ASME B89.4.23-2020

X-Ray Computed Tomography (CT) Performance Evaluation

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: November 30, 2020

The next edition of this Standard is scheduled for publication in 2025.

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FOREWORD

The application of X-ray computed tomography (CT) for dimensional metrology has become common in many industries. This is primarily due to the ability of CT systems to measure inside a workpiece without requiring tactile or optical access. However, there are currently no standards that address the performance evaluation of CT systems in a way that includes material influence, which is a dominant source of error when these systems are used to evaluate typical workpieces. For this reason, The American Society of Mechanical Engineers (ASME) decided to form the B89.4.23 Working Group to produce a standard for CT performance evaluation. This Standard is the result of significant effort by the working group to develop a performance evaluation that includes all known sources of error in CT systems.

This Standard provides definitions and a test procedure for the performance evaluation of X-ray CT systems used for dimensional measurements. Manufacturers and users of CT systems may use the results of the test procedure to fulfill contractual requirements or to compare the performance of systems from different suppliers or over time.

The test procedure described in this Standard is intended to report errors that are representative of typical use cases of CT systems. Users of this Standard seeking to determine measurement error or uncertainty for a particular workpiece or system configuration should perform a specific study for that case.

This Standard is available for public review on a continuing basis. This provides an opportunity for additional public review input from industry, academia, regulatory agencies, and the public-at-large.

This first edition of ASME B89.4.23 was approved by the American National Standards Institute on September 3, 2020.

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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.

This Standard is always open for comment, and the Committee welcomes proposals for revisions. 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.

X-RAY COMPUTED TOMOGRAPHY (CT) PERFORMANCE EVALUATION

1 SCOPE

This Standard specifies the dimensional measurement accuracy of industrial X-ray computed tomography (CT) systems for length, size, and form measurands of sphere-based test objects made of homogeneous materials. Medical CT systems are outside the scope of this Standard. The material properties of the measured test objects are restricted to three classes of material selected to be representative of industrial materials: plastic polymers, aluminum alloys, and steel alloys; other materials are outside the scope of this Standard. However, this Standard may be used as a guide for testing the performance of a CT system for other materials. The evaluation of workpieces composed of multiple materials or of materials with density gradients, i.e., gradual density variations within the material, is outside the scope of this Standard.

This Standard is applicable to dimensional measurements made at the surface of the workpiece, i.e., at the workpiece material–air interface, including those of internal cavities. The effect of complex workpiece-material influence is simulated by test objects composed of spheres (serving as the metrological geometric elements) and an obstructing body; the obstructing body's dimensions are uncalibrated and its shape may be arbitrary. The spheres and obstructing body shall be of the same class of material and their combined length shall not exceed the maximum penetration length for this class of material, as stated by the CT system manufacturer.

This Standard applies to a variety of CT systems that may vary by scanning mode and system components involved in the acquisition of images. In cases where a system provides multiple configurations of X-ray sources, detectors, and scanning modes, the dimensional measurement accuracy may be specified for each scanning mode.

This Standard does not mandate testing (by either the CT manufacturer or the user) to verify CT performance. The amount of testing, and which party will bear the cost of testing, is a business decision and must be negotiated between the two parties. Calibrated test objects can be expensive; hence, the parties should recognize the costs involved and plan the testing accordingly.

Due to contrast sensitivity issues that can arise when X-rays must penetrate through large amounts of material, this Standard does not provide maximum permissible error specifications that apply to detecting high spatial-frequency form errors.

2 INTRODUCTION

ASME B89 performance evaluation standards for dimensional coordinate measuring systems specify the dimensional measuring accuracy for common measurements of industrial workpieces. Ideally the uncertainty associated with each point coordinate within the system's measurement work zone would be reported, but because the accuracy of an individual point coordinate in space is impossible to experimentally verify, ASME B89 standards typically use a point-to-point length measurand that is both realizable and practical for system testing. The advantage of evaluating test objects with point-to-point length measurands is twofold: first, test objects are simple to manufacture and calibrate, and second, different point-to-point length measurands can be used to evaluate different effects. Long-range effects are evaluated by the point-to-point length error between the center of two spheres on a test object, which can span the entire work zone. Short-range effects are evaluated by the errors in the point-to-point distance from the center of the test spheres to various points on their surface, i.e., sphere form measurands. Image thresholding issues that are associated with the determination of a surface are evaluated by the error of the size of the test spheres.

A primary goal of ASME B89.4 standards is to define maximum permissible error (MPE) specifications and their associated rated operating conditions, which are useful when the user is measuring similar measurands on a typical workpiece. For example, although a CT system might be tested with a calibrated steel test object, the user should be confident that the combined MPE specifications for center-to-center length, form, and size error would limit the error if a point-to-point length measurement were composed of a point on the exterior of a steel workpiece and a point on an interior surface of a fully enclosed cavity of the workpiece.