

## INTRODUCTION

Air conditioning applications can be broadly categorized as either standard or critical. The former, often called comfort cooling, traditionally just controlled to maintain a zone setpoint dry bulb temperature and the zone relative humidity was allowed to vary over a wide range. However, the relevant ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality, has recently been tightening acceptable design practices to specifically limit the relative humidity. Paragraph 5.9.1 in the 2010 edition requires a maximum of 65% relative humidity with the: a) outdoor air at design dew point and mean coincident dry bulb temperature, b) sensible and latent zone loads at design values, and c) solar load at zero. These conditions define a very low load Sensible Heat Ratio (SHR) for the equipment to meet and force the system designer to now consider relative humidity even for comfort cooling applications.

Critical applications, often called process cooling, require both temperature and relative humidity to be actively controlled, with the humidity typically specified within a maximum range of plus or minus 10%. In a tropical location, often just the maximum relative humidity is specified. Examples include medical applications, laboratories, and the manufacturing of such products as pharmaceuticals. In all cases, the humidity is specified because it has been proven that a relative humidity outside the specified range causes health, test result, or product problems respectively.

It's noteworthy that the air conditioning systems (and their accompanying psychrometrics) for both standard and critical applications are very similar, down to a required zone dew point of about 38°F. Therefore, the "Green Solution" discussed later may be applied on both systems to save significant energy and other operational costs while meeting all code requirements.



Figure 1

Tropical locations are defined as being within 23.5° of the equator (Figure 1). While globally there are some arid areas within this category, there are obviously a huge number of controlled humidity applications in this region. When designing a controlled humidity air conditioning system for those locales, the designer must recognize two important differences between, say, Raleigh (often called a "Southern" city), and San Juan (a true tropical location):

1. The higher tropical absolute ambient design moisture level, whether defined by the traditional Design Dry Bulb and Mean Coincident Wet Bulb, or the newer Design Dew Point and Mean Coincident Dry Bulb, as shown by Figure 2.

ASHRAE 1% Design Condition						
City, State	Design Dry Bulb (°F)	Mean Coincident Wet Bulb (°F)	Dew Point (°F)	Design Dew Point (°F)	Mean Coincident Dry Bulb (°F)	Grains Moisture per Lb of Dry Air
San Juan, P.R.	90	78	73.7	78	84	146.08
Raleigh, N.C.	90	75	69.0	74	81	127.34

Figure 2

The higher design dew point carries nearly 15% more moisture per lb of air, with similar increases at other BIN conditions.

2. The higher tropical hours at all the higher ambient moisture levels, as shown in Figure 3.

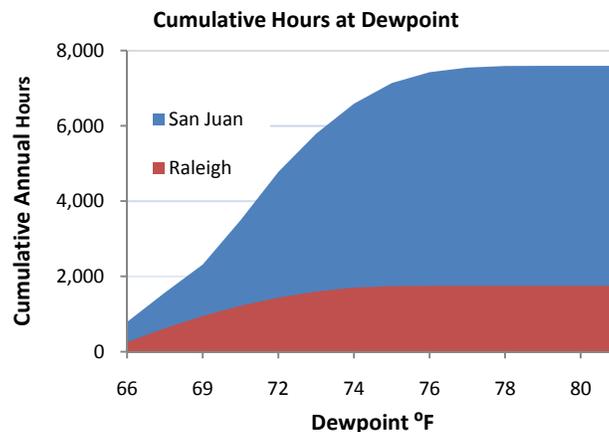


Figure 3

Additionally, if there are higher than normal internal latent loads, or lower sensible loads due to cool roofing, high R-value walls, etc., the system design must be especially thoughtful.

To summarize, while the traditional tropical design dry bulb temperatures may be similar to those of mainland US, a closer scrutiny technically confirms what one would suspect, namely that installations in tropical locations do in fact have a considerably higher moisture load annually with which to contend. Further, with the dry bulb temperatures being similar (a measure of the sensible load), necessarily the moisture load (latent

3load) percentage of the total load will be higher in the tropics. This would also be expressed that the SHR of the load, and therefore of the equipment, is reduced at a tropical location. Even a slight reduction in the SHR has huge implications for the equipment design and selection.

Further, a controlled humidity application traditionally meant an overcool and reheat system. While it does produce the required space conditions, it does so with a huge energy penalty (see following discussion). But amazingly, later we'll discuss a system that actually **reduces** the outside energy required compared to a non-critical application.

Our task is to examine the energy usage of both a traditional and a green air conditioning system for a tropical, controlled humidity application. A brief look at relative first cost and maintenance costs is also given, so together the reader may be provided a good overview of the relative total system life cycle costs to the owner.

## THE TRADITIONAL BRUTE FORCE SOLUTION

Figure 4 shows the essence of the traditional psychrometric process used in commercial/industrial applications to control humidity. The primary components are the chilled water coil which reduces the air to the dew point required to meet the latent load, and the (typically) hot water coil in the reheat position that then raises the air's dry bulb temperature to meet the sensible load.

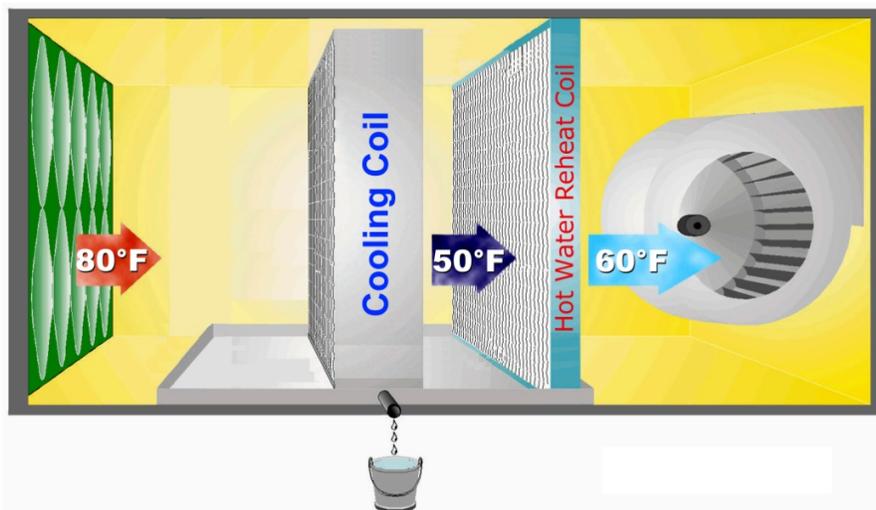


Figure 4

This overcool and reheat psychrometric process is generally disallowed by ASHRAE Standard 90.1-2010, Para 6.5.2.3, but provision (d) does allow this type of system for process applications. It's a little lower in first cost, has been around for many years, and since it does produce the required set point zone temperature and humidity, some system designers stop further investigation. However, this system requires huge energy

outlays, causing a very costly life cycle burden to the building owner, or more precisely, to whomever pays the energy bills. “Why” will be seen shortly!

These systems are typically run 24/7. Although a mixed air system is shown, 100% outside air systems are also very common in critical applications and, in fact, the energy use of the traditional brute force system is even higher in tropical locations. However and to some peoples’ surprise, because the weighted average (by hours) enthalpy of mixed air systems is higher in non-tropical locations than 100% outside air systems, the reverse is generally true in non-tropical locations!

The annual energy cost of such a typical mixed air system of 10,000 CFM in San Juan supplying constant 62°F dry bulb and 53°F dew point air is about \$53,900 (24/7, 50% OA, 75°F DB/50% RH Return Air, .70 Kw/ton cooling and 70% heating system efficiencies, \$.15/Kwh, \$1.50/therm).

## THE GREEN SOLUTION

Figure 5 shows today’s green solution, devised and applied since the eighties, with heat pipes wrapped around the cooling coil.

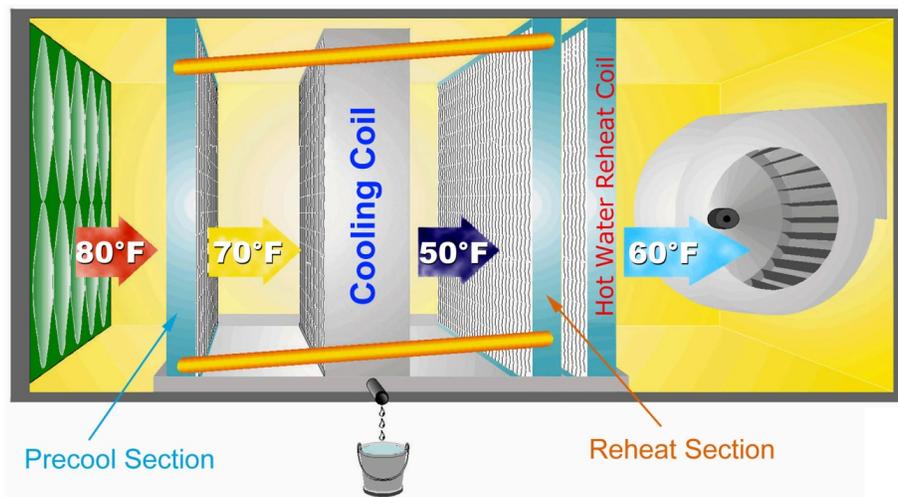


Figure 5

Referring to Figure 6 representing design conditions in the previously mentioned system, since the air is cooled by the cooling coil, the upstream precool heat pipe is exposed to a higher dry bulb temperature (point MA) than the downstream reheat heat pipe (point LA). Heat from the air (BTUs) is absorbed by evaporation of the critically charged refrigerant in the precool heat pipe, transported to the downstream reheat heat pipe

through connecting tubes, and released to the airstream by condensation of the refrigerant (points LA to SA). Thus free reheat is provided, and very importantly, free precooling is also provided, doubling the system savings!

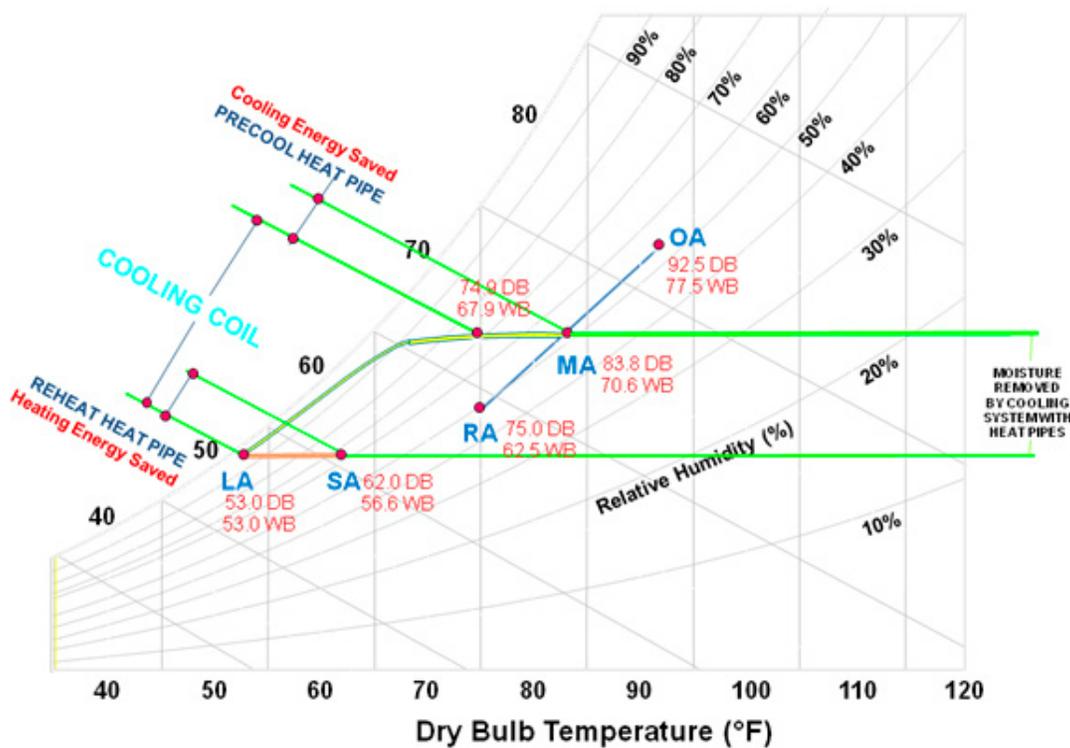


Figure 6

Interestingly, provision (e) of the previously mentioned ASHRAE Standard 90.1 specifically allows the use of such systems that make use of site-recovered heat, including heat from the precooling effect in the case of wrap around heat pipes.

At less than design ambient conditions, both heat pipes will have a decreased temperature change across them, so (typically) a hot water reheat coil is designed to make up the difference from the reduced reheated air dry bulb for systems designed for a constant supply air temperature.

While sometimes an air handling unit (AHU) serves a single zone, often zones with similar absolute dew point (humidity) but different temperature requirements are served by a single AHU. This application moves the hot water reheat coil from inside the AHU to inside one, some or all of the ductwork branches serving the different zones, but the basic psychrometrics are the same. When designing a multiple zone AHU with heat pipes, there are two approaches, and both start from the idea that to save maximum energy, the heat pipes should be sized for as large a delta T in the reheat heat pipes as possible:

1. Size the heat pipes to carry the minimum reheat temperature change in all the zones, and let the duct mounted hot water reheat coils trim to maintain its zone dry bulb set point.
2. Install a small sensible load only air conditioner (fan coil unit) in one or two of the small (or zero) zones that are “forcing” a downsizing of the heat pipes. While some energy savings are lost in those zones, all the other zones save additional energy on both the precool and reheat sides, for even more overall energy savings.

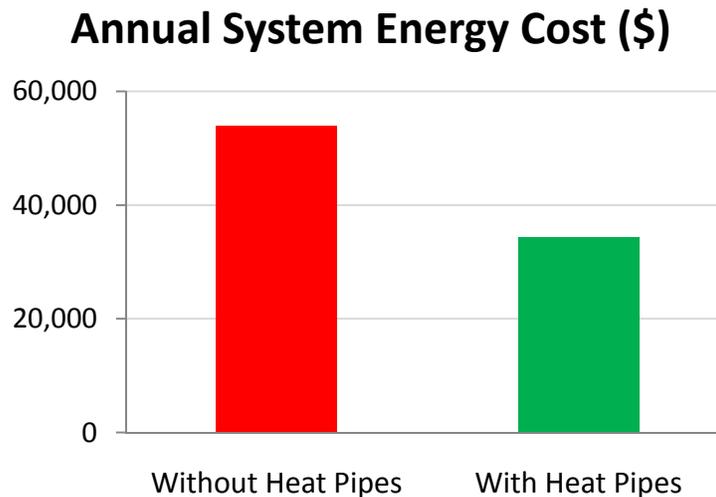


Figure 7

Here's the payoff: while the “Brute Force” solution has an annual energy cost of \$53,900 (Figure 7), the “Green” solution costs only \$34,400, for a 36% annual savings. But that's not all ... The heat pipes also:

1. Have no moving parts so no additional maintenance beyond normal coil cleaning.
2. Have exactly the same materials and methods of construction as the cooling coils for time-proven duty.
3. Allow either downsizing of the cooling and heating central plants when heat pipes are installed in new AHUs, or postponing capital expenditures of growing plants when heat pipes are installed in existing AHUs.
4. Are used on both chilled water and Direct Expansion systems.
5. Use the same control sequence as the “Brute Force” method. Further, with today's Building Management Systems, it's easy to add some sensors and a few simple formulae to show and document real time and trending energy savings.

Heat pipes are also the most economical solution (a specific example is given in the next section) to fix an existing humidity problem. Perhaps the outside air amount has increased, more people are being served, or lighting retrofits and/or solar film has been added to the windows reducing the sensible load but increasing the latent percentage. In any event, most AHUs can be site custom fitted with wrap around heat pipes for the most cost effective solution to a high humidity problem. If reheat coils are not used to control humidity, the

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heat pipes will reduce the Sensible Heat Ratio (SHR) so that the AHU does additional latent cooling, less sensible cooling and about the same total cooling.

## LIFE CYCLE COSTS

Life cycle costs are the first cost and operating costs, and the latter includes the maintenance and utilities cost. With today's pricing (February 2011), the incremental first cost of furnishing and installing wrap around heat pipes into a new 10,000 CFM AHU is about \$13K total, or about \$21K for a site retrofit.

There are no moving parts associated with the heat pipes, and the materials of construction are the same as the other coil surfaces in the AHU. Therefore, the only additional maintenance would be cleaning the heat pipe coil surfaces at the same frequency as the other coil surfaces in the AHU, and with the same procedures. Based on \$80 for one man-hour fully burdened twice a year and an estimate of \$50 for materials used, we find an incremental annual maintenance cost of \$210.

The annual reduced utilities cost has already been determined to be \$19,500. Please note that this figure already accounts for the slightly increased fan motor BHP needed for the heat pipes' static pressure loss.

So, the paybacks are 9 and 13 months for heat pipes installed in new or existing equipment respectively, surely a welcome return on investment!

## SUMMARY

Wrap around heat pipes have been used for decades in the most demanding and critical applications where humidity is of concern. They provide exactly the same psychrometrics as when reheat is used to control humidity, are nearly maintenance free, need no special controls or attention, and offer exceptional economics. There is even an Air Conditioning Heating Refrigeration Institute (AHRI) task force developing a rating standard (AHRI Standard 930P), which will set the stage for a certification program. What more could one ask for?

Heat Pipe Technology pioneered the use of heat pipes for dehumidification over a quarter century ago, and since then has continually led the HVAC industry in heat pipe science with thousands of installations in critical applications. Heat pipes are also available for HVAC and process heat recovery in side-by-side, split and pumped versions.