appropriate cockpit activities during taxiing including taxi route planning, briefing the location of hot spots, communicating and coordinating with ATC.
3. Procedures for steering, maneuvering, maintaining taxiway, runway position, and situational awareness.
4. The relevance/importance of hold lines.
5. Procedures for ensuring the pilot maintains strict focus on the movement of the aircraft and ATC communications, including the elimination of all distractive activities (i.e. cell phone, texting, conversations with passengers) during aircraft taxi, takeoff and climb out to cruise altitude.
6. Procedures for holding the pilot's workload to a minimum during taxi operations which should increase the pilot's awareness while taxiing.
7. Taxi operation planning procedures, such as recording taxi instructions, reading back taxi clearances, and reviewing taxi routes on the airport diagram,
8. Procedures for ensuring that clearance or instructions that are actually received are adhered to rather than the ones expected to be received.
9. Procedures for maintaining/enhancing situational awareness when conducting taxi operations in relation to other aircraft operations in the vicinity as well as to other vehicles moving on the airport.
10. Procedures for briefing if a landing rollout to a taxiway exit will place the pilot in close proximity to another runway which can result in a runway incursion.
11. Appropriate after landing/taxi procedures in the event the aircraft is on a taxiway that is between parallel runways.
12. Specific procedures for operations at an airport with an operating air traffic control tower, with emphasis on ATC communications and runway entry/crossing authorizations.
13. ATC communications and pilot actions before takeoff, before landing, and after landing at towered and nontowered airports.
14. Procedures unique to night operations.
15. Operations at non-towered airports.
16. Use of aircraft exterior lighting.
17. Low visibility operations.

PPL/CPL ACS

Objective: To determine that the applicant:

1. Computes weight and balance. Determines the computed weight and center of gravity is within the airplane's operating limitations, and if the weight and center of gravity will remain within limits during all phases of flight.

Be prepared to walk a student through an example.

CG = gross weight/moment

Fwd vs aft CG (decreased stall speed, slower cruise speed, more stable, harder to flare, easier to recover from a stall—opposite and improbable spin recovery for aft CG)

Piper has datum at tip of spinner

172RG Battery at back for W&B because of retractable gear at front

As you burn fuel, normally CG moves forward, further away from center of lift

As gross weight decreases, Vx goes down, Vy goes down, Vg goes down

As altitude increases, Vx goes up, Vy goes down, Vg goes down

You don't need to calculate it before each flight, but you are required to ensure the plane is within W&B