UGANDA

ADVISORY CIRCULAR

CAA-AC-OPS006
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APPROVAL OF OPERATOR'S MASS AND BALANCE CONTROL PROGRAMME

1.0 PURPOSE

1.0.1 This advisory circular provides operators with guidance on how to develop and receive approval for a mass and balance control program for aircraft operated under the requirements of Uganda Civil Aviation Regulations.

1.0.2 The guidance in this AC is useful for anyone involved in developing or implementing a mass and balance control program.

1.1 This document provides guidance to both passenger and cargo operators that are either—
1.1.1 Required to have an approved mass & balance control program under UCARs or
1.1.2 Choose to use actual or average aircraft, passenger, or baggage weights when operating under UCARs.

1.2 This AC details methods to develop a mass & balance control program with greater accuracy and increased flexibility.

1.3 This Advisory Circular (AC) is an initial issue dated November 2022.

2.0 REFERENCES

2.1 Regulation 48 of the Civil Aviation (Air Operators Certification and Administration) Regulations, 2022;

3.0 GENERAL

3.0.1 Accurately calculating an aircraft's weight and center of gravity (CG) before flight is essential to comply with the certification limits established for the aircraft. These limits include both mass and CG limits. By complying with these limits and operating under the procedures established by the manufacturer, an operator is able to meet the mass & balance requirements specified in the aircraft flight manual (AFM).

3.0.2 Typically, an operator calculates takeoff weight by adding the operational empty weight (OEW) of the aircraft, the weight of the passenger, cargo payload, and the weight of fuel. The objective is to calculate the takeoff weight and CG of an aircraft as accurately as possible.

3.0.3 When using average weights for passengers and bags, the operator must be vigilant to ensure that the mass & balance control program reflects the reality of aircraft loading.

3.0.4 The UCAA will periodically review the guidance in this AC and update this AC if average weights of the traveling public should change or if regulatory requirements for carry-on bags or personal items should change.

3.0.5 Ultimately, the operator is responsible for determining if the procedures described in this AC are appropriate for use in its type of operation.

3.1 DEFINITIONS & ACRONYMS

The following definitions are used in this advisory circular—

Loading Schedule. A document used to show compliance with the certificated mass & balance limitations contained in the manufacturer's AFM and mass & balance manual.

Basic empty weight. The aircraft empty weight, adjusted for variations in standard items.

Cargo. As used in this advisory circular (AC), cargo refers to everything carried in the cargo compartments of the aircraft. This includes bags, mail, freight, express, and company material. It also includes live animals, dangerous goods, and hazardous materials as subcategories of the above.

Carry-on bag. A bag that the operator allows the passenger to carry onboard. It should be of a size and shape that will allow it to be stowed under the passenger seat or in a storage compartment. The operator establishes the exact dimensional limits based on the particular aircraft stowage limits.

Certificated weight and CG limits. Weight and center of gravity (CG) limits are established at the time of aircraft certification. They are specified in the applicable aircraft flight manual (AFM).

Checked bags. Checked bags are those bags placed in the cargo compartment of the aircraft. This includes bags that are too large to be placed in the cabin of the aircraft or those bags that are required to be carried in the cargo compartment by regulation, security program, or company policy. For bags checked plane-side, see the definition for plane-side loaded bags.

Curtailment. Creating an operational loading envelope that is more restrictive than the manufacturers' CG envelope, to assure the aircraft will be operated within limits during all phases of flight. Curtailment typically accounts for, but is not limited to, in-flight movement, gear and flap movement, cargo variation, fuel density, fuel burn-off, and seating variation.

Fleet operational empty weight (FOEW). Average operational empty weight (OEW) used for a fleet or group of aircraft of the same model and configuration.

Freight. Cargo carried for hire in the cargo compartment that is not mail or passenger bags.

Heavy bags. Heavy bags are considered any bag that weighs more than 50 pounds but less than 100 pounds. Bags that are 100 pounds or more are considered freight.

Large cabin aircraft. Aircraft originally type-certificated with a maximum seating capacity of 71 or more passenger seats.

Loading envelope. Weight and CG envelope used in a loading schedule. Loading the aircraft within the loading envelope will maintain the aircraft weight and CG within the manufacturer's type-certificated limits throughout the flight.

Loading schedule. Method for calculating and documenting aircraft mass & balance prior to taxiing, to ensure the aircraft will remain within all required mass & balance limitations throughout the flight.

Maximum landing weight. The maximum weight at which the aircraft may normally be landed.

Maximum takeoff weight. The maximum allowable aircraft weight at the start of the takeoff run.

Maximum taxi weight. The maximum allowable aircraft weight for taxiing.

Maximum zero-fuel weight. The maximum permissible weight of an aircraft with no disposable fuel and oil.

Mean Aerodynamic Chord (MAC). The MAC is established by the manufacturer, which defines its leading edge and its trailing edge in terms of distance (usually inches) from the datum.

Medium cabin aircraft. Aircraft originally type-certificated with a maximum seating capacity between 70 and 30 passenger seats, inclusive.

Moment. The moment is the product of a weight multiplied by its arm. The moment of an item about the datum is obtained by multiplying the weight of the item by its horizontal distance from the datum.

Onboard mass & balance system. A system that weighs an aircraft and payload, then computes the CG using equipment onboard the aircraft.

Operational empty weight (OEW). Basic empty weight or fleet empty weight plus operational items.

Operational items. Personnel, equipment, and supplies necessary for a particular operation but not included in basic empty weight. These items may carry for a particular aircraft and may include, but are not limited to, the following—

(a) Crew members, supernumeraries, and bags;
(b) Manuals and navigation equipment;
(c) Passenger service equipment, including pillows, blankets, and magazines;
(d) Removable service equipment for cabin, galley, and bar;
(e) Food and beverage, including liquor;
(f) Usable fluids, other than those in useful load;
(g) Required emergency equipment for all flights;
(h) Life rafts, life vests, and emergency transmitters;
(i) Aircraft unit load devices;
(j) Potable water;
(k) Drainable unusable fuel;
(l) Spare parts normally carried aboard and not accounted for as cargo; and
(m) All other equipment considered standard by the operator.

Passenger assist/comfort animals and devices. These include, but are not limited to, canes, crutches, walkers, wheelchairs, medically-required animal comfort companions, or animals required to assist the vision impaired.

Passenger weight. Passenger weight is the actual weight or the approved average weight of the passenger.

(a) An adult is defined as an individual 13 years or older.
(b) A child is defined as an individual aged 2 to less than 13 years of age.
(c) Infants are children who have not yet reached their second birthday and are considered part of the adult standard average and segmented passenger weight.

Personal item. Items the operator may allow a passenger to carry aboard, in addition to a carry-on bag.

- Typically, an operator may allow one personal item such as a purse, briefcase, computer and case, camera and case, diaper bag, or an item of similar size.
- Other items, such as coats, umbrellas, reading material, food for immediate consumption, infant restraining device, and passenger assist/comfort animals and devices, are allowed to be carried on the aircraft and are not counted against the personal item allowance.

Plane-side loaded bag. Any bag or item that is placed at the door or steps of an aircraft and subsequently placed in the aircraft cargo compartment or cargo bin.

Reference Balance Arm (BA). The horizontal distance from the reference datum to the CG of an item.

Segmented weights. Passenger weights derived by adding a portion of the standard deviation to an average weight to increase the confidence that the actual weight will not exceed the average weight.

Small cabin aircraft. Aircraft originally type certificated with a maximum seating capacity between 5 and 29 passenger seats, inclusive.

Standard deviation. One of several indexes of variability that statisticians use to characterize the dispersion among the measures in a given population.

Standard items. Equipment and fluids not considered an integral part of a particular aircraft and not a variation for the same type of aircraft. These items may include, but are not limited to, the following—

(a) Unusable fuel and other unusable fluids;

(b) Engine oil;

(c) Toilet fluid and chemical;

(d) Fire extinguishers, pyrotechnics, and emergency oxygen equipment;

(e) Structure in galley, buffet, and bar; and

(f) Supplementary electronic equipment.

Useful Load. Difference between takeoff weight and OEW. It includes payload, usable fuel, and other usable fluids not included as operational items.

3.2 ACRONYMS

The following acronyms and abbreviations are used in this advisory circular—

1) **AC** – Advisory Circular
2) **AFM** – Approved Flight Manual
3) **CG** – Center of Gravity
4) **FOEW** – Fleet Operating Empty Weight
5) **LOA** – Letter of Authorization
6) **MAC** – Mean Aerodynamic Chord
7) **OEW** – Operational Empty Weight
8) **OpSpecs** – Operations Specifications
9) **UCAA** – Uganda Civil Aviation Authority
10) **UCAR** – Uganda Civil Aviation Regulation

4.0 OPERATOR-DRIVEN APPROVALS

a) All operators are required to submit and implement an actual weights program unless they desire to use average or segmented weights.

b) It is the responsibility of the operators desiring to use those weights to research, submit and obtain approval for the use of suggestions contained in this AC.

c) The operator's proposal must submit a program with substantiating documentation to the UCAA for the use of weights in its mass & balance control program to include—

   1) Appropriate combinations of standard average weights;
   2) Average weights based on survey results; or
   3) Actual weights.

4.1 UCAA APPROVAL OF MASS & BALANCE CONTROL PROGRAM

a) UCAA will normally issue their approval of an operator's mass & balance control program through the issuance of operations specifications.

b) The approval will address—

1) Average passenger and bag weights;
2) Situations when the use of average weights is inappropriate;
3) The treatment of charter flights or special groups, if applicable;
4) The type of loading schedule and instructions for its use;
5) Aircraft weighing schedules; and
6) Other procedures that the operator may require to assure control of mass & balance.

4.2 THREE CATEGORIES OF AIRCRAFT BY CABIN SIZE

a) As shown in the following table UCAA has divided aircraft into three categories for this AC to provide guidance appropriate to the size of the aircraft.

Note: Aircraft with fewer than five passenger seats must use actual passenger and baggage weights.

For this AC, an aircraft originally type-certificated with—	Is considered a—
71+ Passenger seats	**Large-cabin aircraft**
30 to 70 passenger seats	**Medium-cabin aircraft**
05 to 29 passenger seats	**Small-cabin aircraft**

These categories are discussed in greater detail later in this AC.

4.3 STANDARD AVERAGE VS SEGMENTED WEIGHTS

4.3.1 Standard Average Weights

a) Use of standard average weights is limited to operators of multiengine turbine-powered aircraft originally type-certificated for five or more passenger seats who hold an approval from the UCAA consisting of an OpSpecs; and

b) These operators must prove to the UCAA that the aircraft can meet the performance requirements prescribed by the UCARs.

4.3.2 Segmented Weights

a) Segmented weights are provided for, but not limited to those aircraft that are multiengine turbine-powered aircraft originally type-certificated for five or more passenger seats and that do not meet the unrestricted performance requirements of UCARs.

b) Segmented passenger weights are listed in this AC.

4.4 RESTRICTION ON USE OF AVERAGE OR SEGMENTED WEIGHTS

a) The UCAA's recommendations and advice on the safe use of standard average weights and segmented weights are contained in this document.

b) In the UCAA's view, it would be unsafe for an aircraft operator to use standard average weights or segmented weights in any of the following aircraft—

1) All single-engine piston-powered aircraft.
2) All multiengine piston-powered aircraft.

3) All turbine-powered single-engine aircraft.

4.5 UCAA STANDARD AVERAGE WEIGHTS

a) UCAA will periodically review the standard average passenger weights listed in this AC.

b) If the UCAA finds that the survey data indicates a weight change of more than 2 percent, UCAA will revise this AC to update the standard average weights.

5.0 ESTABLISHING AIRCRAFT EMPTY WEIGHT

5.1 Establishing the Initial Weight of an Aircraft

5.1.1 New Aircraft

a) New aircraft are normally weighed at the factory and are eligible to be placed into operation without reweighing.

b) This policy assumes that the mass & balance records were adjusted for alterations and modifications to the aircraft during the manufacturing process.

Note: If this assumption is not correct the aircraft must be reweighed prior to being placed into service, and the empty weight and CG location established.

5.1.2 Aircraft Transferred Between Operators

5.1.2.1 Approved Mass & Balance Program

Aircraft transferred from one operator that has an approved mass & balance program, to another operator with an approved program, does not need to be weighed prior to use by the receiving operator.

Note: This policy would not apply if more than 36 calendar-months have elapsed since last individual or fleet weighing, or unless some other modification to the aircraft warrants that the aircraft be weighed

5.1.2.2 No Approved Mass & Balance Program

Aircraft transferred, purchased, or leased from an operator without an approved mass & balance program, and that have been unmodified or only minimally modified, can be placed into service without being reweighed if—

1) The last weighing was accomplished by an acceptable method (for example, manufacturer's instructions) within the last 12 calendar-months; and
2) A mass & balance change record was maintained by the operator.

5.2 Documenting Changes to an Aircraft's Mass & Balance

5.2.1 The mass & balance system should include methods, such as a log, ledger, or other equivalent electronic means, by which the operator will maintain a complete, current, and continuous record of the weight and CG of each aircraft.

5.2.2 Changes in the amount of weight or in the location of weight in or on the aircraft should be recorded whenever the weight change is at or exceeds the weights listed in the following table.

INCREMENTAL WEIGHT CHANGES THAT SHOULD BE RECORDED IN A MASS & BALANCE CHANGE RECORD	
In the mass change record of a—	**An operator should record any mass changes of—**
Large-cabin aircraft	**Plus or Minus 10 lb. or greater**
Medium-cabin aircraft	**Plus or Minus 5 lb. or greater**
Small-cabin aircraft	**Plus or Minus 1 lb. or greater**

5.2.3 Maintain the Operational Empty Weight

The loading schedule may utilize the individual weight of the aircraft in computing operational mass & balance, or the operator may choose to establish fleet empty weights for a fleet or group of aircraft.

5.3 Re-Establishment of OEW

a) The OEW and CG position of each aircraft should be reestablished at the prescribed reweighing periods outlined in this AC. When reestablishing the aircraft OEW between reweighing periods, the weight changes may be computed provided the weight and CG location of the modifications are known. If this information is not available, the aircraft must be reweighed.

b) In addition, the OEW should be reestablished through calculation whenever the—

1) Cumulative change to the mass and balance log is more than plus or minus one-half of 1 percent (0.5 percent) of the maximum landing weight; or
2) Cumulative change in the CG position exceeds one-half of 1 percent (0.5 percent) of the mean aerodynamic chord (MAC).

c) In the case of helicopters and aeroplanes that do not have a MAC-based CG envelope (e.g., canard equipped aeroplane), whenever the cumulative change in the CG position exceeds one-half of 1 percent (0.5 percent) of the total CG range, the mass & balance should be reestablished.

5.4 Fleet Operating Empty Weights (FOEW)

a) An operator may choose to use one weight for a fleet or group of aircraft if the weight and CG of each aircraft is within the limits stated above for establishment of OEW.

b) When the cumulative changes to an aircraft mass & balance log exceed the weight or CG limits for the established fleet weight, the empty weight for that aircraft should be reestablished.

5.5 Prescribed Re-Weighing Periods

5.5.1 Individual Aircraft Weighing Program

a) Aircraft are normally weighed at intervals of 60 calendar-months.

b) An operator may, however, extend this weighing period for a particular model aircraft when—

1) Pertinent records of actual routine weighing during the preceding period of operation show that mass & balance records accurately reflect aircraft weights; and
2) CG positions are within the cumulative limits specified for establishment of OEW.

c) Under an individual aircraft weighing program, an increase should not be granted which would permit any aircraft to exceed 60 calendar-months since the last weighing, including when an aircraft is transferred from one operator to another.

d) In the case of helicopters, increases should not exceed a time that is equivalent to the aircraft overhaul period.

5.5.2 Fleet Weighing

5.5.2.1 General Policy

An operator may choose to weigh only a portion of the fleet every 60 months and apply the weight and moment change determined by this sample weighing's to the remainder of the fleet.

- For each aircraft weighed, the new aircraft empty weight (and moment) is determined by the weighing and entered in the aircraft weight log.
- The difference between this new aircraft weight (and moment) and the previous aircraft weight (and moment) shown in the log is the unaccounted weight (and moment) change.
- The average of the unaccounted weight and moment changes for the aircraft weighed as part of this fleet weighing is then entered as an adjustment to the aircraft weight logs for each of the aircraft in the fleet that were not weighed.

A fleet is composed of a number of aircraft of the same model.

- For example, B747-200s in a passenger configuration and B747-200 freighters should be considered different fleets.
- Likewise, B757-200s and B757-300s should be considered different fleets.

5.5.2.2 **Defining a Fleet**

The primary purpose of defining a fleet is to determine how many aircraft should be weighed in each weighing cycle. A fleet may be further divided into groups to establish FOEWs.

INCREMENTAL WEIGHT CHANGES THAT SHOULD BE RECORDED IN A MASS & BALANCE CHANGE RECORD	
For fleets of—	**An operator must weigh (at minimum)—**
1 to 3 aircraft	**All aircraft**
4 to 9 aircraft	**3 aircraft, plus at least 50% of the number greater than 3**
More than 9 aircraft	**6 aircraft, plus at least 10% of the number greater than 9**

a) In choosing the aircraft to be weighed, the aircraft in the fleet having the most hours flown since last weighing should be selected.
b) An operator should establish a time limit such that all aircraft in a fleet are eventually weighed.
c) Based on the length of time that a fleet of aircraft typically remains in service with an operator, the time limit should not exceed 18 years (six 3-year weighing cycles).

Note: In the event that business conditions result in retirement of a fleet before all aircraft have been weighed this policy would not be applicable.

5.6 Weighing Aircraft Modifications

a) For some modifications, such as interior re-configurations, the large number of parts removed, replaced, and installed may make an accurate determination of the mass & balance change by computation impractical.
b) In those instances when the accuracy of the calculation is questionable, the weight and moment change estimate should be verified by reweighing the aircraft. The operator should weigh two or more aircraft to confirm the computed weight change estimate.
c) The operator may choose to weigh the aircraft before and after the modification, or just after the modification.
d) If the weighing's are inconsistent with the computed weight change estimate, then additional aircraft should be weighed based on the size of the fleet.

Note: An operator should weigh the air- craft in still air.

5.7 Prescribed Weighing Procedures

a) An operator should take precautions to ensure that it weighs an aircraft as accurately as possible. These precautions include checking to ensure that all required items are aboard the aircraft and the quantity of all fluids aboard the aircraft is considered.
b) An operator should establish and follow instructions for weighing the aircraft that are consistent with the recommendations of the aircraft manufacturer and scale manufacturer. If manufacturer's

data is not available, the operator is responsible for developing appropriate weighing instructions for its particular aircraft.

c) The operator should ensure that all scales are certified and calibrated by the manufacturer or a certified laboratory, such as a civil department of weights and measures, or the operator may calibrate the scale under an approved calibration program.

d) The operator should also ensure that the scale is calibrated within the manufacturer's recommended time period, or time periods, as specified in the operator's approved calibration program.

6.0 LOADING SCHEDULES & ENVELOPES

6.1 Aircraft Loading Schedules

6.1.1 Operator Developed

The loading schedule is developed by the operator based on its specific loading calculation procedures and provides the operational limits for use with the operator's mass & balance program approved under this AC. These approved operational limits are typically more restrictive but may not exceed the manufacturer's certificated limits. This is because the loading schedule is generally designed to check only specific conditions (e.g., takeoff and zero fuel) known prior to takeoff, and must account for variations in mass & balance in flight. It must also account for factors selected to be excluded, for ease of use, from the calculation process.

6.1.2 Basic Development Strategies

Development of a loading schedule represents a trade-off between ease of use and loading flexibility. A schedule can provide more loading flexibility by requiring more detailed inputs. It can also be made easier to use by further limiting the operational limits to account for the uncertainty caused by the less detailed inputs.

Several types of loading schedules are commonly used, including computer programs as well as "paper" schedules, which can be either—

1) Graphical, such as an alignment ("chase around chart") system,
2) Slide rule; or
3) Numerical, such as an adjusted weight or index system.

It is often more convenient to compute the balance effects of combined loads and to display the results by using "balance units" or "index units."

1) This is done by adding the respective moments (weight times arm) of each item. Graphing the moments results in a "fan grid" where lines of constant balance arms (BA) or percent MAC are closer together at lower weights and further apart at higher weights.
2) Direct graphical or numerical addition of the balance effects are possible using these moment values.
3) To make the magnitude of the numbers more manageable, moments can be converted to an index unit.

For example—

Index Unit = _Weight X (BA – datum)_ + K M

- Where *datum* is the reference BA that will plot as a vertical line on the fan grid,
- *M* and *K* are constants that are selected by the operator.
- *M* is used to scale the index values, and *K* is used to set the index value of the reference BA.

6.1.3 **Determining Fluid Weights**

An operator should use one of the following to determine the fluid weights on the aircraft—

1) The actual weight of each fluid,
2) A standard volume conversion for each fluid, or
3) A volume conversion that includes a correction factor for temperature.

6.2 **Constructing a Loading Envelope**

6.2.1 **Operator Considerations**

Each operator complying with this AC must construct a "loading envelope" applicable to each aircraft being operated. It will be used to ensure that the aircraft is always operated within appropriate mass & balance limitations, and will include—

1) Provisions to account for the loading of passengers, fuel, and cargo;
2) The in-flight movement of passengers, aircraft components, and other loaded items; and
3) The usage or transfer of fuel and other consumable.

6.2.2 **Use of Aircraft Manufacturer Information**

The construction of the loading envelope will begin with the mass & balance limitations provided by the aircraft manufacturer in the mass & balance manual, type certificate data sheet, or similar approved document.

These limitations will include, at minimum, the following items, as applicable—

1) Maximum zero-fuel weight.
2) Maximum takeoff weight.
3) Maximum taxi weight.
4) Takeoff and landing CG limitations.
5) In-flight CG limitations.
6) Maximum floor loadings, including both running and per square foot limitations.
7) Maximum compartment weights.
8) Fuselage shear limitations.
9) Any other limitations provided by the manufacturer.

6.2.3 **Further Restricting the Manufacturer's Loading Envelope**

The operator should further restrict the manufacturer's loading limitations by curtailing the values to account for loading variations and in-flight movement that are encountered in normal operations.

For example, if passengers are expected to move about the cabin in flight, the operator must further restrict ("curtail") the manufacturer's CG envelope by an amount necessary to ensure that movement of passengers does not take the aircraft outside its certified envelope.

In some cases, an aircraft may have more than one loading envelope for preflight planning and loading. Each envelope must have the appropriate curtailments applied for those variables that are expected to be relevant for that envelope.

For example, an aircraft might have separate takeoff, in-flight, and landing envelopes. Upon determination of the curtailed version of each envelope, the most restrictive points (for each condition the operator's program will check) generated by an "overlay" of the envelopes will form the aircraft operational envelopes.

1) The limits of these envelopes must be observed during operation.
2) By restricting operation to these "operational envelopes," compliance with the manufacturer's certified envelope will be ensured in all phases of flight, based upon the assumptions within the curtailment process.

3) Optionally, an operator may choose to not combine the envelopes but observe each envelope independently.

6.2.4 Common Curtailments of The Manufacturer’s Loading Envelope

Operators using an approved mass & balance control program must include curtailments appropriate to the operations being conducted. The total curtailment of the manufacturer’s envelope is computed by combining the curtailments resulting from each of these factors.

6.2.4.1 Passenger Seating

A. The operator must account for the seating of passengers in the cabin.
B. The loading envelope does not need to be curtailed if the actual seating location of each passenger is known.
C. If assigned seating is used to determine passenger location, the operator must implement procedures to ensure that the assignment of passenger seating is incorporated into the loading procedure.
D. If the actual seating location of each passenger is not known, the operator may assume that all passengers are seated uniformly throughout the cabin or a specified subsection of the cabin.
   1) If this assumption is made, the operator must curtail the loading envelope to account for the fact that the passenger loading may not be uniform.
   2) The curtailment may make reasonable assumptions about the manner in which people distribute themselves throughout the cabin.

For example, the operator may assume that window seats are occupied first, followed by aisle seats, followed by the remaining seats (window-aisle-remaining seating). Both forward and rear loading conditions should be considered. That is, the passengers may fill up the window, aisle, and remaining seats from the front of the aircraft to the back, or the back to the front. If necessary, the operator may divide the passenger cabin into subsections or “zones” and manage the loading of each zone individually.

6.2.4.2 Fuel

The operator’s curtailed loading envelope must account for the effects of fuel. Fuel-related curtailments should be considered for the following—

1) Fuel density—
   (a) A certain fuel density may be assumed and a curtailment included to account for the possibility of different fuel density values.
   (b) Fuel density curtailments only pertain to differences in fuel moment caused by carrying fuel volumes, not to differences in total fuel weight. The fuel gauges in most transport category aircraft measure weight, not volume. on these aircraft, the indicated weight of the fuel load can be assumed to be accurate.
2) Fuel movement—
   The movement or transfer of fuel in flight.
3) Fuel usage in flight—
   The burning of fuel may cause the CG of the fuel load to change. The effect of fuel burning down to the required reserve fuel or to an acceptable fuel amount established by the operator should be accounted for. A curtailment may be included to ensure that this change does not cause the CG of the aircraft to move outside of the acceptable envelope.

6.2.4.3 Fluids

The operator’s curtailed CG envelope must account for the effects of galley and lavatory fluids. These factors include such things as—

- Use of potable water in flight.
- Movement of water or lavatory fluids.

6.2.4.4 **General In-Flight Movement Considerations**

The operational envelope must account for the in-flight movement of passengers, crew, and equipment. This may be done by including a curtailment equal to the moment change caused by the motion being considered. It may be assumed that all passengers, crew, and equipment are secured when the aircraft is in the takeoff or landing configuration.

6.2.4.5 **In-Flight Movement of Flight Crew**

Flight deck crew members may move to the most forward lavatory in accordance with the security procedures prescribed for crews leaving the cockpit. An offsetting credit may be taken if another crew member moves to the flight deck during such lavatory trip.

6.2.4.6 **In-flight Movement of the Cabin Crew & Service Carts**

If procedures do not dictate otherwise, it should be assumed that the cabin crew members can travel anywhere within the compartment to which they are assigned. If procedures do not dictate otherwise, it should be assumed that the service carts can travel anywhere within the compartment to which they are assigned. If multiple carts are in a given compartment, and no restrictions are placed on their movement, then the maximum number of carts, moving the maximum distance, must be considered. The weight of the number of cabin crew members assigned to each cart must also be considered. The assumed weight of each cart may be the maximum anticipated cart-load or the maximum design load, as appropriate to the operator's procedures.

6.2.4.7 **In-flight Movement of Passengers**

Allowances should be made for the possibility that passengers may move about the cabin in flight. Operators should account for the CG change caused by passengers moving to the lavatory by developing reasonable scenarios for the movement of passengers in their cabins and consider the CG shifts that can be expected to occur. Generally, it may be assumed that passengers move to the lavatories closest to their seats. In aircraft with a single lavatory, movement from the "most adverse" seat must be taken into account. These scenarios should incorporate assumptions may be made which reflect operator lavatory and seating policies, such as restrictions on numbers of passengers who may stand and wait for opportunity to enter the lavatory and restrictions requiring that coach passengers may only use the lavatories in the coach cabin, if that is the operator's normal policy.

If a lounge or other passenger gathering area is provided, the operator should assume that passengers move there from the centroid of the passenger cabin(s).

6.2.4.8 **Movement of Flaps and Landing Gear**

If the manufacturer has not already done so, the operator must account for the movement of landing gear, flaps, wing leading edge devices, or any other moveable components of the aircraft. Devices deployed only while in contact with the ground, such as ground spoilers or thrust reversers, may be excluded from such curtailments.

6.2.4.9 **Baggage and Freight**

It can be assumed that baggage and freight may be loaded at the centroid of each baggage compartment. Operators do not need to include a curtailment if procedures are used which ensure that the cargo is loaded uniformly and physically restrained (secured) to prevent the contents from becoming a hazard by shifting between zones or compartments.

7.0 ONBOARD MASS & BALANCE SYSTEMS

7.1 Comparison to a Conventional Weight Buildup Method

An operator may use an onboard mass & balance system to measure an aircraft's mass & balance as a primary means to dispatch an aircraft, provided—

1) UCAA has certified the system; and
2) Approved the system for use in an operator's mass & balance control program.

Like operators using a conventional weight buildup method to calculate mass & balance, an operator using an onboard mass & balance system as a primary mass & balance control system should curtail the manufacturer's loading envelope to ensure the aircraft does not exceed the manufacturer's certificated weight and CG limits.

Because an onboard mass & balance system measures the actual weight and CG location of an aircraft, an operator may not need to include certain curtailments to the loading envelope to account for variables such as passenger seating variation or variation in passenger weight.

Note: This policy does not relieve the operator from the responsibility to curtail the loading envelope for any system tolerances that may result in CG errors.

7.2 Obtaining Operational Approval

7.2.1 System Calibration

An operator should develop procedures to calibrate its onboard mass & balance system equipment periodically in accordance with the manufacturer's instructions.

An operator may calibrate its system with operational items or fuel aboard the aircraft to test the system at a representative operational weight.

7.2.2 Demonstration of System Accuracy

As part of the approval process, an operator should demonstrate that the onboard mass & balance system maintains its certificated accuracy. For the demonstration, the operator should use the accuracy demonstration test provided in the maintenance manual portion of the Supplemental Type Certificate or type certificate of the onboard mass & balance system.

7.3 Operational Considerations

7.3.1 Certification Limits

An operator using an onboard mass & balance system as its primary means of calculating mass & balance should have procedures in place to ensure that the system is operated within the limits established during the system's certification process.

7.3.2 Environmental Considerations

An operator using an onboard mass & balance system should ensure that it uses the system within the environmental limits established by the manufacturer. Environmental conditions that may affect the performance of an onboard mass & balance system include, but is not limited to—

- Temperature
- Barometric pressure
- Wind
- Ramp slope
- Rain
- Snow
- Ice
- Frost
- Dew

- Deicing fluid,

7.3.3 **Aircraft Considerations**

An operator using an onboard mass & balance system should ensure the weight and CG measured by the system are not affected by the aircraft configuration, such as the movement of—

- Flaps
- Stabilizers
- Doors
- Stairways or jetways
- Any connections to ground service equipment.

Other factors that an operator should consider include—

- Engine thrust
- Oleo strut extension
- Aircraft taxi movement.

7.3.4 **Takeoff Trim Settings**

If the aircraft manufacturer provides trim settings for takeoff based on the aircraft's CG location, an operator using an onboard mass & balance system should ensure that the onboard mass & balance system provides flight crew members with adequate information to determine the appropriate trim setting.

7.3.5 **Operational Envelope**

The operational envelope for onboard mass & balance systems should be developed using the same procedures described in other parts of this AC, with the exception that the operational envelope does not need to be curtailed for—

1) Passenger random seating; and
2) Passenger weight variance.

Also note that, instead of being added to the zero fuel weight as part of the load buildup, the fuel load is subtracted from the measured takeoff weight to determine the zero fuel weight and CG.

7.3.6 **Complying with Compartment or Unit Load Device (ULD) Load Limits**

When using an onboard mass & balance system, an operator should develop in its mass & balance control program a method to ensure that it does not exceed the limits specified for a compartment or ULD regarding

1) Floor loads;
2) Linear loads; or
3) Running loads.

The following are two examples of acceptable means to demonstrate compliance with compartment load limits—

1) An operator may assign a standard average weight to bags. Based on that standard average weight, the operator may place a placard in each compartment stating the maximum number of bags permitted.
2) An operator may also create a table that lists the total weight associated with a given number of bags to ensure the operator does not exceed the load limit of a compartment or ULD.

7.4 Developing a Backup System

An operator using an onboard mass & balance system as its primary means of measuring mass & balance may use the guidance in this AC to develop a backup system based on a conventional weight buildup provided that the backup system has been approved by the UCAA.

Should the primary onboard mass & balance system become inoperative, the operator must have provisions for deferring the inoperative equipment until repairs can be made or the system must be repaired prior to further flight.

UCAA may grant the operator relief for an onboard mass & balance system through the operator's minimum equipment list (MEL).

An operator using an onboard mass & balance system may not use the backup system unless—

1. The onboard system is inoperative;
2. The onboard system has been deferred in accordance with the aircraft MEL; and
3. The operator has been approved to use average weights/conventional weight buildup.

7.5 Determining Weight of Passengers & Bags

7.5.1 Choosing The Appropriate Method

For many years, operators of transport category aircraft have used average weights for passengers and bags to calculate an aircraft's mass & balance, in accordance with standards and recommended practices.

1) This method eliminates many potential sources of error associated with accounting for a large number of relatively light weights.
2) However, differences between the actual weight of passengers and bags and the average weight of passengers and bags can occur when using average weights.

Statistical probability dictates that the smaller the sample size (i.e., cabin size), the more the average of the sample will deviate from the average of the larger universe.

7.5.2 Large Cabin Aircraft

Operators of large cabin aircraft may use the standard average weights for passengers and bags. If an operator determines that the standard average weights are not representative of its operation for some route or regions, it is encouraged to conduct a survey to establish more appropriate average weights for its operation.

7.5.3 Medium Cabin Aircraft

Medium cabin aircraft should be evaluated to determine if the aircraft should be treated more like large or small cabin aircraft. For UCAA to recommend that medium cabin aircraft be treated as a large cabin aircraft, the aircraft must meet either—

1) both loadability criteria, or
2) the loading schedule criteria.

Loadabiity criteria—

- ➢ The CG of the OEW is within the manufacturer's loading envelope
- ➢ The CG of the zero fuel weight is within the manufacturer's loading envelope when loaded with a full load of passengers and all cargo compartments are filled with a density of 10 pounds per cubic foot.

Loading schedule criteria—

- ➢ The operator must use a loading schedule based upon zones

- The aircraft cabin may have no more than four rows of seats per zone with not less than four zones

7.5.4 Small Cabin Aircraft

Operators of small cabin aircraft may request approval to use any one of the following methods when calculating the aircraft mass & balance.

1. The operator may use actual passenger and bag weights, or
2. The operator may use segmented passenger weights and bag weights prescribed for large cabin aircraft, or
3. The operator may use the standard average passenger and bag weights prescribed for large cabin aircraft or average weights based on a UCAA-accepted survey if—
    1. The aircraft was capable of meeting the unrestricted performance requirements of UCARs, and
    2. The operator applies the additional curtailments.

7.6 Standard & Average Weights

The standard average passenger weights provided in this Sub paragraph were established based on data from mature civil aviation authority surveys.

7.6.1 Standard Average Weights: Passengers

The standard average passenger weights provided here include—

1) 5 pounds for summer clothing;
2) 10 pounds for winter clothing; and
3) A 16-pound allowance for personal items and carry-on bags.

Note: Where no gender is given, the standard average passenger weights are based on the assumption that—

- 50 percent of passengers are male and
- 50 percent of passengers are female.

STANDARD AVERAGE PASSENGER WEIGHT	**WEIGHT PER PASSENGER**
SUMMER WEIGHTS	
Average adult passenger weight	**190 lb.**
Average adult male passenger weight	**200 lb.**
Average adult female passenger weight	**179 lb.**
Child weight (2 years to less than 13 years of age)	**82 lb.**
WINTER WEIGHTS	
Average adult passenger weight	**195 lb.**
Average adult male passenger weight	**205 lb.**
Average adult female passenger weight	**184 lb.**
Child weight (2 years to less than 13 years of age)	**87 lb.**

An operator may use summer weights from May 1 to October 31 and winter weights from November 1 to April 30.

1. However, these dates may not be appropriate for all routes or operators.
2. For routes with no seasonal variation, an operator may use the average weights appropriate to the climate.
3. Use of year-round average weights for operators with seasonal variation should avoid using an average weight that falls between the summer and winter average weights.
4. Operators with seasonal variation that elect to use a year-round average weight should use the winter average weight.
5. Use of seasonal dates, other than those listed above, will be entered as nonstandard text and approved through the operator's OpSpecs as applicable.

7.6.2 Average Weight Assumptions: Carry-On Bags & Personal Items

An operator using standard average passenger weights should include the weight of carry- on bags and personal items in the passenger's weight. The standard average passenger weights in paragraph 7.6.1 include a 16-pound allowance for personal items and carry-on bags, based on the assumption that—

1. One-third of passengers carry one personal item and one carry-on bag.
2. One-third of passengers carry one personal item or carry-on bag.
3. One-third of passengers carry neither a personal item nor a carry-on bag.
4. The average weight allowance of a personal item or a carry-on bag is 16 pounds.

Note: An operator should not use an allowance of less than 16 pounds for personal items and carry- on bags unless the operator conducts a survey or unless the operator has a no-carry-on bag program.

If an operator believes the 16-pound allowance for personal items and carry-on bags is not appropriate for its operations or receives notification from UCAA that the assumptions provided in the previous paragraph are inconsistent with the operator's approved program, the operator should conduct a survey to determine what percentage of passengers carry personal items or carry-on bags aboard the aircraft.

7.6.3 Average Weights: Checked Bags

An operator that chooses to use standard average weights for checked bags should use a standard average weight of at least 30 pounds.

An operator that requests approval to use a standard average weight of less than 30 pounds for checked bags should have current, valid survey data to support a lesser weight.

An operator also may conduct a study to establish different standard average bag weights for portions of its operation to account for—

- Regional
- Seasonal
- Demographic
- Aircraft
- Route variation.

7.6.4 Heavy Bags

Heavy bags are considered any bag that weighs more than 50 pounds but less than 100 pounds.

An operator should account for a heavy bag by using one of the following weights—

1) A standard average weight of 60 pounds,
2) An average weight based on the results of a survey of heavy bags, or
3) The actual weight of the heavy bag.

7.6.5 Non-Luggage Bags

A non-luggage bag is any bag that does not meet the normal criteria for luggage.
Examples of these bags include—

- golf bags
- fishing equipment packages
- wheelchairs and strollers in their shipping configuration
- windsurfing kits
- boxed bicycles

For non-luggage bags, operators may use any appropriate combination of—

1. Actual weights;
2. Average weights based on survey results; or
3. Standard average bag weights.

Operators that wish to establish an average weight for a particular type of non-luggage bag, such as a golf bag, must conduct a survey in accordance with the procedures established in Section 8. Operators also should establish a method to calculate the effect on CG of a large non-luggage bag, such as a surfboard, that may occupy more than one compartment on the aircraft.

7.6.6 Plane-Side Loaded & Checked Bags

Charter and other adhoc operators conducting on-demand operations using standard average bag weights should consider all bags not stored in the cabin as checked bags. However, operators may develop procedures for identifying bags that would typically be considered carry-on and/or plane-side loaded baggage and incorporate such average weights into their approved carry-on and mass & balance control program. If such procedures are developed, the operator may use the standard average weights specified for carryon, plane-side loaded, and checked baggage.
Charter and general aviation operators conducting flights in which all passenger bags are typically loaded plane-side or all bags are carried into the cabin for further storage, should develop guidelines to inform pilots when it is appropriate to use the heavier standard average checked bag weights, heavy bag weights, or actual weights.

Note: In no case should an operator only use plane-side loaded standard aver- age weights for all baggage loaded plane-side.

7.6.7 Average Weight: Bags Checked Plane-Side [Large Cabin Aircraft]

Operators with a carry-on bag program that use standard average weights should account for the weight of each carry-on bag checked plane-side as 30 pounds. An operator may request approval to use a weight other than 30 pounds if the operator has current, valid survey data to support a different average weight for plane-side loaded bags.

7.7 Average Weights: No-Carry-On Bag Program

An operator with a no-carry-on bag program may allow passengers to carry only personal items aboard the aircraft. Because these passengers do not have carry-on bags, an operator may use standard average passenger weights that are 6 pounds lighter than those for an operator with an approved carry-on bag program.

AVERAGE PASSENGER WEIGHTS FOR OPERATORS WITH A NO-CARRY-ON BAG PROGRAM	
AVERAGE PASSENGER WEIGHT	**WEIGHT PER PASSENGER**
SUMMER WEIGHTS	
Average adult passenger weight	**184 lb**
Average adult male passenger weight	**194 lb**
Average adult female passenger weight	**173 lb**
Child weight (2 years to less than 13 years of age)	**76 lb**
WINTER WEIGHTS	
Average adult passenger weight	**189 lb**
Average adult male passenger weight	**199 lb**
Average adult female passenger weight	**178 lb**
Child weight (2 years to less than 13 years of age)	**81 lb**

An operator that has a no-carry-on bag program may account for a plane-side loaded bag as 20 pounds. To receive authorization to use 20 pounds as the average weight for a plane-side loaded bag, an operator should demonstrate that sufficient controls exist to ensure that passengers do not bring carry-on bags aboard the aircraft.

An operator also should demonstrate that sufficient controls exist to ensure the personal items brought aboard the aircraft can fit completely under a passenger seat or in an approved stowage compartment. If an operator discovers that a plane-side loaded bag should have been treated as a checked bag, the operator should account for that bag at the standard average weight of 30 pounds for a checked bag. The Operator should develop procedures for identifying bags that would typically be considered carry-on/plane-side loaded and/ or traditional checked baggage.

7.8 Average Weights: Crew Members

An operator may choose to use the standard crew member weights shown in Table 2-3 or conduct a survey to establish average crew member weights appropriate for its operation.

STANDARD CREW MEMBER WEIGHTS		
Crew Member	**Average Weight**	**Average Weight with Bags**
Flight Crew Member	**190 lb**	**240 lb**
Cabin Crew Member	**170 lb**	**210 lb**
Male Cabin Crew Member	**180 lb**	**220 lb**
Female Crew Member	**160 lb**	**200 lb**
Crew Member Roller Bag	**30 lb**	**NA**
Pilot Flight Bag	**20 lb**	**NA**
Cabin Crew Member Kit	**10 lb**	**NA**

The flight crew member weights provided in the table above were derived from weights listed on all first- and second-class medical certificates sampled at a mature civil aviation authority. The flight crew member weight with bags assumes that each flight crew member has one crew member roller bag and one pilot flight bag. The cabin crew member weights provided in the table were derived from an operational survey. The cabin crew member weights with bags assume that each cabin crew member has one crew member roller bag and one cabin crew member kit.

7.9 Weights for Company Materials, Freight & Mail

Company Materials and Freight. An operator should use actual weights for company materials, aircraft parts, and freight carried aboard an aircraft.

Mail. An operator should use the weights provided with manifested mail shipments to account for the weight of the mail.

If an operator has to separate a shipment of mail, the operator may make actual estimates about the weight of the individual pieces, provided the sum of the estimated weights is equal to the actual manifested weight of the entire shipment.

7.10 Average Weights for Special Passenger Groups

Actual passenger weights should be used for nonstandard weight groups (sports teams, etc.) unless average weights have been established for such groups. When such groups form only a part of the total passenger load, actual weights, or established average weights for the nonstandard group, may be used for such exception groups and average weights used for the balance of the passenger load. Roster weights may be used for determining the actual passenger weight.

A standard allowance of 16 pounds per person may be used to account for carry-on and personal items as provided in the operator's approved carry-on bag program. If the carry-on bags are representative of the operator's profile but do not meet the number of bags authorized per person, the operator may count bags and use a 16-pound per bag allocation. Actual weights must be used in cases where the carry-on bags are not representative of the operator's profile. Groups that are predominantly male or female should use the standard average weights for males or females. For military groups, actual passenger and cargo weights must be used in computing the aircraft mass & balance.

8.0 OPERATOR-CONDUCTED SURVEYS

8.1 Designing an Operator Survey

8.1.1 This section provides operators with an acceptable survey method to use in determining average weights for a mass & balance control program.

8.1.2 This section also describes how an operator can conduct a survey to count personal items and carry-on bags to determine an appropriate allowance for those items to include in passenger weight.

8.1.3 In addition, an operator may use the methods described in this section to conduct a survey to determine the percentage of male and female passengers, to calculate an average passenger weight. Surveys conducted correctly allow an operator to draw reliable inferences about large populations based on relatively small sample sizes. In designing a survey, an operator should consider—

1) The sample size required to achieve the desired reliability,
2) The sample selection process, and
3) The type of survey (average weights or a count of items).

8.2 **Sample Size**

Several factors must be considered when determining an adequate sample size. The more varied the population, the larger the sample size required to obtain a reliable estimate.

- Paragraph 8.2.1 provides a formula to derive the absolute minimum sample size to achieve a 95- percent confidence level.
- The following table has been provided for those operators that wish to use calculations other than those listed in paragraph 8.2.1.
- This table provides the operator with an acceptable number of samples that may be collected to obtain a 95-percent confidence level and lists the tolerable error associated with each category.

MINIMUM SAMPLE SIZES		
SURVEY SUBJECT	**MINIMUM SAMPLE SIZE**	**TOLERABLE ERROR**
Adult (standard adult/male/female	**2,700**	**1%**
Child	**2,700**	**2%**
Checked bags	**1,400**	**2%**
Heavy bag	**1,400**	**2%**
Plane-side loaded bags	**1,400**	**2%**
Personal items only (no carry-on bag program)	**1,400**	**2%**

8.2.1 **Smaller Sample Sizes**

If the operator has chosen to use a sample size that is smaller than that provided in the above Table, the operator should collect a sufficient number of samples to satisfy the following formulas—

$$s = \frac{\sqrt{\sum_{j=1}^{n}(x_j - \bar{x})^2}}{\sqrt{n-1}}$$

Where:

s is the standard deviation

n is the number of points surveyed

x_j is the individual survey weights

$\bar{x}$ is the sample average

$$e = \frac{1.96 * s * 100}{\sqrt{n} * \bar{x}}$$

Where:

e is the tolerable error percentage

8.2.2 Acceptable Sample Methods

8.2.2.1 General Techniques

An operator conducting a survey must employ random sampling techniques. Random sampling means that every member of a group has an equal chance of being selected for inclusion in the sample.

If an operator conducts a survey that does not employ random sampling, the characteristics of the selected sample may not be indicative of the larger group as a whole.

The following are two examples of random sampling methods that an operator may find appropriate for the type of survey conducted. An operator may also consult a basic textbook on statistics to determine if another random sampling method is more appropriate.

Simple Random Selection

1. An operator should assign a sequential number to each item in a group (such as passengers waiting on a line or bag claim tickets).
2. Then the operator randomly selects numbers and includes the item corresponding with the number in the sample.
3. The operator repeats this process until it has obtained the minimum sample size.

Systematic Random Selection

1. An operator should randomly select an item in sequence to begin the process of obtaining samples.
2. The operator should then use a predetermined, systematic process to select the remaining samples following the first sample.

- For example, an operator selects the third person in line to participate in the survey.
- The operator then selects every fifth person after that to participate in the survey.
- The operator continues selecting items to include in the sample until it has obtained the minimum sample size.

8.2.2.2 Passenger Declines to Participate

Regardless of the sampling method used, an operator has the option of surveying each passenger and bag aboard the aircraft and should always give a passenger the right to decline to participate in any passenger or bag weight survey. If a passenger declines to participate, the operator should select the next passenger based on the operator's random selection method rather than select the next passenger in a line.

8.2.3 Implementing an Acceptable Survey Plan

8.2.3.1 Developing a Survey Plan

1. Before conducting a survey, an operator should develop a survey plan.
2. The plan should describe the dates, times, and locations the survey will take place.
3. In developing a survey plan, the operator should consider its type of operation, hours of operation, markets served, and frequency of flights on particular routes.
4. An operator should avoid conducting surveys on holidays unless it has a valid reason to request the particular date.

8.2.3.2 Submitting the Survey Plan to UCAA

1. It is recommended that an operator submit its survey plan to UCAA at least 2 weeks before the survey is expected to begin.

2. Before the survey begins, the operator's principal inspectors (PI) will review the plan and work with the operator to develop a mutually acceptable plan.
3. During the survey, the PI will oversee the survey process to validate the execution of the survey plan.
4. After the survey is complete, the PI will review the survey results and issue the appropriate OpSpecs.
5. Once a survey begins, the operator should continue the survey until complete, even if the initial survey data indicates that the average weights are lighter or heavier than expected.

8.2.4 General Survey Procedures

8.2.4.1 Survey Locations

1. An operator should accomplish a survey at one or more airports that represent at least 15 percent of an operator's daily departures.
2. To provide connecting passengers with an equal chance of being selected in the survey, an operator should conduct its survey within the secure area of the airport.
3. An operator should select locations to conduct its survey that would provide a sample that is random and representative of its operations.
   For example, an operator should not conduct a survey at a gate used by shuttle operations unless the operator is conducting a survey specific to that route or the operator only conducts shuttle operations.

8.2.4.2 Weighing Passengers

1. An operator that chooses to weigh passengers as part of a survey should take care to protect the privacy of passengers.
2. The scale readout should remain hidden from public view.
3. An operator should ensure that any passenger weight data collected remains confidential.

8.2.4.3 Weighing Bags

1. When weighing bags on a particular flight, an operator should take care to ensure that it is properly accounting for all items taken aboard the aircraft.
2. The following table consolidates the results of surveys of the weights for different types of bags in aircraft of 10 to 19 passengers as a reference point for future operator surveys.

BAG SURVEY RESULTS		
Item Surveyed	**Average Weight**	**Standard Deviation**
Personal items & carry-on bags	**15.1 lb**	**8.2 lb**
Checked bags	**28.9 lb**	**10.8 lb**
Heavy bags	**58.7 lb**	**7.2 lb**

8.2.4.4 Rounding Sample Results

1. If the operator uses rounding in the mass & balance calculations, it is recommended that the operator round passenger weights to the nearest pound and bag weights to the nearest half-pound.
2. An operator should ensure that rounding is done consistently in all calculations.

8.2.4.5 **Surveys for Particular Routes**

1. An operator may conduct a survey for a particular route if the operator believes that the average weights on that route may differ from those in the rest of its operations.
2. To establish a standard average passenger weight along the route, an operator may survey passengers at only one location.
3. However, an operator should conduct surveys of personal items and bags at the departure and arrival locations, unless the operator can verify there is no significant difference in the weight and number of bags in either direction along the route.

8.2.4.6 **Count Survey Only**

1. An operator may conduct a survey to count certain items without determining the weight of those items.

   For example, an operator may determine that the standard average weights for male and female passengers are appropriate for its operations, but on some routes the passengers are predominantly male or female. In this case, an operator may conduct a survey to determine the percentage of male and female passengers. The operator could use the results of the survey to justify a weight other than the standard weights, which assume a 50-percent male and 50-percent female mix of passengers.
2. Similarly, an operator may conduct a survey to determine the number of personal items and carry-on bags passengers carry aboard aircraft to determine if the allowance of 16 pounds per passenger is appropriate to its operations.

   For example, an operator conducts a survey on a particular route (or multiple routes if amending the program average weight) to count the percentage of passengers carrying personal items and carry-on bags. The operator finds that—
   1) Fifty percent of passengers carry one carry-on bag and one personal item.
   2) Thirty percent of passengers carry one carry-on bag or one personal item.
   3) Twenty percent of passengers carry neither a carry-on bag nor a personal item.
   4) The survey results show that the average passenger carries approximately 21 pounds of personal items and carry-on bags rather than the standard allowance of 16 pounds.

$$[0.50 \times (16 \text{ pounds} + 16 \text{ pounds})] + [0.30 \times (16 \text{ pounds})] + [0.20 \times (0 \text{ pounds})] = 20.8 \text{ pounds}$$

8.2.4.7 **Revalidating an Earlier Survey**

In order to use survey-derived average weights, an operator must revalidate such survey data every 36 calendar-months or revert to the standard average weights, provided the new survey average weight results are within 2 percent of the standard average weights listed in this AC.

9.0 SEGMENTED PASSENGER WEIGHTS

9.1 Using Segmented Weights

The concept of segmented weights involves adding a portion of the standard deviation to an average weight to increase the confidence that the actual weight will not exceed the average weight. Like the standard average weights in Section 7 of this AC, the segmented weights in the following table were derived from average weights and standard deviations, assuming a 95-percent confidence interval and 1-percent tolerable error.

SEGUMENTED WEIGHTS FOR ADULT PASSENGERS (IN POUNDS – SUMMER WEIGHTS)											
Maximum Certificated Passenger Seating Capacity	Ratio of Male to Female Passengers										
	0/ 100	10/ 90	20/ 80	30/ 70	40/ 60	50/ 50	60/ 40	70/ 30	80/ 20	90/ 10	100 /0
1 to 4	Use actual weights or asked (volunteered) weights plus 10 lb										
5	231	233	235	237	239	241	243	245	247	249	251
6 to 8	219	221	223	225	227	229	231	233	235	237	239
9 to 11	209	211	213	215	217	219	221	223	225	227	229
12 to 16	203	205	207	209	211	213	215	217	219	221	223
17 to 25	198	200	202	204	206	208	210	212	214	216	218
26 to 30	194	196	198	200	202	204	206	208	210	212	214
31 to 53	191	193	195	197	199	201	203	205	207	209	211
54 to 70+	188	190	192	194	196	198	200	202	204	206	208

An operator may make the following adjustments to the table above—

1) An operator may subtract 6 pounds from the passenger weight outlined above if it has a no-carry-on bag program or does not allow any carry-on baggage into the cabin of the aircraft.
2) An operator should add 5 pounds to the weights above during the winter season.

An operator may interpolate between columns on the chart if the operator’s assumed ratio of male passengers to female passengers does not exactly match the values given. To account for a child’s weight, for children ages 2 years to less than 13 years of age, the standard average child weight located in Table 2-1 may be used. Weights of children under the age of 2 have been factored into the segmented adult passenger weight.

9.2 Loading Envelope Curtailment & Bag Weight with Segmented Weights

9.2.1 Loading Envelope Curtailment

An operator using segmented passenger weights may use the standard average passenger weights when curtailing its operational loading envelope using the methods described in Appendices B and C.

9.2.2 Bag Weights

An operator using segmented weights may use actual weights for bags or the standard average bag weights provided in Section 7.

9.2.2.1 Example of Use of UCAA Approved Segmented Weights

An operator of a 30 passenger-seat aircraft conducts a survey to count the percentage of male and female passengers on its flights and determines that 50 percent of the passengers are male and 50 percent are female.

- If the operator has an approved carry-on bag program, the operator should use 204 pounds in the summer and 209 pounds in the winter.

- If the operator has a no carry-on bag program, the operator should use 198 pounds in the summer and 203 pounds in the winter and account for all plane-side loaded bags as 20 pounds each.

10.0 ACTUAL WEIGHT PROGRAMS

10.1 Determining Actual Passenger Weights

An operator may determine the actual weight of passengers by—

1) Weighing each passenger on a scale before boarding the aircraft (types of weight scales and scale tolerances will be defined in the operator's approved mass & balance control program); **or**
2) Asking each passenger his or her weight.
   (a) An operator should add to this asked (volunteered) weight at least 10 pounds to account for clothing.
   (b) An operator may increase this allowance for clothing on certain routes or during certain seasons, if appropriate.

10.2 Determining Actual Weights of Personal Items & Bags

To determine the actual weight of a personal item, carry-on bag, checked bag, plane-side loaded bag, or a heavy bag, an operator should weigh the item on a scale.

10.3 Recording Actual Weights

An operator using actual weights should record all weights used in the load buildup.

11.0 OPERATOR REPORTING SYSTEMS & UCAA OVERSIGHT

11.1 Pilot & Agent Reporting Systems

Each operator should develop a reporting system and encourage employees to report any discrepancies in aircraft loading or manifest preparation. These discrepancies may include errors in documentation or calculation, or issues with aircraft performance and handling qualities that indicate the aircraft weight or balance is not accurate. Operators should attempt to determine the cause of each discrepancy and take appropriate corrective action. This would include a load audit on affected flights or conducting a passenger or bag weight survey in accordance with this AC if trends indicate it is warranted.

11.2 UCAA Oversight

UCAA has divided the responsibility of overseeing an operator's mass & balance control program between the Flight operations inspector (FOI) and Airworthiness inspector (AWI). An operator that wishes to change aspects of its mass & balance control program, including average weights, should submit all applicable supporting data to the FOI and AWI, as applicable, for approval.

If UCAA approves the changes, it will issue revised operations specifications containing the appropriate approvals.

As a minimum annual requirement, each operator's mass and balance program will be inspected in detail each 12 consecutive month period and each time there is an occurrence that may be related to this program.

APPENDIX A
Sample Operational Loading Envelope

Loading Envelope

1. Introduction

A. The following is an example of how to develop an operational loading envelope.
B. For this example, a hypothetical 19-seat commuter category aircraft is used.
C. Although this example uses inches to measure fuselage station, an operator may choose to use an index system for convenience.

2. Assumptions for This Example

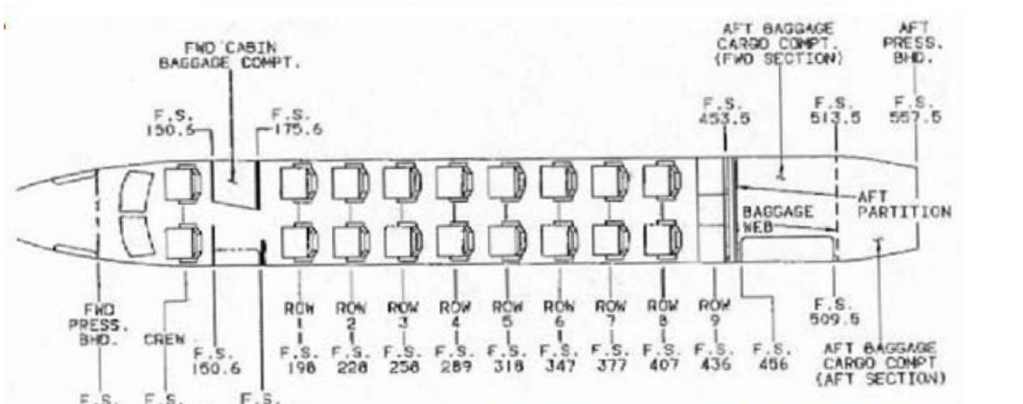
A. Passenger weight

1) Because the aircraft is originally type-certificated for 5 or more passenger seats, it would be appropriate to use the average weights listed in Section 7.
2) For this example, it is assumed that the operator has a no-carry-on baggage program. Therefore, the operator should use a standard average passenger weight of 189 pounds in winter and 184 pounds in summer.
3) For this example, a standard average passenger weight of 189 pounds is used.
4) The operator also assumes that passengers are distributed throughout the cabin in accordance with the window-aisle-remaining method.

Note: that because this aircraft has only two window seats per row, the operator may reasonably assume that passengers begin seating themselves in the front of the cabin and select the most forward seat available.

B. Bag weights. For this example, the operator assumes that a checked bag weighs 30 pounds and a plane-side loaded bag weighs 20 pounds.

C. Interior seating. For this example, consider a commuter category 19-seat aircraft with the interior seating diagram shown below. For this example, the fuselage station (F.S.) of each seat row is the seated passenger centroid. (For other diagrams this may not be true.)



(Diagram courtesy of Raytheon Aircraft Company)

FIGURE 3-1. SAMPLE AIRCRAFT INTERIOR SEATING DIAGRAM

3. Curtailments for Passenger Seating variation

A. Establishing zones. The operator elects to separate the passenger cabin into three zones. Zone 1 will contain rows 1 to 3, zone 2 will contain rows 4 to 6, and zone 3 will contain rows 7 to 9.

B. Determining the centroid of each zone. When using cabin zones, an operator assumes that all passengers are sitting at the centroid of their zone. To find the centroid of each zone—

1) Multiply the number of seats in each row of the zone by the location of the row,
2) Add each number calculated in step 1, and
3) Divide the number in step 2 by the total number of seats in the zone.

FIGURE A-1: Calculation of Zone 1 Centroid

Row No.	No. of Seats	Row Location	No. of Seats × Row Location
1	2	198 in	396 in
2	2	228 in	456 in
3	2	258 in	516 in
TOTAL	6	NA	1,368 in
1,368 in / 6 seats = 228 in			

FIGURE A-2: Calculation of Zone 2 Centroid

Row No.	No. of Seats	Row Location	No. of Seats × Row Location
4	2	289 in	578 in
5	2	318 in	636 in
6	2	347 in	694 in
TOTAL	6	NA	1,908 in
1,908 in / 6 seats = 318 in			

FIGURE A-3: Calculation of Zone 3 Centroid

Row No.	No. of Seats	Row Location	No. of Seats × Row Location
7	2	377 in	754 in
8	2	407 in	814 in
9	3	436 in	1,308 in
TOTAL	7	NA	2,876 in
2,876 in / 7 seats = 411 in			

C. Comparing loading assumptions. To determine the appropriate amount of curtailment, the operator should compare aircraft loading based on the window-aisle-remaining assumption with aircraft loaded based on the assumption that passengers are sitting at the centroid of their respective zones. An operator may determine the appropriate curtailment by comparing the moments resulting from these assumptions and identifying the loading scenarios that result in the most forward or aft center of gravity (CG) location. See Figure A-4 through A-15 below**.**

4. Curtailment Calculation for Zone 1

FIGURE A-4: Moments resulting from the Zone Centroid Assumption for Zone 1

Row No.	No. of Seats	Row Location	No. of Seats × Row Location
7	2	377 in	754 in
8	2	407 in	814 in
9	3	436 in	1,308 in
TOTAL	7	NA	2,876 in
2,876 in / 7 seats = 411 in			

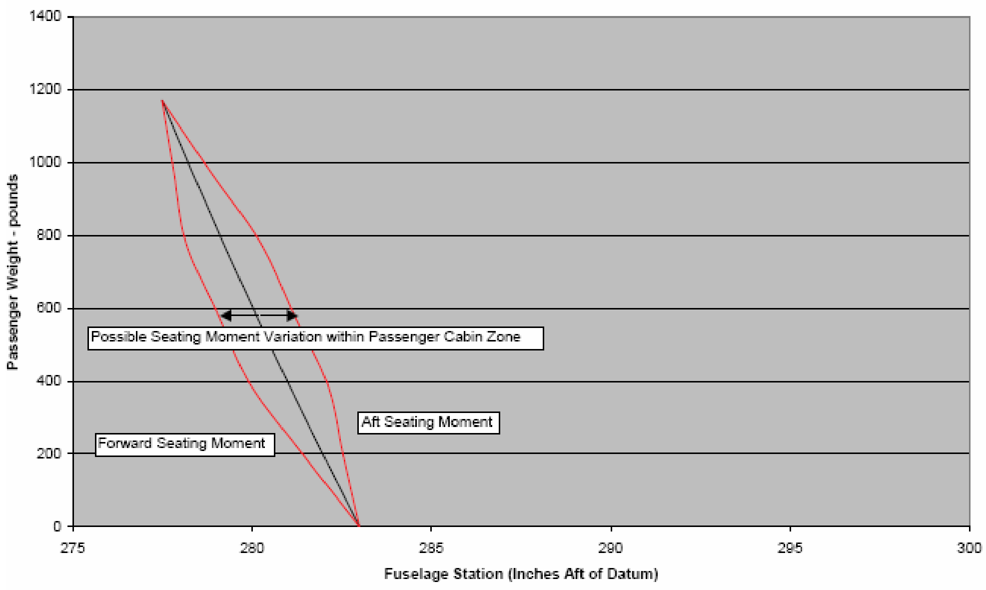
FIGURE A-5: Moments resulting from the Window-Aisle-Remaining Assumption for Zone 1

Passenger No.	Assumed Weight	Assumed Arm	Moment	Cumulative Moment
1	189 lb	228 in	43,092 in-lb	43,092 in-lb
2	189 lb	228 in	43,092 in-lb	86,184 in-lb
3	189 lb	228 in	43,092 in-lb	129,276 in-lb
4	189 lb	228 in	43,092 in-lb	172,368 in-lb
5	189 lb	228 in	43,092 in-lb	215,460 in-lb
6	189 lb	228 in	43,092 in-lb	258,552 in-lb

FIGURE A-6: Comparison of Moments for Zone 1

Passenger No.	Assumed Row	Weight	Arm	Moment	Cumulative Moment
1	1	189 lb	198 in	37,422 in-lb	37,422 in-lb
2	1	189 lb	198 in	37,422 in-lb	74,844 in-lb
3	2	189 lb	228 in	43,092 in-lb	117,936 in-lb
4	2	189 lb	228 in	43,092 in-lb	161,028 in-lb
5	3	189 lb	258 in	48,762 in-lb	209,790 in-lb
6	3	189 lb	258 in	48,762 in-lb	258,552 in-lb

FIGURE A-7: Sample Passenger Seating Moment (Zone 1)



5. Curtailment Calculation For Zone 2

FIGURE A-8: Moments Resulting from the Zone Centroid Assumption for Zone 2

Passenger No.	Cumulative Moment from the Zone Centroid Assumption	Cumulative Moment from the Window-Aisle-Remaining Assumption	Difference
7	60,102 in-lb	54,621 in-lb	-5,481 in-lb
8	120,204 in-lb	109,242 in-lb	-10,962 in-lb
9	180,306 in-lb	169,344 in-lb	-10,962 in-lb
10	240,408 in-lb	229,446 in-lb	-10,962 in-lb
11	300,510 in-lb	295,029 in-lb	-5,481 in-lb
12	360,612 in-lb	360,612 in-lb	0 in-lb

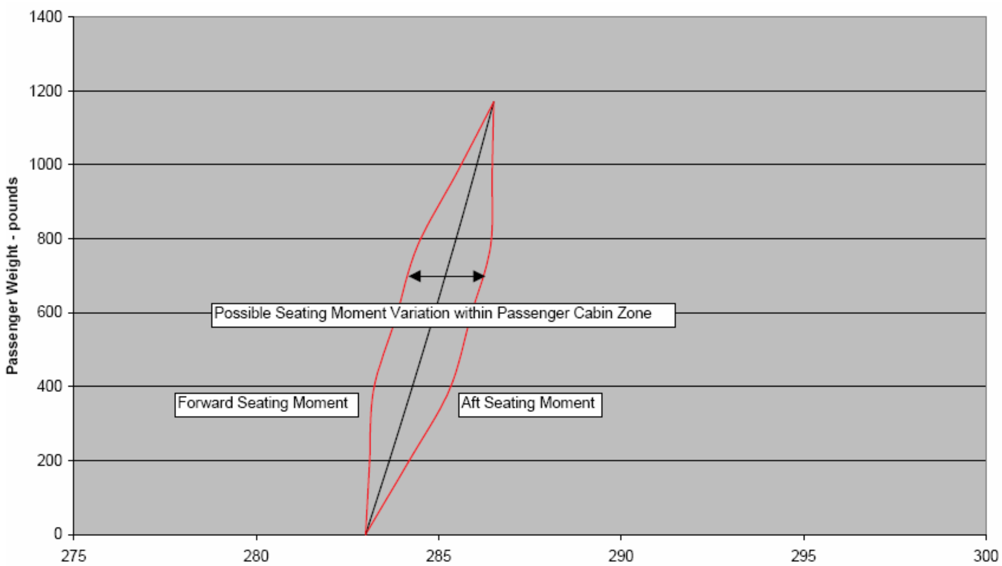
FIGURE A-9: Moments Resulting from the Window-Aisle-Remaining Assumption for Zone 2

Passenger No.	Assumed Row	Weight	Arm	Moment	Cumulative Moment
7	4	189 lb	289 in	54,621 in-lb	54,621 in-lb
8	4	189 lb	289 in	54,621 in-lb	109,242 in-lb
9	5	189 lb	318 in	60,102 in-lb	169,344 in-lb
10	5	189 lb	318 in	60,102 in-lb	229,446 in-lb
11	6	189 lb	347 in	65,583 in-lb	295,029 in-lb
12	6	189 lb	347 in	65,583 in-lb	360,612 in-lb

FIGURE A-10: Comparison of Moments for Zone 2

Passenger No.	Assumed Weight	Assumed Arm	Moment	Cumulative Moment
7	189 lb	318 in	60,102 in-lb	60,102 in-lb
8	189 lb	318 in	60,102 in-lb	120,204 in-lb
9	189 lb	318 in	60,102 in-lb	180,306 in-lb
10	189 lb	318 in	60,102 in-lb	240,408 in-lb
11	189 lb	318 in	60,102 in-lb	300,510 in-lb
12	189 lb	318 in	60,102 in-lb	360,612 in-lb

FIGURE A-11: Sample Passenger Seating Moment (Zone 2)



6. Curtailment Calculation For Zone 3

FIGURE A-12: Moments Resulting from the Zone Centroid Assumption for Zone 3

Passenger No.	Assumed Weight	Assumed Arm	Moment	Cumulative Moment
13	189 lb	411 in	77,679 in-lb	77,679 in-lb
14	189 lb	411 in	77,679 in-lb	155,358 in-lb
15	189 lb	411 in	77,679 in-lb	233,037 in-lb
16	189 lb	411 in	77,679 in-lb	310,716 in-lb
17	189 lb	411 in	77,679 in-lb	388,395 in-lb
18	189 lb	411 in	77,679 in-lb	466,074 in-lb
19	189 lb	411 in	77,679 in-lb	543,753 in-lb

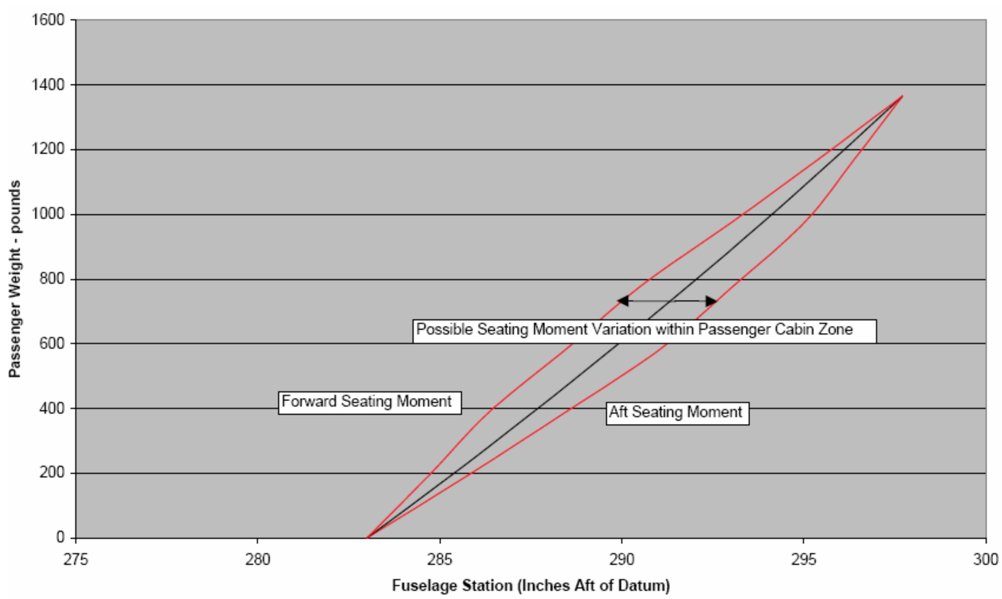
FIGURE A-13: Moments Resulting from the Window-Aisle-Remaining Assumption for Zone 3.

Passenger No.	Assumed Row	Weight	Arm	Moment	Cumulative Moment
13	7	189 lb	377 in	71,253 in-lb	71,253 in-lb
14	7	189 lb	377 in	71,253 in-lb	142,506 in-lb
15	8	189 lb	407 in	76,923 in-lb	219,429 in-lb
16	8	189 lb	407 in	76,923 in-lb	296,352 in-lb
17	9	189 lb	436 in	82,404 in-lb	378,756 in-lb
18	9	189 lb	436 in	82,404 in-lb	461,160 in-lb
19	9	189 lb	436 in	82,404 in-lb	543,564 in-lb

FIGURE A-14: Comparison of Moments for Zone 3

Passenger No.	Cumulative Moment from the Zone Centroid Assumption	Cumulative Moment from the Window-Aisle-Remaining Assumption	Difference
13	77,679 in-lb	71,253 in-lb	-6,426 in-lb
14	155,358 in-lb	142,506 in-lb	-12,852 in-lb
15	233,037 in-lb	219,429 in-lb	-13,608 in-lb
16	310,716 in-lb	296,352 in-lb	-14,364 in-lb
17	388,395 in-lb	378,756 in-lb	-9,639 in-lb
18	466,074 in-lb	461,160 in-lb	-4,914 in-lb
19	543,753 in-lb	543,564 in-lb	-189 in-lb

FIGURE A-15: Sample Passenger Seating Moment (Zone 3)



1) Determining the most adverse loading. It is important that an operator examine the above results (from Figures A-4 through A-15) for each zone and determine which loading scenario results in the greatest difference in moments.

   (a) For zones 1 and 2, having two, three, or four passengers in the zone results in the largest difference between the moments.
   (b) For zone 3, having four passengers in the zone results in the largest difference.
   (c) In this case, the operator should curtail the manufacturer's loading envelope forward and aft by the sum of these moments, 36,666 inch-pounds, to account for the potential variation in passenger seating.
   (d) In this example, the 36,666 inch-pounds is the sum of 11,340 from Figure A-6; 10,962 from Figure A-10; and 14,364 from Figure A-14.

2) Using actual seating location. Alternatively, an operator may reasonably avoid the above curtailment calculations by determining the actual seating location of each passenger in the cabin.
   (a) By eliminating potential variation in passenger seating, an operator would not need to make assumptions about passenger seating and would not need to curtail the loading envelope accordingly.
   (b) An operator choosing to use actual seating location should have procedures in place to ensure that passengers sit in their assigned location.

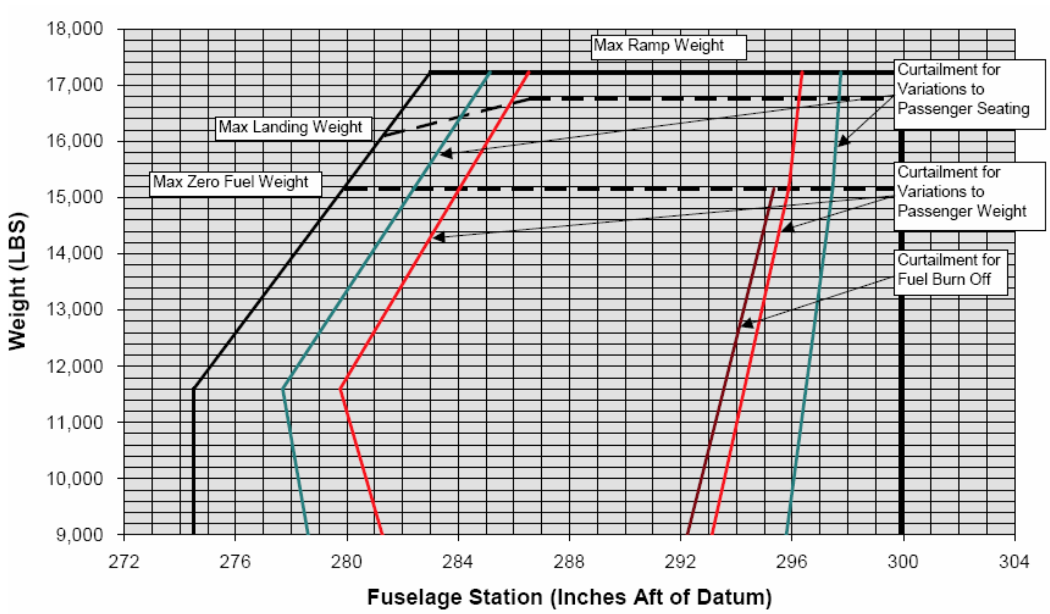
7. Other Curtailments to the Manufacturer's Loading Envelope

A. variation in passenger weight. Because the operator in this example elects to use standard average weights on a small-cabin aircraft, an additional curtailment for potential variation in passenger weight is required. The operator should curtail the manufacturer's loading envelope as described in Appendix B.
B. variation in fuel density. Because the loading of fuel does not significantly change the CG of the aircraft, the operator would not need to provide a curtailment for variation in fuel density.
C. Fuel movement in flight. For this sample aircraft, the manufacturer has considered the movement of fuel in flight. Therefore, the operator does not need to include additional curtailments in the operational loading envelope.
D. Fluids. The sample aircraft does not have a lavatory or catering.
E. Bags and freight. The sample aircraft has an aft bag compartment split into two sections. If the operator has procedures in place to restrict the movement of bags between the two sections, no additional curtailment to the envelope is required.
F. In-flight movement of passengers and crew members. Because there are no cabin crew members and the aircraft is not equipped with a lavatory, it is reasonable to assume that passengers or crew members will not move about the cabin in flight.
G. Movement of flaps and landing gear. The manufacturer of the sample aircraft has considered the movement of flaps and landing gear in the development of its loading envelope. The operator does not need to include any additional curtailments in its operational loading envelope for the movement of those items.
H. Fuel consumption. The fuel vector for the sample aircraft provides a small aft movement that requires a -8,900 inch-pounds curtailment to the aft zero fuel weight limits to ensure the aircraft does not exceed the aft limit as fuel is burned. This equates to a -0.8 inch curtailment at an estimated operational empty weight of 11,000 pounds with a linear transition to a -0.6 inch curtailment at maximum zero fuel weight (MZFW) of 16,155 pounds. In this example, the 8,900 inch-pounds is the fuel burn deviation that would bring the aircraft outside the aft CG limit during the course of flight.

8. Operational Loading Envelope Diagrams

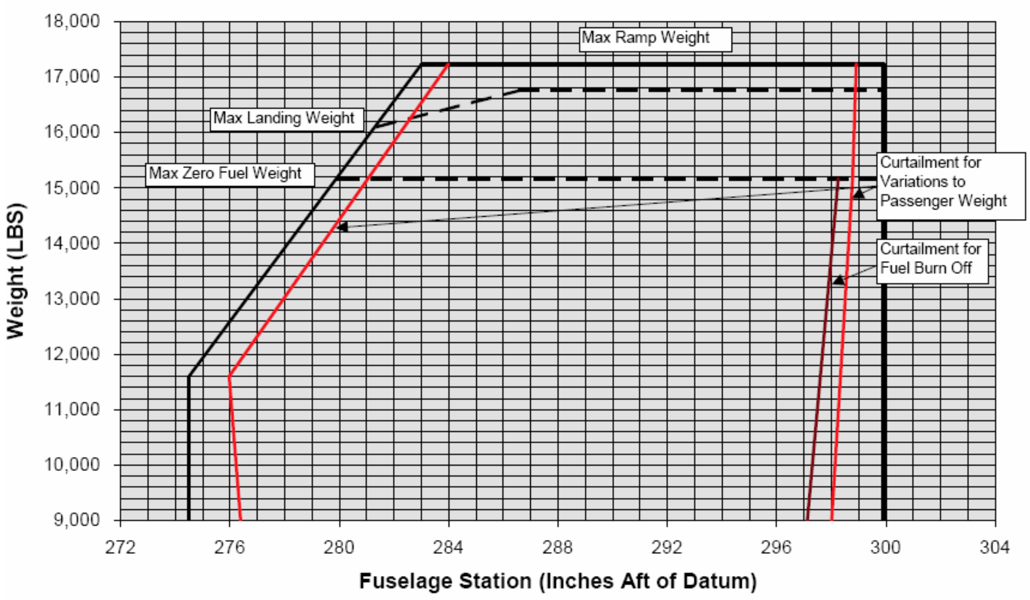
Figure A-16 below shows the operator's curtailments to the manufacturer's loading envelope, based on the assumptions made about variations in passenger seating and weight, as well as fuel consumption.

FIGURE A-16: Operational Loading Envelope of Curtailment for variations in Passenger Seating.



To expand the operational loading envelope, an operator could choose to use the actual seating location of passengers in the cabin and reduce the curtailment for variations in passenger seating. Figure A-17 below shows the expansion of the operational loading envelope

FIGURE A-17: Operational Loading Envelope using actual Seating Location of Passengers.



APPENDIX B
Additional Curtailment to CG Envelopes in Small Cabin Aircraft

Curtailment to CG Envelopes in Small Cabin Aircraft

A. The use of average weights for small cabin aircraft requires consideration of an additional curtailment to the center of gravity (CG) envelope for passenger weight variations and male/female passenger ratio. This curtailment is in addition to the standard curtailments discussed in Section 4 of this AC, with examples in Appendix A.

1) Passenger weight variation is determined by multiplying the standard deviation (from the source of the average passenger weight used) by the row factor from Figure B-1. The following Figure is a statistical measure that ensures a 95% confidence level of passenger weight variation, using the window-aisle-remaining seating method

FIGURE B-1: Row Factor.

No. of Rows	2-abreast	3-abreast	4-abreast
2	2.96	2.73	2.63
3	2.41	2.31	2.26
4	2.15	2.09	2.06
5	2.00	1.95	1.93
6	1.89	1.86	1.84
7	1.81	1.79	1.77
8	1.75	1.73	1.69
9	1.70	1.68	1.65
10	1.66	1.65	1.62
11	1.63	1.59	1.59
12	1.60	1.57	1.57
13	1.57	1.54	1.54
14	1.55	1.52	1.52
15	1.53	1.51	1.51
16	1.49	1.49	1.49
17	1.48	1.48	1.48
18	1.46	1.46	1.46

2) Protect against the possibility of an all-male flight by subtracting the difference between the male and average passenger weight.

3) The sum of these two provides an additional weight to be used for CG curtailment, similar to the way in which passenger seating variation is calculated.

B. Calculation of the curtailment passenger weight variation is decided by multiplying the standard deviation by the correction factor and adding the difference between the average all-male and average passenger weight.

- For example, assuming a 47-pound standard deviation, the difference between the average all-male and average passenger weight is 10 pounds (from 1999–2000 National Health and Nutrition

Examination Survey (survey) data), and a sample aircraft with 9 rows in a 2-abreast configuration. The additional weight to be curtailed is determined as—

$$\text{Weight for Additional Curtailment} = (47 \times 1.70) + (10) = 90 \text{ lb}$$

C. For the example, the additional curtailment should be accomplished by assuming passenger loading at 90 pounds using the program method for passenger seating variation (e.g., window-aisle-remaining).

- Using the window-aisle-remaining method, the additional curtailment in the example is determined to be 59,031 inch-pounds forward and aft. Figure B-2 displays the calculations used in this example.

FIGURE B-2: Sample Curtailment due to variations in Passenger Weight and Male/Female Ratio using the Window-Aisle Method

Passenger Weight: 90 Coach Class (Y) Cabin Centroid: 323.8

Forward Seating						Aft Seating					
Row	Seat Centroid	Seat Moment	Total Weight	Total Moment	Moment Deviation	Row	Seat Centroid	Seat Moment	Total Weight	Total Moment	Moment Deviation
1	198.0	17,820	90	17,820	-11,321	9	436.0	39,240	90	39,240	10,099
1	198.0	17,820	180	35,640	-22,642	9	436.0	39,240	180	78,480	20,198
2	228.0	20,520	270	56,160	-31,263	9	436.0	39,240	270	117,720	30,297
2	228.0	20,520	360	76,680	-39,884	8	407.0	36,630	360	154,350	37,786
3	258.0	23,220	450	99,900	-45,805	8	407.0	36,630	450	190,980	45,275
3	258.0	23,220	540	123,120	-51,726	7	377.0	33,930	540	224,910	50,064
4	289.0	26,010	630	149,130	-54,857	7	377.0	33,930	630	258,840	54,853
4	289.0	26,010	720	175,140	-57,988	6	347.0	31,230	720	290,070	56,942
5	318.0	28,620	810	203,760	-58,509	6	347.0	31,230	810	321,300	59,031
5	318.0	28,620	900	232,380	-59,031	5	318.0	28,620	900	349,920	58,509
6	347.0	31,230	990	263,610	-56,942	5	318.0	28,620	990	378,540	57,988
6	347.0	31,230	1,080	294,840	-54,853	4	289.0	26,010	1,080	404,550	54,857
7	377.0	33,930	1,170	328,770	-50,064	4	289.0	26,010	1,170	430,560	51,726
7	377.0	33,930	1,260	362,700	-45,275	3	258.0	23,220	1,260	453,780	45,805
8	407.0	36,630	1,350	399,330	-37,786	3	258.0	23,220	1,350	477,000	39,884
8	407.0	36,630	1,440	435,960	-30,297	2	228.0	20,520	1,440	497,520	31,263
9	436.0	39,240	1,530	475,200	-20,198	2	228.0	20,520	1,530	518,040	22,642
9	436.0	39,240	1,620	514,440	-10,099	1	198.0	17,820	1,620	535,860	11,321
9	436.0	39,240	1,710	553,680	0	1	198.0	17,820	1,710	553,680	0

- The following definitions describe the parameters used in the samples in Figures B-2 and B-3—
  - ♦ Seat Centroid: Location of passenger weight at seat
  - ♦ Seat Moment: Additional passenger weight × seat centroid
  - ♦ Total Weight: Sum of additional passenger weights (running total)
  - ♦ Total Moment: Sum of additional passenger moments
  - ♦ Moment Deviation: Difference between total moment and moment generated by assuming additional passenger weight is located at the cabin centroid (323.8 in)

D. If the operator chooses to use the passenger cabin zone concept (as described in Appendix A) and apply this concept to account for variation in passenger weight, then the row factor in Figure B-1 corresponding to the number of rows in each zone should be used.

1) Considering three cabin zones with each zone containing three rows in a 2-abreast configuration, the required row factor (see Figure B-1) is 2.41.

- ♦ The row factor is multiplied by the standard deviation and the difference between average all- male and average passenger weights is added to provide the additional weight consideration.
- ♦ In the example, the standard deviation is calculated from the survey data as 47 pounds, and the difference between average all-male and average passenger weights is 10 pounds.
- ♦ The resulting additional weight for curtailment is 47 × 2.41 + 10 = 123 pounds.
- ♦ This additional weight is applied per the window-aisle-remaining concept for each cabin zone independently and the results are summed to determine the amount of curtailment.
- ♦ In this case, the curtailment is found to be 23,791 inch-pounds forward and aft.

2) If an operator chooses to use row count, the operator must use the row factor for two rows.

- ♦ In this example the required row factor is 2.96 (see Figure B-1).
- ♦ The row factor is multiplied by the standard deviation and the difference between average all- male and average passenger weight is added to provide the additional weight consideration.
- ♦ In the example, the standard deviation is calculated from the survey data as 47 pounds, and the difference between average all-male and average passenger weights is 10 pounds.
- ♦ The resulting additional weight for curtailment is 47 × 2.96 + 10 = 149 pounds.
- ♦ This additional weight is applied as if a two-row passenger zone concept is used for passenger seating.
- ♦ The resulting curtailment is determined to be 17,880 inch-pounds forward and aft (see Figure B-3)

FIGURE B-3: Sample Curtailment Due To variations In Passenger Weight And Male/female Ratio

Coach Class (Y) Cabin Centroid (Rows 1-2): 213.0
Coach Class (Y) Cabin Centroid (Rows 3-4): 273.5
Coach Class (Y) Cabin Centroid (Rows 5-6): 332.5
Coach Class (Y) Cabin Centroid (Rows 7-8): 392.0
Passenger Weight: 149 Coach Class (Y) Cabin Centroid (Row 9): 436.0

Forward Seating						Aft Seating					
Row	Seat Centroid	Seat Moment	Total Weight	Total Moment	Moment Deviation	Row	Seat Centroid	Seat Moment	Total Weight	Total Moment	Moment Deviation
1	198.0	29,502	149	29,502	-2,235	9	436.0	64,964	149	64,964	0
1	198.0	29,502	298	59,004	-4,470	9	436.0	64,964	298	129,928	0
2	228.0	33,972	447	92,976	-2,235	9	436.0	64,964	447	194,892	0
2	228.0	33,972	596	126,948	0	8	407.0	60,643	149	60,643	2,235
3	258.0	38,442	149	38,442	-2,310	8	407.0	60,643	298	121,286	4,470
3	258.0	38,442	298	76,884	-4,619	7	377.0	56,173	447	177,459	2,235
4	289.0	43,061	447	119,945	-2,310	7	377.0	56,173	596	233,632	0
4	289.0	43,061	596	163,006	0	6	347.0	51,703	149	51,703	2,161
5	318.0	47,382	149	47,382	-2,161	6	347.0	51,703	298	103,406	4,321
5	318.0	47,382	298	94,764	-4,321	5	318.0	47,382	447	150,788	2,161
6	347.0	51,703	447	146,467	-2,161	5	318.0	47,382	596	198,170	0
6	347.0	51,703	596	198,170	0	4	289.0	43,061	149	43,061	2,310
7	377.0	56,173	149	56,173	-2,235	4	289.0	43,061	298	86,122	4,619
7	377.0	56,173	298	112,346	-4,470	3	258.0	38,442	447	124,564	2,310
8	407.0	60,643	447	172,989	-2,235	3	258.0	38,442	596	163,006	0
8	407.0	60,643	596	233,632	0	2	228.0	33,972	149	33,972	2,235
9	436.0	64,964	149	64,964	0	2	228.0	33,972	298	67,944	4,470
9	436.0	64,964	298	129,928	0	1	198.0	29,502	447	97,446	2,235
9	436.0	64,964	447	194,892	0	1	198.0	29,502	596	126,948	0

Sum of Minimum Moment Deviations -17,880 Sum of Maximum Moment Deviations 17,880
Sum of Minimum Moment Deviations -17,880 Sum of Maximum Moment Deviations 17,880

APPENDIX C
Options to Improve Accuracy

A number of options are available that enable operators to deviate from standard assumed weights and may also provide relief from constraints required when assumed averages are used. These options include—

1. Surveys

A. Surveys may be accomplished for passenger weights (to include carry-on bags), checked baggage weights, male/female ratios, and fuel densities.

B. These surveys may be conducted for entire operator route systems, or by specific market or region.

C. Surveys practices and data reduction must conform to the requirements defined in this advisory circular (AC).

D. Use of surveys may allow an operator to use passenger and baggage weights less than the standard specified in this AC.

E. Also, a survey may find that the assumed male/female ratio is incorrect and appropriate adjustments must be made.

1) For example, let’s assume the following results from an approved passenger and baggage survey.—
   - ♦ Male passenger weight (M) = 183.3 pounds Female passenger weight (F) = 135.8 pounds
   - ♦ Difference between male and average passenger weights = 24.0 pounds
   - ♦ Standard deviation of total sample (Sigma) = 47.6 pounds
   - ♦ Male/female ratio (Pax Ratio) = 50.6 percent Checked baggage weight = 29.2 pounds Baggage checked plane-side = 21.3 pounds
   - ♦ Carry-on and personal items weight (CO Wt) = 10.4 pounds
   - ♦ Carry-on and personal items per passenger ratio (CO Ratio) = 0.82 pounds
   - ♦ Survey conducted in summer months

2) The resulting assumed passenger weight for loading is expressed as—
   - ♦ Passenger Weight = (M x Pax Ratio) + (F x (1 - Pax Ratio)) + (CO Wt x CO Ratio) And is determined as—
   - ♦ Summer Passenger Weight = (183.3 x 0.506) + (135.8 x (1 - 0.506)) + (10.4 x 0.82) = 169 lb
   - ♦ Winter Passenger Weight = 169 + 5 = 174 lb

3) Survey results would also be used to determine the additional curtailment for variations to passenger weight. Assuming a 19-seat aircraft in 2-abreast configuration in this example, the additional weight to be curtailed would be—
   - ♦ Additional Weight for Curtailment = (47 x 1.70) + 24 = 104 lb

4) Also in the example, the assumed checked baggage weight is 30 pounds.
   - ♦ Plane-side loaded bags would be assumed to weigh 20 pounds. (These weights are the standard average weights provided for a no-carry-on baggage program as described in Chapter 2, Section 2).

2. Actual Weights

A. It is permissible to use actual weights in lieu of standard average, segmented, or survey- derived average weights (if applicable).

B. Parameters that may use actual weights include—

1) passenger weights,
2) checked baggage weights,
3) carry-on bag weights,
4) crew weights, and
5) fuel density/weight.

3. Passenger Cabin Zones and Row Count

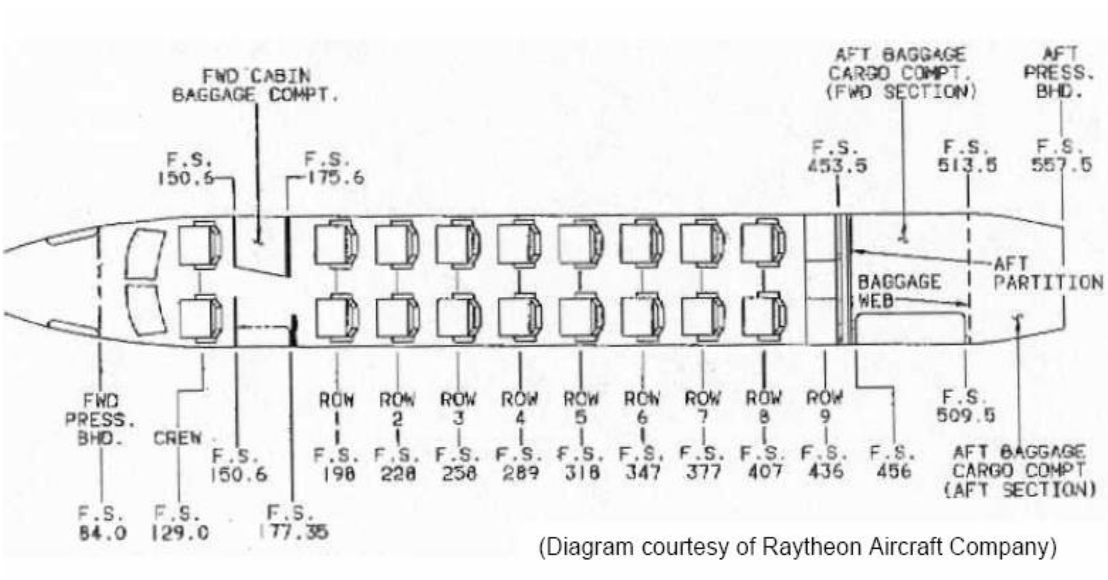
A. Passenger cabins may be split up into zones provided an acceptable procedure for determination of passenger seating is included (e.g., use of seat assignments or the crew counts each seated passengers by zone).

B. If zones are used, it may be reasonable for the operator to reduce the center of gravity (CG) passenger seating curtailment by accommodating variations within each individual zone separately and totaling the results.

C. Passenger row count allows the operator to reduce the seating variation by accounting for the row in which the passenger is actually seated. An example of use of passenger zones follows.

1) Assume an aircraft interior as displayed in Figure C-1.

FIGURE C-1: Sample Aircraft Interior Seating Diagram



(Diagram courtesy of Raytheon Aircraft Company)

2) Assume that for mass & balance purposes, it is desirable to break up the cabin into passenger zones.

3) Appendix B provides a sample calculation of curtailing for passenger seating variations using a hypothetical commuter category 19-seat aircraft with 3 passenger zones.
4) A more accurate mass & balance calculation requiring less curtailment may be provided by increasing the number of passenger zones.
5) For example, an increase to 5 passenger zones would result in the following—
   - ♦ Zone 1 (rows 1−2)
   - ♦ Zone 2 (rows 3−4)
   - ♦ Zone 3 (rows 5−6)
   - ♦ Zone 4 (rows 7−8)
   - ♦ Zone 5 (row 9)
6) Use of the window-aisle-remaining method will be used in each zone to provide a total curtailment to the CG envelope. (For this sample aircraft, window-aisle-remaining method simply becomes forward and aft end loading).
7) For each zone, a zone centroid must be calculated by counting the total number of seats and averaging their location.
   - ♦ Zone 1 centroid = (2 x 198.0 + 2 x 228.0) / (2 + 2) = 213.0 in
   - ♦ Zone 2 centroid = (2 x 258.0 + 2 x 289.0) / (2 + 2) = 273.5 in
   - ♦ Zone 3 centroid = (2 x 318.0 + 2 x 347.0) / (2 + 2) = 332.5 in
   - ♦ Zone 4 centroid = (2 x 347.0 + 2 x 377.0) / (2 + 2) = 392.0 in
   - ♦ Zone 5 centroid = (3 x 436.0) / (3) = 436.0 in
8) Assuming the standard winter passenger weight of 189 pounds is used in the curtailment, the calculation of the total moment is required for comparison to the zone moment, assuming each passenger is seated at the centroid of each passenger zone.
9) The total moment is found by summing the individual moments calculated at each occupied seat in the window-aisle-remaining progression

FIGURE C-2: Forward Curtailment Calculations – Zone 1

Pax	Row	Arm	Total Moment	Zone Centroid	Zone Moment	Delta Moment
1	1	198.0	37,422	213.0	40,257	-2,835
2	1	198.0	74,844	213.0	80,514	-5,670
3	2	228.0	117,936	213.0	120,771	-2,835
4	2	228.0	161,028	213.0	161,028	0

FIGURE C-3: Forward Curtailment Calculations – Zone 2

Pax	Row	Arm	Total Moment	Zone Centroid	Zone Moment	Delta Moment
1	3	258.0	48,762	273.5	51,692	-2,930
2	3	258.0	97,524	273.5	103,383	-5,859
3	4	289.0	152,145	273.5	155,075	-2,930
4	4	289.0	206,766	273.5	206,766	0

FIGURE C-4: Forward Curtailment Calculations – Zone 3

Pax	Row	Arm	Total Moment	Zone Centroid	Zone Moment	Delta Moment
1	5	318.0	60,102	332.5	62,843	-2,741
2	5	318.0	120,204	332.5	125,685	-5,481
3	6	347.0	185,787	332.5	188,528	-2,741
4	6	347.0	251,370	332.5	251,370	0

FIGURE C-5: Forward Curtailment Calculations – Zone 4

Pax	Row	Arm	Total Moment	Zone Centroid	Zone Moment	Delta Moment
1	7	377.0	71,253	392.0	74,088	-2,835
2	7	377.0	142,506	392.0	148,176	-5,670
3	8	407.0	219,429	392.0	222,264	-2,835
4	8	407.0	296,352	392.0	296,352	0

FIGURE C-6: Forward Curtailment Calculations – Zone 5

Pax	Row	Arm	Total Moment	Zone Centroid	Zone Moment	Delta Moment
1	9	436.0	82,404	436.0	82,404	0
2	9	436.0	164,808	436.0	164,808	0
3	9	436.0	247,212	436.0	247,212	0

A. The curtailment for passenger seating variation is determined by adding the largest delta moments from each of the passenger zones.

B. In the example, the curtailment to the forward CG limit for passenger seating variation is - 22,680 inch-pounds (-5,670 + -5,859 + -5,481 + -5,670 + 0).

C. Similarly, the curtailment to the aft limit of the CG envelope using the window-aisle remaining method loading from the most aft seat row moving forward (in each zone) would result in an adjustment of +22,680 inch-pounds.

D. These curtailments compare favorably to the curtailments of + 36,666 inch-pounds determined in the sample provided for three passenger zones in Appendix B.

4. Actual Male/Female Counts

A. Loading systems may use separate male and female assumed passenger weights for each operation.

1) If the operator's mass & balance program is approved for use of male/female weights, then the operator must count the number of male passengers and female passengers separately.
2) The male and female weights used may be from the development of standard passenger weight or they may be determined through an operator-developed survey.
3) Use of male/female weights may be for entire operations or for a particular route and/or region of flying.

B. An example of how male/female ratios can be applied to mass & balance systems follows—

1) Assuming the operator is using the survey results as described in subparagraph (1) above, the assumed male and female passenger weights, including average carry-on baggage, are computed as—
   (a) Male passenger weight (summer) = 183.3 + 10.4 × 0.82 = 192 lb
   (b) Male passenger weight (winter) = 192 + 5 = 197 lb
   (c) Female passenger weight (summer) = 135.8 + 10.4 × 0.82 = 144 lb
   (d) Female passenger weight (winter) = 144 + 5 = 149 lb
2) The mass & balance manifest would provide for identification of male/female identification and the passenger weights would be summed accordingly.
   ♦For instance, 7 male and 11 female passengers would result in a total passenger weight of (7 × 192) + (11 × 144) = 2,928 pounds.

5. Adolescent (Child) Weights

In most circumstances, an operator may consider any passenger who is less than 13 years of age and is occupying a seat to weigh less than an adult passenger.

6. Standard Weights with Approved No-Carry-on Baggage Program

- Summer Passenger Weight = 184 lb
- Winter Passenger Weight = 189 lb
- Checked Baggage Weight = 30 lb each
- Baggage Checked Plane-side = 20 lb each

Inclusion in the no-carry-on baggage program does not preclude use of actual or surveyed weights for passengers, carry-on/personal items, checked baggage, or baggage checked plane-side.

7. Automation

A. Automation may also be used to provide a more accurate mass & balance program.

B. Examples of automation include—

1) Use of seat assignments for the determination of passenger moment and
2) Historical seating to determine passenger moment.