INTERNATIONAL STANDARD

ISO 21250-1

First edition
2020-07

Rolling bearings — Noise testing of rolling bearing greases —

Part 1: Basic principles, testing assembly and test machine

Roulement — Essais de bruit de graisse pour roulement —

Partie 1: Règles de base, arrangement d'essais, machine de test

Reference number
ISO 21250-1:2020(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 4, *Rolling bearings*.

A list of all parts in the ISO 21250 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The rolling bearing life theory emphasizes the use of pure and homogeneous lubricants as essential for a long bearing service life. The lubrication of rolling bearings is described in several national standards. The GfT worksheet 3[11] contains theoretical and practical knowledge of rolling bearing lubrication.

Grease lubrication is the most common type of rolling bearing lubrication. The purity grade of bearing grease is influenced by thickeners, base oils, additives and solid lubricant additives as well as the manufacturing process and is reflected in the running noise. Therefore, noise testing of rolling bearing greases is recommended.

In addition, grease noise testing in accordance with this document allows the grease manufacturers to develop low-noise lubricants with better damping properties. This document can also support the rolling bearing manufacturers and end-users in the selection of low noise grease with better damping properties.

This document covers basic principles, requirements for the testing assembly and the test machine to determine and assess the noise characteristics of bearing grease jointly with ISO 21250-2, ISO 21250-3 and ISO 21250-4.

Rolling bearings — Noise testing of rolling bearing greases —

Part 1: Basic principles, testing assembly and test machine

1 Scope

This document specifies:

— basic principles, testing assembly and the test machine for noise testing of rolling bearing greases;

— symbols used in the test methods BQ+, MQ and NQ.

This document is applicable for testing rolling bearing greases, especially of unused grease.

NOTE Suitable greases are greases of NLGI classes 1 to 3 according to DIN 51818[6]. Suitable greases for lubrication of rolling bearings are especially greases according to ISO 12924. The test method according to this document delivers meaningful results for rolling bearings; however, it can also be applied for greases in similar applications[12][13].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 492, *Rolling bearings — Radial bearings — Geometrical product specifications (GPS) and tolerance values*

ISO 5593, *Rolling bearings — Vocabulary*

ISO 5753-1, *Rolling bearings — Internal clearance — Part 1: Radial internal clearance for radial bearings*

ISO 15242-1:2015, *Rolling bearings — Measuring methods for vibration — Part 1: Fundamentals*

ISO 21250-2, *Rolling bearings — Noise test of rolling bearing greases — Part 2: Test and evaluation method BQ+*

ISO 21250-3, *Rolling bearings — Noise test of rolling bearing greases — Part 3: Test and evaluation method MQ*

ISO 21250-4, *Rolling bearings — Noise test of rolling bearing greases — Part 4: Test and evaluation method NQ*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5593, ISO 15242-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
noise
vibration that is a random mechanical energy process of spectral density varying continuously with frequency and perceived as acoustic actions that are neither acoustic shocks nor a series of harmonic tones nor complex tones and which are substantially uniform over time

Note 1 to entry: Noise can be represented mathematically, that is as Fourier integral which can be expressed as the sum of a series of plain vibrations. Its distinguishing characteristic, as opposed to other acoustic actions with discrete frequencies, is a spectrum with irregular amplitudes of each frequency.

3.2
start-up noise
v_{SUN}
noise (3.1) at the start of the bearing testing

3.3
noise level
v_{NL}
noise (3.1) of the bearing calculated as the average value or rms of measuring points

Note 1 to entry: The number of measuring points and measuring time depend on the test method.

3.4
noise peak
v_{NP}
peak value of the bearing *noise* (3.1)

3.5
peak count
number of peak signals exceeding a defined threshold level

3.6
calibrator
measurement standard that provides a sinusoidal vibration speed at certain frequencies and defined amplitudes

3.7
grease damping
GD
attenuating effect of the lubricant, which is related to the vibration excitation of the bearing

4 Symbols, abbreviated terms and subscripts

The symbols and abbreviated terms contained in Table 1 and the subscripts contained in Table 2 apply to the noise testing of greases according to test methods BQ+, MQ and NQ.

Table 1 — Symbols and abbreviated terms

Symbol	Unit	Description
BQ+[a]	—	Method BQ+ according to ISO 21250-2
GD	—	Grease damping
H[a]	—	High band, H-band (1 800 Hz to 10 000 Hz)
i[a]	—	Consecutive number
L[a,b]	—	Low band, L-band (50 Hz to 300 Hz)

[a] Can be used as subscript, too, where necessary.

[b] The L-band is used in noise and vibration analysis in the ISO 15242 series. However, this document does not consider this frequency range for grease noise testing and its analysis.

Table 1 *(continued)*

Symbol	Unit	Description
M[a]	—	Medium band, M-band (300 Hz to 1 800 Hz)
MQ[a]	—	Method MQ according to ISO 21250-3
M&H[a]	—	Medium band and high band, M&H band (300 Hz to 10 000 Hz)
n	—	Number of noise counts
NQ[a]	—	Method NQ according to ISO 21250-4
v	$\mu m \cdot s^{-1}$	Vibration velocity
$\overline{v}_i$	$\mu m \cdot s^{-1}$	Vibration velocity, twice smoothed to the counting point i

[a] Can be used as subscript, too, where necessary.

[b] The L-band is used in noise and vibration analysis in the ISO 15242 series. However, this document does not consider this frequency range for grease noise testing and its analysis.

Table 2 — Subscripts

Subscript-symbol	Description
grease[a]	Greased bearing
NL[b]	Noise level, average value (of vibration velocity)
normal	Acceptable level of normal noise, greased bearing
NP[b]	Noise peak
pk	Peak value
ref	Reference, ungreased bearing
rms	Root mean square value of sinusoidal signal which has the same amplitude with actual peak value range of raceway noise
0–32	Starting interval 0 s to 32 s
32–64	Operating interval 32 s to 64 s
SUN [b]	Start-up noise of the greased bearing

[a] This subscript usually is not written (default).

[b] In the MQ method, noise values with this subscript can be expressed in $\mu m \cdot s^{-1}$ or in % based on the reference value of 16,9 $\mu m \cdot s^{-1}$.

5 Basics

In the case of grease lubrication, many factors can affect the degree of cleanliness during operation. For the initial lubrication and relubrication, clean grease is always required. Also, in applications where the fatigue life is not an issue (e.g. at very low load), the use of clean greases can be extremely important, for example, as a contribution to a low bearing noise, which is required for applications such as electric motors, fans, etc.

The purpose of assessing grease noise is the determination of the grease noise quality or identifying low-noise (quieter) greases. It can contribute to the development and improvement of low noise grease as well as support.

The comparison of damping properties of different lubricants shall be made on one bearing type and size, and the bearing shall be mounted in the same way. If all these provisions are followed, the selection of the lubricant with optimum damping characteristics can be performed successfully.

It has been found that many factors within the lubricant contribute to the attenuation. For greases, the main parameters are the viscosity, the type of base oil and additive types used. An improvement of damping characteristics can be observed when increasing the base oil viscosity. In addition, the thickener type and its micro-structure, as well as additives, can cause irregular damping properties.

NOTE 1 When abrasive or hard particles (impurities) are over-rolled, raceways (tracks) are damaged. It can result in indentations and increase the stress level (see also ISO 15243). Thus, the fatigue process is accelerated, leading to surface distress including asperity related micro-cracks and micro-spalls where material is released. This in turn leads to noise increase and finally bearing fatigue and bearing failure. In ISO 281, the existence of contamination is described by the factor e_c and incorporated in the life modification factor a_{ISO}.

NOTE 2 Currently, no sufficient evidence about noise testing of used greases is existing. Therefore, this document is primarily intended for testing of unused greases.

6 Grease noise evaluation method

6.1 General and overview

The evaluation method of the grease noise is as follows:

— rotate the deep groove ball bearing in which testing grease is enclosed, and

— analyse the vibration frequencies of the bearing.

The analysis method of grease noise varies with each method. Table 3 gives an overview of the features of the methods.

Table 3 — Features of each measuring method

Feature	Method		
	BQ+	MQ	NQ
Transducer	moving coil type		
Rotational frequency (spindle speed) in min^{-1}	1 800[a]		
Frequency domain in Hz	300 to 1 800 (M-band) 1 800 to 10 000 (H-band)	300 to 1 800 (M-band) 1 800 to 10 000 (H-band)	300 to 10 000 (M&H-band)
Filter 1[b]	800 to 10 000 Hz	—	—
Filter 2[b]	25 to 400 Hz	—	—
Measuring duration in s	3,2	0 to 32/32 to 64	3/10/30/120
Criterion for classification of grease noise	peak level (and “damping factor”)	worse value of “standard deviation of peak level” and/or “grease damping factor”	peak count

[a] Inner ring rotation, outer ring stationary.

[b] Envelope for peak value.

6.2 Calculation method for the grease damping

Grease damping GD compares the noise level of a greased bearing v_{NL} with a reference $v_{NL, ref}$ (ungreased bearing with preservative).

The comparison of the two levels v_{NL} and $v_{NL, ref}$ may be performed by ratio, see Formula (1), or by difference/ratio, see Formula (2):

by ratio
$$GD = \frac{v_{NL, ref}}{v_{NL}} \tag{1}$$

by difference/ratio $$GD = \frac{v_{\text{NL, ref}} - v_{\text{NL}}}{v_{\text{NL, ref}}} \quad (2)$$

The grease damping *GD* may be performed in the different bands (M, H). To distinguish them, the corresponding term is added as subscript.

Grease damping for the different test methods shall be calculated in accordance with Table 4. For method NQ, the determination of a grease damping factor is not foreseen.

Table 4 — Grease damping calculation

Band	BQ+[a] for assessment in accordance with ISO 21250-2	Formula No.	MQ[b] for assessment in accordance with ISO 21250-3	Formula No.	NQ
M	$GD_{\text{M BQ+}} = \frac{v_{\text{NL, M ref}} - v_{\text{NL, M}}}{v_{\text{NL, M ref}}}$	(3)	$GD_{\text{M MQ}} = \frac{\frac{1}{256} \cdot \sum_{i=257}^{512} v_{\text{NL, M}\ i\ \text{ref}}}{\frac{1}{256} \cdot \sum_{i=257}^{512} v_{\text{NL, M}\ i}}$	(5)	Not applicable
H	$GD_{\text{H BQ+}} = \frac{v_{\text{NL, H ref}} - v_{\text{NL, H}}}{v_{\text{NL, H ref}}}$	(4)	$GD_{\text{H MQ}} = \frac{\frac{1}{256} \cdot \sum_{i=257}^{512} v_{\text{NL, H}\ i\ \text{ref}}}{\frac{1}{256} \cdot \sum_{i=257}^{512} v_{\text{NL, H}\ i}}$	(6)	Not applicable

[a] Negative values for $GD_{\text{BQ+}}$ mean an increase in noise for the greased bearings.

[b] Values < 1 for GD_{MQ} mean an increase in noise for the greased bearings.

6.3 Calculation method for peak analysis

The peak analysis is performed by a mathematical treatment of the input signal:

— raw/input signal coming from the transducer;

— filtered signal: the signal after filtration;

— the filter used shall be indicated in the result;

— rectification: all amplitudes are set to positive;

— counter: the number of vibrations peaks over a reference value that shall be indicated in the result.

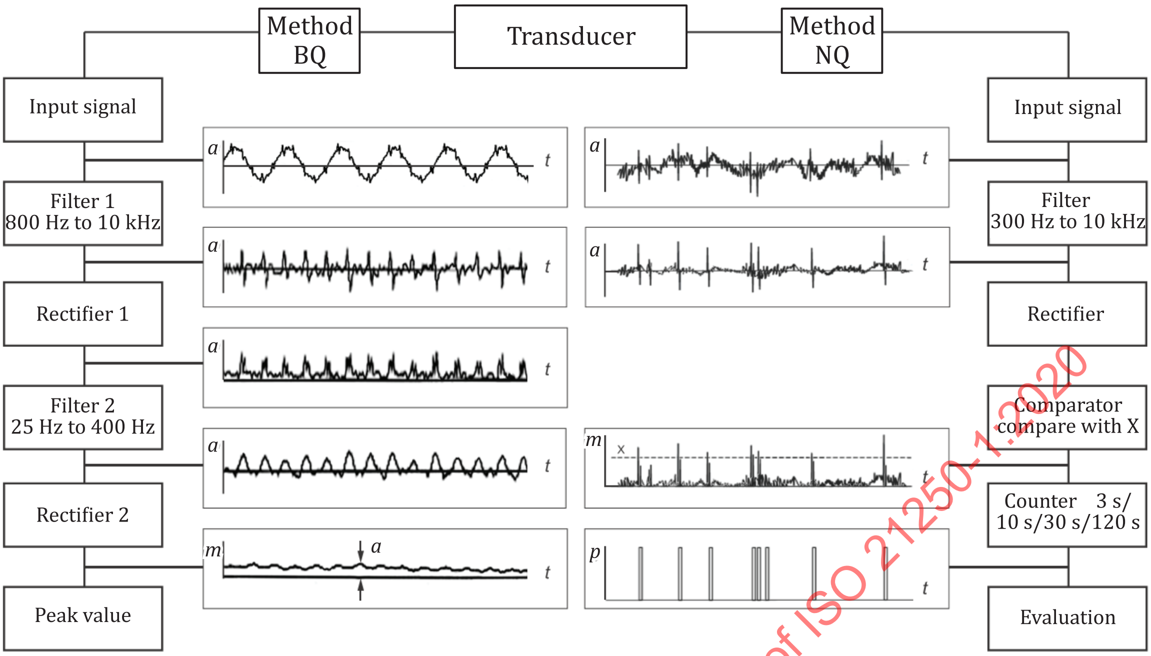
Peak values for the evaluation of the running noise for the different test methods shall be calculated in accordance with Table 5 and Figure 1.

Table 5 — Peak values

BQ+	MQ			NQ[a]	
for assessment in accordance with ISO 21250-2	for assessment in accordance with ISO 21250-3	Formula No.	Explanations	for assessment in accordance with ISO 21250-4	Formula No.
The peak detection algorithm for the processing of the input signal is shown in Figure 1. It shall use a sampling rate of 25 600 readings per second.	$v_{\text{NP, M 0–32}} = 2 \cdot \left[\sum_{i=1}^{256} \frac{\left(v_i - \overline{v}_i\right)^2}{256} \right]^{\frac{1}{2}}$	(7)	A sampling rate of eight readings per second shall be used, i.e. within 32 s, 256 points are required.	$v_{\text{M\&H pk}} = 4 \cdot v_{\text{M\&H normal}}$ [b]	(11)
	$v_{\text{NP, H 0–32}} = 2 \cdot \left[\sum_{i=1}^{256} \frac{\left(v_i - \overline{v}_i\right)^2}{256} \right]^{\frac{1}{2}}$	(8)		$v_{\text{M\&H pk}} = \sqrt{2} \cdot v_{\text{M\&H rms}}$	(12)
	$v_{\text{NP, M 32–64}} = 2 \cdot \left[\sum_{i=257}^{512} \frac{\left(v_i - \overline{v}_i\right)^2}{256} \right]^{\frac{1}{2}}$	(9)		$v_{\text{M\&H rms}} = \left(\frac{1}{\sqrt{2}}\right) \cdot v_{\text{M\&H pk}}$	(13)
	$v_{\text{NP, H 32–64}} = 2 \cdot \left[\sum_{i=257}^{512} \frac{\left(v_i - \overline{v}_i\right)^2}{256} \right]^{\frac{1}{2}}$	(10)			

a The considered band is M&H.

b From experience.



a) Methods BQ+ (ISO 21250-2) b) Method NQ (ISO 21250-4)

Key

a amplitude

m magnitude for peak detection

p pulse (count; here 8 counts)

t time

X threshold level (comparator level)

Figure 1 — Graphical representation of the peak detection algorithm for assessment in accordance with different methods

6.4 Calculation for SUN analysis

The start-up noise (SUN) value is evaluated by measurement of the noise level during the first rotations of the bearing. The interval of time for this analysis is 0 s to 30 s.

7 Noise testing of greases

7.1 General information

The evaluation of grease noise testing shall be carried out with a test machine in accordance with this document.

The following parameters shall be observed:

— smooth running classification of lubricants based on particle over-rolling;

— lubricant damping properties;

— start-up behaviour;

— uniformity of the running noise;

— determination of permanent bearing damage due to the lubricant.

Furthermore, the parameters, when compared with other lubricants, may be used.

7.2 Measuring principle

The inner ring of the bearing rotates at 1 800 min^{-1}. A speed-proportional transducer (sensor) placed on the (non-rotating) outer ring measures the radial vibration movement of the outer ring.

The software filters out three frequency band ranges from the measured vibration signal (low: L-band, medium: M-band, and high: H-band). Experience has shown that the L-band essentially covers only imperfections of the raceways themselves. For this reason, only the medium and high frequency bands for the analysis of noise behaviour of tested greases shall be used. The measured signal is filtered mathematically and is appropriate to analyse.

NOTE The measurement according to this document is based on ISO 15242-1 and ISO 15242-2. These International Standards define appropriate frequency bands and other boundary conditions for the assessment of the noise quality.

7.3 Test machine

The test machine shall have the following main components:

— a high-quality spindle with a speed of 1 800 min^{-1} ($^{+1\,\%}_{-2\,\%}$ speed deviation) and a rotation of the inner ring in one direction;

NOTE The lower speed limit is considered to be 1 764 min^{-1} and the upper speed limit 1 818 min^{-1}.

— a loading device for loading on the bearing.

Further, it is recommended to have:

— electronics with evaluation software;

— a special interface to the fully automated measurements, storage of collected readings and interpretation of results.

7.4 Test setup

The test bearing shall be pushed onto a mandrel firmly connected with the spindle. The axial force shall be applied via an adapter onto the outer ring.

7.5 Test bearings and amount of grease

Test bearings shall be deep groove ball bearings chosen to have the following features:

— increased dimensional and running accuracy; preferably tolerance class 4 (in accordance with ISO 492);

— pressed steel cage or polymeric cage;

— clearance group N in accordance with ISO 5753-1; and

— best possible quietness, i.e. peak value $v_{pk} < 5\ \mu m \cdot s^{-1}$.

NOTE Group N is called C0 by several national standards.

For testing according to methods MQ and NQ, test bearings shall be cleaned (so that no residual grease is to be found) and preserved as described by the bearing manufacturer. For testing according to the procedure of method BQ+, such preparation is not required.

The amount of grease shall be set after checking bearing size in accordance with Table 6.

Air bubbles are not allowed. Methods BQ+ and NQ specify the mass of grease while method MQ uses the volume of grease.

Table 6 — Test bearing and amount of grease

Basic bearing designation	Amount of grease		
	BQ+ g	MQ cm^3	NQ g
608	$0{,}15\ ^{+0{,}044}_{-0{,}011}$	0,37 (±5 %)	0,16
6202	—	0,93 (±5 %)	0,7

NOTE 1 The grease quantity for Method MQ applied to bearing 608 is based on 55 % to 60 % of the free volume in the bearing, for greases with a density 0,9 $g \cdot cm^{-3}$ equal to 0,33 g ± 0,02 g).

NOTE 2 Grease noise test procedure for method MQ applied to 6202 is still under development.

7.6 Test load

The test load shall be chosen according to the test bearing and with Table 7.

Table 7 — Test bearing and test load

Basic bearing designation	Test load N	
	BQ+; MQ	NQ
608	30 (±10 %)	29,4
6202	60 (±10 %)	29,4

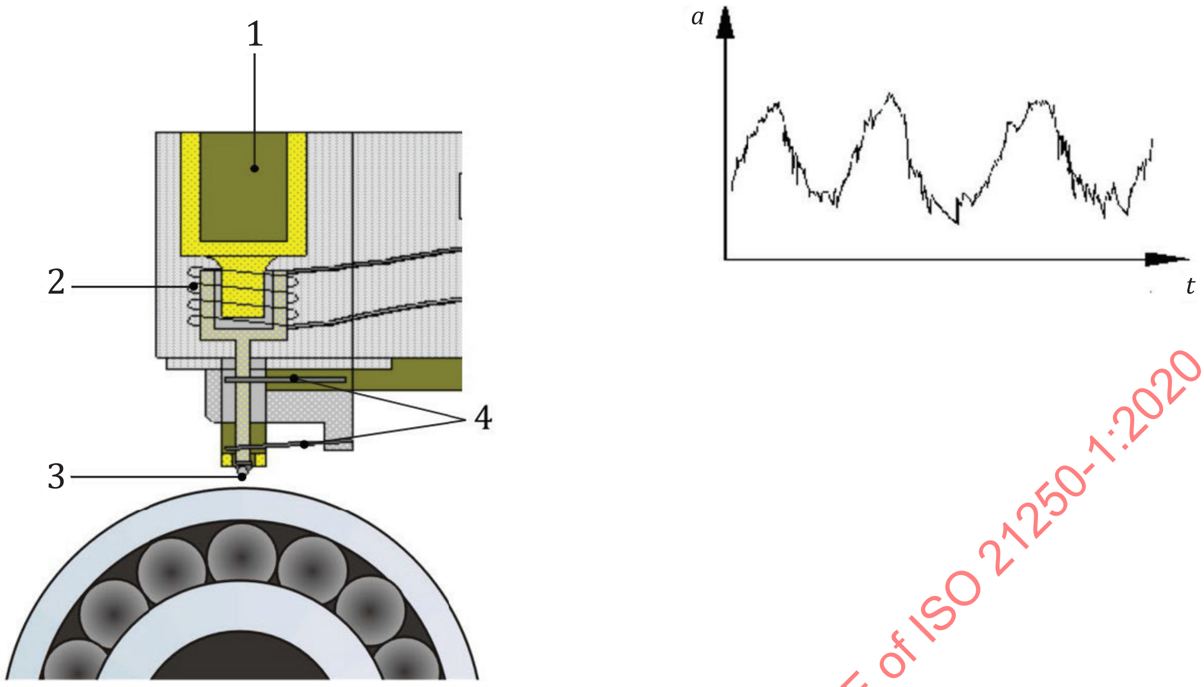
7.7 Spindle speed

The speed of the spindle shall be 1 800 min^{-1} (30 s^{-1}). The lower limit is considered to be 1 764 min^{-1} (−2 %) and the upper limit 1 818 min^{-1} (+1 %).

7.8 Signal recording

The running noise of the bearing is taken up by a speed-proportional transducer in the electronics as (digital) amplified signal. Thus, time occurring vibration amplitudes are generated; see Figure 2.

Transducer response and filter characteristics are specified in ISO 15242-1:2015, 6.4.



Key

1 permanent magnet
2 moving coil
3 sensor tip
4 two parallel springs
t time
a amplitude

Figure 2 — Example of a signal recording

7.9 Display

The measuring results shall be displayed in a feasible way.

8 Calibration

8.1 General

Calibration is used to achieve a reliably reproducible determination and documentation of the deviation of a measuring device to another device, which is called a reference standard. Also a second step of the calibration is mandatory, namely taking into account the determined deviation in the subsequent use of the measuring device to make corrections of the readings.

Calibration is made with a traceable standard source. Such a standard source has itself a calibration that has a relationship to the definitions of the SI units through a sustained chain of calibrations. This relationship is expressed by two parameters: deviation and calibration uncertainty. If the result of the calibration is again expressed with variance and uncertainty, the result of this calibration is traceable. Traceability is the property of a result and not a device.

The uncertainty increases with each calibration along the traceability chain. The calibrated objects are always of lower quality (by low order) than the standards with which they were calibrated.

