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QUALITY AND TECHNICAL ISSUES RELATED TO TRACEABLE MEASUREMENTS OF ACOUSTIC NOISE EMISSIONS OF COMPUTER AND BUSINESS EQUIPMENT

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INTRODUCTION

The measurement and reporting of noise emissions of computer and business equipment is required by regulatory requirements, purchase specifications and ECO-label programs throughout the world. Many of these requirements specify that results of the measurements of the noise emissions of the device be traceable to national standards of measure. Some also require that the measurements be conducted under the control of a quality system, such as that defined by ISO Guide 25. This paper will address the application of the technical and quality requirements of ISO Guide 25 to an acoustics laboratory that makes traceable computer and business equipment noise emission measurements.

MEASUREMENT TRACEABILITY

The term traceability is often used to describe the concept of making measurements that are fundamentally related, through a series of comparison-based calibrations, to standards of measure maintained by national standards agencies. In the US, the national standard agency is the National Institute of Standards and Technology. In the case of noise emission measurements of computer and business equipment, traceability implies that the values expressed for the noise emissions of a device have been obtained by making pressure measurements with transducers and reference standards that have been calibrated relative to national standards maintained for pressure reference.

While measurement traceability is often viewed as simply a calibration issue, traceability involves many other factors. Traceablity of measurement results is achieved by maintaining good documentation of what was tested, conducting the tests in a consistent manner in accordance with industry test standards and by employing a quality assurance system in the laboratory. All aspects of the laboratory's quality system contribute to the traceability of the measurement.

QUALITY SYSTEMS

The most commonly employed requirements for a quality system by agencies that regulate or specify measurement of computer and business equipment noise emissions are those defined in ISO Guide 25 [1]. ISO Guide 25 outlines a series of quality system and technical requirements for calibration and testing laboratories. Satisfaction of the ISO Guide 25 requirements insures that the laboratory has not only a quality system in place to guarantee that work is conducted in a

consistent and properly documented manner, but that laboratory personnel, equipment and procedures are technically competent. The quality system requirements of ISO Guide 25 are equivalent to those specified in the more commonly known ISO 9000 series of standards. However, ISO Guide 25 addresses technical requirements that go beyond the ISO 9000 series requirements.

ISO Guide 25 defines a quality system as "The organizational structure, responsibilities, procedures and resources for implementing quality management." The quality system for a laboratory is typically outlined in a document known as a quality manual, which states the laboratory's policies and procedures for implementing each of the requirements of ISO Guide 25. A quality manual with policies and procedures in the following areas can address the primary requirements of ISO Guide 25 that are applicable to acoustical laboratories that make traceable measurements of computer and business equipment noise emissions:

- Organization and Management
- Facilities, Equipment and Reference Materials
- Personnel and Training
- Document Control Procedures
- Calibration
- Quality Assurance
- Audit
- Complaints

ISO Guide 25 also includes requirements that address the use of outside support services and supplies and the subcontracting of testing services. These requirements are generally not applicable in manufacturer or independent computer and business equipment test laboratories and are not addressed in detail in this paper.

ELEMENTS OF AN ISO GUIDE 25 QUALITY PROGRAM FOR ACOUSTICS LABORATORIES

An acoustics laboratory that is charged with the responsibility for measuring and reporting traceable computer and business equipment noise emission test results must implement the requirements of ISO Guide 25 in a way that addresses the specific requirements of their laboratory. Each laboratory is a unique situation and the requirements of the Guide can be applied in many different ways. The typical acoustics laboratory's quality program must document and address each of the primary areas of ISO Guide 25 requirements as listed above.

Organization and Management. In order to insure that the quality objective is achieved, a commitment to the laboratory's quality program must begin with company management. Laboratory personnel must have a mandate from company management to design a quality program and must have the authority to properly implement it.

Quality programs are often viewed as an additional burden on laboratory operations or as an unnecessary expense to the company. However, a well-designed quality program will facilitate the day-to-day operations of the laboratory, rather than burden it with unnecessary overhead, and should result in the lowest overall expense to the company. Management and laboratory personnel must agree that the primary objective is that all tests that are conducted should be properly documented and conducted in a consistent and competent manner. Then, the implementation of a quality program that addresses the requirements of ISO Guide 25 makes good business sense and addresses the regulatory or purchase specification requirements of the computer and business equipment customer.

As part of the organization and management of the laboratory a technical and/or quality manager must be designated. In smaller laboratories this may be the same individual while in larger organizations the functions may be separated. The quality manager is responsible for the design and implementation of the quality system and may not necessarily have technical expertise in the area of acoustic measurements. The technical manager is responsible for the laboratory test procedures, equipment and technical training and should have specific experience and expertise in acoustic measurements.

Facilities, Equipment and Reference Materials. An ISO Guide 25 quality program not only requires that the laboratory have a quality system to control and document the test it performs, but also that it has the facilities and equipment to properly implement the industry test standards. In the case of a laboratory that measures computer and business equipment noise emissions, the laboratory would need to have the facilities and equipment to measure noise emissions in accordance with ISO 7779 [2] (i.e. anechoic, hemi-anechoic or reverberation chambers and Type 1 sound level measurement equipment). In addition, the laboratory needs to have written test procedures that adapt the requirements of ISO 7779 to the specific facilities and equipment of the laboratory and these test procedures need to be readily available and rigorously utilized by laboratory personnel.

Personnel and Training. An ISO Guide 25 quality program requires that the laboratory employ technically competent personnel and that they are properly trained for the specific acoustic measurements to be conducted. The laboratory should have a technical manager that has both the background and experience to oversee the development and implementation of the laboratory's test procedures. Laboratory technicians must be properly trained on the use of the equipment and the test procedures. Written procedures for training personnel and documenting the training should be outlined in the laboratory quality manual. Both initial and periodic training records for personnel should be kept current.

Document Control Procedures. At the heart of an ISO Guide 25 quality program is the concept of documentation. Laboratories are required to develop written policies and procedures to address each applicable requirement of the checklist. The traceability of the measurement results are inherently related to the laboratory quality programs that insure that what is tested is properly documented and that the tests are conducted in accordance with the laboratory's written test procedures. Many quality programs implement documentation programs by creating standardized forms and logs that facilitate thorough and efficient documentation of the test.

Also important in the laboratory document control program are defined procedures for how documents are controlled and revised on a periodic, or as-needed, basis. Procedures to insure that laboratory personnel utilize the most recent and approved versions of the laboratory documents must be established. One way to implement these requirements is to establish a process for creating, maintaining and identifying "controlled documents" within the laboratory. Binding or original copies, hand initialing or electronic security measures are all methods of creating such controlled documents.

ISO Guide 25 requirements for certificates and reports may also be addressed as a part of the document control program by creating controlled document test report templates that are to be utilized by laboratory personnel in the reporting of noise emission test results. Such test report templates insure that all test report data is presented in a consistent and technically competent manner and meet the detailed test report requirements of ISO Guide 25 and ISO 7779.

Calibration. While calibration is not the only component of the quality program that insures traceability of noise emission measurements, it is a fundamentally important element of measurement traceability. The laboratory calibration program should facilitate an understanding of the calibration process as it applies to noise emission measurement, insure traceability to national standards of measure and insure that the laboratory properly utilizes calibration data.

The most important reference standards used in acoustics laboratories that make computer and business equipment noise emission measurements are microphone calibrators and/or reference sound sources (RSS). Direct method sound power measurements primarily rely on the use of a traceably calibrated microphone calibrator and a test environment that has been qualified in accordance with the industry test standard to insure measurement traceability. Comparison method based sound power measurements primarily rely on the use of a traceably calibrated RSS to insure traceability, but may also rely on a traceably calibrated microphone calibrator if RSS comparison measurements are not made during each measurement session.

The primary transducers and reference standards (i.e. microphones, microphone calibrators and RSS) used in computer and business equipment noise emission measurements cannot be adjusted during the calibration process. Calibration of these devices involves a functionality check and a measurement of the response or output of the device. The acoustics laboratory calibration program should include procedures for a "post-calibration review" that requires laboratory personnel to review all information on calibration certificates and to make any adjustments to software or equipment that utilizes the measured calibration data. For example, if data analysis software make a correction for the frequency response of the microphone(s), the post-calibration review process would include instructions for updating this information in the software at the completion of each calibration cycle. On the other hand, if the laboratory makes the assumption that the frequency response of the microphones is flat to the upper measurement frequency, the post-calibration review process should include instructions to the laboratory technical director to review the calibration laboratory measured frequency response reported on the calibration certificate. Consideration should them be given to rather or not such assumptions are still valid.

Other laboratory measurement instruments, such as real-time analyzers, voltmeters, temperature gauges, humidity gauges and strobes may also contribute to the traceability of the measurement and must also be considered in the calibration program. The calibration process for these devices may involve an adjustment that brings the device back into calibration. For such devices, it is important to specify that calibration laboratories provide "as found" measurements prior to making any adjustments. The post-calibration review process should include instructions for reviewing the magnitude of any adjustments made to such instruments to bring them into calibration. The laboratory technical director should consider the affect these adjustments may have on the uncertainty in any data reported using these devices prior to the calibration. The magnitude of any adjustments made to such devices, or the change in response or output of reference standards and transducers, may also cause the laboratory technical director to consider changing the calibration interval for the device.

In order to insure traceability of measurements it is important that calibration laboratories utilized by the acoustics laboratory have a quality program in place. Many bodies that accredit acoustics laboratories to ISO Guide 25 will require that the calibration laboratory used by the acoustics laboratory also have a quality program in place that meets ISO Guide 25 requirements. A fundamental element of the traceability of the noise emission measurements made by the acoustics laboratory is that it can rely on the traceability of the calibration data provided by the calibration laboratories it utilizes.

The calibration program may also address ISO Guide 25 requirements for estimation of the uncertainty of noise emission measurements. Calibration laboratories should be required to provide the acoustics laboratory an uncertainty estimate with each calibration. The acoustics laboratory

should consider this calibration uncertainty in its estimate of the uncertainty of the noise emission measurement. Source of uncertainty in the noise emission measurement may include calibration uncertainty in one or more instruments, internal repeatability of sound power measurement and inter-laboratory reproducibility of sound power measurements.

Quality Assurance. ISO Guide 25 requires a laboratory to define and implement a series of activities to insure the quality of the laboratory's work. These activities provide an ongoing check of the laboratory's measurement program that is designed to detect and correct measurement errors. Quality assurance activities that may be performed in acoustics laboratories that makes computer and business equipment noise emission measurements include validation of software calculations, proficiency and repeatability testing, and transducer sensitivity monitoring.

Most modern noise emission measurement programs rely on some form of computer software to convert the basic acoustic measurements into the noise emission test results. The laboratory quality assurance program must insure that the computations made by this software are both mathematically correct and in accordance with the industry test standard. A common method for validating software is to conduct and keep on file either hand calculations or independent computer calculations that check the computations of the software used by the laboratory. The laboratory technical manager should insure that such validation calculations test all possible conditions that the software may encounter when making such measurements.

Proficiency and repeatability testing generally involves the periodic measurement of the sound power of the laboratory RSS. The results of these periodic measurements can be used to evaluate the proficiency of laboratory personnel to operate equipment, follow test procedures and derive valid test results. They can also be used to quantify the intra-laboratory repeatability of sound power measurements, which can be used as a part of uncertainty estimates. These measurements can also assist laboratory personnel in identifying equipment or calibration problems.

Transducer sensitivity monitoring involves the tracking of the calibrated sensitivity of the laboratory microphones. Microphones are typically calibrated using the traceably calibrated reference standard (i.e. microphone calibrator) during each measurement session. The distribution of the calibration sensitivities over time can be a useful quality assurance check. Systematic drift or sudden changes in sensitivity may be a pre-cursor to microphone failure or may indicate calibration drift or malfunction of the microphone calibrator. Small, random fluctuations on the microphone sensitivity over time may be useful in the laboratory's measurement uncertainty estimates.

A complete ISO Guide 25 quality assurance program for an acoustics laboratory will most likely include other periodic activities other than those listed above. Other quality assurance activities may include an inter-laboratory comparison program, participation in round-robin testing programs, equipment monitoring and periodic checks of the laboratory logs.

Audit. The laboratory quality manual is not a static document. ISO Guide 25 requires that the quality program and its implementation be reviewed on a periodic basis and updated as needed. The very nature of the quality program is that it is constantly being reviewed and improved.

The laboratory quality program must establish a periodic program of both internal review and independent audit of the quality program. The individual responsible for initiating the review or audit and a schedule for these activities should be outlined in the quality program. Such reviews should include an evaluation of whether the quality program meets all of the requirements of ISO Guide 25 and whether laboratory personnel are properly implementing the quality program. A common method for conducting such reviews or audits is to use the ISO Guide 25 requirements in a checklist format to determine if the laboratory quality program satisfies all of the requirements. The audit also includes a review of recent laboratory work to insure it complies with the documented

quality program. The results of such reviews and audits should be documented, reviewed with company management and kept in the laboratory's files.

Many agencies that regulate the noise emissions of computer and business equipment require that laboratories be accredited to the requirements of ISO Guide 25. The accreditation process requires a periodic audit of the laboratory by an independent assessor. While the accreditation process insures that independent audits are conducted on a periodic basis (usually at least every two years), such audits are usually time-limited and can only insure compliance and competence at an overall level. The laboratory technical and/or quality manager is generally in a better position to conduct more frequent and detailed reviews of the laboratory quality program and should take an active role in the review and revision of the laboratory quality program. In addition, outside auditors retained by the laboratory are often useful to provide a more detailed, independent audit than can be provided by the laboratory manager or an accreditation assessment.

Complaints. ISO Guide 25 requires the laboratory to establish a documented process that laboratory clients or other parties may use to register complaints about laboratory activities. Such complaints my involve a questioning of laboratory test results, the laboratory's compliance with the requirements of ISO Guide 25 or compliance with its quality program. Such complaints should result in a review and/or audit of the laboratory test procedures, quality program or activities and, if determined to be valid, a revision of the laboratory's policies and procedures.

SUMMARY

An increasing number of regulatory agencies, ECO-labels and purchase specifications for computer and business equipment are requiring the reporting of acoustic noise emissions. Many of these require that measurements be conducted so as to be traceable to national standards of measure. Some also require the measurements to be conducted under the control of a quality system, such as that specified by ISO Guide 25. The quality system and technical requirements of ISO Guide 25 are easily and efficiently adapted to laboratories that make acoustic noise emission measurements of computer and business equipment. ISO Guide 25 provides a checklist of requirements that can be readily adapted to a "quality manual template" which can then be customized to the needs of a specific laboratory. Traceability of noise emission measurement relies not only on traceable calibration of instrumentation but also on the entire quality system. A well-designed quality system works with the day-to-day operations of the acoustics laboratory and can provide not only quality test results but an efficient and the lowest cost laboratory operation.

REFERENCES

1. ISO/IEC Guide 25-1990, "General requirements for the competence of calibration and testing laboratories"
2. ISO 7779-1988, "Measurement of airborne noise emitted by computer and business equipment"