Australian Government
Civil Aviation Safety Authority

Advisory Circular

AC 21-35(1.1) AUGUST 2015

CALIBRATION OF INSPECTION AND TEST EQUIPMENT

CONTENTS

1. REFERENCES

- AS/NZS ISO 10012:2004 Quality assurance requirements for measuring equipment-Metrological confirmation system for measuring equipment
- AS/NZS IEC 60300.1:2015 Dependability management – Guidance for management and application
- ISO/IEC Guide 99 (2007) International vocabulary of metrology – Basic and general concepts and associated terms (VIM)
- ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories
- NATA Accreditation http://www.nata.com.au/accreditation
- National Measurement Act 1960
- National Measurement Regulations 1999
- Part 21 of CASR 1998, Certification and Airworthiness Requirements for Aircraft and Parts
- Part 145 of CASR 1998, Continuing airworthiness – Part 145 approved maintenance organisations and its Manual of Standards
- Regulation 30 of CAR 1988 – Certificates of Approval
- SAA HB86.1:1996 The Selection Care Calibration and Checking of Measuring Instruments in Industry

Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Where an AC is referred to in a 'Note' below the regulation, the AC remains as guidance material.
ACs should always be read in conjunction with the referenced regulations.

This AC has been approved for release by the Executive Manager, Standards Division.

2. PURPOSE

2.1 This Advisory Circular (AC) provides one method of providing control and calibration requirements for tools and test equipment. The method satisfies the *Civil Aviation Regulations 1988* (CAR 1988) and the *Civil Aviation Safety Regulations 1998* (CASR 1998) calibration requirements for aircraft/aeronautical product manufacture and maintenance.

2.2 This AC applies to those responsible for the calibration of equipment used for measuring and testing of aircraft and aeronautical products:

- manufactured under Part 21 of CASR 1998;
- maintained by Part 145 of CASR 1998 approval certificate holders;
- maintained by Regulation 30 of CAR 1988 certificate of approval holders; and
- maintained by independent Licensed Aircraft Maintenance Engineers (LAME) and LAME/pilots carrying out Schedule 8 of CAR 1988.

2.3 Companies involved in the manufacture and maintenance of aircraft and aeronautical products have an obligation to exercise due care and diligence in ensuring the quality of the services and products they provide. Demonstrating the fitness of purpose of test equipment used is part of this due diligence.

3. STATUS OF THIS ADVISORY CIRCULAR

This is the second issue of this AC. It has been updated to incorporate information previously published in Civil Aviation Advisory Publication 30-2 (now cancelled) and in response to the introduction of Part 145 of CASR 1998. Changes to this AC are shown with shading.

4. ACRONYMS

AC Advisory Circular

AMO Approved Maintenance Organisation

AS Australian Standard

CASA Civil Aviation Safety Authority

CASR Civil Aviation Safety Regulations 1998

CAR Civil Aviation Regulations 1988

CIPM Comité International des Points et Measures

CMC Calibration and Measurement Capability

IEC International Electromechanical Commission

ILAC International Laboratory Accreditation Cooperation

ISO International Organisation for Standardization

LAME Licensed Aircraft Maintenance Engineers

MRA Mutual Recognition Arrangement

MOS Manual of Standards

NATA National Association of Testing Authorities (Australia)

NDT Non-Destructive Testing

SAA Designator preceding an Australian Standard

5. REGULATORY REQUIREMENTS

5.1 Manufacturing. Paragraph 21.125 (2) (e) of CASR 1998 - Production Inspection Systems: Materials Review Board requires that the production inspection system must provide for inspection of items for conformity to the type design data. Paragraph 21.144 (d) of CASR 1998 - Production Inspection Systems requires that the production system make accurate determinations that products conform to the design data. Paragraph 21.303 (11) (e) of CASR 1998 – Replacement and Modification Parts – requires the fabrication inspection system provide for the inspection of parts in process for conformity with the design data.

5.2 Maintenance under Part 145. Paragraph 145.A.40 (b) of the Part 145 Manual of Standards requires the Approved Maintenance Organisation (AMO) to ensure that all tools, equipment and test equipment that requires calibration to be controlled and calibrated at a periodicity to ensure serviceability and accuracy in accordance with:

- the tool or equipment manufacturers recommendations;
- a nationally recognised standard; and/or
- the procedures set out in the AMOs exposition.

5.3 Maintenance under Regulation 30 of CAR 1988. Regulation 30 requires a person, who is a certificate of approval holder engaged in maintenance of aircraft, aircraft components or aircraft materials, to have a system of quality control containing the maintenance, control and calibration of equipment.

5.4 The preceding regulatory requirements require tools and test equipment, where used, to be correctly calibrated in order to have evidence of measurement traceability.

6. WHY CALIBRATION IS PERFORMED

6.1 Calibration is an operation that in the first step, establishes a measured relationship between the item being calibrated and a measurement standard, and, in a second step determines the possible errors in measurement between the item being calibrated and said measurement standard. The calibration operation ensures the inspection, measuring and test equipment used to manufacture and maintain aircraft and aeronautical products are fit for purpose within defined acceptable error or accuracy limits.

6.2 Calibration tolerance limits are often established by the manufacturers of the tools and test equipment or by the aircraft manufacturers. The required outcome is the maintenance of the equipment within the defined accuracy of the manufacturers design tolerances and specifications.

6.3 For test results to be reliable and provide a high level of confidence in the result, they must be derived from equipment that has been suitably calibrated for their intended use. When preparing a calibration schedule or procedure for test equipment the following measures require incorporation:

- evidence of measurement traceability to a suitable measurement reference or standard;
- the equipment has been calibrated across the range of measurement for which it is to be used;
- a suitable interval between calibrations has been determined based on stability of the test equipment or manufacturers recommendations;
- procedures for test equipment maintenances and verification of the calibration methods; and
- records maintained.

7. CALIBRATION POLICIES

Metrological Traceability

7.1 Metrological *(or measurement)* traceability is the property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty (ISO/IEC Guide 99 (2007) – 2.41). The ultimate goal of each calibration activity is to provide evidence of measurement traceability to an acceptable measurement or reference standard.

7.2 A suitable measurement or reference standard is an artefact or working standard held by the National Measurement Institute of Australia or a similar national measurement institute that is a signatory of the Comité International des Poinds et Mesures (CIPM) Mutual Recognition Arrangement (MRA).

7.3 The evidence is in the form of a calibration report directly from one of the national measurement institutes identified above, or a calibration report that will support evidence of an unbroken chain of calibrations back to a measurement or reference standard including a determination of the accumulation of measurement errors or measurement uncertainty for each step of the chain.

Note: Calibration reports that include the National Association of Testing Authorities (Australia) (NATA) endorsement or a similar national accreditation body that is a member of the International Laboratory Accreditation Cooperation (ILAC) MRA will provide this evidence.

7.4 In certain circumstances evidence of traceability back to a national measurement institute cannot be provided. In these cases calibration shall provide confidence in measurements by establishing traceability to appropriate measurement standards such as the use of:

- certified reference material provided by a competent supplier to give a reliable physical or chemical characterisation of a material; or
- specified methods and/or consensus standards that are clearly described and agreed by all parties concerned.

7.5 If evidence of measurement traceability cannot be supported, the assurance and confidence in the test equipment will be unknown. This affects how results obtained today can be compared to results obtained in the future for validity. Furthermore, the user of the tool or test equipment may not be able to demonstrate and prove the suitability of their equipment.

7.6 Traceability is necessary both to ensure that all measurements are derived from and consistent with Australian Primary Standards as well as meeting the legal requirements of section 10 of the *National Measurement Act 1960*. Regular calibration ensures accuracy is maintained to a standard traceable to the Australian National Standards, or to equivalent International Standards.

Note: The National Measurement Regulations 1999 contain schedules listing the maximum permissible variations and maximum permissible uncertainties that are required for various reference standards and measuring instruments.

Calibration, Checking and Adjustment

7.7 Test equipment may be used across a range of measurements such as a thermometer which is used from -50 to 100^{o}C or at only one measurement point such as a torque wrench which is only used at 50 Nm. When determining calibration requirements for test equipment, care must be taken to ensure the measurements performed during the calibration cover the entire range for which the item is used, or designed to be used. In addition a suitable number of measurements in between need to be considered in order to confirm the item being calibrated still meets the required specifications, accuracy, linearity and ultimately is still fit for purpose.

Notes:

1. *Partial calibration of test equipment is acceptable as long as the ranges that are calibrated are clearly identified in accordance with SAA HB86.1:1996. Partial calibration is only possible if the equipment design is not dependent on full calibration to function correctly.*
2. *The reference or transfer standard should be 3 to 10 times more accurate than the instrument being tested. See ISO 10012:2004.*

7.8 A *'Check'* is a measurement of at least one point in a range of a measuring instrument or material against a known value to confirm that it has not deviated significantly from its original calibrated value. It is also an examination of the condition of an item to determine that it has not been adversely affected by constant use. By performing a check on an instrument, a facility is able to determine if the instrument has changed since its last calibration. By performing regular checks, the interval between periodic calibrations may be extended. Alternatively, in some applications, where an instrument is used for comparative results and it has been determined that measurement traceability is not required, a check of the instrument's measurement functionality may be deemed acceptable.

7.9 An *'Adjustment'* is to change the sensitivity of the test equipment against a known reference. Some items of equipment such as sound level meters are designed to have a level adjustment before each use by applying a known source to the input of the instrument. Other items such as modern electronic weighing devices (balances) routinely perform an internal adjustment (self-testing) against an internal mass when first switched on. Although sometimes called a 'calibration' or 'internal calibration' by the manufacturer, it is a single point level adjustment and is not to be confused with a full calibration which provides measurement traceability across the instrument's full measurement range. Auto zeroing, such as that performed on electronic balances, only compensates for short term drift and still requires a regular calibration check.

Calibration Intervals

7.10 Recalibration intervals should be appropriate to the accuracy of the measurement to be performed and the stability of the equipment as guaranteed by the manufacturer. The calibration periods should be such that any tool or instrument is measured at regular intervals to ensure that it conforms to manufacturer's accuracy standards.

7.11 The periodicity of calibration for test equipment must be determined and recorded as reported by the test equipment manufacturer or in the absence of such information in response to an evaluation based on its intended use. Calibration of equipment should be performed at certain key junctures of overall equipment life:

- initial purchase;
- after repair;

- periodic recalibration; and
- when accuracy is in doubt.

7.12 Where an equipment manufacturer does not specify a calibration interval then an initial maximum interval of twelve months should be applied prior to further adjustment. Once this initial period has elapsed the calibration interval may be adjusted giving consideration to the following:

- quality of the tool;
- history of stability;
- frequency of internal checks;
- operating environment (usage level, where used, storage etc.);
- interval for other similar equipment; and
- the accuracy of measurement required.

Note: An equipment table providing guidance on recommended calibration intervals as found on the NATA website may be used to assess calibration intervals of some equipment.

7.13 Where a tool is marked 'Calibrate Before Use' the transfer standard against which that tool is measured or adjusted against prior to use should have a log book where each 'calibration' prior to use is recorded. This activity ensures that there is an auditable trail relating to the use of that tool. The policy regarding the use of such tools and 'masters' should be highlighted within the appropriate section the Policy and Procedures Manual (or equivalent document).

7.14 There will be some tools and equipment that aren't subjected to periodic calibration as no test data is required/recorded. For example, for null indication, waveform monitoring, continuity checking, troubleshooting or the determination or assessing the feasibility of repairing versus scrapping an item etc. Such equipment must be clearly identified as 'UNCALIBRATED', 'NO CALIBRATION REQUIRED' or 'UNCONTROLLED' or similar. Equipment so identified cannot be utilised for conformance acceptance or during return to service or heading directly to a return to service.

7.15 Personal equipment must be appropriately marked whether it is calibrated or not. Where the maintenance or production organisation elects to control the calibration of personal tools and test equipment then details of the process must be included in the calibration procedures. Where the maintenance organisation elects not to control this equipment then all such equipment must be suitably marked.

7.16 There may be some instances where the aircraft or equipment manufacturer specifies more stringent calibration requirements for a particular piece of test equipment than the test equipment manufacturer requires. This additional requirement must be considered when setting calibration intervals.

Procedures

7.17 Procedures or measurement methods used for the calibration of equipment should, in the first instance, be those as recommended by the manufacturer of the test equipment or the holder of the production type certificate. Procedures are normally derived from national or international standards and are developed by an engineer in a related field and trained in metrology procedures. Some important aspects that have been considered in developing a procedure are:

- the sensitivity, hysteresis and linearity of the item being calibrated across the range of measurement (simple pass/fail criteria may be insufficient for equipment used across a range of values);

- the item being calibrated does not excessively load the observed measurement;
- the accuracy of the reference including the uncertainty of measurement attributed to the reference is adequate for the accuracy of the item being calibrated;
- inherent drift in sensitivity is observed and recorded;
- inherent stability of the item being calibrated;
- various influence variables in its work environment have negligible effect or are controlled and considered in the accumulated errors;
- an estimation of the accumulated errors attributed to the calibration method through a calculation of the measurement uncertainty (calculation of the measurement uncertainty is a critical component in providing evidence of measurement traceability as stated in section 7.1 above); and
- the appropriate recalibration interval – with justification that would enable accurate and repeatable results.

7.18 Procedures for the maintenance, control and calibration requirements of equipment need to include the way in which uncalibrated tools and equipment are identified. Uncalibrated tools and equipment cannot be used for a task requiring test data to be recorded or to establish return to service of aircraft or aircraft components.

7.19 The procedures when followed need to ensure that equipment used to certify aircraft and aeronautical products is labelled and tracked for calibration purposes. Compliance with equipment manufacturers test and calibration methods and periods is a suitable method of demonstrating accuracy provisions for calibration purposes and such details should be listed or cross referred within the procedures. Environmental factors (storage and usage) should be considered by the procedures.

Note: AS/NZS ISO 10012:2004 - Quality assurance requirements for measuring equipment - Metrological confirmation system for measuring equipment - provides information on methods to ensure that measurements are made with the intended accuracy.

7.20 The test equipment maintenance procedures should contain (as a minimum) the following:

- a list of all test equipment that require calibration;
- a list of calibration service providers, per equipment;
- a method of tracking when calibration is due and a notification procedure;
- a method of retention of calibration reports current and historic;
- a process to control publications issued to calibration service providers;
- the audit requirements and processes for calibration service providers;
- a process for control of personal equipment that the company takes responsibility for, including a list of equipment and serial numbers;
- procedures for a calibration interval variation (if used);
- procedures for out of tolerance actions; and
- details of any contract for total tool calibration management.

Out of Tolerance Actions

7.21 Out of tolerance actions are required when a piece of test equipment is found to be out of tolerance. This may occur as a result of a pre-calibration check or if there is a suspicion of an out of tolerance situation when crosschecking a suspect result.

7.22 Such an out of tolerance finding results in a degree of uncertainty that all components or aircraft systems etc. whose determination of being either serviceable or conforming was dependent upon that test equipment were actually within tolerance. If test equipment is found to be out of specification then all measurements made since the last calibration are potentially suspect.

7.23 The maintenance or production organisation should have procedures to deal with out of tolerance findings. These procedures include:

- a risk assessment of the affect of the out of tolerance finding;
- the procedures used to assess the risk;
- an audit trail to determine what equipment, systems etc. the tool was used in determining the return to service criteria (hence a good practice would be to detail test equipment used as part of a work package);
- procedures for any recall that may be determined necessary; and
- documentation to support the above process.

Record Keeping

7.24 Calibration records need to provide a tool and test equipment history that is free of missing service actions. If missing service actions are present, they should be detectable. The record for an item should include the following information as a minimum:

- identification of the item serviced;
- identification of the customer or owner of the item being calibrated
- any special usage classification or designation;
- date of service;
- condition received prior to adjustment or other corrective service;
- service action taken;
- condition released; and
- condition received into calibration facility (pre-calibration check).

7.25 All calibration results and work performed on equipment, including adjustments and alignment, should be recorded on the equipment history record and calibration certificate. As a minimum, the equipment should be labelled with the date the calibration was performed, when recalibration is due, who performed the calibration and a calibration report number.

8. WHO MAY CALIBRATE

8.1 Calibration encompasses visual assessments coupled with experience and professional judgement, together with suitable training; therefore care should be taken in selecting who may perform the calibration. Calibrations can be performed by contracting the work to an external laboratory or performed by in-house calibration.

8.2 External Laboratory. If calibration is to be performed by an accredited calibration organisation then CASA accepts the NATA or ILAC partners' accreditation at face value. As long as the accreditation remains current and covers the type of calibration being sought (described as a competence); then that person or organisation must have already demonstrated their technical competence in relation to the calibrations they perform. No further checks by the AMO or aircraft manufacturer need to be made as the accreditation can be relied on.

8.3 External In-House Calibration Provider. If calibration services are being contracted from a calibration service provider, that cannot demonstrate accreditation by NATA or ILAC partners, then each aircraft AMO or manufacturing organisation contracting the service is required to confirm that the calibration provider has the competence to provide the calibration service being sought. Appendix A of this AC provides guidance on what needs to be confirmed when determining the technical competence of an external in-house calibration service provider (with re-confirmation suggested at a periodicity of two years).

8.4 In-House Calibration. CAR 30 and 145 AMO and manufacturing organisations that choose to carry out calibration using in-house resources need to be able to demonstrate they meet the calibration policies of Section 7. These organisations can carry out self-assessment of their calibration capacity using the guidance provided within Appendix A of this AC.

8.5 The accreditation mentioned at paragraph 8.2 is carried out by external accreditation bodies such as NATA and the ILAC MRA partners. It includes performance of a technical assessment of a calibration laboratory's competence for each type of calibration which is covered by the accreditation using the assistance of technical experts in each area. National measurement institutes who are members of the CIPM MRA also undergo a peer review process from other members of the MRA.

8.6 In both the NATA/ILAC MRA and CIPM MRA each calibration laboratory has their measurement capability externally published. These 'scopes of accreditation' list the Calibration and Measurement Capability (CMC) for which the laboratory has demonstrated technical competence and in each case the measurement parameter plus the range of measurement the laboratory can achieve is listed, together with the accumulated error estimate or measurement uncertainty for each measurement parameter. Endorsed calibration reports can only be issued if they fall within this CMC.

9. NON-DESTRUCTIVE TESTING EQUIPMENT AND TEST SAMPLES

9.1 Equipment such as blacklight ultraviolet measuring equipment, and other Non-Destructive Testing (NDT) equipment, are subject to calibration in accordance with manufacturer's instructions.

9.2 NDT test samples and standards are not subject to the calibration of section 7 of this AC. NDT is primarily a sensitivity based inspection system using known reference samples to verify and set test equipment prior to performing an inspection. These samples are based on the item being inspected and are used to 'nul' the equipment, not to produce an exact result. NDT reference standards are manufactured to ensure conformance with applicable specifications and generally do not require re-conformance unless subjected to conditions warranting a review.

10. SUMMARY

10.1 The four main points that a calibration service should provide are:

- evidence of measurement traceability across the entire measurement range;
- that they have been assessed to be technical competent to perform the calibrations;
- records of the calibration measurement contain sufficient information to meet the end users' needs; and
- the calibration methods are based on published standards or are valid and have been suitably verified.

10.2 Only organisations with qualified and trained personnel and having procedures in place or an accredited laboratory with procedures and appropriately trained staff should calibrate inspection and test equipment that is used for either determining conformance to a standard or return to service.

Executive Manager
Standards Division

August 2015

APPENDIX A

ACCREDITED AND NON ACCREDITED CALIBRATION FACILITIES GUIDANCE

National Association of Testing Authorities

The National Association of Testing Authorities (NATA) is Australia's only national and internationally recognised provider of laboratory accreditation for test and calibration activities. Through the accreditation process the laboratories provide evidence of measurement traceability, that their methods are valid and verified, and that their staff have been suitably trained and competent. Laboratories are accredited against criteria based on the ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories of which a partial summary of these requirements are listed below.

Laboratory accreditation provides assurance and risk mitigation to the user of test equipment that it has been calibrated by a technically competent laboratory. Accreditation enables customers to identify a reliable testing and calibration service through the listing of the CMC on the scope of accreditation. If a calibration report holder wishes to confirm the measurements contained in the report are covered by the scope of the accreditation then details can be found on the NATA website http://www.nata.com.au or by contacting NATA.

By only accepting an endorsed calibration report, the owner of the tool or test equipment has the extra assurance that the measurement contained in the calibration report have been externally peer reviewed and demonstrated meeting the requirement listed below.

Guidance to determining the suitability of a calibration facility

As calibration facilities and calibrations performed in-house have no requirement to be approved by the Civil Aviation Safety Authority, the AMO or manufacturing organisation will need to determine the suitability and competence of the calibration service or activity. This determination is to give some consideration to the level of rigour needed for the calibration being considered; for example low level single point 'check measurements before use' would require less rigour and detail than high level calibration of power analysers which involve hundreds of measurements across many measurement parameters.

As a guide, an AMO or manufacturing organisation can use the checklist below, which is based on the requirements of ISO/IEC 17025:2005; in making these determinations. Focus should be given to demonstrating technical competence in meeting the requirements for training of personnel, measurement traceability, verification of methods and suitability of calibration reports. Accredited calibration laboratories have already demonstrated their capability to meet all of these requirements.

Quality Management System

- Is there a Quality Assurance/Quality Control program/manual?
- Are there internal/external audit programs?
- Does the audit program have appropriate corrective actions processes for findings?
- Are audit findings available to the customer?
- Are there audit procedures for sub-contractors?
- Have staff that perform critical activities been authorised to do so?
- Is there a procedure for dealing with non-conforming (out of tolerance) work?

Receipt of Calibration Items and review of orders

- Is there a documented procedure for handling of calibration items including visual assessment on receipt?
- Is there a documented procedure for review of purchase orders ensuring the laboratory has the capability to perform the work ordered?

Data Control

- Is there a procedure to ensure that technical data is current and original observations are kept?
- Is there a process to maintain a revision process and record of document status?
- Is there a process to have approved procedures to control manual revisions that are on loan or borrowed?
- Is there a process that records deviations from original equipment manufacturer specifications?

Equipment Calibration

- Is there a calibration program for reference equipment?
- Are all calibration equipment listed?
- Can the laboratory provide evidence of measurement traceability?
- Are the calibration methods valid and have they been suitably verified through proficiency testing or external measurement comparisons?
- Are there procedures in place to prevent the use of uncalibrated equipment?

Training

- Is there a documented training program?
- Are the technicians/inspectors included in that training program?
- Does that training program include any refresher training?

Facilities

- Are storage areas separate from the work area?
- Is the storage area environmentally controlled?
- Is there an electrostatic discharge sensitive equipment policy and is that policy supported by training (where appropriate)?

Work Processing

- Is there a process to validate tooling or equipment used in the calibration process that differs from the manufacturers requirements?
- Is there a copy of its operating and maintenance manuals?
- Is there a process to identify and track customer's equipment?
- Do the work records contain:
  - a description of work performed;
  - pre-calibration check details;
  - date of completion;
  - a work package reference number to allow full traceability; and

- are there procedures relating to out of tolerance actions and discrepancies noted during calibration?

Calibration Reports

- The organisation should be able to provide a copy of any certification held.
- Calibration reports should be required to record:
  - name and address of facility;
  - unique identification of report;
  - description of the condition of and unambiguous identification of the item being calibrated (tested);
  - should the item be repaired or adjusted before calibration, the calibration results before and after repair or adjustment;
  - identification of specific method;
  - results of measurement including correction charts and tables;
  - units of measurement;
  - a statement of measurement uncertainties achieved including coverage (k) factor and confidence interval plus any limitations of detection that apply to the end users requirements;
  - an indication of any tests (if applicable) that have been subcontracted out to other facilities;
  - printed details, signature and title of an authorised member of the facility that accepts responsibility for the report and the testing work upon which it was based;
  - means of measurement traceability including identification of reference test equipment; and
  - environmental conditions under which the calibration was performed.