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What defines a Sound Level Meter in the US has changed. ANSI/ASA S1.4 equals IEC 61672. Understanding the differences.

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ABSTRACT
What had been previously described as "The Atlantic Divide" in sound level meters (SLM) is gone. With the adoption of ANSI/ASA S1.4 (all three parts) from IEC 61672 (all three parts) in July 2014, the harmonization of the ANSI and ISO standard for Sound Level Meters is complete. Users of SLMs do not need to be expert in the details. However, a good understanding of the new regulation is needed if measurement results are ever challenged. We will review the new regulation from an end-user's view. We will describe what documentation verifies that a Class 1 sound level meter fulfills ANSI/ASA S1.4. Each part of ANSI/ASA S1.4/IEC 61672 has its intended audience from the SLM designer/manufacturer, accreditation body, to the calibration laboratory.

1 INTRODUCTION

Despite "The Atlantic Divide," the differences between the ANSI and ISO sound level meter standards were not large. The US ANSI/ASA and international IEC standards were kept intentionally similar.

This paper will review the divergent history of sound level standards in the US and the international ISO before the complete adoption of all parts of IEC 61672 in the US in 2014.

Two significant developments in the IEC standards from 2000 were:

- A process for independent pattern approval of a sound level meter design;
- The need to account for the uncertainty of measurement during pattern approval testing and laboratory calibration.

1.1 Purpose of standards

Standardization in general serves several purposes:

- Ensures that instruments and procedures are done in a repeatable way by different organizations;
- Codifies lessons learned from previous iterations.

When comparing results from different noise consultants, clients benefit from having the measurements and calculations done to the same standard with instruments of a known and documented precision.

For measurement standards, the tester also benefits working to a well-documented procedure such as ASTM E336 sound insulation testing. Instead of explaining/defending the measurement process and calculations in detail, a noise consultant can simply state that the measurement was done in accordance to a recognized standard.

Manufacturers, noise consultants, their clients, calibration laboratories and ultimately any person or organization using the results benefit from the documentation of details, framework, and assurance that standards provide.

Different parts of many standards are relevant to different parties. Like other high-level systems based on standards, for example the ISO *Open System Interconnection Reference Model* that underpins the Internet and web applications, multiple layers build on each other. The recipient of a noise report does not need to be master of the of IEC 61672 Part 1 any more than someone watching a movie on Netflix needs to understand the Internet's underlying Transport Layer. However, each layer needs to function as documented to allow the layers above to correctly operate.

Standards often vary from region to region reflecting differences like local laws, building construction methods and preferences of local practitioners. In measurement technology, there are sometimes multiple alternatives to approximate a true answer which is difficult or impossible measure.

In the measurement of sound, the effect that a physical microphone has on the sound field being measured is one area with multiple alternatives.

1.2 Why the US ANSI/ASA standards were historically different from IEC standards

The first standard for sound level meters IEC 123 was introduced in 1961. Standards represent the current technology and best practices in a field. As the knowledge contained in the standard increases, the amount of detail also tends to increase. Revisions and new standards also represent the institutional "lessons learned."

Various revisions of IEC 123 were released over the years. In 1979 a new sound level meter standard, IEC 651, was published without the vote of the US. The US had requested tighter calibration requirements to ensure precise measurements.

Four years later the American standard ANSI S1.4-1983 was published by the American Institute of Physics for the Acoustical Society of America. It conformed as closely as possible to the IEC 651:1979 standard for sound level meters; the principal differences were:

- Requirement for random-incidence calibration, as was customary in US, rather than the free-field method.
- Additional requirement for crest factor capability for Type 1 instruments, regardless of the inclusion of an impulse exponential-time-averaging characteristic.
- Deletion of Type 3 survey instrument.

The US' preference for more accurate measurements in random/reverberant/indoor conditions versus the ISO preference for more accurate measurement in free-field/outdoor conditions led to what Per Brüel described as "The Atlantic Divide."

The ANSI S1.4-1983 standard covering sound level meters with time-weighting, e.g. Fast and Slow, was reaffirmed multiple times and continued until 2014.

We will not review the relative merits of the different techniques; that has been well covered elsewhere. The "divide" was eventually bridged by technology, in this case advances in digital signal processing.

Figure 1: Brüel & Kjær Technical Review from 1983

Improvements in electronics technology allowed the time-averaged or equivalent continuous sound pressure level to be measured by integrating sound level meters. IEC 804 was adopted in 1985 to cover these new integrating sound level meters. Later in 1997 the standard ANSI S1.43 was adopted to cover integrating sound level meters in the US. It was intended to be consistent with IEC 804. Note that the introduction of ANSI S1.43 significantly lagged IEC 804s.

ANSI S1.43 and IEC 804 had the same principle differences as ANSI S1.4 and IEC 651: random incidence instead of free-field calibration and deletion of the Type 3 accuracy class. The "divide" persisted in the 1990s.

2 DEVELOPMENT OF IEC STANDARDS

The standard IEC 651 was renamed to IEC 60651 in 2000. It included all the technical specifications of a sound level meter, the required tests for pattern approval and the list of basic characteristic verifications by calibration labs. The idea of pattern approval in 2000 was something that was not adopted in any parallel ANSI/ASA standard. This was a significant divide which was not bridged until the adoption of IEC 61672 Part 2 in 2014.

In a major revision in 2002, IEC 60651 was separated into three parts of the new standard IEC 61672. The first edition of IEC 61672 accounted for the applicable specifications and the measurement uncertainty in testing for conformity.

At least as measured by output, the IEC was more active in the 2000s. While the US ANSI/ASA committees continued to reaffirm ANSI S1.4-1983, the parallel IEC committees were revising and amending their standards. Standards take significant effort to draft, review, release and update. There is efficiency to be gained by having a standard cover a larger region. It allows a larger pool of technical resources to share the work and creates a larger market for products that fulfill the standard.

A further revision to IEC 61672 followed in 2013. It amended the criteria for assessing conformance to a specification by a refining the calculation of measurement uncertainty. The update distinguished between the acceptance, the tolerance interval and the maximum-permitted uncertainty of measurement. The IEC committee definitely knew the meaning of the term meticulous.

Per Brüel's Atlantic Divide was effectively bridged in the 1990s. First by physical random incidence correctors clipped onto free-field microphones. Later in the 1990s, advances in digital signal processing allowed for the creation of digital filters that could correct a free-field microphone to measure more accurately in a random sound field or a random microphone in a free-field. The relevant measurement standards could now specify the appropriate correction for the application (e.g. sound insulation using diffuse field correction and outdoor, handheld sound using free-field). Technology had bridged the "divide" in practice. Now it was time for the standards to reflect what was now possible.

In 2014, ANSI/ASA S1.4 adopted IEC 61672-1:2013 and IEC 61672-3:2013. This was not a big change noticed by most users. North America's and the international standards were already very similar so most sound level meters already conformed to both sets of standards. IEC 61672 Part 2 was the part of the standard, inherited from IEC 60651 in 2000, that covered pattern evaluation.

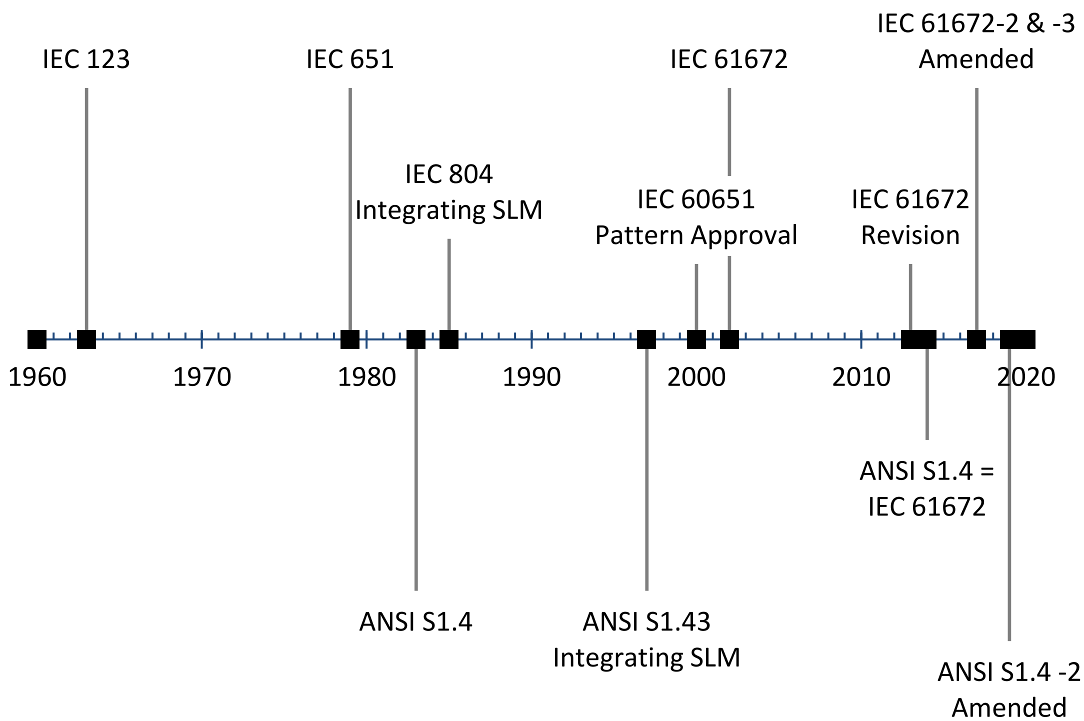

Figure 2: Timeline of ANSI/ASA and IEC standards by year

Table 1 is a list of the various IEC parts and their current ANSI/ASA S1.4 aliases

IEC	Title	ANSI/ASA S1.4 aliases
IEC 61672-1:2013	Electroacoustics - Sound level meters – Part 1: Specifications	ANSI/ASA S1.4:2014 PART 1
IEC 61672-2:2013 +AMD1:2017	Electroacoustics - Sound level meters – Part 2: Pattern evaluation tests	ANSI/ASA S1.4:2014 PART 2 (R2019)
IEC 61672-3:2013	Electroacoustics - Sound level meters – Part 3: Periodic tests	ANSI/ASA S1.4:2014 PART 3

Table 1: IEC 61672 parts, titles, and ANSI/ASA S1.4 aliases

3 IEC 61672-1:2013 SPECIFICATIONS OF SOUND LEVEL METERS

There are benefits to testing organizations and clients of a standard describing the capabilities of the instrumentation used. Results from different manufacturers and models can be compared, with documented uncertainties of measurement, without an appendix in each report going into detail of the capabilities of the measurement device.

Besides benefiting end users and practitioners, manufacturers of instrumentation benefit from standardization. Standards document the requirement, the limits and tolerances for each measurement and finally the reporting format.

Standards do act as a barrier to keep sub-standard devices out of a market, but standards also benefit competition. Models that fulfill a standard are objectively documented to be interchangeable in regards to type approved measurements. This allows users to decide between models based on usability, cost of ownership, or other features without needing to exhaustively investigate the technical details.

Part 1 of the IEC 61672 standard defines what a sound level meter is. All the specifications for the later Parts 2 and 3 come from Part 1. It is approximately 50 pages. Part 1 has sections covering:

- Terms and definitions
- Reference environmental conditions
- Performance specifications
- Environmental, electrostatic, and radio-frequency requirements
- Provision for use with auxiliary devices
- Marking
- Instruction Manual
- Two informative annexes and the three normative

The requirements in Part 1 is what a manufacturer needs to design to (e.g., precision, within a defined range, to environmental conditions like temperature, vibration and radio-frequency interference). Where a parameter's limits are not prescribed, the standard defines how that parameter is documented through an instruction manual.

3.1 Terms and definitions

The commonly used sound level meter parameters like time-weighted sound level (e.g. L_{AF}, L_{CS}), time-averaged sound level or equivalent continuous sound level (e.g. $L_{Aeq,T}$) and sound exposure level (e.g. $L_{AE,T}$) are defined.

In addition, this section defines terms relative in both field measurement and verification of sound level meters like sound-incidence angle and linear operating range. Mostly the section defines terms like directivity factor and coverage probability.

The terms and definition section includes six equations with details on each parameter.

3.2 Reference environmental conditions

The specified reference environmental conditions are an air temperature of 23 °C, a static pressure of 101,325 kPa and a relative humidity 50 %.

3.3 Performance specifications

This briefly describes the major components of a sound level meter: a microphone, a preamplifier, a signal processor, and a display device.

This section defines the minimum capabilities for a Class 1 sound level meters such as A- and C-weighting with Z-weighting optional. Other sub-sections cover: windscreen corrections, directional response, frequency weightings, level linearity, self-generated noise, time-weighting F and S, toneburst response, overload indication, under-range indication, stability during continuous operation (30 minutes), high-level stability (5 minutes), display and many others.

Measurement parameters, like frequency weighting and tone burst response, include acceptance limits for performance Class 1 and Class 2. Other parameters, like a digital display's update rate and the characteristics of the analogue or digital output, simply require documentation in the instruction manual.

3.4 Environmental, electrostatic, and radio-frequency requirements

The performance specifications for class 1 sound level meters apply to a static pressure range from 85 kPa to 108 kPa, an air temperature range from -10 °C to +50 °C and a relative humidity from 25 % to 90 %. Also sound level meter shall perform reliable measurements during an exposure to the specified electrostatic discharges and radio-frequency fields.

3.5 Provision for use with auxiliary devices

Sound Level Meters may be operated with auxiliary devices, such as a cable between the preamplifier and the analyzer part of the sound level meter. Another example is a weather protection for permanent outdoor noise monitoring applications. Any applicable corrections to the measurement data need to be listed in the instruction manual.

3.6 Marking

A short section on marking describes the information required to appear on the meter or shown on a screen of the display device:

- IEC standard and year of publication
- Supplier responsible for the technical specification
- Model number and serial number
- Performance class

3.7 Instruction Manual

IEC 61672 Part 1 requires that an instruction manual be supplied with each sound level meter. Throughout the various sections the standard defines what details need to appear in the instruction manual. In addition, the last section goes into greater detail about what needs to be included. For a user the most relevant details are:

- Class 1 or Class 2
- Model numbers of microphones that allow it to conform to the specified class
- Any windscreen correction
- Highest anticipated level of self-generated noise for each microphone
- Lower and upper boundaries of the linear operating ranges for A-, C- and Z-weightings (or sub-set of weightings in the meter)
- At least one model of sound calibrator conforming the matching class in IEC 60942

The instruction manual is what is verified by the pattern approval organization for IEC 61672-2 and taken as a reference by the calibration laboratory for testing in accordance with IEC 61672-3. Eventually the instruction manual is used by the sound level meter's operator. The instruction manual is a useful resource for advanced users looking for more detail than what is provided in a sound level meter's specification.

Part 1 acts as a requirement specification for what the sound level meter needs to do and what the instruction manual needs to contain. A sound level meter's instruction manual, the information it contains and its format is a significant part of IEC 61672-1 (as it was in ANSI/ASA S1.4 and S1.43).

3.8 Additional details relevant to end users

A Class 2 sound level meter can meet certain requirements of Class 1. However, a sound level meter must meet all the Class 1 requirements to be Class 1.

Section 5.1.16 requires that the microphone capsule be removable to allow insertion of electrical test signals. Many of the test signals would be difficult or impossible to produce acoustically with the required uncertainty needed for pattern approval, Part 2, and calibration, Part 3.

A consequence of this requirement is that a sound level meter with a non-removable microphone capsule cannot be type approved currently.

Level linearity for the sound level meter model is tested for pattern approval and the individual sound level meter's level linearity is tested as part of calibration. There is a requirement for the linear range being at least 60 dB at 1 kHz in the reference level range. If a meter has multiple input ranges, the overlap in linear ranges needs to be at least 40 dB for integrating sound level meters (or 30 dB for sound level meters that only measure time-weighted sound levels).

4 PATTERN EVALUATION TESTS

As discussed earlier, being able to claim that a sound level meter meets a standard has significant value to a manufacturer. Before IEC 60651:2000 and the US's adoption of ANSI/ASA S1.4:2014 (IEC 61672-2:2013), it was left to the manufacturer to document conformance through the instruction manual.

There is value in an external organization independently verifying that an instrument fulfills a standard. An external accrediting organization has the technical expertise and objectivity required. Of course, laboratories doing the pattern evaluation need a standard describing what measurement they need to make and how to document them.

IEC 61672 Part 2 states:

> *This part of IEC 61672 provides details of the tests necessary to verify conformance to all mandatory specifications given in IEC 61672-1 for time-weighting sound level meters, integrating-averaging sound level meters, and integrating sound level meters. Pattern evaluation tests apply for each channel of a multi-channel sound level meter, as necessary. Tests and test methods are applicable to class 1 and class 2 sound level meters. The aim is to ensure that all laboratories use consistent methods to perform pattern-evaluation tests.*

The manufacturer submits three samples with the instruction manual and all items or accessories identified as integral for normal mode of operation. Also, a calibrator specified in the sound level meter's instruction and the calibrator's instruction manual must be submitted.

If the sound level meter doesn't have the correct markings and instruction manual, no pattern-evaluation tests will be performed. The instruction manual is as much a part of the submittal as the actual sound level meter

The key deliverable from IEC 61672-2 is the type-examination certificate. It documents the standard tested to, the class of the instrument and configuration of the instrument: microphone, accessories and firmware version.

5 PERIODIC TESTS

Instrumentation, especially hand-held devices or those left outdoors, can fail or be damaged. A field check with an acoustic calibrator at a single tone and sound pressure level may detect some of these problems. IEC 61672 Part 1 requires at least one compatible field calibrator be listed in the instruction manual. Other problems like a change to the microphone's frequency response or an increased noise floor can best be detected with a laboratory calibration. IEC 61672 Part 3 details the tests that a calibration laboratory should perform on an individual sound level meter to ensure it is still operating correctly. The tests in Part 3 are only a subset the tests done in Part 2.

Part 3 states clearly that it is not a full and exhaustive test:

> *The purpose of periodic testing is to assure the user that the performance of a sound level meter conforms to the applicable specifications of IEC 61672-1 for a limited set of key tests and for the environmental conditions under which the tests were performed. The extent of the tests in this part of IEC 61672 is deliberately restricted to the minimum considered necessary for periodic tests.*

Sending in a sound level meter for calibration does not require an instruction manual to be added in the box but it needs to be available to the calibrating laboratory; access to the user manual via the manufacturer's website is acceptable.

However, if there are no markings (or at least evidence they were there) in accordance with IEC 61672 Part 1, then the statement that calibration had been carried out in accordance with procedures from IEC 61672 Part 3 should not appear on the calibration certificate. IEC 61672 Part 3 also says that the certificate should mention availability or non-availability of pattern-evaluation tests to IEC 61672-2. Calibration laboratories performing periodic tests to IEC 61672 Part 3 should check for evidence of a type-examination certificate, that the sound level meter conforms to all parts of IEC 61672-1.

6 HOW TO CHECK IF A SOUND LEVEL METER IS TYPE APPROVED

The first document to check for is the type-examination certificate for the sound level meter model. The sound level meter's manufacturer should make the type-examination certificate available. It is important to check the configuration of the instrument: microphone, accessories and firmware version.

The second document is the calibration certificate for an individual sound level meter. The certificate should state conformance to IEC 61672 or ANSI/ASA 1.4:2014 Part 3. The configuration calibrated, including firmware, should match a configuration listed on a type-examination certificate.

Again, both documents are necessary to show a sound level meter is type approved. As IEC 61672 Part 3 states:

> *Because of the limited extent of the periodic tests, if evidence of pattern approval is not publicly available, no general conclusion about conformance to the specifications of IEC 61672-1 can be made, even if the results of the periodic tests conform to all applicable requirements of this edition of IEC 61672-3.*

7 WHEN IS A TYPE APPROVED SOUND LEVEL METER IS REQUIRED?

ANSI/ASA S1.4 and IEC 61672 are very definite and proscribed. However, when a type approved sound level meter is required is not listed. This information is part of application standards for sound level measurements, which may differ from country to country.

There are instances when a measurement standard or local noise ordinance clearly states that the sound level meter used must conform to class 1 of the ANSI/ASA S1.4:2014 or "current version" ANSI/ASA S1.4 or IEC 61672. For older standards and laws that require conformance to a previous version of the standard or reference "type" instead of "class" it is less clear. Having a fully typed approved sound level meter with current calibration to ANSI/ASA S1.4 Part 3 would definitely fulfil any measurement standard or noise ordinance.

The general statement is "a type approved sound level meter with current calibration to ANSI/ASA S1.4 Part 3 is recommended when measurement data could be challenged in court".

Clients, governing bodies, or other organizations may require measurements from only type approved instruments. Just measurements intended for internal use, like product evaluation, do not require type approval.

Summarized, all sound level meters with type-examination certificate for the model and a current calibration certificate are "good" instruments.

It is helpful to recall what measurement functions are verified as part of pattern evaluation and subsequent periodic verifications. Parameters like broadband LAeq and 1/3-octave filters (to IEC 61260) are tested. Other parameters like reverberation time RT60 are not verified as part of pattern evaluation but do have standards defining their measurement and calculation. There are other parameters like level statistics Ln that are verified just by some pattern-approval laboratories according national standards. This can lead to differences between sound level meter.

8 SUMMARY

Originally there was an Atlantic Divide between the American ASTM and international ISO based mainly on local preferences to using pressure (random incidence) or free-field microphones.

Digital filters to allow one microphone to be corrected for measurements in either diffuse or free-fields bridged the original divide. This is reflected in ANSI/ASA's adoption of IEC 61672 Parts 1 and 3 in 2014.

However, during the separation ANSI/ASA standards in the US, the international IEC standards continued to evolve.

One significant change with the adoption of IEC 61672 Part 2 in the US in 2014 is the concept of pattern evaluation of a sound level meter's hardware and any firmware leading to type approval. This independent testing of a sound level meter model and its instruction manual's conformance to the IEC 61672 Part 1 requirements produce another document, the type approval certificate.

The type approval certificate for the sound level meter model and an individual sound level meter's calibration certificate, defined under IEC 61672 Part 3, document that a sound level meter can be used for measurement requiring a type approved instrument. Neither document alone is sufficient to show compliance since they build on each other.

9 ACKNOWLEDGEMENTS

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