API STANDARD 616 - SCOPES FOR DIFFERENT INTERPRETATIONS

G. K. ROY
GTBF Division
Larsen & Toubro Limited
Bombay, India

ABSTRACT

The intention of API standard 616 is to help manufacturer, or buyer of gas turbines in specifying the equipment, and is based on experience and good engineering practices over many years. Like any other standard, the definitions are broad-based to cover possibly the majority of manufacturers, and are based on experiences gathered in the industries in general. However, different interpretations are possible on some of the clauses of the standard.

Each gas turbine customer has specific requirements, and the manufacturer’s objective is “Customer Focus” which means it has to fulfill the requirements of the customer totally, or even to take it a step further identify the needs that the customer has not even recognized. The common objective of providing a machine satisfying the specific requirements is difficult to achieve, when attempts are made to bridge the gaps between the customer and the manufacturer through the API standard 616.

Few clauses of API standard 616 are controversial in nature, where possibly more than one explanations are possible, and a more clear guide-line from API is needed to direct the users and the manufacturers. Turbine firing temperature, rotor insensitivity test, API 614, turbine baseplate, post-test bearing inspection, etc are some of them. In this paper these were discussed with some of the available gas turbine purchasing standards.

It was concluded that standard like API 616 needs to be general in nature, so that it can be used for each specific customer, however, definitions and its’ scopes need to be clearly identified to avoid mis-use or incorrect use of the standard.

INTRODUCTION

API standards are design guide to specify and manufacture equipment, and are based on the experience gathered over the years in the petroleum industries. API standard 616, latest edition is applicable for land-based heavy duty and aeroderivative industrial gas turbines. The API standards 614, 615, 670, 671 and 678 also form a part of API 616.

Many gas turbine manufacturers, however, do not follow the API standards strictly, and follow their own specifications which have been developed and proven over the years. As API standards are more conservative, it is costlier to comply with all its’ clauses when cheaper substitutes give same or even better results in certain cases. On the other hand, there are customers who do not have much knowledge about the equipment, and consider API standards as ‘sacrosanct and unchangeable’ or a safe measure of quality of the equipment when he does not have the in-house expertise to evaluate a vendor’s offer.
While it is true that if the customer so desires it is possible to provide machine following API standards for a price, there are few clauses in API standards which are difficult to comply with because of the various possible interpretations. There may be still other areas where API standards should provide more design guidance to the vendor or customer which is not available at present.

The manufacturers are continuously striving to improve the reliability, availability, and maintainability (RAM) of the units supplied. “Customer Focus” is a term which is heard very often today. It covers all decisions and deeds where they affect the customer, with time and quality as the primary criteria, and even identify the needs that the customer has not even recognized. In this scenario it is felt that there is a need to re-evaluate the standards.

This article investigates few clauses in API 616 (third edition, Jan 1992) and API 614 (third edition, August 1992) to show that there is a need to bridge the gap between these specifications and current trends in the manufacturing standards.

FIRING TEMPERATURE

The gas turbine cycle efficiency increases with higher firing temperature, and falls with higher exhaust temperature. With increasing pressure ratio, the efficiency rises to a maximum point for a particular firing temperature, and decreases thereafter. More efficient a gas turbine is for a particular firing temperature, the more capable it is of converting this heat energy into mechanical work, resulting in a lower exhaust temperature. This is the basis of comparing different gas turbines of the same power rating.

Improved materials, coatings, and cooling techniques permit the state-of-the-art machines to operate with higher firing temperature, or turbine inlet temperatures (TIT), yielding both increased output and efficiency. The firing temperatures for the latest machines are in the range of 1290°C, compared to only 1105°C for earlier designs. One rule-of-thumb says that every 35°C rise in firing temperature yields a 10-13% increase in output and a 2-4% gain in simple cycle efficiency.

Double-shell construction with inner wall metallic heat-shield pads, impingement air cooling and film cooling to minimize hot spots, external cooling air and inter-cooled compressor-extraction air to cool various stages of the power turbine are some of the cooling methods used.

API defines the “rated firing temperature” as vendor’s stated turbine inlet total temperature immediately upstream of the first stage turbine nozzles for continuous service at ISO rated power output. Obviously, this temperature is higher than the temperature at inlet to the first stage bucket, and particularly so, if the nozzles are air-cooled. This definition tends to show higher thermal efficiency compared to one leading turbine manufacturer who defines TRIT (Turbine Rotor Inlet Temperature) as the mean gas temperature immediately upstream of the first stage rotor rotating blades, or immediately downstream of the first stage nozzle trailing edge plane.

The latter definition takes into account the nozzle cooling. According to the turbine manufacturer, this definition takes the highest temperature in the heat cycle available for conversion (thermal to mechanical) and is more realistic.

On the other extreme, the ISO 2314-1989 derives the firing temperature by calculation of a heat balance on the combustion system inclusive of ducting associated with it, generally obtained during site acceptance testing. The firing temperature calculated by ISO 2314 is always less than the true firing temperatures defined by above definitions. The thermal efficiency based on ISO 2314 is conservative, but does not represent the actual.

The Japanese turbine manufacturers define the firing temperature at the first stage nozzle after the gas leaves the combustion chamber, and before it does any work. This definition clearly tends to show higher efficiency compared to others. This definition is closer to API definition as far as location of the firing temperature is concerned.

ROTOR INSENSITIVITY TEST

If the calculated critical speed, or the actual critical speed falls within the operating margin, or the separation margin requirements can not be fulfilled at all cost, then API recommends that a rotor insensitivity test be carried out. This test is done by actual test-stand operation of the machine at the critical speed in question with an induced unbalance. The API standard however does not specify the duration of such test or if any safety precautions to be taken for the equipment.

API 614 FOR 616

API 616 specifies that unless otherwise specified, pressurized oil systems for the gas turbine shall conform to the requirements of API 614, implies
that there exists a flexibility in a given requirement. Although the onus of designing and supplying in accordance to API 614 is on the gas turbine manufacturer, in the absence of a specific requirement from the customer, if a vendor specifies another design, he has not violated the requirements of API 616. The API 614, however, clearly states that it does not apply to internal combustion engines. Therefore, although the customer may insist the requirement of a lubrication system be as per API 614, the vendor can always choose to supply another design on the pretext that API 614 is not applicable to gas turbine. This is obviously a gross contradiction.

Broadly, the following needs to be fulfilled if the gas turbine has to fulfill the API 614 requirements.

- Lube oil reservoir separate from equipment base plate. Reservoir and all appendages welded to it fabricated from stainless steel.
- When purchaser specifies to provide a separately mounted emergency lube oil rundown tank, it shall be Series 300 stainless steel and no less than 3 minutes holding time.
- Each pump shall have its own driver, main pump steam turbine and stand by pump electric motor driven. Shaft-driven pump can be provided, subject to approval by the purchaser.
- All pumps installed with flooded-suction to ensure self-priming.
- Oil piping shall be of seamless stainless steel.
- The oil system shall be suitable for ‘special purpose application’ and the design shall allow for the transfer between and shutdown of main and spare components of the system for maintenance without interrupting the operation of the system of equipment it serves. The term ‘special purpose application’ is a design requirement as understood in code API 614.

It is possible to provide the basic oil system which satisfies the above requirements. As we know, the majority of the gas turbine manufacturers would normally offer lubrication system of their present design philosophy in future. What would normally be offered for lubrication system of the gas turbine is a baseplate (structural steel) forming a part of the carbon steel lube oil reservoir. There is no emergency rundown tank. The main lube oil pump is accessory gear driven, the auxiliary lube oil pump is AC driven and DC emergency pump is provided.

While the accessory (shaft) driven main lube oil pump is permitted by API 614 and 616 (subject to customer’s approval), it does not satisfy the criteria of change-over from main to auxiliary pump for maintenance during operation of the gas turbine which is an API standard requirement.

The customer may have the following reservations against the shaft driven pump:

- If the main pump (shaft-driven) fails during the operation of the gas turbine and the AC auxiliary pump runs to supply the required delivery pressure (if the operator can not stop the machine for emergency power requirements), there is no stand-by pump available. The single contingency protection provided in case of shaft driven main pump and one AC driven auxiliary pump does not allow for the transfer between and shutdown of main and spare components of the system for maintenance without interrupting the operation of the system or equivalent it serves.

- As the delivery of the shaft driven main pump is related to the speed of the gas turbine, if there is a total black out of AC power during the coasting down, flow of lube oil to the bearings till zero speed is attained shall be totally dependent on the DC emergency pump. Due to non-use for a long time, or for already discharged batteries in a previous operation, the DC pump may not spring into action when warranted. These are the reasons put forward by many customers to insist upon an oil rundown tank, collection tank, centrifuge system additionally as a double contingency failure protection to coast down the turbine safely to rest and protect the bearings.

Even though the shaft-driven pump has good reliability history and possibly the most viable alternative, many customers show strong reservations against it. On the other hand, rundown tank increases the space requirements, and has a heavy price impact, and somewhat not always practical.

While API standard 616, second edition, June 1982 is specific to heavy-duty industrial combustion gas turbines, API standard 616, third edition, January 1992 does not differentiate between aero-derivative industrial, or heavy duty industrial machines and is general in nature.

A typical aero-derivative gas turbine will essentially have antifriction bearings. A shaft-driven positive displacement supply and scavenge pump, a distribution piping system and a set of oil jets are mounted on the engine. The engine operates with dry sumps. Oil from each sump and the accessory gearbox is scavenged by a separate positive displacement element. This configuration does not match to API 614 requirements, and therefore API 614 is not applicable to this type of machines.

Therefore, it can be concluded that most of the present gas turbine manufacturers satisfy the intent of API 614 to a large extent, but do not make machines conforming totally to lubrication and control oil requirements specified in the standard.
TURBINE BASEPLATE

API standard 616 specifies that the bottom of the baseplate of the turbine between structural members shall be open. This clause is probably a reminiscence of the API 614 clause which specifies that the lube oil reservoir shall be separate from the baseplate of the turbine. Most of the turbine manufacturers who normally would not supply the lube oil system as per API standard 614 can not comply with this clause.

POST-TEST BEARING INSPECTION

API 616 requires that all bearings shall be removed, inspected and re-assembled following the completion of mechanical running test.

A mechanical run test is intended to check the mechanical integrity of the machine. A strip-down check of the bearings nullifies the purpose of the test. Full-proofness of the re-assembly can not be ascertained without repeating the test.

The intention of the test as specified in API standard is probably to ascertain if there has been proper contacts between the journal and the bearing pads, or if there is any unhealthy tell-tale marks which need proper attention.

The bearings are monitored for temperature and vibration over a period of, say 4 hrs, during the mechanical running test. Once the machine has reached a steady state, the bearings should indicate the design vibration and temperature predicted in manufacturer’s specification. Any unusual behavior would indicate a bearing problem. Therefore, the requirement of bearing inspection after mechanical run test appears to be excessive.

If a purchaser wishes a re-test after the inspection, it should be specified. The inspection can reveal the presence of electromagnetic or electrostatic discharges during the test. Also, it should not be assumed that low vibration and temperature measurements mean everything is alright. Vibration sensors could have been located at node points and if embedded temperature sensors were used they may not have been at the full insertion depth: such improper installation of sensors would give misleading information about the bearings’ condition. Therefore, the requirement of bearing inspection after mechanical run test should be required with probable cause for problems, only if, there were problems during the mechanical run test.

A strip-down check without repetition of the run test for a second time can not necessarily guarantee a satisfactory re-assembly.

NON-CONVENTIONAL FUELS

Non-conventional fuels like liquid naphtha have become very popular in countries like India for turbines in 20 to 30 MW range, mostly for captive requirement. The reason for such use is mostly gas non-availability, and an under-developed market for downstream products.

The major problem of handling naphtha fuel in gas turbines stems from the variability of the fuel composition. There is no single definition of naphtha fuel. The variation of important properties is significant. It is a must to work with each potential vendor.

The ASTM D2880 standard specifies no. 0-GT grade fuel to cover low-flash naphthas. Limiting values are placed on a number of properties of the fuel that are believed to be of the greatest significance in determining performance characteristics.

ANSI/ASME B 133.7M-1985 standard for gas turbine fuels defines specific requirements for gaseous fuels, as for example, supply pressure and temperature, gas composition, calorific value and variation, flammability limits, contaminants and corrosion agents. The appendices of the standard which are not part of it, informs about liquid fuel contaminants & trace metals, storage requirements for light as well as heavy fuels. Many of these informations are not available in API 616.

ASME B 133.7 standard covers the requirements for fuels for gas turbines (except aircraft turbines), and is derived from ASTM gas turbine oil specification D 2880 and proposed ISO document on gaseous fuels for gas turbines.

Naphtha, having low viscosity and being corrosive in nature, damages the fuel pump and flow-divider. The manufacturers recommend two types of systems for firing liquid naphtha:

- Pressure Flow division (PFD) system utilizing an off-base fuel skid. Hazardous area to Class I, Division -2 , Group-D meets the area classification requirements. There is no requirements of flow-divider or on-base fuel pump.

- Conventional Fuel system using fuel pump and flow-divider. In this system an additive is used to protect the fuel system against corrosion and increase the flowability of the fuel. Pressurization of the enclosures enable the area to be classified as Class I, Division-2, Group-D, barring few flame-proof equipment which need to be energized before pressurization commences, or after it has stopped. The dosage
rate of additive is different for different viscosities.

API 616 does not provide any guideline on these systems for their design, and therefore the customer remains largely in the 'dark' to select a system. ISO 3977-1991 for gas turbines-procurement provides some information on this topic.

CONCLUSIONS

API, or for that matter any good standard is dynamic in nature which means that it is possible to improve the standard in course of time based on experience and knowledge gathered by the users and manufacturers of the equipment. API 616 can not be any exception.

One of the issues raised in this paper is firing temperature which may be interpreted differently based on the battery limit where it is defined. As more conservative, or less conservative definitions which tend to show respectively lesser or higher thermal efficiencies are widely used, API 616 should put these differences in a proper perspective.

API 616 recommends API 614 for lube oil system design, unless specified otherwise. As API 614 is not applicable for gas turbine, manufacturers take many deviations from it. Some of these deviations are difficult to be accepted by customers, however the manufacturers tend to take advantage of the applicability clause of API 614.

API 616 has certain shortcomings in terms of design informations as far as rotor insensitivity test, non-conventional fuels are concerned. The requirements for post-test bearing inspection also seems to be incomplete.

It is generally accepted that a standard can not be absolute, and sometimes the intention needs to be understood in a broader spectrum of the specification, however the definitions and its’ scopes need to be clearly identified to avoid mis-use or incorrect use of the standard.

Most manufacturers have written exceptions to the API standards. Any equipment purchaser should understand why these exceptions were taken and resolve any differences before an order is placed.

BIBLIOGRAPHY


ANSI/ASME B 133.7M-1985, “Gas Turbine Fuels,” The American Society of Mechanical Engineers, NY, USA