Bullard Industrial Technologies, Inc.

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Energy Savings Associated With Absorption Chillers

When replacing an existing chiller or installing an entirely new chiller plant, an often overlooked option is the Absorption design. The refrigeration cycle for conventional vapor (hydrofluorocarbon or perfluorocarbon refrigerant) compression (reciprocating, centrifugal, screw) chillers and an absorption chiller are similar in some respects and significantly different in other respects.

Since the basis for this article is the economics rather than operating principles of absorbers versus mechanical compression chillers the operating principle comparison will be left as such:
Both utilize the evaporation condensation of a refrigerant at different pressures within the machine, but that is where the basic similarities end. The conventional chiller uses a mechanical means to compress and transport the refrigerant vapor to the condenser whereas the absorption chiller depends on a thermo-chemical process (heat in the form of steam, hot water, natural gas, waste heat, etc.) utilizing lithium bromide and water to establish the pressure differential to create the cooling effect.

The advantages of absorption chillers over mechanical compression chillers are:

- No CFCs (hydrofluorocarbon or perfluorocarbon refrigerant) to deal with. Meaning no purchasing of refrigerant, handling of refrigerant, including re-claiming and no refrigerant leakage to deal with, hence no EPA regulations and documents with chain-of-custody requirements to deal with. The absorber's refrigerant is distilled water.
- 1 moving part. The motor driving the solution pump. Hence less overall maintenance and repairs required during the life of the machine. The solution pump is a triple impeller pump with all 3 impellers in the same casing driven by one motor.
- Uses minimal electricity since there the solution pump is the only component requiring power to operate. As an example a 600 ton absorber requires less than 6 kw to operate compared with a 600 ton centrifugal which can require over 600 kw to operate.
- Significantly quiet operation. No hearing protection required.
- Significantly low power requirements (Kilowatt/hours and demand charges) and overall lower operating costs under certain conditions.

The disadvantages of absorption chillers (none of which are major deal-breakers, including the COP) compared with mechanical compression chillers are:

- They are heavier primarily due to the lithium bromide charge. Lithium bromide has a specific gravity of 1.5 – 1.6. Weight is no a significant drawback. Just make sure the floor can support the weight.
- They require more overhead clearance than a typical mechanical compression chiller. This is also usually not a significant issue as there is usually ample overhead clearance in a chiller plant to facilitate using some sort of crane to set the chiller, regardless of the type of chiller.
- Since the interior of an absorption chiller is under vacuum it is essential that the entire vessel be hermetically sealed and any air intrusion be purged from the machine via a vacuum pump. The presence of air can cause interior corrosion of the metal and also cause the lithium bromide solution to solidify. Run the vacuum pump at regular intervals and air intrusion does not become an issue.
- Low coefficient of performance (COP = chiller load/heat load). Absorbers have a COP of @ 1.1 compared with vapor compression chillers at 4-5. The COP is a non-issue with certain sources of heat, which will be explained.

Regardless of the advantages and somewhat insignificant disadvantages of the absorption chiller, the final determining factor affecting the choice between absorption chillers and mechanical compression chillers usually ends up being the operating cost. The COP alone indicates that mechanical compression refrigeration should be the choice, but the COP can be negated, depending on the source of heat used for the absorption process. In the case of an absorber, a heat source is required to produce the low pressure steam or hot water required of the absorption process. The cost of biofuels such as landfill gas, digester gas from municipal wastewater treatment processes and biodiesel are typically cheaper than electricity and waste heat from sources such as incinerators, chemical and petrochemical distillation processes, kilns and gas turbine exhaust are basically free sources of heat from which to generate steam and/or hot water. If any of these heat sources is/are available, absorption chillers definitely need to be considered as a viable option to mechanical compression chillers and as such will be demonstrated later in this article.

Since the above-described sources of heat are pretty much specialty applications and industries, there is the inevitable question of whether or not there are other viable sources of heat readily available that would permit absorption chillers to be considered as an option? Yes. The utilization of exhaust steam from backpressure steam turbine drives. If a facility has steam boilers capable of generating steam at 100 psig or high, on or several steam turbines can be a viable source of the heat need for the absorption chilling process.

When there is sufficient low pressure steam load in a facility, steam turbine drives are an attractive alternative to induction electric motors to drive rotating equipment such as pumps, blowers and fans.

Low pressure steam required for building heat, process work, feedwater deaeration, food preparation, absorption chillers, etc. that is supplied from a pressure reducing valve results in 100% of the steam lost to the low pressure system. Utilizing a backpressure steam turbine to drive a rotating machine and then using the exhaust steam for the low pressure system results in re-use of the majority of the heat in the steam for the low pressure needs and eliminates the cost of running an induction electric motor.

Steam turbines require only 2,545 BTUs per horsepower per hour to drive or spin the turbine. The balance of the heat is used to satisfy the low pressure steam load for the facility. Using the constants 778 foot pounds per BTU and 33,000 foot pounds per minute per horsepower this factor is calculated as follows:

33,000 x 60 minutes = 1,980,000 ft. lbs per hour/778 = 2,544.9871 BTUs per hour.

As an example, consider a relatively small 50 horsepower steam turbine with a water rate of 50 lbs/hp/hr at 150 psi (1,196 btu/lb enthalpy) will have a steam consumption of 50 hp x 50 lb/hp/hr = 2500 lbs/hr.

50 x 2,545 = 127,250 btu/hr to operate the turbine = 127,250/1,196 =
106.4 lbs/hr of steam to spin the turbine. 2,500 – 106.4 = 2,393.6 lbs/hr available as exhaust steam to use for low pressure steam applications.

Using worst/best case scenarios, at $14.00 per thousand pounds of steam and $0.05 /kwh for an electric cost, the following table illustrates the cost savings associate with running 50 hp steam turbine VS a 50 hp electric motor:

106.4 x 24 = 2,553.6 lbs/day consumed by the turbine. 2,553.6/1,000 = 2.5336 x $14.00/thousand lbs = $35.75 per day to spin the turbine.

50 hp motor X .746 kw/hp = 37.3 x 24 = 895.2/.95 kwhrs x $0.05/kwh = $47.11 to run a comparable electric motor.

The above data proves that steam turbine drives are more economical to operate than induction motors providing there is a use for the exhaust steam. To prove the economics of utilizing absorption chillers supplied with steam turbine exhaust we have developed an Excel spreadsheet. Below are screen shots from this spreadsheet using the same low power cost of $0.05 per KWH and extremely high steam cost of $14.00 per 1000 lbs. of steam to illustrate that even under these conditions, absorption chillers are more economical to operate than mechanical vapor compression chillers, when supplied with exhaust steam from one or more steam turbine drives.

600 Ton Chiller

COST COMPARISON: CENTRIFUGAL CHILLER VS ABSORPTION CHILLER

CENTRIFUGAL CHILLER OPERATING COST

600	tonnage
7,632	kwh/day
$0.05	cost/kwh
$381.60	**Operating cost/day**

ABSORBER OPERATING COST

	Live Steam
Absorber	
11,220	mlbs steam/hr
$14.00	cost/mlbs steam
$3,769.92	operating cost/day
$3,769.92	**Total operating cost/day**

	Exhaust Steam			**Steam Turbine Application**	
Steam cost		$14.00	mlbs	270	hp
Enthalpy of supply steam		1,161.8	btu/lb	45	water rate lb/hr/hr
Operating hours		24		12,150	supply stm lb/hr
Turbine efficiency		95	%	591.45	stm to oper lb/hr
Turbine size (Chilled & condensing wtr pumps)		270	hp	11,559	exhaust stm lb/hr
Turbine water rate		45	lb/hp/hr	13,428,720	exhaust BTU
Supply steam	11400	12,150	lb/hr	$209.19	cost/day
Steam required to operate the turbine		591	lb/hr	$241.70	Comparable motor drive operating cost/day
Net exhaust steam available		11,559	lb/hr		
Exhaust steam available		13,407,915	btu/hr		
Turbine operating cost		$209.19	per day		
Solution pump size		25	hp		
Solution pump operating cost		$22.38	per day		
Absorber operating cost on exhaust steam		**$231.57**	per day		

150 Ton Chiller

COST COMPARISON: CENTRIFUGAL CHILLER VS ABSORPTION CHILLER

CENTRIFUGAL CHILLER OPERATING COST

150	tonnage
1,908	kwh/day
$0.05	cost/kwh
$95.40	**Operating cost/day**

ABSORBER OPERATING COST

	Live Steam
Absorber	
2,805	mlbs steam/hr
$14.00	cost/mlbs steam
$942.48	operating cost/day
$942.48	**Total operating cost/day**

	Exhaust Steam			**Steam Turbine Application**	
Steam cost		$14.00	mlbs	65	hp
Enthalpy of supply steam		1,161.8	btu/lb	45	water rate lb/hr/hr
Operating hours		24		2,925	supply stm lb/hr
Turbine efficiency		95	%	142.39	stm to oper lb/hr
Turbine size (Chilled & condensing wtr pumps)		65	hp	2,783	exhaust stm lb/hr
Turbine water rate		45	lb/hp/hr	3,232,840	exhaust BTU
Supply steam	2850	2,925	lb/hr	$50.36	cost/day
Steam required to operate the turbine		142	lb/hr	$58.19	Comparable motor drive
Net exhaust steam available		2,783	lb/hr		operating cost/day
Exhaust steam available		3,227,831	btu/hr		
Turbine operating cost		$50.36	per day		
Solution pump size		10	hp		
Solution pump operating cost		$8.95	per day		
Absorber operating cost on exhaust steam		**$59.31**	per day		

Ideally, the best application for any conversion to a steam turbine drive is a piece of equipment that is constantly in operation. Some examples are boiler feedwater pumps, condensate pumps, boiler forced draft fans, booster pumps, etc. The key to absorption chiller operating cost effectiveness is to assure that the total number of steam turbines in operation at any given time are capable of supplying 100% of the steam needed for the absorption chillers on line. Keep in mind that the steam turbines are saving money even when the absorbers are not running, provided there is a demand for their exhaust steam.

The low COP of absorption chillers can be negated when biofuels, waste heat from chemical and distillation processes and the use of steam turbine exhaust provide the source of heat for low pressure steam or hot water, making absorption chillers the all-around economic choice when installing new chillers.

If you would like a copy of the spreadsheet from which these screen shots were derived please email me a rick@bullardindustrialtech.com.

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