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Engineers Newsletter

Gas Chillers: The Right COP

Coefficient of Performance = Refrigeration Effect/Net Work Input[1]

For years, the Coefficient of Performance (COP) has been used by engineers to help building owners and developers make informed choices regarding cooling equipment for their buildings. One reason COP's are used is to ensure that an "apples to apples" comparison is being made. When electric chillers are being compared, 1 kw always equals 3,413 Btuh. However, with increased demand on utility electrical grids, options that reduce electrical demand during peak daytime hours are being encouraged by utilities. These options include load shifting (thermal storage), cogeneration, gas engine-driven chillers and absorption chillers. Since some of these options use fuels other than electricity, engineers need to ensure that apples are still compared to apples.

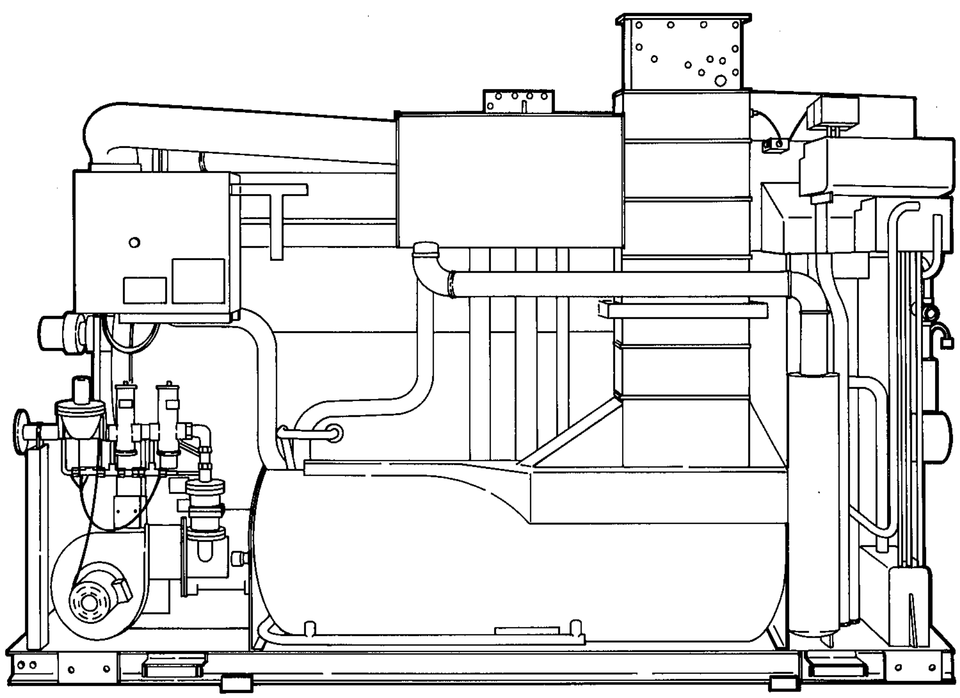
Combustible fuels such as natural gas have two heating values. . . or amounts of heat that can be extracted during combustion. (The combustion of hydrocarbons with oxygen yields carbon dioxide and water.)

"Higher heating value . . . is determined when water vapor in fuel combustion products is condensed and the latent heat of vaporization is included in the fuel's heating value. Conversely, lower heating value. . . is obtained when latent heat of vaporization is not included."[2]

"Methane, the primary constituent of natural gas, has a higher heating value (HHV) of 1,012 Btu/cubic foot and a lower heating value (LHV) of 911 Btu/cubic foot at 60 degrees F and 30 inches of mercury."[3]

In the United States, natural gas utilities measure gas by the cubic foot and use the HHV to calculate heat content. Although sales are made on a per-cubic-foot basis, gas utilities also speak with their customers

[1] ASHRAE 1989 Handbook of Fundamentals, p. 1.4
[2] IBID, p 15.3.
[3] IBID.



Direct-fired absorption chillers: Chilled water with the energy of natural gas.

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about MCF, CCF or therms. Here are some helpful definitions:

BTU	Heat needed to raise or lower the temperature of one pound of water one degree F.
MBH	1,000 Btu per hour (may also be written as 1,000 Btuh).
Therm	100,000 Btu — also about one CCF.
Cubic Foot	A volume of natural gas containing approximately 1,000 Btu.
CCF	100 cubic feet.
MCF	1,000 cubic feet.
Ton	12,000 Btuh.

An example, using the LHV and HHV, will show the difference that can result in COP. Testing has shown that, for a direct-fired absorption chiller, 1171 cubic feet of gas per hour are required to produce 100 tons of cooling. Its fuel consumption (in MBh) can be calculated:

$$\frac{1171\ ft^3}{Hour} \times \frac{1012\ Btu}{ft^3} \times \frac{1\ MBh}{1000\ Btuh} = 1185\ MBh$$

COP (HHV) = Refrigeration Effect/Net Work Input = (100 Tons x 12 MBh/ton)/1185 MBh = 1.013

If, instead, the same calculation is performed using the LHV (911 Btu/ft^3):

COP(LHV) = (100 Tons x 12 MBh/ton)/1077 MBh = 1.125

Thus, simply by picking the LHV for our calculation, the COP is increased by 11 percent. This raises the question of which heating value to use. In most combustion processes, e.g. direct-fired absorption, the water is not condensed during the process. Using the LHV would not account for the vaporization of water, **therefore the higher heating value should be used.**

Chiller	COP	Elec Cons	Elec Demand	Gas Cons	Elec Cons	Elec Demand	Gas	Total
		KWH	KW	Therms	$	$	$	$
RTHA	4.95	203147	156	0	10157	3282	0	13439
DFA-HHV	1.013	0	0	33880	0	0	15246	15246
DFA-LHV	1.125	0	0	30507	0	0	13728	13728

RTHA — A water-cooled chiller with a helical rotary compressor.
DFA-HHV — A direct-fired absorption chiller using the higher heating value.
DFA-LHV — A direct-fired absorption chiller using the lower heating value.

Figure 1

Can this difference in COP's cause the conclusions from an energy analysis to change? Suppose an owner is considering a 120,000 square-foot office building in St. Louis and wants to know if a direct-fired chiller should be considered. Two analyses will be made. The first, a simple example. The second more rigorous and performed using TRACE™ 600.

Simple Example

For the simple example only chiller energy is considered. . . obviously not a rigorous analysis. It is also assumed that the office building is 220 tons at design and has 1,300 equivalent full-load hours. Utility rate assumptions are gas rates of $0.45 per therm, electric consumption rates of $0.05 per kilowatt hour and a demand charge of $3.50 per kw for six months. A water-cooled helical rotary chiller (RTHA, 4.95 COP) is compared to the direct-fired absorption chillers, Figure 1.

It can be seen from this simple analysis that the gas chiller energy costs are quite dependent on which heating value is used. If the compressor energy costs were to be the sole criteria for installing equipment, using the improper LHV could lead to the wrong conclusion.

Rigorous Analysis

TRACE 600 can be used to perform a more rigorous analysis. A template of a mid-rise office building, supplied with the program, is used. Actual utility rates for St. Louis were used for this more rigorous analysis. The RTHA, DFA-HHV and DFA-LHV give yearly utility costs for the building for cooling, lighting and receptacles, Figure 2.

Chiller	Utility Cost $
RTHA	75320
DFA-HHV	73418
DFA-LHV	72479

Figure 2

In the rigorous analysis, the overall utility costs are still close to one another. Yet it can be seen that by using the LHV basis, the direct-fired absorber utility costs are underestimated.

Conclusion

When presented with a COP for a chiller using gas, **always** ask which heating value was used in the COP's calculation. Some gas chiller manufacturers catalog LHV and others catalog HHV. This often leads to confusion. When performing an analysis, know which values have been cataloged. And, if comparing chillers with different fuels, always use the HHV.