OPERATION SYNOPSIS OF GAS-FIRED DOUBLE-EFFECT ABSORPTION CHILLERS

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ABSTRACT

Absorption refrigeration systems are one of the oldest systems available. The fundamentals of absorption refrigeration were formulated about 1777, and the first successful absorption machine was developed in 1850[1]. The first U.S. patent for an absorption refrigeration system was issued in 1860[1]. Absorption systems can use many different heat sources to produce the refrigeration effect: natural gas, steam, solar, and oil.

While absorption systems were popular in the U.S. in the early part of the 20th century, their use declined in the mid twentieth century for several reasons: (1) increased reliability of vapor compression systems, (2) dropping electric prices (in real dollars), and (3) rapidly increasing gas prices.

In recent years, there has been a resurgence of interest in absorption refrigeration and cooling. Natural gas prices have moderated while electric prices continue to rise. The reliability and performance of absorption systems have been substantially improved with new technology from Japan.

This paper summarizes the results of the operation of three absorption systems located in the greater Dallas/Ft. Worth area.

INTRODUCTION

Lone Star Gas Co. has initiated a demonstration program to evaluate the performance and economics of gas-fired, double-effect absorption chillers/heaters for Texas applications. All the systems are lithium bromide/water absorption systems.

The "double-effect" operation refers to a process by which a secondary quantity of refrigerant vapor is generated without an outside energy source. The double-effect chiller uses the latent heat of the original refrigerant vapor. The hot vapor heats the intermediate lithium bromide solution in the low temperature generator, boiling off more refrigerant vapor from the solution. This secondary generation of the refrigeration doubles the efficiency of the double-effect absorption chiller over that of a conventional single-stage unit. Both the cooled primary vapor and the newly formed vapor flow into the condenser section. Then the refrigerant vapor flows into the evaporator section where the water evaporates, absorbing ten times per unit mass than a refrigerant-22 based vapor compression system.

All of the aborption chillers use modulated (or step) burner control which means the burners can be varied from approximately 20% to 100% of full capacity. This type of control allows the chiller to better adapt to the building load in an efficient manner. For instance, when the building load lightens, some building fan coils typically cycle off. This reduces the load on the chiller. The burners in the chiller adjust to this reduced load by reducing their firing rate. The net result is a substantial improvement in performance.

An important aspect of the economics of gas absorption chillers are the fuel costs and maintenance costs. If gas absorption systems are going to penetrate the cooling market in the Southwestern U.S. they will have to compete economically with electric vapor compression systems. Currently, in Texas, electricity costs range from $15 to $23 per million Btus, compared to approximately $4 to $5 per million Btus for natural gas. In addition, commercial and industrial customers must also pay a demand charge on top of the eletrical energy charge. Typically, these range from $5 to $12 per kw per month.

The best vapor compression systems have coefficients of performance (COPs) from 3 to 4. The double-effect gas absorption chiller has a COP of approximately 1.1. Based on fuel prices alone, the absorption chiller would appear to economically compete with the best vapor compression systems. When the electrical demand charge is also included the absorption chiller should have an economic advantage.

Another potential advantage of the absorption chiller is the maintenance. Because absorption systems have fewer moving parts than an electrical vapor

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compression system, they should have lower maintenance costs. The major operating parts on a new gas-fired absorption chiller are the gas burner, a solution pump, electronic pump, and two external water pumps for the cooling tower and chilled water.

FIELD TEST INFORMATION

A total of three chillers were installed and monitored. The first installation is at the Metro Label Corporation in Garland, Texas. A 50 ton absorption chiller was installed in August 1984 that had the characteristics shown in Table 1.

Table 1 - Chiller characteristics for the Metro Label Corporation location.

Rating	Value
Gas Consumption	631 cfh
Electric Consumption	2 kw
Cooling Output	600 kbtu/h
Heating Output	524 kbtu/h
Auxiliaries:	
Cooling Tower	2 kw
Fan Coils (3)	5 kw
Pumps (2)	2 kw
Make-up water	0.5 gpm

The second installation was at the Lone Star Gas Company office in Grand Praire, Texas. The unit was nominally rated for 20 tons of air conditioning and was installed in 1981. The characteristics of the chiller and auxiliary systems are shown in Table 2.

Table 2 - Chiller characteristics for the Lone Star Gas, Grand Praire Location.

Rating	Value
Gas Consumption	253 cfh
Electric Consumption	1 kw
Cooling Output	240 kbtu/h
Heating Output	210 kbtu/h
Auxiliaries:	
Cooling Tower	1.5 kw
Fan Coils (3)	2.5 kw
Pumps (2)	1 kw
Make-up water	0.1 gpm

The third installation is in the Dallas offices of Lone Star Gas Company. The unit is nominally rated for 345 tons of cooling and was installed in late August of 1985. The basic characteristics of the chiller/heater are shown in Table 3.

Table 3 - Chiller characteristics for the Lone Star Gas, Dallas Installation.

Rating	Value
Gas Consumption	4448 cfh
Electric Consumption	9 kw
Cooling Output	4140 kbtu/h
Heating Output	4140 kbtu/h

PERFORMANCE RESULTS

Monthly gas, electrical, and water usage and costs were collected for each site. Figure 1 and 2 show the monthly gas and electrical usage in 1984 for the chiller located at the Metro Label Corporation. Gas usage is highest during the summer months and peaked at 98.5 MCF during August. Annual operational costs from 1984 are summarized in Table 4.

Table 4 - Annual operating usage and costs in 1984 for the Metro Label Corporation Chiller.

Item	Usage		Cost($)
Gas	699.6	MCF	$3498
Electricity	26082	kwh	$1901
Water	259200	gal	$ 372
TOTAL			$5771

For the chiller located in the Lone Star Gas Company building in Grand Prairie only six months of data were available for May through October of 1984. As with the Metro Label location, gas usage was high in August. Table 5 summarizes the six months usage for this facility.

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Table 5 - Operating usage and costs for May through October at the Grand Prairie Lone Star Gas Office.

Item	Usage		Cost($)
Gas	583	MCF	$2015
Electricity	9084	kwh	$ 573
Water	17245	gal	$ 48
TOTAL			$3436

Because the chiller at the Dallas office of Lone Star Gas was not installed until late August of 1985, we have not yet accumulated a complete year's worth of data at the writing of this paper. However, usage data are available from November, 1985 through May, 1986. These data are presented in Table 6.

Table 6 - Operating usage and costs for November, 1985 through May, 1986 at the Dallas Office of the Lone Star Gas Company.

Item	Usage		Cost($)
Gas	15521	MCF	$48060
Electricity	31455	kwh	$ 1547
TOTAL			$49607

COMPARATIVE ECONOMICS

For gas abosrption systems to effectively compete in the air conditioning marketplace, they must, at a minimum, be able to produce the comfort cooling at a cost comparable to or less than that provided by electrical cooling. To set up an experiment to compare the two alternatives, one would want to have two identical buildings side-by-side that were operated in the same manner. One building would have the absorption unit, while the other would have the electical unit. To do this type of experiment requires more resources than were allocated for this demonstration project.

As an alternative to the above experiment, we estimated the electrical cooling performance based on the measured operational time of the gas chillers. The operational time was estimated using the equivalent full-load firing hours(EFLFH) of the chiller. The EFLFH was estimated by dividing the monthly gas usage by the rated capacity of the chiller. The EFLFH is a measure of the time the chiller would be on at full capacity for the particular month. An electrical chiller of the same capacity would have to run the same number of hours to meet the load on the building.

The Metro Label Corporation had the following electrical rates:

Energy: $0.04/kwh
Demand: $6.00/kw, Oct. through March
$7.00/kw, Apr. through Sept.

Assuming electrical direct expansion units are used, the monthly electrical demand and energy costs were calculated and are shown in Table 7. With the electrical system, demand can be a very large fraction of the total bill. The costs for the electrical air conditioning system in this case is about $3600 more to operate than the chiller ($9411 versus $5771).

Table 7 - Estimated electrical demand and energy costs for a DX unit at Metro Label.

	Demand		Energy		
Month	KW	$	kwh	$	Total $
JAN	100	600	7290	292	892
FEB	81	486	12672	507	993
MAR	62	372	6090	244	616
APR	54	378	4212	168	546
MAY	63	441	7560	302	743
JUN	75	525	8550	342	867
JUL	83	581	10541	422	1003
AUG	83	581	12948	518	1098
SEP	63	441	8253	330	771
OCT	50	300	6256	250	550
NOV	57	342	6325	273	615
DEC	81	486	5760	230	716
TOTAL $		5533		3878	9411

Another comparison was made at the Dallas Lone Star Gas office building (Table 8, 9, 10). Recall that total costs for the gas chiller were $49,607. If a single-stage absorption system were used rather than the double-effect absorption chiller, the estimated operating costs for November 1985 through 1986 would be $87,811. This assumes that gas costs are $3.10 per MCF and electrical costs are $0.049 per kwh.

If an electrical centrifugal chiller were used instead, the annual operating costs would be $46097. Thus, the electrical chiller would have comparable operating costs to the double-effect absorption chiller. The Dallas Lone Star Gas office application has a much larger chiller than does either of the other two applications.

CONCLUSIONS

In comparing the operating cost of a gas-fired double-effect absorption chiller to an electric chiller the utility rate is the most critical factor. High rate vs. low rate on either gas or electric utilities make or break a system's operating cost. Also found to be critical, is the amount unit operation time per month. Since the electric demand charge is based on the highest 15-minute period per month, long hours produce a low average cost while short hours result in a high average cost per kilowatt hour. The break even point is about 300 to 350 full load operating hours per month. Below this value, savings accrue to the gas absorption chiller, above this value savings accrue to the electric chiller while constant long loads favor the electric chiller.

REFERENCE

1. Air Conditioning Manual, The Trane Company, LaCrosse, WI. 1965.