Accident Prevention Program

WEIGHT AND BALANCE

An Important Safety Consideration for Pilots

Aircraft performance and handling characteristics are affected by the gross weight and center of gravity limits. If every pilot were to understand and respect this fact, general aviation accidents could be reduced dramatically. An overloaded or improperly balanced aircraft will require more power and greater fuel consumption to maintain flight, and the stability and controllability will be seriously affected. Lack of appreciation for the effects of weight and balance on the performance of aircraft particularly in combination with such performance reducing factors as high density altitude, frost or ice on the wings, low engine power, severe or uncoordinated maneuvers, and emergency situations, is a prime factor in many accidents.

This review of the fundamentals of aircraft weight and balance is provided to acquaint pilots with the effects adverse loading can have on aircraft performance. Greater understanding of the problem should encourage caution.

AIRCRAFT WEIGHT

The lifting capability of an aircraft depends upon the airfoil design of the wing, the speed at which the wing moves through the air, and the density of the air. It is the design of the aircraft wing that limits the amount of available lift and it is the available power from the engine(s) that likewise limits the speed at which the wing can be made to move through the air. The efficiency of the engine/wing combination is reduced when air is less dense than the established standard day (barometric sea level pressure of 29.92 inches of mercury at a temperature of 59°F). Therefore, every pilot should ascertain during preflight preparation that the aircraft gross weight is within safe limits for the intended flight, considering the aircraft performance capabilities. The total weight of baggage, cargo, and fuel load should be adjusted accordingly to provide an adequate margin of safety.

Pilots must understand that in many general aviation aircraft it is not possible to fill all seats, load the baggage companment to capacity, carry full fuel, and remain within approved weight and balance center of gravity (c.g.) limits. In many four-place and six-place airplanes, the fuel tanks may not be filled to capacity when a full complement of passengers and their baggage is carried. It will be necessary to reduce the number of passengers or baggage weight if the proposed flight distance requires a full fuel load.

The aircraft performance characteristics adversely affected by overweight are:

- Increased takeoff speed.
- Increased takeoff runway length.
- Rate of climb.

- Maximum altitude capability.
- Operational range.
- Maneuverability.
- Controllability.
- Stall Speed.
- Approach speed.
- Landing distance.

Every pilot must consider how these characteristics would affect the aircraft in an emergency situation. Another consideration is high elevations, and/or hot and humid weather (density altitude) which is the subject of another publication in the Accident Prevention Program series.

AIRCRAFT BALANCE

Balance refers to the location of the c.g. along the longitudinal axis of the aircraft. This is of primary importance to safety of flight. There are forward and aft limits beyond which the c.g. should not be located for flight. These limits are established by the aircraft design engineers to assure proper predictable aircraft control about the horizontal, vertical, and lateral axis. The operational weight and balance limits for each aircraft are contained in the aircraft owners or flight manual. This information may also be obtained from the FAA Aircraft Specification or Data Sheets available at most aircraft maintenance facilities. The weight and balance information for each aircraft must be amended when repairs or alterations have been made that effect a change in the aircraft empty weight or c.g. location (reference FARs 43.5(a)(4) and 91.31 (b)). To assure aircraft controllability during flight the aircraft must be loaded within the design weight and c.g. limits.

A forward c.g. limit is specified to assure that sufficient elevator deflection is available at minimum speed as for landing. The aft c.g. limit is the most critical during flight maneuvers or operation of the aircraft. Aircraft stability decreases as the c.g. moves aft, and the ability of the aircraft to right itself after maneuvering will be correspondingly decreased. The aircraft will be highly unstable in gusting or turbulent air, making attitude and directional control extremely difficult.

If after the aircraft is loaded the c.g. does not fall within the allowable limits it will be necessary to shift loads before flight is attempted. The actual location of the c.g. is determined by a number of factors under control of the pilot:

—Placement of baggage and cargo.

—Assignment of seats to passengers according to each in dividual s weight.

—Fuel load. Selective use of fuel from various tank locations during flight may aid in maintaining safe balance conditions.

MANAGEMENT OF AIRCRAFT WEIGHT AND BALANCE CONTROL

All aircraft are delivered with the empty weight and c.g. data which shall remain with the aircraft records. The aircraft owner is responsible to ensure that maintenance personnel make appropriate entries in the aircraft records when repairs or alterations are made to the aircraft. Unless the aircraft flight manual is amended when the aircraft empty weight or e.g. changes the pilot has no base line for loading calculations and decisions.

TERMS ALL PILOTS SHOULD KNOW

All pilots need to be familiar with the terms related to aircraft weight and balance. Some of the more common terms are:

arm (moment arm)—the horizontal distance in inches from the reference datum to the item. The algebraic sign is plus (+) If measured aft of the datum and minus (-) if measured forward of the datum;

center of gravity (c.g.)—the point about which an aircraft would balance if it were possible to suspend it at that point. It is the mass center of the aircraft or the theoretical point at which the entire weight of the aircraft is assumed to be concentrated;

center of gravity limits—the speelfled forward and aft points beyond which the c.g. must not be located during flight. The c.g. moment envelope is contained in the aircraft ftight manual and FAA Aircraft Specifications or Data Sheets;

center of gravity range—the distance between the forward and aft c.g. Iimits;

datum line—an imaginary vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. After the datum is selected all moment arms and the c.g. range must be computed with reference to that point;

fuel load—the expendable part of the aircraft load. Fuel load includes only usable fuel and not the fuel required to fill the lines or that which remains trapped in the tank sumps;

moment—the product of the weight of an item multiplied by its arm. Moments are expressed in inch pound (in.-lb.);

total moment—the weight of the aircraft multiplied by the distance between the datum and the c.g.;

moment index—the moment divided by a constant such as 100, 1,000, or 10,000. The purpose of using a moment index is to simplify computations of weight and balance on large aircraft where heavy items and long arms result in large unmanageable numbers. It is simply a matter of reduction to the least common denominator;

mean aerodynamic chord (MAC)—the average distance from the leading edge to the trailing edge of the wing. The MAC is specified for the aircraft by determining the average chord of an imaginary wing which has tile same aerodynamic characteristics of the actual wing. Center of gravity is usually located at or near the forward 25 percent of the chord;

station—a location in the aircraft which is identified by a number designating its distance in inches from the datum. The datum is therfore identified as zero and the station and arm are usually Identieal;

useful load—the weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil;

empty weight—the airframe, engines, and all items of operating equipment that have fixed locations and are permanently installed in the aircraft. It includes optional and special equipment, fixed ballast, hydraulic fluid, unusable (residual) fuel, and undrainable (residual) oil.

A simple and fundamental weight check should always be made before flight to assure that the aircraft useful load is not exceeded.

If there is the slightest doubt about the loading, it will be advisable to calculate it by using actual weights and moment arms to determine that the aircraft is loaded within safe limits.

LOADING INFORMATION:

Aircraft Empty WT x C.G.(ARM) = Moment
Oil WT x ARM = Moment
Pilot and Passenger WT x SEAT (ARM) = Moment
Passengers WT x Seat (ARM) = Moment
Baggage WT x Compartment(ARM)=Moment
Fuel WT x Tank (ARM) = Moment
Aux. Fuel WT x Tank (ARM) = Moment

Add total weight and check against maximum takeoff weight. If within limits add the the total moment and divide by total weight to determine loaded e.g. The loaded e.g. should be within the fore and aft c.g. limits shown in the aircraft flight manual weight and balance information. If not a few minor load adjustments may correct the problem.

For your safety and the safety of your passengers check the weight and balance of your aircraft before each flight. Keep the aircraft gross weight and center of gravity within prescribed limits.

This publication was prepared to inform pilots of the adverse effects of improperly loaded aircraft. An in-depth explanation of the subject of weight and balance is provided

in several FAA advisory circulars available from the Superintendent of Documents U.S. Government Printing Office Washington D.C. 20402. They are:

AC 91-23A Pilot's Weight and Balance Handbook
SN 050-007-00405-2

AC 61-23A Pilot's Handbook of Aeronautical Knowledge
SN 050-011-00051-8

AC 43.13-1A Acceptable Methods Techniques and Practices—Aircraft Inspection and Repair
SN 050-011-00058-5

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