

ASME PTC 1-2022
(Revision of ASME PTC 1-2015)

General Instructions

Performance Test Codes

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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FOREWORD

This Code on General Instructions was first printed in preliminary form in *Mechanical Engineering* in 1920 and was presented at a public hearing at the spring meeting of The American Society of Mechanical Engineers (ASME) held in Chicago, Illinois, in 1921. It was approved and adopted as a standard practice of ASME in 1924.

During the years 1920 through 1970, the function of the Power Test Codes (as they were then known) continued to evolve and broaden. In recognition of these developments, the Code on General Instructions was revised twice. The revisions were approved by the Council on Standards and Certification on June 17, 1945, and May 7, 1970, respectively.

During the years 1970 through 1985, the scope of the Power Test Codes, now known as Performance Test Codes (PTCs), was further broadened as a result of

- (a) their designation as American National Standards by the American National Standards Institute (ANSI)
- (b) an increased awareness of the relationship between U.S. domestic standards and their international counterparts and a related need to reconcile substantially conflicting requirements between U.S. and international documents
- (c) clarification on the use of uncertainty in test codes

These developments resulted in several additional revisions to the Code on General Instructions that were approved by the Board on Performance Test Codes (BPTC) on May 13, 1970 (with the October 1971 Addenda); October 29, 1979; June 18, 1986; and June 12, 1991.

The subsequent revision of the Code was initiated in mid-1998. A Project Team was appointed by the BPTC to develop this revision under the ASME Redesign Process. The revised document was approved by the BPTC on November 19, 1998.

The next revision was a major updating of the Code, now called ASME PTC 1. The existing information contained in ASME PTC 1 was divided into two separate documents. One is the Code writer's guide, the ASME PTC 1 Template, available on the ASME PTC Committee web page. The other, ASME PTC 1, contains mandatory information for all code users. This revision was approved by the BPTC on December 9, 2003. It was also approved as an American National Standard by the ANSI Board of Standards Review on March 10, 2004.

The 2011 revision contained modifications to the 2004 version whereby some new committees were added and others discontinued. The template was not updated at this time. The 2011 revision was approved by the PTC Standards Committee (formerly BPTC) on May 24, 2011, and approved and adopted as a standard practice of ASME by action of the Board on Standardization and Testing on August 8, 2011. It was also approved as an American National Standard by the ANSI Board of Standards Review on November 14, 2011.

In the 2015 revision of PTC 1, the template was no longer required but was retained as a recommended document. In recognition of the need for an acceptable method to prepare for and validate the acceptability of a test, another permissible use of test uncertainty was added to PTC 1. This addition allows flexibility in the individual contributions to the specified measurement's uncertainty contributors while ensuring that the overall total test uncertainty is achieved. This method strictly specifies each measurement's systematic uncertainty along with its permissible variation (data fluctuation) or a total measurement uncertainty, including both systematic and random effects for each measured parameter and/or variable or each type of measured parameter or variable. While a pretest and post-test uncertainty analysis is always required, it is limited to demonstrate the achievement of uncertainty limits placed upon each individual measurement without having to calculate a total test uncertainty for the result. However, if the user of the Code wishes to exceed any of the specified uncertainty limits in any parameter or variable, a complete test uncertainty analysis is required to establish that the Code's limit level of uncertainty for the test result has been met. This requires using the systematic, random, and total measurements' uncertainty limits of each parameter and variable in accordance with PTC 19.1. Once the Code Limit Uncertainty is determined for the result, exceeding the upper limit of any individual parameter's or variable's specified uncertainty is allowable only if it is demonstrated that the selection of all instrumentation used will result in an overall test uncertainty equal to or less than what it would have been had all parameters' uncertainty requirements been met.

This 2022 edition has been produced to clearly define the meaning of a "Code Test." Specifically, text has been added to expand upon the philosophy of the ASME PTCs and how users shall apply the ASME PTCs. In addition, clarification of parties to a test has been better defined and specific language has been added to advise how parties to a commercial test should be defined within the contract, along with responsibility delineation for when the Code calls for the parties to a test to take action. This edition of ASME PTC 1-2022 was approved as an American National Standard by the ANSI Board of Standards Review on February 18, 2022.

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Performance Test Codes

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

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Secretary, PTC 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 PTC 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 PTC 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 PTC 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 PTC 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 PTC Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at <http://go.asme.org/PTCcommittee>.

INTRODUCTION

APPLICATIONS AND LIMITATIONS. This Code provides direction to users, parties to a test, and the ASME committees responsible for writing Performance Test Codes (PTCs). Code users and parties to a test shall consider this Code as part of each test, and all the requirements herein shall be applicable in addition to those within the individual PTCs covering a particular test.

The objectives of ASME PTC 1, General Instructions, are as follows:

- (a) to define the purpose and scope of ASME PTCs
- (b) to list major industry applications where PTCs can be used
- (c) to provide direction on the use of PTCs concerning the planning, preparation, execution, and reporting of test results.

Test results determined by a PTC or a group of PTCs can be used as defined by a contract as the basis for determining fulfillment of contract performance guarantees. Test results can also be used for comparison to a design number, to trend performance changes over time, to help evaluate possible modifications or to validate them, or for any application in which the performance is needed.

The results of a test conducted in accordance with PTCs will not provide the sole basis for comparing the thermo-economic effectiveness of different plant and equipment designs or different generation technologies.

GUIDANCE IN USING ASME PERFORMANCE TEST CODES. ASME PTCs are developed primarily to address the needs of contract acceptance and/or compliance testing. This is not intended, however, to limit or prevent the use of PTCs for other types of testing where the accurate determination of performance is required.

PTCs are not tutorials: they are intended for use by persons experienced in testing power plants and equipment performance by following the rules of any Code. Prerequisites include detailed knowledge of power-plant operations, thermodynamic analyses, calculations of heat balance, testing and measurement uncertainties and their analyses, testing methods, and the use, control, and calibration of test-equipment and measuring instrumentation.

ASME PTCs are developed to support the achievement of specific test goals. Test goals are the overall objective and achievement of the test execution (corrected or uncorrected performance parameter or guarantee performance parameter desired to be determined: power output, heat rate, capacity, steam rate, efficiency, performance ratio, etc.) at a specific set of reference conditions and operating criterion.

ASME PTCs provide rules and procedures for designing and executing a test setup that is used to support the test goal. A test setup is a detailed approach that encompasses the test strategy, required measurements, corrections, assumptions, estimations, operating limitations, deliverables, and resources required to perform testing for determination of a test goal.

The test setup rules and practices within the ASME PTCs are the same as in any field of practice where the scientific method is applied to ensure a controlled experiment or test. The test setup is implemented to ensure accuracy of the results from the test. When a controlled experiment or test is conducted, the test must be designed to limit or minimize the effects of variables other than those of the independent variables over which the parties to the test have no control. Uncontrolled variables that influence the dependent variables will be determined from the test.

Ideally, a test setup of a controlled experiment or test on a power plant or equipment would be designed, planned, executed, and reported whereby all of the influential parameters are specifically set to a desired value and under the control of the parties to the test.

For example, if a control set consisting of all exogenous factors (such as the influential parameters of ambient temperature, relative humidity, barometric pressure, wind speed, wind direction, fuel composition, fuel temperature, load disposition, valve isolation, valve lineup, and auxiliary alignments) at the test boundary and within the control system were matched perfectly to the conditions that support determination of the test goals or the guaranteed performance parameters (e.g., heat rate, power output, steam rate, capacity, and performance ratio), then analytical corrections would be unnecessary.

Therefore, the test would directly measure the performance parameters that could then be compared to the guarantee at reference and operating conditions. Such a design would put the measured results on the same basis as the guarantees for comparisons without any analytical manipulations. However, the ability to achieve this ideal state, where the Test Goal and Test Setup are perfectly matched, is very impractical in practice, and thus requires a Test Setup that is as close as

possible to the Test Goal's specified conditions, balancing uncertainty, cost, and the value of information obtained from the test.

So, when conducting a PTC test, the Test Setup should determine performance at specific operating conditions and with certain fixed parameters at the boundary and within the limits of the plant or the equipment being tested. Such setups, that limit analytic corrections to yield results of the highest level of accuracy based on current engineering knowledge, take into account test costs and the value of the information obtained from testing. To accomplish this, one must have thorough knowledge of which influential parameters are within their control and which influential parameters are outside their control. The main part of test setup is control of equipment and/or plant operating conditions and reference conditions, when possible, to be consistent with the specified performance. If a difference from the specified operating or reference condition cannot be eliminated, then parties to the test must agree upon and develop analytical methods to correct for their influence on the performance test results.

It important to recognize that part of the test setup is knowing how the choice of controlled or imposed upon operating modes affects the plant or equipment performance calculations and calculation methodology. For a properly designed test, the thermal performance model should develop the plant or equipment correction curves based on the established test setup and the planned or imposed mode of operation during the test. During the performance test, the plant or equipment shall then be operated in accordance with the operating philosophy upon which the correction curves or models are based. Care must be taken to ensure that when a correction is applied, it does not result in a performance at a condition at which the equipment could not actually operate, such as beyond a pressure, temperature, or flow capacity limit.

Section 1

Purpose, Scope, and Organization

1-1 DEFINITION AND PURPOSE

ASME PTCs provide uniform rules and procedures for the planning, preparation, execution, and reporting of performance test results. Test results provide numerical characteristics to the performance of equipment, systems, and plants being tested. A performance test is an engineering setup and evaluation where measurements of key parameters are taken under controlled circumstances to provide inputs to calculations. These results can be used to benchmark or ascertain performance at a particular time and can indicate how well the performance of the specified equipment compares to an established design, predicted criteria, or previous test results. Throughout ASME PTC 1, when the term “equipment” is used with reference to the object of a performance test, it can refer to specific equipment, systems, or entire plants.

1-2 STANDARDS COMMITTEES

ASME PTCs are developed by technical committees that are governed, organized, and appointed by the Performance Test Codes Supervisory Committee under the auspices of the Board on Standardization and Testing. Each code-writing committee is organized to include representatives of several interest groups. The qualifications of each member of a code-writing committee are subject to examination and approval by the Supervisory Committee. Members of the code-writing committees are highly qualified, technically competent professionals, generally members of ASME, who have expertise in the field or in an area of expertise needed by the committee, such as special instrumentation. Each member presents their views on matters under consideration as members of a learned profession, not as representatives of employers or special interest groups.

1-3 SCOPE AND ORGANIZATION OF PTCs

Most ASME PTCs are applicable to a specified type of equipment defined by the Code. There may be several sub-categories of equipment covered by a single code. Types of equipment to which PTCs apply can be classified into the following five broad categories:

- (a) power production, energy conversion, and storage
- (b) combustion and heat transfer
- (c) performance monitoring
- (d) fluid handling
- (e) emissions

The quantities that characterize performance are defined in each code for the equipment within its scope. Absolute performance characteristics determined by adherence to a PTC can be evaluated and compared to design or predicted characteristics or previous test results, or they can be used to benchmark or ascertain performance at a particular time.

Some PTCs are written as general reference documents in support of the equipment PTCs. These can be considered as technical reference material for the equipment codes. Three types of reference codes exist.

The first type covers guidance and reference information. It currently consists of ASME PTC 2, which contains standards for terms, units, values of constants, and technical nomenclature.

The second type covers instrumentation used in the measurement of thermodynamic or process fluid parameters, such as pressure, temperature, flow, and shaft power. Individual codes referring to process or thermodynamic quantities are known as Performance Test Code Instruments and Apparatus Supplements. They are supplementary to the information on mandatory instrumentation requirements contained in the equipment codes. Instrumentation information in equipment test codes supersedes the information given in these supplements, but otherwise these supplements can be incorporated by reference in equipment test codes where deemed appropriate by the committee.

The third type addresses how to analyze the uncertainties associated with measurement of all primary parameters to develop overall test uncertainty. It currently consists of PTC 19.1.

Over time, the Performance Test Codes Supervisory Committee, under the auspices of the Board on Standardization and Testing, review the PTCs in order to judge their relevancy, technical evolution, development, and applicability, whereby a code may be withdrawn or discontinued.

Figures 1-3-1 and 1-3-2 show the organization of ASME PTC categories. Table 1-3-1 provides a list of withdrawn and discontinued ASME PTCs.

1-4 PHILOSOPHY

PTCs provide guidelines for test procedures that yield results of the highest level of accuracy based on current engineering knowledge, considering testing costs and the value of information obtained from testing. Code committees, Code users, and parties to the test shall ensure that the philosophy of “unbiased test method” is maintained throughout the design of a fair and balanced test, whereby the test is objective and without bias toward any one particular interest group. Transparency shall be maintained, whereby all parties to the test are made 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. Precision and reliability of test results shall underlie all considerations in the development of an ASME PTC, consistent with economic considerations as judged appropriate by each technical committee and in keeping with the philosophy of the ASME Performance Test Codes Supervisory Committee.

1-5 APPLICATIONS OF PTCs

Code tests are suitable whenever performance shall be determined with minimum uncertainty. They are meant specifically for equipment operating in an industrial setting. Typical uses include

- (a) determining if the equipment meets design or expected performance criteria.
- (b) being incorporated by reference into contracts to serve to determine fulfillment of guarantees.
- (c) being incorporated by reference or adopted by governments or government agencies into regulations or laws.
- (d) evaluating performance following modification, change in operating conditions, or any suspected change in performance for which such investigation is required.
- (e) conducting studies to help determine the value of possible upgrades or modifications to equipment.
- (f) benchmarking performance, sometimes to help determine the necessity for specific preventive maintenance or possible upgrade or modification.
- (g) tracking trends in performance in time by scheduling performance tests at regular intervals. Such trends are also used to help determine necessity for specific preventive maintenance or possible upgrade or modification.
- (h) validating results from online or continuous performance-monitoring systems, which are usually less accurate than results of tests conducted in accordance with PTCs.

PTCs can be used to quantify the magnitude of performance anomalies of equipment that is suspected to be performing poorly or to confirm the need for maintenance if simpler means are not adequate. PTCs are excellent sources or references for simpler routine or special equipment test procedures.

Conducting periodic performance tests on equipment can uncover the need for further investigation, which can lead to preventive maintenance or modification.

1-6 TEST UNCERTAINTY

1-6.1 Definition

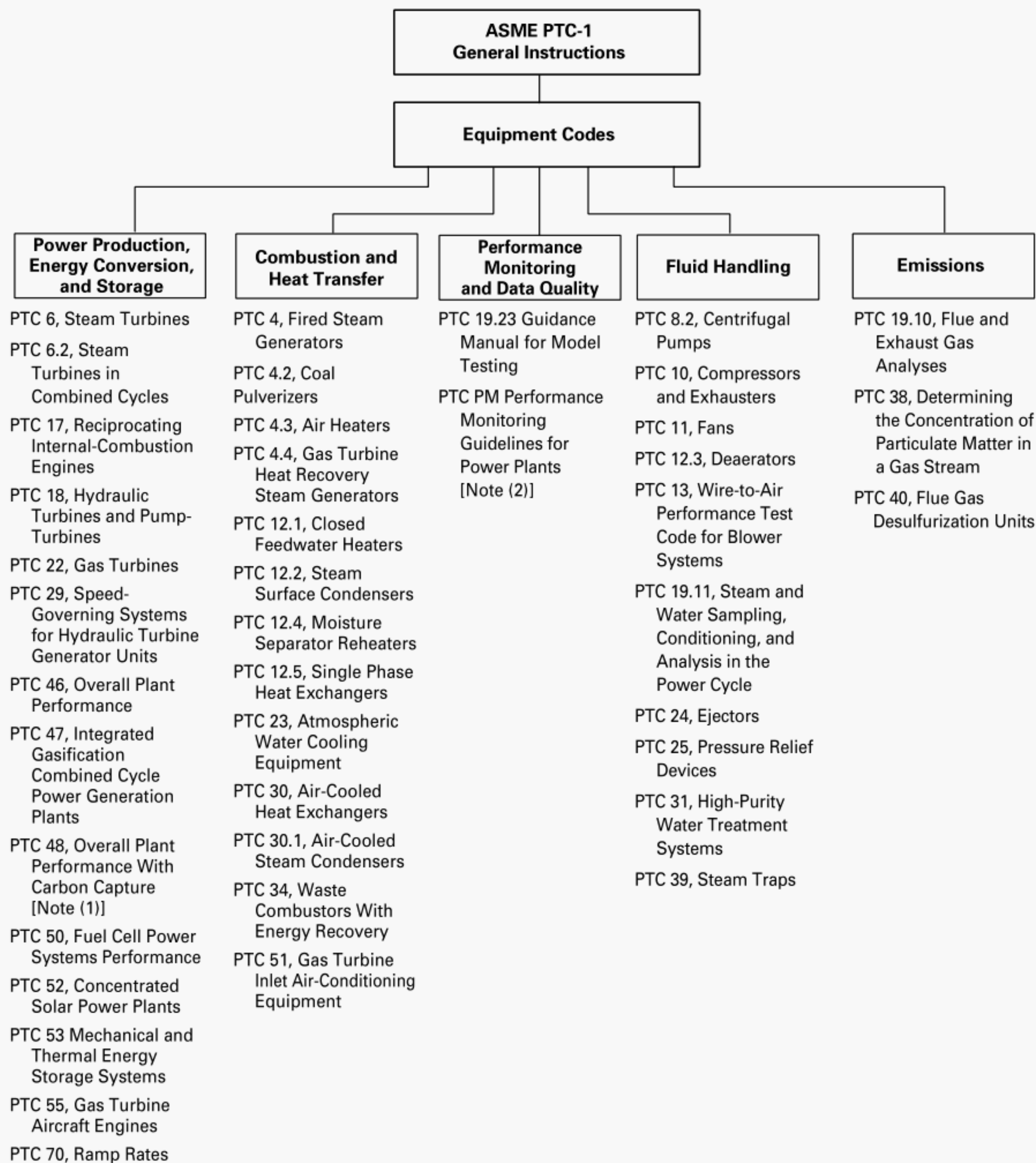
Test uncertainty is an estimate of the limit of error of a test result. It is the interval of a test result that contains the true value with a given probability or level of confidence. It is based on calculations using statistics, instrumentation information, calculation procedure, and actual test data. ASME PTC 19.1 is the PTC Supplement that covers general procedures for calculation of test uncertainty. PTCs maintain a 95% level of confidence for which uncertainty is calculated as their standard. This confidence level therefore represents a 95% chance that the uncertainty interval contains the true value.

1-6.2 Applications of Test Uncertainty Analysis — General

Analysis of test uncertainty is useful because it

- (a) identifies dominant error sources, their effects on a test result, and estimates of their limits
- (b) validates quality of test results
- (c) facilitates communication regarding results
- (d) facilitates the choice of appropriate and cost-effective measurement devices and procedures
- (e) reduces the risk of making erroneous decisions

**Figure 1-3-1
Organization of Equipment PTCs**



NOTES:

(1) PTC 48 is in the course of preparation.

(2) Note that the PTC-PM document is now under the auspices of the Reliability, Availability, and Performance (RAP) Standards Committee.

Figure 1-3-2
Organization of Supplemental Documents

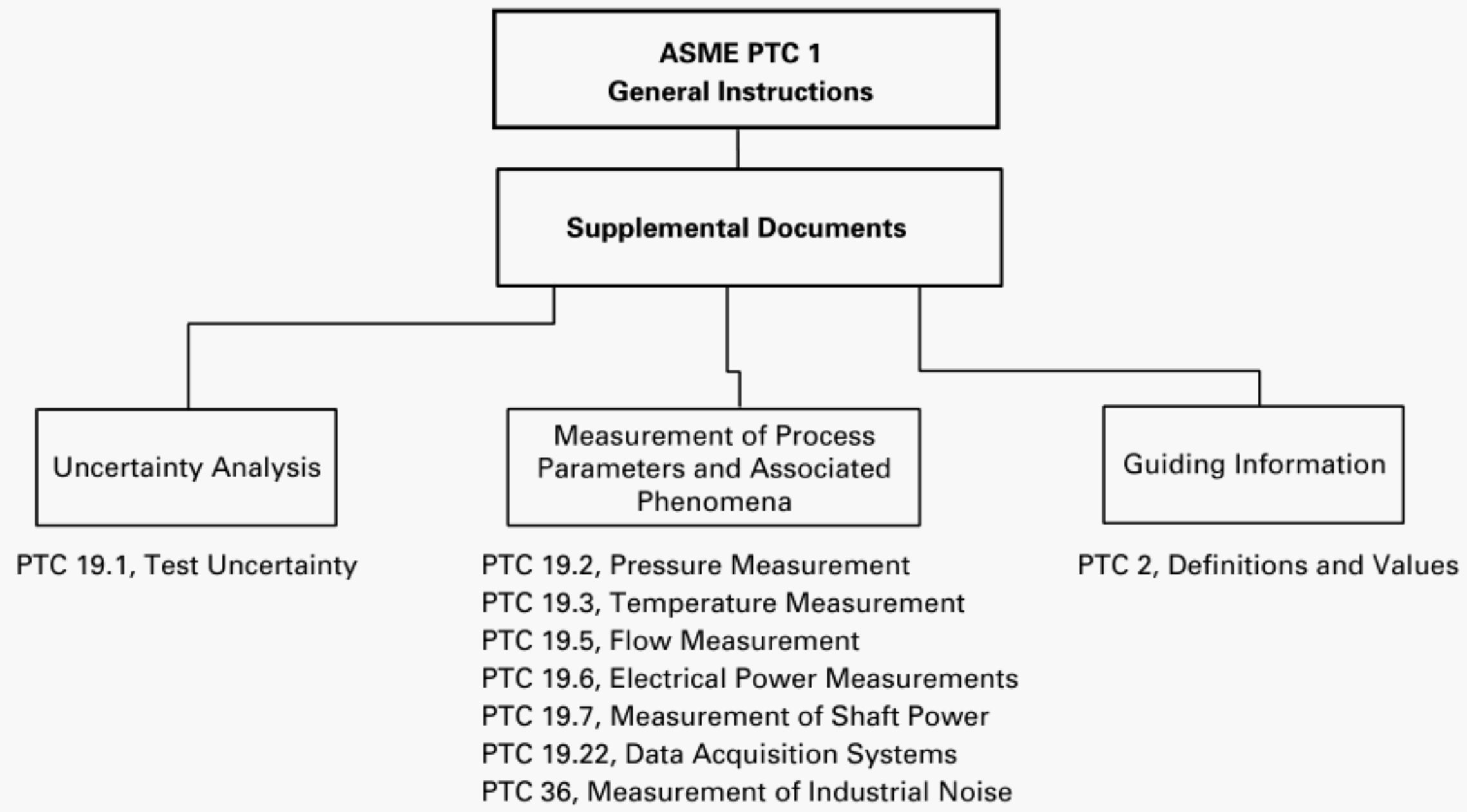


Table 1-3-1
List of Withdrawn and Discontinued ASME PTCs

Designation	Title	Year Withdrawn
PTC 3.1-1958 (R1992)	Diesel and Burner Fuel	2003
PTC 3.2-1990	Coal and Coke	2002
PTC 3.3-1969 (R1992)	Gaseous Fuels	2003
PTC 5-1949	Reciprocating Steam Engines [Note (1)]	2002
PTC 6 Report-1985 (R2003)	Guidance for Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines	2008
PTC 7-1946 (R1969)	Reciprocating Steam Driven Displacement Pumps [Note (1)]	[Note (2)]
PTC 7.1-1962 (R1969)	Displacement Pumps [Note (1)]	2002
PTC 9-1970 (R1997)	Displacement Compressors, Vacuum Pumps and Blowers	2003
PTC 14-1970 (R1991)	Evaporating Apparatus	2002
PTC 16-1958 (R1991)	Gas Producers and Continuous Gas Generators	2002
PTC 18.1-1978 (R1984)	Pump Mode of Pump/Turbines	2002
PTC 19.5.1-1964	Weighting Scales [Note (1)]	2002
PTC 19.8-1970 (1985)	Measurement of Indication Power	2002
PTC 19.12-1958	Measurement of Time [Note (1)]	[Note (2)]
PTC 19.13-1961	Measurement of Rotary Speed [Note (1)]	[Note (2)]
PTC 19.14-1958	Linear Measurement [Note (1)]	2002
PTC 19.16-1965	Density Determinations of Solids and Liquids [Note (1)]	[Note (2)]
PTC 19.17-1965	Determinations of Viscosity of Liquids [Note (1)]	[Note (2)]
PTC 20.1-1977 (R1988)	Speed and Load Governing Systems for Steam Turbine Generator Units	2003
PTC 20.2-1965 (R1986)	Overspeed Trip Systems for Steam Turbine Generator Units	2003
PTC 20.3-1970 (R1986)	Pressure Control Systems Used on Steam Turbine Generator Units	2003
PTC 21-1991	Particulate Matter Collection Equipment	2006
PTC 23.1-1983	Spray Cooling Systems	2001
PTC 26-1962	Speed Governing Systems for Internal Combustion Engine Generator Units [Note (1)]	2002
PTC 28-1965 (R1985)	Determining the Properties of Fine Particulate Matter	2003
PTC 32.1-1978 (R1992)	Nuclear Steam Supply Systems	2002
PTC 32.2 Report-1978 (R1992)	Methods of Measuring the Performance of Nuclear Reactor Fuel in Light-Water Reactors	1998
PTC 33-1978 (R1991)	Performance Test Code — Large Incinerators	2004
PTC 33a-1980 (R1987)	Appendix to ASME PTC 33, Performance Test Code — Large Incinerators	2004
PTC 42-1998 (R2004)	Wind Turbines	2008

NOTES:

(1) This PTC was not an ANSI code.

(2) Official withdrawal date is unknown.

(f) demonstrates compliance with test requirements

(g) facilitates interpretation of test results

1-6.2.1 Pretest Uncertainty Analysis. PTCs require a pretest uncertainty analysis, inclusive of estimates of systematic and random errors, in order to effectively plan the test and demonstrate that the test can be designed to meet the Code requirements. A pretest uncertainty analysis helps to determine if the proposed test measurements and the number and quality of the test instruments meet the requirements for compliance with Code. A pretest uncertainty analysis allows corrective action to be taken prior to the test, either to decrease the uncertainty to a level consistent with the overall objective of the test or to reduce the cost of the test while still attaining the objective. In addition, a pretest uncertainty analysis can be used to determine the significance of correction factors that may be applied to correct test results. PTCs require that the pretest uncertainty analysis includes an analysis of random uncertainties to establish permissible fluctuations of key parameters in order to attain allowable uncertainties.

1-6.2.2 Post-Test Uncertainty Analysis. PTCs require a post-test uncertainty analysis to determine the uncertainty intervals for the actual test results. The post-test uncertainty analysis will reveal the quality of the test in comparison to the pretest systematic and random uncertainty estimates to determine whether the allowable test uncertainty described within the Code has been realized. It serves to either validate the quality of the test results or expose problems.

1-6.3 ASME PTC Treatment and Uses of Test Uncertainty

Code-writing committees shall state the magnitude of the uncertainties expected in individual measurements and instruct the user in calculation of uncertainty of the final test results. A sample post-test uncertainty analysis based on ASME PTC 19.1 shall be included. This shall include typical random uncertainties based on the experience of the committee.

Application of test uncertainty analysis can vary based on the experience of each committee and on the many different types of equipment for which Codes are written. There are several acceptable ways to use test uncertainty analysis in ASME PTCs (see [paras. 1-6.3.1](#) and [1-6.3.2](#)).

1-6.3.1 Permissible Uses of Test Uncertainty. The following uses of test uncertainty are permissible to prepare for and validate the acceptability of a test. One or more shall be used in a single Code.

(a) Specify the maximum test result uncertainty above which the test result is not acceptable for each type or configuration of equipment. The maximum test results' uncertainty is a limit and not a target in designing a test.

(b) Specify the typical test result uncertainty of a test for each type or configuration of equipment. This can be done only if the range of acceptable test result uncertainties is small — no more than 20% of a typical mean uncertainty, based on the experience of the committee. A statement should be included that significant deviations from the typical test result uncertainty — in either direction — indicate that uncertainty assumptions may be invalid, or the test was not typical. For example, if a “typical test result uncertainty” of 1.0% were reported, then the committee would not expect a valid test with an uncertainty of larger than 1.2%; likewise, a calculated post-test uncertainty of less than 0.8% is unlikely although possible if superior instrumentation or procedures are used for a particular test.

(c) Specify a typical range of acceptable uncertainties for each type or configuration of equipment. This approach is preferable when sensitivity factors tend to be very nonlinear and much higher during some acceptable test conditions than during others. This should be done if treating uncertainty per (b) above, in order to determine the validity of a test in which the range of typical uncertainties is larger than 20%. The range of acceptable test uncertainties based on the causative sensitivities should be indicated.

(d) Specify the total uncertainty for each measurement parameter/variable (e.g., main steam throttle pressure, compressor inlet temperature, fan inlet air flow) or measurement parameter/variable type (e.g., flow, temperature, pressure). The total uncertainty can be specified directly or by specifying the systematic and random uncertainty. The random uncertainty may be specified directly or as a variation or data fluctuation. This is equivalent to establishing an upper limit on the test result uncertainty per (a) since the test result uncertainty is calculated from the total uncertainty and sensitivity of the individual parameter/variable upon the test result. A pretest and post-test uncertainty is still required; however, it is limited to demonstrating that the uncertainty limits placed upon each individual measurement parameter/variable have been met. In this case, the sensitivity coefficients shall be very nearly linear so that the total test result uncertainty is not affected by the magnitude of any corrections.

(e) Specify the instrumentation requirements and uncertainty limits as per (d) along with the additional allowance for the total test result uncertainty that shall be determined pretest from those requirements to establish a Code limit for the uncertainty. Once this limit is established, any of the specified parameter/variable limits set can be exceeded if the total test result uncertainty is lesser than or equal to the established Code-limiting total test result uncertainty. This requires that total test result uncertainty for the actual pre- and post-test be determined using the same uncertainty analysis approach (e.g., same assumptions, same sources, same mathematical steps) that was performed to establish the Code's limit for the total test result uncertainty. In cases of equipment for which there are usually large uncertainties, which are acceptable based on the committee's experience, the reasons should be discussed. Details should be given in an uncertainty calculation appendix.

Examples of such reasons are as follows:

- (1) inhomogeneous fuels
- (2) high and variable sensitivity factors

It should be discussed broadly how to minimize uncertainty, with further details given in the body of the Code. Then, any of the acceptable methods of using the test uncertainty principles listed in (a) through (e), or a combination of them, to prepare for and validate a test shall be used.

1-6.3.2 Nonpermissible Uses of Test Uncertainty. The following uses of, or references to, test uncertainty are not permissible in a Code:

(a) The minimum achievable test uncertainty cannot be given exclusively without reference to a range or a typical or maximum allowable test uncertainty per [paras. 1-6.3.1\(a\)](#) through [1-6.3.1\(d\)](#). Stating only the best achievable uncertainty gives no guidance to the Code user as to whether a test is valid or not and allows for poor tests to be conducted in violation of the philosophy of PTCs.

(b) PTCs specify test methods to determine the performance of the equipment. Commercial issues are wholly outside the scope of PTCs. It is not permissible to refer to any commercial issues typically contained in contracts, such as the method of comparing a test result to a contract guarantee by offsets or deadbands related to test uncertainty.

1-7 OTHER CODES AND STANDARDS

PTCs shall be developed in strict accordance with the philosophy stated in [subsection 1-4](#). Related codes and standards or additional measuring procedures developed by other organizations, such as the American Society for Testing and Materials, Institute of Electrical and Electronics Engineers, American Institute of Chemical Engineers, and the Environmental Protection Agency, may be referenced by PTCs. Consideration should be given to techniques and rules published in other international codes and standards, such as those of the International Standards Organization (ISO). Some equations and techniques are referenced as joint ASME/ISO equations or techniques in the professional literature.

Section 2

Standard Form of Individual Equipment Test Codes

2-1 INTRODUCTION

Individual test codes and their revisions shall contain a table of contents and the standard form, arrangement, scope, and contents shall comply with the following specifications.

2-2 SECTION 1, OBJECT AND SCOPE

Under this Section, the individual codes shall outline the test objectives and define the scope of the test, size and types of equipment, and processes embraced by, or excluded from, the Code.

2-2.1 Object

The Object shall state

- (a) the type(s) of equipment covered.
- (b) the physical results that can be determined regarding the performance of the covered equipment (e.g., capacity, efficiency, power output or input, and specific process results such as temperatures and sulfur capture). Not all results that can be determined by application of the Code must be included in the objectives of a specific test.
- (c) the specific goals of tests that can be designed according to the Code, such as determination of performance at specific operating conditions or with certain fixed parameters.

2-2.2 Scope

The Scope shall clearly state

- (a) a specific definition of the types of equipment to which the Code may be applied
- (b) identification of any similar equipment to which the Code does not apply
- (c) other minimum conditions that shall be met for the Code to be applied
- (d) similar tests that can be performed on the equipment within the scope of the Code, but which are not part of the Code

2-2.3 Uncertainty

This Section shall also address the uncertainty of tests performed using the Code. It shall include a discussion of the test uncertainty per one or more of the approaches in [para. 1-6.3](#). For cases in which there are various industrial applications and configurations of mechanical equipment, processes, or systems that might be addressed by a particular Code committee, the uncertainty of several representative configurations shall be addressed.

2-3 SECTION 2, DEFINITIONS AND DESCRIPTIONS OF TERMS

Section 2 shall contain a list of terms with definitions for those not given in ASME PTC 2. Symbols and abbreviations shall be specified for equations and should conform to ASME PTC 2. Figures that are useful for the clarification of terms or symbols may also be included.

2-4 SECTION 3, GUIDING PRINCIPLES

Section 3 shall discuss in detail those items that shall be completed prior to the test and describe all those who have test responsibilities (i.e., parties to the test) (see [subsection 3-3](#) for further discussion).

These include the following (see also [para. 3-4.3](#)):

- (a) rules covering test preparations
- (b) arrangements of the test apparatus
- (c) starting and stopping procedures

- (d) selection and qualifications of testing personnel, including the test's coordinator
- (e) methods of operation during a test
- (f) provisions for equipment inspection
- (g) provisions for preliminary tests
- (h) permissible and impermissible adjustments during a test
- (i) degree of constancy of testing conditions
- (j) duration of test runs
- (k) recommended number of test runs
- (l) repeatability requirements
- (m) causes for rejection of inconsistent test readings or results
- (n) methods of comparing results with the specified performance
- (o) limits of uncertainty not promulgated in the Object and Scope
- (p) pretest agreements

A table of permissible data fluctuations is not required if a maximum allowable uncertainty or an uncertainty range is mandated in the Code. Fluctuations do affect the random component of test uncertainty and that effect can be estimated prior to starting a test. Maximum permissible data fluctuations of multiple parameters, when combined in aggregate, can lead to a very high final test uncertainty.

2-5 SECTION 4, INSTRUMENTS AND METHODS OF MEASUREMENT

Section 4 shall provide the mandatory provisions for quantity and choice, required sensitivity or precision, expected or required uncertainty, and calibration requirements for instruments used in the implementation of a Code test. Instructions for methods of measurement, location of measuring systems, and precautions to be taken shall be included in this Section. This section shall define the uncertainty requirements for specific measurements. The uncertainty requirement must be clearly defined as to what type of uncertainty the requirement indicates (i.e., systematic component or total measurement inclusive of random and systematic components).

To avoid repetition, individual Codes shall refer to the applicable PTC 19 Supplement(s). The Instruments and Apparatus Supplements to ASME PTCs (ASME PTC 19 series) outline the methods of measurement, instrument types, limits, sources of error, corrections, and calibration details concerning instrumentation that comprise the governing requirements of instrumentation for all ASME Code-level performance testing.

When specific references are made to an ASME PTC 19 Supplement, it shall be made by section(s), or paragraph(s), and the date of the Supplement to make the supplement reference mandatory to the individual Code. The individual Codes must define the uncertainty requirement for specific measurements since the Supplements may define optional measurement methods, calibration requirements, instruments, etc., to achieve different levels of measurement uncertainty.

General references to a PTC 19 Supplement are also permitted, but only in cases where specific requirements are not necessary within the Code. Any exceptions to the instrumentation requirements in the Instrument and Apparatus Supplement shall be stated within the individual test Code.

Only in the case whereby guidance and requirements are not covered by the Instruments and Apparatus Supplements are individual Codes permitted to have further rules and precautions described completely in this Section.

If the Instruments and Apparatus Supplements are updated to include guidance and requirements contained within the Section 4 of an individual Code, that Code shall be updated during the next revision cycle to remove the replicated text and replace it with reference to the appropriate Instruments and Apparatus Supplements.

2-6 SECTION 5, COMPUTATION OF RESULTS

Section 5 shall contain formulas and directions for calculating results from the test's observations, including the correction of instrument readings. It shall address calculation and application of corrections for deviations of test operating conditions from the base reference conditions. The details of computations and data assembled shall be included either here or in an appendix, along with the derivations of pertinent equations and determinations of test uncertainty.

2-7 SECTION 6, REPORT OF RESULTS

Section 6 shall state what general information regarding the plant and the particular equipment under test shall be reported. For acceptance tests, this Section shall state that the report includes

- (a) an outline of specified operations conditions and guarantees
- (b) corrections for deviation from specified conditions

- (c) magnitude of the uncertainty of test observations and overall results, if agreed to by the parties to the test
- (d) methods adopted for measurement if choices are permitted
- (e) test methods when those prescribed have, by prior agreement, not been followed
- (f) mean observations
- (g) test results under the test operating conditions and corrected to specified conditions
- (h) test conclusions

If a post-test uncertainty analysis is to be used to establish the validity of the test, Section 6 shall require that the report documents such validity.

2-8 SECTION 7, TEST UNCERTAINTY

This Section shall contain formulas and directions for calculating uncertainty of test results. ASME PTC 19.1 is the primary reference for uncertainty calculations, and any uncertainty analysis that conforms to ASME PTC 19.1 shall be acceptable. Any deviations from the methods described in ASME PTC 19.1 shall be noted and explained in detail. Additionally, this Section should provide guidance for estimating the systematic component(s) of uncertainty. This Section, taken together with ASME PTC 19.1, shall enable users of the Code to perform complete pretest and post-test uncertainty analyses, which are sufficient for the uses of uncertainty described in [para. 1-6.3](#).

2-9 ADDITIONAL SECTIONS AND APPENDICES

Additional sections may be included to present detailed background information that illustrates or supports methods or formulas included in the Code or present additional data and guidance to the user. Subjects that may be included in additional sections are, for example, rationale and derivation of expected uncertainty, derivation of formulae, derivation of figures, examples of the proper use of figures or curves, detailed description of methods of measurement or techniques not covered in the ASME PTC 19 series, a list of references, sample calculations, alternative test method, and detailed requirements for use of a Performance Model for test calculations. It should be noted that it is not mandatory that Codes have additional sections. However, additional sections (in the body of the Code, such as Sections 8 and 9 and Appendices I and II) are mandatory if the Committee deems them necessary. Lettered appendices are not mandatory; they provide expository information explaining the rationale for the body of the Code or additional information to the Code user.

The number of such expository sections shall be minimized to maintain the clarity of the Code.

2-10 ALTERNATIVE METHOD

If an individual Code provides for an alternative testing method, that Code shall

- (a) indicate the specific conditions under which any one method should be used
- (b) require prior agreement among the interested parties as to which of the methods is to be adopted
- (c) determine and report the effect of the alternative testing method(s) on test uncertainty

Section 3

Information for ASME Performance Test Code Users

3-1 INTRODUCTION

This Section contains common rules for conducting tests on most equipment. An official test is any test conducted in accordance with a PTC.

3-2 CODE TEST

A Code test is a test that is designed, planned, executed and reported in compliance with the ASME PTC philosophy of [Section 1-4](#). To be considered a Code-compliant test, the user of the Code shall plan, execute, and report a test that meets the following two approaches:

3-2.1 Explicit Compliance Test

A test can be considered a Code Test if the user(s) of the Code or parties to the test ensure that all the explicit procedures, methods, requirements, and acceptance criteria of the Code are met. It is ASME Code practice to use the word “shall” to express a mandatory requirement of the Code. However, in some cases the words “must,” “ensure,” “will,” and “is to be” will be used to express a mandatory requirement of the Code. Use of the words “should” or “may” in a Code clause indicates that a statement is a recommendation and shall not be considered explicit procedures, methods, requirements, and acceptance criteria of the Code.

3-2.2 Agreements Compliance Test

Any departure from Code requirements could introduce additional uncertainty beyond that considered acceptable to meet the objectives of the Code. Tests should be conducted with the strictest possible adherence to the provisions of a Code.

However, it is recognized that there is a diverse range of power plants and equipment designs that cannot be generally categorized for purposes of establishing explicit testing methods and uncertainty limits that will cover all encounters within the industry. Further, events outside the control of the parties of a test or facility/equipment limitations could dictate that the parties cannot comply with one or more Code requirements. In these circumstances, agreement between the parties is necessary.

Further, in such cases, the Code user shall conform to the intent of the Code as closely as possible and shall define in detail how to manage departures from specific Code requirements and establish the magnitude of the uncertainty imposed by those departures. For a test to be considered Code compliant, any departure from the Code requirements shall be agreed upon in writing by the parties to the test and conform to the intent of the Code. In the absence of written agreement by the parties to the test, the Code requirements shall be mandatory.

Care shall be taken by the parties to ensure that they engage persons experienced in power-plant performance and testing per ASME PTCs and with detailed knowledge of power-plant operations, thermodynamic analysis, heat balance development, test-measurement methods, and the use, control, and calibration of measuring and test equipment to ensure that informed and well evaluated agreements are made. Though allowed, agreements of the parties should not be made lightly.

3-3 PARTIES TO A TEST

The parties to a test are those persons and companies interested in the results. In commercial tests, it may include the owner(s), supplier(s), equipment manufacturers, architects, and engineers, firms hired to conduct or witness the tests, engineering analysts, financiers, and any of their representatives. In a commercial test, it is important that the contract delineate who the actual parties to the test are and who will be responsible for the requirements within the Code for “parties to a test” duties and actions.

In other noncommercial tests, the parties to a test may all be from the same company but represent different functions and interests (e.g., testing, analysis, plant operations, performance engineering, purchasing, research, and plant maintenance).

Regardless of whether it is a commercial or noncommercial test, each party to the test shall designate a representative to the test team who will observe the test and confirm that it was conducted in accordance with the test's requirements. This representative should also have the authority, if necessary, to fulfill individual code's "parties to the test" responsibilities, such as but not limited to approving any agreed-upon revisions to the test approach, deviations, procedures, or calculations during the planning, execution, and reporting of the test.

3-4 PREPARATIONS FOR TESTING

3-4.1 General Precautions

Reasonable precautions shall be taken when preparing to conduct a Code test. Indisputable records shall be established and maintained to identify and distinguish the equipment to be tested and the exact method of testing selected. Descriptions, drawings, test measurement forms, or photographs are effective methods to a permanent, explicit record. Instrument locations shall be predetermined and described in detail in test records. Redundant or spare calibrated instruments should be provided for those instruments susceptible to in-service failure or breakage.

3-4.2 Test Coordinator

The parties to the test shall designate a person to direct the test, hereafter called the test coordinator. Intercommunication arrangements between the test coordinator and all test personnel and parties to the test should be established.

3-4.3 Agreements

Section 3 of each Code shall contain language providing general guidance for the application of a Code. This guidance shall include a tabulation of preparatory items that shall be completed, understood, and agreed to among the parties to a test and that are recommended for the legitimate execution of a Code test; recommendations for the timing of testing of new or modified equipment; and allowance for equipment inspections. These include the following:

- (a) object of test
- (b) location and timing of test
- (c) test boundaries
- (d) selection of instruments
- (e) method of calibration of instruments
- (f) confidentiality of test results
- (g) number of copies of original data required
- (h) data to be recorded and method of recording and archiving data
- (i) values of measurement uncertainty and method of determining overall test uncertainty
- (j) method of operating equipment under test, including that of any auxiliary equipment, the performance of which may influence the test result
- (k) methods of maintaining constant operating conditions as near as possible to those specified
- (l) method of determining duration of operation under testing conditions before test readings are started
- (m) system alignment or isolation
- (n) organization of personnel, including designation of engineer in charge of the test
- (o) duration and number of test runs
- (p) frequency of observations
- (q) base reference conditions
- (r) applicable range of correction, methods of correction, and values used for corrections for deviations of test conditions from those specified
- (s) methods of computing individual test runs and average test results
- (t) method of comparing test results with specified performance
- (u) conditions for rejection of outlier data or runs
- (v) intent of contract or specification if ambiguities or omissions appear evident
- (w) pretest inspections
- (x) resolution of non-repeatable test runs and their results

3-4.4 Timing

For a commercial test, the purchase contract can specify the time limit, following first dependable commercial operation, within which a field acceptance test should be undertaken. Failing this, an acceptance test should be undertaken within the period stated in the test Code but not over 6 months from the time the equipment is first put into operation, except with written agreement to the contrary. Deterioration from use of the equipment during such prior operation, which may adversely affect the results, should be corrected by the purchaser before acceptance tests are conducted, or agreement should be reached for adjusting the test results to compensate for such deterioration. The parties to a commercial test should recognize the impracticability of exact prediction of the equipment's availability for test purposes and should seek a mutually satisfactory adjustment of any unforeseen situation. An official test for other purposes may be conducted at any time.

3-4.5 Preparation

For acceptance and other official tests, the manufacturer or supplier shall have reasonable opportunity to examine the equipment, correct defects, and render the equipment suitable to test. The manufacturer, however, is not thereby empowered to alter or adjust equipment or conditions in such a way that regulations, contract, safety, or other stipulations are altered or voided. The manufacturer may not adjust the equipment for test purposes that may prevent immediate, continuous, and reliable operation at all capacities or outputs under all specified operating conditions. Any actions taken shall be documented and immediately reported to all parties to the test.

All parties to the test shall be given timely notification, as defined by prior agreement, to allow them the necessary time to respond and to prepare personnel, equipment, or documentation. Updated information shall be provided as it becomes known.

3-4.6 Starting and Stopping

Acceptance and other official tests shall be conducted as promptly as possible following initial operation and preliminary test runs. The equipment shall be operated for a sufficient time to demonstrate that the intended test conditions have been established (e.g., steady state). The means to determine that intended operating conditions have been attained are equipment specific and, therefore, are specified in the respective individual equipment's test codes. Agreement on procedures and time shall be reached before commencing the test.

The test coordinator is responsible for ensuring that all data collection begins at the agreed-upon start of the test and that all parties to the test are informed of the starting time. Tests are normally stopped when the test coordinator is satisfied that requirements for a complete test run have been satisfied. The test coordinator should verify that the specified methods of operation during test have been satisfied. The test coordinator may extend or terminate the test if the requirements are not met.

3-4.7 Acceptability of Equipment and Instruments

Equipment and instruments shall be examined as necessary to ensure the validity of the test and operating procedures and the suitability of the instruments. Calibrated redundant instruments shall be provided for those instruments susceptible to in-service failure or breakage. Redundant instruments should also be considered for the measurement of key parameters that have a large effect on test results or the test uncertainty. Instrumentation used for data collection shall be at least as accurate as instrumentation identified in the pretest uncertainty analysis and the Code. This instrumentation can be either permanent plant instrumentation or temporary test instrumentation.

3-4.8 Preliminary Test Runs

Preliminary test runs with records serve to determine if the equipment is in suitable condition to

- (a) test
- (b) check instruments and methods of measurement
- (c) check adequacy of organization and procedures
- (d) train personnel

All parties to the test may make reasonable preliminary test runs as necessary. Observations during preliminary test runs should be carried through to the calculation of results as an overall check of procedure, layout, and organization. If such a preliminary test run complies with all the necessary requirements of the appropriate test Code, it may be used as an official test run within the meaning of the applicable Code.

3-5 TESTS

3-5.1 Readjustments

Once testing has started, readjustments to the equipment that can influence the test results require the repetition of all test runs conducted prior to the adjustment(s). No adjustments are permissible, solely for the purpose of a test, that are inappropriate for reliable and continuous service or operation following a test.

3-5.2 Data Collection

Data shall be recorded by automatic data collecting equipment or by competent observers. Automatic data logging and advanced instrument systems shall be calibrated to the required accuracy. No observer shall be required to take so many readings that lack of time may result in insufficient care and precision. Consideration shall be given to specifying duplicate instrumentation and taking simultaneous readings for certain test points to attain the specified accuracy of the test.

3-5.3 Conduct of Test

Complete written records of the test, even including details that at the time may seem irrelevant, should be reported. Controls by ordinary operating (indicating, reporting, or integrating) instruments, preparation of graphical logs, and close supervision should be established to assure that the equipment under test is operating in substantial accord with the intended conditions. If a commercial test, accredited representatives of the purchaser and supplier should be present at all times to assure that the tests are being conducted according to the test Code and prior agreements.

3-6 INSTRUMENTS

3-6.1 Use of Supplements on Instrumentation and Apparatus

The ASME PTC 19 Supplements contain guidance for developing test uncertainty and descriptions of instruments, devices, and methods of measurement likely to be required in any test of equipment. They include directions regarding instrument applications, limits and sources of error, range, sensitivity, precision, and methods of calibration. Individual test Codes shall specify instruments and methods of measurement applicable to that Code. In selecting the instruments and methods of measurement and in arranging the tests, the Code user should ensure that

- (a) the requisite uncertainty of measurement is attainable
- (b) the selected test apparatus and methods are practicable

When an individual test Code references a Supplement, it and the referenced provisions shall be treated in the same manner as the Code.

If the instrumentation requirements in the Instrument and Apparatus Supplement become more rigorous as they are updated, due to advances in the state of the art, their requirements shall supersede those set forth in a Code unless the Code expressly states an exception to the Instrument and Apparatus Supplement or a contract between the parties specifies that the test be performed according to particular revisions of a Code or Instrument and Apparatus Supplement. New devices, apparatus, and methods may be employed in lieu of any instrumentation recommended in a Code or Instrument and Apparatus Supplement as they become available, provided they meet the allowable uncertainty specified within the Code.

3-6.2 Location and Identification of Instruments

Instruments shall be located to minimize the effect of environmental conditions on uncertainty, e.g., temperature or temperature variations, vibrations, electromagnetic interference. Care shall be used in routing lead wires to the data collection equipment to prevent electrical noise in the signal. Care shall be used in the placement of instruments for wireless applications to avoid interference that results in erroneous readings, reduced sampling rates, repetition of previous readings, or skipped scans. Manual instruments shall be located so that they can be read with precision and convenience by the observer. All instruments shall be marked uniquely and unmistakably for identification. Calibration tables, charts, or mathematical relationships shall be readily available to all parties to the test. Observers recording data shall be instructed on the desired precision of readings.

3-6.3 Frequency and Timing of Observations

The timing of instrument observations will be determined by an analysis of the time lag of both the instrument and the process so that a correct and meaningful mean value and departure from allowable operating conditions may be determined. Sufficient observations shall be recorded to prove that steady-state conditions existed during the test where this is

a requirement. A sufficient number of observations shall be taken to reduce the random component of uncertainty to an acceptable level.

3-7 OPERATING CONDITIONS

3-7.1 Operating Philosophy

The tests shall be conducted as closely as possible to the specified operating conditions; this reduces and minimizes the magnitude and number of corrections for deviations from specified conditions. If there are conditions outside the boundary of the test that cannot be rectified or if the conditions are out of the control of the parties to the test and prevent the test from being conducted as closely as possible to the specified operating conditions, then the parties to the test shall agree on how to address such an event (e.g., not test, delay test, additional corrections, alternative testing techniques).

3-7.2 Permissible Deviations

The equipment tested shall be operated to ensure its performance is bounded by the permissible fluctuations and permissible deviations specified within the Code.

3-7.3 Inconsistent Measurements

If any measurement influencing the result of a test is inconsistent with a similar measurement even though either or both of them may have been made strictly in accordance with the rules of the individual test Code, the cause of the inconsistency shall be identified and eliminated.

3-8 DATA RECORDS AND TEST LOG

For all acceptance and other official tests, a complete set of data and a complete copy of the test's log shall become the property of each of the parties to the test. The original log, which may include data sheets, files, disks, and recorder charts, shall permit clear and legible reproduction. Copying by hand is not permitted. The completed data records shall include the date and time of day the observation was recorded. The observations shall be the actual readings without application of any instrument corrections. The test log should constitute a complete record of events including details that at the time may seem trivial or irrelevant. Erasures, destruction or deletion of any data recorded, page of the test log, or any recorded observation is not permitted. If a correction is made, the alteration shall be entered so that the original entry remains legible and an explanation is included.

For manual data collection, the test observations shall be entered on carefully prepared forms that constitute the original data sheets and are authenticated by the observers' signatures. For automatic data collection, printed output or electronic files shall be authenticated by the engineer in charge and other representatives of the parties to the test. When no paper copy is generated, the parties to the test shall agree in advance on the method used for authenticating, reproducing, and distributing the data. Copies of the electronic data files shall be distributed as soon as possible to each of the parties to the test. The data files shall be in a format that is easily accessible to all. A backup, permanent copy should be made for any data residing on a single machine.

3-9 TESTING TECHNIQUE

3-9.1 Technical Considerations

Technical aspects of carrying out tests of equipment and the making of measurements should be considered so computed results may be reliable and acceptable.

Such considerations require a working knowledge of

- (a) theory, precision, and uncertainty of methods and measurements
- (b) practical limitations imposed by the testing of equipment

3-9.2 Precision and Accuracy

In all scientific and engineering testing, results may be precise and/or accurate. The former is a relative quantity, whereas the latter is an absolute quantity. A high degree of precision does not necessarily imply a high degree of accuracy. For example, a given object may be measured for length with a specific measuring scale. Several measurements may show but slight deviation from one another and from the mean. Individual deviations show the degree of precision of

measurement. This degree of precision, however, bears no relationship to the accuracy of the chosen scale for measuring standard units of length. The specific scale may fail to agree with the official legal unit of length. This deviation is of an absolute systematic nature. The readings obtained on the given object when referred to this absolute standard are said to show error or degree of accuracy. A thorough discussion of accuracy and uncertainty in test measurements is given in ASME PTC 19.1. Therefore, precision and accuracy in scientific work shall be clearly distinguished. Extreme care shall prevail in the use of the terms and in their application to testing methods and techniques. ASME PTC-2 is the reference for interpreting such terms.

3-10 ERRORS

3-10.1 Sources of Errors

The following sources of errors may influence the test's uncertainty:

- (a) instrument errors
- (b) errors of observation
- (c) errors resulting from failure to obtain representative samples
- (d) errors resulting from misplaced instruments that do not respond to conditions at the required point of measurement
- (e) errors resulting from instruments having insufficient sensitivity to respond to changes of conditions during a test
- (f) errors resulting from local disturbance in connection to instruments from unpredictable or unexplained causes even though the instruments are located and attached in accordance with the Code or contracted requirements
- (g) calibration errors
- (h) errors in correcting readings, e.g., water legs
- (i) errors of correction factors or methods

3-10.2 Proper Identification and Propagation of Errors

Instrumentation errors are discussed in the Instruments and Apparatus Supplements (ASME PTC 19 series). PTC 19.1 provides guidance and direction on the propagation of the estimates of those errors. Each PTC shall quantify the expected uncertainties associated with the test measurements on that specific component or system.

3-11 MISTAKES

Mistakes are another source of errors and are the result of carelessness, inexperience, poor technique, unstable processes, malfunctioning equipment, incorrect calculation, or bias in the test procedures or execution. A test instrument may be used incorrectly or it may be malfunctioning; poor technique may be used in taking a measurement, or a measurement bias may be introduced by expecting (and inadvertently forcing) the results to agree with the expected outcome. Errors of this nature shall be avoided and corrected if discovered.

Within PTCs, these errors would not be included in any uncertainty analysis because it is assumed that the test result was obtained by following correct and well-defined procedures established within the Code that are carefully implemented by competent users of the Code.

Mistakes can be identified by using the accepted industry practices of pretest and calibration checks, redundant instrument identification, and independent review and validation. Once identified, the mistakes shall be corrected. Not correcting identified mistakes is prohibited in the planning, execution, and reporting of a Code test.

3-12 COMPUTATION OF RESULTS

3-12.1 Data Reduction

Following each test, when all test logs and records have been completed and assembled, the results should be examined critically to determine whether the limits of permissible deviations from specified operating conditions have exceeded those prescribed by the individual test Code. Adjustments of any kind should be agreed upon and explained in the test report. If adjustments cannot be agreed upon, the test run(s) may have to be repeated. Inconsistencies in the test record or test result may require tests to be repeated in whole or in part to attain the test objectives. Corrections resulting from deviations of any of the test operating conditions from those specified are applied when computing the test's results.

3-12.2 Inconsistencies in Test Results

3-12.2.1 Recorded Data. Some data recorded from instruments may not be consistent with observed data recorded from other instruments when both have been acquired in accordance with the rules of an individual Code. In such cases, it shall be the duty of the test coordinator to assess the data sources, evaluate the conditions leading to the inconsistencies, and determine which set of observed data is correct, if any.

3-12.2.2 Analysis and Interpretation. During the conduct of a test or during the subsequent analyses or interpretations of the observed data, an obvious inconsistency may be found. If so, a reasonable effort shall be made to adjust or eliminate the inconsistency. Failing this, test runs shall be repeated.

3-12.3 Data Presentation

Test data should be plotted or tabulated as determined by the Code calculation procedure. Additional calculations shall be made to establish the test's uncertainty in accordance with PTC 19.1. For additional guidance, refer to [subsection 1-6](#). All test results should be reported from the test observations.

3-12.4 Graphical Presentation and Scales

Graphical presentation of test data and results is useful in engineering analysis. Standard graphical formats prevail for many specific types of machinery, and these forms shall be used wherever practical.

3-12.5 Analysis and Requirements

The complete analysis of the results of a performance test requires a working knowledge of

- (a) the concepts of statistics including averages, means, standard deviations, variances, probability distributions, and uncertainties
- (b) the theory, application, and acceptability of significant figures and numerical standards
- (c) the specific computational method(s) applicable to the equipment

3-12.6 Data Reduction and Averaging

Each PTC shall specify the method to be used for reducing and averaging test data. These methods shall be the most appropriate engineering practices available. Guidance should be provided to ensure correct unit conversions.

3-12.7 Curve Construction

In constructing graphs from test data, individual test points shall be retained and clearly identified by specific symbols. This facilitates the understanding of the deviations between the plotted curve shape and the actual test points. Plotted test points can consist of raw data, corrected data, and/or calculated results and shall be described clearly in a legend.

3-13 TEST REPORT

3-13.1 Completion and Approval

The report of an ASME Code test should be complete in all respects and approved by all appropriate parties to the test.

3-13.2 Test Report: Contents

The report should include the following distinctive sections:

- (a) an executive summary containing a brief description of the object, result, and conclusions reached
- (b) the detailed report of
 - (1) authorization for the tests, their scope and object, contractual obligations and guarantees, stipulated agreements, acceptance criteria, the individual who directed the test, and the representative parties to the test if it is a commercial test
 - (2) description of the equipment tested and any other auxiliary apparatus, the operation of which may influence the test result
 - (3) method of test, giving arrangement of testing equipment, instruments used and their location, operating conditions, and a complete description of methods of measurement not prescribed by the individual Code
 - (4) summary of measurements and observations
 - (5) methods of calculation from observed data and calculation of probable uncertainty

- (6) correction factors to be applied because of deviations, if any, of test conditions from those specified
- (7) primary measurement uncertainties, including method of application
- (8) the test performances stated under the following headings:
 - (-a) results computed based on the test operating conditions, instrument calibrations only having been applied
 - (-b) results corrected to specified conditions if test operating conditions have deviated from those specified
- (9) presentation of the test results
- (10) discussion and details of the test results uncertainties
- (11) discussion of the test, its results, and conclusions
- (12) appendices and illustrations to clarify description of the circumstances, equipment, and methodology of the test; description of methods of calibrations of instruments; outline of details of calculations including a sample set of raw data, computations, descriptions, and statements depicting special testing apparatus; result of preliminary inspections and trials; and any supporting information required to make the report a complete, self-contained document of the entire undertaking

3-14 PRACTICE OF BIASING

Biasing is the practice whereby an individual party to the test selects test or measurement conditions or omits corrections to realize, satisfy, fulfill, or validate a desired performance determination. Examples of biasing include the following:

- (a) selecting test instruments that fall within the uncertainty criterion of the Code yet produce a reading of known error in a direction which is purposely not corrected
- (b) selecting test instruments that fall within the uncertainty criterion of the Code yet are biased in a direction that, when employed in a test, biases the test results to a favorable or desired outcome of that individual
- (c) selecting a test period or periods or conversely excluding a test period or periods that do meet the stability and deviation from design criterion of the Code but that bias the test results to a favorable or desired outcome of that individual
- (d) employment of correction curves or modeling that knowingly provides a different corrected result than the result if the test was conducted at the conditions the corrected result is to reflect

No matter the form, the practice of biasing is strictly prohibited and violates the principles of ASME PTCs.

Section 4

Acceptance Tests: Responsibilities and Purchase Contracts

4-1 INTRODUCTION

One of the applications for equipment Performance Test Codes is to conduct an acceptance test to determine if the equipment satisfactorily meets its performance criteria, permitting the purchaser to accept it from the supplier. ASME PTCs specify the technical details of tests that can be used as acceptance tests. ASME PTCs do not specify the commercial details of these tests, which should be specified by the contract. The following paragraphs represent common practices and are recommended to be covered in contracts for acceptance tests.

4-2 COST AND LOCATION OF ACCEPTANCE TESTS

Apportionment of costs or division of responsibility for acceptance tests should be stated in the purchase contract. Failing this, the contracting parties should agree upon cost and responsibility in writing. The acceptance test's location should be specified to be either at the manufacturer's facilities, a test laboratory, or in the field after installation.

4-3 TESTING RESPONSIBILITIES

The contract should delineate a clear division of responsibilities, which includes all tasks required to prepare and conduct a test in accordance with the Code either at a manufacturer's facilities or in the field. The contract should define the parties to the test with a clear division of responsibilities amongst the parties to the test.

4-4 PARTIES TO THE TEST

If a Code is used for guaranteed performance and guaranteed acceptance testing or for any other tests where there are multiple parties represented, those parties shall agree and document the agreement(s) on the exact method of testing and the methods of measurement, pretest agreements, and any necessary exceptions from the Code requirements. The contract should define the parties to the test that will have decision-making responsibility for the design, execution, witness, and approval for any necessary exceptions to Code requirements. They should also have the authority, if necessary, to approve any agreed-upon revisions and exceptions to the test requirements during the testing activities.

4-5 Agreements Between Parties To The Test

Even with the best planning and documenting, there are times when material issues are not explicitly prescribed by the contract or a test Code. Further, circumstances or events may occur whereby strict adherence to the contract or Code is not attainable or cost effective. The contract should include a mechanism by which the parties to the test can reach agreement on exceptions to the contract or test and on material issues not explicitly prescribed by the contract or test Code. The contract should also provide rules and steps for when the parties to the test cannot reach agreement on necessary material issues not explicitly prescribed by the contract or a test Code.

The contract should allow the parties to the test to adjust the test plan or procedures in response to situations that become apparent just before or during testing. The contract should stipulate the following:

- (a) Each party to the test shall/should designate a representative to the test team who will observe the test and confirm that it was conducted in accordance with the test requirements.
- (b) The test coordinator shall/should schedule the test to occur when equipment is operating as close as possible to reference conditions.
- (c) All parties to the test shall/should be notified sufficiently in advance of the test to arrange for their representatives to be present for the test.
- (d) The test team shall/should have the opportunity to examine the plant, sufficient time to prepare the test, and the ability to determine that the plant is ready to test.

(e) The parties to the test shall/should agree on the test coordinator or test personnel that shall/should document any modifications to the test plan that result from preliminary testing.

(f) The test coordinator or test personnel should/shall take permissible actions in the event that site conditions before or during the test fall outside the limits listed in the Code. The contract shall/should list the permissible actions.

(g) The test coordinator or test personnel shall/should have the ability to make permissible adjustments to plant operations during stabilization and between test runs.

(h) The test coordinator or test personnel shall/should have the ability to change the duration of test runs, allowing fewer or more test runs.

(i) The test coordinator or test personnel shall/should have the ability to analyze data in real time and, if appropriate, subsequently reject or accept test readings or results.

4-6 TEST EXCEPTIONS

If this Code is used for guarantee acceptance testing or for any other tests where there are multiple parties represented, those parties shall agree and document deviations and exceptions from the Code requirements. Any exceptions from the methods recommended by a Code are acceptable only if it can be demonstrated they provide equal or lower uncertainty or they are made by mutual agreement by the parties to the test. If the test is for commercial acceptance, this philosophy is in the best interest of all parties to the test.

4-7 RESOLUTION OF DISPUTES

Sometimes a dispute or claim between the parties to the purchase contract agreement cannot be resolved. In such cases, the dispute shall be resolved in accordance with the governing contract.

4-8 COMPARISON OF TEST RESULTS TO CONTRACTUAL GUARANTEES

The method for comparing test results to contractual guarantees should be specified, addressed, and agreed to in writing. For example, the method of comparing a test result to a contract's guarantee by allowance or no allowance for any tolerances, offsets, or deadbands should be addressed in a contract.

4-9 INTEGRITY AND CHAIN OF CUSTODY FOR MODELS AND CORRECTIONS

The parties to the test shall, at a minimum, use the methods in this section to ensure integrity and chain of custody of the plant and equipment performance model, correction curves, and correction factors used to support the calculation of final performance parameters. All models, correction curves, and correction factors that are used to support the calculations of final performance in support of a performance test shall be captured in a revision record with the date of origination, date of change, what changes were made, explanation of the change, the impact of change on the determination of performance parameters, and the person(s) who originated the record or made the changes. This revision record shall be shared amongst and approved by the parties to the test prior to utilization and calculation of the reported results of the test. If a model is used but cannot be shared between the parties due to commercial reasons, the model shall be used to produce a set of validating cases (heat balance cases). These validating cases will be run either at various reference conditions around the basis of design or at the guaranteed reference conditions used to define the performance parameters in order to "fossilize" the model's performance determination. These validating cases shall be identified by author, date, time, and revision. The validating cases can be produced on an absolute or relative basis. These cases will provide the parties to the test the ability to rerun these cases to compare to the model to establish that the model is still predicting the same performance as that of the validating cases. Alternatively, if the model is provided as an unalterable stand-alone deliverable amongst the parties, meaning a fossilized version of the model, the requirement of running a set of validating cases will not be necessary. Parties to the test shall agree on the timing of planned changes in the plant performance model, correction curves and/or correction factors, and what integrity and chain-of-custody methods beyond those listed in this section can be used to further the goals of the model's integrity and chain of custody.

4-10 SUGGESTED CLAUSE FOR INCORPORATING ASME PTCs IN EQUIPMENT PURCHASE CONTRACTS

Insertion of the following clause or equivalent statement in an equipment purchase contract will incorporate the ASME PTC as part of the contract: "If an acceptance test is performed, the performance guarantees on the equipment covered herein shall be verified according to the provisions of the current edition (in effect at the time of contract signing) of the ASME Performance Test Code for _____ (dated) _____. All the conditions of that Code shall be binding on all parties, excepting contrary stipulations in the contract."

PERFORMANCE TEST CODES (PTC)

PTC 1-2022	General Instructions
PTC 2-2001 (R2014)	Definitions and Values
PTC 4-2013	Fired Steam Generators
PTC 4.2-1969 (R2016)	Coal Pulverizers
PTC 4.3-2017	Air Heaters
PTC 4.4-2008 (R2013)	Gas Turbine Heat Recovery Steam Generators
PTC 6-2004 (R2014)	Steam Turbines
PTC 6.2-2011 (R2016)	Steam Turbines in Combined Cycles
PTC 6A-2000 (R2021)	Appendix A to PTC 6, The Test Code for Steam Turbines
PTC 6	PTC 6 on Steam Turbines – Interpretations 1977-1983
PTC 6S-1988 (R2019)	Procedures for Routine Performance Tests of Steam Turbines
PTC 8.2-1990	Centrifugal Pumps
PTC 10-1997 (R2014)	Compressors and Exhausters
PTC 11-2008 (R2018)	Fans
PTC 12.1-2015 (R2020)	Closed Feedwater Heaters
PTC 12.2-2010 (R2020)	Steam Surface Condensers
PTC 12.3-1997 (R2019)	Deaerators
PTC 12.4-1992 (R2019)	Moisture Separator Reheaters
PTC 12.5-2000 (R2015)	Single Phase Heat Exchangers
PTC 13-2018	Wire-to-Air Performance Test Code for Blower Systems
PTC 17-1973 (R2012)	Reciprocating Internal-Combustion Engines
PTC 18-2020	Hydraulic Turbines and Pump-Turbines
PTC 19.1-2018	Test Uncertainty
PTC 19.2-2010 (R2020)	Pressure Measurement
PTC 19.3-1974 (R2004)	Temperature Measurement
PTC 19.3 TW-2016	Thermowells
PTC 19.5-2004 (R2013)	Flow Measurement
PTC 19.6-2018	Electrical Power Measurements
PTC 19.7-1980 (R1988)	Measurement of Shaft Power
PTC 19.10-1981	Flue and Exhaust Gas Analyses
PTC 19.11-2008 (R2018)	Steam and Water Sampling, Conditioning, and Analysis in the Power Cycle
PTC 19.22-2007 (R2017)	Data Acquisition Systems
PTC 19.23-1980 (R1985)	Guidance Manual for Model Testing
PTC 22-2014	Gas Turbines
PTC 23-2003 (R2014)	Atmospheric Water Cooling Equipment
PTC 24-1976 (R1982)	Ejectors
PTC 25-2018	Pressure Relief Devices
PTC 29-2005 (R2020)	Speed-Governing Systems for Hydraulic Turbine-Generator Units
PTC 30-1991 (R2021)	Air Cooled Heat Exchangers
PTC 30.1-2007 (R2020)	Air-Cooled Steam Condensers
PTC 31-2011 (R2017)	High-Purity Water Treatment Systems
PTC 34-2007	Waste Combustors With Energy Recovery
PTC 36-2018	Measurement of Industrial Noise

PTC 38-1980 (R1985)	Determining the Concentration of Particulate Matter in a Gas Stream
PTC 39-2005 (R2020)	Steam Traps
PTC 40-1991	Flue Gas Desulfurization Units
PTC 46-2015	Overall Plant Performance
PTC 47-2020	Integrated Gasification Combined Cycle Power Generation Plants
PTC 47.1-2017	Cryogenic Air Separation Unit of an Integrated Gasification Combined Cycle Power Plant
PTC 47.2-2019	Gasification Block of an Integrated Gasification Combined Cycle Power Plant
PTC 47.3-2021	Syngas-Conditioning Block of an Integrated Gasification Combined Cycle Power Plant
PTC 47.4-2015 (R2020)	Power Block of an Integrated Gasification Combined Cycle Power Plant
PTC 50-2002 (R2019)	Fuel Cell Power Systems Performance
PTC 51-2011 (R2016)	Gas Turbine Inlet Air-Conditioning Equipment
PTC 52-2020	Concentrating Solar Power Plants
PTC 55-2013 (R2018)	Gas Turbine Aircraft Engines
PTC 70-2009 (R2019)	Ramp Rates

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