ASME PTC 4.3-2017

[Revision of ASME PTC 4.3-1968 (R1991)]

Air Heaters

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

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Interpretations are published on the Committee Web page and under go.asme.org/InterpsDatabase. Periodically certain actions of the ASME PTC Committee may be published as Cases. Cases are published on the ASME Web site under the PTC Committee Page at go.asme.org/PTCcommittee as they are issued.

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The American Society of Mechanical Engineers
Two 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

Performance Test Code Committee No. 4 on Stationary Steam-Generating Units was reorganized in May 1958 to rewrite and bring up to date the 1946 edition of the Test Code for Stationary Steam Generating Units.

During the formulation of the new test code, PTC 4.1-1964, the technical committee brought to the attention of the Performance Test Codes Committee that for the air heater, an auxiliary heat-absorption equipment common to all large steam generating units, there existed no performance test code. PTC Committee No. 4 recommended the development of such a test code as part of its assignment.

The Performance Test Codes Committee instructed PTC Committee No. 4 to prepare such a test code as a supplement to be known as PTC 4.3, on air heaters. This test code was developed and its format follows closely that of PTC 4.1, the Test Code for Steam Generating Units.

This test code was approved by the Performance Test Codes Committee on June 9, 1966. Final publication was delayed, however, until a number of suggestions made by the standing Committee were considered and satisfactorily resolved. It was approved and adopted by the Council as a standard practice of the Society by action of the Policy Board, Codes and Standards on November 8, 1967.

The code was subsequently approved as an American National Standard in 1974 by the American National Standards Institute (ANSI).

Work on the current revision began with the first meeting of the reorganized committee on December 16 and 17, 1999, following the publication of PTC 4, on fired steam generators.

The reasons for undertaking this revision were multifold: (a) to include test uncertainty; (b) to minimize the prescriptive guidelines and emphasize the performance-based approach; (c) to address air heater configurations with multiple flow streams; (d) to update measurement methods to include improved instrumentation currently available, and to base combustion calculations on O_2 instead of CO_2; (e) to update nomenclature; and (f) to comply with Society Policy on SI units.

This Code was approved by the PTC Standards Committee on October 12, 2016. It was then approved and adopted by the Council as a Standard practice of the Society by action of the Board on Standardization and Testing on January 5, 2017. The Performance Test Code was also approved as an American National Standard by the ANSI Board of Standards Review on February 14, 2017.

ASME PTC COMMITTEE
Performance Test Codes

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

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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 or a case, and attending Committee meetings. Correspondence should be addressed to:

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 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 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 Code 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 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.

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 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. 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.

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 go.asme.org/PTCcommittee.

INTRODUCTION

ASME Performance Test Codes (PTCs) provide uniform rules and procedures for the planning, preparation, execution, and reporting of performance test results. These codes provide guidelines for test procedures that yield results of the highest level of accuracy based on current engineering knowledge, taking into account test costs and the value of information obtained from testing. PTCs were developed by balanced committees representing many concerned interests.

When tests are conducted in accordance with this Code, the test results themselves, without adjustment for uncertainty, yield the best available indication of actual performance of the equipment tested. ASME PTCs 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 prior to signing the contract, on the method to be used for comparing the results to the contractual guarantees. It is beyond the scope of any PTC to determine or interpret how such comparisons are made.

Test uncertainty is an estimate of the limit of error of a test result. It is the interval about a test result that contains the true value with a given probability or level of confidence. It is based on calculations utilizing statistics, instrumentation information, calculation procedure, and actual test data. Code tests are suitable for use whenever performance must be determined with minimum uncertainty. They are meant specifically for equipment operating in an industrial setting.

PTCs are generally not used in troubleshooting equipment. However, they 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, and this Code includes a nonmandatory appendix on routine testing and performance monitoring. Conducting periodic performance tests on equipment can uncover the need for further investigation, which can lead to preventive maintenance or modification.

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AIR HEATERS

Section 1
Object and Scope

1-1 OBJECT

(a) This Code provides procedures for conducting performance tests of air heaters to determine the following results:

(1) exit gas temperature
(2) air to gas leakage
(3) fluid pressure losses
(4) other fluid temperatures

(b) It also provides procedures to determine the heat capacity ratio (*X*-ratio) and any or all of the performance results specified above that may be necessary for

(1) checking actual performance against standard or design performance
(2) comparing changes in performance over time with standard or design performance
(3) comparing performance under various operating conditions
(4) determining the effect of changes in equipment

1-2 SCOPE

This Code applies to all air heaters used in industrial application, e.g., air heaters servicing steam generators and industrial furnaces. This specifically includes

(a) combustion gas-to-air heat exchanger including air heaters with multisection air streams
(b) air preheater coils utilizing noncondensing (single phase) steam, water, or other hot fluids

This Code does not cover direct-fired air heaters or gas-to-gas heat exchangers. In the latter application, this Code may be used to determine both the thermal and pressure drop performance, while alternate methods of leakage measurement should be agreed upon between the parties. This Code also does not cover heat exchangers where the heating fluid is condensed while passing through the heater.

Air heaters in parallel shall be tested individually (wherever possible) for purposes of checking actual performance.

1-3 MEASUREMENT UNCERTAINTY

This Code requires pretest and post-test uncertainty analysis in accordance with ASME PTC 19.1. The pretest uncertainty analysis is required in order to effectively plan the test. It allows corrective action to be taken prior to the test, either to decrease the uncertainty to a level consistent with the agreed-upon uncertainty, or to reduce the cost of the test while still attaining the objective. The post-test uncertainty analysis is used to determine the uncertainty intervals for the actual test. This analysis should confirm the pretest systematic and random uncertainty estimates. It serves to either validate the quality of the test results or to expose problems.

Typical values of test uncertainties for various unit configurations and performance parameters for an air heater undergoing a performance test in accordance with this Code are presented in Table 1-3-1.

Table 1-3-1 Typical Test Uncertainties

Parameters	Bi-Sector	Multi-Sector
Corrected exit gas temperature, °F (°C)	2–6 (1–3)	2–6 (1–3)
Corrected air-to-gas leakage, % leakage	1–2	1–2
Corrected fluid pressure differential, in. wg (Pa)	±0.5 (±125)	±0.5 (±125)
Corrected exit air temperature, °F (°C)	2–6 (1–3)	Not applicable
Corrected exit air temperature, weighted average, °F (°C)	Not applicable	2–6 (1–3)

Section 2
Definitions of Terms and Symbols

2-1 GENERAL

The Code on Definitions and Values (ASME PTC 2) defines the meaning and values of basic technical terms and numerical constants that are used throughout this Code.

NOTE: For the purposes of this Code, the term *flue gas* shall be used interchangeably with the term *hot fluid* to describe the hot heat transfer fluid passing through the air heater.

2-2 DEFINITIONS

absolute sensitivity (influence) coefficient: unit change in result per unit change of the measured parameter.

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.

accuracy check: the process of comparing the response of an instrument to a standard over some measurement range (also see *calibration*).

additive: a substance added to a gas, liquid, or solid stream to cause a chemical or mechanical reaction.

air, corrected theoretical: the theoretical air adjusted for unburned carbon and additional oxygen required to complete the sulfation reaction.

air, excess: air supplied to burn a fuel in addition to the corrected theoretical air. Excess air is expressed as a percentage of the corrected theoretical air in this Code.

air heater: a heat exchanger that transfers heat from a high-temperature medium, e.g., hot gas, to an incoming air stream. Regenerative air heaters include bi-sector, tri-sector, and quad-sector types with fixed or rotating heating elements. Recuperative air heaters include tubular, plate, and heat pipe types.

air heater air-to-air leakage: air that leaks from a high pressure air stream to a lower pressure air stream, e.g., primary air to secondary air leakage.

air heater leakage: mass of airflow passing from all air-side streams to the heat transfer fluid. Note that this calculated value will include any ingress air that may be present between the air heater gas inlet and gas outlet test planes.

air, infiltration/ingress: air that leaks into the steam generator and/or air heater setting (same as *setting infiltration*).

air, other: combustion air other than primary air, secondary air, and infiltration air, e.g., tertiary air, that is encountered in the combustion processes covered by this Code.

air preheater coils: a heat exchanger that typically uses steam, condensate, and/or glycol to heat air entering the steam generator and is often used to control corrosion in regenerative and recuperative air heaters.

air, primary: the transport and drying air for the coal from the pulverizers to the burners in pulverized coal fired applications. The primary air is often at a temperature different from that of the secondary air as it leaves the regenerative air heaters in large steam generators, and typically represents less than 25% of the total combustion air. Oil and gas fired steam generators usually do not have primary air. Primary air is the air used for fluidizing the bed material at the base of the combustion chamber in circulating fluidized beds.

air, secondary: the balance of the combustion air not provided as primary air in pulverized and fluid bed applications. All of the combustion air leaving the air heater is usually referred to as secondary air in oil and gas fired steam generators. Secondary air may be split into overfire air or other streams as it enters the furnace; however, it remains secondary air up to and including the wind box.

air temperature rise: the increase in temperature of the airflow passing through the air heater. For multi-sector air heaters, this parameter is defined as the composite air temperature increase of the total airflow (from all streams) passing through the air heater.

air, theoretical: amount of air required to supply the exact amount of oxygen necessary for complete combustion of a given quantity of fuel. Theoretical air and stoichiometric air are synonymous.

analysis, proximate: laboratory analysis, in accordance with the appropriate ASTM standard, of a fuel sample providing the mass percentages of fixed carbon, volatile matter, moisture, and noncombustibles (ash).

analysis, ultimate: laboratory analysis, in accordance with the appropriate ASTM standard, of a fuel sample providing the mass percentages of carbon, hydrogen (excluding hydrogen in moisture), oxygen (excluding oxygen in moisture), nitrogen, sulfur, moisture, and ash.

as-fired fuel: fuel in the condition as it enters the steam generator boundary.

ash: the noncombustible mineral-matter constituent of fuel that remains after complete burning of a fuel sample in accordance with appropriate ASTM standards.

ash, bottom: all residue removed from the combustion chamber other than that entrained in the flue gas leaving the steam generator boundary.

ash, fly: particles of residue entrained in the flue gas leaving the steam generator boundary.

ash pit: a pit or hopper located below a furnace where residue is collected and removed.

bias error: see *error, systematic*.

calcination: the endothermic chemical reaction that takes place when carbon dioxide is released from calcium carbonate to form calcium oxide, or from magnesium carbonate to form magnesium oxide.

calcium to sulfur molar ratio (Ca/S): the total moles of calcium in the sorbent feed divided by the total moles of sulfur in the fuel feed.

calcium utilization: the percent of calcium in the sorbent that reacts with sulfur dioxide (SO_2) to form calcium sulfate ($CaSO_4$). It is sometimes called sorbent utilization.

calibration: the process of comparing the response of an instrument to a standard over some measurement range and adjusting the instrument to match the standard if appropriate (also see *accuracy check*).

capacity: the maximum main steam mass flow rate the steam generator is capable of producing on a continuous basis with specified steam conditions and cycle configuration (including specified blowdown and auxiliary steam flow). This is frequently referred to as maximum continuous rating.

capacity, peak: the maximum main steam mass flow rate the steam generator is capable of producing with specified steam conditions and cycle configuration (including specified blowdown and auxiliary steam flow) for intermittent operation, i.e., for a specified period of time without affecting future operation of the unit.

combustion chamber: an enclosed space provided for the combustion of fuel.

combustion efficiency: a measure of the completeness of oxidation of all fuel compounds. It is usually quantified as the ratio of actual heat released by combustion to the maximum heat of combustion available.

combustion split: the portion of energy released in the dense bed region of a fluidized bed, expressed as a percentage of the total energy released.

composite air temperature: the mass weighted average temperature of all the air streams either entering or leaving a multi-sector air heater.

coverage: the percentage of observations (measurements) of a parameter that can be expected to differ from the true value of the parameter by no more than the uncertainty.

credits: energy entering the steam generator envelope other than the chemical energy in the as-fired fuel. These credits include sensible heat (a function of specific heat and temperature) in the fuel, entering air, and atomizing steam; energy from power conversion in the pulverizers, circulating pumps, primary air fans, and gas recirculation fans; and chemical reactions, e.g., sulfation. Credits can be negative, e.g., when the air temperature is below the reference temperature.

dehydration: the endothermic chemical reaction that takes place when water is released from calcium hydroxide to form calcium oxide, or from magnesium hydroxide to form magnesium oxide.

design conditions: see *specified conditions*.

dilute phase: the portion of the bed in a circulating fluidized bed combustion chamber above the secondary air inlet ducts (made up primarily of the circulating particulate material).

efficiency, fuel: the ratio of the output to the input as chemical energy of fuel.

efficiency, gross: the ratio of the output to the total energy entering the steam generator envelope.

energy-balance method: Formerly the "heat loss method." A method of determining steam generator efficiency by a detailed accounting of all energy entering and leaving the steam generator envelope.

error, random: sometimes called precision error, random error is a statistical quantity and is expected to be normally distributed. Random error results from the fact that repeated measurements of the same quantity by the same measuring system, operated by the same personnel, do not yield identical values.

error, systematic: sometimes called bias error; the difference between the average of the total population and the true value. The true systematic or fixed error that characterizes every member of any set of measurements from the population.

error, total: combination of systematic error and random error.

exit gas temperature: the average temperature of the flue gas leaving the steam generator boundary. This temperature may or may not be adjusted for air heater leakage.

fixed carbon: the carbonaceous residue less the ash remaining in the test container after moisture and the volatile matter has been driven off in making the proximate analysis of a solid fuel in accordance with the appropriate ASTM standard. Also see *volatile matter*.

flue gas: the gaseous products of combustion including excess air.

flue gas (hot fluid) exit temperature — excluding leakage: the temperature at which the flue gas would have exited the air heater if there were no leakage. If leakage is present, this parameter is calculated by energy balance. For the purposes of the energy-balance calculations, the temperature of the leakage flow, including any ingress air, is assumed to be the same as the entering air stream(s).

flue gas (hot fluid) exit temperature — including leakage: the measured temperature of the flue gas exiting the air heater.

flue gas (hot fluid) side effectiveness: the ratio of the flue gas temperature drop, excluding leakage, to the temperature head.

flue gas (hot fluid) temperature drop — excluding leakage: the decrease in the temperature of the flue gas passing through the air heater, based on the fluid exit temperature excluding leakage.

fluidized bed: a bed of suitably sized combustible and noncombustible particles through which a fluid (air in fluidized bed steam generators) is caused to flow upward at a sufficient velocity to suspend the particles and to impart to them a fluid-like motion.

fluidized bed, bubbling: a fluidized bed in which the fluidizing air velocity is less than the terminal velocity of most of the individual particles. Part of the gas passes through the bed as bubbles. This results in a distinct bed region because an insignificant amount of the bed is carried away by the fluidizing air.

fluidized bed, circulating: a fluidized bed in which the fluidizing air velocity exceeds the terminal velocity of most of the individual particles, so that they are carried from the combustion chamber and later reinjected.

furnace: an enclosed space provided for the combustion of fuel.

heat capacity ratio (X-ratio): the ratio of the mean heat capacity of the air passing through the air heater to the mean heat capacity of the flue gas passing through the air heater. For a multi-sector air heater, the air-side component is based on the composite air-side temperatures. See para. 5-5.9.

heating value, higher: the total energy liberated per unit mass of fuel upon complete combustion as determined by appropriate ASTM standards. The higher heating value includes the latent heat of the water vapor. When the heating value is measured at constant volume, it must be converted to a constant pressure value for use in this Code.

heating value, lower: the total heat liberated per unit mass of fuel minus the latent heat of the water vapor in the products of combustion as determined by appropriate ASTM standards (not used in this Code).

humidity ratio: mass of water vapor in a gas per pound of dry gas (also see *specific humidity*).

influence coefficient: see *absolute* and/or *relative sensitivity (influence) coefficient*.

input from fuel: the total chemical energy available from the fuel. Input is based on the higher heating value.

input–output method: a method of determining steam generator efficiency by direct measurement of output and input (I/O method).

instrument: any tool or device used in the measurement of the present value of a physical, electrical, or chemical variable. These variables can include pressure, temperature, fluid flow, voltage, electric current, chemical composition, density, viscosity, size, and power. This includes sensors and any ancillary equipment used to transmit, display, and record these variables.

losses: the energy that exits the steam generator envelope other than the energy in the output stream(s).

loss on ignition: commonly referred to as LOI. The loss in mass of a dried dust sample, expressed as a percentage of the initial mass, that occurs when the sample is heated in the presence of oxygen. Typically used to approximate unburned carbon in residue.

maximum continuous rating: see *capacity*.

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

moisture: water in fuel or sorbent as determined by the appropriate ASTM standard(s), or water in the liquid or vapor phase, present in other streams.

outliers: a data point judged to be spurious or erroneous.

output: energy absorbed by the working fluid that is not recovered within the steam generator envelope.

parties to a test: those persons and companies participating in the test.

precision error: see *error, random*.

primary variables: those used in calculations of test results. They are further classified as shown below.

Class 1: those that have a relative sensitivity (influence) coefficient of 0.2 or greater

Class 2: those that have a relative sensitivity (influence) coefficient of less than 0.2 [Refer to ASME PTC 19.1 for the determination of relative sensitivity (influence) coefficients.]

purge: to introduce air into the furnace or the boiler flue passages in such volume and manner as to completely replace the air or gas–air mixture contained within.

recycle rate: the mass flow rate of material being reinjected into a furnace or combustion chamber.

recycle ratio: the recycle rate divided by the fuel mass flow rate.