ASME PTC 47.3-2021

Syngas-Conditioning Block of an Integrated Gasification Combined Cycle Power Plant

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 Code. Interpretations are published on the Committee web page and under http://go.asme.org/InterpsDatabase. Periodically certain actions of the ASME PTC Committee may be published as Cases. Cases are published on the ASME website under the PTC Committee Page at http://go.asme.org/PTCcommittee as they are issued.

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NOTICE

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

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

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

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

FOREWORD

ASME Performance Test Codes (PTCs) have been developed and have long been used for determining the performance of most major components of electric power production facilities. A PTC has not previously addressed the overall performance of an integrated gasification combined cycle (IGCC) power generation plant. The ability to fire a wide range of fuels has been a key advantage of gas turbines over competing technologies. Until recently, the traditional fuels for gas turbines have been natural gas and liquid fuels. Today, environmental concerns and economic forecasts are encouraging power generation suppliers to develop gasification systems that can use solid as well as liquid fuels (e.g., coal, biomass, waste, heavy oils). Preparation of an alternative fuel suitable for a gas turbine includes removal of ash, contaminants, and erodents/corrodents. In response to these needs, the ASME Board on PTCs approved the formation of the PTC 47 Committee in 1993 with the charter to develop a Code determining overall power plant performance for gasification power generation plants. The organizational meeting of this committee was held in November 1993. Members of the resulting committee included experienced and qualified users and manufacturers.

The committee has striven to develop an objective code that addresses the multiple needs for explicit testing methods and procedures, while attempting to provide maximum flexibility in recognition of the wide range of plant designs and the multiple needs for this Code.

ASME PTC 47.3-2021 was approved by the PTC 47 Committee and the PTC Standards Committee on September 27, 2021. It was then approved as an American National Standard by the American National Standards Institute (ANSI) Board of Standards Review on December 14, 2021.

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

Secretary, 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

ASME PTC 47 comprises five Performance Test Codes (PTCs) that describe testing procedures for an integrated gasification combined cycle (IGCC) power plant. ASME PTC 47, Integrated Gasification Combined Cycle Power Generation Plants, is used for testing the overall performance of an IGCC plant. If a plant passes the ASME PTC 47 test, no further testing is required. If a plant does not pass the ASME PTC 47 test, one or more secondary subsystems may be tested to isolate the problem(s), using the following PTCs:

(a) ASME PTC 47.1, Cryogenic Air Separation Unit of an Integrated Gasification Combined Cycle Power Plant, for testing the performance of the air separation unit (ASU)

(b) ASME PTC 47.2, Gasification Block of an Integrated Gasification Combined Cycle Power Plant, for testing the thermal performance of the gasification equipment

(c) ASME PTC 47.3, Syngas-Conditioning Block of an Integrated Gasification Combined Cycle Power Plant, for testing the thermal performance of the syngas cleaning equipment

(d) ASME PTC 47.4, Power Block of an Integrated Gasification Combined Cycle Power Plant, for testing the thermal performance of the gas turbine combined cycle power block

Overall plant and subsystems should be tested separately rather than simultaneously to accommodate any boundary constraints and valve isolations and lineups that may be needed for subsystem testing. In highly integrated IGCC plants, the entire plant may need to be operating during a subsystem test, even though only subsystem performance parameters are being measured.

Plant owners can use test results to determine the fulfillment of contract guarantees. Plant owners can also use the test results to compare plant performance to a design number or to track plant performance changes over time. However, test results conducted in accordance with this Code will not provide a basis for comparing the thermoeconomic effectiveness of different plant designs.

Section 1
Object and Scope

1-1 OBJECT

The object of this Code is to provide uniform test methods and procedures for the determination of the performance of the syngas-conditioning block, which is located between the gasification block and the power block. The functions of the syngas-conditioning block include one or more of the following:

(a) to prepare the syngas to fuel the gas turbine to meet environmental constraints by the removal of acid gas compounds, such as hydrogen sulfide (H_2S), carbonyl sulfide (COS), and possibly carbon in the form of carbon dioxide (CO_2).

(b) in the case of a system designed to capture carbon, to convert a significant fraction of the CO in the syngas to CO_2 and separate the CO_2 from the syngas. Any captured CO_2 would either be sequestered or put to a beneficial reuse. Either of these dispositions for the captured CO_2 would likely require conditioning and/or compression. Such post-separation processing is not within the scope of this Code unless the parties to the test decide otherwise.

(c) to condition and convert the acid gas compounds separated from the syngas to useable products such as elemental sulfur, or sulfuric acid.

(d) to remove mercury (Hg), ammonia (NH_3), and other minor contaminant materials to meet environmental requirements.

(e) to use heat recovery equipment (heat exchangers) to transfer as much of the inlet syngas's energy as possible to useful energy for the power block. Inlet syngas energy includes thermal energy and latent heat of vaporization. This action will meet the requirements of the block's components as the gas temperature is adjusted throughout the syngas-conditioning block.

This Code evaluates only thermal performance, not regulatory compliance or contaminant-removal effectiveness. The thermal performance determined by this Code compares the syngas fuel energy flow at the exit from the syngas-conditioning block with the syngas fuel energy flow at the inlet to the syngas-conditioning block. This includes consideration of all recovered thermal energy, heats of reaction and vaporization, and all electric, steam, oxidant, and other auxiliary requirements used by the syngas-conditioning block. Emissions tests, operational demonstration tests, and reliability tests are outside the scope of this Code.

A performance test conducted under this Code is considered valid only if the equipment is operated in accordance with its primary function and within all applicable permitting limits and manufacturer requirements for equipment (combustion turbine) protection.

The primary purpose of the conditioning block is to remove acid gas compounds from the syngas that, if not removed, would violate environmental limits imposed upon the integrated gasification combined cycle (IGCC) facility. Acid gas compounds are generally removed from syngas by contact with a medium that selectively transfers the acidic components from the gas phase to either a liquid phase (absorption possibly with reaction) or a solid phase (adsorption possibly with reaction). A desirable characteristic of any medium used for acid gas removal, whether liquid or solid, is the minimal loss of the valuable (combustible) components of the syngas. In liquid-based acid gas removal systems, typically the largest expenditure of energy is in the form of heat, generally as steam, for regeneration of the solvent. Other expenditures of energy include, but are not limited to, compression of recovered gases (recycle), cooling of the solvent, and pumping of solvent solutions. Liquid-based acid gas removal systems typically must operate at much lower temperatures than the syngas entering the block. The syngas entering the block also typically contains a significant fraction of water vapor. Effective recovery of this sensible and latent heat as useful energy for the power block is key to the thermal efficiency of the gas-conditioning block. In solid-based acid gas removal systems, expenditures of energy may include, but are not limited to, heat for regeneration of the solid medium, heating of the syngas, compression of removed gases, and co-adsorption of valuable syngas components. The removed sulfur species must be converted to a benign and useful byproduct, i.e., elemental sulfur or sulfuric acid (H_2SO_4). These sulfur conversion systems consume and produce energy in various forms (steam, auxiliary power, and sometimes oxidant).

Table 1-3-1
Largest Expected Test Uncertainties of Performance Parameters

Test Result	Test Uncertainty, %
Corrected product syngas energy, kW	3 [Note (1)]
Corrected conditioning effectiveness	3 [Note (1)]

NOTE: (1) The 3% values are for a conditioning system comprising COS hydrolysis, acid gas removal, and a sulfur recovery unit. Systems with additional components, such as those shown as dashed blocks in Figure 3-1-1, would require additional measurements with additional uncertainties.

Syngas entering the gas-conditioning block contains carbonyl sulfide (COS), a sulfur compound that must be removed to meet permit limits. If the acid gas removal system does not remove it directly, a COS hydrolysis system is included to convert the COS to hydrogen sulfide (H_2S), which the acid gas removal system can accommodate. COS hydrolysis requires gas temperature adjustment, which consumes energy.

Syngas entering the gas-conditioning block also contains ammonia (NH_3), which must be removed since NH_3 is almost entirely converted to nitrogen oxides (NOX) in the combustion turbine, thus exceeding permit limits. This often requires an ammonia stripper, which uses steam.

IGCC facilities with modest-to-high levels of carbon capture require the conversion of the carbon monoxide (CO) and water vapor in the syngas to hydrogen (H_2) and carbon dioxide (CO_2) prior to combustion. This conversion is widely recognized as the water–gas shift reaction, which reduces the heating value of the syngas. This Code covers the evaluation of the performance of systems that do incorporate the water–gas shift reaction and systems that do not.

1-2 SCOPE

This Code applies to a variety of syngas-conditioning processes that are required for upgrading the raw syngas leaving the gasification block. It is assumed that the gas entering the conditioning block is essentially free of particulates, so particulate removal systems are not considered in this Code.

The Code addresses the principal streams crossing the boundary of the conditioning block (see Figure 3-1-1) and provides methods for measuring stream parameters of interest.

(a) Since the syngas-conditioning block is being tested for its ability to prepare the syngas to serve as fuel for the gas turbine, the measured quantities are

(1) syngas inlet and outlet mass flow rates and compositions
(2) syngas inlet and exit pressures and temperatures
(3) steam and steam turbine condensate inlet and outlet mass flow rate and enthalpy
(4) oxidant consumption rate
(5) auxiliary power requirements

(b) The following list is a summary of the principal measurements needed for testing:

(1) syngas inlet mass flow rate, kg/s
(2) syngas outlet mass flow rate, kg/s
(3) syngas inlet composition
(4) syngas outlet composition
(5) auxiliary power consumption, kWe
(6) steam and steam condensate entering and leaving the block (flow, temperature, pressure)
(7) O_2 entering the system (if applicable) (flow)

1-3 UNCERTAINTY

The explicit measurement methods and procedures to be used for the conditioning block of an IGCC facility have been developed to 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. Calculation procedures, in accordance with those set forth in ASME PTC 19.1, are presented for performance testing of the conditioning block.

A pretest uncertainty analysis shall be performed to establish the expected level of uncertainties for the test. Most tests conducted in accordance with this Code will result in uncertainties that are lower than those shown in Table 1-3-1. If the pretest uncertainty analysis indicates that the uncertainty of any of the test results is greater than those shown in