GAS TURBINE INLET CHILLING FOR PIPELINE OPERATORS

By Philip Levine and Jeffrey Phillips

Introduction

It is well known that gas turbines produce less power when the inlet air temperature is hotter. This is due primarily to the lower density of hotter air, which means less mass is flowing through the engine.

A popular and cost-effective technique for lowering the inlet air temperature of gas turbines in power generation is evaporative cooling using inlet fogging, in which a fine mist of demineralized water is sprayed into the air. However, many gas turbines that are used in pipeline compression service do not have easy access to demineralized water. In addition, they may be located in regions of high humidity, which limits the amount cooling that can be achieved by evaporation.

The use of mechanical refrigeration systems to produce chilled water for inlet air cooling, is another technique that is gaining favor in gas turbine power generation applications. Unlike evaporative cooling, inlet chilling systems can cool the air to less than 50°F (10°C) regardless of the ambient wet-bulb temperature.

Fern Engineering Inc., a consulting firm specializing in turbomachinery, has recently completed a state-of-the-art review of gas turbine inlet chilling systems for the Electric Power Research Institute (EPRI). As a result of this study, Fern believes that inlet chilling may also be an attractive option for boosting capacity of gas turbines in pipeline compression applications.

Inlet Chilling

A schematic diagram of a typical gas turbine inlet refrigeration, or chilling, system is shown in Figure 1. A packaged chiller system consists of only three major components: 1) chiller skid, 2) inlet cooling coil, and 3) cooling tower. An air-cooled condenser can be substituted for a wet cooling tower in locations where raw water is not available.

The use of packaged systems with an intermediate water cooling loop, as shown in Figure 1, allows the refrigeration components to be fully integrated on a single skid. The chiller skid package contains the evaporator, condenser, compressor, all of the refrigerant, and also includes the chilled water and condenser cooling (cooling tower) pumps and the power and control connections. The packaged systems benefit from high efficiency, lower costs of assembly, improved factory testing and lower installed costs.

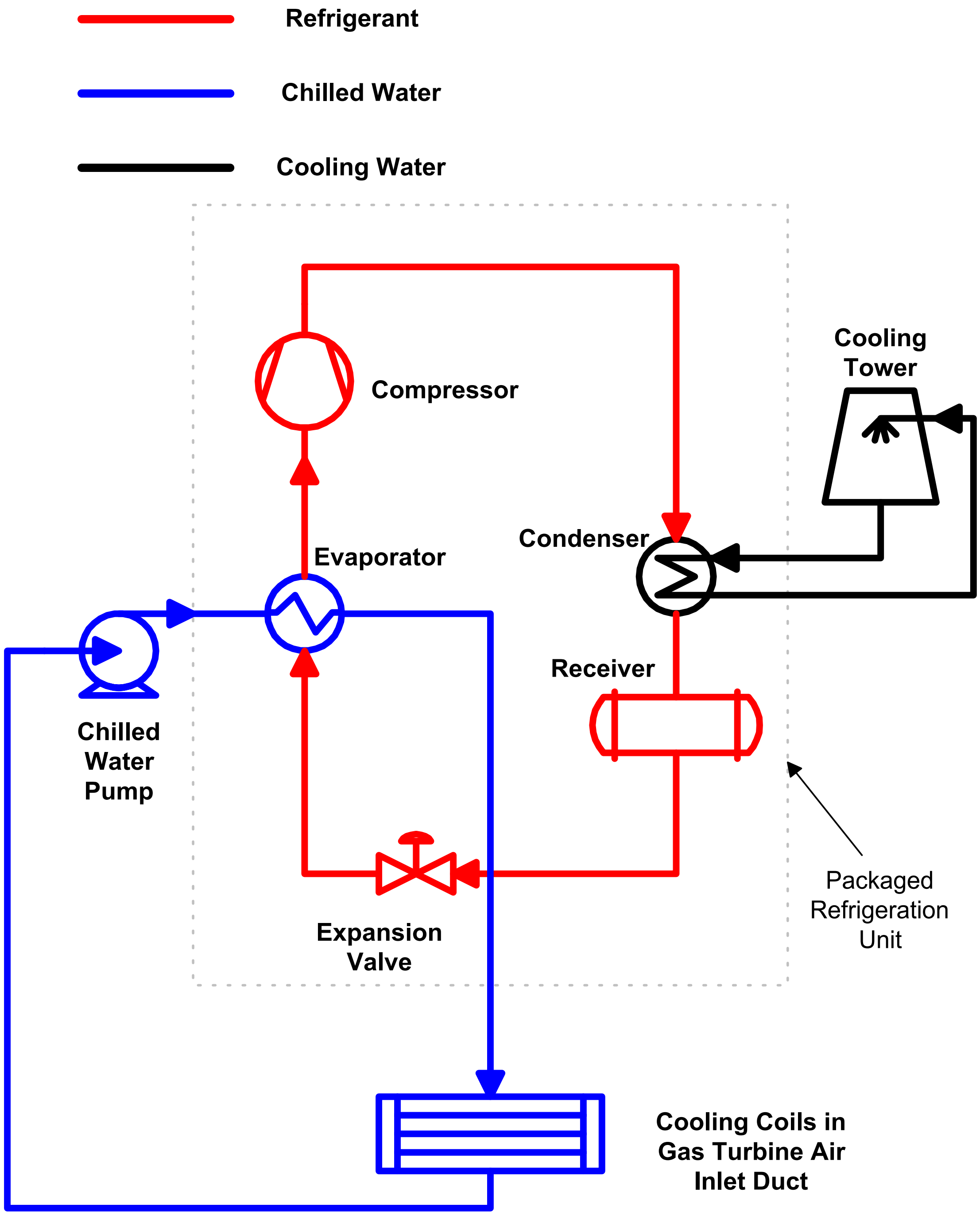

Figure 1 – Schematic diagram of a typical inlet chilling system for a gas turbine.

Two key components of a chiller skid are the compressor and evaporator. These are typically close-coupled devices as shown in Figure 2.

Figure 2 – Carrier Evergreen™ chiller, Model 19XR, high-efficiency, hermetic, centrifugal, liquid chiller, 50/60 Hz, HFC-134a refrigerant.

<u>Safety, Maintenance & Reliability</u>

There are also issues of safety, maintenance, and reliability. New halocarbon refrigerant options have evolved that are safe, efficient, and friendly to the environment. Packaged systems are designed so that all of the refrigerant can be pumped into the evaporator or a separate tank when maintenance work is required. Certified operator and maintenance training are available, because the commercial and industrial refrigeration technology is so well developed. Multi-skid and duplex compressor arrangements result in redundancy and the ability to repair one compressor while still operating the system with the remaining compressors.

A basic limit to an application may be the space needed for the skids and cooling towers. However, packagers have recognized that layout space may be limited and have incorporated design features such as vertical pumps to help reduce the footprint. In fact, the total space required for the skids and the cooling tower may be as low as four tons of refrigeration per square foot (151 kW per square meter). A ton of refrigeration equals 12,000 Btu/hr or 3.516 kW.

<u>Analysis of Cost Effectiveness</u>

Fern has developed design and economic evaluation methods for quickly evaluating the annual benefits of chilling and the cost-effectiveness of this approach. A typical pipeline compressor located at a humid site such as Lake Charles, Louisiana, U.S.A. would benefit from chilling in accordance with the results in Table 1.

Without chilling, the cumulative annual output of the gas turbine during the 7436 hours of operation with ambient temperatures ranging from 50 to 95°F (10 to 35°C) is 71,047,461 hp-hrs (53,001,406 kW-hr). With chilling to 40°F (4.4°C), the power output is a constant 10,900 shp (8131 kW), resulting in 81,178,000 hp-hrs (60,559,000 kW-hr) during 7436 hours of operation for an increase of 10,131,000 hp-hrs (7,558,000 kW-hr). This represents an average increase in output of 1362 hp (1016 kW) or approximately 14% of nameplate capacity.

The capacity factor for the chilling system is the ratio of actual ton-hrs of chilling used divided by the rated tons of the chilling system times 8760 (the number of hours in a year). For the example in Table 1, the capacity factor is 64% and the percentage of time the chilling system is in use is 85%. Cost-effective chilling systems must have a high capacity factor and a high percentage of time in use such as the one in this example.

Table 1 does not tell the full story because the chilling system will require electric power to operate. Typical parasitic loads for a chilling system are about 0.7 kW per ton of refrigeration. The increased electrical power required to run the chilling system is about 15%-20% of the increase in gas turbine shaft power. Consequently, using an electrically driven mechanical chiller system is a more effective use of electric power for boosting compression than using electric motors to drive additional compressors.

Table 1 – Effect of inlet chilling on annual performance of a GE M3912R gas turbine.

Tdb, ambient temp. range	Hours in range annually	Chilling required to reach 40°F	Chilling ton-hrs in Tdb range	GT power w/o chilling	GT power with chilling	GT power increase from chilling	GT power increase from chilling
°F	hrs	tons	ton-hrs	hp	hp	%	hp-hr
90-95	177	877	155,229	8625	10,900	26.5	402,675
85-90	518	863	447,034	8850	10,900	23.3	1,061,900
80-85	982	771	757,122	9084	10,900	20.2	1,783,312
75-80	1569	716	1,123,404	9304	10,900	17.3	2,504,124
70-75	1214	596	723,544	9525	10,900	14.5	1,669,250
65-70	832	483	401,856	9745	10,900	12.0	960,960
60-65	934	381	355,854	9963	10,900	9.5	875,158
55-60	648	227	147,096	10,180	10,900	7.2	466,560
50-55	562	146	82,052	10,400	10,900	5.0	281,000
Totals	7436		4,193,191				10,131,000

<u>Site Evaluations</u>

For pipeline companies interested in exploring the option of inlet chilling further, Fern Engineering can perform site evaluations from preliminary conceptual estimates to complete specifications. Because Fern is not a supplier of inlet chilling systems, the evaluations will not be biased by a desire to sell a system. Please contact:

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