Control of APS Measuring and Test Equipment

Section where used:

This procedure shall be used by all APS technical groups utilizing calibrated monitoring and test equipment.

Changes made in this revision:

- Author updated (changed from ASD Associate Division Director and XSD ESH/QA Representative) to N. Sempowicz; added XSD ESH/QA Representative as a reviewer
- Updated Procedure/Section 1.1 Purpose
- Updated Procedure/Section 1.3 Reference Documents
- Added APS QE to Section 2.1 4th row
- Revised beam energy for x-ray properties section
- Revised beam energy for swap-out interlocks section; there are two interlocks now, one on booster side and one on storage ring side.
- Updated obsolete/archived calibration procedures that were referenced (APS_1193979 → APS_2286939; APS_1192186 → APS_228790; and APS_1284261 → APSU_2288261)

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Control of APS Measuring and Test Equipment

POLICY

The APS has identified measurements that will ensure that the APS delivers beams that meet defined operating parameters and within safe operating limits (see Appendix A for the list of the parameters). The accuracy of these measurements is ensured by the calibration and control of the measurement and test equipment (M&TE) used to monitor the parameters. This M&TE will be calibrated in accordance with this policy and the Argonne procedure Control and Calibration of Measuring and Test Equipment (LMS-PROC-50).

(This approach is consistent with standards (e.g., ISO 9001) requiring the calibration and control of equipment that provides evidence of conformity of a facility's product to determined requirements. In this case, the product of the APS, as a facility, is the stored beam.)

In addition, APS technical Groups may require calibration and control of M&TE important to facility operations and safety in accordance with Argonne LMS-PROC-50.

M&TE is to be calibrated per manufacturer specifications on a periodic calibration cycle and whenever accuracy of M&TE is suspect. Calibration is to be traceable to the National Institute of Standards and Technology (NIST) or other nationally recognized standards when available and appropriate. Reference standards are to have a minimum accuracy four times greater than that of the M&TE being calibrated to guarantee that the reference standards contribute no more than one-fourth of the allowable calibration tolerance when available and appropriate. This is often referred to as the Test Uncertainty Ratio (TUR). Where this 4:1 ratio cannot be maintained, the basis for selection of the standard in question is to be technically justified (e.g., Guard-banding, engineering evaluation, use of derived standards).

APS M&TE shall be:

1. Identified and managed by the APS technical groups and via the APS Component Database (CDB).
2. Calibrated or verified at specified intervals.
3. Identified to enable the calibration status to be determined.
4. Safeguarded from adjustments that would invalidate the measurement result.
5. Protected from damage and deterioration during handling, maintenance, and storage.

PROCEDURE

1.0 INTRODUCTION

1.1 Purpose

This procedure defines the APS process for managing M&TE in conformance with Argonne procedure LMS-PROC-50. APS M&TE is to be calibrated per manufacturer specifications on a periodic calibration cycle, when used to provide evidence of conformity to established requirements that include ensuring the validity of research measurements and tests, or whenever the accuracy of the M&TE is suspect.

1.2 Applicability

This procedure applies to APS technical groups, the QA Representatives, and employees who require the calibration of their measurement and test equipment.

1.3 Reference Documents

- Argonne Quality Assurance Program Plan
- Quality Manual (anl.gov), LMS-MNL-7, Quality Manual
- ANL LMS PROC-50, *Control and Calibration of Measuring and Test Equipment*
- DOE Order 414.1D, *Quality Assurance*
- ISO 9001: 2015, *Quality management systems requirements*

2.0 STEP-BY-STEP PROCEDURE

A video tutorial link has been provided describing:

1. How to find the tool
2. How to identify the specific tool under inventory
3. How to upload calibration documents and change the calibration due dates

https://anl.box.com/s/vxkbnksugub37l7852davihswmsehvwn

2.1 Roles and Responsibilities

Responsible Person	Required Activities
APS Group Leader/Designee or PI	• Determine the M&TE that requires calibration. Consider: ○ Appendix A, detailing critical operating parameters that may require the use of calibrated M&TE ○ M&TE that is important to facility operations and safety ○ M&TE that is important to the APS-Upgrade • Designate a custodian for M&TE requiring calibration.

Responsible Person	Required Activities
M&TE Custodian	• Manage the assigned M&TE in CDB: ○ Identify the make and model of M&TE at the *Catalog* level, and indicate that the Function is "Calibrated M&TE". ○ Identify the inventory associated with the M&TE at the *Inventory* level ○ Designate the details for each inventory item, using the *Calibration Status/Performed* property, and filling in the required metadata ○ When the M&TE's calibration method is anything other than that recommended by its Manufacturer, prepare a written technical justification of that methodology, and ensure it is linked to the M&TE via its Properties. ○ Keep the M&TE records within CDB current; and • Ensure calibrations are performed in accordance with LMS PROC-50. • Ensure MT&E calibration procedures are reviewed and kept up to date. • When M&TE is discovered to be out-of-tolerance, complete Xink form ANL-626A, *Nonconformance Report - Existing or Purchased Items/Services.* • When M&TE under your control is used by others: ○ Assign the M&TE to user and maintain the following information (at a minimum): ▪ Date issued ▪ Person issued to ▪ Job M&TE issued for (e.g., specific surveillance requirement, procedure, etc.) ▪ Range to be used *Note: M&TE must be traceable to the processes and/or items it has been applied to, so that in the event the M&TE is found to be out-of-tolerance, the affected items or processes can be reviewed for potential impact.*

Responsible Person	Required Activities
M&TE User	• Review the calibration sticker on M&TE equipment for the following: ○ Unique identifier (QR code or serial number) ○ Date of last calibration ○ Calibration due date ○ Any restrictions on range of service • Complete training in accordance with LMS PROC-50. • Notify the M&TE custodian of any equipment that is overdue for calibration, found to be out of tolerance, missing the calibration label, damaged or malfunctioning • Use the M&TE per manufacturer instructions. • If equipment does not perform as required, stop work and notify the M&TE custodian. • Upon completion of work, return M&TE to M&TE custodian.
Division QARs (ANL/WSE personnel assigned to the APS Divisions) / APS Quality Engineer	• Assist Divisional personnel with ensuring that required M&TE calibrations are identified and completed. • With the periodic review of this policy and procedure, review CDB to ensure completeness of MT&E listings. A summary report of calibrated equipment is available here. • Provide training on the calibration requirements to APS technical groups when requested. • Assist division personnel in completing Xink form ANL-626A, *Nonconformance Report - Existing or Purchased Items/Services.*
APS Policy and Procedure Administrator (PP Admin)	• Circulate this policy and procedure for periodic review. • As part of the periodic review, circulate to the ASD Associate Division Director to review the requirements of Appendix A.

2.2 Preparation-Pre-requisite Actions

All personnel who will perform M&TE calibrations are required to read the following documents prior to execution of this procedure:

- Quality Manual, LMS-MNL-7
  - Control and Calibration of Measuring and Test Equipment - LMS PROC-50
  - Receipt Inspection – LMS-PROC-49

3.0 DOCUMENTS/ RECORDS CREATED BY THIS PROCEDURE

The documents/records listed below will be created in the execution of this procedure and must be retained as indicated.

Description of Document/Record (include ID number, if applicable)	Custodian	Storage Location and Medium	Retention Requirement
List of devices that will be calibrated in accordance with this policy.	APS Technical Group	Component Database	6 years
Records of calibration results	M&TE Custodian	Component Database	6 Years
Xink ANL-626A, Nonconformance Report for Existing or Purchased Items/Services	M&TE Custodian	Argonne Xink system, electronic	6 years
Calibration procedures, other than by Manufacturer	M&TE Custodian	Component Database	6 years

The following minimum metadata is required in order for these documents to appear in the Calibration Database:

- Document Type: Report
- Title: must contain the text 'Calibration Record'. It is also recommended that the equipment name, model, and serial number be included in the document title.

4.0 FEEDBACK AND IMPROVEMENT

If you are using this procedure and have comments or suggested improvements for it, please go to the APS Policies and Procedures Comment Form* to submit your input to a Procedure Administrator. If you are reviewing this procedure in workflow, your input must be entered in the comment box when you approve or reject the procedure.

Instructions for execution-time modifications to a policy/procedure can be found in the following document: Field Modification of APS Policy/Procedure (APS_1408152).

* https://www.aps.anl.gov/Document-Central/APS-Policies-and-Procedures-Comment-Form

Appendix A – Required Parameters for APS Operations

I. X-ray Properties

Those x-ray properties under APS control are determined by the stored beam current, the stored beam energy, the bunch spacing, the beam size and divergence, and the insertion device in use at a particular beamline. The beam stability (in terms of centroid position and pointing angle) is also an important deliverable.

Operating Parameter	Calibration Requirement	Calibration Procedure
Stored Beam Current	Beam current is determined by the DCCT (Direct Current-Current Transformer). An accuracy of 1% is required.	APSU_2288261
Stored Beam Energy	The stored electron beam energy will be within 2% of 6 GeV, or best effort. The 2% accuracy is achieved by current supply settings determined by magnetic measurements, which are precise to at least 0.1%.	Not required
Bunch Spacing	Bunch spacing is an integral multiple of the rf period, which is determined by the frequency of the storage ring rf system. The required accuracy of the bunch spacing is 1%, which implies a 1% accuracy requirement for the ring rf frequency.	Not required

Operating Parameter	Calibration Requirement	Calibration Procedure
Beam Size & Divergence	Beam size and divergence naturally vary for different x-ray source points in the storage ring, as well as varying in time. Values for individual x-ray source points are inferred from the accelerator model and measurements at a reference location. The required accuracy of the beam size and divergence measurements is 20% in the horizontal plane. In the vertical plane, the beam may have up to twice the size and divergence stated. The accelerator model is calibrated using the LOCO (Linear Optics from Closed Orbits) method, which has an accuracy requirement of 5% for $\sqrt{\beta}$. A technical document (APS_1662163) describes how this accuracy is ensured. Beam size and divergence measurements at the reference location rely on measurements from the x-ray pinhole camera and the accelerator model. Reference location size and divergence measurements must be accurate to 15% to support the 20% requirement for beam size and divergence inferred at other locations. A technical note APS_1284034 describes the calibrations required to support this accuracy.	LOCO method for calibration (APS_1662163) APS_1284034

Operating Parameter	Calibration Requirement	Calibration Procedure
Beam Stability	Beam stability measurements are specified in microns for specified frequency bands in the horizontal and vertical planes. An accuracy of 10% is required. The measurements make use of beam position monitors, which are calibrated at the 5% level by the lattice calibration software (see above).	APS_1424354

Operating Parameter	Calibration Requirement	Calibration Procedure
Insertion Device Properties	Several properties of each insertion device (ID) are relevant to the x-ray properties, namely, the ID period, field strength as a function of an accurately reproducible measurement of the gap, length (number of periods), and the undulator magnetic field phase errors. The number of periods (an integer or half-integer) is set during fabrication. The period length is also determined by the fabrication of the magnetic structure and confirmed by QA during fabrication (outside of APS), using a coordinate measurement machine. The field strength varies with the ID gap and is typically adjusted by the users (experimenters) to suit their requirements. The user gets the readback from encoders as a report of the gap, and the relationship between the encoder readings and the magnetic field strength is measured during the ID magnetic tuning and is available online within the ID control system. The mechanical reproducibility of the gap has its origin in a set of ceramic gauge blocks that serve as an internal calibration standard. The quality of the undulator magnetic field—the smallness of the magnetic field phase errors—helps determine the brightness of the photon beams created in the undulators. Calibration of the magnetic field probe is good to better than 100 ppm, which is more than adequate. The calibration is with respect to an NMR teslameter. According to the manufacturer, the NMR is accurate to 5 ppm and drifts by ±2 ppm/year; hence it does not require calibration within the lifetime of the APS.	Gauge Block Calibration

II. Compliance with Safe Operating Limits

Compliance with safe operating limits refers to the following:

1. Operation within the accelerator safety envelope.
2. Proper operation of radiation limiting interlocks.
3. Proper operation of collimators, beam stops, x-ray absorbers, and shutters
4. Beam current and energy above minimum allowed values during swap-out operation.

In this context, when we refer to proper operation of interlock systems, we do not refer to testing to verify interlock logic or wiring. Rather, we refer to verification that interlock systems use sufficiently accurate measurements of relevant physical quantities.

Operating Parameter	Calibration Requirement	Calibration Procedure
Safety Envelope Enforcement	The safety envelopes are expressed in terms of allowed average beam current through various current sensing devices. The trip levels for these devices are validated periodically or following certain maintenance activities using calibrated references. These validations are covered by APS procedure APS_1192873 and APS procedure APS_1283821, which reflect a revised approach, namely, that the trip points are set 10% or more below the desired maximum current. Required calibration accuracy for the trip points is thus 10%.	APS Procedure APS_1192873 APS Procedure APS_1283821
Radiation Limiting Interlocks	Radiation outside the shield wall is sensed and limited by a number of radiation monitors around the facility. These are calibrated periodically using a check source. The strength of the check source must be calibrated to an accuracy of 15%. RP maintains and periodically calibrates these monitors. RP is responsible for affixing calibration stickers to the monitors and maintaining calibration documents and records.	Maintained by RP

Operating Parameter	Calibration Requirement	Calibration Procedure
Collimators, Beam Stops, X-Ray Absorbers, and Shutters	Collimators, beam stops, X-ray absorbers and shutters are fixed and movable devices that are used to prevent electron and x-ray beams from entering areas where their presence could create a hazard. The dimensions of a collimator, beam stop, absorber, or shutter and its position, when inserted, determine whether it will perform the desired function. Dimensions that are critical to safety are verified to be within tolerances by QA processes per the APS Change Control for Radiation Safety Shielding procedure (APS_1685081) and the Laboratory Receipt Inspection procedure (LMS-PROC-49). Positioning of these components, when installed, is assured to be within tolerances by alignment per APS procedure APS_1200799. Calibration requirements for the instruments used are stated in the inspection records for these components. In addition, X-ray absorbers serve as electron beam apertures that limit beam excursions, thus ensuring swap-out can be safely performed. The final location of absorbers in the storage ring chambers is determined by the design of the chambers and the absorber assemblies. The tolerance budget associated with positioning of storage ring chambers and magnets for swap-out safety are given in APS report APS_2286939.	APS Procedure APS_1685081 APS Procedure APS_1200799 APS Report APS_2286939

Operating Parameter	Calibration Requirement	Calibration Procedure
Swap-out Interlocks	Swap-out operation cannot be performed unless there is stored beam, nor can it be performed at energies below 5.5 GeV. The former requirement is enforced by the swap-out stored beam monitor, which is periodically validated according to APS procedure APS_1191883; no calibration is required. The 6-GeV beam energy requirement is enforced by interlocks in the booster and in the storage ring, separately. The booster's extraction energy error is limited to 2% through the BEFI interlock. The stored beam energy is limited by a software permissive periodically checking the readbacks of magnet current supplies (APS_2289279) and also a M1 dipole hardware interlock per APS procedure (APS_2287903). Procedure APSU_2288261 is followed for calibrating the current transducer electronics.	APS Procedure APS_1191883 APS Procedure APS_2289279 APS Procedure APS_2287903 APS-U Procedure APSU_2288261