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Equipment Maintenance

INTRODUCTION TO ON-SITE CALIBRATION OF AUTOMATIC TEST EQUIPMENT

This pamphlet introduces system calibration to Air Force personnel involved in acquiring test equipment (ATE). It outlines a technical concept for calibration support of ATE and describes organizational relationships needed to make it work. Key hardware and software components are discussed.

Section A—Introduction

1. General Information. The Air Force used computer-controlled ATE to check and diagnose the performance of sophisticated weapon systems at all levels of maintenance. Organizational- and intermediate-level activities need ATE to directly support weapon systems, so we must try to eliminate anything which causes ATE downtime when possible, without compromising ATE integrity. Calibration is essential to effective ATE performance, and a well-conceived calibration scheme is the key to determining system performance and to building confidence in results.

2. Background. Computer-controlled ATE evolved from numerically-controlled test stations, which grew from dedicated collections of manual test equipment. Early calibration support did not keep pace with the different technical and logistics requirements the test stations imposed. The ATE was calibrated as a collection of individual test instruments, rather than as a test system. As a result, sources of measurement error were missed and ATE downtime was severely aggravated by the logistics shortcomings of the individual test instruments.

3. System Calibration. In the early 1970s, the Directorate of Metrology at the Aerospace Guidance and Metrology Center (AGMC/ML) developed portable calibration standards for Minuteman ATE. An environmentally-protected standards set was taken to the ATE site and the entire ATE station was calibrated at one time. Under the portable automatic test equipment calibrator (PATEC) concept, the standards go to the test station instead of tearing the station apart one instrument at a time for calibration in the laboratory. Calibration is done at the ATE interface and is designed to measure all sources of system error. The concept has been successfully applied to ATE stations for many major Air Force weapon systems.

4. Core PATEC. After several applications of the PATEC concept and as PATEC-calibrated ATE became widely distributed, the engineers found many of the same standards being used in each system-peculiar PATEC. Because calibration of even the largest ATE station seldom takes more than a few days, twice a year, they decided it would be logistically advantageous to deploy the set of common standards to precision measurement equipment laboratories (PMEL) worldwide, with the one "Core" PATEC able to support many weapon systems' ATE stations. That way, if a weapon system and its ATE were moved to another place, a basic level of calibration support would already be available. See paragraph 14 for handling calibration requirements peculiar to a particular ATE station.

Section B—Organizational Relationships

5. General Information. Some basic interrelationships are vital to smoothly develop and deploy ATE calibration capability. Usually, three major parties outside AGMC are involved: the ATE-acquiring program office, the prime contractor, and the ATE-using command. This section outlines the relationship between AGMC/ML and each of the other parties.

6. ATE Acquisition Agency and AGMC/ML. During development of ATE calibration capability, AGMC is the acquiring agency's technical

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OPR: AGMC/MLSE (Mr Jon W. Morrison)
Approved by: AGMC/ML (Col Peter S. Miner)
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agent. This may include: input to the Request for Proposal; participation in Preliminary and Critical Design Reviews, Calibration/Measurement Requirements Summary (CMRS) reviews, operational test and evaluation, and Calibration Test Program Set (Cal-TPS) specification development and review; arrangement for support of any standards supplied for CAL-TPS development; and purchase of additional needed standards. The CMRS and Cal-TPS are described in detail later. The decision on whether additional standards are funded by AGMC or the acquisition agency is usually decided by how early the requirement is identified and budgeted.

7. Using Major Commands (MAJCOM) and AGMC. The primary goal of on-site ATE calibration is to provide effective support to the operational forces. AGMC's main scheme is to send PATECs to PMELs for their use in support of customers. However, where good sense dictates, AGMC supports PATEC ownership by the ATE owner-user. When the using MAJCOMs want to provide PATECs to ATE owner-users, they must make this known as early as possible during the acquisition process. AGMC will then review the circumstances and prepare a recommendation detailing cost and schedule considerations and any technical problems the approach might create. If, after reviewing the AGMC recommendation, the MAJCOM decides that a dedicated, user-owned PATEC is the most appropriate approach, AGMC will then assist in determining a source of funding for the additional PATEC equipment.

8. Contractor and AGMC. During development, AGMC gives technical support to the contractor, including such things as technical information on calibration techniques, calibration test program software design, technical order (TO) preparation, and Calibration Interface Test Adapter (Cal-ITA) design. AGMC may give the contractor a PATEC to use during Cal-TPS development and to return after completion.

9. PMEL and AGMC. AGMC's basic job is to provide measurement traceability to the National Bureau of Standards for all weapon systems. For ATE, they do so by giving PMELs ATE calibration standards and TOs. Core PATEC is the means by which PMEL personnel calibrate ATE on-site. In addition to a Core PATEC for each PMEL, AGMC provides software to govern setup and use of the equipment.

Section C—Calibration/Measurement Requirements Summary

10. General Information. The CMRS includes all calibration requirements generated by a weapon system, its ATE, and its calibration standards. It is usually prepared by the contractor according to MIL-STD-1839 and Data Item Description DI-QCIC-80278.

11. Purpose. The CMRS is often used as a software requirements document for the Cal-TPS; it also assures the Cal-TPS can calibrate the ATE well enough to meet weapon system requirements. CMRS data are organized into three columns: weapon system test requirements under Category I; ATE calibration requirements in Category II; and performance specifications for the calibration standards under Category III.

12. Transfer Accuracy Ratio. Category I data reflect weapon system mission requirements and must include only the maximum performance parameters dictated by the mission to be performed. Overstatement of requirements will cause an exponential rise in calibration support costs. Category II entries come from Category I requirements. For example, if a system voltage must be measured to a certain accuracy, the ATE voltmeter accuracy in Category II must reflect an appropriate improvement in accuracy. The specifications for the standards to calibrate the ATE are shown in Category III and have the same relationship to Category II data as the latter do to Category I, i.e. an accuracy improvement must be present. Good measurement practices and Air Force policy define the desired transfer accuracy ratio at each step to be four-to-one, as set out in DI-QCIC-80278. Thus, with two transfers between the weapon system and the ATE calibration standard, the latter would typically need to be some 16 times more accurate than the weapon system's needs.

13. Review and Approval. AGMC reviews each CMRS for compliance with current established guidance and sends its recommendation for approval or improvements to the ATE acquisition office. After approval, it may be used as the performance baseline for the Cal-TPS, for which it represents the "design-to" goals.

Section D—Portable Automatic Test Equipment Calibrator

14. General Information. As noted above, the AGMC scheme for ATE calibration support is to provide a Core PATEC to every PMEL. They may use it to calibrate a variety of ATE stations; experience shows many of them are made up of instrumentation covering the same measurement parameters. Manufacturer and model number vary, but there is a strong tendency for the parameters to recur. AGMC handles ATE system-unique requirements by fielding tailored augmentation packages with the standards not found in the Core PATEC. From time to time, it becomes obvious virtually every new system requires a particular standard in its augmentation package. When that occurs, the standard is made a part of the Core PATEC and distributed to all PMELs.

15. Core PATEC Composition. As of this writing, the Core PATEC covers the following measurement parameters:

a. DC and Low Frequency Stimuli: DC voltage and current, AC voltage and current, and resistance.

b. Time and Frequency Measurements: frequency, period, time interval, rise and fall time, and frequency difference.

c. Oscilloscope and Digitizer Measurements: precision pulse, time mark, and leveled sine wave.

d. Angular Position Measurements: three-wire synchro and four-wire resolver.

e. RF, Microwave, and Modulation Measurements: RF power, attenuation, frequency, phase noise, amplitude modulation, frequency modulation, and phase modulation.

Section E—Calibration Test Program Set

16. General Information. A Cal-TPS is like any other ATE test program, except the unit under test is the ATE itself. It's like the ATE self-test, though not limited to the assets available in the ATE station. The calibration standards become extra assets the ATE can use during its calibration. The Cal-TPS has three parts: software, an interface test adapter, and a TO. They are designed to work with the calibration standards and the ATE station's integral assets to satisfy the requirements documented in the CMRS.

17. Cal-TPS Software. The software guides the ATE calibration process. The operator interacts with it to test, report, and evaluate results. One of the most useful ways to organize the program is to parallel the main components and functions of the ATE, using a menu-driven technique. The menu follows a logical order based on the calibration hierarchy of the ATE, i.e. items needed to calibrate other components of the station must be calibrated earlier in the process. The software is usually written to run on the ATE's host computer.

18. Calibration Interface Test Adapter and Cables. Few ATE stations connect directly to the weapon system components under test. Most have a combination of interface panel, switch box, cables, and connector adapters to link the ATE and the weapon system. A similar system is needed to connect the calibration standards to the ATE. Ideally, this is designed to calibrate the ATE through the same interface that connects it to the weapon system. If such is impractical or impossible, a special interface test adapter and cables may need to be developed to achieve the connectivity. When this approach is contemplated, it is necessary to assess the technical risk and potential error contributions of the adapter/cable set. The issue of how to connect the ATE station to the calibration standards is complex and defies reduction to a one-size-fits-all, handy set of rules and guidelines. Each case requires individual attention.

19. Calibration Technical Order. The calibration TO is the document unifying the software, the interface adapter, and the calibration standards. It tells how to run the process up until the point where the software's instructions take over control. The TO is prepared according to MIL-M-38793A, and contains four principal parts: ATE specifications, specifications of the calibration standards, starting instructions, and detailed performance tables with ranges, test points, and error limits for each parameter calibrated.

Section F—Summary

20. Assistance With ATE Calibration Support Needs. ATE calibration support is evolving rapidly. The basic idea of calibrating the whole ATE station as a system will endure, but the details of how to make it possible will change as improvements occur in test instrumentation, test and system software design, and calibration

standards and techniques. AGMC has additional documents with detailed information on calibration standards, communications interfaces and protocols, Cal-ITA design, and other implementation-specific issues. For more information, write AGMC/MLSE, Newark AFB OH 43057-5475, or call commercial (614) 522-7398 (AUTOVON 580-7398).

BY ORDER OF THE SECRETARY OF THE AIR FORCE

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LARRY D. WELCH, General, USAF
Chief of Staff

WILLIAM O. NATIONS, Colonel, USAF
Director of Information Management
and Administration

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