

Advanced Photon Source

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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:

- Revised Section 3 regarding accessing records in ICMS
- Replaced APS_1282405 with APS_1685081 and LMS-PROC-49 on page 12
- Revised procedure to comply with LMS-PROC-50, Revision 6
- Updated second paragraph on page 9 (Beam Size & Divergence section)
- Edits for style

Prepared by:

ASD Associate Division Director
AES Technical Operations Specialist

Reviewed by:

ASD Storage Ring Manager
HSE - PSC Safety Manager
HSE - AES ESH/QA Representative
HSE - ASD ESH/QA Representative
HSE - XSD ESH/QA Representative

Approved by:

AES Division Director
ASD Division Director
XSD Division Director

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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. APS document [APS 1660775](#) is a directory pointing to group-specific calibration requirements. This M&TE shall be:

1. Identified by the APS technical groups and included on the group's calibration list ([APS 1660775](#)).
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. Required calibrations will be traceable to recognized international and national measurement standards, such as those of the National Institute of Standards and Technology (NIST). When no such standards exist, the basis used for calibration or verification shall be recorded (e.g., Lab notebook).

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
- [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 detailed step-by-step flowchart for the calibration process with clear roles and responsibilities is included in [Figure 1](#).

2.1 Roles and Responsibilities

Responsible Person	Required Activities
APS Group Leader/Designee or PI	<ul style="list-style-type: none"> • Maintain in ICMS a list of the Group’s M&TE that require calibration per the above policy: <ul style="list-style-type: none"> ○ Review appendix A of this document for the operating parameters that may require the use of the Group’s calibrated M&TE; ○ Identify Group’s M&TE important to facility operations and safety; ○ Keep the Group’s list current; and ○ Provide an ICMS link to the list to a QA Representative (link to be included in APS_1660775) • Ensure calibrations are performed in accordance with LMS PROC-50. • Ensure relevant Group’s MT&E calibration procedures are reviewed and kept up-to-date.
M&TE User	<ul style="list-style-type: none"> • Complete training requirements in accordance with LMS PROC-50. • Coordinate calibrations suppliers. • Review and file calibration results records

Responsible Person	Required Activities
Division QARs (ANL/HSE personnel assigned to the APS Divisions)	<ul style="list-style-type: none"> Assist Divisional personnel with ensuring that required M&TE calibrations are identified and completed. With the periodic review of this policy and procedure, review Group Calibration Lists from their Division (APS_1660775). Provide training on the calibration requirements to APS technical groups when requested. Assist division personnel in completing Xink ANL-626A Reports of Nonconformance.
APS Policy and Procedure Administrator (PP Admin)	<ul style="list-style-type: none"> 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:

- Applying the Graded Approach to Quality for Procured Items or Services – LMS PROC-125
- Control and Calibration of Measuring and Test Equipment - [LMS PROC-50](#)
- [Receipt Inspection – LMS-PROC-49](#)
- Managing APS Facility Procedures - (ICMS Content ID # [APS_1001409](#))

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.	The Technical Group	ICMS APS_1660775 , electronic	6 years
Records of calibration results	M&TE Owner	ICMS, electronics	6 Years
Xink ANL-626A, Nonconformance Report for Existing or Purchased Items/Services	M&TE Owner	Argonne Xink system, electronic	6 years
Revised calibration procedures	M&TE Owner	ICMS, electronic	6 years

The following minimum metadata is required in order for these documents to appear in the ICMS library folder titled 'Instrument Calibration Records':

- Document Type: Report

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- 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.

To retrieve these ICMS calibration record documents:

- Log into [ICMS](#) (if you don’t login, as a guest, you won’t see the files).
- The [home page](#) will have a list of library folders (If you’re logged in, clicking on the red ORACLE log on the top of an ICMS page to go to the home page). You can also get to the folders using the Browse Content pull down on the top of an ICMS page.
- Click on the [Instrument Calibration Records](#).
- Click on the Group name to bring up a list of the Group’s calibration records.

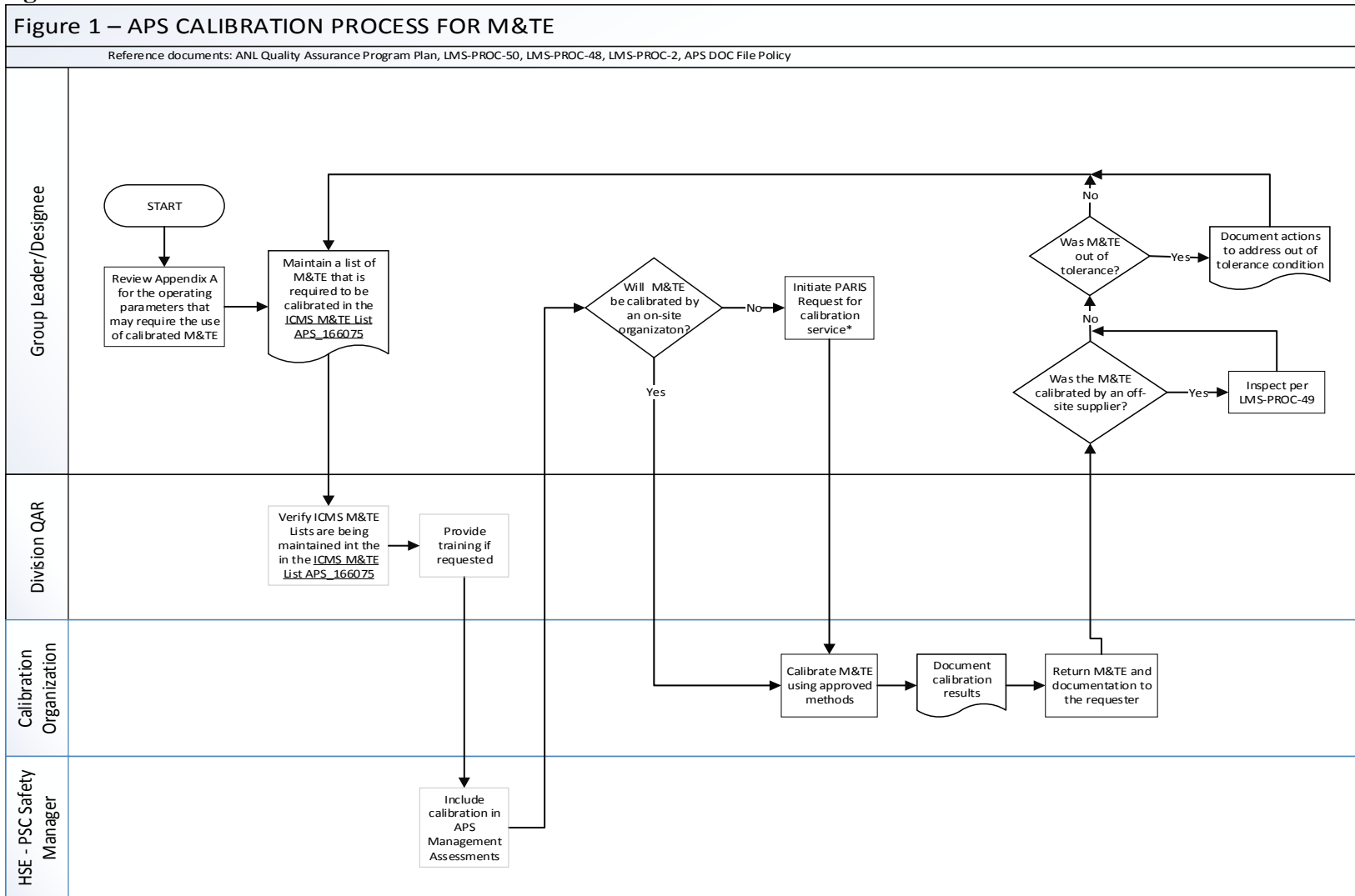
4.0 Feedback and Improvement

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>

Figure 1-APS CALIBRATION PROCESS for M&TE 4-8-2018



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PARIS requisitions for calibration must be Quality Level C, and include forms ANL-407A, and ANL-266

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.	APS 1284261
Stored Beam Energy	The stored electron beam energy is not directly measured, but is instead determined by the strength of the dipole magnets, which is directly measured using a reference magnet with an NMR (Nuclear Magnetic Resonance) probe. The required accuracy of the energy determination is 2.5%. Variation of 2% from the nominal energy is possible due to adjustment of the rf frequency and uncertainty in the magnetic length of the dipole magnets. 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 life of the APS.	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	<p>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.</p> <p>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.</p> <p>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.</p>	LOCO method for calibration (APS 1662163) APS 1284034
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
<p>Insertion Device Properties</p>	<p>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.</p> <p>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.</p> <p>The quality of the undulator magnetic field—the smallness of the magnetic field phase errors—helps determine the brilliance 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.</p>	<p>Gauge Block Calibration</p>

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 top-up 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%. HSE-RSO maintains and periodically calibrates these monitors. HSE-RSO is responsible for affixing calibration stickers to the monitors and maintaining calibration documents and records.	Maintained by HSE-RSO

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Operating Parameter	Calibration Requirement	Calibration Procedure
Collimators, Beam Stops, X-Ray Absorbers, and Shutters	<p>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 top-up 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 chambers are then positioned via fiducials, surveyed by S&A to the correct position. Positions of storage ring vacuum chambers in the magnets are verified using APS procedure APS 1194658. This procedure does use go/no-go gauges to verify that the chambers are within ± 2 mm relative to the quadrupoles and sextupoles. This is done during every maintenance period to ensure that SR apertures are safe for machine operation in top-up mode. The tolerance budget associated with positioning of storage ring chambers and magnets for top-up safety are given in APS procedure APS 1193979.</p>	<p>APS Procedure APS 1685081</p> <p>APS Procedure APS 1200799</p> <p>APS Procedure APS 1194658</p> <p>APS Procedure APS 1193979</p>

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Operating Parameter	Calibration Requirement	Calibration Procedure
Top-up Interlocks	Top-up operation cannot be performed unless there is stored beam, nor can it be performed at energies below 6 GeV. The former requirement is enforced by the top-up stored beam monitor, which is periodically validated according to APS procedure APS 1191883 ; no calibration is required. The 6-GeV requirement is enforced by voltage and current interlocks on the storage ring dipole power supply. These are calibrated to the required 1% level per APS procedure APS 1192186) for a precision meter and procedure APS 1284261 for the current transducer electronics.	APS Procedure APS 1191883 APS Procedure APS 1192186) APS Procedure APS 1284261