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NEUTRAL AIR UNITS WITH HEAT PIPES IN CHILLED WATER SYSTEMS

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INTRODUCTION:

With today's higher ventilation requirements and more efficient buildings, moisture becomes a higher percentage of the total load that a mixed air handling unit must handle. What happens? Both the supply air dry bulb temperature and supply air dewpoint rise, reducing the supply air's sensible cooling capacity and resulting in a higher indoor relative humidity. Plus, cooling must be provided at all times so that wet untreated air won't be introduced into the space. The solution is to have dedicated outside air units that supply one or more zones with dry outside air with terminal units designed primarily for the sensible loads.

Fundamentally, dedicated outside air units are used to provide the correct ventilation amount per ASHRAE 62.1 under all operating conditions, and to reliably and energy efficiently remove the bulk of the total moisture load. Further, the design engineer is tasked to design the rest of the system to meet ASHRAE 90.1. Because the dedicated outside air units cool, heat, dehumidify and provide filtration, they are often also given the term dedicated outside air systems (DOAS).

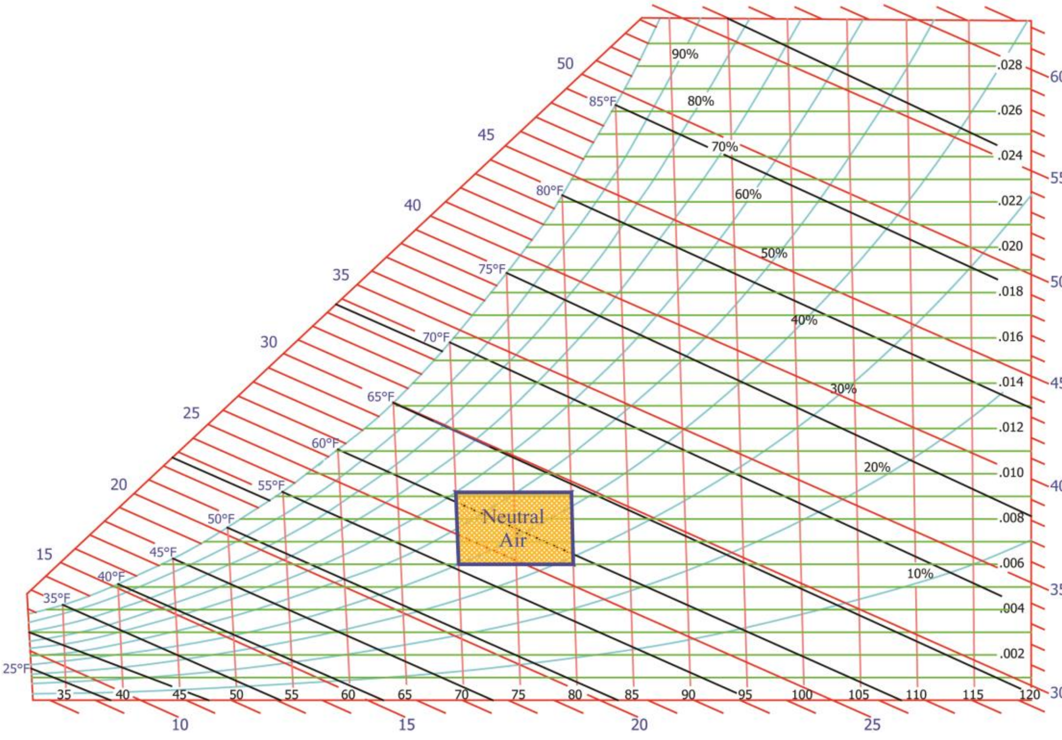

Figure 1

WHAT IS NEUTRAL AIR?

Neutral air is outside air supplied at the space dry bulb temperature but at a dewpoint low enough so the space will be at the specified relative humidity when allowing for the space moisture load. There is no standard numerical definition of neutral air, but rather it depends on the individual space requirements and the moisture load. An example of neutral supply air for a simple office area to be maintained at

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75.0ºF dry bulb (DB) and 50%RH would be 75.0ºF DB and 55.1 ºF dewpoint (DP) maximum. Neutral air for a process space to be maintained at 70ºF DB and 45%RH would be 70.0ºF DB and 47.7ºF DP maximum. Most applications will fall into the range shown in FIGURE 1. In all cases, the strategy is to design the dedicated outside air unit to maintain zone relative humidity, and the local terminal units are primarily designed to maintain temperature.

WHY NEUTRAL AIR?

Some dedicated outside air systems supply the outside air saturated and cold at 55ºF. While this appears to provide some sensible cooling to help the terminal unit, upon reflection there are many applications where neutral air is psychrometrically preferred:

- ✓ All interior zones and corridors (hotels/motels, dormitories, offices, and many other facilities), because there's little or no interior sensible load and cold supply air would overcool.
- ✓ Applications where the outside air is delivered to open ceiling plenums, because return air humidity can condense on surfaces exposed to cold outside air.
- ✓ Applications where the conditioned outside air is being delivered to multiple zones, because it's likely that at least one of the zones periodically has little sensible load and it would be overcooled by cold supply air.
- ✓ When the outside air is used with packaged DX systems (PTAC, RTU) and some FCU systems, because the cold outside air would reduce the load below the factory designed CFM/ton of the standard equipment.
- ✓ Specialized applications such as museums, archives, manufacturing facilities and some libraries that require a lower relative humidity. Air supplied at the dry bulb corresponding to the necessary dewpoint would overcool the space.

In addition, the consequence of supplying cold saturated air means that reheat must be provided at lower ambient conditions; otherwise the zone(s) will be overcooled. This means that additional energy will be required. This additional reheat energy is discussed and compared further on p. 4.
Supplying neutral air by the outside air machine means the terminal unit only has to provide local cooling or heating based on the space heating or cooling load. The terminal units sidestep the outside air conditions. With correct design, comfortable space conditions will be met with only a thermostat under all reasonable room sensible and latent loads.

While neutral supply air is recognized as psychrometrically preferable to cold supply air, a concern that might limit its application is that more energy is required. That is certainly true for traditional systems that cool and then reheat, but wrap around heat pipes are a proven method to get the neutral condition with **LESS** actual energy usage!

WHY HEAT PIPES?

FIGURE 2 shows the physical installation of the heat pipes with the upstream (precool) heat pipe being exposed to the higher outside air dry bulb temperature and the downstream (reheat) heat pipe being exposed to the lower air dry bulb leaving the cooling coil. Thus sensible heat is transferred from the precool heat pipe through connecting tubes to the reheat heat pipe. The heat pipes are sealed and completely self contained in the air handling unit (AHU).

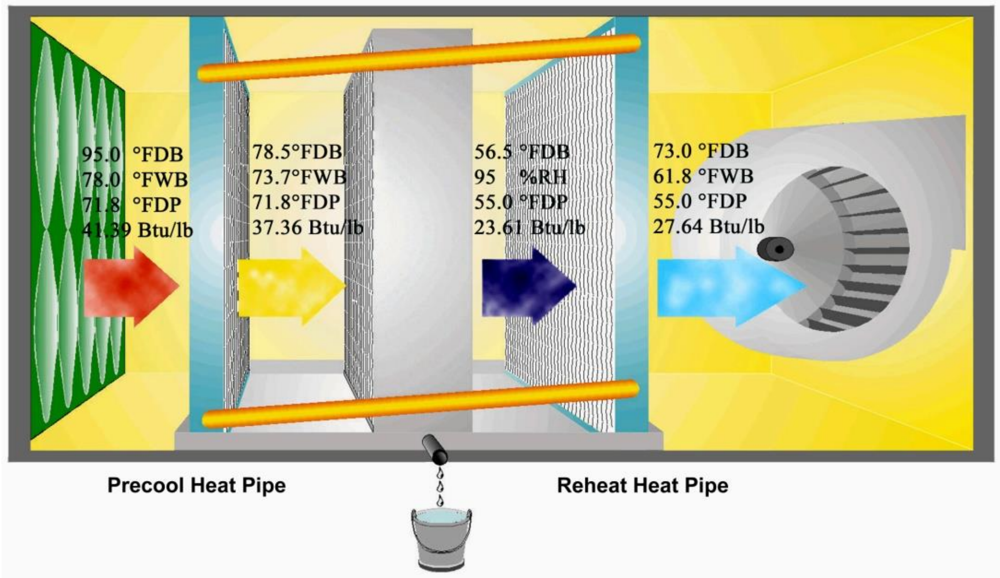

Figure 2

The result is:

- **FREE COOLING AND REHEAT**
- **NO MOVING PARTS**

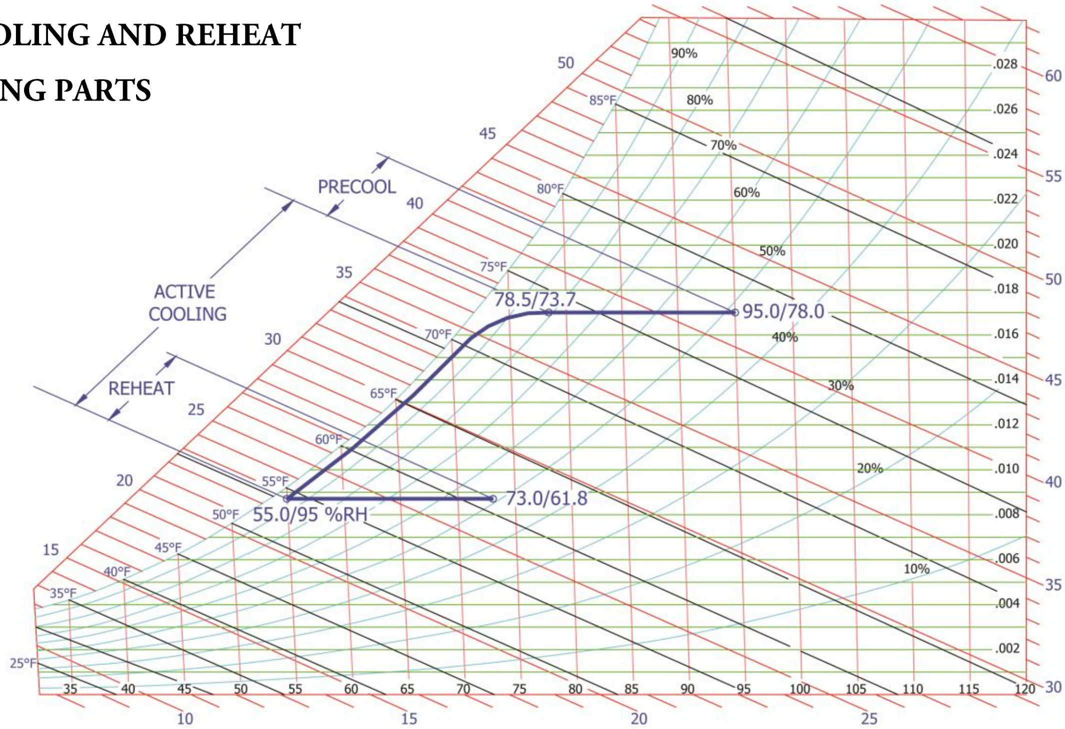

Figure 3

FIGURE 3 shows the psychrometrics within the air handling unit for an example of 95/78 entering outside air, 75/55 leaving supply air, including 2ºF of fan motor reheat. With 95% saturated air off the cooling coil, the remaining reheat amount is 16.5ºF. Note the enthalpy savings of the heat pipes of 4.03 BTU/lb on both the cooling and heating required.

ASHRAE Standard 90.1 provides a minimum energy standard, and it generally does not allow for cooling and reheating of the same airstream. However, it does specifically allow for reheating with recovered energy such as wrap around heat pipes.

The first column in FIGURE 4 shows the energy cost for the traditional cooling and hot water reheat to supply neutral air. The third column shows the energy cost to supply the same neutral air with wrap around heat pipes. Note the reduction in cooling energy required, the trim reheat cost because the heat pipes provide less reheat at lower ambient conditions, and the additional energy cost from the pressure drop of the heat pipes in the airstream. Overall, the heat pipes reduce the energy use by 32%. Given the preference for supplying neutral air, the wrap around heat pipes are the preferred economical approach.

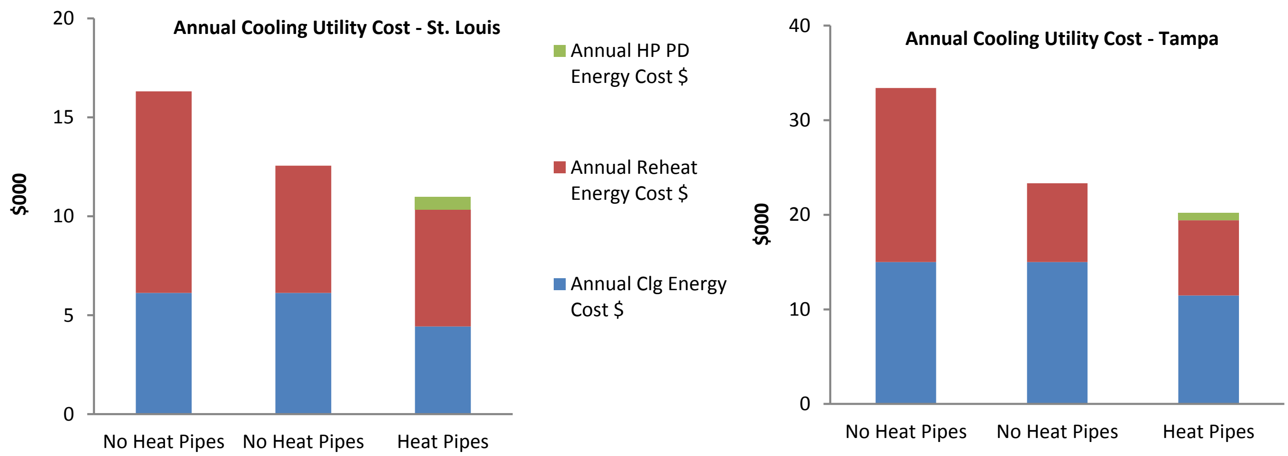

Figure 4

(ASHRAE 1% DB/MCWB, 10000 CFM, 73LDB/55LDP, .70 system kw/ton, $.08/kwh, 75% Htg efficiency, $.90/therm)

As discussed earlier, the traditional approach to preconditioning outside air was to supply cold saturated air. To prevent overcooling, the cold supply air must be reheated during lower ambient conditions, and this reheat requires additional energy. The middle column in FIGURE 4 shows the energy cost to supply cold saturated air for the hours at all ambient dry bulb temperatures above 75°F, but, so that the space will not be overcooled, reheated to neutral conditions for the hours when the ambient dry bulb is below 75°F. This energy analysis shows that using wrap around heat pipes to provide neutral air uses less system energy than providing cold supply air with reheat as necessary to prevent overcooling. The improvement will be greater for air cooled systems, and systems with reciprocating, scroll, or screw compressors.

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In summary, the wrap around heat pipes' energy advantage plus their psychrometric advantage provides compelling reasons to use wrap around heat pipes to supply neutral air in all dedicated outside air systems.

WHEN MORE IS LESS:

A surprising, but important, effect of the wrap around heat pipes is that, given a constant entering air temperature and leaving dewpoint, the higher the leaving supply air dry bulb temperature, the lower the utility cooling and heating energy. A higher leaving supply dry bulb temperature necessarily means that more reheat is provided by the reheat heat pipe, and that additional reheat comes from additional heat pipe precooling, thereby reducing compressor energy.

Figure 5 illustrates this point for the combined cooling and reheating energy in the above St. Louis example, and shows the magnitude of the difference. For example, an increase in the leaving air dry bulb from 66°F to 72°F saves over 20% in energy.

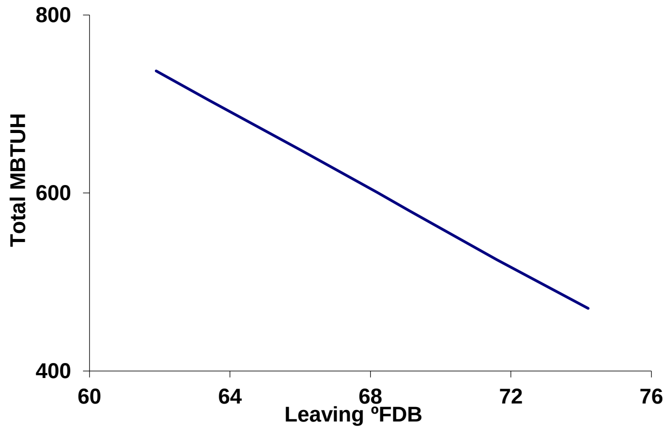

FIGURE 5

CONTROLLABLE HEAT PIPES:

The dehumidifying heat pipes are often intentionally sized so that at design conditions, they provide exactly the design reheat amount, say 73ºF to allow for 2ºF of fan motor reheat for 75ºF supply air. With standard heat pipes and the reliability of no moving parts, this approach provides the maximum amount of both precool and reheat energy savings without the concern of either over heating or over cooling the space. But at all lower entering ambient dry bulb conditions, the heat pipes will provide less reheat. For example, while the heat pipes in the St. Louis example provide 68.0ºF DB leaving supply air (with the fan motor heat) even at 77.5ºF dry bulb ambient, the space still has the need for the same 75ºF supply air.

Here's where another Heat Pipe Technology advancement is introduced … controllable heat pipes. Controllable heat pipes are used so that the heat pipes may be "oversized" at design conditions. While they're throttled back at design conditions when all the reheat they're capable of would be too much, they're controlled to function more completely at lower ambient conditions. Thus, the reheat amount is allowed to more closely match the ideal constant design supply leaving air temperature, and more energy is saved at all part load conditions.

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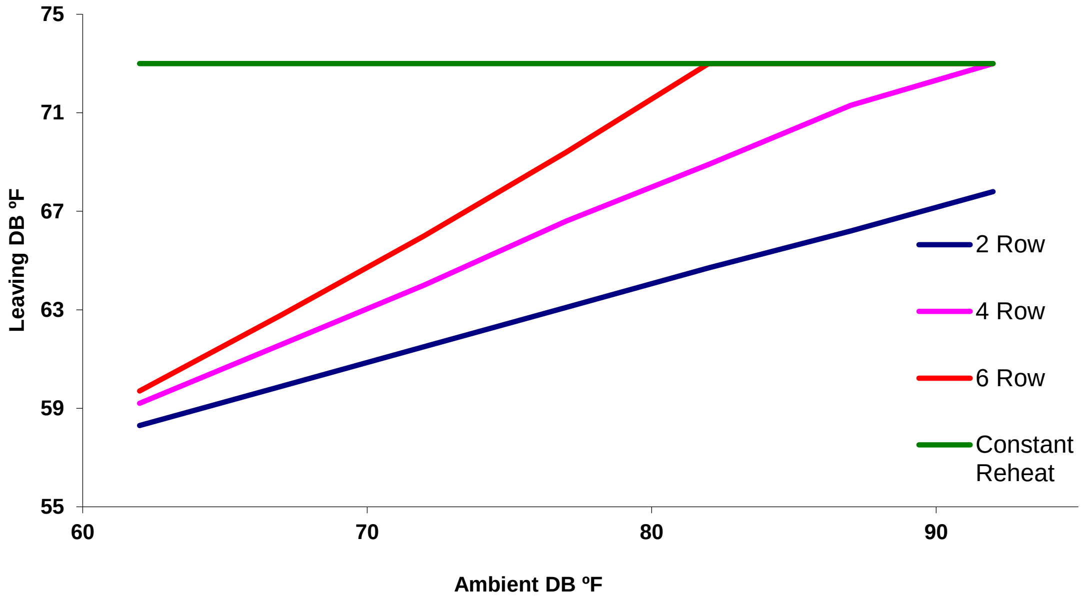

Figure 6

FIGURE 6 shows that additional heat pipe rows will provide additional energy savings at lower ambient conditions while maintaining the constant supply air temperature. Remember that the more heat pipe reheat that is generated, the higher the precool heat pipe energy savings are, which results in lower cooling energy. The control of the heat pipes is easily and precisely accomplished by modulating either the refrigerant flow or airflow depending on the size of the system and other characteristics.

While deeper heat pipes are recommended to save energy, any heat pipe will not be capable of supplying the full reheat amount at some lower ambient condition. The final polishing step is using active reheat downstream of the reheat heat pipe to trim to maintain the constant supply air temperature. Active reheat options from all manufacturers include hot water, steam, and natural and LP gas.

THE COMPLETE NEUTRAL AIR AHU:

With the fundamentals established, Heat Pipe Technology now introduces a 100% outside air system that provides neutral air with the lowest energy usage in the industry! Here's how to get it:

1. Specify a modular or custom AHU with a chilled water coil from any manufacturer.
2. Specify wrap around heat pipes manufactured by Heat Pipe Technology be included in the AHU. The heat pipes are custom engineered for that specific AHU to produce a specific psychrometric result with a specific airside pressure drop.

The heat pipe installation is either at the Heat Pipe Technology factory or the AHU manufacturer's facility, depending on the type of AHU. Heat Pipe Technology has installed thousands of heat pipes into all manufacturers' equipment for all types of facilities all around the world for over 20 years. The heat

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pipes are totally self-contained in the AHU and no installation or startup service attention is required at the project site.

The major benefits of this approach include:

- ✓ Allows the owner, engineer and contractor to use preferred, existing AHU vendors.
- ✓ Maintains clear responsibilities. Heat Pipe Technology is the only heat pipe manufacturer in the world that also installs heat pipes in other manufacturer's equipment.
- ✓ Standard AHU systems are available up to 65,000 CFM, and larger with custom AHUs.
- ✓ Both indoor and outdoor AHUs are available.
- ✓ Both vertical and horizontal discharge are available.
- ✓ More sizes available to better match project schedules (smaller increments between sizes).
- ✓ ARI performance certification on the AHU.
- ✓ All standard materials of construction are available, including double wall.
- ✓ All standard AHU options are easily available: fans, filters, electric, hot water, steam, and gas heating, dampers, controls, coils, curbs, and hoods, energy recovery heat pipes and enthalpy wheels as necessary for ASHRAE Standard 90.1, VFD options, service and access sections, humidification, and others.
- ✓ These systems provide neutral supply air at the lowest energy use in the industry.
- ✓ Because the cooling tonnage is less, the central plant may be downsized and the electrical service requirement is less expensive.

Figure 7
Chilled Water Modular AHU with Heat Pipes Installed Indoors for 100% Outside Air for Dormitory at Major University
(Hot water reheat trims to maintain supply air dry bulb)

SELECTION PROCEDURE FOR 100% OUTSIDE AIR NEUTRAL AIR SYSTEM WITH WRAP AROUND HEAT PIPES:

1. Establish design outside air dry bulb and wet bulb (or other moisture level measurement). Have a psychrometric chart handy.
2. Establish design CFM and at what dry bulb and wet bulb conditions the air is to be delivered.
3. To determine the AHU size, begin with a maximum coil face velocity of 400 fpm. This allows for the drainage of the higher outside air moisture loading on the coils and reduces the operating costs. Most modular AHU manufacturers have a quick select table to determine the cooling coil face area needed.
4. Allowing 2ºF (or another amount based on the actual CFM and total static pressure) for temperature rise due to the fan motor, determine the enthalpy difference between the air leaving the CW coil (air will leave the CW coil 95% saturated at the dewpoint in step 2) and the air entering the fan (assuming a draw through configuration).
5. The enthalpy of the air entering the CW coil is the outside air enthalpy minus the enthalpy determined in step 4. The wrap around heat pipe face area will match the CW coil face area and the rows and fpi will be selected to transfer exactly this enthalpy amount from the outside air to the air after it leaves the CW coil. The enthalpy of the air actually entering the CW coil will also be lower than the outside air by this exact amount.
6. Pick the intersecting point of that enthalpy amount and the expected coil pull down curve (likely horizontally to the left indicating sensible heat pipe precooling). Make a chilled water coil selection using those reduced entering conditions and leaving the CW coil at 95%RH and the dewpoint of the supply air.
7. Check the tons saved by the heat pipes.

Note: Your local Heat Pipe Technology representative can furnish computer printouts showing the exact psychrometrics and heat pipe selection.

EXAMPLE SELECTION:

1. Design conditions are 95ºF DB/78ºF WB.
2. 10,000 CFM supply air is required at 75ºF dry bulb and 55ºF dewpoint.
3. An AHU size 30 with a 29 ft^2 CW coil would be a good selection. This provides 345 fpm face velocity.
4. The dry bulb of the air leaving the CW coil at 95% saturation and 55ºF dewpoint is 56.5ºF. For 75ºF dry bulb supply air, air would enter the draw through fan at 73ºF so the heat pipe reheat is 16.5ºF. This equates to an enthalpy savings of 4.03 BTU/lb on both the precool and reheat heat pipes.
5. The enthalpy of 95ºFDB/78ºFWB design outside air is 41.39 BTU/lb. The enthalpy of the air entering the CW coil is 41.39 – 4.03 = 37.36 BTU/lb. The air entering the CW coil will be along this enthalpy line.
6. By inspection of the pull down line starting from 95/78, the outside air is only sensibly cooled with no latent cooling by the precool heat pipe. Therefore, the air entering the CW coil is at 78.5

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ºFDB/73.7ºWB. The CW coil will need to condition the air from 78.5/73.7 down to 56.5/55.0DP, or an enthalpy of 13.75.

7. 10,000 CFM from 95ºF DB/78ºF WB to 56.5ºF DB/55.0ºF DP requires 801.6 MBH, but from 78.5ºF DB/73.7ºF WB only requires 618.7 MBH, for a 15.2 ton (23%) heat pipe cooling savings. The heat pipes also save 182.9 MBH of reheating. The cooling percentage will apply at all operating conditions.

EQUIPMENT GUIDELINES:

1. The heat pipes should be centered in dedicated spacer/access sections in the modular AHU. While the heat pipes themselves will be less than 12" deep, the section should be a minimum of 20" deep to allow for maintenance and controls. If a separate access section is to be added both upstream and downstream of all coil sections including the heat pipes, then the spacer/access sections only need to be 12" deep as shown in FIGURE 8.

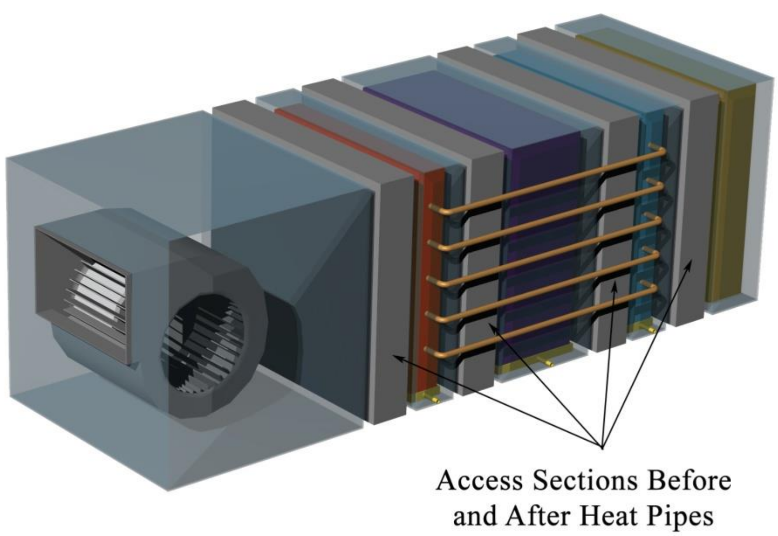

Figure 8

Include a drain pan in the spacer sections under both the precool and reheat heat pipes for future cleaning, although only the upstream heat pipe will have condensation. The drain pan should be of the same materials of construction, insulation, and slope as the drain pan under the main cooling coil, and each drain pan must have its own condensate connection and trap. Specify the heat pipes to be of the same materials of construction as the heating and cooling coils, e.g., copper fins and/or stainless casings. If a coil corrosion coating is needed, the same should be specified for the heat pipes. All heat pipe connecting tubes will be on the side opposite the cooling coil connections to allow for future cooling coil replacement if necessary. Access for maintenance will be on the cooling coil connection side.

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2. If indirect gas heating is used, whether for winter heating or trimming to maintain neutral air dry bulb at part load conditions, locate it in a blow through configuration to allow the fan's positive pressure to keep combustion gases out of the supply air stream. Select a gas furnace with adequate turndown for operation at expected conditions.

3. Given enough space in the AHU, heat pipes can also be added to existing AHUs in a renovation project. The same employees that install heat pipes in the Heat Pipe Technology factory do the field installation.

4. Heat pipe performance is very sensitive to face velocity. As the face velocity reduces, both the effectiveness (a measure of efficiency) increases and the pressure drop decreases. This double effect has a strong effect on the heat pipe power ratio (BTUH output due to the heat pipes divided by their airside PD penalty measured in BTUH) as shown in FIGURE 9. The lower the cooling coil and heat pipe face velocity, the more efficient the system.

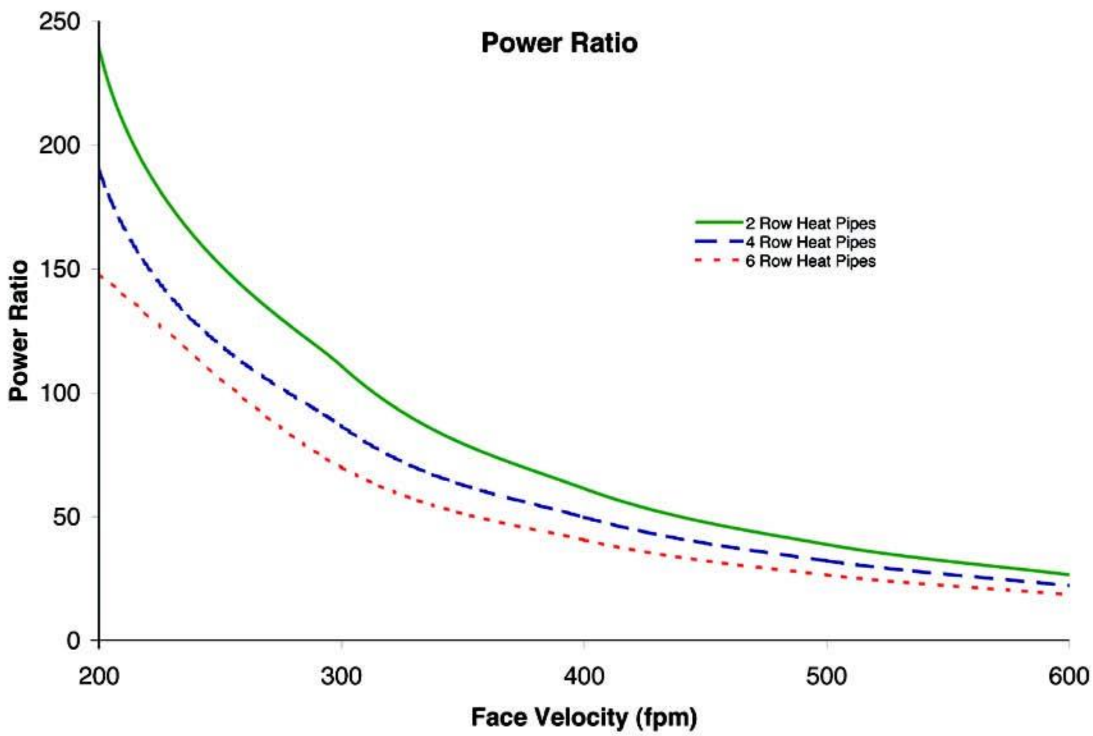

Figure 9

5. Some Neutral Air applications use VFDs to modulate the outside airflow and provide zone pressure control. A reduced CFM will cause a greater temperature change across both the precool and reheat heat pipes. While the additional precooling savings may be desired, the additional reheat may limit the available sensible cooling. This is another application that benefits from the use of controllable heat pipes.

6. Heat recovery heat pipes straddle the exhaust and outside air streams and are designed to transfer only sensible heat without any moisture transfer. Further, they have no moving parts that may leak or breakdown. Therefore, Heat Pipe Technology recommends the use of heat recovery heat pipes not only in applications with corrosive or contaminated exhaust air streams, but also in those applications that can not afford equipment breakdowns. Heat recovery heat pipes are easily fitted within both standard modular and custom AHUs. Heat Pipe Technology also has pumped heat pipe systems that allow the exhaust and outside air ducts to be separated by over 100'.

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