Ground Lesson: Performance and Limitations

Objectives:

1. To understand stability and the effects varying CG's have on performance
2. To understand how to read common performance charts, tables, and data
3. To understand how to properly calculate weight and balance
4. To understand the effects atmospheric conditions have on performance

Justification:

1. Understanding an aircraft's performance and limitations is critical to all aspects of flight, especially takeoff and landing
2. Cross country planning requires the ability to read and interpret performance data
3. Understanding the effects of atmospheric conditions on performance is critical to safety during takeoffs and landings
4. Checkrides require and understanding of performance and limitations

Schedule:

Activity	Est. Time
Ground	1.5
Total	1.50

Elements Ground:

- CG and stability
- atmospheric conditions on performance
- weight and balance
- performance charts, tables, data

Completion Standards:

1. When the student is able to properly read and interpret performance tables, charts, and data
2. when the student exhibits knowledge relating to aircraft performance, limitations, and the varying effects of different environments

Presentation Ground:

CG and Stability

1. stability overview
   (1) stability *:inherent quality of an airplane to correct for conditions that may disturb its equilibrium, and to return or to continue on the original flightpath*
   (2) there are 2 kinds of stability
      i. static stability *:initial tendency the airplane displays after its equilibrium is disturbed*
      ii. dynamic stability *:overall tendency the airplane displays after its equilibrium is disturbed*
      iii. our aircraft's display positive static stability, and positive dynamic stability, which means the aircraft tends to return to it's original flight path after being disturbed
      iv. there is also neutral and negative stability as well
2. CG overview
   (1) CG (center of gravity) is the point at which a plane would balance if it were suspended at that point
   (2) it is significant because the CG is the common point of the 3 axes as well as the measuring point for all weight and balance calculations
   (3) CG can significantly effect the aircraft's performance and controllability
   (4) the CG of an aircraft is not a stationary point, and can be changed via loading of the aircraft
      i. note that the CG will also change in flight as expendable material (mainly fuel) are reduced
3. stability along the axes
   (1) in designing a plane, significant effort is put into designing stability into each of the axes
   (2) longitudinal - stability about it's lateral axis
      i. dependent on location of CG vs center of lift, tail surfaces and thrustline, as well as the area of the tail surface
      ii. our aircraft is designed to have the CG in front of the CL, and the tail behind the CL
         (i) therefore, the tail's down force counteracts the nose heavy characteristic.
   (3) lateral - stability about it's longitudinal axis
      i. dependent on dihedral, sweepback, keel effect and weight distribution
      ii. *dihedral* is the angle between the lateral axis and the wing's lateral line
         (i) dihedral improves positive lateral stability by varying each wing's AoA when the aircraft is disturbed by a roll (and then slip)
      iii. sweepback is the angle greater (or less than) 90° from the longitudinal axis at which an aircraft's wing is connect to the fuselage
         (i) swept back wings contribute to positive lateral stability during a slip because the wing into the wind has more lift while the wing out of the wind has less lift
      iv. keel effect and weight distribution
         (i) with a greater portion of the "keel" above the CG, in a side slip, the effect tends to roll the aircraft back to wings level
   (4) vertical - stability about the vertical axis (yawing)
      i. achieved by the area of the vertical fin and side of the fuselage behind the CG vs in front of the CG
      ii. with more behind the CG, the aircraft effectively acts as a weathervane

(i) if the airplane yaws left, the right side of the vertical fin and fuselage is exposed, and forced back to straight (and visa versa)

4. characteristics of differing CGs

(1) forward CG - forward CG adds additional nose heavy characteristic to the plane causing:

i. more longitudinal stability

ii. more load on the wing (due to additional tail down force required)

iii. higher stalling speed (due to higher wing loading)

(2) aft CG

i. less longitudinal stability (due to lack of down force on tail required)

ii. less wing load

iii. lower stall speeds

iv. better cruise performance

(3) out of limit CGs

i. out of limit CGs can be very detrimental to an airplanes stability and control

ii. CG too far forward can cause

(i) longer takeoff distances

(ii) very high stall speeds

(iii) inability to raise nose (not enough elevator effectiveness) during takeoff or landing

iii. CG too far aft can cause

(i) elevator effectiveness becomes unusable

(ii) in a stall or spin, the aircraft may not be able to nose down, causing an unrecoverable situation

atmospheric conditions on performance

1. density altitude *:density altitude is pressure altitude corrected for non-standard temperature*

(1) at low density altitudes (high air pressure), the aircraft performs better

(2) at high density altitudes (low air pressure), the aircraft does not perform as well

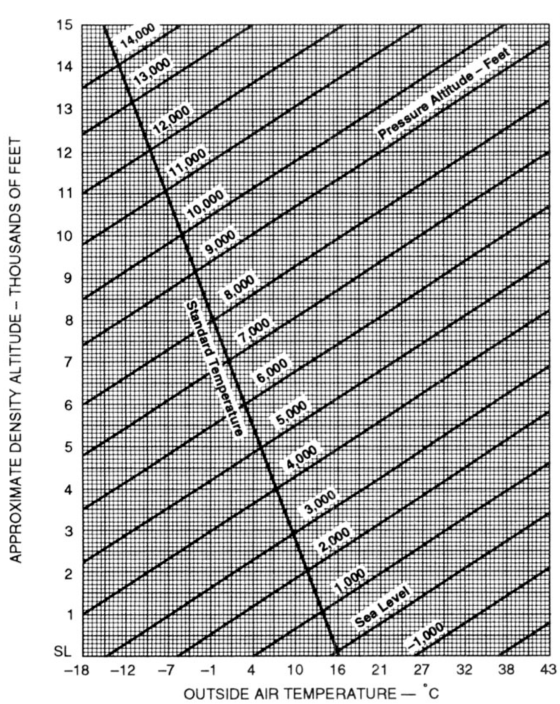
(3) density altitude is used to calculate aircraft performance

2. pressure - directly proportional

3. temperature - inversely proportional

4. humidity - inversely proportional (since moist air is lighter that dry air)

DENSITY ALTITUDE CHART



Altimeter Setting (" Hg)	Pressure Altitude Conversion Factor
28.0	1,824
28.1	1,727
28.2	1,630
28.3	1,533
28.4	1,436
28.5	1,340
28.6	1,244
28.7	1,148
28.8	1,053
28.9	957
29.0	863
29.1	768
29.2	673
29.3	579
29.4	485
29.5	392
29.6	298
29.7	205
29.8	112
29.9	20
29.92	0
30.0	–73
30.1	–165
30.2	–257
30.3	–348
30.4	–440
30.5	–531
30.6	–622
30.7	–712
30.8	–803
30.9	–893
31.0	–983

weight and balance

1. effects of weight

(1) an overloaded aircraft does not perform as well as a lighter aircraft

i. higher stall speeds, longer takeoff rolls, reduced rate of climb, longer landing roll, etc

2. weight and balance limits
   (1) weight and balance limits are defined to allow for safe loading of aircraft.
   (2) within these limits, the aircraft has been tested to be able to perform within the specified POH standards
   (3) by using weight and balance calculations, the PIC can determine if for a given weight, and a certain loading configuration, the aircraft is within the forward and aft cg limits
3. definitions
   (1) center of gravity - point at which an item would balance if it were balanced there. In an aircraft, it is expressed as inches away from datum
   (2) datum - imaginary vertical plane from which all measurements are taken. datum is defined by the manufacturer
   (3) arm (moment arm) - horizontal distance from the reference datum line to the center of gravity of an item. (+) used if measured aft of datum, (-) used if measured fwd of datum
   (4) station - equivalent to the arm, a location in the airplane that is identified by a number designating its distance in inches from the datum
   (5) moment - the product of the weight of and item multiplied by its arm.
      i. unit is pound-inches
   (6) stadard empty weight - consists of the airframe, engine, all items of operating equipment that have fixed locations and are permanently installed in the airplane. This includes hydraulic fluid, unusable fuel, and full engine oil
   (7) basic empty weight - standard empty weight plus optional and special equipment that has been installed
   (8) maximum takeoff weight - maximum allowable weight for takeoff
   (9) maximum ramp weight - total weight of a loaded aircraft including fuel. It's greater than MTW due to fuel burn during start-up, run-up, taxiing
   (10) useful load - weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil
4. basic weight and balance computations
   (1) the idea is to distribute weight properly to balance the aircraft around a specific CG envelope
   (2) to calculate weight and balance for an aircraft, there are 3 things that need to be calculated: total weight, total moment, and CG location
      i. total weight = basic empty weight + all items loaded into the aircraft
         (i) this includes passengers, baggage, fuel, etc.
      ii. moment = weight of item x arm of item
         (i) large moments are produced by heavy items, and items with long arms
      iii. CG = moment / weight
      iv. note that with any two items (moment, weight, CG), we can calculate the third
   (3) essentially, we calculate the moment for each item, add them up, and divide by the total weight
   (4) the POH provides arm's for each major location (i.e. front seats, rear seats, baggage compartments, fuel tanks, etc.
   (5) the POH also provides the basic empty weight AND the CG location (or moment)
   (6) see weight and balance worksheets, loading graphs, and CG moment envelope graphs in POH

performance charts, tables, data

1. overview
   (1) actual vs practical chart reading
      i. the environment in which performance charts are designed are similar to car manufacturers. they want to show the best numbers, thus they use the most ideal situations
      ii. perfect environment, perfect plane, perfect pilot
      iii. thus, the charts should be taken with a grain of salt. our planes are used, our experience is not that of a test pilot, and we rarely fly in ideal conditions
   (2) interpolation
      i. some table may not give the exact values for the conditions we are flying in. in this case we must interpolate the values from available data
         (i) i.e. if we are flying in 20° temps, and the table has 10° and 30° columns, we must add each of those two values together, and divide by 2 to get the interpolated value
2. charts and tables
   (1) overview
      i. the graphs and charts available in the POH can be very detailed and confusing at first
      ii. it is important to read ALL notes on a given chart as they may effect how you will do a calculation
   (2) density altitude - see chart above
   (3) takeoff - see POH
   (4) climb and cruise - see POH
   (5) x-wind/headwind chart - see POH
   (6) landing chart - see POH
   (7) stall speed performance chart - see POH