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THE UTILIZATION OF DIRECT & INDIRECT EVAPORATIVE COOLING FOR THE HIGH WET-BULB CLIMATES

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Evaporative cooling has been in existence since the pharaohs in Egypt had slaves fanning the air towards them over containers of water. In the drier regions of the United States, like the Southwest, evaporative cooling is the common mode for comfort cooling in all types of facilities. Saving 60-90% electrical energy is quite a normal result of this technology. However, in the higher humidity areas east of the Rockies, it was not considered efficient enough to utilize. Developments in the past three years have improved the efficiencies of evaporative technology by close to 50%. Therefore, all climates can now use this technology to save valuable energy dollars and attain a condition only previously associated with mechanical cooling.

INTRODUCTION

The development of the fluted cellulose and fiberglass media vs the old aspen and seltzer pads have enhanced direct evaporative efficiencies by better than 35%.

Being able to impregnate a water-holding material of fiberglass and mylar on an aluminum heat exchanger plate has increased the efficiencies of indirect cooling by 45%. Two years ago a chemical treatment applied to a polymer plate provided the same type of substrate on a plastic heat exchanger plate increasing the efficiencies by 40%.

By combining the two improvements of close to 50% in evaporative technology, one can achieve comfort conditions in any facility in any geography throughout North America.

Slowly, an education of the engineers east of the Rockies has been occurring and we are now seeing implementation of this technology in these higher humidity areas. Several companies have already received utility savings of over $400,000 annually by implementation of this advanced technology.

DIRECT EVAPORATIVE COOLING

Evaporative cooling operates on the difference between the dry and the wet bulb. Typically, a differential of 10-15°F will occur during the early morning, escalating to a 35-50°F difference by the late afternoon hours, receding to the 10-15°F differential by midnight. Prior technology's utilization of aspen pads, straw, lined metal, dipping pads, seltzer pads, and other types could bring the dry bulb closer to the wet bulb by only a maximum of 55%.

In the Montreal area where the ASHRAE summer design is 83/73, the best attainment on a design day previously was 78-79°F. In order to keep people comfortable, a wind tunnel environment would be required. However, the development of the fluted media enhanced the efficiency to 90% or for practical considerations, within 1°F of the wet bulb. Going back to the Montreal example again, now one can attain a maximum of 74°F on the worst condition of the summer. In fact, better than 90% of the summer direct evaporative cooling will provide less than 70°F air. A gain of better than 20% in a given technology is considered major. However, here we have a gain that exceeds 35%.

Direct evaporative cooling trades the latent heat of vaporization for sensible cooling. This is accomplished by recirculating water over this revolutionary media with a fractional horsepower submersible pump, while outside air blows through this media with a low pressure drop resistance of less than 0.25".

Psychrometries show a constant enthalpy adiabatic process that goes straight up the wet-bulb line. Yet this now effective comfort cooling is accomplished for 90% less energy compared to mechanical cooling.

Several other developments enhanced the life expectancy of the media, which should last a minimum of 10-12 years. The first and second of these is the use of an orifice header spraying upward, deflected by a clamshell envelope, forming a lake over an impregnated media distribution pad. The impregnated media distribution pad protects the media from liquid abrasion and erosion, along with providing an even liquid flow through 100% of the media. The use of the upward liquid spray prevents plugging from the heavier solids which will settle on the bottom of the header. Twice a year these can be easily removed with a tube brush.

It is very critical to have a constant liquid flow throughout the complete bed and not to have any liquid irrigation rate deviation. The use of the conventional spray nozzles produce a fluctuating irrigation rate. Since the evaporation of water creates solids, these solids can either plug these nozzles, or by a sandblasting effect, enlarge the orifices. Therefore, units using spray nozzles should have these headers replaced quarterly-biannually, depending upon the hardness of the water being utilized. Obviously, this fluctuation does not occur with the upward header-clamshell design.

The third and most critical item is the bleed. What is the bleed? Again we repeat that the evaporation of water increases the solids concentration, so if one does not compensate for this, eventually one will be recirculating a slurry. By blowing down and making up a proper amount of water to compensate for the extra solids being formed, the liquid being recirculated stays a liquid. Normally one will blow down about 3% of the recirculation rate if relatively clean water is being used, like city water. With well water or real brackish varieties, one will blow down about 6% of the liquid recirculating rate. The former practice for controlling the bleed is to drain the appropriate amount from the line returning the liquid to the sump to a storm drain. A needle valve was used to throttle the proper amount. Unfortunately, solids would get behind the needle, restricting the flow and eventually the bleed ceases. By using an air pressure flagellated flow meter, where no control parts are contacted by the solids, the bleed stays at the proper rate and does not fluctuate. This type of bleed regulator costs three-five times more than an inexpensive needle valve, but is a major key in design.

Other items, like using stainless steel or fiberglass materials for construction of the sump and the housing, are important but not as critical as the three aforementioned entities.

In most cases, a pint of blèach every 30 days will suffice for water treatment. In large installations a biocide and descaler injected via a timer will frequently be incorporated.

INDIRECT EVAPORATIVE COOLING

An indirect evaporative cooling cycle can be accomplished by evaporating water inside an air-to-air heat exchanger, thus cooling the exchanger plate surfaces. Supply air passing through the opposite passages of the heat exchanger can then be cooled without the addition of moisture. Indirect evaporative cooling reduces the enthalpy level of the air and lowers the wet-bulb temperature. This is the quintessential difference between the indirect and direct evaporative cooling cycles. On the psychrometric chart the indirect process is a horizontal line running from right to left, or the same as a mechanical compressor.

The only way to accomplish a net change in the energy level of the air is to incorporate a heat sink that continuously carries the heat away. On a mechanical system this is accomplished with the condenser. On indirect evaporative coolers, an outdoor airstream, called the scavenger airstream, passes through the wet side of the heat exchanger, picks up the heat, and then discharges it to atmosphere.

The most common method of achieving indirect cooling has been through the use of a shell and tube heat exchanger, usually constructed of PVC or mylar tubes with wettable socks to retain water. This is the cheapest type of heat exchanger to fabricate, but has the drawback of low operating efficiencies. In addition, proper wetting of the tubes is a major practical problem that has not been solved. If the heat exchanger pipes are artificially wetted by spraying with a water hose so that all surfaces are thoroughly wetted, efficiencies of about 60% are possible. Many manufacturers actually use this method to rate the efficiency of their equipment. But, field studies show considerably less than half this efficiency is actually achieved due to the lack of a distribution system that can keep the tubes thoroughly wetted.

Recently a high efficiency flat plate heat exchanger was developed with a fiberglass and mylar film mat bonded to the plate surfaces. Flat plate heat exchangers are more expensive, but have triple the surface area of the shell and tube type, resulting in considerably higher efficiencies. In addition, the fiberglass mat acts not only as a wettable sponge, but also as a paper towel-like wicking surface that rapidly spreads the water out across the plates, ensuring thorough coverage. This is crucial since only the wetted surfaces contribute to the cooling process. At the University of Texas in Austin, there is a test facility maintained specifically for testing evaporative cooling equipment. Tests performed at the facility verified efficiencies in excess of 80%, far above the former state-of-the-art shell and tube exchangers.

An even more recent development, which achieved nearly the same high efficiencies but with greatly reduced manufacturing costs, is a chemically-treated polymer plate heat exchanger certified at 75% wet efficiency.

The psychrometric chart shows this process to be identical to mechanical cooling, wholly sensible. The wet bulb is depressed substantially. Using our Montreal design conditions of 83/73, one achieves an indirect leaving condition of 76/70.

On applications with large amounts of outdoor air, but where the performance of an indirect/direct system falls short of the minimum required space humidity levels, the indirect cooler can be made to operate in conjunction with a second-stage mechanical cooling. Frequently the indirect cooler can reduce the size of the mechanical plant by better than half, but the chief benefit is the continuous savings in operating costs.

What makes this combination especially appealing is that mechanical air conditioners, running with all or very high amounts of outdoor air, are temperamental and have unusually high failure rates since they are not really designed for the extreme range and volatility of outdoor air. With the use of an indirect precooler, equipment life and maintenance operations are increased substantially.

Retrofit applications for indirect precoolers have become popular where the required ventilation requirements have been increased. Those areas of the country responding to the recent tripling of ASHRAE recommended ventilation levels are requiring existing facilities to conform by updating their equipment. Using indirect evaporative coolers to precool the increased outdoor air is often less expensive than upgrading the mechanical system and, of course, will operate at lower energy consumption rates.

When employing an indirect/mechanical system, use the building exhaust to scavenger air, if this is possible. System performance can sometimes be doubled due to the lower wet-bulb temperature of the building air verses the outdoor air.

In Chicago, we have seen compressor operating hours of 2480 reduced to less than 35 with the installation of an indirect module before the mechanical unit. Now instead of a ten-year life, we project a 30-year life.

A project at a hospital in Toronto involved the precooling of 22 existing air handlers currently using chilled water for cooling. Table 2 shows that 290 tons of cooling was used to process the outside air. The operating economics shown on Table 3 reflect paybacks from the utility savings to be less than a year in all cases.

INDIRECT/DIRECT EVAPORATIVE COOLING

The combination of the two improved technologies become applicable for all comfort cooling applications, thereby allowing all geographies to save substantial utility operating bills. By using the indirect to knock the wet bulb down and putting a direct section after it, produces a discharge within 1°F of the new wet bulb. One can easily save 40-90% on the normal utility bills.

Using the Montreal design of 83/73, going through the indirect produces a discharge of 76/70 and finally through the direct section resulting in a final discharge of 71/70. The latter depicts the worst condition, which possibly occurs 20 hours/summer. All of the other 1843 cooling hours will be well below a 70°F discharge.

Several design tricks allow one to achieve even better results:
Blow-Through Supply Blower. This inflates the incoming dry bulb and also prevents heat from being added to the air previously cooled. This results in a lower discharge of 1.5°F in an average application.

APPLICATION STRATEGIES

Facilities that require large amounts of outdoor air to make up for ventilation or process exhaust systems, represents the choicest application for evaporative cooling. This is due to the unique nature of the psychrometric process that allows evaporative cooling systems to use outdoor air without incurring an energy penalty. What this means is that when calculating the cooling load, both the latent and sensible components of the outdoor air load can be ignored.

Additionally, internal latent loads can be ignored since these loads are exhausted from the space rather than returned to cooling coils for removal at an energy penalty.

Also, discharging supply air down low and stratifying hot air at the ceilings, allows exhaust fans to remove most of the roof load and part of the wall load before it can reach the space. Such a strategy can reduce the effective building load in half.

The bottom line is that although an evaporative cooler operating in high wet bulb area does not produce air as cold as a mechanical system, intelligently devised strategies can effectively reduce the real load that must be met to as little as 1/3 the load that a mechanical system must confront.

An additional strategy locates discharge air diffusers to cause air movement past building occupants. This allows higher space temperatures to be maintained with the same level of comfort.

INDIRECT/DIRECT WITH HEAT RECOVERY

In areas north of the Mason-Dixon line, a second payback in the winter can be obtained by draining the water from the indirect section and now using it as a heat recovery module. In addition to the water shutoff, the resetting of several dampers is all that is required to accomplish this. The potential of employee comfort all year-round for minimal energy usage is readily accomplished.

Amp Corporation, the largest gold plater in the world, has initiated this process on 14 of their plants. Since the winter operation is processing corrosive exhausts, an extra blower is used to throw these exhausts away during the summer operation. Their utility saving payback was 18 months on the cooling payback and 14 months on the heat recovery benefit, resulting a net payback annually of 8 months.

INDIRECT/DIRECT WITH WINTER HUMIDITY CONTROL

It is quite easy to humidify the winter air with this system. Generally it is a no-cost operation. Recovered heat, heated outside air, or building return can be brought through the direct section producing exact humidity control. The added benefit, in addition to utility savings, is 99% cleaner air. The direct evaporative unit will remove tobacco smoke, urea, formaldehyde, and other known indoor contaminants.

The commonly used steam method puts water treatment chemicals into the atmosphere and, of course, does no air cleaning. Is it any wonder that direct evaporative is becoming the state-of-the-art for humidifying hospital operating rooms? A printout for the Montreal area shows a utility saving of $3,656 for a 10,000 CFM air handler. The United States telephone companies have adopted the "Climate Processor" as the standard air handler to utilize.

In 1991, a technical presentation on the Climate Processor was presented at the National ASHRAE Meeting in New York City. It won first place for ASHRAE technology in 1991. This presentation is available upon request.

Some printouts for the Montreal climate show that using direct evaporative for humidity control vs steam will save over $3500/year on a 10,000 CFM operation. These printouts mention certain terms which may require some explanation.

The column titled "Adiabatic Outdoor Air" refers to the amount of outdoor air that the economizer would use when operating in conjunction with the adiabatic saturator model. The column "Sensible Outdoor Air" is the amount of outdoor air that a normal economizer would draw without the Adiabatic Saturator in the loop. In all cases, the Adiabatic Outdoor Air is less than the "Sensible Outdoor Air", since the process works by using a warmer mixed air temperature than internal building conditions would normally call for. As the supply air passes through the Adiabatic Saturator it will be cooled back down to the desired temperature so space conditions can be properly met. In this manner, the warm return air is used as the heat source that supplies the energy of vaporization for free, in lieu of a typical steam system where a boiler supplies the energy necessary to put moisture into the air.

The column "Adiabatic Energy Required" is the total amount of heat of vaporization that can be supplied by the adiabatic saturator process under a given set of outdoor conditions. The column "Sensible Energy Required" is the total amount of energy required to put the necessary moisture into supply air in order to meet the building RH requirements. The Adiabatic Energy Required is the energy expenditure of the Climate Processor. The first column minus the last is the savings accrued by using the basic strategy underlying the Climate Processor design.

BROWN PRINTING

In the Spring of 1991, 1800 tons of mechanical cooling at Brown Printing in Waseca, Minnesota, were replaced with indirect/direct evaporative cooling with winter humidity control. A preliminary paper on this application was presented at the 1992 National ASHRAE Meeting in Anaheim, California. This paper also is available upon request. A final paper will be presented at the 1993 National ASHRAE Meeting in Chicago. This application is favored to win the 1993 ASHRAE energy award.

Even with 1800 mechanical tons, Brown experienced indoor temperatures of close to 120°F during their severe outdoor conditions! By the replacement with indirect/-direct evaporative cooling Brown now experiences an indoor condition of 85°F for 5% of the summer and well below 80° for the remainder. Waseca has an ASHRAE design of 98/76. The highest discharge to date from these four 120,000 CFM units has been 67°F.

A projection of $300,000 first summer utility savings was made. This projection was found to be in error. The first summer resulted in $426,000 of utility savings. This doe not take into account the $228,975 saving in winter humidification costs that resulted versus their old steam systems, or the cleaner air inside the plant.

SUMMARY

The technology of indirect/direct evaporative cooling can save substantial operating dollars in all climates now, due to an improvement of close to 50% better efficiency in the last three years. Unfortunately, few people east of the Rockies know this. It is a matter of educating owners and engineers that this process can provide comfortable conditions in their buildings and applications. In addition to no CFCs, valuable utility operating dollars can now be saved by using this improved technology.

CLIMATE PROCESSOR ENERGY SAVINGS

SYSTEM CFM	10,000
MINIMUM OUTSIDE AIR CFM	2,000
SUPPLY AIR TEMP	55
RETURN AIR TEMP	78
SPACE HUMIDITY RATIO (GR/LB)@	72
ECONOMIZER ON POINT	95
HUMIDITY RESET SCHEDULE (DEGR	3

MAXIMUM 50% AT 60 DEGREES FAHRENHEIT
MINIMUM 30% AT 0 DEGREES FAHRENHEIT

ENERGY SAVINGS (BTU/CFM-H)
COST AVOIDANCE ($/CFM-H)

MONTREAL QUEBEC
CANADA CANADA

OUTSIDE AIR TEMP	MEAN COINCID WETBULB	ANNUAL HOURS	MEAN W oa (GR/LB)	SENSIBLE OUTSIDE AIR CFM	ADIABATIC OUTSIDE AIR CFM	SENSIBLE ENERGY REQUIRED	ADIABATIC ENERGY REQUIRED	ADIABATIC ENERGY SAVINGS	SENSIBLE OUTSIDE AIR MIN
102	72	0	63	2,000	2,000	0.00E+00	0.00E+00	0.00E+00	2,000
97	74	1	63	2,000	2,000	2.82E+05	2.82E+05	0.00E+00	2,000
92	74	19	63	10,000	10,000	6.53E+06	6.53E+06	0.00E+00	10,000
87	72	81	63	10,000	10,000	2.34E+07	2.34E+07	0.00E+00	10,000
82	69	193	63	10,000	10,000	4.51E+07	4.51E+07	0.00E+00	10,000
77	66	333	63	10,000	10,000	5.95E+07	5.95E+07	0.00E+00	10,000
72	64	537	63	10,000	10,000	6.65E+07	6.65E+07	0.00E+00	10,000
67	61	699	63	10,000	10,000	4.82E+07	4.82E+07	0.00E+00	10,000
62	57	795	63	10,000	10,000	1.12E+07	1.12E+07	0.00E+00	10,000
57	52	745	63	10,000	8,760	2.67E+07	0.00E+00	-2.67E+07	10,000
52	48	733	63	8,846	7,545	3.20E+07	0.00E+00	-3.20E+07	8,846
47	43	667	63	7,419	6,625	2.02E+07	0.00E+00	-2.02E+07	7,419
42	38	717	63	6,389	5,904	1.49E+07	0.00E+00	-1.49E+07	6,389
37	34	804	63	5,610	5,325	1.09E+07	0.00E+00	-1.09E+07	5,610
32	29	803	63	5,000	4,849	6.33E+06	0.00E+00	-6.33E+06	5,000
27	24	563	63	4,510	4,451	1.89E+06	0.00E+00	-1.89E+06	4,510
22	20	401	63	4,107	4,113	1.36E+05	0.00E+00	-1.36E+05	4,107
17	15	284	63	3,770	3,822	9.71E+05	0.00E+00	-9.71E+05	3,770
12	10	193	63	3,485	3,570	1.16E+06	0.00E+00	-1.16E+06	3,485
7	6	109	63	3,239	3,349	8.99E+05	0.00E+00	-8.99E+05	3,239
2	1	53	63	3,026	3,153	5.39E+05	0.00E+00	-5.39E+05	3,026
-3	-4	22	63	2,840	2,979	2.60E+05	0.00E+00	-2.60E+05	2,840
-8	-8	8	63	2,674	2,823	1.06E+05	0.00E+00	-1.06E+05	2,674
-13	-13	1	63	2,527	2,683	1.46E+04	0.00E+00	-1.46E+04	2,527
-18	-16	0	63	2,396	2,556	0.00E+00	0.00E+00	0.00E+00	2,396
-23				2,277	2,000	0.00E+00	0.00E+00	0.00E+00	2,277
-28				2,170	2,000	0.00E+00	0.00E+00	0.00E+00	2,170

SENSIBLE ENERGY LOAD (BTU/YR)	3.78E+08
ADIABATIC ENERGY LOAD (BTU/YR)	2.61E+08
ADIABATIC ENERGY SAVINGS (BTU/YR)	1.17E+08
PERCENT ENERGY SAVED	30.97%

FUEL COSTS:		EQUIVALENT ANNUAL COST SAVINGS:
OIL @ ($/THERM	$0.08	$125
GAS @ ($/THERM	$0.38	$593
ELECTRICITY @	$0.08	$3,656

CLIMATE PROCESSOR ENERGY SAVINGS

SYSTEM CFM	20,000	ENERGY SAVINGS (BTU/CFM-H)	
MINIMUM OUTSIDE AIR CFM	4,000	COST AVOIDANCE ($/CFM-H)	
SUPPLY AIR TEMP	55		
RETURN AIR TEMP	78	MONTREAL	QUEBEC
SPACE HUMIDITY RATIO (GR/LB)@	72	CANADA	CANADA
ECONOMIZER ON POINT	95		
HUMIDITY RESET SCHEDULE (DEGR	3		

MAXIMUM 50% AT 60 DEGREES FAHRENHEIT
MINIMUM 30% AT 0 DEGREES FAHRENHEIT

OUTSIDE AIR TEMP	MEAN COINCID WETBULB	ANNUAL HOURS	MEAN W oa (GR/LB)	SENSIBLE OUTSIDE AIR CFM	ADIABATIC OUTSIDE AIR CFM	SENSIBLE ENERGY REQUIRED	ADIABATIC ENERGY REQUIRED	ADIABATIC ENERGY SAVINGS	SENSIBLE OUTSIDE AIR MIN
102	72	0	63	4,000	4,000	0.00E+00	0.00E+00	0.00E+00	4,000
97	74	1	63	4,000	4,000	5.64E+05	5.64E+05	0.00E+00	4,000
92	74	19	63	20,000	20,000	1.31E+07	1.31E+07	0.00E+00	20,000
87	72	81	63	20,000	20,000	4.67E+07	4.67E+07	0.00E+00	20,000
82	69	193	63	20,000	20,000	9.02E+07	9.02E+07	0.00E+00	20,000
77	66	333	63	20,000	20,000	1.19E+08	1.19E+08	0.00E+00	20,000
72	64	537	63	20,000	20,000	1.33E+08	1.33E+08	0.00E+00	20,000
67	61	699	63	20,000	20,000	9.64E+07	9.64E+07	0.00E+00	20,000
62	57	795	63	20,000	20,000	2.24E+07	2.24E+07	0.00E+00	20,000
57	52	745	63	20,000	17,521	5.34E+07	0.00E+00	-5.34E+07	20,000
52	48	733	63	17,692	15,089	6.40E+07	0.00E+00	-6.40E+07	17,692
47	43	667	63	14,839	13,249	4.05E+07	0.00E+00	-4.05E+07	14,839
42	38	717	63	12,778	11,809	2.98E+07	0.00E+00	-2.98E+07	12,778
37	34	804	63	11,220	10,650	2.17E+07	0.00E+00	-2.17E+07	11,220
32	29	803	63	10,000	9,698	1.27E+07	0.00E+00	-1.27E+07	10,000
27	24	563	63	9,020	8,901	3.78E+06	0.00E+00	-3.78E+06	9,020
22	20	401	63	8,214	8,225	2.72E+05	0.00E+00	-2.72E+05	8,214
17	15	284	63	7,541	7,645	1.94E+06	0.00E+00	-1.94E+06	7,541
12	10	193	63	6,970	7,140	2.32E+06	0.00E+00	-2.32E+06	6,970
7	6	109	63	6,479	6,698	1.80E+06	0.00E+00	-1.80E+06	6,479
2	1	53	63	6,053	6,307	1.08E+06	0.00E+00	-1.08E+06	6,053
-3	-4	22	63	5,679	5,959	5.21E+05	0.00E+00	-5.21E+05	5,679
-8	-8	8	63	5,349	5,647	2.13E+05	0.00E+00	-2.13E+05	5,349
-13	-13	1	63	5,055	5,366	2.92E+04	0.00E+00	-2.92E+04	5,055
-18	-16	0	63	4,792	5,112	0.00E+00	0.00E+00	0.00E+00	4,792
-23				4,554	4,000	0.00E+00	0.00E+00	0.00E+00	4,554
-28				4,340	4,000	0.00E+00	0.00E+00	0.00E+00	4,340

SENSIBLE ENERGY LOAD (BTU/YR)	7.55E+08
ADIABATIC ENERGY LOAD (BTU/YR)	5.21E+08
ADIABATIC ENERGY SAVINGS (BTU/YR)	2.34E+08
PERCENT ENERGY SAVED	30.97%

FUEL COSTS:		EQUIVALENT ANNUAL COST SAVINGS:
OIL @ ($/THERM	$0.08	$250
GAS @ ($/THERM	$0.38	$1,185
ELECTRICITY @	$0.08	$7,311

CLIMATE PROCESSOR ENERGY SAVINGS

SYSTEM CFM	30,000	ENERGY SAVINGS (BTU/CFM-H)
MINIMUM OUTSIDE AIR CFM	6,000	COST AVOIDANCE ($/CFM-H)
SUPPLY AIR TEMP	55	
RETURN AIR TEMP	78	MONTREAL QUEBEC
SPACE HUMIDITY RATIO (GR/LB)@	72	CANADA CANADA
ECONOMIZER ON POINT	95	
HUMIDITY RESET SCHEDULE (DEGR	3	

MAXIMUM 50% AT 60 DEGREES FAHRENHEIT
MINIMUM 30% AT 0 DEGREES FAHRENHEIT

OUTSIDE AIR TEMP	MEAN COINCID WETBULB	ANNUAL HOURS	MEAN W oa (GR/LB)	SENSIBLE OUTSIDE AIR CFM	ADIABATIC OUTSIDE AIR CFM	SENSIBLE ENERGY REQUIRED	ADIABATIC ENERGY REQUIRED	ADIABATIC ENERGY SAVINGS	SENSIBLE OUTSIDE AIR MIN
102	72	0	63	6,000	6,000	0.00E+00	0.00E+00	0.00E+00	6,000
97	74	1	63	6,000	6,000	8.47E+05	8.47E+05	0.00E+00	6,000
92	74	19	63	30,000	30,000	1.96E+07	1.96E+07	0.00E+00	30,000
87	72	81	63	30,000	30,000	7.01E+07	7.01E+07	0.00E+00	30,000
82	69	193	63	30,000	30,000	1.35E+08	1.35E+08	0.00E+00	30,000
77	66	333	63	30,000	30,000	1.79E+08	1.79E+08	0.00E+00	30,000
72	64	537	63	30,000	30,000	2.00E+08	2.00E+08	0.00E+00	30,000
67	61	699	63	30,000	30,000	1.45E+08	1.45E+08	0.00E+00	30,000
62	57	795	63	30,000	30,000	3.35E+07	3.35E+07	0.00E+00	30,000
57	52	745	63	30,000	26,281	8.00E+07	0.00E+00	-8.00E+07	30,000
52	48	733	63	26,538	22,634	9.60E+07	0.00E+00	-9.60E+07	26,538
47	43	667	63	22,258	19,874	6.07E+07	0.00E+00	-6.07E+07	22,258
42	38	717	63	19,167	17,713	4.46E+07	0.00E+00	-4.46E+07	19,167
37	34	804	63	16,829	15,975	3.26E+07	0.00E+00	-3.26E+07	16,829
32	29	803	63	15,000	14,546	1.90E+07	0.00E+00	-1.90E+07	15,000
27	24	563	63	13,529	13,352	5.67E+06	0.00E+00	-5.67E+06	13,529
22	20	401	63	12,321	12,338	4.08E+05	0.00E+00	-4.08E+05	12,321
17	15	284	63	11,311	11,467	2.91E+06	0.00E+00	-2.91E+06	11,311
12	10	193	63	10,455	10,710	3.49E+06	0.00E+00	-3.49E+06	10,455
7	6	109	63	9,718	10,047	2.70E+06	0.00E+00	-2.70E+06	9,718
2	1	53	63	9,079	9,460	1.62E+06	0.00E+00	-1.62E+06	9,079
-3	-4	22	63	8,519	8,938	7.81E+05	0.00E+00	-7.81E+05	8,519
-8	-8	8	63	8,023	8,470	3.19E+05	0.00E+00	-3.19E+05	8,023
-13	-13	1	63	7,582	8,049	4.38E+04	0.00E+00	-4.38E+04	7,582
-18	-16	0	63	7,188	7,667	0.00E+00	0.00E+00	0.00E+00	7,188
-23				6,832	6,000	0.00E+00	0.00E+00	0.00E+00	6,832
-28				6,509	6,000	0.00E+00	0.00E+00	0.00E+00	6,509

SENSIBLE ENERGY LOAD (BTU/YR)	1.13E+09
ADIABATIC ENERGY LOAD (BTU/YR)	7.82E+08
ADIABATIC ENERGY SAVINGS (BTU/YR)	3.51E+08
PERCENT ENERGY SAVED	30.97%

FUEL COSTS:		EQUIVALENT ANNUAL COST SAVINGS:
OIL @ ($/THERM	$0.08	$374
GAS @ ($/THERM	$0.38	$1,778
ELECTRICITY @	$0.08	$10,967