ASME PTC 70-2009

Ramp Rates

Performance Test Codes

AN AMERICAN NATIONAL STANDARD

The American Society of
Mechanical Engineers

ASME
SETTING THE STANDARD

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This Code will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to ASME PTC 70-2009.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Code. Periodically certain actions of the ASME PTC Committee may be published as Code Cases. Code Cases and interpretations are published on the ASME Web site under the Committee Pages at http://cstools.asme.org as they are issued.

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

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NOTICE

All Performance Test Codes must adhere to the requirements of ASME PTC 1, General Instructions. The following information is based on that document and is included here for emphasis and for the convenience of the user of the Code. It is expected that the Code user is fully cognizant of Sections 1 and 3 of ASME PTC 1 and has read them prior to applying this Code.

ASME Performance Test Codes provide test procedures that yield results of the highest level of accuracy consistent with the best engineering knowledge and practice currently available. They were developed by balanced committees representing all concerned interests and specify procedures, instrumentation, equipment-operating requirements, calculation methods, and uncertainty analysis.

When tests are run in accordance with a Code, the test results themselves, without adjustment for uncertainty, yield the best available indication of the actual performance of the tested equipment. ASME Performance Test Codes do not specify means to compare those results to contractual guarantees. Therefore, it is recommended that the parties to a commercial test 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 Code to determine or interpret how such comparisons shall be made.

FOREWORD

The PTC Standards Committee approved the development of a test code on ramp rates. During their June 2007 meeting, a proposed Charter was approved, and the effort to constitute a committee was undertaken. An organizational meeting (via teleconferencing) was held in September 2007. After several teleconferences, a document was completed for industry review by the end of March 2008.

This Code was approved as a Standard practice of the Society by action of the Board on Standardization and Testing on December 8, 2008. It was also approved as an American National Standard by the ANSI Board of Standards Review on February 2, 2009.

ASME PTC COMMITTEE
Performance Test Codes

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

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CORRESPONDENCE WITH THE PTC COMMITTEE

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

Secretary, PTC Standards Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

Proposing Revisions. Revisions are made periodically to the Code 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 periodically.

The Committee welcomes proposals for revisions to this Code. 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 for the purpose of providing 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 Code, 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 Code to which the proposed Case applies.

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

The request for 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.
Edition:	Cite the applicable edition of the Code 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. 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 this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

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, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the PTC Standards Committee.

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RAMP RATES

Section 1
Object and Scope

1-1 OBJECT

This Code provides the procedures, direction, and guidance for the accurate determination, via testing, of the maximum repeatable load change ramp rate, startup load change rate, or shutdown load change rate of a power plant. The load change rate is distinguished by starting from one operating point at steady state condition and transitioning to another. Startup commences at a shutdown condition, or intermediary startup condition, and proceeds to a defined running condition. Shutdown begins at a running condition and proceeds to a shutdown condition or intermediary shutdown condition.

Measurements of actual net generation as a function of time are the primary test parameters. Additional data and information will be collected as part of this analysis to determine the long- and short-term effects of various ramp rates on the equipment and systems in the power plant of interest. This information includes and is not limited to design specifications and actual operating conditions.

1-2 SCOPE

This Code is applicable to all electrical generating facilities, independent of fuel source or prime movers.

This Code is directed at providing guidelines for measuring the machinery impact of controlled transients that are initiated by the operator. It is not the intent of this Code to address uncontrolled transients that may be initiated by system activity such as load rejection or governor response to grid frequency disturbances.

1-3 EXPECTED MEASUREMENT UNCERTAINTY

Uncertainties shall be determined utilizing techniques specified in ASME PTC 19.1. The expected uncertainties of tests completed following this Code are dependent upon the type of power plant, its size, and the test objective(s). For a simple ramp rate test from one operating load to another, resulting in an average MW/min value, uncertainties of better than 0.2% should be achievable when following this Code.

Section 2
Terms and Definitions

acceptance test: the evaluating action(s) to determine if a new or modified piece of equipment satisfactorily meets its performance criteria, permitting the purchaser to "accept" it from the supplier.

accuracy: the closeness of agreement between a measured value and the true value.

auxiliary power: electrical power used in the operation of the gas turbine power plant or elsewhere as defined by the test boundary.

bias error: see *systematic error.*

calibration: the process of comparing the response of an instrument to a standard instrument over some measurement range and adjusting the instrument to match the standard, if appropriate.

emissions: air, solids, and water discharges from power plant systems or noise from power plant systems that are regulated by authorities having jurisdiction, such as air pollutants, waste streams, and noise.

influence coefficient: see *sensitivity;* the ratio of the change in a result to a unit change in a parameter.

instrument: a tool or device used to measure physical dimensions of length, thickness, width, weight, or any other value of a variable. These variables can include: size, weight, pressure, temperature, fluid flow, voltage, electric current, density, viscosity, and power. Sensors are included, which may not, by themselves, incorporate a display but transmit signals to remote data acquisition system or computer type devices for display, processing, or process control. Also included are items of ancillary equipment directly affecting the display of the primary instrument, e.g., ammeter shunt. Also included are tools or fixtures used as the basis for determining part acceptability.

measurement error: the true, unknown difference between the measured value and the true value.

measurement uncertainty: estimated uncertainty associated with the measurement of a process parameter or variable.

net power: the electrical power leaving the test boundary minus any electrical power entering the test boundary.

opacity: the degree to which light is blocked. With respect to industrial facilities, it is the measure of impenetrability of visible light to pass through the gases exhausted to the atmosphere.

parameter: a physical quantity at a location that is sensed by direct measurement of a single instrument, or determined by the averaged measurements of several similar instruments.

parties to the test: for acceptance tests, those individuals designated in writing by the purchaser, lender's engineer, architect engineer (or facility supplier), and machine suppliers to make the decisions required in this Code. Other agents, advisors, engineers, etc., hired by the parties to the test to act on their behalf or otherwise, may or may not be considered, by this Code, to be parties to the test.

precision: the closeness of agreement between a group of measured values.

precision error: see *random error.*

ramp rate: the average ramp rate is the load change divided by the amount of time required to move from the initial load to the final load. The instantaneous ramp rate is the slope at a given load in the measured load change process.

random error: sometimes called *precision error;* the true random error, which characterizes a member of a set of measurements [varies in a random, Gaussian (normal) manner, from measurement to measurement].

rated power: the power output of the power system when operating at specified control and ambient conditions.

secondary variables: variables that are measured but do not enter into the calculation.

sensitivity: see *influence coefficient;* the ratio of the change in a result to a unit change in a parameter.

shutdown: the actions required to safely stop the electrical generation from an operating power producing facility.

startup: the actions required to safely reach a predefined minimum load for an electrical generation facility in a shutdown or off-line condition.

systematic error, β: sometimes called bias; the true systematic or fixed error, which characterizes every member of any set of measurements from the population. It is the constant component of the total measurement error, δ.

systematic uncertainty: an estimate of the ± limits of systematic error with a defined level of confidence (usually 95%).

test: a group of test runs adequate to establish the performance over the specified range of operating conditions.

test run: the readings and/or recordings sufficient to calculate performance through one set of operating conditions.

test uncertainty: uncertainty associated with a corrected test result.

uncertainty: the interval about the measurement or result that contains the true value for a given confidence level.

variable: a quantity that cannot be measured directly, but is calculated from other measured parameters.

Section 3
Guiding Principles

3-1 OBJECT OF TEST

The object of the test shall be agreed upon by the parties to the test and shall be defined in writing before the test(s) commences.

Test objectives may include the determination of the following:

(a) startup ramp rate or elapsed time
(b) shutdown ramp rate or elapsed time
(c) overall ramp rate from 0% to 100% load
(d) ramp rates from minimum load to maximum load or from maximum to minimum load
(e) ramp rates from one nominal load to another
(f) ramp rates for a given set of equipment in operation
(g) ramp rates for power augmentation equipment (such as chillers or duct burners)
(h) ramp rates from one specified process or equipment condition to another

Elapsed time between test start and stop conditions may be the objective rather than a ramp rate. In the case where ramp rate varies over the course of the test, elapsed time rather than a rate may be preferable to avoid ambiguity.

3-2 PREPARATIONS FOR TESTING

3-2.1 General Precautions

Reasonable precautions should be taken when preparing to conduct a Code test. Indisputable records shall be made to identify and distinguish the equipment to be tested and the exact method of testing selected. Descriptions, drawings, or photographs all may be used to give a permanent, explicit record. Instrument location shall be predetermined, agreed to by the parties to the test, and described in detail in test records. Redundant, calibrated instruments should be provided for those instruments susceptible to in-service failure or breakage and to improve the uncertainty of the results.

3-2.2 Agreements

Prior to any tests there shall be agreement on the exact method of testing and the methods of measurement, including the following:

(a) object of test.
(b) location and timing of test.
(c) test boundaries.
(d) selection of instruments: number, location, type.
(e) method of calibration of instruments.
(f) confidentiality of test results.
(g) number of copies of original data required.
(h) data to be recorded, 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 establishing operating conditions as near as possible to those specified at the beginning of, during, and at the conclusion of the test.
(l) system alignment or isolation.
(m) organization of personnel, including designation of engineer in responsible charge of test.
(n) duration and number of test runs.
(o) frequency of observations.
(p) initial conditions, including equipment temperature and pressures at the start of the ramp.
(q) methods of computing results.
(r) method of comparing test results with specified performance objectives.
(s) conditions for rejection of outlier data or runs.
(t) intent of contract or specification if ambiguities or omissions appear evident.
(u) pretest inspections.
(v) the starting and ending generation levels, between which ramp rates will be measured.
(w) the definition of the starting and ending points of a ramp. Does the ramp commence and/or cease at exactly those points or does it pass through those points without stopping? Ensure emissions are maintained at levels that comply with requirements set forth in all environmental regulatory permits applicable to the facility. The endpoint conditions may be electrical output or another observable parameter for which an associated electrical output can be established or measured directly.
(x) operating limits, including component temperature or pressure limits that may limit the operation of the unit during the test.

The items agreed upon shall be included in the test procedure in advance of the test, and all shall be listed in the test report issued upon conclusion of the test.

3-2.3 Preliminary Test Runs

Preliminary test runs, with records, serve to determine if equipment is in suitable condition to test, to check instruments and methods of measurement, to check adequacy of organization and procedures, and to train personnel. All parties to the test may conduct 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 preliminary test run complies with all the necessary requirements of this Code, it may be used as an official test run within the meaning of this Code.

3-3 TESTS

3-3.1 Preparation

For acceptance and other official tests, the manufacturer, supplier, and owner shall have reasonable opportunity to examine the equipment, correct defects, and render the equipment suitable to test including manufacturer prescribed commissioning procedures successfully completed. 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 make adjustments to the equipment for purpose of this test that may prevent immediate, continuous, and reliable operation at all capacities or outputs under all specified operating conditions as would otherwise be present, unless agreed to by all parties. Any actions taken that are material to the object of this Code must be documented and immediately reported to all parties to the test.

3-3.2 Starting and Stopping

Initial acceptance tests shall be conducted as promptly as possible following initial equipment operation, completion of commissioning, controls tuning, and preliminary test runs. Other official tests, such as demonstration to grid system officials of the plant ramp rate capabilities shall be conducted at mutually agreeable times. The equipment should be operated for sufficient time to demonstrate that intended pretest conditions have been established, e.g., steady state at agreed-to operating conditions. Agreement on procedures and time should be reached before commencing the test. If gradual or asymptotic approach to an endpoint condition is required, prior agreement to necessary closeness for acceptance on having reached the end condition should be determined. If the test end condition may exhibit variation, such as a small continuous plant output change when connected to a noisy or unstable grid, the method for determining end of test considering the variation will be previously agreed to. An example is the first time passing of endpoint condition ends the test. (The subsequent momentary reductions below end condition being ignored.) Follow the pretest agreement if the ramp commences and/or ceases at precise points and the unit load attains steady state or the unit load increases or decreases through those points without stopping.

3-3.3 Readjustments

Once testing has started, readjustments to the equipment that can influence the results of the test shall require repetition of any test runs conducted prior to the readjustments. Adjustments that are inappropriate for reliable and continuous operation following a test under any and all of the specified outputs and operating conditions shall not be made for the purpose of a test.

3-3.4 Data Collection

Data shall be taken by automatic data collecting equipment or by a sufficient number of 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.

3-3.5 Conduct of Test

The parties to the test shall designate a person to direct the test hereafter called test coordinator. Intercommunication arrangements among all test personnel, all test parties, and the test coordinator shall be established. Complete written records of the test, including details that at the time may seem irrelevant, shall be reported. If a commercial test, accredited representatives of the purchaser and the manufacturer, supplier, or grid system officials should be present at all times to assure themselves that the tests are being conducted with the test code and prior agreement.

3-4 INSTRUMENTATION

3-4.1 Location and Identification of Instruments

Ramp rate tests will normally be conducted using calibrated installed plant instruments. If test instruments are utilized, the following provisions apply:

(a) They shall be located to minimize the effect of ambient conditions on uncertainty, e.g., temperature or temperature variations.

(b) Care shall be used in routing lead wires to the data collection equipment to prevent electrical noise in the signal.

(c) Locally indicating instruments shall be positioned so that they can be read with precision and convenience by the observer.

(d) All instruments shall be marked uniquely and unmistakably for identification.

(e) Calibration tables, charts, or mathematical relationships shall be readily available to all parties of the test.

(f) Observers recording data shall be instructed on the desired degree of precision of readings.

3-4.2 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, as agreed to in the pretest agreement, so that a correct and meaningful mean value may be determined. Sufficient observations shall be recorded to prove that required operating conditions exist 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.

3-5 OPERATING CONDITIONS

3-5.1 Operating Philosophy

The tests should be conducted as closely as possible to specified operating conditions and thus reduce and minimize the magnitude and number of corrections for deviations from specified conditions.

3-5.2 Permissible Deviations

The equipment tested should be operated to ensure its performance is bounded by the permissible fluctuations and permissible deviations specified in the pretest agreement.

3-5.3 Inconsistent Measurements

If any measurement influencing the result of a test is inconsistent with some other like measurement, although 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, if possible, eliminated. ASME PTC 19.1 contains methodology to recognize outliers in a set of test data.

3-6 RECORDS

3-6.1 Data Records and Test Log

For all acceptance and other official tests, a complete set of data and a complete copy of the test log shall become the property of each of the parties to the test. The original log; data sheets, files, and disks; recorder charts; tapes; etc., being the only evidence of actual test conditions, must 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 on or destruction or deletion of any data record, page of the test log, or of any recorded observation are not permitted. If corrected, 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 original data sheets authenticated by the observer's 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 must agree in advance to the method used for authenticating, reproducing, and distributing the data. Copies of the electronic data files must be copied onto tape or disks and distributed to each of the parties to the test. The data files shall be in a format that is easily accessible to all. Data residing on a machine should not remain there unless a backup, permanent copy is made.

3-6.2 Analysis and Interpretation

During the conduct of a test or during the subsequent analysis or interpretation of the observed data, an obvious inconsistency may be found. If so, reasonable effort should be made to adjust or eliminate the inconsistency. Failing this, test runs should be repeated.

Section 4
Instrumentation and Methods of Measurement

4-1 INSTRUMENTATION REQUIREMENTS

For most power generating facilities no special instrumentation is necessary. Using plant watt-hour meters, data acquisition systems, plant historians, and the embedded timing mechanisms are sufficient to conduct a ramp rate test. It is recommended to use revenue watt-hour meters if the meters are of sufficient accuracy and have been calibrated within the required timeframe. A stopwatch and a portable generation metering system may be used in lieu of plant instrumentation. In all cases the instruments used for these ramp rate tests must be calibrated within the Original Equipment Manufacturer's (OEM) suggested calibration cycle in accordance to the instrument's OEM requirements. The results of the calibration and the choice of instrumentation are inputs to the uncertainty calculations, therefore the test engineers and test coordinator should understand the effect of their instrumentation decisions upon the test results.

If using a plant historian for data collection, the compression limits should be relaxed and set to permit all the variations in data recorded and not to "lock" the input stream to a constant value during the test period.

Data sampling rate shall be sufficiently fast to show all important events in detail and allow accurate calculation of test elapsed time. For tests over no more than a few hours, a sample time of 1 sec should be considered, the resulting data file size while large being well within the capability of a modern computer.

If data is to be collected from more than one time stamped source, the internal clocks of all such sources should be synchronized. In a rare circumstance where synchronization is impossible, testing should be performed to determine the differentials between the various time stamp clocks and the results included in the test record so that the data can be manually correlated by time shifting after the test.

4-2 TEST METHODOLOGY

(a) The testing may commence once the data recording mechanisms and personnel are ready.

(b) Put the unit into the control mode preferred for the test [manual or automatic generation control (AGC)]. Ensure the plant and control room operators are aware of the test, its purpose, and its temporary effect on the plant. Both the plant operators and the test personnel agree upon the beginning and ending loads of each ramp prior to the test run commencing.

(c) Initiate the ramp. Record the time the ramp started and the generation level. Where possible, record output as a function of time via the plant historian or other automated data acquisition devices. Additional data may be collected that will help define, understand, and perhaps alleviate the limiting factors to a ramp rate. Where applicable these may include

(1) power factor

(2) bus voltages

(3) opacity

(4) emissions

(5) generator temperatures

(6) steam drum level

(7) steam pressures, temperatures, and flows

(8) steam turbine valve positions, steam bypass valve positions

(9) steam turbine metal temperatures, stress, and differential expansion

(10) gas turbine fuel flow, inlet guide vane (IGV) position, exhaust temperature, and indicated exhaust flow

(11) turbine governor set-point or load rate command

(12) coal mills in service

(13) feedwater pumps in service

(14) component vibration levels

(d) Once the end of the ramp is attained, record the time and generation and cease data collection. Repeat these actions until the results of two test runs match within 5%. For plants where operating characteristics change with ambient conditions, some interpretation and correction may be necessary when making comparisons between tests at different ambient conditions. The basis of 100% will be previously agreed to. In case of a gas turbine output it may be base load at current conditions or base load at a specified ambient condition or an arbitrary electrical output level.

(e) Ensure operating and test personnel are informed of the conclusion of each test run and the conclusion of testing each day or shift.

(f) Ramp rate tests over larger load ranges may include operator actions that are not precisely repeatable, e.g., starting an additional feedwater pump, putting another mill in service. The ramp rates determined in those cases may vary more than 5% from run to run.

The test coordinator should ensure the results are representative of normal operation by discarding outliers, and results reported should be the average of multiple test runs, not a single representation of the fastest or slowest ramp rates.

(g) The end of the ramp is predefined by the parties to the test. In most cases the end may be when the unit generation level passes the predefined limit of electrical output or other condition. It also may be when the unit generation level is within the tolerance of the predefined ending generation value, and the unit does not pass it, over or below depending upon the direction; either increasing or decreasing. The ramp rates in this case will be slower. A decreasing ramp rate may result in zero net generation, but with the unit still connected to the grid.

Section 5
Computation of Results

5-1 REPORTED RAMP RATE

The reported ramp rate will be the average of all acceptable test runs throughout a previously agreed number of runs to be performed. Any power producing facility may have highly variable ramp rates, dependent upon the following:

(a) its load at the time of the ramp

(b) the direction of the ramp

(c) ambient conditions

(d) the physical condition of the power generating facility

(e) staffing levels

(f) operation of equipment only used over a limited load range

(g) plant initial condition such as duration of previous shutdown

(h) equipment condition such as HRSG or steam turbine initial temperature

5-2 DETERMINATION OF RAMP RATE

Two ramp rate values are of interest. The average ramp rate is the load change over the course of the test divided by the amount of time required to move from the start of test condition to end of test condition. The instantaneous ramp rate is the slope at a given load in the measured load change process.

5-3 DATA REDUCTION AND TRACEABILITY

Data should be treated equally and independent of the collection method. Calculations performed with the data may be done manually or automatically, i.e., by computer programs. All equations used should be visible. The process of transforming raw data, in this case, time and power level, should be clearly stated. Any meter or calibration corrections should be stated plainly and visibly in the calculations. Each calculation should identify the source of the data, e.g., plant, meter, date, and time.

5-4 GRAPHICAL PRESENTATION

If possible during data collection, a graph of load versus time should be plotted and monitored. The slope of this curve is the ramp rate. Large variations in slope should be investigated, understood, or accounted for, e.g., starting a mill. Discontinuities may be but are not necessarily signs of problems that require resolution including the termination of the test run. Gas turbines equipped with dry low NO_x type combustion systems may exhibit steps in load during combustion mode transfers as normal operation. Steam turbines in combined cycle plants may go through brief periods of rapid load change during startup prior to transfer to boiler following mode. Upon conclusion of the testing, the variation in ramp rates as a function of net generation may be presented in tabular or graphical formats.

Section 6 Test Uncertainty

6-1 PRETEST UNCERTAINTY ANALYSIS

In planning a test, 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. This is most important when deviations from code-specified instruments or methods are expected. An uncertainty analysis is useful to determine the number of observations.

6-2 POST-TEST UNCERTAINTY ANALYSIS

A post-test uncertainty analysis determines the uncertainty intervals for the actual test. This analysis should confirm the pretest systematic and random uncertainty estimates. It serves to validate the quality of the test results or to expose problems.

6-3 CALCULATING RAMP RATE UNCERTAINTY

The uncertainty of the final test result shall be calculated in accordance with ASME PTC 19.1. A sample uncertainty calculation is included in Nonmandatory Appendix A. The uncertainty of any specific ramp rate test will depend on the design and objective of the specific test.

Because ramp rate tests are, by design, not run at steady state, the random component of measured data is not available within the test data. In order to determine the random uncertainty of measured data, a stability test should be run prior to the ramp rate test. The stability test should be either one hour in duration, or the same duration as expected for the actual test. The standard deviations in the measured data during the stability test can be used as the random component of the uncertainty for the test's uncertainty calculation. Data collection during the actual test should be on the same frequency (i.e., once per second) as that taken during the stability test.

Section 7
Reporting of Results

7-1 TEST REPORT CONTENTS

At a minimum the report should include the following distinctive sections:

(a) An executive summary containing the following:

(1) a brief description of the object, result, and conclusions reached

(2) signature of test director(s)

(3) signature of reviewer(s)

(4) approval signature(s)

(5) name and location of the power generating facility tested

(b) The detailed report of the following:

(1) authorization for the tests, their object, contractual obligations and guarantees, stipulated agreements, by whom the test is directed, and the representative parties to the test

(2) description of the plant tested, including major components 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 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 performance stated under the following:

(a) test results computed on the basis of the test operating conditions, instrument calibrations only having been applied

(b) test results corrected to specified conditions if test operating conditions have deviated from those specified

(9) tabular and graphical presentation of the test results

(10) discussion and details of the test results' uncertainties

(11) discussion of the test, its results, and conclusions

(c) 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 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.

(d) All data captured and available in digital form such as data files on CD or other media should be included to allow additional analysis in the future if necessary or desired.

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NONMANDATORY APPENDIX A
SAMPLE UNCERTAINTY CALCULATION

See Tables A-1 and A-2 for a sample uncertainty calculation.

Table A-1 Average Ramp Rate

Inputs	Sensitivity to: Starting Load	Ending Load	Starting Time	Ending Time
Starting Load: 50.0 MW	50.5	50.0	50.0	50.0
Ending Load: 150.0 MW	150.0	151.5	150.0	150.0
Starting Time: 0.0 sec	0.0	0.0	0.0	0.0
Ending Time: 1800.0 sec	1800.0	1800.0	1800.0	1818.0
Result ΔLoad/ΔTime: 3.33 MW/min	3.32	3.38	3.33	3.30
Sensitivity Result	−0.50%	1.50%	0.00%	−0.99%

GENERAL NOTE: Average ramp rate is calculated by taking a load reading at the start of the test, then a second load reading at the end of the test, and dividing the difference between those readings by the difference between the time reading taken at the end of the test and the time reading taken at the start of the test.

Table A-2 Ramp Rate Uncertainty Analysis

Measurement Description	Number of Independent Measurements, A	Sensitivity, B (% per %)	Instrument Systematic Uncertainty, C	Result Systematic Uncertainty, $B \times C$, S	Standard Deviation of the Mean, D	Instrument Random Uncertainty, $B \times D$, R	Result Random Uncertainty, $\mathrm{Sqrt}[S^2 + (2 \times R)^2]$, U	Notes
Starting Load								
Potential transformers	1	0.33	Note (1)	. . .	0.05%	0.02%	0.03%	. . .
Current transformers	1	1.00	. . .	. . .	0.05%	0.02%	0.03%	. . .
Watt-meter	1	1.00	. . .	. . .	0.04%	0.04%	0.08%	Note (2)
Subtotal Uncertainty for Starting Load						**0.046%**	**0.093%**	
Ending Load								
Potential transformers	1	0.33	Note (1)	. . .	0.05%	0.02%	0.03%	. . .
Current transformers	1	0.33	. . .	. . .	0.05%	0.02%	0.03%	. . .
Watt-meter	1	1.00	. . .	. . .	0.04%	0.04%	0.08%	Note (2)
Subtotal Uncertainty for Ending Load						**0.046%**	**0.093%**	
Result Uncertainty								
Starting load	1	0.50%	. . .	. . .	. . .	0.046%	0.09%	Sensitivity from perturbation calculation; systematic and random uncertainties from above
Ending load	1	1.50%	. . .	. . .	. . .	0.046%	0.09%	Sensitivity from perturbation calculation; systematic and random uncertainties from above
Starting time	1	0.00%	0.0278%	0.0000%	0.00%	0.00%	0.00%	Estimated as one second uncertainty on a one-hour test run
Ending time	1	0.99%	0.0278%	0.0003%	0.00%	0.00%	0.00%	Estimated as one second uncertainty on a one-hour test run
Total Result Uncertainty				**0.0003%**		**0.066%**	**0.131%**	

GENERAL NOTES:

(a) Power measurement made using kW readings during test period.

(b) The following variables apply:

A = number of independent measurements used in calculation result
B = determined from codes, standards, or perturbation of result calculation
C = from instrument manufacturer, codes or standards
D = from measured data; standard deviation of the mean is equal to the standard deviation of the data, divided by the square root of the number of measurements taken (PTC 19.1-2005, eq. 4-3.3). A separate test at stable load (one at the starting load and one at the ending load) will need to be performed to determine the random uncertainty component.
S = systematic uncertainty contribution
R = random uncertainty contribution
U = total uncertainty, the 2 multiplier on the R component is based on the assumption that there are sufficient measurement points taken during the stability test used to determine D to warrant this low of a "Student t" value

NOTES:

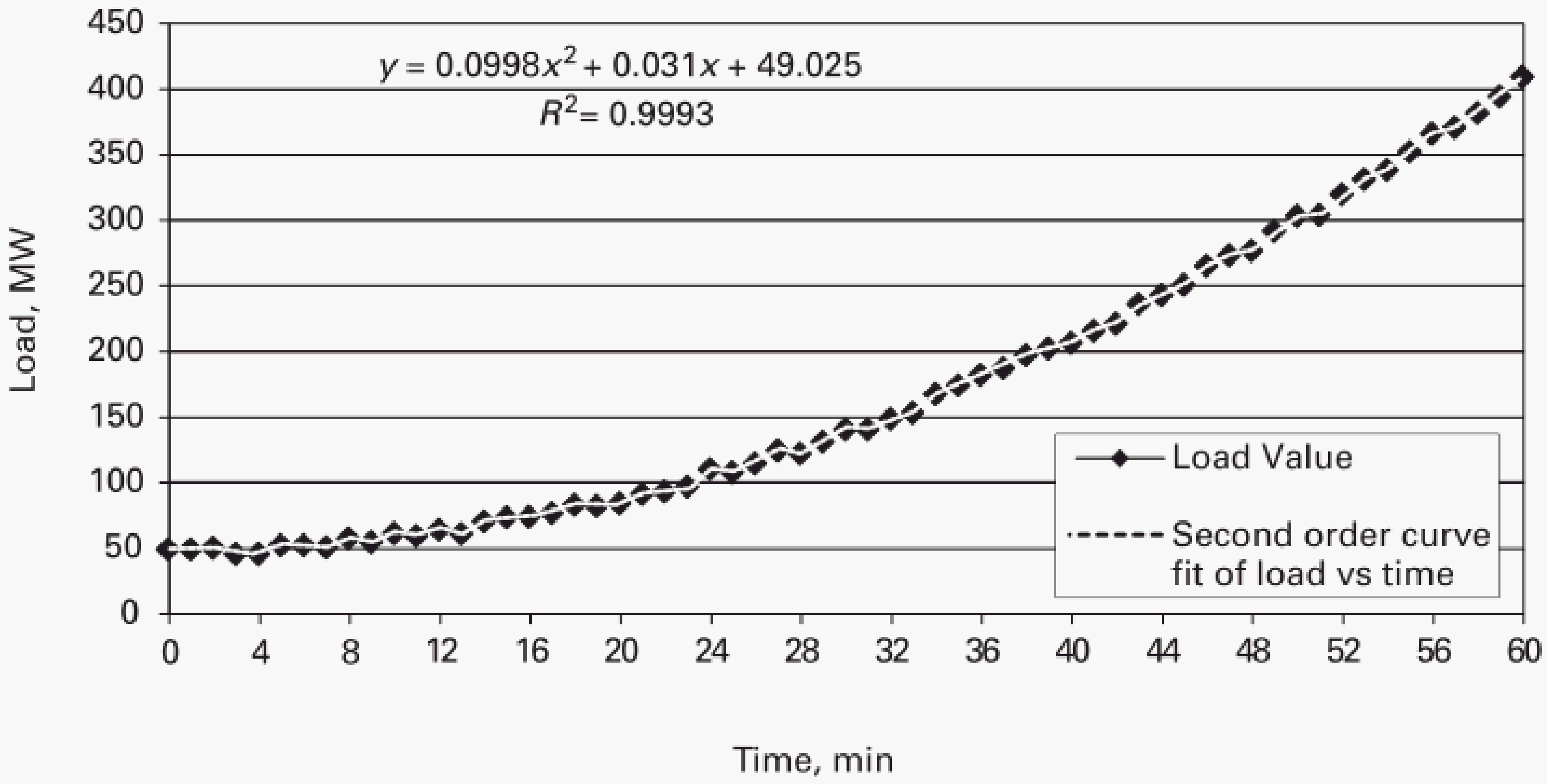
(1) Since the ramp rate test is dealing with relative loads, the bias uncertainty in the power meter cancels out, as long as the same power meter is used for both the starting and ending load measurements.

(2) The random uncertainty of the power meter is determined during an independent stability test.

NONMANDATORY APPENDIX B
SAMPLE RAMP RATE DATA AND CALCULATION

See Fig. B-1 and Table B-1 for sample ramp rate data and sample calculation.

Fig. B-1 Sample Ramp Test Data



GENERAL NOTES:

(a) Trendline of load, MW, versus time

$a_2 = 9.97934\text{E} - 02$

$a_1 = 3.10053\text{E} - 02$

$a_0 = 4.90252\text{E} + 01$

y (MW) $= a_2 \cdot x^2 + a_1 \cdot x + a_0$ where x = minutes from start of ramp

(b) Instantaneous ramp (dy/dx)

$b_1 = 1.99587\text{E} - 01$

$b_0 = 3.10053\text{E} - 02$

dy/dx (MW/min) $= b_1 \cdot x + b_0$ where x = minutes from start of ramp

(c) Overall/average ramp ($\Delta y/\Delta x$)

(410.66 − 50.51)/(60.0 − 0.0) = 6.00 MW/min

Table B-1 Sample Ramp Test Data

Time, min	Load Value	Instantaneous Ramp Rate
0.0	50.51	0.03
1.0	50.37	0.23
2.0	51.70	0.43
3.0	46.99	0.63
4.0	46.76	0.83
5.0	53.46	1.03
6.0	53.63	1.23
7.0	52.14	1.43
8.0	58.89	1.63
9.0	56.15	1.83
10.0	62.76	2.03
11.0	60.68	2.23
12.0	65.49	2.43
13.0	62.26	2.63
14.0	71.91	2.83
15.0	74.81	3.02
16.0	75.28	3.22
17.0	77.92	3.42
18.0	84.24	3.62
19.0	83.74	3.82
20.0	85.65	4.02
21.0	92.82	4.22
22.0	94.56	4.42
23.0	98.39	4.62
24.0	111.69	4.82
25.0	109.21	5.02
26.0	115.94	5.22
27.0	125.96	5.42
28.0	123.53	5.62
29.0	132.45	5.82
30.0	141.96	6.02
31.0	141.87	6.22
32.0	149.96	6.42
33.0	154.54	6.62
34.0	168.64	6.82
35.0	175.32	7.02
36.0	183.39	7.22
37.0	188.53	7.42
38.0	198.33	7.62
39.0	203.55	7.81
40.0	207.79	8.01
41.0	216.84	8.21
42.0	222.37	8.41
43.0	237.33	8.61
44.0	244.07	8.81
45.0	252.07	9.01
46.0	266.48	9.21
47.0	274.33	9.41
48.0	278.22	9.61
49.0	293.20	9.81
50.0	304.57	10.01
51.0	305.15	10.21
52.0	321.04	10.41
53.0	332.50	10.61
54.0	339.57	10.81
55.0	353.35	11.01
56.0	367.13	11.21
57.0	371.79	11.41
58.0	382.84	11.61
59.0	395.75	11.81
60.0	410.66	12.01

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