

ASME PTC 53-2022

# Mechanical and Thermal Energy Storage Systems

---

Performance Test Codes

AN AMERICAN NATIONAL STANDARD



The American Society of  
Mechanical Engineers

**ASME PTC 53-2022**

# **Mechanical and Thermal Energy Storage Systems**

---

**Performance Test Codes**

**AN AMERICAN NATIONAL STANDARD**



**The American Society of  
Mechanical Engineers**

Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: June 21, 2023

This Code will be revised when the Society approves the issuance of a new edition.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The standards committee that approved the code or standard was balanced to ensure that individuals from competent and concerned interests had an opportunity to participate. The proposed code or standard was made available for public review and comment, which provided an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not “approve,” “certify,” “rate,” or “endorse” any item, construction, proprietary device, or activity. ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor does ASME assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representatives or persons affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

The endnotes and preamble in this document (if any) are part of this American National Standard.



ASME Collective Membership Mark

“ASME” and the above ASME symbol are registered trademarks of The American Society of Mechanical Engineers.

No part of this document may be reproduced in any form,  
in an electronic retrieval system or otherwise,  
without the prior written permission of the publisher.

The American Society of Mechanical Engineers  
Two Park Avenue, New York, NY 10016-5990

Copyright © 2023 by  
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS  
All rights reserved

# CONTENTS

Notice .....	v	
Foreword .....	vii	
Committee Roster .....	viii	
Correspondence With the PTC Committee .....	ix	
<b>Section 1</b>	<b>Object and Scope</b> .....	<b>1</b>
1-1	Object .....	1
1-2	Scope .....	1
1-3	Uncertainty .....	2
1-4	References .....	2
<b>Section 2</b>	<b>Definitions and Descriptions of Terms</b> .....	<b>3</b>
2-1	Definitions .....	3
2-2	Symbols and Subscripts .....	4
<b>Section 3</b>	<b>Guiding Principles</b> .....	<b>7</b>
3-1	Introduction .....	7
3-2	Test Plan .....	11
3-3	Test Preparations .....	12
3-4	Conduct of Test .....	13
3-5	Calculation and Reporting of Results .....	17
<b>Section 4</b>	<b>Instruments and Methods of Measurement</b> .....	<b>18</b>
4-1	Introduction .....	18
4-2	Instrument Accuracy .....	18
4-3	Instrument Calibration .....	18
4-4	Instrument Verification .....	19
4-5	Reference Standards .....	20
4-6	Energy and Power Measurement .....	20
4-7	Pressure Measurement .....	23
4-8	Flow Measurement .....	27
4-9	Temperature Measurement .....	32
4-10	Data Collection and Handling .....	34
<b>Section 5</b>	<b>Computation of Results</b> .....	<b>36</b>
5-1	Introduction .....	36
5-2	Test Methods .....	36
5-3	State of Charge .....	37
5-4	Test Objectives .....	38
5-5	Equations for Interval Tests .....	40
5-6	Secondary Energy .....	42
5-7	Correction Factors .....	42
5-8	Equations for Cycle Tests .....	43

<b>Section 6</b>	<b>Report of Results</b> .....	47
6-1	General Requirements .....	47
6-2	Executive Summary .....	47
6-3	Introduction .....	47
6-4	Control Boundary .....	48
6-5	Calculations and Results .....	48
6-6	Instrumentation .....	48
6-7	Results Discussion .....	48
6-8	Conclusions .....	49
6-9	Appendices .....	49
<b>Section 7</b>	<b>Test Uncertainty</b> .....	50
7-1	Introduction .....	50
7-2	Pretest Uncertainty Analysis .....	50
7-3	Posttest Uncertainty Analysis .....	50
7-4	Inputs for an Uncertainty Analysis .....	50
 <b>Nonmandatory Appendices</b>		
A	Sample Calculations for a Combined Cycle Power Plant ESS .....	51
B	Representative ESS Test Boundaries .....	65
 <b>Figures</b>		
3-1.5-1	Generic Test Boundary .....	9
3-4.12.3-1	Three Posttest Cases .....	16
4-7.6.2-1	Five-Way Manifold .....	28
5-4.1-1	Extrapolation of Energy Flow From Storage to Determine Corrected Discharge Duration for Linear ESSs .....	39
5-4.2-1	Idealized Cycle Test Beginning and Ending at the Same State of Charge .....	40
A-3-1	System Boundary for Energy Storage Combined Cycle Power Plant, With Boundaries for Discharge Test and Charge Test .....	52
A-4.5.1-1	Ambient Temperature Multiplicative Correction Factors .....	57
A-4.5.2-1	Ambient Pressure Multiplicative Correction Factors .....	58
A-4.5.3-1	Ambient Relative Humidity Multiplicative Correction Factors .....	59
A-4-5.4-1	Blowdown Flow Rate Correction Factors .....	60
A-4.5.5-1	Salt Temperature Correction Factors .....	61
B-2-1	Pumped Storage Hydro ESS Test Boundary .....	66
B-3-1	Compressed Air ESS Test Boundary .....	67
B-4-1	Energy Storage Combined Cycle ESS Test Boundary .....	68
B-5-1	Flow Battery ESS Test Boundary .....	69
 <b>Tables</b>		
2-2-1	Symbols and Abbreviations Used in ASME PTC 53 .....	5
2-2-2	Subscripts Used in ASME PTC 53 .....	6
4-8-1-1	Recommended Flowmeters for Various Fluids .....	28
5-7.1-1	Correction Factors for Discharge Performance .....	45
5-7.2-1	Correction Factors for Charge Performance .....	46
5-7.3-1	Correction Factors for Standby Performance .....	46

A-4.1-1	Plant Ratings .....	54
A-4.3-1	Rating and Test Conditions .....	55
A-4.5.1-1	Predicted Performance at Different Ambient Temperatures .....	57
A-4.5.1-2	Coefficients for Ambient Temperature Correction Factors .....	57
A-4.5.2-1	Predicted Performance at Different Ambient Pressures .....	58
A-4.5.2-2	Curve Fit Coefficients for Ambient Pressure Correction Factors .....	58
A-4.5.3-1	Predicted Performance at Different Ambient Relative Humidities .....	59
A-4.5.3-2	Curve Fit Coefficients for Ambient Relative Humidity Correction Factors .....	59
A-4.5.4-1	Predicted Performance at Different Blowdown Flow Rates .....	60
A-4.5.4-2	Curve Fit Coefficients for Blowdown Flow Rate Correction Factors .....	60
A-4.5.5-1	Predicted Performance at Different Salt Temperatures .....	61
A-4.5.5-2	Coefficients for Multiplicative Correction Curve Fit for Salt Flow Rate .....	61
A-4.6-1	Calculated Corrections Based on Measured Values .....	62
A-5.1-1	Rating and Test Conditions .....	62
A-5.3-1	Charge Rating and Test Conditions .....	63
A-7.1-1	Summary Performance Comparison .....	64

## NOTICE

All ASME Performance Test Codes (PTCs) shall adhere to the requirements of ASME PTC 1, General Instructions. It is expected that the Code user is fully cognizant of the requirements of ASME PTC 1 and has read them before applying ASME PTCs.

ASME PTCs provide unbiased test methods for both the equipment supplier and the users of the equipment or systems. The Codes are developed by balanced committees representing all concerned interests and specify procedures, instrumentation, equipment-operating requirements, calculation methods, and uncertainty analysis. Parties to the test can reference an ASME PTC confident that it represents the highest level of accuracy consistent with the best engineering knowledge and standard practice available, taking into account test costs and the value of information obtained from testing. Precision and reliability of test results shall also underlie all considerations in the development of an ASME PTC, consistent with economic considerations as judged appropriate by each technical committee under the jurisdiction of the ASME Board on Standardization and Testing.

When tests are run in accordance with a Code, the test results, without adjustment for uncertainty, yield the best available indication of the actual performance of the tested equipment. Parties to the test shall ensure that the test is objective and transparent. All parties to the test shall be aware of the goals of the test, technical limitations, challenges, and compromises that shall be considered when designing, executing, and reporting a test under the ASME PTC guidelines.

ASME PTCs do not specify means to compare test results to contractual guarantees. Therefore, the parties to a commercial test should agree before starting the test, and preferably before signing the contract, on the method to be used for comparing the test results to the contractual guarantees. It is beyond the scope of any ASME PTC to determine or interpret how such comparisons shall be made.

## FOREWORD

ASME PTC 53, Mechanical and Thermal Energy Storage Systems, defines uniform test procedures and quantifiable test methods for assessing and reporting the performance of mechanical or thermal energy storage systems (ESSs) across various technology platforms. ASME PTC 53 is intended to have broad applicability; however, this Code is not intended to overlap the scope of similar codes published by other organizations such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Institute of Electrical and Electronics Engineers (IEEE). ASME PTC 53 covers mechanical and thermal technologies including compressed air, flywheels, thermal storage ranging from molten salts to cryogenic liquids, and pumped hydromechanical energy.

The ASME PTC 53 Committee issued ASME PTC 53 as a Draft Standard for Trial Use in 2016 to allow technology developers, engineers, and consumers to consider consistent strategies, methods, and systems for performance testing. ASME PTC 53-2022 builds on the Draft Standard, adding Sections on instrumentation and measurement, computation and reporting of results, and uncertainty. ASME PTC 53-2022 is a complete PTC for industry use.

ASME PTC 53-2022 was approved by the American National Standards Institute as an American National Standard on September 15, 2022.

# ASME PTC COMMITTEE

## Performance Test Codes

(The following is the roster of the committee at the time of approval of this Code.)

### STANDARDS COMMITTEE OFFICERS

**S. A. Scavuzzo**, *Chair*  
**T. K. Kirkpatrick**, *Vice Chair*  
**D. Alonzo**, *Secretary*

### STANDARDS COMMITTEE PERSONNEL

**P. G. Albert**, Consultant  
**D. Alonzo**, The American Society of Mechanical Engineers  
**J. M. Burns**, Burns Engineering Services, Inc.  
**A. E. Butler**, GE Power and Water  
**W. C. Campbell**, True North Consulting, LLC  
**J. González**, Iberdrola Generación SAU  
**R. E. Henry**, Consultant  
**D. R. Keyser**, Survice Engineering Co.  
**T. K. Kirkpatrick**, McHale & Associates, Inc.  
**M. P. McHale**, McHale & Associates, Inc.  
**J. W. Milton**, Chevron USA

**S. P. Nuspl**, Consultant  
**R. Pearce**, Kansas City Power & Light  
**S. A. Scavuzzo**, The Babcock & Wilcox Co.  
**J. A. Silvaggio, Jr.**, Siemens Gamesa Renewable Energy Turbomachinery, Inc.  
**T. L. Toburen**, T2E3  
**W. C. Wood**, Consultant  
**R. P. Allen**, *Honorary Member*  
**P. M. McHale**, *Honorary Member*, McHale & Associates, Inc.  
**R. R. Priestley**, *Honorary Member*  
**R. E. Sommers**, *Honorary Member*

### PTC 53 COMMITTEE — MECHANICAL AND THERMAL ENERGY STORAGE SYSTEMS

**A. D. Thelen**, *Chair*, Consumers Energy  
**F. Buckingham**, *Vice Chair*, NAES Corp.  
**D. Alonzo**, *Staff Secretary*, The American Society of Mechanical Engineers  
**J. Barnold III**, Bechtel Corp.  
**W. M. Conlon**, Pintail Power, LLC  
**J. Darguzas**, JoCo  
**S. Farhad**, University of Akron  
**S. Hume**, Electric Power Research Institute  
**S. Kaercher**, Detroit Edison Co.

**L. Kelley**, Consultant  
**S. Kinsey**, Consultant  
**C. Molnar**, Chromalox, Inc.  
**M. Thornbloom**, Kelelo Engineering  
**B. Toon**, American Electric Power  
**J. Vandussen**, Consumers Energy  
**T. Gainza**, *Contributing Member*, SENER Ingenieria Y Sistemas S.A.  
**H. Gajjar**, *Contributing Member*, Torrent Power, Ltd.  
**V. J. Ott**, *Contributing Member*, Cryogel

## CORRESPONDENCE WITH THE PTC COMMITTEE

**General.** ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Code should be sent to the staff secretary noted on the committee's web page, accessible at <https://go.asme.org/PTCcommittee>.

**Revisions and Errata.** The committee processes revisions to this Code on a periodic basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata.

This Code 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 background information and supporting documentation.

### Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code and the paragraph, figure, or table number(s)

(4) the edition(s) of the Code to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

**Interpretations.** Upon request, the committee will issue an interpretation of any requirement of this Code. An interpretation can be issued only in response to a request submitted through the online Interpretation Submittal Form at <https://go.asme.org/InterpretationRequest>. Upon submitting the form, the inquirer will receive an automatic e-mail confirming receipt.

ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers can track the status of their requests at <https://go.asme.org/Interpretations>.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect 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.

Interpretations are published in the ASME Interpretations Database at <https://go.asme.org/Interpretations> as they are issued.

**Committee Meetings.** The PTC Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the committee. Information on future committee meetings can be found on the committee web page at <https://go.asme.org/PTCcommittee>.

# Section 1

## Object and Scope

### 1-1 OBJECT

The object of this Code is to establish uniform test methods and procedures for conducting performance tests of mechanical or thermal energy storage systems (ESSs). An ESS is a system that consumes energy to increase the internal energy of the storage media and releases that stored energy to produce useful power or heat. The standard test procedures for ESSs established by this Code provide the highest level of accuracy consistent with current engineering practice.

This Code provides procedures for measuring the following parameters:

- (a) the quantity of energy input
- (b) the rate of energy input (power)
- (c) the quantity of non-useful energy flows in and out of the system during input, steady-state storage, and discharge
- (d) the quantity of useful energy output
- (e) the rate of useful energy output (power)

This Code provides quantifiable methods to assess the performance of mechanical or thermal ESSs in various technology platforms and applications.

When tests are conducted in accordance with a code, the test results themselves, without adjustment for uncertainty, yield the best available indication of actual performance of the equipment tested within the operational parameters defined in a Performance Test Code (PTC). This Code does not specify means to compare results to contractual guarantees. Therefore, parties to a commercial test should agree on the method for comparing results to commercial guarantees before starting the test.<sup>1</sup> It is beyond the scope of this Code to determine or interpret how such comparisons are made.

This Code shall not be used to troubleshoot equipment. However, this Code can be used to quantify the magnitude of performance anomalies of equipment suspected of performing poorly or to confirm the need for maintenance if simpler means are not adequate. This Code can be used as a source or reference for simple routine or special equipment test procedures.

### 1-2 SCOPE

#### 1-2.1 Types of Systems to Which This Code May Apply

This Code applies to ESSs in which mechanical or thermal means are used to affect the storage and release of energy from suitable mechanical, thermal, or fluid media.

This Code applies to the measurement of the performance of an ESS at the specified conditions, with all equipment associated with the system functioning in accordance with those conditions.

An ESS may use any of various media, including, but not limited to, the following:

- (a) thermal energy storage media, such as phase-change media (e.g., liquefied air or water-ice) or sensible heating media (e.g., molten salt or thermal fluids and oils)
- (b) compression media, such as compressed air or springs
- (c) gravitational media, such as pumped hydromechanical energy or railcars on inclines
- (d) chemical media, such as hydrogen or ammonia reactions
- (e) kinetic media, such as flywheels

This Code provides methods to measure energy and material flows to and from an ESS that are relevant to assessment of ESS performance. For example, some ESSs may use energy inputs from multiple external sources. Some ESSs may also produce by-products such as water, carbon dioxide, or industrial gases that may have economic value or disposal costs of interest to users of this Code.

---

<sup>1</sup> Manufacturers typically provide correction curves or multiplication factors to adjust the performance guarantees for off-design conditions typically encountered during a test.