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OPTIMIZING WRAP AROUND HEAT PIPES

By Tom Brooke PE, CEM

INTRODUCTION:

Wrap around heat pipes are air-to-air heat exchangers that are installed in the airstream upstream and downstream of a cooling coil to deliberately reduce the Sensible Heat Ratio (SHR) below a standard air conditioning system's .75. Depending on the application, they're also used to replace all, or part of, the necessary reheat in a system to minimize energy usage. The energy ramifications are especially powerful because the energy savings occur not just on the reheating side but also on the cooling side, unlike in the other very common usage of air-to-air heat exchangers as used to transfer energy between exhaust air and outside air. Given then that some form of reheat is needed, this analysis examines the effect on energy savings of changing the different parameters of the air conditioning system design.

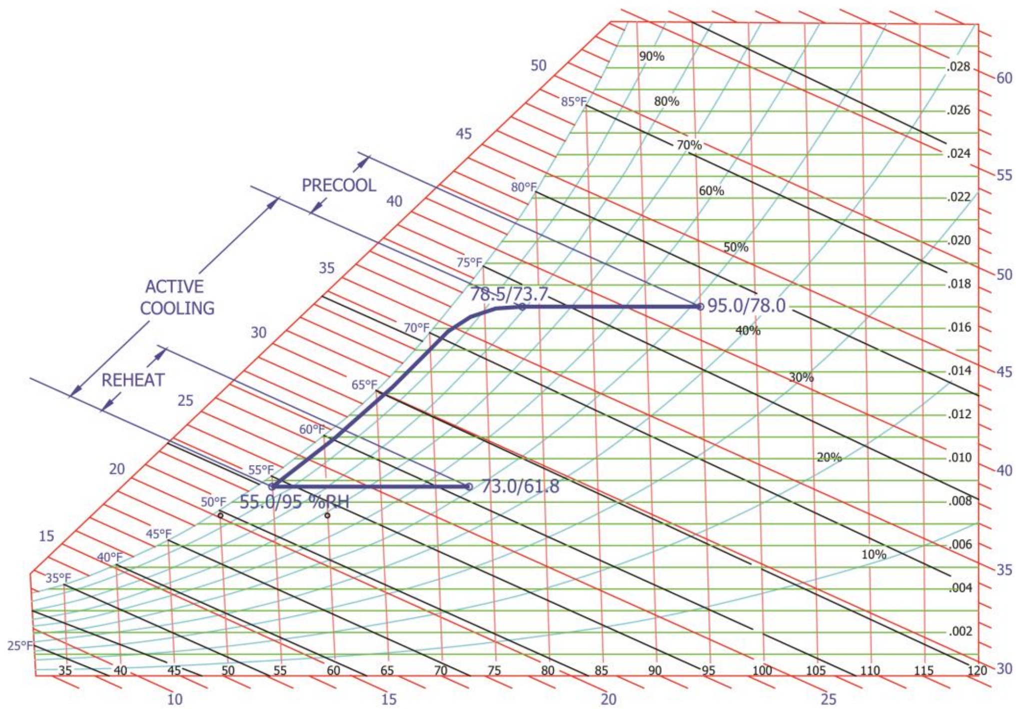

Figure 1

Figure 1 shows the psychrometrics of the wrap around heat pipe installed in an air conditioning system. The upstream heat pipes sensibly precool the air to 78.5DB/73.7WB which then enters the cooling coil. The cooling coil cools and dehumidifies the air to 56.5DB/95%RH/55.0DP. The downstream heat pipe then sensibly reheats the air the same amount to 73DB/61.8WB. The heat pipes then replace 16.5ºF of reheat energy and 16.5ºF of cooling energy.

As an alternative to a system with a lower SHR with reheat is considered, it is helpful for the HVAC system designer to have some general rules of thumb on not only the performance of the heat pipes, but more importantly their payback. In this analysis, the payback is compared to using the very common hot water reheat and it looks at the sensitivity of the payback to different variables used in the system design compared to a base case. Some variables are under the control of the designer, but many are not. While the results of changing multiple variables at the same time should generally not be considered additive, two cases are examined to determine if the model can be used for changing up to six variables at a time.

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BASE CASE:

The base case is for heat pipes installed in a new HVAC system located in St. Louis, MO, roughly in the geographical center of the US. It is a 20% OA system supplying 20,000 CFM of 59DB/54DP air (moderate 5ºF of reheat) at a 400 fpm coil face velocity. RA is 78/50%, and ASHRAE design 1% OA DB/MCWB conditions are used and BIN data. System characteristics are a .75 kw/ton central plant efficiency, a .75 central heating plant efficiency, .92 motor and .70 fan efficiencies respectively, $.07/kwh blended electrical cost and $.80/therm natural gas cost. R22 is used as the heat transfer fluid. All pricing is as of Feb, 2007. Higher or lower CFM amounts should have comparable results overall. Motor reheat is downstream of the reheat heat pipe and thus not included (although it is a part of the final calculations of supply air conditions). The payback for this base case is 26.1 months.

LOCATION:

As expected, the geographical location has a major influence on the payback. Since the design OA dry bulb is relatively consistent, and the heat pipe is a sensible heat transfer device that reacts only to dry bulb temperature, the same heat pipe selection is actually used for all locations. The southerly locations do have more hours when cooling is required and the heat pipes can become operative. Note that the payback is surprisingly low at 26 and 28 months even as far north as St. Louis and Boston respectively, decreasing to 12 months in Puerto Rico. While the location is not a variable for a given project site, this does provide organizations with multiple sites a way to prioritize their interest.

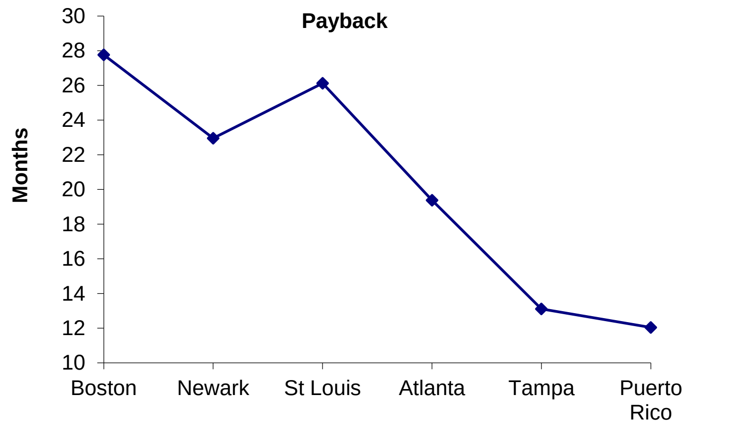

Figure 2

FLOWRATE (CFM):

As seen in Figure 3, there is a slight adjustment if the total project CFM is more or less than the baseline case of 20,000 CFM. This is because of nothing more than the project volume, which translates into pricing breaks. Although each heat pipe is individually engineered and built, larger projects inherently cost less on a per CFM basis.

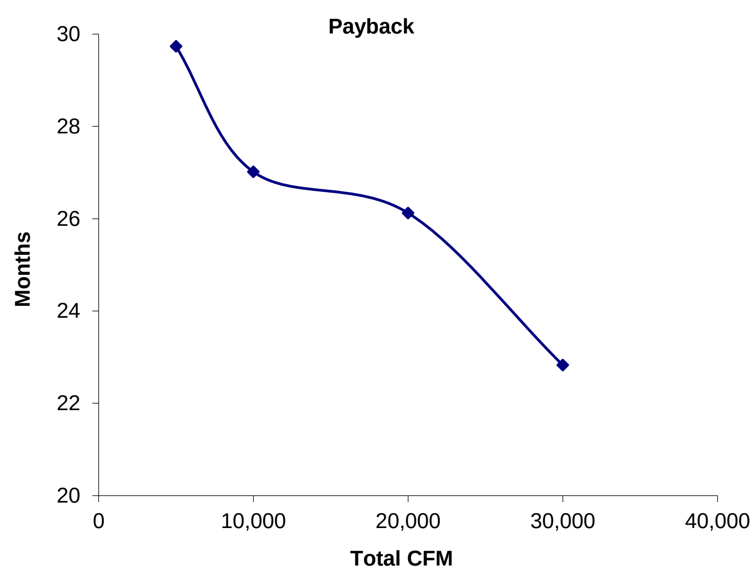

Figure 3

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PLANT EFFICIENCIES AND UTILITIES COST:

Figures 4 and 5 affect the heat pipe cooling savings, and Figures 6 and 7 affect the heat pipe heating savings. The cooling system kw/ton includes the tower and AHU fan motors and pumps. The system kw/ton range covers typical centrifugal chiller central plants, but local complete air cooled chiller systems, especially if older, may have a kw/ton above this range. The electrical cost is for a blended total cost, i.e., including the demand charges in the base rate. No cost escalation is built into the electrical rates. The heating efficiency is the overall efficiency to convert natural gas into a hot water heating system. The electrical cost does also effect the heating payback since electrical energy is used for the fan motor seeing air side pressure drop losses, but while included, it's relatively minor.

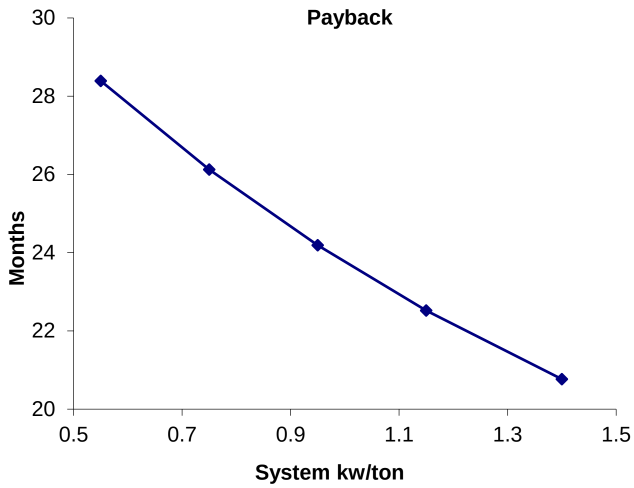

Figure 4

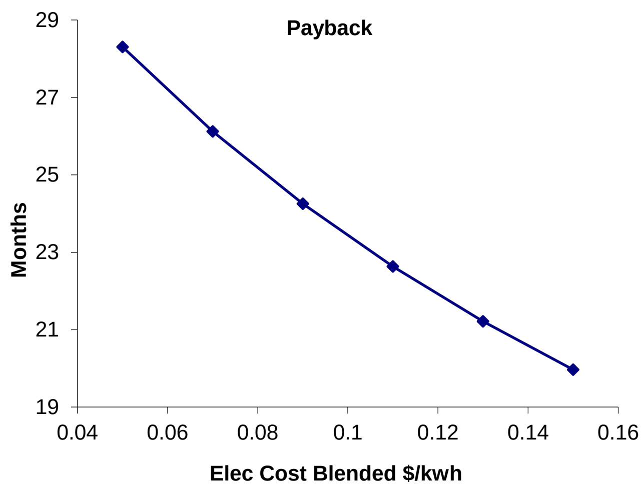

Figure 5

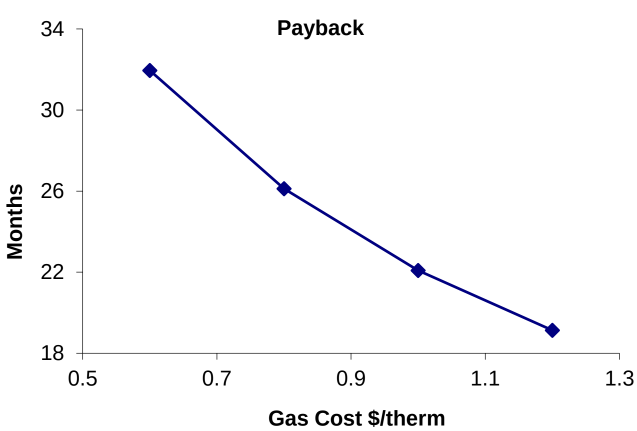

Figure 6

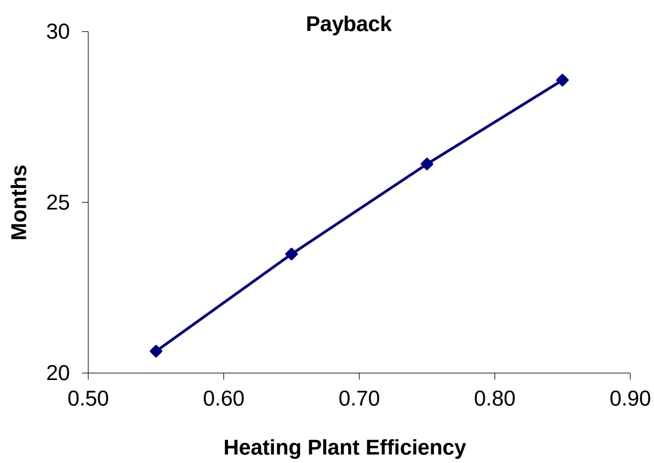

Figure 7

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FACE VELOCITY:

Figure 8 is perhaps one of the more surprising results. While lower face velocities are used to minimize the chance of water blow off and to decrease the airside pressure drop, at least for the heat pipes, a higher velocity provides a shorter payback. The reader is reminded that the face velocity also typically applies to the cooling coil, and that even 30 month paybacks are acceptable for most projects

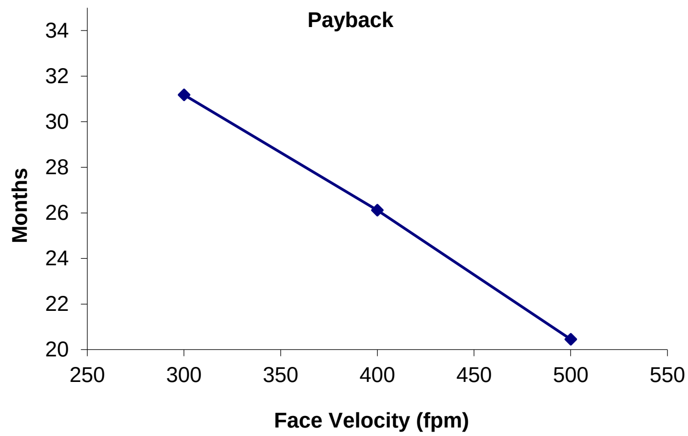

Figure 8

PERCENT OUTSIDE AIR:

Figure 9 shows that 100% Outside Air applications actually increase the payback compared to mixed air applications with typical 78ºF DB return air, so it's another surprising result because the wrap around heat pipes are sometimes only thought to be for 100% OA applications. While the wrap around heat pipes do provide the most BTU transfer at design conditions, the nature of OA is that there are more operating hours in the range of 55–75ºF DB, which brings down the average entering dry bulb temperature below typical mixed air conditions. For example, Figure 10 shows the distribution of the cooling BIN annual hours in St. Louis above 55ºFDB.

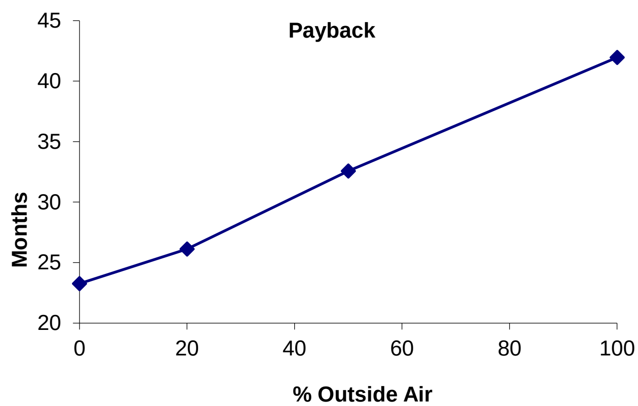

Figure 9

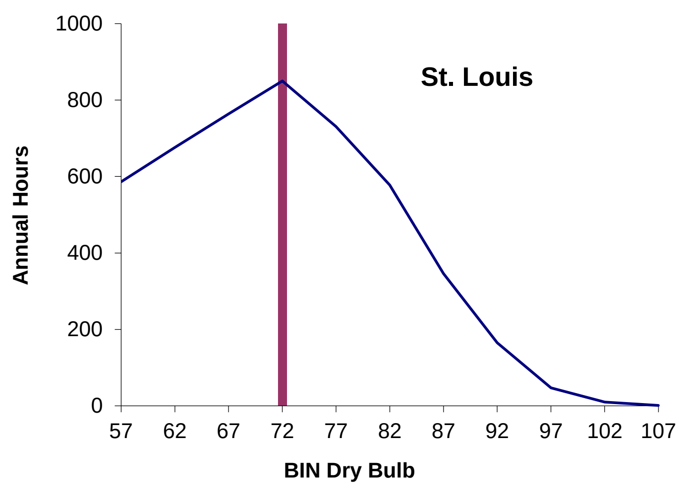

Figure 10

There are 165 hours at the 92ºFDB BIN and 764 hours at the 67ºFDB BIN. However, the average temperature (as shown by the vertical bar where there are equal hours above and below that temperature) is 72ºFDB. So clearly, decreasing the proportion of outside air entering the precool heat pipe increases the mixed air temperature and thus the heat pipe BTU transfer and energy savings, so wrap around heat pipes are well suited for applications with only 5-20% outside air.

While the above is true for most of North America, there are particular situations for which the results would be different. For example, the average cooling BIN in Puerto Rico is 77.8ºFDB. Therefore, any applications in Puerto Rico with the return air condition below 77.8ºFDB will have a decreasing payback with increasing outside air percentages.

LEAVING DEWPOINT AND REHEAT AMOUNT:

These are not something under the control of the HVAC system designer, who is trying to produce specific psychrometric results to maintain a space condition specified by the owner. A given reheat amount is needed, and it'll be either produced by utility fueled reheat or heat pipe reheat. Figure 11 establishes that the heat pipe payback is largely unaffected by the leaving dewpoint itself, given a specific reheat amount. However, a lower dewpoint needed for space humidity reasons increases the likelihood that additional reheat will be needed to provide for comfort conditions. Figure 12 establishes that a lower payback results after an initial dramatic improvement.

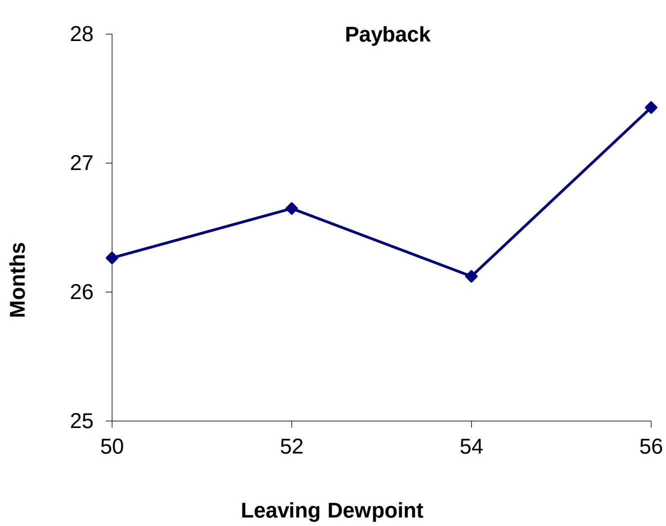

Figure 11

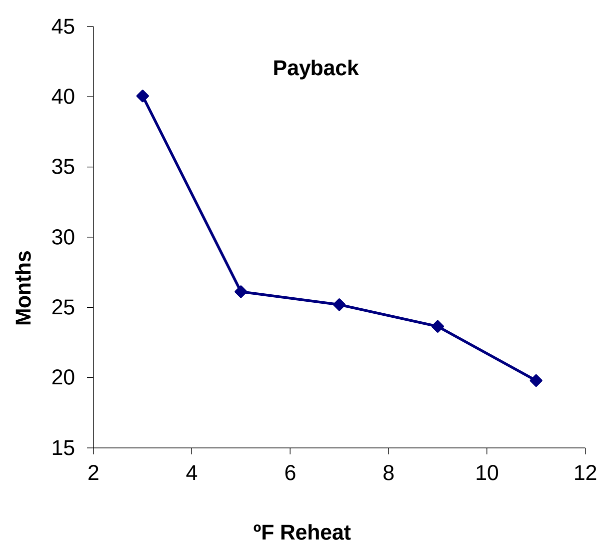

Figure 12

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EXAMPLES:

Of course, there'll never be an application where an actual selection is exactly at the base case conditions with only one variable changed. Let's examine two cases with multiple variables changed and compare the results to the models. Ideally, the results will be additive when multiple variables are changed.

Case 1 – *20,000 CFM at 500 fpm of 10% OA in Newark*. Plant efficiencies at .75 kw/ton cooling and .75 heating, utility costs at $.10/kwh and $1.00/therm and standard motor efficiencies. Leaving air at 57ºF DB and 50ºF DP(7ºF reheat), and return air at 78/65.

Running the actual computer BIN program establishes a 12.5 month payback or a 52% payback reduction from the base case. Variables for which we'd expect a quicker payback than the base case are a 500 fpm face velocity (21% quicker payback), 10% outside air (5% quicker payback) 7ºF of reheat (3% quicker payback), $.10/kwh (10% quicker payback), and $1.00/therm (15% quicker payback). Totaling the model payback improvements (multiplying their reciprocals) indicates a total payback reduction of 45%. The model is slightly conservative for Case 1.

Case 2 – *10,000 CFM at 400 fpm of 100% OA in Atlanta*. Plant efficiencies at 1.4kw/ton (an older air cooled chiller) and .75 heating, utility costs at $.09/kwh and $.90/therm and standard motor efficiencies. Leaving air at 60ºF DB and 50ºF DP (10ºF reheat).

Running the actual computer BIN program establishes a 17.5 month payback or a 33% payback reduction from the base case. Variables for which we'd expect a different payback than the base case are 10,000 CFM (3% longer payback), 100% outside air (61% longer payback), 1.4 cooling kw/ton (20% shorter payback), $.09/kwh (7% shorter payback), $.90/therm (8% shorter payback), and 10ºF reheat (17% shorter payback). Totaling the model payback changes (multiplying their reciprocals) indicates a total payback reduction of 6%. The model again is a little conservative for Case 2.

SUMMARY:

Wrap around heat pipes are popular because of their benefits. In addition to their economic benefits as we've seen above, there are no moving parts and multiple circuits for extreme reliability and redundancy, they require the smallest physical volume compared to other technologies that produce the same psychrometric results, and they can be added to any manufacturer's equipment.

Wrap around heat pipes are a powerful tool that an HVAC designer has at his disposal. While software for heat pipe product selections is available, the effect on cost is not as easily obtainable. Therefore, this analysis determines results as measured by simple payback as different engineering and costing parameters are adjusted. It is recognized that not all the variables are under the control of the designer.

Some further points can be noted:

1. If reheat is needed, numbers should show good payback for ALL selections, just shorter for some
2. For marginal cases, use face and bypass dampers to bypass air when cooling not needed (winter)
3. Controllable heat pipes are also available that modulate refrigerant or airflow

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