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Energy Profiles of Steam vs Adiabatic Humidification Systems

TL-201, September 12, 2008

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Forward

Humidification systems are used to increase the moisture content of environmental air for office buildings, manufacturing facilities, clean rooms, laboratories and hospitals. The decision to humidify is driven by the need to control the environment for manufacturing process stabilization, e.g. paper in the printing process, for the comfort and well being of the inhabitants in office building, or to satisfy industry code requirements. Most commercial office buildings and institutional facilities, as well as many manufacturing facilities, require cooling year round because of the heat loads of lighting and office equipment or machinery and processes operating in industrial environments. The constant heat load makes it beneficial to use economizer cycles on the HVAC units. The energy savings potential when operating HVAC systems on economizer cycles is tremendous. Economizer cycles have an effect on the humidification loads which needs to be taken into account when designing the system.

System Operation

Steam Humidification Systems

Steam humidification systems have been in service for many years. The steam can be generated by central steam plants, localized steam boilers, gas to steam units, or electric boilers. The steam humidification process uses the energy in the steam to increase the rate of vaporization and absorption of the water particles. As the steam is introduced into the air, the heat of vaporization is given up by the steam, and the steam turns into fine water droplets. The heat released increases the air temperature which accelerates the absorption process. When absorption is complete, the energy content of the air has increased by the amount of moisture added and the temperature is higher due to the differences in the enthalpy of the mixed air and the hot water particles(212˚F). This increase in the air temperature is automatically offset by the economizer controls on the HVAC system. The higher mixed air temperature causes the economizer cycle to increase the amount of outside air to bring the mixed air temperature back down to set point. This increase in outside air becomes added load for the humidification system. With direct injection in-space steam humidification systems, the localized heating of the air from the steam causes the heated, moisture laden air to rise towards the ceiling. The hotter air displaces cooler drier air near the ceiling, which results in very moist warm air collecting at the ceiling. Long term exposure to this humidified air can cause roof and structure damage.

Adiabatic Humidification Systems

The adiabatic humidification process relies on the heat in the air to provide the energy for vaporization and absorption. In HVAC applications, the moisture is injected into the moving air stream and mixes with the air. The absorption efficiency is dependent on the humidification chamber configuration, air temperature, RH and velocity of the air. Absorption efficiencies of 70-80% are fairly typical and the use of a droplet filter down stream of the humidifier to remove any un-absorbed water particles is recommended. The droplet filter can also act as a secondary means of evaporation by exposing the collected water to the moving air stream. The heat used to absorb the moisture cools the air. This cooling process on an economizer HVAC system causes the economizer to close the outside air dampers enough to offset the cooling effect. This results in less outside air to humidify and a lower load for the humidification system. On in-space applications, the moisture is injected near the ceiling, the humidified air is cooler than the surrounding air and falls towards the floor. The air is replaced with hotter dryer air from below. The natural circulation resulting from adiabatic humidification increases the efficiency of the plant heating system and provides free cooling for the workers.   Because the cooler air falls towards the floor, the air near the ceiling does not become saturated or cause the roofing or structural components to degrade.

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Energy Balance

Economizer Systems

It is easier to see the differences in the energy requirements of steam and adiabatic if we use an example for a system in the Cleveland area, as shown on the “Humidification Work Sheet” , **Figure 1.0**.

In the system shown, the design conditions are 72 FDB at 40% RH in the conditioned space. The bin temperatures, hours and grains are compiled from ASHRAE and government data bases. The full load hours are calculated by determining the largest load and using that as a divisor on all of the other bins loads times the hours at each bin. The offset in outside air required by an economizer system on an adiabatic humidification system is a well documented effect. The reduced load shown on the adiabatic system is the result of the cooling effect reducing the amount of outside air needed to match the discharge set point.

At each Bin Temperature, the mixing ratio of the outside air and the return air to maintain the mixed air discharge temperature is calculated. The Humidity load is then calculated for this condition and the temperature drop from the adiabatic moisture absorption is also calculated. The temperature drop, called DeltaT in the program, is then introduced into the mixing ratio formula and a new mixed air ratio is determined, and the new humidity load and DeltaT are calculated. This process continues until the process has come to equilibrium for each Bin temperature. This is obviously a laborious procedure and is one that lends itself to computer modeling. In the past it was not commonly known that the “economizer knee” in the humidity load graph existed, and the humidity load was typically calculated based on the lowest ambient temperature. With the new computer modeling developed over the last few years, this erroneous methodology has given way to more accurate calculations of the actual process. The outside air and humidity load graphs shown in **Figure 2.0** are the true curves of what is happening in the air handler and conditioned space. Installations throughout the U.S. have proven the concept of adiabatic load reduction on economizer air handler systems.

On systems installed directly in a manufacturing plant, the economizer effect is lessened and typically not taken into account when sizing the humidifier system. In a manufacturing environment, any free cooling that is provided by the adiabatic system is quickly used up by the excess heat load in the space. This cooling is welcomed by the plant personnel, but has little effect on the actual humidification load.

The Energy Analysis of the sample systems is shown on **Figures 3.1 & 3.2**. The Summary sheet, **Figure 3.2**, shows the energy profiles for each technology. **Figure 4.0** gives the 10 Year cost of ownership for each technology.

An example of the typical energy required for each technology is shown in the chart below.

Load Description	Electric Steam, kWh	Gas Steam MBH	Air Water kWh	Ultrasonic kWh	High Pressure kWh
System Load	150 #/hr	150 #/hr	100 #/hr	100 #/hr	100 #/hr
Connected Load kW or MBH	42.6	182	4.1	2.6	0.2
Humidifier Consumption	175,043	747,838	17,446	11,063	851
Energy To Raise Water To 212	31,043	106,012			
Distribution Loses @ 15%	30,998	105,858			
Flushing Loses @ 15%	4,656	15,902			
Water Treatment Power, kwh			2,000	2,000	2,000
Total Energy Consumption	**241,741**	**975,610**	**19,446**	**13,063**	**2,851**
Total Energy Cost	**$15,713**	**$8,780**	**$1,263**	**$850**	**$185**
First Cost	**40%**	**80%**	**45%**	**100%**	**70%**
Energy Ratio	**100%**	**56%**	**8%**	**5%**	**< 1%**

Conclusion

Control System Advances

With the advances in digital control system capabilities along with improved processing power of the controllers, the economizer cycles on modern air handlers can handle many different operating conditions while still maintaining the building environment to the desired set points. For the economizer cycle to detect the adiabatic cooling effect and compensate for it properly, the mixed air/discharge sensor must be located downstream of the humidification section and the supply fan. As the supply air temperature starts to drop from the adiabatic moisture absorption, the temperature sensor will detect this change and drive the economizer O.A. dampers closed a small amount. In addition to temperature control of the economizer cycle, many systems are now using enthalpy control to measure the temperature and humidity of the outside air introduced into the building environment, producing a total energy picture of the supply air system.

Humidification System Technologies

With the experience gained from many HVAC installations using adiabatic technology, it is now easier to design and install adiabatic humidification systems with confidence. Many HVAC and Industrial installations with steam humidification systems are being converted to adiabatic systems with large reductions in energy and maintenance costs.

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HUMIDIFICATION WORK SHEET

By Edge Mechanical 09-20-2008

Company : General Hospital
Contact : Chief Engineer
Project: Typical AHU

Prepared By : Larry Cluchey, PE
Project Location : Cleveland, OH

Base Conditions

Design Temperature : 72 F
Design Humidity : 40 %RH
Hours of Operation : 168 Hrs/Week

Ambient Temperature : 5 F
Bin Location : Cleveland, OH

Mechanical System - AHU-1

Supply CFM : 30,000
Economizer : Y
Min OA Set Point : 20%

Ducted Return
Mixed Air Temp : 55 F
Maximum OA : 100%

System is being controlled by Min O.A. set point, not mixed air temperature.

Humidification Requirements	Adiabatic	Steam
Required Capacity :	162.5 #/hr	238.6 #/hr
Full Load Humidifier Hours/Year :	4,221	4,050

Economizer Operation

Ambient Temp	Design RH	Bin Hours	Ambient Gr	Adiabatic O.A.	Adiabatic #/hr	Adiabatic Delta T	Steam O.A.	Steam #/hr
5	40.	41	5.1	7,612	157.8	-5.3*	7,612	200.2
10	40.	47	4.8	8,226	158.9	-5.3*	8,226	217.8
15	40.	127	7.7	8,947	154.1	-	8,947	220.8
20	40.	263	10.7	9,808	155.5	-	9,808	223.8
25	40.	349	13.1	10,851	159.2	-	10,851	231.4
30	40.	518	15.8	12,143	162.5	-	12,143	238.6
35	40.	800	21.4	13,784	155.1	-	13,784	222.9
40	40.	920	24.6	15,938	156.6	-	15,938	226.0
45	40.	499	30.0	18,889	146.0	-	18,889	204.5
50	40.	540	34.8	23,182	134.1	-	23,182	181.9
55	40.	705	42.1	30,000	83.1	-	30,000	99.3
60	40.	727	49.9	6,000	-	-	6,000	-
65	40.	936	62.3	6,000	-	-	6,000	-
70	40.	682	74.3	6,000	-	-	6,000	-
75	40.	707	79.3	6,000	-	-	6,000	-
80	40.	491	83.9	6,000	-	-	6,000	-
85	40.	324	88.6	6,000	-	-	6,000	-
90	40.	62	96.3	6,000	-	-	6,000	-
95	40.	22	96.2	6,000	-	-	6,000	-

Figure 1.0

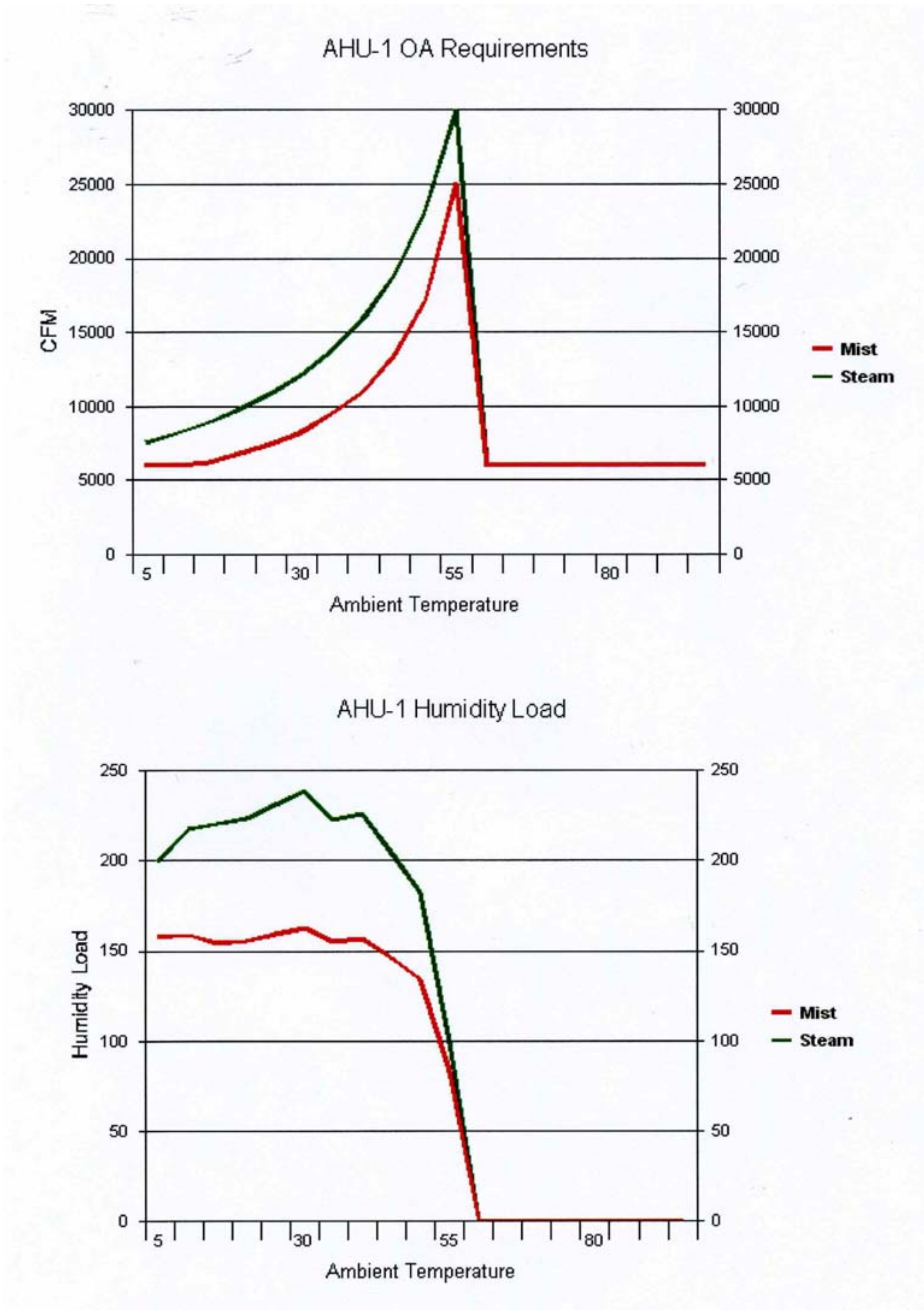
AHU-1 OA Requirements
30000
25000
20000
15000
10000
5000
0
CFM
5
30
55
80
Ambient Temperature
Mist
Steam
AHU-1 Humidity Load
250
200
150
100
50
0
Humidity Load
5
30
55
80
Ambient Temperature
Mist
Steam

Figure 2.0

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Humidification System Energy Analysis

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Company: General Hospital
Contact: Chief Engineer

Prepared By: Larry Cluchey, PE
Project Location: Cleveland, OH

Project: Typical AHU

<u>Steam to Steam System</u>

System ID	AHU-1
Calc FL Hours/Yr	4,061
Equip Manuf	Dri-Steem
Model	DS-300
Quantity	1
Unit Capacity, #/hr	250
System Capacity, #/hr	250.0
Energy Demand, MBH	354.0
Equip Cost, $	$
Install Cost, $	$
Maintenance/Yr, $	$1,000

Total Equipment Cost:	$
Total Install Cost:	$
Total Maintenance Cost:	$1,000
Total System Capacity, #/hr:	250.0
Total Energy Demand:	354.0

<u>Mee Fog System</u>

System ID	AHU-1
Calc FL Hours/Yr	3,078
Equip Manuf	Mee Fog
Model	FM-100
Quantity	1
Unit Capacity, #/hr	260
System Capacity, #/hr	260.0
Energy Demand, kW	.5
Equip Cost, $	$20,000
Water Treat Cost, $	$
Install Cost, $	$5,000
Maintenance/Yr, $	$100

Total Equipment Cost:	$20,000
Total Install Cost:	$5,000
Total Maintenance Cost:	$100
Total System Capacity, #/hr:	260.0
Total Energy Demand:	.5

<u>Energy Prices</u>

Electric Rate:	$.065/kWh
Gas Rate:	$.90/ccf
Steam Rate:	$14.00/1000#

Figure 3.1

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Humidification System Energy Analysis

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Project: Typical AHU

Summary Data

	Steam to Steam System	Mee Fog System
Connected Load	354 MBH	.5 kW
Humidifier Consumption	1,437,594 MBH	1,539 kWh
Flushing Energy Lost @ 15%	26,193 MBH	
Distribution Loses, MBH/yr @ 15%	174,369 MBH	
Make-Up Heat, MBH/yr		17,422 MBH
Total Energy Consumption	1,638,157 MBH/yr	1,539 kWh/yr
Make Up Energy Cost, $/Yr		$157
Droplet Filter Loses, kWh		2,726.7
Total Energy Cost	$14,743	$434
Total Installed Cost	$	$25,000
Total Annual Maintenance Cost	$1,000	$100
Annual Water Useage, Gal	160,991	95,957

Compare Mee Fog System vs Steam to Steam System

Annual Energy Savings	$14,309
Annual Maintenance Savings	$900
Total Annual Cost Savings	$15,209
Pay Back in Months	19.7

Figure 3.2

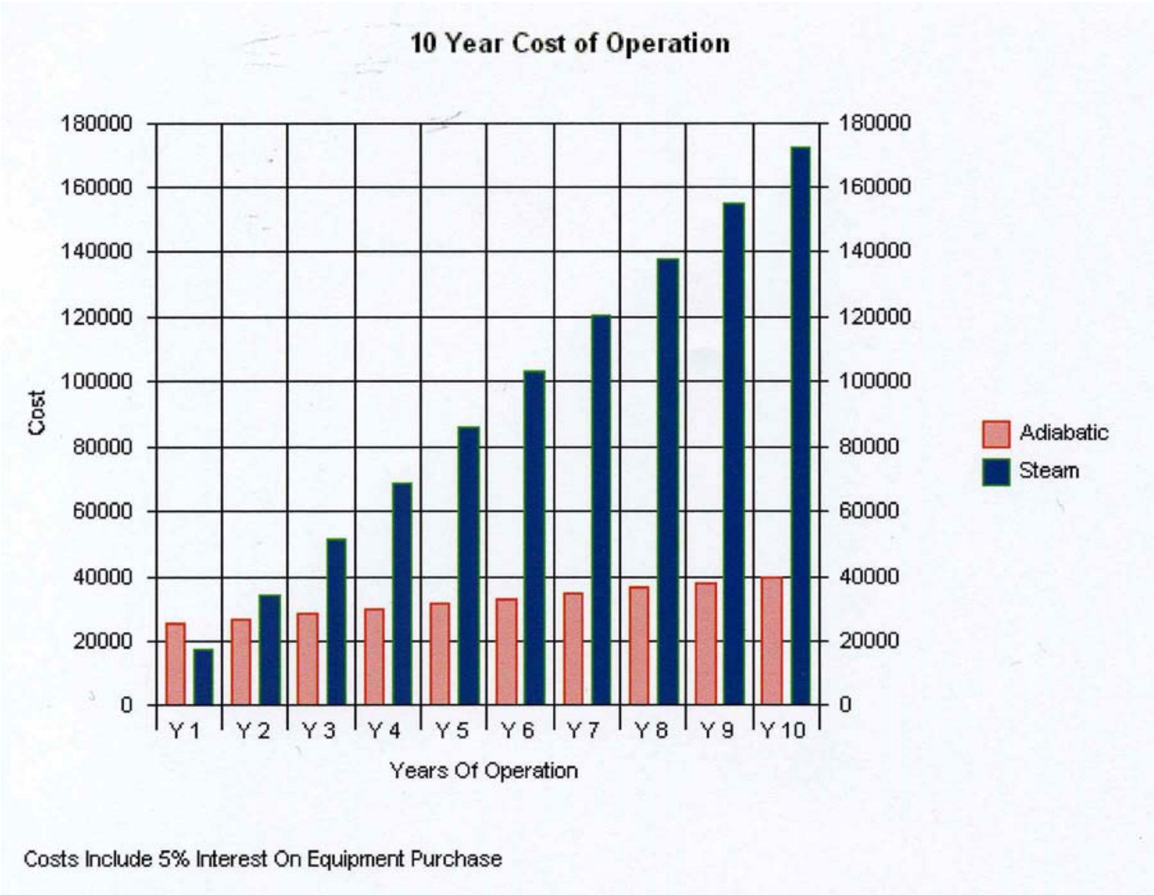
10 Year Cost of Operation
Cost
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Y 1
Y 2
Y 3
Y 4
Y 5
Y 6
Y 7
Y 8
Y 9
Y 10
Years Of Operation
Adiabatic
Steam
Costs Include 5% Interest On Equipment Purchase

Figure 4.0