Personal Noise Exposure

Understanding Noise Measurement Uncertainty

LARSON DAVIS
A PCB DIVISION

Introduction

Ken Cox

- Larson Davis experience
  - Larson Davis BDM (2023 – current)
  - Larson Davis Product Manager (2011 - 2023)
  - Engineering management (2001 - 2011)
  - Product development (1987 - 2001)
- Individual expert ANSI/ASA S1 & S12 (2005 – current)
- Individual expert IEC TC/29 (2006 – current)

Agenda

- Current practice
- Measurement uncertainty
- Example

Quality measurements take work

How do I know the results are correct?

Metrology

Legal Metrology – A process to ensure data is accurate and will stand legal scrutiny

- Traceability – ability to verify accuracy through reference to national standards
- Calibration – Verify accuracy through traceable testing
  - Verify instrument complies with stated specifications (ANSI S1.25, ANSI S1.4, etc.)

How to ensure a high quality calibration

- ISO 17025 – Standard for good metrology practices
- Testing facility is periodically reviewed by independent auditor
  - ILAC, A2LA, SCC, CALA, etc.
- Pattern Approval (SLM)

ilac-MRA

ACCREDITED
Cert. #3622.01

Traceability

Ability to track measurement back to a national standard

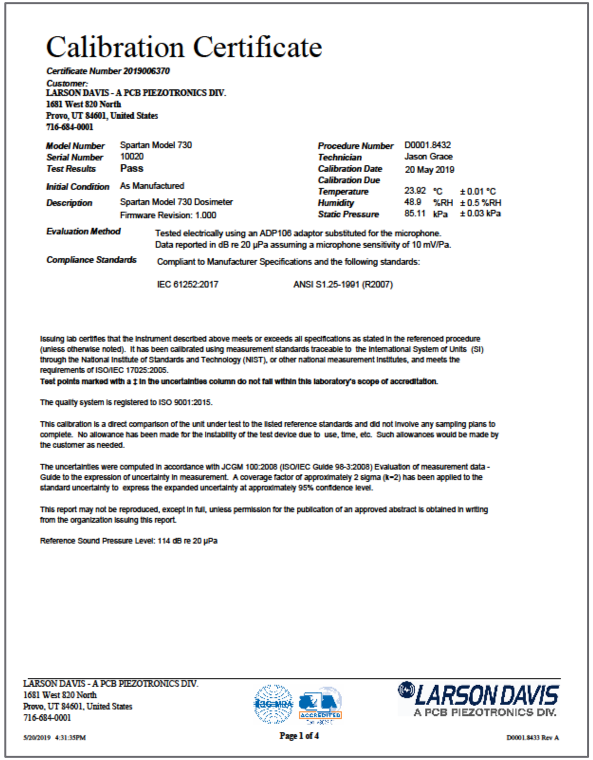
Examples:

- Calibrator calibrated using reference microphone
- Microphone calibrated using EA
- Voltage measurement made with calibrated volt meter
- Voltage reference from national lab

Certification

Product tested by manufacturer or independent lab

- Consider lab quality
- Lab has measurement uncertainty



Calibration Certificate

Certificate Number 2019006370

Customer:
LARSON DAVIS - A PCB PIEZOTRONICS DIV.
1681 West 820 North
Provo, UT 84601, United States
716-684-0001

Model Number	Spartan Model 730	***Procedure Number***	D0001.8432
Serial Number	10020	***Technician***	Jason Grace
Test Results	Pass	***Calibration Date***	20 May 2019
		Calibration Due	
Initial Condition	As Manufactured	***Temperature***	23.92 °C ± 0.01 °C
Description	Spartan Model 730 Dosimeter	***Humidity***	48.9 %RH ± 0.5 %RH
	Firmware Revision: 1.000	***Static Pressure***	85.11 kPa ± 0.03 kPa

Evaluation Method Tested electrically using an ADP106 adaptor substituted for the microphone. Data reported in dB re 20 μPa assuming a microphone sensitivity of 10 mV/Pa.

Compliance Standards Compliant to Manufacturer Specifications and the following standards:

IEC 61252:2017 ANSI S1.25-1991 (R2007)

Issuing lab certifies that the instrument described above meets or exceeds all specifications as stated in the referenced procedure (unless otherwise noted). It has been calibrated using measurement standards traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST), or other national measurement institutes, and meets the requirements of ISO/IEC 17025:2005.
Test points marked with a ‡ in the uncertainties column do not fall within this laboratory's scope of accreditation.

The quality system is registered to ISO 9001:2015.

This calibration is a direct comparison of the unit under test to the listed reference standards and did not involve any sampling plans to complete. No allowance has been made for the instability of the test device due to use, time, etc. Such allowances would be made by the customer as needed.

The uncertainties were computed in accordance with JCGM 100:2008 (ISO/IEC Guide 98-3:2008) Evaluation of measurement data - Guide to the expression of uncertainty in measurement. A coverage factor of approximately 2 sigma (k=2) has been applied to the standard uncertainty to express the expanded uncertainty at approximately 95% confidence level.

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Reference Sound Pressure Level: 114 dB re 20 μPa

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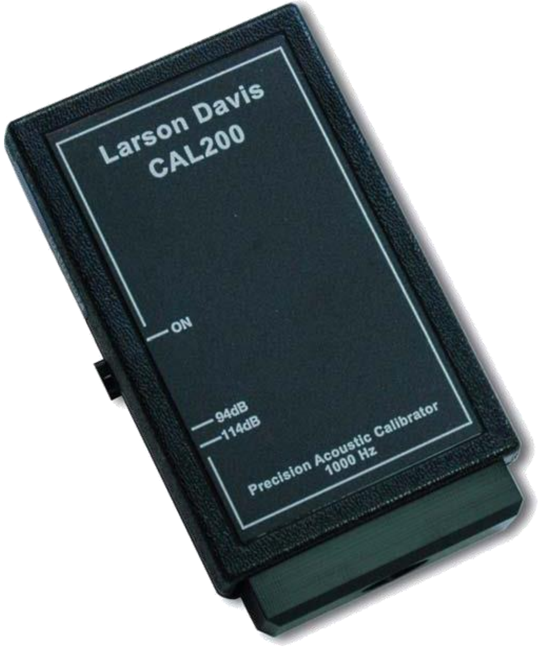
D0001.8433 Rev A

Ensuring meter results

- Does calibration lab make accurate measurements?
  - Traceability
  - ISO 17025 accreditation
- Is calibration lab test suite inclusive?
  - ANSI S1.4 part 3 compliance for SLM
- Is my meter as accurate as the manufacturer claims?
  - ANSI S1.4 part 2 pattern approval

Ensuring measurement results

- Calibrate before measurement
- Check calibration after measurement



How Accurately Does My Measurement Reflect Actual Exposure?

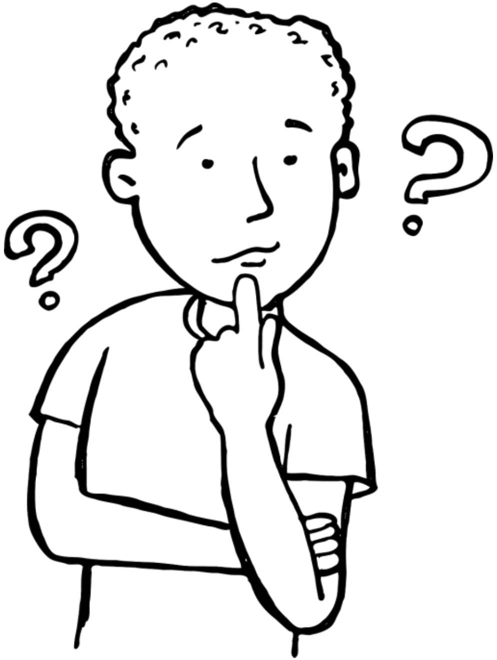
- When my SLM shows sound level as some dB, is it accurate?
- How accurate is the dose reported by my noise dosimeter?

Measurement Uncertainty (MU)

- Uncertainty – “doubt about the validity of results of a measurement”
- Measurement Uncertainty – “parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand”
- GUM standardized how to express measurement uncertainty

JCGM 100:2008 GUM - https://www.bipm.org/documents/20126/2071204/JCGM_100_2008_E.pdf

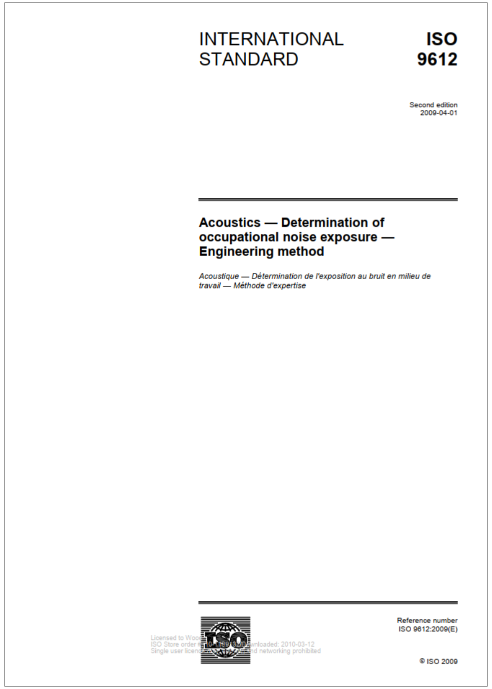
ISO 9612 Measurement Uncertainty



Scientific analysis of measurement accuracy

- Sources of uncertainty
  - Variations in daily work, operating, conditions, etc.
  - Instrumentation and calibration
  - Microphone position
  - False noises like rubbing on clothing or wind
  - Non-typical noise sources like music or alarms

ISO 9612 – Occupational Noise Level


INTERNATIONAL STANDARD

ISO 9612

Second edition
2009-04-01

Acoustics — Determination of occupational noise exposure — Engineering method

Acoustique — Détermination de l'exposition au bruit en milieu de travail — Méthode d'expertise

Reference number
ISO 9612:2009(E)

© ISO 2009

- Presents three methods
  1. Task based
  2. Job based
  3. Full shift measurement
- Provides measurement uncertainty

MU - Time

Potential variation in results due to variations in time a worker spends at noisy or quiet tasks

MU - Samples

N	Uncertainty contribution c_1u_1 of measured values $L_{p,A,eqT,n}$ dB											
	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6
3	0,6	1,6	3,1	**5,2**	**8,0**	**11,5**	**15,7**	**20,6**	**26,1**	**32,2**	**39,0**	**46,5**
4	0,4	0,9	1,6	2,5	**3,6**	**5,0**	**6,7**	**8,6**	**10,9**	**13,4**	**16,1**	**19,2**
5	0,3	0,7	1,2	1,7	2,4	3,3	**4,4**	**5,6**	**6,9**	**8,5**	**10,2**	**12,1**
6	0,3	0,6	0,9	1,4	1,9	2,6	3,3	**4,2**	**5,2**	**6,3**	**7,6**	**8,9**
7	0,2	0,5	0,8	1,2	1,6	2,2	2,8	3,5	**4,3**	**5,1**	**6,1**	**7,2**
8	0,2	0,5	0,7	1,1	1,4	1,9	2,4	3,0	**3,6**	**4,4**	**5,2**	**6,1**
9	0,2	0,4	0,7	1,0	1,3	1,7	2,1	2,6	3,2	**3,9**	**4,6**	**5,4**
10	0,2	0,4	0,6	0,9	1,2	1,5	1,9	2,4	2,9	3,5	**4,1**	**4,8**
12	0,2	0,3	0,5	0,8	1,0	1,3	1,7	2,0	2,5	2,9	3,5	**4,0**
14	0,1	0,3	0,5	0,7	0,9	1,2	1,5	1,8	2,2	2,6	3,0	3,5
16	0,1	0,3	0,5	0,6	0,8	1,1	1,3	1,6	2,0	2,3	2,7	3,2
18	0,1	0,3	0,4	0,6	0,8	1,0	1,2	1,5	1,8	2,1	2,5	2,9
20	0,1	0,3	0,4	0,5	0,7	0,9	1,1	1,4	1,7	2,0	2,3	2,6
25	0,1	0,2	0,3	0,5	0,6	0,8	1,0	1,2	1,4	1,7	2,0	2,3
30	0,1	0,2	0,3	0,4	0,6	0,7	0,9	1,1	1,3	1,5	1,7	2,0

Standard deviation of job measurements (LAeq)

More samples = lower uncertainty

MU – Operation Conditions

Examples

- Equipment condition
- Varying materials in use
- HVAC or fans
- Doors open / closed
- Equipment currently in use

MU - Instrumentation

Potential inaccuracies of measurement instrumentation

- ISO 9612
  - Class 1 SLM = 0.7 dB
  - Class 2 SLM = 1.5 dB
  - Noise dosimeter = 1.5 dB

MU – Microphone Position

Sound level tends to vary by measurement location

- ISO 9612
  - Location uncertainty = 1.0 dB
  - Due to effects of microphone worn on body

MU – False Noises

- Dropped meter
- Tampering
- Rubbing against clothing

Must be managed during measurement. Not accounted for in ISO 9612

MU – Atypical Noise Sources

- Radios
- Alarms or other unusual noises

Must be managed during measurement. Not accounted for in ISO 9612

Noise at Work History

- Noise is among the oldest occupational hazards. An 18th century report noted hearing loss among coppersmiths whose "ears are injured by that perpetual din" from hammering on metal.
- **1963**: UK minister of Labour publication highlighted noise at work and set a 90 dB threshold
- **1968**: Japan passes first workplace noise law
- **1971**: OSHA 29 CFR 1910.95 noise regulation published at 90 dB
- **1972**: NIOSH publishes 85 dB recommended exposure level
- **1975**: NIOSH publishes Noise Control Manual
- **1979**: Netherland enacted national noise control
- **1981**: OSHA HC level of 85 dB published
- **1989**: UK published Noise at Work regulations

ISO 9612 LEX?

- OSHA was one of first to implement noise regulation
  - Remains unchanged today from 1971
  - Now one of the least protective
- Rest of world has moved on
  - LEX “Level EXposure” is now commonly used
    - LEX = Leq normalized to 8 hours
    - LEX PEL = 85 dB is now common

Confidence Interval

- ISO 9612 uses a one sided confidence interval of 95%
  - 95% of all actual measurement are less than Lex + U
    - U = expanded measurement uncertainty
    - U = ku where
      - k = 1.65
      - u = standard measurement uncertainty

ISO 9612 Uncertainty Examples

- Annex C = procedure
- Annex E = Example
- 95% confidence interval
- >3 dB expanded uncertainty is common

Measuring Noise – Task based

Task Based (ISO 9612)

- Typically uses SLM
- Sound level at each task
- Time for worker at each task
- Can be used with $L_{Aeq,T}$ as input to get results & measurement uncertainty

ISO 9612 **Evaluation of measurement uncertainties (Annex C)** **Task-based measurement**

Data

Slm Utility-G3

For each task :
- Use yellow cells to enter the measured values Lp,A,eqT,mi and (if needed) a task name
- Use green cells to enter daily duration, in hours (ex : 7,5 for 7 h 30 min) ; indicate, at least, one value,
- Use violet cells to enter u2, uncertainty due to measuring instrumentation (see Annex C, Table C.5 : u2 = 0,7 or 1,5 dB)

Results obtained from the input of data

Daily noise level

$L_{EX,8h}$ =

Tasks defined

Number

Duration total (h)
0.0

	Task 1		Task 2		Task 3		Task 4		Task 5		Task 6		Task 7	
Task name	Press;		Drill;		Saw;		Grinder;							
Sample number	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)	Noise Levels (dB)	Task duration (h)
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
Measur.	u2		u2		u2		u2		u2		u2		u2	
Instrum.	1.5		1.5		1.5									

	Task 1		Task 2		Task 3		Task 4		Task 5		Task 6		Task 7	
Number of measured values	0		0		0		0		0		0		0	
Lp,A,eqT,m : Energy average														
Standard uncertainty u1a														
Tm : Duration of task m (h)														
Standard uncertainty u1b														

Measuring Noise – Job based

Job Based (ISO 9612)

- Typically uses dosimeter
- Worn for entire shift
- Can be use $L_{Aeq,T}$ for measurement uncertainty

ISO 9612 Evaluation of measurement uncertainties (Annex C)
Job-based measurement and full day measurement

To enter data : use the yellow cells only

Measured values

	Noise levels (dB)
$L_{p,A,eqT,1}$	88.1
$L_{p,A,eqT,2}$	86.1
$L_{p,A,eqT,3}$	89.7
$L_{p,A,eqT,4}$	86.5
$L_{p,A,eqT,5}$	91.1
$L_{p,A,eqT,6}$	
$L_{p,A,eqT,7}$	
$L_{p,A,eqT,8}$	
$L_{p,A,eqT,9}$	
$L_{p,A,eqT,10}$	
$L_{p,A,eqT,11}$	
$L_{p,A,eqT,12}$	
$L_{p,A,eqT,13}$	
$L_{p,A,eqT,14}$	
$L_{p,A,eqT,15}$	
$L_{p,A,eqT,16}$	
$L_{p,A,eqT,17}$	
$L_{p,A,eqT,18}$	
$L_{p,A,eqT,19}$	
$L_{p,A,eqT,20}$	

Number of measured values N = 5

Parameters

To (h) = 8

Effective duration Te of the working day (in hours)

Te = 7.5

Standard uncertainty of measuring instrumentation (Table C.5)

u_2 = 1.5

Standard uncertainty due to imperfect selection of measurement position

u_3 = 1

Calculations
(ISO references)

(Eq. C.8)	$L_{EX,8h}$ =	**88.4**
(Eq. 11)	$L_{p,A,eqTe}$ =	88.7
(Eq. C.12)	u_1 =	2.12
(Table C.4 for N and u1)	$c_1{*}u_1$ =	1.88

Combined standard uncertainty

Sources of uncertainty =

1) Noise levels	$(c_1{*}u_1)^2$ =	3.52
2) Instrumentation Q2	$(u_2)^2$ =	2.25
3) Microphone position Q3	$(u_3)^2$ =	1
Sum (C.9)	$u^2(L_{EX,8h})$ =	6.77
	$u(L_{EX,8h})$ =	2.6

$U(L_{EX,8h}) = 1{,}65 * u(L_{EX,8h})$ = **4.3**

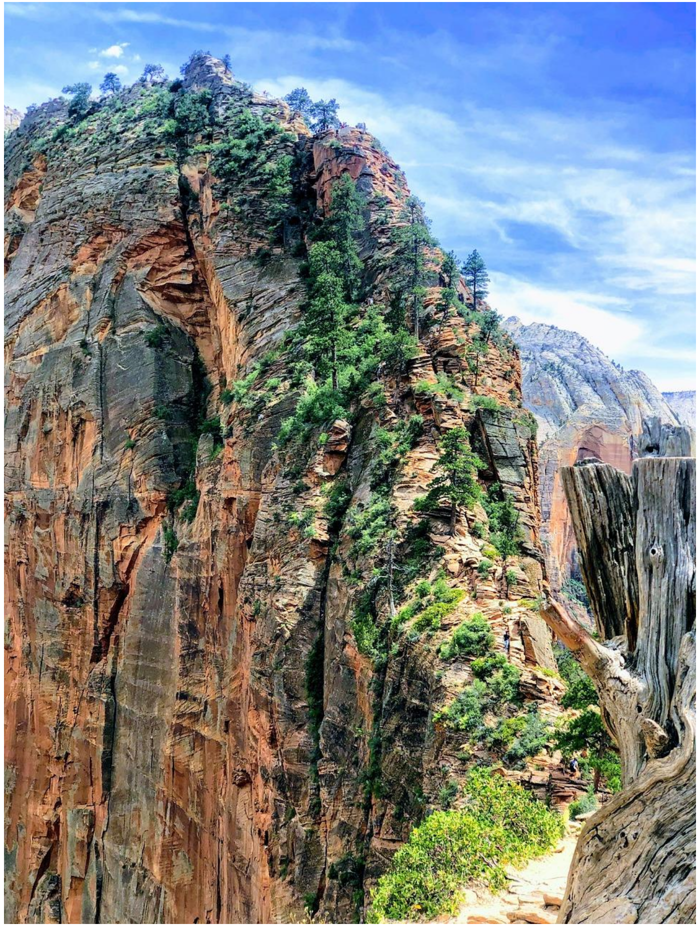
Daily noise exposure level	**88.4**	dB
Expanded uncertainty	**4.3**	dB

Questions and Answers

- **How accurate is my measurement?**
  - Annual calibration with traceability
    - ISO 17025 preferred
  - Acoustic calibration before and after measurement
  - For SLM, pattern approval available
- **Do measurements reflect actual noise exposure?**
  - Check for atypical or false noises
  - Evaluate measurement uncertainty

Follow Procedures

- Avoid shortcuts
- You get what you pay for
- Leverage learning opportunities



Questions