Flight Advisor Corner by Hobie Tomlinson

December 2012 **<u>Flying Multi-Engine Aircraft</u> (Pt. VII)**

Continuing our series on flying FAR Part 23 (CFR 14, Chapter 1, Subchapter C, and Part 23) certified, small multi-engine airplanes, we continue looking at the issues involved in a multi-engine transition course. This month we will be continuing our tour through a typical General Aviation Manufactures Association (GAMA) standard format Airplane Flight Manual (AFM) issued for FAR Part 23 certificated airplanes.

***"Glacier Girl"*-** Lockheed P-38F-1-LO Lightning/AirVenture 2012

Aircraft was part of a formation flight to Europe that was intentionally landed on the Greenland Ice Cap on 15 July 1942, due to unforecast weather. – Hobie *Tomlinson Image*

<u>Last Month</u> we stopped after completing Section V on Performance. This month we will pick up our discussion with **Section VI** on **Weight and Balance.**

<u>Section VI</u> (Weight and Balance) is a subject that has had a lot written about it. However, I want to take a little different slant on Weight and Balance and talk about how it affects us in the cockpit. Most articles that I have seen on the subject of Weight and Balance either delves into engineering theory or goes into intricate detail on how weight and balance is computed by the Aviation Maintenance Technicians (AMTs) who periodically recompute the official aircraft weight and balance documents for their customers. Today there are so many different weight and balance computation formats used by the different manufacturers that picking a sample to go through would largely be a waste of time. In addition, more and more manufacturers (and/or secondary service providers) now have electronic weight and balance formats available in which the crew only has to accurately input the actual people, baggage, and fuel on-board to derive an accurate weight and balance calculation. (GIGO, **Garbage In, Garbage Out** still applies, however!) So, let's take a look at weight and balance from the cockpit and see if we can understand what it actually means to us as pilots.

The Starting Point when checking out in any airplane is to memorize the associated weight limitations and know their definitions and applications. For airplanes certified after 1978 that have an Aircraft Flight Manual (AFM), the applicable weight limitations will be located in **Section II (Limitations)** of the AFM. For Aircraft certified earlier under Civil Air Regulations (CAR) Part 3 prior to January 1, 1958, or between that date and the emergence of FAR Part 23 AFMs in 1978, the weight data will be found in the aircraft's **Type Certificate Data Sheets (TCDS).** For many of these aircraft, the information may also be found in the aircraft owner's manual and/or placards.

The Weights, which we need to know, will include some (or all) of the following:

- **Maximum Taxi Weight (MTW**), also known as Maximum Ramp Weight (MRW), is the maximum weight authorized for maneuvering (either by taxiing or towing) the aircraft on the ground as limited by aircraft strength or airworthiness requirements. It includes the weight of fuel required for start, taxi and run-up of the engine(s) and the Auxiliary Power Unit (APU) when the aircraft is so equipped. This additional weight increment (above Maximum Takeoff Weight – MTOW) is based on the fuel required for an estimated 10 to 15 minutes of taxi and engine run-up time.

- **Maximum Takeoff Weight (MTOW),** also known as Maximum Brake-Release Weight, is the maximum structural weight allowable at brake-release for the start of the takeoff roll. The actual MTOW may be limited by factors other than aircraft structural considerations, such as runway length and runway slope, runway contamination, limiting tire speeds, brake energy limits for a possible aborted takeoff, second segment climb requirements, obstacle clearance departure climb requirements, and maximum allowable landing weight at the flight's destination. Twin engine aircraft tend to be limited by engine inoperative (EI) climb requirements.

- **Maximum Landing Weight (MLW)** is the maximum structural weight authorized for a normal landing touchdown of the aircraft. (An Emergency Landing may be made at higher weights when the situation requires, but that event must be written up in the aircraft logbook as an "**Overweight Landing**." All overweight landings require that an AMT make a structural inspection of the aircraft and enter that inspection in the aircraft logbook prior to further flight.) The actual maximum landing weight may also be limited by factors other than structural considerations, such as available runway length and runway slope, runway contamination, brake energy limits, maximum tire speeds, inoperative components such as anti-skid, and missed approach and rejected landing climb requirements.

- **Maximum Zero-Fuel Weight (MZFW)** is the maximum allowable structural weight of the aircraft less all useable fuel. (It is the maximum weight permitted for the aircraft before any useable fuel is loaded in the appropriate aircraft tanks.) MZFW can be thought of as determining the maximum structural cabin load permitted for the aircraft, irrespective of the aircraft fuel load. Because wing bending moments are dampened by wing fuel, MZFW typically respects the maximum wing bending moments when flying with very light fuel loads.

- **Minimum Flight Weight (MFW)** is the lowest weight at which the aircraft will meet all the applicable airworthiness requirements. Because an aircraft's inertia lowers as the aircraft's weight is reduced, the aircraft suffers increasingly sharper displacement from turbulence (gusts) at the lighter weights. This minimum weight may also be because the very low takeoff and approach speeds associated with weights blow this value could introduce engine inoperative (EI) control issues. These weights are usually so low that they are never a factor except for the ferrying of "green" (i.e. unfurnished) aircraft.

- **Maximum Compartment Weights** are the maximum weights allowable for individual baggage compartments and are usually restricted by either the maximum permissible structural floor loading or the maximum structural restraint capability of the compartment.

- **Floor Load Limit** is the maximum weight the floor can sustain per square inch/foot as provided from the aircraft manufacturer.

- **Standard Empty Weight** (GAMA AFMs) is the weight of the airframe, engines, and all items of operating weight that have a fixed location and are permanently installed in a standard airplane. Standard Empty Weight also includes unusable fuel, full engine oil, and full operating fluids (i.e. such as brake and hydraulic fluids). This weight must be recorded in the aircraft's weight and balance records.

- **Basic Empty Weight** (GAMA AFMs) is the Standard Empty Weight plus the weight of all optional equipment installed in the airplane.

- **Useful Load** is the weight of the pilot, copilot, passengers, baggage, useable fuel, and drainable oil. This term applies to general aviation aircraft only and is determined by subtracting the basic empty weight from the maximum allowable gross weight.

- **Payload** is the weight of occupants, cargo and baggage.

- **Standard Weights** have been established by the FAA for numerous items to provide uniformity in computing weight and balance calculations. Some standard weights are as follows:

  - Aviation Gasoline . . . . 6.0 lb./US gallon
  - Jet A or A-1 . . . . 6.8 lb./US gallon
  - Engine Oil. . . . . .7.5 lb./US gallon

- **Maximum Lateral Fuel Imbalance** is the maximum lateral fuel out-of-balance condition during which the aircraft is able to demonstrate adequate controllability during the landing maneuver. Although lateral CG is not computed for airplanes (as it is for helicopters), it can still have a significant impact on the aircraft's controllability.

The Iconic Accident directly relating to attempted flight with an airplane significantly out of its maximum lateral fuel imbalance limits occurred in Butte, Montana on March 22, 2009. The disregard of this important limitation was discovered to be the principle cause of the resultant and tragic Pilatus PC-12 accident. A lateral fuel imbalance caused by fuel icing conditions occurred because the pilot had neglected to fuel the aircraft with fuel containing an icing inhibitor as required by the aircraft's AFM. The subsequently developing lateral fuel imbalance condition was either missed or ignored until it had been allowed to reach a point where it was no longer possible for the ailerons to maintain adequate lateral control. The pilot elected to make an unplanned diversion to Butte, Montana very late in the game with the aircraft rolling "out-of-control" and crashing while maneuvering into the pattern for an attempted unscheduled landing. The resultant crash was fatal to all the 13 occupants of the aircraft.

Once the Aircraft's CG location has been determined, it is plotted on a chart similar to the one depicted below in figure 4-12. This particular chart uses the loaded airplane weight versus the loaded airplane CG location as expressed in inches from the datum. **Note:** The **datum** is an imaginary vertical plane which is established by the aircraft manufacturer and from which all moment arms and the location of the CG range is measured.

Other Manufacturers use CG Range Charts which depict the loaded aircraft weight versus the loaded aircraft total moment – expressed in pound-inches (lb-in). **Note:** The **moment** is the product of the weight of an item (lbs.) multiplied by its arm (inches). **Total moment** is the weight of the airplane multiplied by the distance between the aircraft datum and its CG

<u>The Arm</u> (Moment Arm) is the horizontal distance in inches from the reference datum line to the center of gravity of an item. **<u>Note</u>:** The algebraic sign is plus (+) if measured aft of the datum, and minus (-) if it is measured forward of the datum.

Center of Gravity (CG) Range Chart

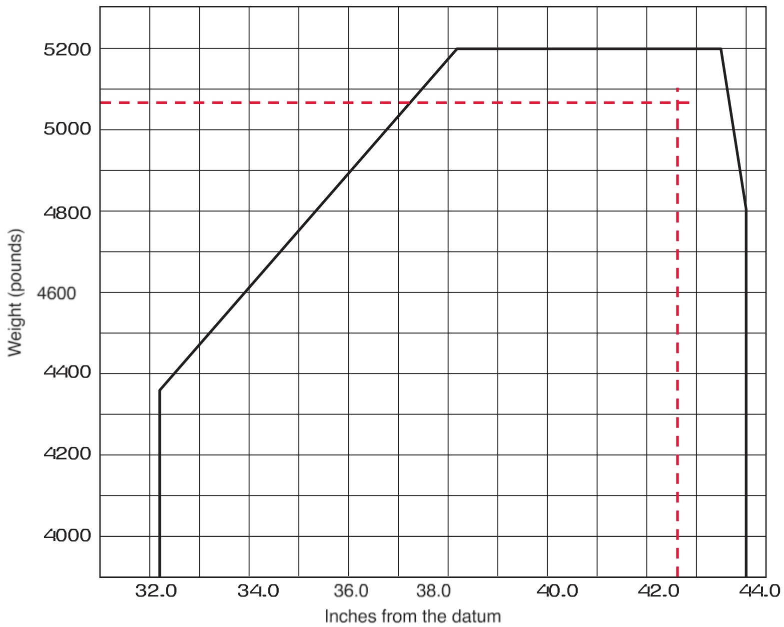


Figure 4-12 – *FAA-H-8083-1A*

<u>The Third Way</u> the CG Range chart may be depicted is loaded aircraft weight versus the percent of Mean Aerodynamic Chord (**MAC**). **<u>Note</u>:** The **Mean Aerodynamic Chord** is the average distance from the leading edge of the wing to the wing's trailing edge. The percentage of MAC is measured from the leading edge of the wing toward the wing's trailing edge.

<u>As Previously Stated</u>, we want to discuss aircraft handling qualities associated with the aircraft's weight and balance (i.e. what it means to us in the cockpit) rather than trudge down the well-worn path of how the actual weight and balance computations are made.

<u>When "Checking-Out</u>" in a new aircraft, I recommend working some problems to "box the parameters" of that particular aircraft. What is meant by the phrase "boxing the parameters" is to set one parameter at its maximum value in order to determine how much of the other parameter is allowed, as in the following examples:

- **<u>When Maximum Fuel</u>** is carried.
  - How much payload can be carried?
  - What is the available aircraft range?

- **<u>When Maximum Payload</u>** is carried.
  - How much fuel can be carried?
  - What is the available aircraft range?

- **<u>What is the Sequence</u>** of Seating Passengers?
  - One that always keeps the aircraft CG within the allowable range.
  - One that still considers the maximum comfort available to passengers.

<u>Knowledge</u> of the above parameters will usually instantly let you know whether or not a proposed operation is workable in a particular aircraft and will save a lot of explaining by preventing your discovery of that fact after the passengers have arrived for departure.

<u>Conceptually</u>, when looking at a Center of Gravity (CG) range chart, we need to realize that vertical lines represent the limits of acceptable aircraft controllability while the top horizontal line represents either minimum acceptable aircraft performance or minimum acceptable aircraft structural integrity.

<u>The Left Vertical Line</u> represents the maximum allowable forward CG location for the airplane. The maximum allowable forward CG for an airplane is usually determined by the landing characteristics of the airplane. As the aircraft's Center of Gravity moves forward (described as the aircraft becoming "nose-heavy") the following events occur:

- <u>The aircraft's "tail-download" increases</u> (i.e. the downward lift that the horizontal stabilizer is required to produce).
- <u>The aircraft's performance decreases</u> because the wing must produce enough additional lift in order to support the weight of the aircraft <u>and the required tail download</u>. Thus the aircraft acts as though it is actually heavier than it really is.
- <u>The aircraft's stall speed increases</u> because of the "effective" heavier weight that the wing must support.
- <u>The aircrafts stall characteristics tend to become docile</u> at forward CG locations.
- <u>The aircraft's stability increases</u> due to the horizontal stabilizer's authority working through a longer arm.

- The aircraft's Vmc (velocity – minimum control) decreases due to the aircraft's rudder authority working through a longer arm.
- The aircraft's maneuverability decreases due to its increased stability.
- The aircraft's control forces increase during maneuvering due to the aircraft's increased stability.
- The aircraft's susceptibility to tail-plane stall during icing conditions increases due to the greater tail-download required from the horizontal stabilizer.
- The aircraft becomes more difficult to land due to the greater elevator deflection required to achieve the proper landing attitude.
- The aircraft experiences higher (even possibly excessive) nosewheel loads with resultant improving of nosewheel steering effectiveness or a higher tendency to "nose-over" in tailwheel airplanes with decrease in the effectiveness of tailwheel steering.
- These effects increase as the aircraft's gross weight increases with a corresponding increase in the aircraft's inertia.

The Maximum Forward Center of Gravity limit for most aircraft is determined by the point where the elevator authority is no longer adequate to provide the necessary low speed maneuverability capability required during takeoff and landing. At this point it will be necessary to use full up elevator for either rotating the aircraft during takeoff or for properly flaring the aircraft during landing. This will be especially evident in Part 23 aircraft during the performance of short field takeoffs or short field landings. When Piper changed to a T-tail on their PA28R (Arrow) in 1978, they found that takeoff distances had to increase because the T-tail did not retain adequate authority to rotate the aircraft at the required short-field liftoff speed. This was because they had neglected to adequately consider the loss of tail effectiveness which occurred when the stabilizer was removed from the effects of aircraft's prop-wash. The T-tail was subsequently dropped in later production airplanes.

The Aft Slant occurring in the forward center of gravity limit-line at heavier aircraft weights is due reaching the maximum tail authority (full up elevator) at that weight. Thus to be able to continue to rotate the aircraft for takeoff at even heavier weights, the aircraft's center of gravity must start moving aft in order to allow aircraft rotation to occur with the same tail-download force (full up elevator). As the aircraft's inertia increases with increasing weight it has a dampening effect on the aircraft's maneuverability.

The Iconic Accident directly relating to attempted flight with an airplane significantly out of its forward center of gravity limits occurred at Teterboro, New Jersey on February

2, 2005. The flight crew had inadvertently loaded their Challenger CL600 aircraft beyond its forward CG limits in an attempt to "tanker" extra fuel to the next destination. Upon reaching the appropriate rotation speed (Vr) the crew found that the elevator did not have sufficient authority to rotate the aircraft to the liftoff attitude. A high-speed abort (above V1) was attempted with the aircraft departing the end of the runway, going through the airport perimeter fence, crossing a road, and then crashing into a factory building located beyond the road on the extended centerline of Runway 6. Fortunately, no fatalities occurred during this accident, but the aircraft was destroyed.

The Right Vertical Line represents the maximum allowable aft CG location for the airplane. The aft CG location is the most reward position at which the aft CG can be located for the most critical maneuver or operation that the aircraft is required to demonstrate for certification. As the aircraft's Center of Gravity moves aft (described as the aircraft becoming "tail-heavy") the following events occur:

- The aircraft's "tail download" decreases (i.e. the downward lift that the horizontal stabilizer is required to produce).
- The aircraft's performance increases because the wing must now produce less lift in order to support the weight of the aircraft and the reduced tail download required. The aircraft now acts as though it is closer to its actual weight.
- The aircraft's stall speed decreases because of the "effective" lower weight that the wing must support.
- The aircrafts stall characteristics tend to become more violent at aft CG locations.
- The aircraft's stability decreases due to the horizontal stabilizer's authority working through a shorter arm.
- The aircraft's Vmc (velocity – minimum control) increases due to the aircraft's rudder authority working through a shorter arm.
- The aircraft's maneuverability increases due to its decreased stability.
- The aircraft's control forces decrease during maneuvering due to the aircraft's decreased stability. When an aircraft is loaded at its maximum aft CG location, it becomes close to its neutral stability point with very light control forces. It is very easy to over-control an aircraft in this condition, resulting in an aircraft that is quite easy to cause to stall, to create pilot induced oscillations (PIO) and/or to produce structural overload events.
- The aircraft's susceptibility to tail-plane stall during icing conditions decreases due to the lower tail-download required from the horizontal stabilizer.
- The aircraft becomes less difficult to land due to the lower elevator deflection required to achieve the proper landing attitude.

- The aircraft experiences lower nosewheel loads with resultant lowering of nosewheel steering effectiveness or a lower tendency to "nose-over" in tailwheel airplanes with increase in the effectiveness of tailwheel steering.
- These effects increase as the aircraft's gross weight decreases with a corresponding decrease in the aircraft's inertia.

The Forward Slant, moving the aft CG limit forward at the heavier weights, is an indication that the aircraft manufacturer needed to slightly increase the aircraft's stability for these heaver weights in order to stay in compliance with all the aircraft's certification requirements.

Aircraft Loaded at their aft Center of Gravity limits demonstrate the minimum acceptable stability and can be quite near their neutral stability point. This condition produces relatively light control forces while maneuvering. I am personally convinced that some of the stall and/or structural overload induced accidents we see during this condition are because pilots are still using relative high control pressures and are not aware of the larger control deflections they are producing. Although all we tend to fly by using control pressures, it is the actual resultant control deflections produced that control the aircraft's response. Thus pilots can rapidly get into trouble at aft CG locations by not being aware of the fact that they are using excessive control deflections. This situation is exacerbated by the fact that almost all flight training occurs at or near the aircraft's forward CG limits.

Aircraft Loaded beyond their aft CG limits rapidly go through neutral stability into the negative stability region. In this condition, the aircraft will rapidly diverge from its steady state condition and any pitch movement caused by an elevator control input has to be immediately stopped by an opposing elevator control input. If this pitch divergence is not immediately contained, it will rapidly exceed the elevator controls authority to contain it and the aircraft will diverge uncontrollably. Flying an aircraft even slightly out of its aft CG limits is a full time task, allowing no ability to divert even momentary attention to any of the other ancillary tasks of the flight. Any momentary inattention to the flight controls in this condition will immediately result in total loss of control of the aircraft. As the CG continues to move aft, the divergences rapidly become quicker and more severe, causing the aircraft to become totally uncontrollable in flight.

The Iconic Accident directly relating to attempted flight with an airplane significantly out of its aft center of gravity limits occurred on January 8, 2003 at Charlotte, North Carolina. A US Airways Express Beechcraft 1900D had been loaded well beyond its aft CG limit with excessive baggage. When the aircraft was rotated for takeoff, it continued to pitch up uncontrollably. The crew was unable to contain the uncommanded pitch-up with forward elevator and the aircraft eventually stalled at 1200 feet AGL and 52 degrees nose-up pitch. Subsequent to the aircraft's "roll-off" at stall, it impacted a US Airways hangar with 21 fatalities. **Note:** It was subsequently also discovered that the aircraft's elevator controls had been improperly rigged, limiting the amount of down elevator deflection available to the crew to less than the specified amount.

The Top Horizontal Line, represents the aircraft's maximum takeoff weight (MTOW), and is limited by either reaching the aircraft maximum structural integrity limits or its minimum acceptable performance limits. Low-powered aircraft typically are limited by minimum acceptable performance considerations, while higher powered aircraft are more apt to be limited by maximum structural considerations. A good example of this is the Piper PA28 Cherokee series of aircraft, where the aircraft's gross weight increases (with the same relative airframe) as the aircraft's horsepower increases.

The Performance Limiting Event is often the requirement that an aircraft be able to climb at MTOW with full landing flaps extended (Balked Landing Climb). Anyone who has ever attempted to climb a Cessna 172N at a heavy weight with 40 degrees of landing flaps extended understands why Cessna limited subsequent CE-172 models to 30 degrees of landing flaps.

Aircraft Loaded beyond their maximum certified takeoff weight (MTOW) experience reduced safety margins. This condition becomes even more hazardous when other performance reducing factors, such as a high density altitude, are combined with an overweight condition. These performance deficiencies can have catastrophic consequences if they become combined with a subsequent emergency such as an engine inoperative (EI) condition or airframe icing. It is then too late to reconsider overloading the aircraft. ***Overloading an aircraft is in fact an irrevocable wager that no unplanned events will occur during the flight!***

Overweight Aircraft will experience the following important performance reductions and deficiencies:

- Higher takeoff speed is required.
- Longer takeoff run is required.
- Reduced rate and angle of climb occur with engine inoperative (EI) performance being severely compromised.
- Lower maximum obtainable altitude occurs with engine inoperative (EI) performance being severely compromised.
- Shorter range is experienced.
- Reduced cruising speed occurs.
- Reduced maneuverability occurs due to higher aircraft inertia.
- Higher stalling speed occurs.
- Lower structural integrity is available.

- Higher approach and landing speeds are required.
- Longer landing roll is required with additional brake heating and wear.
- Excessive weight on the nosewheel or tailwheel occurs.

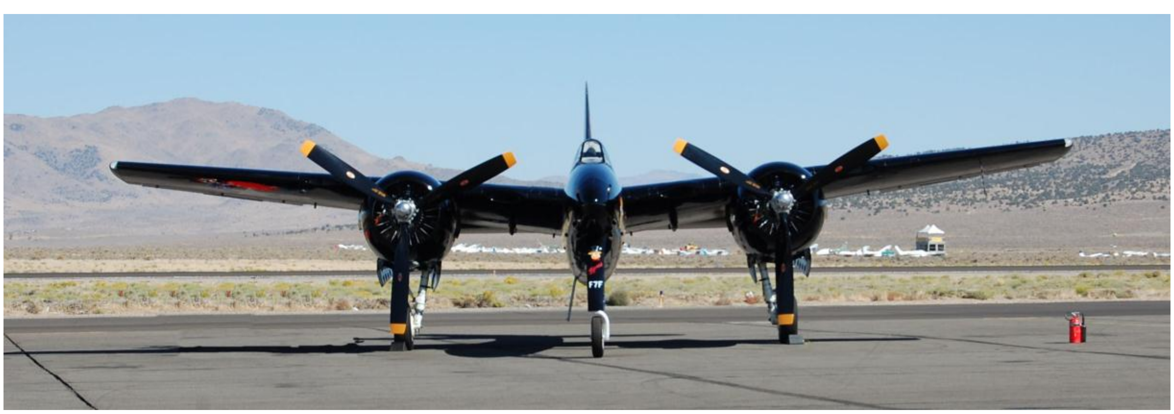
The Iconic Accident directly relating to attempted flight with an airplane significantly over its Maximum Takeoff Weight (MTOW) occurred at Long Beach, California on March 16, 2011. The pilot was attempting takeoff in a Beechcraft King Air 200 (BE-200) at a weight 650 pounds in excess of the aircraft's MTOW. *Unfortunately during this particular takeoff an engine failure actually occurred right after liftoff*! The pilot was subsequently unable to maintain adequate directional control of the aircraft and crashed, causing 5 fatalities and 1 serious injury. Even though the primary cause of the crash was the pilot's inability to maintain proper directional control of the aircraft with an engine inoperative (EI), the decision to operate the aircraft in an overweight condition certainly exacerbated the problem. **Note:** The BE-200 is limited by the manufacturer to 12,500 pounds MTOW in the United States in order to prelude the necessity for the pilots to obtaining a type rating in order to operate the aircraft. It is certified for and operated at higher weights both by U.S. military and in ICAO (International Civil Aviation Organization) countries.

This looks like a good stopping point for this month. Next month we will pick it up again with **Section VII, Systems Description** and look at the typical aircraft systems found on both light piston and turboprop multiengine aircraft

The thought for this month is: **Experience is a good teacher, but she sends in terrific bills." ~ *Minna Antrim*, American Writer.**

So, until next month, remember to **Think Right to FliRite!**

Grumman F7F-3N Tigercat "Big Bossman" at the 2007 Reno Air Races



The Tigercat was designed to have a very small frontal area Wikipedia Image

Hobietw@att.net (802) 363-3411