U.S. DEPARTMENT

OF TRANSPORTATION

Federal Aviation Administration

Advisory Circular

Subject: AIRCRAFT WEIGHT AND BALANCE CONTROL

Date: ____ [10/25/90] AC No: 120-27C[B]
Initiated by: AFS-330 Change:

1. PURPOSE. This advisory circular (AC) provides a method and procedures for developing a weight ***and*** balance control system.

2. FOCUS. This document provides guidance to certificate holders that are required to have an approved weight and balance program by Federal Aviation Regulations (FAR) Part 121 or elect to have an approved program under FAR Part 135.

3. CANCELLATION. AC 120-27B[A], Aircraft Weight and Balance Control, dated [May 14, 1980] ***October 25, 1990.***

4. DISCUSSION. An operator may submit, for inclusion into its operations specifications, any method and procedure which shows that an aircraft will be properly loaded and will not exceed approved weight and balance limitations during operation. The approval of such a weight and balance control system is based on an evaluation of the program presented for a particular aircraft and of a particular operator's ability to implement that program. Whatever method is used, the program should account for all probable loading conditions which may be experienced in service and show that the loading schedule developed will ensure satisfactory aircraft loading within the approved limits during ground operations and throughout each flight.

5. CONTENTS. Weight and balance control systems encompass the following:

a. Methods for establishing, monitoring, and adjusting individual aircraft or fleet empty weight and center of gravity (CG) in conjunction with the initial and periodic[al] reweighing of aircraft.

b. A loading schedule composed of graphs, tables, and computations, ***and/or computer programs,*** etc., whereby the various weight and balance conditions of an aircraft may be established based on pertinent data for use in loading that particular aircraft in a satisfactory manner.

c. Procedures for using the loading schedule to establish that the loaded condition of the aircraft is within approved weight and CG limits.

d. A load manifest to document loading information by personnel responsible for weight and balance control and procedures for its preparation.

e. Procedures for ***all applicable*** [crewmembers, cargo handlers, and other] personnel concerned with aircraft loading ***and operations***, giving complete details regarding distribution of passengers, fuel, cargo, and necessary restrictions to passenger movement on the ground and during flight.

f. The program should provide for operational performance factors such as takeoff and landing ***weight*** [away] accountability***; extension and retraction of landing gear, flaps, slats and thrust reversers;*** and en route and taxi fuel burnoff.

6. TERMS, DESCRIPTIONS, AND GENERAL STANDARDS.

a. Empty Weight. The weight of the airframe, engines, propellers, rotors, and fixed equipment. Empty weight excludes the weight of the crew and payload but includes the weight of all fixed ballast, unusable fuel [supply], undrainable oil, [total quantity of engine coolant,] and total quantity of hydraulic fluid [(see FAR Section 135.2(e)(2))]. The empty weight of an aircraft is the gross weight less the following:

(1) All ***drainable*** fuel and oil, except system fuel and oil. System fuel and oil are the amounts required to fill both systems and the tanks, where applicable, up to the outlets to the engines. When oil is used for propeller feathering, such oil is included as system oil.

(*2*[3]) ***Other drainable fluids, including potable water and lavatory service water,*** [Drainable antidetonant injection,] ***thrust*** augmentation, and deicing fluids.

(*3*[2]) Crew and crew baggage.

(4) Passengers and cargo (revenue and nonrevenue).

(5) Removable passenger service equipment, food, magazines, etc., including ***service carts, dishes and beverages*** [drainable washing and potable water].

(6) ***Removable e***[E]mergency equipment [(overwater, tropical, and frigid)].

(7) Other equipment variable for flights.

(8) ***Spare parts.*** [Flight spares (spark plugs, wheel, cylinder, etc.)]

b. Operating Weight. The basic operating weight established by the operator for a particular model aircraft should include the following standard items in addition to the empty weight of the aircraft or as otherwise specified by the operator.

(1) Normal oil quantity.

(2) ***Lavatory servicing fluid, potable water, etc.*** [Antidetonant injection, augmentation, and deicing fluids.]

(3) ***Drainable unuseable fuel.*** [Crew and crew baggage.]

(4) ***Crew and crew baggage.*** [Passenger service equipment, including washing and potable water, magazines, etc.]

(5) ***Passenger service equipment, including service carts, food, trays, dishes, beverages, magazines, etc.*** [All other items of equipment considered standard by the operator concerned.]

(6) ***Spare parts normally carried on-board and not accounted for as cargo.*** [Emergency equipment, if required, for all flights.]

(7) Required emergency equipment for all flights.

(8) All other items of equipment considered standard by the operator.

c. A detailed listing of the items comprising empty weight and operating weight should be included in the operator's program.

d. Structural Limits. Weight and CG limits are established at the time of aircraft certification. They are specifi***ed***[cally] in, or referenced by, the applicable type certificate data sheet or aircraft specification. The operator's weight and balance program should provide for maintaining these limits ***and*** [. The operator's program] should stress the point ***that*** the aircraft must be operated at or below its maximum certificated operating weight. Following are general definitions of structural weight limits normally considered in weight and balance programs.

(1) Maximum Zero Fuel Weight. The maximum zero fuel weight means the maximum permissible weight of an aircraft with no disposable fuel or oil (see FAR Sections 121.198(b) and 135.2(e)(3)).

(2) Maximum Landing Weight. The landing weight limit is the maximum weight at which the aircraft may normally be landed. Some aircraft are equipped to jettison fuel as an abnormal measure to reduce aircraft weight down to the landing limit.

(3) Maximum Takeoff Weight. This is the maximum allowable, total loaded aircraft weight at the start of the takeoff run.

(4) Maximum Ramp Weight. This is the maximum allowable, total loaded aircraft weight for taxi.

7. AIRCRAFT WEIGHT ESTABLISHMENT. Aircraft weight and balance control systems normally contain provisions for determining aircraft weight in accordance with the following procedures:

a. Individual Aircraft Weight and Changes. The loading schedule may utilize the individual weight of the aircraft in computing pertinent gross weight and balance. The individual weight and CG position of each aircraft should be confirmed at the specified reweighing periods. In addition, it should be reestablished by ***computing or*** reweighing whenever the cumulative change to the operating weight exceeds plus or minus one-half of 1 percent of the maximum landing weight or the cumulative change in the CG position exceeds one-half of 1 percent of the mean aerodynamic chord (MAC).

In the case of helicopters, whenever the cumulative change in the CG position exceeds one-half of 1 percent of the total CG range, the weight and balance should be reestablished.

b. Fleet Weights, Establishment, and Changes. For a fleet group of aircraft of the same model and configuration, an average operating fleet weight may be utilized if the operating weights and CG position are within the limits established herein. The fleet weight should be calculated on the following basis:

(1) An operator's empty fleet weight is usually determined by weighing aircraft according to the following table: for a fleet of 1 to 3, weigh all aircraft; for a fleet of 4 to 9, weigh 3 aircraft plus at least 50 percent of the number over 3; for fleets of over 9, weigh 6 aircraft plus at least 10 percent of the number over 9.

(2) In choosing the aircraft to be weighed, the aircraft in the fleet having the highest time since last weighing should be selected. When the average empty weight and CG position have been determined for aircraft weighed and the fleet operating weight established, necessary data should be computed for aircraft not weighed but which are considered eligible under such fleet weight. If the operating weight of any aircraft weighed or the calculated operating weight of any of the remaining aircraft in the fleet varies by an amount exceeding plus or minus one-half of 1 percent of the maximum landing weight from the established operating fleet weight or the CG position varies more than plus or minus one-half of 1 percent of the ***length of the*** MAC from the fleet ***weight*** CG, the aircraft should be omitted from that group and operated on its actual ***or calculated*** operating weight and CG position. If it falls within the limits of another fleet or group, it may [then] become part of ***that*** [the] fleet. In cases where the aircraft is within the operating fleet weight tolerance but the CG position varies in excess of the tolerance allowed, the aircraft may still be utilized under the applicable operating fleet weight but with an individual CG position.

(3) Reestablishment of the operator's empty fleet weight or operating fleet weight and corresponding CG positions may be accomplished between weighing periods by calculation based on the current empty weight of the aircraft previously weighed for fleet weight purposes. Weighing for reestablishment of fleet weights is normally conducted on a 3-year basis unless a shorter period is desired by the operator.

c. Establishing Initial Weight. Prior to being placed into service, each aircraft should be weighed and the empty weight and CG location established. New aircraft are normally weighed at the factory and are eligible to be placed into operation without reweighing if the weight and balance records have been adjusted for alterations or modifications to the aircraft. Aircraft transferred from one operator within an approved weight and balance program to another operator with an approved program need not be weighed prior to use by the receiving operator unless more than 36 calendar months have elapsed since last weighing. ***Aircraft transferred, purchased or leased from an operator without an approved weight and balance program can be placed into service without being reweighed if the last weighing was accomplished by an acceptable method and was accomplished within the last 12 calendar months.***

d. Periodic Weighing - Aircraft Using Individual Weights. Aircraft operated under a loading schedule utilizing individual aircraft weights in computing the gross weight are normally weighed at intervals of 36 calendar months. An operator may, however, extend this weigh*ing*[t] period for a particular model aircraft when pertinent records of actual routine weighing during the preceding period of operation show that weight and balance records maintained are sufficiently accurate to indicate aircraft weights and CG positions are within the cumulative limits specified in paragraph 7a. Such applications should be limited to increases in increments of 12 months and should be substantiated in each instance with at least two aircraft weighed. Increases should not be granted which would permit any aircraft to exceed 48 calendar months since the last weighing. In the case of helicopters, increases should not exceed a time which is equivalent to the aircraft overhaul period.

e. Periodic Weighing - Aircraft Using Fleet Weights. Aircraft operating under fleet weights should be weighed in accordance with procedures outlined for the establishment of fleet weights. Since each fleet is normally reestablished every 3 years and a specified number of aircraft weighed at such periods, no additional weighing is considered necessary. A rotation program should, however, be incorporated so all aircraft in the fleet will be weighed periodically.

f. Weighing Procedure. Normal precautions, consistent with good practices, should be taken such as checking ***to insure the aircraft has the required items of installed equipment*** [the aircraft equipment list to ensure the aircraft has the items of installed equipment contained in the list], determining that the fluids are properly accounted for, that the aircraft is clean, and that weighing is accomplished in an enclosed building. Any acceptable scales may be used for weighing provided they are properly calibrated, zeroed, and used in accordance with the manufacturer's instructions. Each scale should have been calibrated, either by the manufacturer or by a ***recognized facility such as a*** civil department of weights and measures, within 1 year, ***or as recommended by the manufacturer,*** prior to weighing any aircraft for this purpose unless the operator has evidence which warrants a longer period between calibrations.

8. LOADING SCHEDULE. Loading schedules should be simple and orderly, based on sound principles, thus reducing the elements of human error. Loading schedules may be applied to individual aircraft or to a complete fleet. When an operator utilizes several types of models of aircraft, a loading schedule, which may be index-type, tabular-type, or a computer, should be identified with the type of model or aircraft for which it is designed.

9. LOADING PROVISIONS. All seats, compartments, and other loading stations should be properly marked and the identification used should correspond with the instructions established for computing weight and balance of the aircraft. When the loading schedule provides for blocking off seats or compartments in order to remain within the CG limits, effective means should be provided to ensure that such seats or compartments are not occupied during operations specified.

In such cases, instructions should be prepared for crewmembers, ***load agents,*** cargo handlers, and other personnel concerned, giving complete information regarding distribution of passengers, cargo, fuel, and other items. Information relative to maximum capacities and other pertinent limitations affecting the weight or balance of the aircraft should be included in these instructions. When it is possible by adverse distribution of passengers ***and/or cargo*** to exceed the approved CG limits of the aircraft, special instructions should be issued to the pilot in command and appropriate ***personnel*** [crewmembers] so that the load distribution can be maintained within the approved limitation. A suitable commercial***ly available*** scale should be available for use when passenger, baggage, and cargo weights are otherwise undeterminable.

10. ***STANDARD*** PASSENGER WEIGHTS. Actual or average passenger weights may be used to compute passenger loads over any segment of a certificate holder's operations. However, actual weight should be used for operations with [reciprocating powered] aircraft ***having*** [of] nine or less ***passenger*** seats [and for all operations involving nonstandard weight passenger groups. Both methods may be used interchangeably provided only one method is used for any flight from originating to terminating point, except as indicated in subparagraph b].

The loading system should readily accommodate nonstandard weight groups, and the manifest should indicate whether average or actual weights, or a combination thereof, were used in the computation.

a. Average Passenger Weights. The standard average passenger weights listed in the following table were ***developed for*** [derived from an extensive survey of] conventional airline passenger groups. They should not be arbitrarily adopted for operations with passenger groups that appreciably differ from the basis ***or where the mix of male and female passengers is known to be different than a 60% male/40% female operation.*** Special average weights ***or special ratios*** may be established for particular operations based on surveys ***(a)*** indicating those weights consistently provide for loading within prescribed weight and balance limits ***and (b) meeting the criteria for surveys and statistical analysis outlined in Appendix A of this document.*** Predominantly male passenger groups usually warrant higher averages.

STANDARD AVERAGE PASSENGER WEIGHTS
(Includes carry-on baggage)

Summer - for the period of May 1 through October 31:
Adult Passenger ***(60%/40% male/female mix)***.....***180***[170] pounds
Male.....*195 pounds*
Female.....*155 pounds*

Winter - for the period of November 1 through April 30:
Adult Passenger ***(60%/40% male/female mix)***.....***185***[175] pounds
Male.....***200 pounds***
Female.....***160 pounds***

Summer/Winter
Children.....80 pounds
(Applicable between ages 2 and 12)

b. *Aircraft Typically Operated by Regional Carriers. Aircraft with limited cabin baggage stowage capability, where the operator's approved carry-on baggage program limits each passenger to a maximum of one carry-on bag in the cabin, may use the following standard average weights for passengers and carry-on bags:*

Summer - for the period of May 1 through October 31:

Adult Passenger (60%/40% male/female mix).....170 pounds
Male.....185 pounds
Female.....145 pounds

Winter - for the period of November 1 through April 30:

Adult Passenger (60%/40% male/female mix).....175 pounds
Male.....190 pounds
Female.....150 pounds

Summer/Winter

Children.....80 pounds
(Applicable between ages 2 and 12)

Carry-on bags which cannot be stowed in the passenger cabin, and which are instead taken from passengers during the boarding process and stowed in a baggage compartment, shall be accounted for at an additional weight of 10 pounds per bag located at the compartment's center of gravity.

c. The average weight for children normally is used only when needed to accommodate available payload. Otherwise, as ticketed passengers, they are considered the same as adult passengers. Children less than 2 years old are considered babes-in-arms, and their weight is considered negligible.

Note: The intention of this AC is to provide methods and procedures for developing weight and balance control systems, not to address the entire spectrum of all possible weight configurations. Therefore, the operator should consider providing the Federal Aviation Administration with a reliable survey to establish an average passenger weight for its specific operation.

11. NONSTANDARD PASSENGER WEIGHTS

a. ***Actual Passenger Weights.*** Actual passenger weights are used on flights reserved wholly by nonstandard weight groups, ***unless average weight have been established for those groups.*** This includes athletic squads and other groups which are larger or smaller than the U.S. average; for compliance purposes, actual weights can be verbally solicited and 10 pounds per passenger added to allow for hand baggage, clothing variables, etc.

[NONSTANDARD PASSENGER WEIGHTS--MILITARY GROUPS

Noncombat-Equipped Military Personnel .....195 pounds

Note: This weight includes 20 pounds of hand-carried baggage.

Combat-Equipped Military Personnel.....225 pounds

Note: This represents the standard combat soldier as would be seen on contract flights involving large movements. This includes 195 pounds as shown above, 20 pounds for additional hand-carried mobility pack, and additional 10 pounds for hand-carried weapons.

b. Actual Passenger Weights. Actual passenger weights should be used in the case of flights carrying large groups of passengers whose average weight obviously does not conform to the normal standard weight, such as athletic squads or other groups which are smaller or larger than the U.S. average.]

Where [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. In such instances, a notation should be made in the load manifest indicating the number of persons in the special group and identifying the group; i.e., football squad, etc. [Actual weights should be used for aircraft with small passenger capacities in which deviations from average weights could result in exceeding weight and balance limits. For example, there are numerous commuter type aircraft with a nine or less seating configuration that cannot carry full fuel and passenger loads simultaneously. These aircraft should use actual weights for their passengers and baggage.]

b[c]. *Determination of Actual Passenger Weight*. *Actual passenger weights may* [Actual passenger weight may] be determined by:

(1) Scale weighing of each passenger prior to boarding the aircraft, including *hand bags* [minor articles] carried *on* [a]board by the passenger*; or*[.]

(2) Asking each passenger his/her weight and adding to it a predetermined constant to provide for hand *baggage* [-carried articles] and [also to cover possible seasonal effect upon passenger weight due to variance in] clothing[weight]. This constant may be approved for an operator on the basis of studies by the operator that consider particular routes and seasonal variations, when applicable. Personnel listing passengers on this basis should receive instruction for estimating passenger weights to reasonably confirm their accuracy.

c. *Nonstandard Average Passenger Weights - Military Groups*. *In lieu of actual weights (preferred), the following average weights may be used for military groups:*

Noncombat-Equipped Military Personnel.....195 pounds

Note: This weight includes 20 pounds of hand-carried baggage.

Combat-Equipped Military Personnel.....225 pounds

Note: This represents the standard combat soldier as would be seen on contract flights involving large movements. This includes 195 pounds as shown above, 20 pounds for additional hand-carried mobility pack, and additional 10 pounds for hand-carried weapons.

12[11]. CREW WEIGHT. For crewmembers, the following approved average weights may be used:

a. Male cabin attendants *180* [150] pounds; female cabin attendants 130 pounds*; or 140 pounds average for all flight attendants.*

b. Male flight crewmembers *180* [170] pounds; female flight crewmembers 130.

13[12]. PASSENGER AND CREW BAGGAGE *AND MAIL*. Procedures should be provided so that all baggage, including that carried aboard by the passengers, *and mail* is properly accounted for. If desired by the operator, a standard crew *baggage* weight may be used. *Mail bag and checked baggage average weights may be used as described below.* [The use of a]*A*ctual weights *should be used for* [is critical and required for FAR Part 135 reciprocating engine-powered] aircraft of nine or less passenger *seat*s. [The following average passenger baggage weights may be approved for use in turbine-powered aircraft:]

a. [For FAR Part 135 operations with turbine-powered aircraft and/or aircraft type certificated for 10 or more passenger seats, a]*A*n operator may establish average passenger baggage weights predicated on a study of actual baggage weights for the operations or routes involved that consider seasonal and other variables*; or it may use the following average weights for each piece of checked baggage.*

b. For [FAR Part 121] domestic operations:

(1) [For each piece of checked baggage, a]*A*n average of not less than *25*[23.5] pounds; and

[(2) For each passenger boarding the aircraft, an average of not less than 10 pounds is added for hand baggage whether or not such baggage is carried by the passenger.]

c. For *International (transoceanic)* [FAR Part 121] flag and supplemental operations:

(1) [For each piece of checked baggage, a]*A*n average of not less than *30*[26.5] pounds.

[(2) For each passenger boarding the aircraft, not less than 10 pounds is added for hand baggage whether or not such baggage is carried by the passenger.]

Note: Average passenger baggage weights should not be used in computing the weight and balance of charter flights and other special services involving the carriage of special groups.

d. For normal operations, all mail bag manifested weight should be used in determining the weights of mail bag shipments. Should it be necessary to separate (break bulk) a manifested shipment or should manifested weights not be available, average individual bag weights may be used provided the average has been determined and substantiated by recent surveys that comply with the survey and statistical requirements in Appendix A of this document.

14[13]. *MOVEMENT OF PASSENGERS AND CREWMEMBERS* [TRAVEL] DURING FLIGHT.

The operator should show that the procedures fully account for the extreme variation in CG travel during flight caused by all or any combination of the following variables:

a. The operator should compute the movement of passengers and cabin attendants from their normal position in the aircraft cabin to other areas such as the ***galley*** [lounge] or lavatory. If the capacity of such compartment is one, the movement of either one passenger or one cabin attendant, whichever most adversely affects the CG condition, should be considered. When the capacity of the lavatory or ***galley***[lounge] is two or more, the movement of that number of passengers or cabin attendants from positions evenly distributed throughout the aircraft may be used. Where seats are blocked off and the movement of passengers and/or cabin attendants is evenly distributed throughout, only the actual loaded section of the aircraft should be used. The extreme movements of the cabin attendants carrying out their assigned duties within the cabin should be considered. The various conditions should be combined in such a manner that the most adverse effect on the CG will be obtained and accounted for in the development of the loading schedule to assure the aircraft is loaded within the approved limits at all times during the ground and flight operations.

b. Landing Gear, ***Flaps, Slats and Thrust Reverser Extension and*** Retraction. Possible change in CG position due to ***the extension or retraction of*** landing gear, ***flaps, slats, thrust reverser or other translating equipment, as provided by the manufacturer,*** [retraction] should be investigated and results accounted for.

c. Fuel. The effect of the CG travel within the aircraft during flight, due to fuel used down to the required reserve fuel or to an acceptable minimum reserve fuel established by the operator, should be accounted for.

15[14]. RECORD. The weight and balance system should include methods by which the operator will maintain a complete, current, and continuous record of the weight and CG of each aircraft. Such records should reflect all alterations and changes affecting either the weight or balance of the aircraft and will include a [complete and] current equipment list. ***Operators should have the facility to update the equipment list as may be required for transfer or sublease of the aircraft.*** When fleet weights are used, pertinent computations should also be available in individual aircraft files.

16[15]. WEIGHT OF FLUIDS. The weight of all fluids used in the aircraft may be established on the basis of actual weight, a standard volume conversion, or a volume conversion utilizing appropriate temperature correction factors to accurately determine the weight by computation of the quantity of fluid aboard.

17[16]. CONTENT OF OPERATIONS SPECIFICATIONS PROCEDURES FOR AIRCRAFT WEIGHT AND BALANCE CONTROL. The operations specifications should contain the procedures (or make reference to the operator's approved weight and balance control program document) used to maintain control of weight and balance of all aircraft operated under the terms of the operating certificate which assures that the aircraft, under all operating conditions, is loaded within weight and CG limitations. This description should include a reference to the procedures used for determining weight of passengers/crew, weight of baggage, periodic aircraft weighing, type of loading devices, and identification of the aircraft concerned.

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APPENDIX A. PROCEDURES FOR CONDUCTING SURVEYS AND ESTABLISHING AVERAGE WEIGHTS

1. FOCUS

The methodology presented can be used to determine standard average weights for passengers, checked baggage, carry-on baggage, mail, other normal averaged items and male/female ratios in lieu of using those standard average values specified in the Advisory Circular.

1.0. DETERMINATION OF STANDARD AVERAGE WEIGHT VALUES FOR PASSENGERS, BAGGAGE, AND CARGO/MAIL

Operators must ensure that average weights used for passengers, baggage, and cargo/mail do not adversely affect operational safety. In lieu of using the standard average weight values contained in this Advisory Circular, average weights may be generated by use of a suitable statistical analysis.

Appendix A contains an acceptable methodology for conducting a statistical analysis and establishing suitable average weights.

Average weight values for adults should be based on a male/female ratio of 60/40. Use of a different ratio should be based on acceptable survey data. An acceptable methodology is shown in Appendix A.

For practical reasons passenger weight values may be rounded to the nearest whole number in pounds, and the checked bag weight may be rounded to the nearest 0.5 pounds.

1.1 SAMPLING METHOD

Averages should be determined by a random sample, i.e., every member of the group must have a chance of selection. The process may be determined by ticket selection with random selected numbers, flight selections, airport selections with consideration given to check point or gate/flights within those airports. The process used is dependent on the diversity of the carrier's operation. In addition, the random sample must be of a conventional airline population and should consider the type of operation, the market, and the frequency of flights on various routes. Significant variations in the weights should be taken into consideration. A survey plan should cover the weighing of at least 1500 of the items being sampled or as specified in paragraph 1.4, subparagraph A.1 of this document, whichever is larger.

A. Passenger Weights

1. Adults and Children. Adults may be defined as persons of an age of 12 or more years. They may be further classified as male or female. No differentiation of sex shall be made for children, who are defined as persons between the ages of 2 and 12.

2. Infants are defined as persons less than 2 years of age and usually represent a very small portion of the survey. Survey samples should include infant weights together with the accompanying adult.

3. Survey participants should be given the assurance that all data taken will remain confidential and that under no circumstance are they obligated to participate, although participation should be encouraged. All displays of weight figures shall be arranged so that they are only visible to authorized survey people.

4. Surveys should be conducted inside an airport location and at a site that will not inconvenience participants or other airline passengers.

5. Carry-on baggage should be accounted for as part of the total weight of the passenger. If desired, carry-on baggage may be weighed separately and added to the passenger weight.

6. Survey data should include, but not be limited to: sex, adult or child categorization, survey location, weight with carry-on, weight without carry-on, date conducted, and child carried.

B. Checked Baggage

1. The total of checked baggage and/or mail shall be determined by either the sum total of the actual weights of all the pieces or the actual total weights of the contents of the baggage containers they are in.

2. As an alternative, an approved standard average bag weight, specific to the individual carrier's operation, multiplied by the total count of the number of pieces, may be used. Those average weights may be determined as specified in this document.

3. Checked baggage averages specified in the Advisory Circular may be used in lieu of determining specific averages.

4. A form should be designed to include boarding point, destination, weight of bags or any other information pertinent to the final results. Consideration should be given to size and differences in items being sampled.

C. Mail

1. Mail weights may be as specified in the Advisory Circular, item 13, paragraph d.

2. Survey data should include boarding point, destination, weight of bags or any other information pertinent to the final results. Consideration should be given to size and differences in items being sampled.

1.2 SCALES

The weighing scales to be used for conducting weight surveys shall have a capacity of at least 400 lb. All weights should be displayed at a minimum interval of 1 lb and should be accurate to within ± ½ lb. The tolerance shall not exceed ± 1 lb for every 200 lbs of weight.

1.3 RECORDING OF WEIGHT VALUES

The recording of weight data may be done manually or automatically. All data should be retained for permanent records and as substantiation of data results.

1.4 EVALUATION OF DATA

The methodology described in the following subparagraph A should be used if the survey is being conducted to determine average weights. If the survey is being conducted to determine only male/female percentages, use the methodology in subparagraph B.

A. Calculation of Adult Average Weight

1. Sample size

For calculating the required sample size it is necessary to estimate the standard deviation based on standard deviations calculated for similar populations. It is common practice to compute the precision of a sample estimate for some specified degree of reliability. A reliability of 95% is commonly used, i.e., there is a 95% probability that the true value will fall within the specified confidence interval, around the estimated value. In order to keep the sample size at an economical level and to achieve an acceptable degree of accuracy it is necessary to use this value for calculating the standard passenger average.

Consequently, for the parameters of weight distribution three cases of mean and standard deviation have to be distinguished:

μ,σ = The true value of the average passenger weight and standard deviation which are unknown and which are to be estimated by weighing passenger samples.

μ^1,σ^1 = The initial estimates of the average passenger weight and standard deviation (values obtained from earlier survey samples).

$\bar{x},s$ = The estimates for the current true values of μ and σ calculated from the sample.

2. Formulas. The following formulas will be necessary in determining the correct results:

(a) FORMULA - Calculation of the sample size:

$$n \geq \frac{(1.96*\sigma^1*100)^2}{(e^1*\mu^1)^2}$$

where:

n = No. of passengers to be weighed (sample size),

e^1 = Allowed relative confidence range (accuracy) for the estimate of μ by x.

Note: The allowed relative confidence range specifies the accuracy to be achieved when estimating the true mean. For example, to estimate the true mean to within ± 1%, e^1 will be 1 in the above formula.

1.96 = Value from the Gaussian distribution for 95% significance level of the resulting confidence interval.

(b) FORMULA - Calculation of the arithmetic mean:

If the sample of passengers weighed is random, the arithmetic mean of the sample, $\bar{x}$, is an unbiased estimate of the true average weight μ of the population.

$$\bar{x} = \frac{\sum_{j=1}^{n} x_j}{n}$$

(c) FORMULA - Calculation of the standard deviation:

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

where $(x_j - \bar{x})$ is the deviation of the individual value from the sample mean.

(d) FORMULA - Calculation of the accuracy of the sample mean:

The accuracy (confidence range) which can be ascribed to the sample mean, as an indicator of the true mean, is a function of the standard deviation of the sample (which is why this had to be estimated initially by μ^1 and σ^1). It has to be checked after the sample has been evaluated and can be done using the following formula:

$$e = \frac{1.96 * s * 100}{\sqrt{n} * x} \ (\%).$$

e should not exceed:
1% for an adult average weight;
2% for an average male or female weight; or
4% for checked baggage and mail weights.

(e) FORMULA - Calculation of the confidence range of the sample mean:

This means that with 95% probability, the true average weight μ lies within the interval:

$$\bar{x} \pm \frac{1.96 * s}{\sqrt{n}}.$$

3. Example.

Adult Average Weight

The following example may be applied to any sample item. It shows the various steps required for establishing the sample size and evaluating the sample data. It is provided primarily as a guide for statistical computations. All weight figures used throughout the example are entirely fictitious.

a. Calculation of the required sample size

For calculating the required sample size, estimates of the standard (average) passenger weight and the standard deviation are needed. The initial estimates from an earlier survey may be used for this purpose. If such estimates are not available, a small representative sample of about 100 passengers should be weighed so that the required values can be calculated. However, the representative small sample cannot serve to be the total sample requirement. The following example assumes a 86-passenger sample.

n = 86.

Step 1: Estimated average passenger weight

j	x_j (lb)
1	176.1
2	150.1
3	171.1
4	164.2
5	119.2
6	137.2
7	196.8
8	239.6
.	.
.	.
.	.
.	.
85	139.3
86	166.2
Σ 86	13,385.4

$$\mu = \bar{x} = \frac{\Sigma x_j}{n} = \frac{13385.4}{86} = 155.616 \text{ lb.}$$

Step 2: Estimated standard deviation

$(x_j - \bar{x})$	$(x_j - \bar{x})^2$
+20.5	420.2
- 5.5	30.2
+16.1	259.2
+ 8.6	73.9
-36.4	1324.9
-18.5	342.2
+41.2	1697.4
+84.0	7056.0
.	.
.	.
.	.
.	.
-16.3	265.6
+10.6	112.4
	168559.3

$$\sigma^1 = \frac{\sqrt{\sum_{j=1}^{n}(x_j-\bar{x})^2}}{\sqrt{n-1}} = \frac{\sqrt{168,559.3}}{\sqrt{85}} = 44.53 \text{ lb.}$$

Step 3: The required number of passengers to be weighed should be such that the confidence range, e^1, does not exceed 1%.

$$n \geq \frac{(1.96*\sigma^1*100)^2}{(e^1*\mu^1)^2} = \frac{(1.96*44.53*100)^2}{(1*155.616)^2} = 3146$$

Result: At least 3,146 passengers have to be weighed to achieve the required accuracy. A plan for weighing this sample size of passengers should then be worked out.

b. <u>Determination of passenger average weight</u>

Step 1: After having collected the required number of passenger weight values, the average passenger weight can be calculated. For the purpose of this example, it has been assumed that 3,180 passengers were weighed. The sum of the individual weights amounts to 509,673.0 lbs.

$n = 3180.$

$\Sigma x_j = 509,673.0$ lbs.

$$\bar{x} = \frac{509,673.0}{3180} = 160.27 \text{ lbs.}$$

Step 2: Calculation of the standard deviation.

$\Sigma(x_j-\bar{x})^2 = 3,621,079.6$ (given)

$$s = \frac{\sqrt{\sum_{j=1}^{n}(x_j-\bar{x})^2}}{\sqrt{n-1}} = \frac{\sqrt{3,621,079.6}}{\sqrt{3179}} = 33.75 \text{ lb.}$$

Step 3: Calculation of the accuracy of the sample mean.

$$e = \frac{1.96*s*100}{\sqrt{n} * \bar{x}} (\%) = \frac{1.96*33.75*100}{\sqrt{3180} *160.27} = 0.73\%.$$

Step 4: Calculation of the confidence range of the sample mean.

$$\bar{x} \pm \frac{1.96*s}{\sqrt{n}} = \bar{x} \pm \frac{1.96*33.75}{\sqrt{3180}} = 160.27 \pm 1.2$$

The result of this calculation shows that there is a 95% probability of the actual mean for all passengers lying within the range of 159.07 to 161.47 lbs.

B. Calculation of Male/Female Ratio

The methodology described in this section should be used only if the purpose of the survey is to determine the percentage mix of male/females. Once determined, use the male and female weights from paragraph 10 of the Advisory Circular and the percentages found in the survey to calculate the standard average adult weight.

Let:

n_m = number of males in the sample

n_f = number of females in the sample

$n = n_m + n_f$ = total sample size

p_m = percentage of males

q_f = percentage of females

$p_m + q_f = 100$

$s_p = s_q$ = standard deviation of percentage

$\bar{x}_a$ = standard average adult weight

$\bar{x}_m$ = standard average male weight from para 10 of A/C

$\bar{x}_f$ = standard average female weight from para 10 of A/C

s_m = standard deviation of male weight

s_f = standard deviation of female weight

$s_{\bar{x}a}$ = standard error of average adult weight

1. FORMULAS - The following formulas should be used in determining the correct results:

   (a) FORMULA - Calculation of the percentage of male and female passengers and the standard deviation.

$$p_m = \frac{n_m}{n} * 100 \ (\%)$$

$$q_f = \frac{n_f}{n} * 100 \ (\%)$$

$$s_p = \frac{\sqrt{p_m * q_f}}{\sqrt{n-1}}$$

(b) FORMULA - Calculation of 95% confidence range for both male and female percentages.

$$p_m \pm 1.96 * s_p \ .$$

(c) FORMULA - Calculation of standard average adult weight using male and female weights from paragraph 10 in the Advisory Circular.

$$\bar{x}_a = \frac{\bar{x}_m * p_m}{100} + \frac{\bar{x}_f * p_f}{100} \ .$$

(d) FORMULA - Calculation of the standard deviation of the standard average adult weight.

$$s_{\bar{x}a} = \sqrt{(p_m^2 * \frac{s_m^2}{n_m}) + (q_f^2 * \frac{s_f^2}{n_f}) + (\bar{x}_m^2 * s_p^2) + (\bar{x}_f^2 * s_p^2)}$$

(e) FORMULA - Calculation of the accuracy of the standard average adult weight.

$$e = \frac{1.96 * s_{\bar{x}a}}{\bar{x}_a} * 100 \ (\%)$$

(f) FORMULA - Calculation of the 95% confidence range of the standard average adult weight.

$$\bar{x}_a \pm 1.96 * s_{\bar{x}a}$$

(g) FORMULA - Calculation of the sample size.

$$n = \frac{(\bar{x}_m^2 + \bar{x}_f^2) * p_m * q_f}{(\frac{e * \bar{x}_a}{1.96})^2 - (\frac{p_m^2 * s_m^2}{n_m} + \frac{q_f^2 * s_f^2}{n_f})}$$

Note: Data from the surveys yielding the averages in paragraph 10a of the Advisory Circular may be used to derive the sample size needed for update surveys. These values apply: $n_m = 1039$; $n_f = 640$; $\bar{x}_m = 195$; $\bar{x}_f = 155$;

$p_m = .612$; $q_f = .388$; $\bar{x}_a = 180$; $s_m = 35.1$ and $s_f = 34.8$.

Thus, for male/female averages, e = .02, and

$$n = \frac{((195)^2+(155)^2)*.612*.388}{\left(\frac{.02*180}{1.96}\right)^2 - \left(\frac{(.612)^2*(35.1)^2}{1039}\right) - \left(\frac{(.388)^2*(34.8)^2}{640}\right)}$$

$$= 5571.$$

This sample size can be used until the average weights in the Advisory Circular are updated with later survey data.

2. Example.

Male/Female Average

The following example may be applied to any sample. It shows the various steps required for evaluating the sample data. It is provided primarily as a guide for statistical computations. All weight figures used throughout the example are entirely fictitious.

Given: Sample of 5,600 passengers, 3400 male and 2200 female.

Step 1. Calculating the percentage of males and females.

$$p_m = \frac{n_m}{n} * 100\ (\%) = \frac{3400}{5600} * 100 = 60.7\%$$

$$q_f = 100.0 - 60.7 = 39.3\%.$$

Step 2. Calculation of the standard deviation. Note that the standard deviations for the percentage of men and women are equal.

$$s_p = \frac{\sqrt{p_m*q_f}}{\sqrt{n-1}} = \frac{\sqrt{60.7*39.3}}{\sqrt{5599}} = 0.65\%.$$

Step 3. Calculating the confidence range.

$$p_m \pm 1.96*s_p = 60.7 \pm 1.96*0.65 = 60.7\% \pm 1.28\%$$

This indicates that there is a 95% probability that the actual percentage of men is between 59.4% and 62.0%, and that the percentage of women is between 38.0% and 40.6%, i.e., 59.4/40.6 and 62.0/38.0.

Step 4. Calculation of the standard average adult weight. Use the standard average male and female weights shown in paragraph 10a of the Advisory Circular (assume Summer weights for this

example) and the percentages of men and women found in the survey. When doing this calculation, divide p_m and q_f by 100 to express them in decimal form.

$$\bar{x}_a = \frac{\bar{x}_m * p_m}{100} + \frac{\bar{x}_f * p_f}{100} = \frac{195*60.7}{100} + \frac{155*39.3}{100}$$

$$= 179 \text{ lbs.}$$

Step 5. Calculation of the standard deviation of the average adult weight. When doing this calculation, divide p_m, q_f and s_p by 100 to express them in decimal form.

$$s_{\bar{x}a} = \sqrt{(p_m^2 * \frac{s_m^2}{n_m}) + (q_f^2 * \frac{s_f^2}{n_f}) + (\bar{x}_{m2} * s_p^2) + (\bar{x}_{f2} * s_p^2)}$$

From the survey supporting the Advisory Circular averages: s_m = 35.1; n_m = 1039; s_f = 34.8; n_f = 640; $\bar{x}_m$ = 195; and $\bar{x}_f$ = 155. Thus,

$$s_{\bar{x}a} = \sqrt{((.607)^2 * \frac{(35.1)^2}{1039}) + ((.393)^2 * \frac{(34.8)^2}{640}) + (195*.0065)^2 + (155*.0065)^2}$$

$$= 1.83.$$

Step 6. Calculation of the accuracy of the standard average adult weight.

$$e = \frac{1.96 * s_{\bar{x}a}}{\bar{x}_a} * 100\ (\%) = \frac{1.96*1.83}{179} * 100\% = 2.0\%.$$

Step 7. Calculation of the confidence range of the standard average adult weight.

$$\bar{x}_a \pm 1.96 * s_{\bar{x}a} = 179 \pm 1.96*1.83 = 179 \pm 3.6 \text{ lbs.}$$

This indicates that there is a 95% probability that the actual standard average adult weight is between 175 and 183 lbs.