ASME B89.4.19-2021
[Revision of ASME B89.4.19-2006 (R2015)]

Performance Evaluation of Laser-Based Spherical Coordinate Measurement Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

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CONTENTS

Tables

Forms

FOREWORD

ASME B89 Standards Committee on Dimensional Metrology, under procedures approved by the American National Standards Institute (ANSI), prepares standards that encompass the inspection and the means of measuring characteristics of such various geometric parameters as diameter, length, flatness, parallelism, concentricity, and squareness.

Division 4 of the B89 Committee produces standards and technical reports in the area of coordinate measuring technology, with particular focus on coordinate measuring machines (CMMs). This Standard addressing the performance evaluation of laser trackers and similar large-scale measurement systems is the work of the B89.4.19 Project Team.

Performance evaluation of a laser tracker presents challenges different from those associated with conventional Cartesian CMMs. Because of a laser tracker's very large working volume, no full-scale, three-dimensional calibrated artifacts exist, and the design of the laser beam steering subsystem is such that individual parametric errors cannot, in general, be isolated and measured individually. For any coordinate measurement system, a test of the system's ability to realize the SI unit of length, the meter, is a fundamental requirement. In a laser tracker, the length scale is often a laser interferometer (IFM), and the person checking the system's ability to realize a meter usually does not have a significantly more accurate reference interferometer with which to perform such a test.

For these reasons, the performance evaluation tests in this Standard consist primarily of point-to-point length measurements using calibrated artifacts that can be realized in a number of ways. Measured lengths are compared with the manufacturer's maximum permissible error (MPE) specifications in order to decide conformance. Realization of the SI definition of the meter can be evaluated in a number of ways, including calibration of the laser IFM, measurement of a series of short-calibrated reference lengths, or measurement of a series of long-calibrated reference lengths. Procedures are also included for testing the absolute distance measurement capability of laser trackers that include this option.

All reference lengths used in the performance evaluation tests are required to be traceable per ASME B89.7.5. Guidance is provided on how to demonstrate this traceability, as well as the traceability of subsequent point-to-point length measurements made with a laser tracker that has passed the performance evaluation tests of this Standard.

ASME B89.4.19-2021 was approved by ANSI on September 23, 2021.

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Dimensional Metrology

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B89 Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the B89 Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B89 Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the B89 Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The B89 Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the B89 Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at http://go.asme.org/B89committee.

ASME B89.4.19-2021
SUMMARY OF CHANGES

Following approval by the ASME B89 Committee and ASME, and after public review, ASME B89.4.19-2021 was approved by the American National Standards Institute on September 13, 2021.

The figures, forms, and tables in ASME B89.4.19-2021 have been redesignated based on their parent paragraphs. ASME B89.4.19-2021 also includes the following changes identified by a margin note, **(21)**.

Page	*Location*	*Change*
1	1	Revised
1	2	Revised
2	3	Revised in its entirety
4	4	Revised
5	Form 4-1	Title and subheadings revised
6	Form 4-2	Title revised
4	5	Revised
4	6	Revised in its entirety
13	Table 6.3.1-1	Title revised
18	7	Revised in its entirety
19	Figure 7.1-1	Title revised
22	Figure 7.4.2-1	Title revised
21	8	References updated
23	Mandatory Appendix I	Revised in its entirety
25	Nonmandatory Appendix A	Revised
26	Table A-2-1	Revised
27	B-1	First sentence and subpara. (a) revised
27	B-2.1	Third paragraph revised
27	B-2.2	Second and fifth sentences revised
28	Figure B-2	General Note added
29	B-3	First, second, ninth, and tenth paragraphs revised
34	C-4	Second and fourth paragraphs revised
34	C-	First sentence revised
34	C	First paragraph revised
37	Nonmandatory Appendix D	Revised in its entirety
49	E-1	First sentence revised
	Nonmandatory Appendix F	Revised in its entirety
	Figure F-5.1.2-1	Added
57	Figure F-5.1.2-2	Added
58	Figure F-5.2.2-1	Added

PERFORMANCE EVALUATION OF LASER-BASED SPHERICAL COORDINATE MEASUREMENT SYSTEMS

1 SCOPE (21)

This Standard prescribes methods for the performance evaluation of laser-based spherical coordinate measurement systems and provides a basis for performance comparisons among such systems. Definitions, environmental requirements, and test methods are included with emphasis on point-to-point length measurements. The specified test methods are appropriate for the performance evaluation of a majority of laser-based spherical coordinate measurement systems and are not intended to replace more complete tests that may be required for special applications.

This Standard establishes requirements and methods for specifying and testing the performance of a class of spherical coordinate measurement systems called laser trackers.[1] A laser tracker is a system that directs the light from a range-measuring device to a retroreflecting target (called a retroreflector) by means of a two-axis rotary steering mechanism while monitoring the angular position of these rotary axes, thereby forming a spherical coordinate metrology system. Such a system may measure a static target, track and measure a moving target, or measure (and perhaps track) some combination of static and moving targets. This Standard can also be used to specify and verify the relevant performance tests of other spherical coordinate measurement systems that use cooperative targets, such as laser radar systems.

This Standard focuses specifically on the use of laser trackers as industrial measurement tools rather than on their use in surveying or geodesy. Specified tests are designed to evaluate the static point-to-point length measurement capabilities of these systems. The specified tests are not intended to evaluate the dynamic performance of the laser trackers. Additional tests are included that evaluate the range measurement capability of laser trackers equipped with absolute distance meters (ADMs). The tests do not evaluate workpiece thermal compensation capability and are not sensitive to spherically mounted retroreflector (SMR) imperfections.

2 INTRODUCTION (21)

In addition to providing for the performance evaluation of laser trackers, this Standard facilitates performance comparisons among different systems by unifying the terminology and the treatment of environmental factors. It defines test methods appropriate for evaluating the performance of a majority of laser trackers, but it is not intended to replace more complete tests that may be required for special applications.

Systems that have passed the performance evaluation tests of this Standard are considered capable of producing traceable point-to-point length measurements for the conditions required herein. Application of point-to-point length measurements to a specific workpiece or measurement task may require additional testing and analysis in order to establish metrological traceability. This Standard provides technical guidance that may be useful in the calibration of laser-based spherical coordinate systems for point-to-point length measurements.

The Appendices describe various factors that should be considered when using this Standard.

(a) Mandatory Appendix I discusses metrological traceability, with particular focus on demonstrating traceability of reference lengths used in laser tracker performance evaluation. Requirements for demonstrating metrological traceability are presented per ASME B89.7.5.

(b) Nonmandatory Appendix A discusses the traceability of laser tracker point-to-point length measurements performed subsequent to a system passing the performance evaluation tests described in this Standard.

(c) Nonmandatory Appendix B describes tests and procedures for determining geometric errors in the construction of SMRs so that the suitability of a particular SMR for laser tracker performance testing can be evaluated.

(d) Nonmandatory Appendix C describes environmental factors that influence the refractive index of light in air. These factors affect the wavelength of light and should be carefully understood before proceeding with the tests described in this Standard.

[1] For purposes of this Standard, the terms *spherical coordinate measurement system* and *laser tracker* will be used interchangeably, notwithstanding the ability or inability to track a target.