

## INTRODUCTION:

An increasingly common technical strategy used in the commercial and industrial sectors to provide enhanced dehumidification is an air-to-air heat exchanger wrapped around a cooling coil. The cooling coil may be DX, chilled water, or brine. Because it's exposed to a higher dry bulb temperature, the upstream heat exchanger will absorb BTUs and discharge those same BTUs off the downstream heat exchanger into the lower temperature air. Because these systems reduce the Sensible Heat Ratio (SHR) of the equipment to more closely match the SHR of the load, it is well understood that these psychrometrics are very desirable, and ASHRAE Standard 90.1 allows this type of reheat. Even better, using wrap around systems such as these save not only the reheat energy, but also save the same amount of cooling energy. While the heat pipe is by far the most common heat exchanger used for this application, occasionally a coil pump around system is also considered to save capital costs. These systems are shown in Figures 1 and 2. The circled numbers refer to the psychrometrics at those positions, listed in TABLE 1.

This analysis is a life cycle cost comparison of these two types of systems. Since the system psychrometrics will be identical for both systems, only the relative life cycle costs need to be examined. The specific life cycle costs examined are capital costs, maintenance costs and energy costs. Then other less-quantifiable considerations valuable to the building owner are discussed, which can be even more important than the economic factors.

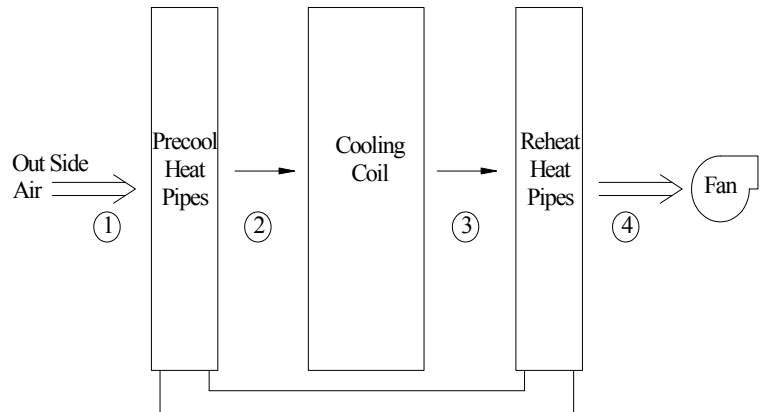


Figure 1 - Heat Pipe System

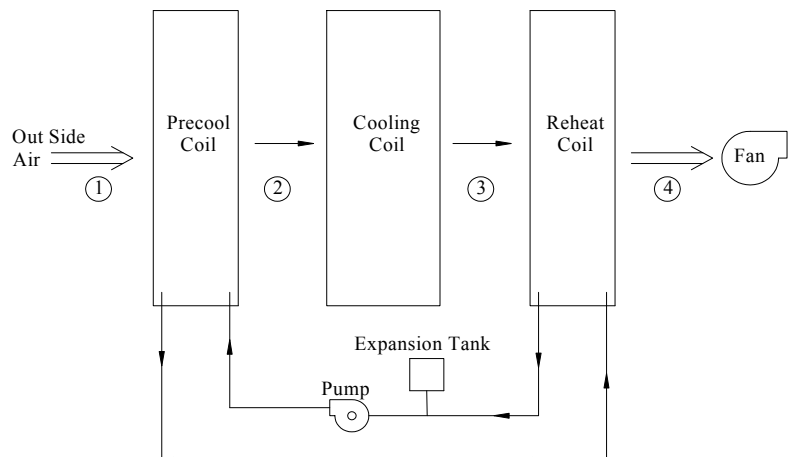


Figure 2 - Coil Pump Around System

## SYSTEM DESCRIPTION:

Four typical HVAC systems are examined. All are at 20,000 CFM except for System 3, which is at 5,000 CFM. System 3 is examined to establish the scale of costs and how they change. Please see the Appendix for additional system assumptions made.

### System 1 – Outside Air Conditioned to Neutral Air at 55°F Dewpoint

A very common application for these precool and reheat systems is to provide 100% outside air conditioned to a neutral state, defined as 75°F and 50 %RH (55°F dewpoint), and supplied directly to the zones or to the returns of a number of AHUs. For all cases, 1.8 °F of motor reheat is allowed for, with 95DB/78WB outside air temperatures. Figure 3 shows the psychrometrics of this type of system.

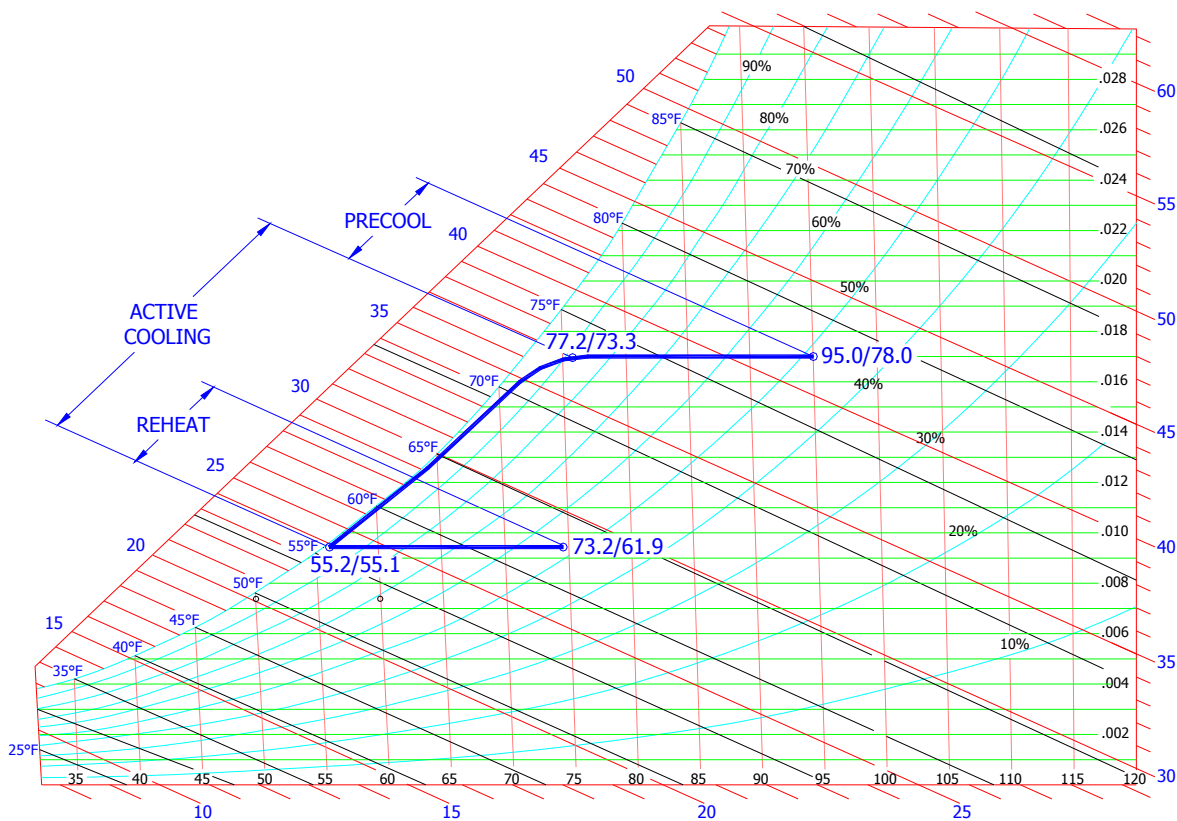


Figure 3 -Outside Air Conditioned to Neutral Air at 55°F Dewpoint

These applications are often with larger airflows, so this example is for 20,000 CFM. Table 1 shows that the equipment selections to match the psychrometrics for this System 1 are 6 rows/12 fpi for the coil pump around system, and 4 rows/10 fpi for the heat pipe system. The airside pressure drops for both systems are provided, as are the water side GPM and pressure drop for the coil pump around system.

## SYSTEM DESCRIPTION:

### System 2 – Outside Air Conditioned to Neutral Air at 45°F Dewpoint

It is becoming increasingly popular to supply 100% outside air that has been conditioned to the same neutral air dry bulb temperature, but at a lower dewpoint, say 45 °F, as shown by Figure 4.

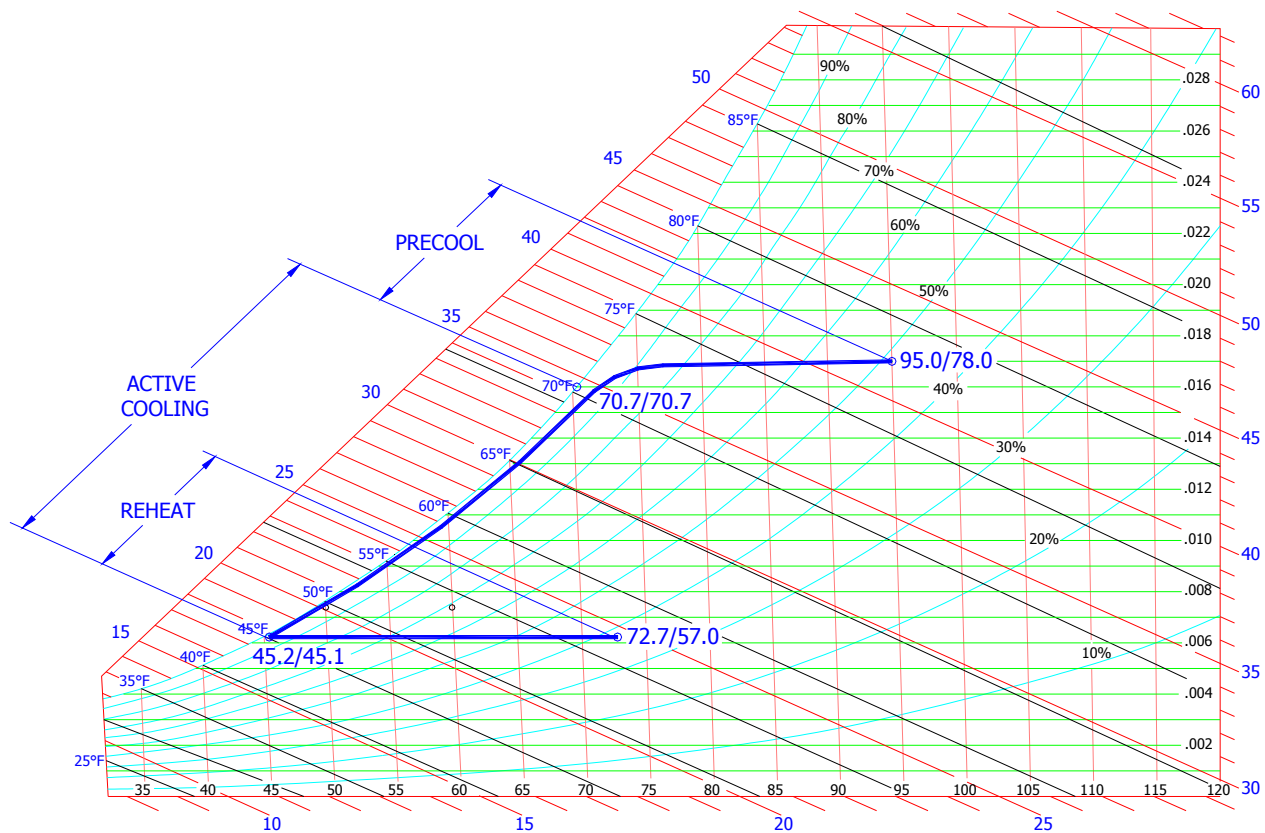


Figure 4 - Outside Air Conditioned to Neutral Air at 45°F Dewpoint

By essentially shifting even the interior latent loads to the dedicated outside air machine, this allows the building to run drier and may allow the interior AHUs to save energy.

### System 3 – Outside Air Conditioned to Neutral Air at 55°F Dewpoint

A smaller 100% outside air system of 5,000 CFM is examined with leaving 75 °F DB neutral air at a 55 °F dewpoint. This has the same psychrometrics as the first system.

## SYSTEM DESCRIPTION:

### System 4 – Mixed Air Conditioned to Tempered Dry Bulb with 55°F Dewpoint

These precool and reheat systems are also frequently used to condition 80°F DB and 67°F WB mixed air. Examples include when there is a higher than normal latent load in the space (schools, restaurants) or there is an established need for a lower humidity in the space (libraries, museums, hospitals). This type of system is shown in Figure 5. Neutral air is not required in this application, but rather it's a tempering of the delivered air specifically to otherwise reduce the space humidity.

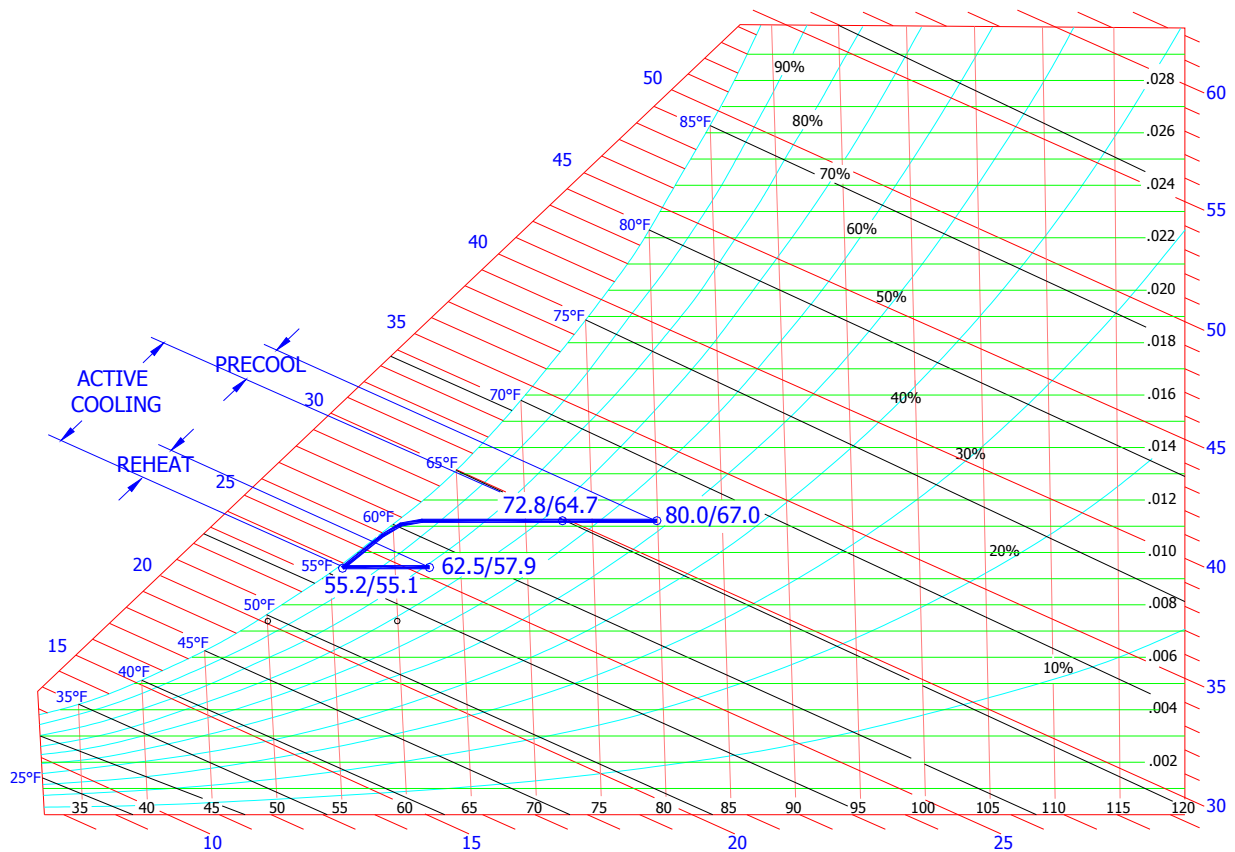


Figure 5 - Mixed Air Conditioned to Tempered Conditions with 55°F Dewpoint

## SYSTEM SELECTION COMPARISON:

By running commonly available computer programs from equipment manufacturers, the equipment selections are shown in TABLE 1.

System Selection Comparison	System 1		System 2		System 3		System 4	
	Neutral Air, High CFM, 55°F Dewpoint		Neutral Air, High CFM, 45°F Dewpoint		Neutral Air, Low CFM, 55°F Dewpoint		Mixed Air, High CFM, 55°F Dewpoint	
Position 1 DB/WB	95.0/78.0		95.0/78.0		95.0/78.0		80.0/67.0	
Position 2 DB/WB	77.2/73.3		70.7/70.7		77.2/73.3		72.8/64.7	
Position 3 DB/WB	55.2/55.1		45.2/45.1		55.2/55.1		55.2/55.1	
Position 4 DB/WB	73.2/61.9		72.7/57.0		73.2/61.9		62.5/57.9	
Heat Exchanger System	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe
Rows*	6	4	8	5	6	4	4	2
FPI*	10	10	12	12	11	10	10	12
“ PD Airside*	.41	.25	.71	.37	.44	.25	.39	.22
‘ PD Waterside*	7.9	-	11.7	-	10.3	-	3.6	-
GPM	95	-	102	-	95	-	78	-

\* All data per side

TABLE 1

In all cases, the pump around system selections match the heat pipes' psychrometrics, although with more heat transfer surface. The heat pipes are more efficient because they use a phase changing heat transfer fluid to take advantage of the high latent heats of vaporization and condensation, whereas the water/glycol mixture stays in the liquid phase.

## ENERGY COSTS COMPARISON:

Energy Costs Comparison	System 1		System 2		System 3		System 4	
	Neutral Air, High CFM, 55°F Dewpoint		Neutral Air, High CFM, 45°F Dewpoint		Neutral Air, Low CFM, 55°F Dewpoint		Mixed Air, High CFM, 55°F Dewpoint	
Heat Exchanger System	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe
Airside BHP	2.02	1.23	3.49	1.82	.54	.31	1.92	1.08
Pump BHP	.82	-	1.14	-	.97	-	.45	-
Total BHP	2.84	1.23	4.63	1.82	1.51	.31	2.37	1.08
Total Annual Energy Costs \$	878	381	1,433	563	467	96	733	334

TABLE 2

From TABLE 1, the additional heat transfer surface of the pump around system causes additional airside pressure drop, which causes the higher airside BHP as shown in TABLE 2. For example, the System 1 coil pump around consumes an additional .79 BHP. There is also an energy penalty due to the required pumping of the water/glycol mixture. For example, System 1 requires an additional .82 BHP to run the coil pump around compared to the wrap around heat pipe to produce exactly the same results. The System 1 coil pump around requires an additional 1.61 BHP.

To determine the \$ cost of each KWH, the latest (July 06) figures from the Energy Information Administration of the US Dept of Energy were used. The average nationwide price across all sectors was \$.0947/kwh, which was a 10.5% increase over the previous year. Most commercial applications are also on a demand rate and peak electrical usage reduction will significantly increase heat pipe energy savings even more than shown. The energy results are compared in FIGURE 6.

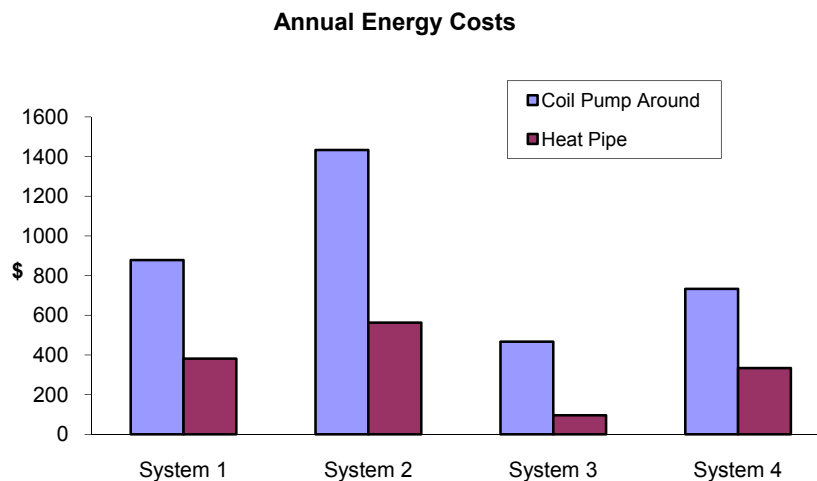


Figure 6

## CAPITAL COSTS COMPARISON:

Capital Costs	System 1		System 2		System 3		System 4	
	Neutral Air, High CFM, 55°F Dewpoint		Neutral Air, High CFM, 45°F Dewpoint		Neutral Air, Low CFM, 55°F Dewpoint		Mixed Air, High CFM, 55°F Dewpoint	
	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe	Pump Around	Heat Pipe
Heat Pipes		8,501		9,909		2,470		5,201
Glycol Coil (2) Installed at AHU Factory	9822		12921		6487		6161	
3/4" Schedule 40 Black Steel Piping	145		145		145		145	
4 Gal Closed Expansion Tank	40		40		40		40	
One Pump	310		370		310		265	
Electrical Wiring/Conduit w/ Disconnect	649		649		649		649	
Ethylene Glycol	120		180		60		60	
Labor to Complete	6,000	12,752	6,000	14,864	3,000	3,705	6,000	7,800
Total Installed \$	17,086	21,253	20,305	24,773	10,691	6,175	13,320	13,001

TABLE 3

The pump around system requires the installation of field water piping between the coils and to the water supply, at least one pump, and electrical service to the pump. It also requires a water makeup connection and water line from a nearby water supply. On site labor to install the pump around system is based on 10 man-days total of work at \$75/hr, a conservative contractor labor rate. See the Appendix for further estimates on the details of the installation.

The heat pipes are completely sealed and installed at the factory with no moving parts. Each of the multiple separate circuits (over 100 circuits on Systems 1 and 2) is individually evacuated, precisely charged and sealed resulting in a relatively high installation labor effort. Most often that work is done in the controlled environment of the factory keeping costs contained and quality high. Although the labor work is shown in TABLE 3, in practice a total turnkey heat pipe price is utilized.



## MAINTENANCE COSTS COMPARISON:

No additional maintenance is required on wrap around heat pipe systems, because they have no moving parts and are installed, sealed and checked at the factory (or by trained and certified factory personnel in the field on retrofit projects).

Practically, on a 20,000 CFM system, it is reasonable to allow an average of at least 15 minutes a week for the ongoing maintenance required by the coil pump around system. This would include attention to leaks, glycol/water chemical treatment, and checking of the electrical system's controls, starters and service. Use \$50/hr for the total burdened cost of the maintenance personnel, or \$650 per year.

However, let's also recognize that there will periodically be more major problems, such as a pump needing to be replaced (\$350 every 5 years), yearly fluid replacement (\$50 plus two hours labor) and miscellaneous other needs (\$100 in parts or 2 hours labor per year). So totaling the maintenance estimates equals \$970 per year. With the same design and number of parts, the 5,000 CFM system should be less and is estimated at \$800 per year.

Both coil pump around and heat pipe systems can be supplied with copper fins, stainless steel casings, and many different types of fin coatings. Both types of systems require similar upstream filtration. In addition, both types of systems should have adequate space upstream and downstream of all coil surfaces for cleaning and installation of controls. Drain pans are also recommended under all coil surfaces. While only the upstream or precool coil will see condensation, provision must also be made for draining the downstream coil after cleaning.

## TOTAL LIFE CYCLE COSTS COMPARISON:

Heat Pipe vs. Pump Around System	Neutral Air, High CFM, 55°F Dewpoint	Neutral Air, High CFM, 45°F Dewpoint	Neutral Air, Low CFM, 55°F Dewpoint	Mixed Air, High CFM, 55°F Dewpoint
Heat Pipe Savings: Annual Energy Costs	497	870	371	399
Heat Pipe Savings: Annual Maintenance Costs	970	970	800	970
Heat Pipe Penalty: Capital Costs	4,167	4,468	-4,516	-319
Simple Payback (months)	34	29	Immediate	Immediate
25 year Savings with Heat Pipes	32,508	41,532	33,791	34,544

TABLE 4



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Paybacks for the heat pipe systems range from immediate to 34 months with large savings for the owner over 25 years. A non-escalating electric rate is used for the 25 year calculations. As with many types of capital equipment, the life cycle savings of the more efficient equipment with the higher first cost will more than pay for the equipment's total capital cost in the first place, in some cases many times over!

## **OTHER IMPORTANT CONSIDERATIONS**

As important as the economics are, there are even more important considerations for the owner and engineer. For most owners, uptime and reliability are very important. The heat pipes have multiple parallel circuits that are fully independent. The 20,000 CFM AHU for neutral air will have well over 100 independent circuits. If one heat pipe circuit should be inadvertently damaged or fail for any unlikely reason, that's less than 1% degradation factor. Even the smaller 5,000 CFM system will have about 25 circuits. If any part of the coil pump around system fails, it's 100% down and space humidity cannot be maintained. For a process application, that's a major and costly concern.

Installation quality is another concern. Experienced factory personnel have installed thousands of heat pipes in units of all types and manufacturers. They know what works and what doesn't. They're installed in a controlled factory environment, factory inspected for quality control and have no moving parts. All these factors insure a trouble free heat pipe installation, compared to potentially more problems with the glycol coils, pumps, piping and electrical service field installed.

Sometimes, enhanced dehumidification needs to be added to an existing AHU. The AHU may have limited space for a wrap around system, or electrical or water service may be inconvenient or expensive to bring to the AHU. Or there may be limited existing additional fan motor BHP available. These considerations only further confirm the heat pipe choice.

Glycol pump around coils can be controlled on/off by the pump operation, or the effect can be modulated with the addition of a bypass valve and controls. The same can be done with heat pipes with several different means of controls, depending on which is most suitable for the application.

Even in traditional coil pump around applications where the precool and reheat coils must be separated by 10 to 25 feet, heat pipes are already being used. For over about 25 – 30 feet and also depending on the relative vertical positions, refrigerant pumps designed for this duty are used.

## **SUMMARY AND CONCLUSIONS:**

This study was designed to illuminate the technical and economic aspects of a niche application that some owners and engineers would not be exposed to or possibly not spend the time investigating. The numbers were put together in good faith and were based on national averages, and while a detail may be arguable, all details are specifically included for inspection and local adjustment. Others are invited to duplicate the process and come up with their own conclusions.

As expected, there is a first cost advantage for the base application (neutral air, 20,000 CFM, 55 °F DP) coil pump around system. However, the additional maintenance and energy costs establish that the owner can expect to spend eight times those savings over that much again over the next 25 years.

If a neutral air system is designed for a lower dewpoint supply, the payback for the heat pipes drops and the 25-year savings increase.

Surprisingly, the 5,000 CFM system has even a first cost advantage when using heat pipes and is clearly the choice for all applications.

Also perhaps surprising to some, the typical large CFM mixed air application also scores very well for the heat pipes with even a first cost savings. While one may think of these precool/reheat systems only in terms of outside air, our experience is that mixed air heat pipe applications out number the outside air applications by some three to one.

There are also extremely significant other advantages to using heat pipes, especially reliability and quality.

This paper shows why building owners and consulting engineers need to continue to exert strong control over the bidding process. When the total life cycle costs and other ramifications of the decision are explained to the owner and engineer, it's hard to imagine an application that's not better with wrap around heat pipes. What may be less expensive up front costs the owner a lot more in the long run, long after the construction process is complete!

## **APPENDIX:**

Other basic parameters used in the analysis:

1. Since nearly all areas of the US see freezing temperatures, for a national average, want freeze protection to  $-10^{\circ}\text{F}$ , so use 40% EG solution.
2. Pumps, fans and motors at 80% efficiency
3. 100% outside air coils sized at 400 fpm; mixed air coils sized at 500 fpm
4. Pumps and fans operate 4,380 hrs/yr (50%). Actual run hours will depend on the type and usage of the facility and will range from 2,600 to 8,760 hrs/yr. Energy paybacks can be easily adjusted.
5. Pressure drop from additional glycol piping between the coils is  $10'$ .
6. All pricing as of May 06.
7. Heat Pipe pricing includes \$500 additional shipping leg to destination.
8. Other pricing from Grainger, Means and actual equipment quotes.
9. Glycol piping pricing based on 5' between the coils, plus 50' to nearest water supply.
10. Electrical wiring/conduit pricing based on 50' distance to nearest electrical panel.