



Cool Your Jets!

An Introduction to Turbine Inlet Cooling

Dr. Punwani

Welcome to the Cool Your Jets column: a new feature in *Energy-Tech* magazine. It is the first of a series of columns that will address technical and economic information as well as issues related to enhancing power output of combustion turbines by cooling inlet air. *Energy-Tech*, in association with the Turbine Inlet Cooling Association (TICA), will publish this column in every issue with this being the first. In addition to this column, *Energy-Tech* plans to publish a cover story on turbine inlet cooling (TIC) in August 2004 along with a special supplement on the subject in October 2004.

The focus of this first column is to provide you an overview of TIC.

WHAT IS TIC?

TIC is cooling of the air before it enters the compressor that supplies high-pressure air to the combustion chamber from which hot air at high pressure enters the combustion turbine. TIC is also called by many other names, including combustion turbine inlet air cooling (CTIAC), turbine inlet air cooling (TIAC), combustion turbine air cooling (CTAC), and gas turbine inlet air cooling (GTIAC).

WHY COOL TURBINE INLET AIR?

The primary reason TIC is used is to enhance the power output of combustion turbines (CTs) when ambient air temperature is above 59°F. The rated capacities of all CTs are based on the standard ambient conditions of 59°F, 14.7 psia at sea level selected by the International Standards Organization (ISO). One of the common and unattractive characteristics of all CTs is that their power output decreases as the inlet air temperature increases as shown in

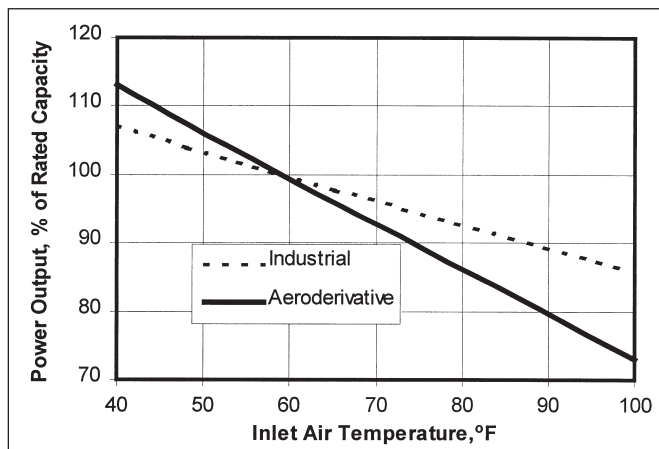


Figure 1. Effect of Inlet Air Temperature on Combustion Turbine Power Output

Figure 1. It shows the effects of inlet air temperature on power output for two types of CTs: Aero derivative and Industrial/Frame. The data in Figure 1 are typical for the two turbine types for discussion purposes. The actual characteristics of each CT could be different and depend on its actual design. The data in Figure 1 shows that for a typical aero derivative CT, as inlet air temperature increases from 59°F to 100°F on a hot summer day (in Las Vegas, for example), its power output decreases to about 73 percent of its rated capacity. This could lead to power producers losing opportunity to sell more power just when the increase in ambient temperature increases power demand for operating air conditioners. By cooling the inlet air from 100°F to 59°F, we could prevent the loss of 27 percent of the rated generation capacity. In fact, if we cool the inlet air to about 42°F, we could enhance the power generation capacity of the CT to 110 percent of the rated capacity. Therefore, if we cool the inlet air from 100°F to 42°F, we could increase power output of an aero derivative CT from 73 percent to 110 percent of the rated capacity or boost the output capacity by about 50 percent of the capacity at 100°F. The primary reason many power plants using CT cool the inlet air is to prevent loss of power output or even increase power output above the rated capacity when the ambient temperature is above 59°F.

WHAT ARE THE BENEFITS OF TIC?

The primary benefit of TIC is that it allows the plant owners to prevent loss of CT output, compared to the rated capacity, when ambient temperature rises above 59°F or the plant is located in a warm/hot climate region. As discussed in the earlier section, TIC can even allow plant owners to increase the CT output above the rated capacity by cooling the inlet air to below 59°F.

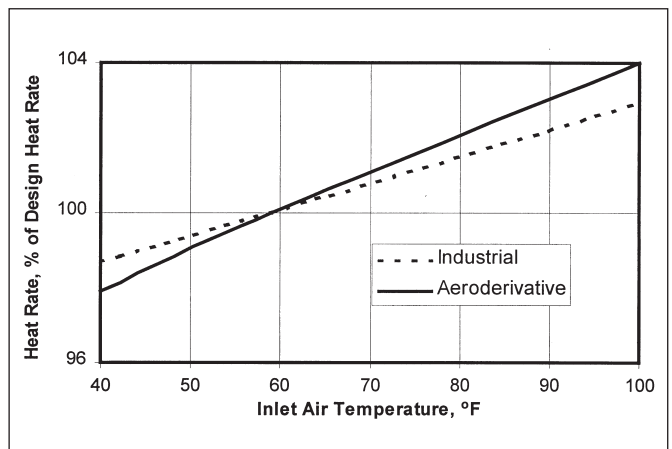


Figure 2. Effect of Ambient Temperature on Combustion Turbine Heat Rate

The secondary benefit of TIC is that it also prevents decrease in fuel efficiency of the CT due to increase in ambient temperature above 59°F. Figure 2 shows the effect of inlet air temperature on heat rate (fuel require per unit of electric energy) for the two types of CTs discussed in the earlier section. It shows that for an aeroderivative, CT increase in inlet air temperature from 59°F to 100°F increases heat rate (and thus, decreases fuel efficiency) by 4 percent (from 100 percent at 59°F to 104 per cent at 100°F) and that cooling the inlet air from 59°F to 42°F reduces the heat rate (increases fuel efficiency) by about 2 percent (from 100 percent to about 98 percent).

The other benefits of TIC include increased steam production in cogeneration plants, and increased power output of steam turbines in combined cycle systems.

In summary, there are many benefits of TIC when the ambient temperature is above 59°F:

- Increased output of CT
- Reduced capital cost for the enhanced power capacity
- Increased fuel efficiency
- Increased steam production in cogeneration plants
- Increased power output of steam turbine in combined cycle plants

HOW DOES TIC HELP INCREASE CT OUTPUT?

Power output of a CT is directly proportional to and limited by the mass flow rate of compressed air available to it from the air compressor that provides high-pressure air to the combustion chamber of the CT system. An air compressor has a fixed capaci-

ty for handling a volumetric flow rate of air. Even though the volumetric capacity of a compressor is fixed, the mass flow rate of air it delivers to the CT changes with changes in ambient air temperature. This mass flow rate of air decreases with increase in ambient temperature because the air density decreases when air temperature increases. Therefore, the power output of a combustion turbine decreases below its rated capacity at the ISO conditions (59°F, 14.7 psia at sea level) with increases in ambient temperature above 59°F. TIC allows increase in air density by lowering the temperature and thus, helps increase mass flow rate of air to the CT and results in increased output of the CT.

WHAT ARE THE AVAILABLE TECHNOLOGY OPTIONS FOR TIC?

Many technologies are commercially available for TIC. These technologies can be divided into the following major categories/groups:

- Evaporative: wetted media, fogging, and wet compression/overspray
- Refrigeration: mechanical and absorption chillers without or with thermal energy storage (TES)
- Special Application Technologies i.e., re-vaporization of liquefied natural gas (LNG)
- Hybrid Systems: a mix of mechanical and absorption chillers

All technologies listed above have advantages and disadvantages. Many published articles are available on these technologies.

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A number of these publications are listed in the Library section of the Turbine Inlet Cooling Association website (www.turbineinletcooling.org).

WHAT ARE THE ECONOMICS OF TIC?

Even though it is difficult to generalize the overall economics of TIC because they depend on many factors, it generally requires less investment (\$/kW) than installing additional uncooled CT to achieve similar increase in plant capacity. It is not unusual for TIC to increase CT output capacity at less than half the capital cost of installing an additional uncooled CT.

The various factors that affect the overall economics of TIC include the following:

- Cooling Technology
- Weather data for the geographic location of the CT plant
- CT plant capacity and operational mode (Peaking, Cogeneration, or Combined Cycle)
- Market value of electric energy and power demand profile
- Price of fuel (Natural gas or fuel oil)
- Market value of cogenerated steam and steam demand profile
- Cost of capital

WHO IS USING TIC?

Many CT plants across the U.S. and around the world are using various TIC technologies that improve their performance and economics. A database of some of these installations is available in the Experience Database section of the Turbine Inlet Cooling Association website.

WHAT ARE THE PLANS FOR THIS COLUMN?

This column will cover the following sequence of TIC topics in the subsequent issues of the *Energy-Tech*:

- Evaporative cooling technologies: wetted media, fogging, and overspraying/wet compression
- Refrigeration/Chiller technologies: mechanical and absorption
- Thermal energy storage technologies: ice, chilled water, and stratified fluid
- Special application technologies and hybrid systems
- Performance test protocol
- Commissioning, Maintenance & Operation

WHAT IS THE MISSION OF TICA?

The mission of the Turbine Inlet Cooling Association (TICA), a not-for-profit organization, is to promote the development and exchange of knowledge related to TIC and to become the premier one-stop source of information on TIC. For more information about TICA, visit its website at www.turbineinletcooling.org.

Dharam Punwani is president of Avalon Consulting, Inc. located in the Chicagoland area (Naperville), and has over 36 years of experience in energy technologies. Avalon provides consulting services related to energy. He also serves as the Executive Director of the TICA.