ASME PTC 50-2002

FUEL CELL POWER SYSTEMS PERFORMANCE

PERFORMANCE TEST CODES

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An American National Standard

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A N A M E R I C A N N A T I O N A L S T A N D A R D

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This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to this edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Interpretations are published on the ASME Web site under the Committee Pages at *http://www.asme.org/codes/* as they are issued.

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FOREWORD

During the mid 1990s the importance of developing fuel cell standards was recognized. Fuel Cell power plants were in the early stages of commercialization. Potential applications included vehicular power, on-site power generation, and larger scale dispersal power generators. There was a growing demand to produce industry standards that would keep pace with the commercialization of this new technology.

ASME had a very active Fuel Cell Power Systems technical committee within the Advanced Energy Systems Division. Through its volunteer membership, it recommended the formation of a standards committee to work on developing a fuel cell standard. ASME Codes and Standard Directorate undertook this task. On October 14, 1996 the Board on Performance Test Codes voted to approve the formation of a performance test code committee, PTC 50.

This Committee had its first meeting on January 23-24, 1997. The membership consisted of some 18 fuel cell experts from Government, academia, manufacturers, and users of fuel cells. Ronald L. Bannister; Westinghouse Electric Corporation; retired, chaired the first meeting. He had been appointed by the Board on PTC as the Board Liaison member to the committee. He chaired and supervised the committee's activities until permanent officers were elected from the membership.

In the Fall 2001, the Committee issued a draft of the proposed Code to Industry for review and comment. The comments were addressed in February 2002 and the Committee by a letter ballot voted to approve the document on March 29, 2002. It was then approved and adopted by the Council as a standard practice of the Society by action of the Board on Performance Test Codes voted on May 6, 2002. It was also approved as an American National Standard by the ANSI Board of Standards Review on July 3, 2002.

NOTICE

All Performance Test Codes **MUST** adhere to the requirements of **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 this Supplement. It is expected that the Code user if fully cognizant of Parts I and III of PTC 1 and has read them prior to applying this Supplement.

ASME Performance Test Codes provide test procedures which 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. They specify procedures, instrumentation, equipment operating requirements, calculation methods, and uncertainty analysis.

When tests are 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 equipement. 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.

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FUEL CELL POWER SYSTEMS PERFORMANCE

INTRODUCTION

Fuel cells convert the energy of a fuel directly into electricity, eliminating the combustion stage that is characteristic of heat engines, and not requiring any moving parts. Instead, the fuel molecules (usually hydrogen often derived from hydrocarbon fuels) interact with the surface of an anode material to form reaction products, liberating electrons. The electrons flow through the electric load to the cathode where they react with an oxidant, typically oxygen from air. Ions migrate between the electrodes through the ionically conducting electrolyte to complete the circuit. The product of this electrochemical energy conversion process is water, but unlike heat engines, the process can take place at close to ambient temperature, or can also be conducted at higher temperatures, depending on the types of anode, electrolyte, and cathode materials.

Since fuel cells are not heat engines, the efficiency of a fuel cell system is not limited by the Carnot principle. It can, in fact, vary over a fairly wide range. When the current density of the fuel cell is very low, the energy conversion efficiency approaches the ratio of the *Free Energy of Combustion* of the fuel divided by the *Enthalpy of Combustion*. For methane this limit is 94%. However, such an operating mode would require a very large fuel cell and would be too expensive for most applications.

In practice, fuel cell systems are designed to operate at a power density reflecting the most economical trade-off of fuel and capital costs. At the design point of the system the power output of the system is specified by the manufacturer for certain standard conditions of fuel and air. It is the purpose of this Code to define in a commonly acceptable manner how the power output and the energy input should be measured and how the efficiency should be calculated.

Section 1 defines the objective and scope of this Code. Section 2 is dedicated to defining a fuel cell system and to definition of terms. It also contains a brief discussion of the major types of fuel cells. In Section 3, methodology of establishing test protocol is outlined. Instrumentation for measuring the energy of the feed stream as well as of the exiting gases and liquids is given in Section 4, as is the instrumentation for measuring electric power. Section 5 describes how the efficiency of the systems shall be calculated from the measurements, and how corrections for nonstandard conditions shall be made.

Typically, this performance test code would be used for an independent verification of the performance of a particular fuel cell system by a customer or test agency. In the view of the members of the Committee, the described procedures are rigorous, and the test will require committing significant resources. For the casual user of fuel cells, it will suffice to determine the electric output of the system under steady state conditions, and to measure the fuel feed rate. As mentioned above, the efficiency of a fuel cell system varies significantly with power density. At power densities below the design point, the efficiency will usually increase, and it will decrease when the power output exceeds the design point. One of the characteristics of fuel cells is the ability to operate them over a wide power range, even exceeding the design point by 50% for a few minutes. Under dynamic operating conditions the efficiency of a fuel cell would be different than at the design point, and would probably be higher, since most loads contain significant segments of low-power operation and normal system control (e.g., for fuel flow) responds fairly quickly to these load conditions. Measuring the efficiency under dynamic conditions goes beyond the scope of the document.

SECTION 1
OBJECT AND SCOPE

1.1 OBJECT

This Code provides test procedures, methods, and definitions for the performance characterization of fuel cell power systems. Fuel cell power systems include all components required in the conversion of input fuel and oxidizer into output electrical and thermal energy. Performance characterization of fuel systems includes evaluating system energy inputs and electrical and thermal outputs to determine fuel-to-electrical energy conversion efficiency and where applicable, the overall thermal effectiveness. These efficiencies will be determined to an absolute uncertainty of less than ±2% at a 95% confidence level. (For example, for a calculated efficiency of 40%, the true value lies between 38% and 42%.)

1.2 SCOPE

This Code applies to all fuel cell power systems regardless of the electrical power output, thermal output, fuel cell type, fuel type, or system application.

Fuel cell power systems contain an assembly of electrochemical cells, which oxidize a fuel to generate direct current electricity. Balance-of-plant subsystems may include controls, thermal management, a fuel processor and a power conditioner. Some fuel cell power systems may contain additional power generating equipment such as steam generators, gas turbine generators, or micro-turbine generators. The net power output and all the fuel input to the system shall be taken into account in the performance test calculations.

This Code applies to the performance of overall fuel cell power systems. The Code addresses combined heat and power systems, that is, the generation of electricity and usable heat at specific thermal conditions. It does not address the performance of specific subsystems nor does it apply to energy storage systems, such as regenerative fuel cells or batteries. It also does not address emissions, reliability, safety issues, or endurance.

This Code contains methods and procedures for conducting and reporting fuel cell system testing, including instrumentation to be used, testing techniques, and methods for calculating and reporting results.

The Code defines the test boundary for fuel and oxidant input, secondary energy input and net electrical and thermal energy output. At these boundaries, this Code provides procedures for measuring temperature, pressure, input fuel flow and composition, electrical power, and thermal output.

The Code provides procedures for determination of electrical efficiency or heat rate and overall thermal effectiveness at rated or any other steady-state condition. The Code also provides the method to correct results from the test to reference conditions.

1.3 TEST UNCERTAINTY

In accordance with ASME PTC 19.1, procedures are provided for determining the uncertainty associated with the calculated performance parameters of this Code (energy input, electrical energy and thermal outputs, and electrical efficiency or heat rate). In the measurements made to determine performance parameters, there are systematic errors produced by the procedures and instrumentation recommended in this Code. A table of these systematic errors may be found in Section 4 of this Code.

Sample calculations of the uncertainties associated with the system performance parameters, which illustrate the effects of systematic errors and data, are presented in Mandatory Appendix I of this Code.

A pretest uncertainty analysis is recommended. The pretest analysis allows corrective action to be taken prior to the test, which will either decrease the uncertainty to an appropriate level consistent with the overall objective of the test or will reduce the cost of the test while still attaining the test uncertainty.

A post-test uncertainty analysis is mandatory. It will make use of empirical data to determine random measurement errors and test observations to establish whether or not the required uncertainty has been achieved.

This uncertainty procedure serves as a guide for pretest and post-test uncertainty calculations when the Code is used.