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Highlights on Performance Standards Used in Gas Turbine Testing

Priyanka Garg
University of Madras, Tamil Nadu, India

Abstract

This paper studied that various engineering applications have included the use of gas turbines for decades to turn the core of an electrical generator to produce power for both industrial and to some extent residential consumption. Discussion includes factors that affecting Gas Turbine Performance, Inlet and exhaust losses, humidity etc.

Keywords: *Generator, Gas Turbine, humidity.*

***Author for Correspondence**
Email: Priyanka.ae116@gmail.com

INTRODUCTION

A gas turbine is a kind of spinning device that uses the action of a gas to produce work. Various engineering applications have included the use of gas turbines for decades to turn the core of an electrical generator to produce power for both industrial and to some extent residential consumption. The gas turbine is a complex machine and its performance is governed by many standards. American Society of Mechanical Engineers (ASME) performance test codes have been written to ensure that the test is conducted in a manner that guarantees that all turbines are tested under the same set of rules and conditions to ensure that the test results can be compared in a judicious manner. [1]

Factors Affecting Gas Turbine Performance

Air Temperature and Site Elevation

Since the gas turbine is an air-breathing engine, its performance is changed by anything that affects the density and/or mass flow of the air intake to the compressor.

Ambient weather conditions are the most obvious changes from the reference conditions of 59 F/15 C and 14.7 psia/1.013 bar. Correction factor for Heat rate is from 0.92 from -29 0C to 1.1 at 45 0C. Correction factor for Power is from 1.25 from -19 0C to 0.83 at 40 0C. [4, 5]

Altitude

Heat rate is not affected by altitude. Correction factor for power from 1 at 0 m (sea level) to 0.8 at 1800 m above sea level, at 1000 m is about 0.89. [5]

Humidity

Humid air, which is less dense than dry air, also affects output and heat rate. In the past, this effect was thought to be too small to be considered. However, with the increasing size of gas turbines and the utilization of humidity to bias water and steam injection for NO_x control, this effect has greater significance. It should be noted that this humidity effect is a result of the control system approximation of firing temperature such as, used on GE heavy-duty gas turbines. [2, 3]

Inlet And Exhaust Losses

Inserting air filtration, silencing, evaporative coolers or chillers into the inlet or heat recovery devices in the exhaust causes pressure losses in the system. The effects of these pressure losses are unique to each design.

Correction factor Heat rate is 0 for 0 mm H_2O inlet losses to 1.02 at 300 mm H_2O. Correction factor Power is from 0 for 0 mm H_2O inlet losses to 0.98 at 300 mm H2O. [4, 5]

Fuels

Work from a gas turbine can be explained as the product of mass flow, heat energy in the combusted gas (C_p), and temperature differential across the turbine. The mass flow in this equation is the sum of compressor airflow and fuel flow. The heat energy is a function of the elements in the fuel and the products of combustion. [4] Several side effects must be considered when burning this kind of lower heating value fuels:

- Amplified turbine mass flow drives up compressor pressure ratio, which eventually invades on the compressor surge limit
- The higher turbine power may exceed fault torque limits. In many cases, a larger generator and other accessory equipment may be needed
- High fuel volumes increased fuel piping and valve sizes (and costs). Low- or medium-Btu coal gases are regularly supplied at high temperatures, which further rises their volume flow
- Lower-Btu gases are frequently saturated with water prior to delivery to the turbine. This growths the combustion products heat transfer coefficients and raises the metal temperatures in the turbine section which may need lower operating firing temperature to preserve parts lives
- As the Btu value drops, more air is required to burn the fuel. Machines with high firing temperatures may not be able to burn low Btu gases. Most air-blown gasifiers practice air supplied from the gas turbine compressor discharge.
- The ability to extract air must be evaluated and factored into the overall heat and material balances [4]

As a result of these effects, each turbine model will have some request guidelines on flows, temperatures and shaft output to preserve its design life. In most cases of operation with lower heating value fuels, it can be assumed that output and efficiency will be equal to or higher than that obtained on natural gas. In the case of higher heating value fuels, such as refinery gases, output and efficiency may be equal to or lower than that obtained on natural gas. [4]

Fuel Heating

Most of the combined cycle turbine installations are designed for maximum efficiency. These plants often utilize integrated fuel gas heaters. Heated fuel have drawbacks in higher turbine efficiency due to the reduced fuel flow required to raise the total gas temperature to firing temperature.

Fuel heating will result in slightly lower gas turbine output because of the incremental volume flow decrease. The source of heat for the fuel typically is the IP feedwater. Since use of this energy in the gas turbine fuel heating system is thermodynamically gainful, the combined cycle efficiency is better-quality by approximately 0.6%. [4]

Air Extraction

In some gas turbine applications, it may be desirable to extract air from the compressor. Generally, up to 5% of the compressor airflow can be removed from the compressor discharge casing without alteration to casings or on-base piping. Pressure and air temperature will depend on the type of machine and site conditions. Air extraction between 6% and 20% may be done , depending on the machine and combustor configuration, with some alterations to the casings, piping and controls. Such applications need to be reviewed on a case-by-case basis. Air extractions above 20% will require extensive modification to the turbine casing and unit configuration. As a "rule of thumb," every 1% in air extraction results in a 2% loss in power. [4]

GAS TURBINES -- ACCEPTANCE TESTS

This International Standard used in to open-cycle gas-turbine power plants with combustion systems supplied with gaseous and/or liquid fuels as well as closed-cycle and semi-closed-cycle gas-turbine power plants. It can also be applied to gas turbines in combined cycle power plants or in connection with other heat-recovery systems.

In cases of gas turbines apply free-piston gas generators or special heat sources (for example synthetic gas of chemical processes, blast furnace gas), this International Standard can be used as a basis but suitable modifications are necessary. [6]

Acceptance tests of gas turbines with emission control and/or power augmentation devices that are based on fluid injection and/or inlet air treatment are also covered by this International Standard and it is necessary that they be taken in the test procedure, provided that such systems are included in the contractual scope of the supply subject to testing. [6]

This International Standard does not apply to emission testing, noise testing, vibration testing, performance of specific components of the gas turbine, performance of power augmentation devices and auxiliary systems, such as air inlet cooling devices, fuel gas compressors, etc., conduct test work aiming at development and research, adequacy of essential protective devices, performance of the governing system and protective systems, and operating characteristics (starting characteristics, reliability testing, etc.). [6]

MECHANICAL STANDARDS

The reliability depends on the mechanical codes that govern the design of many gas turbines.

The mechanical standards and codes have been set by both ASME and the American Petroleum Institute (API). [1]

ASME Test Performance Code

This Code provides directions and rules for conduct and report of results of thermal performances tests for open cycle gas turbine power plants and gas turbine engines, hereafter referred to as gas turbines. The object is to know the thermal performance of the gas turbine when functioning at test conditions, and rectify these test results to specified reference conditions. This Code provides explicit procedures for the determination of correct power output, corrected heat rate (efficiency), corrected exhaust flow, energy, and temperature. Tests may be chosen to satisfy different goals,having absolute performance and comparative performance. It is the intent of the Code to provide results with the highest level of accuracy consistent with the best engineering knowledge and practice in the gas turbine industry. [2]

In planning the test, an uncertainty analysis must demonstrate that the proposed instrumentation and measurement techniques meet the requirements of the Code. [2]

In 1884, the ASME published "Rules for Conducting Boiler Tests." On April 13, 1909, the Power Test Committee was chartered by the Council of ASME to "revise the present testing codes of the Society relating to boilers, pumping engines, locomotives, steam engines, internal combustion engines etc." In 1915, the "Rules for Conducting Performance Test of Power Plant Apparatus" was published. [2]

Over the years numerous test codes and extras have been published. Some have been revised and others withdrawn as novel technological advances have necessitated the issuance of state-of-the-art test codes. Today, some three dozen test codes are available for testing power plant equipment, such as fired steam generators, steam turbines and gas turbines as well as testing fuel cells and combined cycle gasification plants. It is Society policy to review each standard every five years to determine whether a revision is necessary. [2]

ASME Performance Test Codes (PTCs) provide uniform rules and procedures for the planning, preparation, execution, and reporting of performance test results. They provide protocols to set the testing parameters and methods of measurement. They provide mathematical examples on computing the test results and statistical methods to determine the quality of the tests by calculating the test uncertainty. [3]

ASME PTCs Offering Applications

For over 100 years, ASME has been providing industry with a inclusive collection of the best technical documents to perform tests of power plant equipment and systems. ASME now offers 48 Performance Test Codes (PTCs), covering four main categories of equipment and systems – Power Production, Combustion and Heat Transfer, Fluid Handling, and Emissions. There are also "general" documents that cover Analytical Techniques, Measurement of Process Parameters and Associated Phenomena and Guiding Information. [3]

Ensuring Accuracy, Precision, And Reliability. Instilling Confidence

Performance test codes provide a "level playing field" for both manufacturers and users of the equipment or systems. Both parties to the test can use the particular test code, self-assured with the data that it tells the topmost of accuracy based on current engineering knowledge, taking into account test costs and the value of information obtained from testing.

Precision and reliability of test results must 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. [3]

API Performance Test Code

API standard are often used for technical reference when purchasing equipment. It provides the means for customer to normalize the quotation by forcing all vendors to quote on similar scope. API also provides a common rule between vendor and customer to limit misunderstanding. It shall be understood that API code clearly state in their foreword that exception are allowed, if they lead to an improved or safer technical offer. [5]

In general, API 616 is code for gas turbine application in oil and gas industry which is used by many end-users. It is recommended to use API data sheet as they clearly form the technical basis required. In this data sheet, application specific issues are defined, such as customer site, operating condition, basic equipment selection, and equipment integrity requirement. Cross out requirement that are not required or cannot be complied. Include technical note which is considered as critical issue and fill out data sheet as much as info is available. [5]

API 616 generally consists of several topics as follows:

- **Definition**: ISO rating, normal operating point, maximum continuous speed, trip speed and much more.
- **Mechanical Integrity**: Blade natural frequency, critical speed vibration level, balancing requirement, alarm and shutdown requirement.
- **Design Requirement**: Material, welding, accessories, control, instrumentation, inlet/exhaust system, fuel system.
- **Inspection, Testing and Shipment Preparation**: Testing requirement, inspection and certification
- **Documentation and Drawing Requirement**. [5]

Mechanical running test shall refer to API 616 which requires the equipment shall be four hour no load test, full speed (maximum continuous speed). This is to confirm mechanical integrity and verify that the complete gas turbine package (including auxiliary except for inlet/exhaust system) operates within vibration limits. Contract shaft seal and bearing shall be used. [5]

VERIFICATION OF GAS TURBINE PERFORMANCE

Once the gas turbine is installed, a performance test is usually conducted to determine power plant performance. Power, fuel, heat consumption and sufficient supporting data should be recorded to enable as-tested performance to be corrected to the condition of the guarantee. Preferably, this test should be done as soon as practical, with the unit in new and clean condition. In general, a machine is considered to be in new and clean condition if it has less than 200 fired hours of operation. [4]

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