Australian Government
Civil Aviation Safety Authority

Airworthiness Bulletin

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Weighing Equipment

An Airworthiness Bulletin is an advisory document that alerts, educates and makes recommendations about airworthiness matters. Recommendations in this bulletin are not mandatory.

1. Effectivity

Weight Control Authority holders, maintenance personnel and others involved in activities related to aircraft weighing.

2. Purpose

To draw attention to the importance of using appropriately sized & calibrated weighing equipment when carrying out aircraft weighing procedures, and what conversion information should be referenced when converting between SI units and Non-SI Units

3. Background

The purpose of aircraft weighing is to determine the baseline empty weight and empty weight centre of gravity of Australian aircraft in accordance with the provisions of Civil Aviation Order (CAO) 100.7, with the resultant data published in a load data sheet for the accurate loading of aircraft during its operations.

If a weighing is required, personnel involved in the weighing activity of the aircraft should refer to the weighing equipment manufacturer's instructions for the selection of equipment to be used for the aircraft weighing.

In the absence of manufacturers' instructions, publications referenced below are a source of good practices for selecting suitable weighing equipment.

Alternatively, industry personnel may refer to the general recommendations further in the text.

This AWB should also be read in conjunction with AWB 00-023 Issue 1 – 'Weighing Preparations'.

4. Recommendations

4.1 Weighing Equipment Selection:

Industry quote;

'When selecting a scale system it is very important to remember to select a scale that is first and foremost, the correct type, the correct size, and has the correct weight range for the application.'

Consult the aircraft manufacturer's manual for the weighing equipment selection.

The aircraft manufacturer may include the jack point locations and wheel center locations in their manuals, but they may not specify a particular scale or type to be for the aircraft weighing so it will be up to the weight control officer to decide which type of scale to use.

Equipment selection should start with the weight range needed and if the weighing will be performed using either a jack point or if the aircraft's landing gear will be used then the wheel size must be considered for use of either load cell units or weighing platform scales.

Note 1: All weighing equipment must have a capacity suitable for the size of the aircraft.

Note 2: Follow the weighing equipment manufacturer's operating instructions.

4.2 Weight Range, Accuracy, Resolution and Class – Sizing the Scale to the Job;

Industry quotes;

'Scales are like torque wrenches and you would not use a 100 foot-pound torque wrench to torque a 20 inch-pound nut. Why then would you use a 150,000-pound scale system to weigh a light GA aircraft, turboprop, or helicopter?'

'I am aware that modern equipment is reasonably accurate, but if you talk to the Calibration organizations, they will think it is unrealistic to expect accuracy at such low weights with big cells.'

'…it appears that many think that if a scale is calibrated it will be ok to use. For example, using an Intercomp AC45 platform scale that is rated at 45,000 pounds to weigh the tailwheel on a small aircraft that would be rated about 80 pounds. Or using a Revere Loadcell rated at 50,000 pounds to weigh a small helicopter at 250 pounds'.

4.2.1 Weighing Scale Capacity verses Operating Range;

CASA publication "Weight Control of Aircraft" says;

'…three scales with a 2,000kg capacity each would be required for an aircraft with an empty weight of approximately 4,000kg, while an electronic weighing kit with cells of 30,000kg capacity would be needed for a 60,000kg empty weight aircraft.'

Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems says that a weighing scale capacity is the maximum force which the scale is designed to measure.

The operating range of a weighing scale is the range of forces that the scale can measure for any chosen settings within the scale's capacity. The scales are often more accurate at the middle of the range and less accurate at the high and low ends of the range, See 4.3 below.

Determining the operating range of a weighing scale depends several factors; the resolution of the indicated force and the intended use as determined by the calibration authority and the weight control officer.

4.2.2 Accuracy;

Accuracy is the closeness of agreement between a measured value and an accepted standard.

CAO 100.7 Para 4 Weighing Procedure 4.2 states;

> 'Aircraft must be weighed on scales that:
>
> (a) have an accuracy over the temperature range for which the scales are designed of:
>
> (i) 0.2% of the applied load; or
>
> (ii) 2 kg; whichever is the greater; and
>
> (b) are of a type approved for the purpose by an airworthiness officer.'

When selecting scales used for weighing, a weight control officer needs to be aware that when using large scales for weighing small aircraft, accuracy and resolution requirements must be carefully considered to ensure regulatory compliance. An accurate aircraft weight will ensure the allowable weight alteration margin is valid and ensure that a required re-weigh is triggered at an appropriate point in the aircrafts maintenance.

This is important for small aircraft where the allowable weight margin for repairs and modifications can be less than 10lbs before a re-weigh will be required.

To ensure a scale's resolution value is not close to or beyond the re-weigh weight requirements the CASA publication "Weight Control of Aircraft" provides insight when considering weight alterations, re-weigh of the aircraft is required when;

'for aeroplanes;

(i) the empty weight has changed by more than one half of one percent of the maximum take-off weight, or

(ii) the empty weight centre of gravity position has changed by more than one half of one percent of the mean aerodynamic cord

'for rotorcraft;

(iii) the empty weight has changed by more than one percent of the maximum take-off weight, or

(iv) the empty weight centre of gravity position has changed by more than 10mm or 10 percent of the maximum permissible centre of gravity range whichever is less.'

Industry quote;

'As a general rule scales less than 10,000-pound capacity will measure in a 1-pound count and scales over that and up to 25,000 pounds will count in a 2-pound count.

Large jet 50,000-pound scales will measure in a 5-pound count and so on.'

4.2.3 Determining Resolution from the Scale Interval;

Aircraft manufacturers may specify weighing equipment with a required scale interval (graduation division or count).

Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems explain resolution as;

'The smallest value which can be estimated with assurance from the scale.'

Where no aircraft manufacturer's specification is given, Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems recommends the following;

i. Analog Indicator: The resolution is obtained from the ratio of the width of the pointer and the center-to-center distance between the two adjacent scale interval marks using either 1/2 or 1/5 ratios where a minimum spacing of 1.25mm or greater is required for the estimation of the1/5 division on the scale.

ii. Digital Display: One count of the digital display.

4.2.4 Classification;

Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems weighing scales are classified by three properties;

i. Resolution

ii. Repeatability of the indicated force; and

iii. Mean error of the indicated force. (Assessed as the mean of three percentage error readings).

Typically weighing equipment scales are calibrated using test weights/force equipment of Class B or better per the requirements of the Standard.

4.3 Weighing Equipment Calibration, and using the Calibration Information for Scale Adjustment across a Given Range;

4.3.1 Calibration;

Each scale unit used to weigh an aircraft must comply with the accuracy and repeatability standards of CAO 100.7.

4.3.2 Time Interval Between Recalibration;

The scale unit must have been calibrated within one year prior to the weighing of an aircraft. This is achieved by using a State Weights and Measures Authority, a National Association of Testing Authorities, Australia (NATA) accredited calibration authority, an accredited testing facility approved by a CASR (1998) 21.010, a national aviation authority of a recognized country or by returning the unit directly to the scale unit manufacturer for calibration.

Use of an accredited testing facility will ensure traceability of certifications and of the test equipment used for the calibration of the weighing equipment.

4.3.3 Extending the Time Interval Between Recalibration;

An owner may apply for the granting of a standard exemption under CASR (1998) Division 11.F.1 against the one-year re-calibration interval requirement of CAO 100.7.

Under CASR Division 11.F.1, CASA may issue an instrument that will grant an exemption against the one-year re-calibration interval requirement of CAO 100.7 up to a maximum re-calibration interval of three years.

If the owner of the weighing scales would like a recalibration interval greater than one year, then they will need to demonstrate that the scale reliability and drift of a scale reading over a time period greater than that requested, has not changed.

In line with Australian Government policy, CASA is required to recover costs for providing regulatory services to the aviation industry in accordance with Civil Aviation (Fees) Regulation 1995 Schedule 1 Part 23 Exemptions.

An owner will need to consider whether it is cost effective to apply for an exemption to approve an increase in the time interval between recalibration for a set of scale units or to continue to re-calibrate each scale unit at the 1-year re-calibration interval requirement of CAO 100.7.

Industry quote;

‘Mechanical or analogue meter scales have mostly been replaced with the new wireless systems and or digital indicators. These systems and indicators are very accurate and easy to use, making the weighing job faster to accomplish and providing higher quality in readings.’

4.3.4 Confirming Accuracy of a Weighing Scale Using the Calibration Certificate;

A weighing scale may show a rated capacity that may be greater than the calibrated scale range or that the scale may not meet accuracy requirements within a calibrated range.

Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems says that when determining the calibration range during the calibration of an aircraft weighing scale, for the given class of the unit the calibration range depends on the resolution of the indicated force and the intended use determined by the calibration authority and the weight control officer.

Note 3: Weight control officers are reminded to check each weighing scale calibration report to determine the scale's range is what is needed for the job and if the scale will meet the accuracy requirements.

Calibration report information can be used to confirm a weighing scale is reading within the accuracy requirements of CAO 100.7 Para 4 Weighing Procedure 4.2 across its calibration range to ensure accuracy confidence.

A typical calibration report in SI units for a weighing scale will show the percentage mean error and the uncertainty measured in +/- kgf for each applied force in kgf used in the calibration process across the scale's calibration range.

Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems defines uncertainty as an interval about the result of the measurement within which the value of the measurement may be expected to lie with a specified level of confidence set by the test weight's own classification used to do the weighing scale's calibration.

If a weighing scale has been calibrated in accordance with Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and Classification of Force-measuring Systems typically it will achieve a 95% confidence level in the calibration with a Kfactor =2 for the class of scale.

Note 4: A calibration report requires both a percentage mean error and uncertainty figure to be given for each recorded applied force within the annotated range of the weighing scale.

<u>How to Use a Calibration Report to Confirm a Scales Accuracy – Step by Step</u>

<u>Step 1;</u> Calculate ±0.2% of the weighing scale reading and add these figures to the scale reading to determine the minimum and maximum weight accuracy range.

<u>Step 2;</u> Add ±2 kg to the weighing scale reading to determine the minimum and maximum weight accuracy range.

<u>Step 3;</u> Compare the Step 1 and Step 2 minimum and maximum weight accuracy ranges to determine the greater of the two minimum and maximum weight accuracy ranges.

Step 4; From the calibration report locate the applied load that is lower than the weighing scale reading and record the +/- percentage mean error figure and the +/- uncertainty figure for that applied load.

Step 5; Calculate the percentage mean error determined in Step 4 of the weighing scale reading and add these figures to the scale reading to determine the percentage mean error minimum and maximum weight range.

Step 6; Add the uncertainty figures determined in Step 4 to the weighing scale reading to determine the uncertainty minimum and maximum weight range.

Step 7; Compare the Step 5 and Step 6 minimum and maximum weight ranges and determine the greater values.

Step 8; Compare the Step 3 and Step 7 values and ensure the Step 7 values fall within the Step 3 minimum and maximum weight accuracy range to satisfy that the scale reading is within the CAO 100.7 Para 4 Weighing Procedure 4.2 accuracy requirements.

Industry quote;

'Accuracy is usually dominated by the indicator resolution at the low end of the scale, so the uncertainty force of the lower applied load from the calibration report is used to ensure accuracy is less than the +/- 2kg to establish the suitability at that weight. At the higher end of the scale, use of the percentage mean error of the applied load from the calibration report is used to ensure accuracy is within 0.2% of the scale reading load to establish the suitability of the scale for the task for that weight.'

4.4 Conversion of SI Units to Non-SI Units;

Weight control officers are reminded to ensure when carrying out conversion of SI units to non-SI units that;

Use of aircraft manufacturer conversion tables are to be referenced if available in the aircraft maintenance manual (preferred).

- Or -

Alternately, when an aircraft manufacturer does not provide conversion information use of Australian/New Zealand Standard AS/NZ 1376-1996 Conversion Factors is acceptable.

4.5 Significant Figures When Carrying out Weighing;

Care should be taken to ensure when performing weighing calculations particularly when doing conversions between SI and non-SI units that conversion factors may have a higher number of significant figures which may require rounding to the same number of significant figures as the weighing scale equipment resolution to maintain unit consistency for weight and balance/loading system reports presented in both SI units and non-SI units.

Australian/New Zealand Standard AS/NZ 2706-2003 Numerical values - Rounding and Interpretation of Limiting Values provides background to rounding to an appropriate number of significant figures.

4.6 Scale Units Sizing for Jacking Point and Wheel Size

4.6.1 Load Cell Units;

Small to medium aircraft may require use of a small load cell unit with a 1-inch cup size due to the aircraft's small sized jack point. Use of a larger cup size load cell could potentially result in damage to the surrounding jack point structure for small size aircraft.

Larger load cell units will be required for use on larger aircraft weight ranges and larger jack points that use a larger diameter jack point.

The decision point for cell and cup size will be at the medium to large jet selection; regional jet aircraft and large corporate aircraft are usually the aircraft type at which a large cell scale unit kit will have to be used due to their larger diameter jack points.

Industry quote;

"We have often seen a small 50,000-pound cell being used for larger aircraft. In many cases this may have the weight capacity but not the retention and proper fit for the jack point."

Points to consider when using any load cell unit for aircraft weighing;

- The jack points must fit into the load cell unit's concave top and each cell may need to be retained.
- Center the jacks with load cells installed under the jack point so that proper alignment is made between the load cells and the jack point.
- Care is required in placement to prevent side loads, and it is imperative to remove all load cell misalignment due to uneven hanger floors or aircraft structural deflection to prevent the load cell from toppling off the jack during jacking.
- Safety must be paramount when raising or lowering an aircraft during the weighing procedure. Ensure the aircraft is clear of stands, docking and scaffolding.

Figure 1. Airplane on jacks with load cell units in use

Photo Source: 6-20.png (906×1000) (bp.blogspot.com)

4.6.2 Platform Scale Units:

For platforms scale units, consideration should be made to using a platform scale unit that has sufficient space to accommodate the aircraft wheel size and that the correct quantity of platforms for the number of wheels on the aircraft are used.

Care must be taken to prevent movement while the aircraft is positioned on the weighing platforms during weighing procedure.

Appropriate towing equipment used for positioning the aircraft on the weighing platforms and suitable ramps that allow the aircraft to be positioned on each weighing platform are also important points to consider.

Figure 2. A Cessna 182 being weighed with electronic platform scales

Photo Source: 6-18.png (1000×620) (bp.blogspot.com)

4.7 Weighing Equipment Storage

Weight control officers are reminded to follow the weighing equipment manufacturer recommendations when storing weighing equipment.

Load cells and scales are calibrated instruments and should not be stacked on top of each other or have other items stored on them whilst not in use which may throw out the calibration before the calibration period is reached.

5. References

1. AWB 00-023 Issue 1 – 'Weighing Preparations'.
2. CASA publication "Weight Control of Aircraft" Department of Transport 1975. http://www.casa.gov.au/wcmswr/_assets/main/download/orders/cao100/weight_control.pdf
3. FAA Aviation Maintenance Technician Handbook – General; Chapter 4: Aircraft Weight and Balance (FAA-H-8083-30). http://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/amt_handbook/
4. FAA Aircraft Weight and Balance Handbook (FAA-H-8083-1B). https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/FAA-H-8083-1.pdf
5. Australian/New Zealand Standard AS/NZ 1376-1996 Conversion Factors.
6. Australian/New Zealand Standard AS/NZ 2193-2005 Calibration and classification of force-measuring systems.
7. Australian/New Zealand Standard AS/NZ 2706-2003 Numerical values - Rounding and interpretation of limiting values.

8. Enquiries

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