Controlling Wrap-Around Heat Pipes for Systems with Strict Space Humidity Requirements

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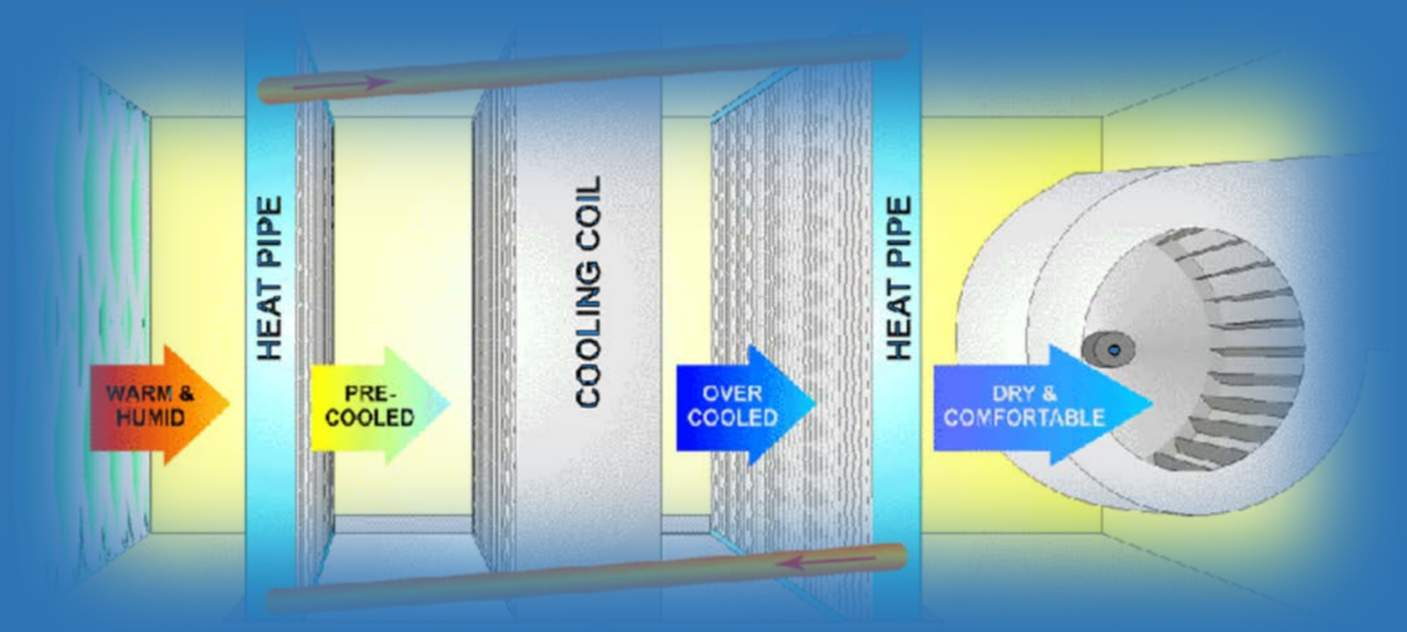
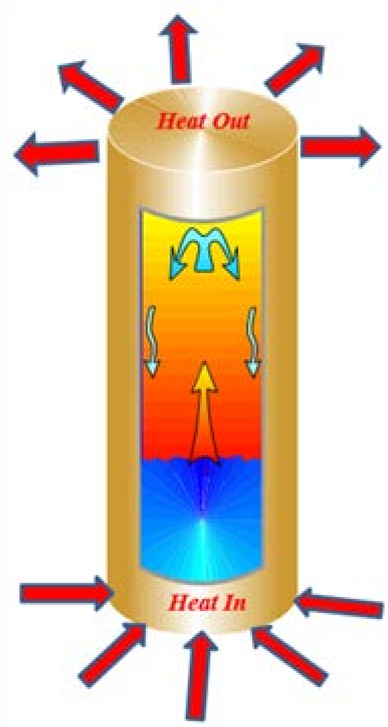


Background:

HVAC systems are often designed to supply a constant discharge air temperature from an air handling system to maintain comfort in the space. Some HVAC systems, especially those that have strict space humidity requirements, should be controlled for a constant discharge air dew point temperature (or maximum discharge air dew point) in addition to controlling to a set discharge dry bulb temperature. Wrap-around heat pipe systems, especially controllable wrap-around heat pipe systems, can be an effective tool to help meet these strict space humidity requirements.



Wrap-around heat pipe systems are air-to-air heat exchangers that are installed in the airstream upstream and downstream of a cooling coil. The upstream precool heat pipe shifts the excess sensible cooling capacity off the cooling coil while the downstream heat pipe provides reheat. Wrap-around heat pipes are passive devices that are driven by the difference in thermal energy between the entering hot air and the cold air leaving the cooling coil. This thermal energy affects a phase change of the refrigerant in the tubes which drives the flow of refrigerant between the two heat pipe sections. As warm air enters the precool heat pipe, refrigerant changes phase from liquid to vapor extracting heat from the air stream thus lowering the air temperature. Refrigerant then flows naturally to the reheat section where it condenses and releases the energy it absorbed from the precool section to the airstream in the form of sensible heat.

The Challenge:

HVAC systems with strict space humidity requirements typically need to provide air with a dew point that is lower than the dry bulb temperature. Operating rooms and many other applications fall under this category. For this article, let's consider another example:

A space with chilled beams is being served by a dedicated outdoor air system (DOAS). A typical DOAS unit uses an air-to-air heat exchanger to transfer energy between the supply and exhaust air streams, followed by a preheat coil, a cooling coil and supply fan(s). The chilled beams in this example require 55 degree air (the supply air dry bulb set point, SASP) with a maximum dew point of 48 degrees (the supply air dew point set point, SADP). In the typical DOAS system, the chilled water coil will cool the air down to the SADP (48 degrees) to remove the necessary moisture. However, reheat is then required to bring the dry bulb temperature up to 55 degrees, as 48 degrees is too cold for the space. By introducing a wrap-around heat pipe, the heat pipe can be selected to help precool the incoming air, relieving sensible load from the cooling coil, then reheat the air from 48 degrees to 55 degrees, which is exactly what the space requires.

Since the wrap-around heat pipe system is a passive device, there is no means to control the amount of reheat applied to the supply air stream. The heat pipe can only reheat with as much energy as is extracted from the air on the precool side. Therefore, if a heat pipe system is selected for a hot day, the heat pipe will underperform on a cool day when the entering heat energy is lower and supply colder air than is needed to the space. If a heat pipe system is selected for a cool day, the heat pipe will over-perform on a hot day when the entering heat energy is higher, and supply warmer air than is needed to the space.

The Solution:

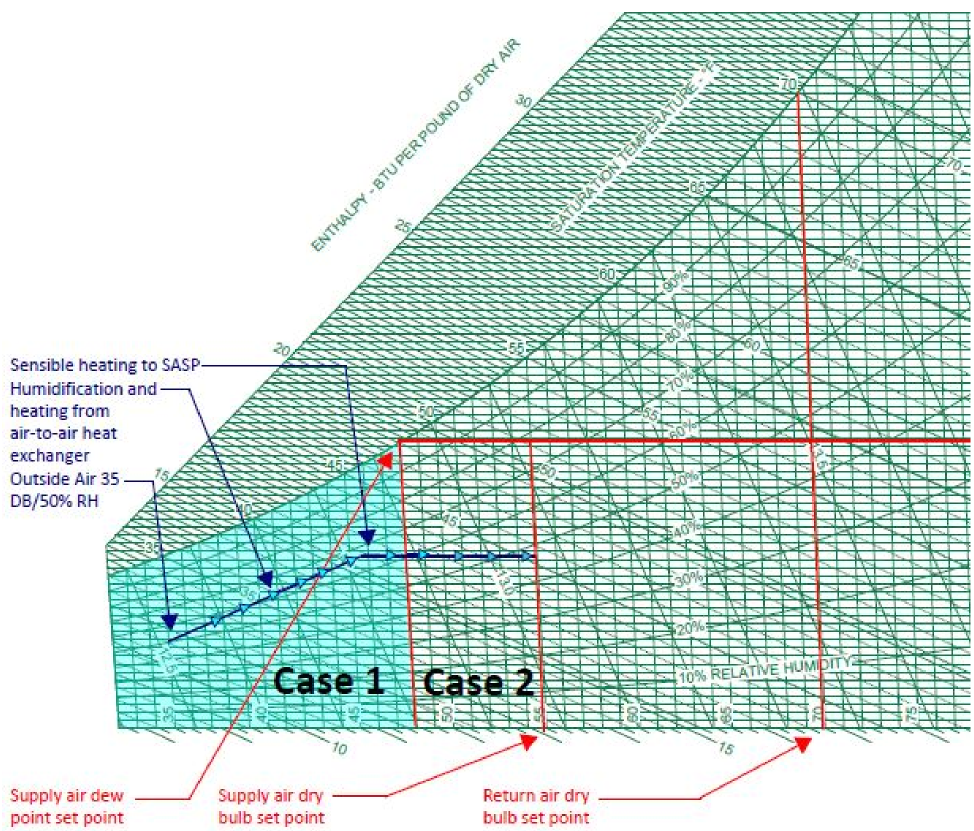
Enter the controllable wrap-around heat pipe. By installing solenoid valves on the refrigerant circuits of the wrap-around heat pipe, the building management system (BMS) can control the amount of refrigerant flow in individual circuits between the precool and reheat heat pipes, and thus effectively control the amount of reheat being applied to the airstream.

In our example, if we select the heat pipe to supply 55 dry bulb/48 dew point air with a 65 degree entering air temperature, for any entering air temperature above 65 degrees, the BMS will stage the solenoid valves closed to prevent overheating of the discharge air. What about other entering outdoor air/humidity scenarios? How would the system be controlled then? The following psychrometric charts portray all possible air condition scenarios and explain how each should most effectively be handled.

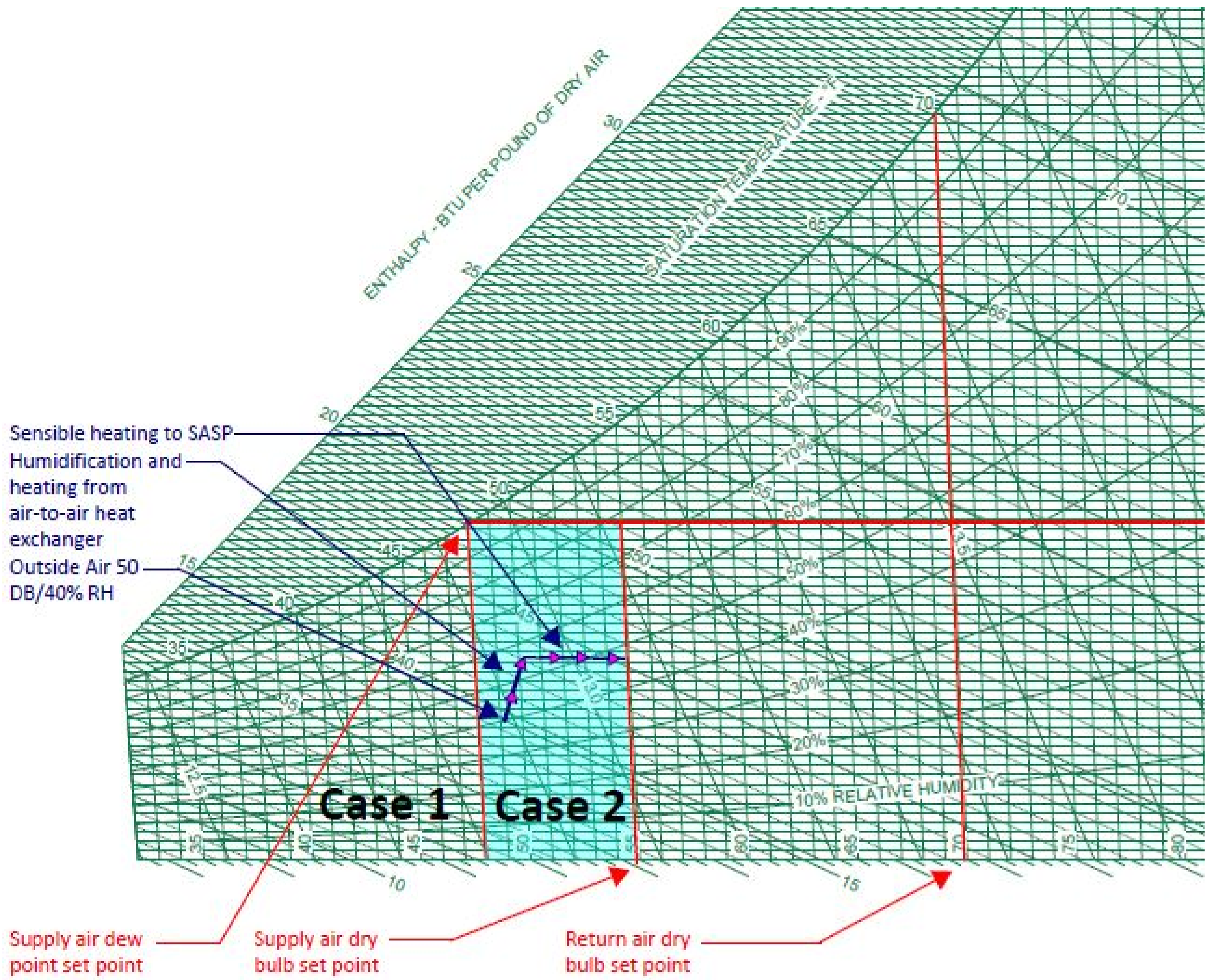
Note: The air-to-air heat exchanger is assumed to transfer total enthalpy for ease of illustration; however the same principles could be applied to a sensible-only energy recovery device.

OADP: Entering outdoor air dew point temperature
OAT: Entering outdoor air dry bulb temperature
SADP: Supply air dew point set point
SASP: Supply air dry bulb set point
RAT: Return air dry bulb temperature from the space to the DOAS

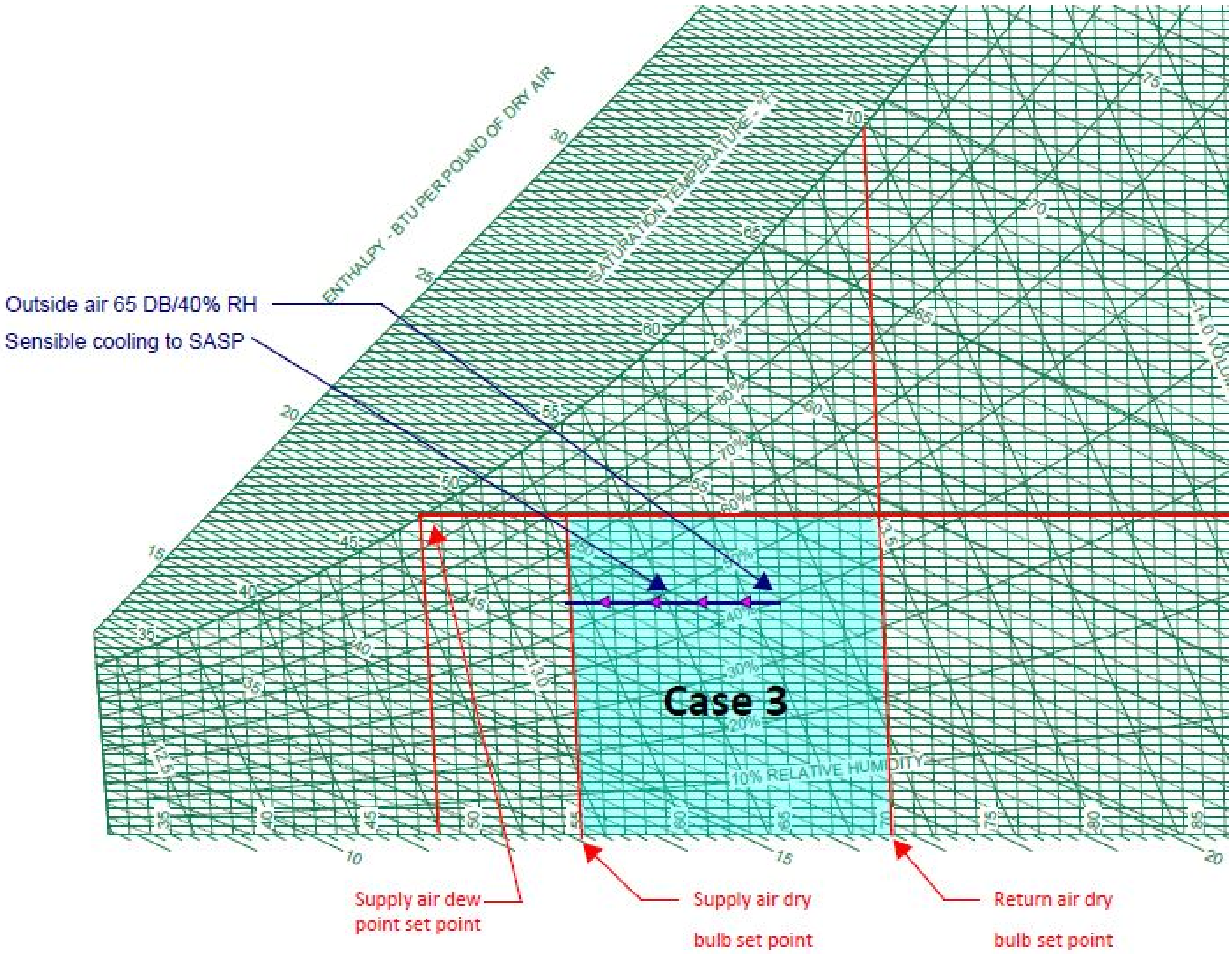
1. **Cold and dry** (OAT < SADP): This is normal heating mode, and the air-to-air heat exchanger and hot water coil will work to reach the supply air dry bulb set point temperature. The heat pipe will do nothing under these conditions.



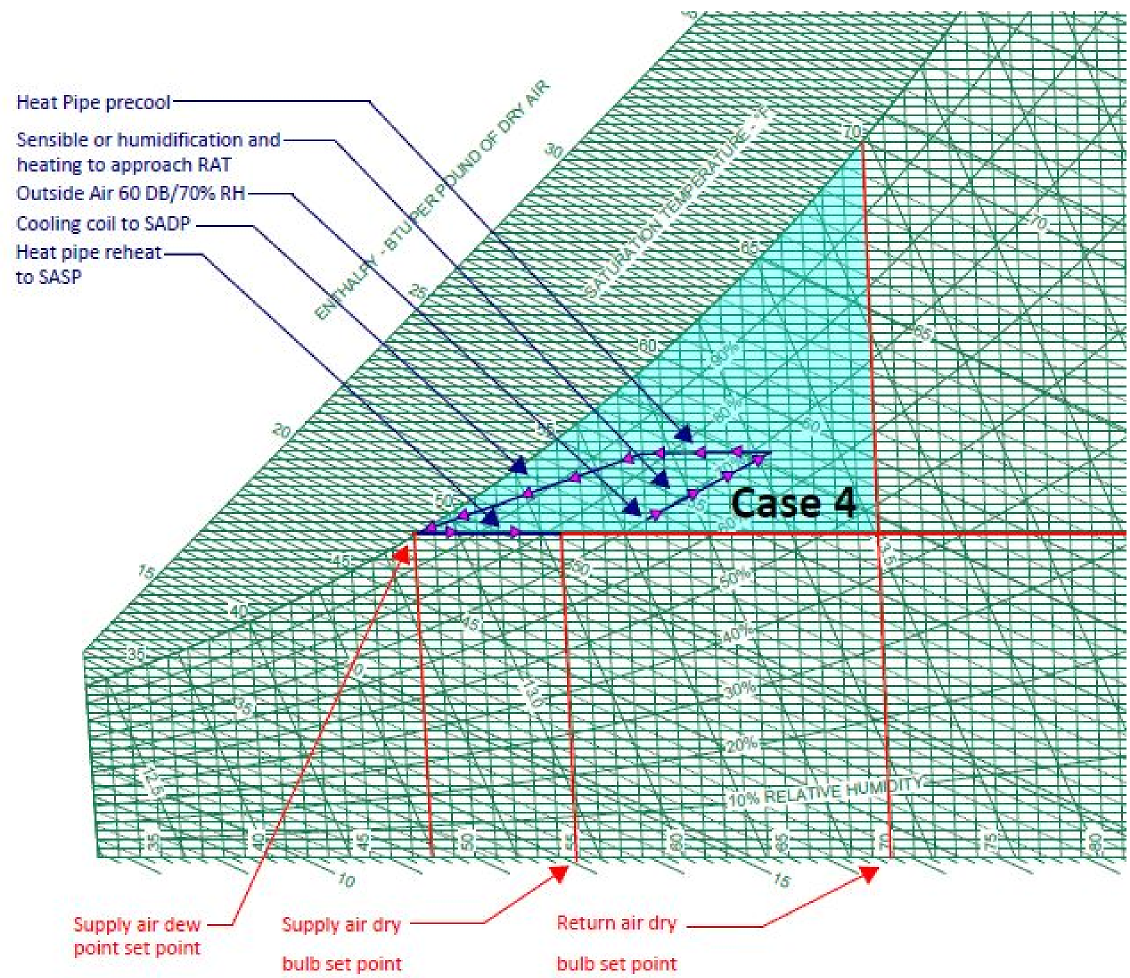
2. **Cool and dry** (OAT < SASP and OAT > SADP and OADP < SADP): This case is for when the outdoor air temperature is between the supply air dew point and dry bulb temperatures, and the air is sufficiently dry to not require dehumidification. As in case 1, the air-to-air heat exchanger and hot water coil will work to reach the supply air dry bulb set point temperature. The heat pipe will do nothing under these conditions.



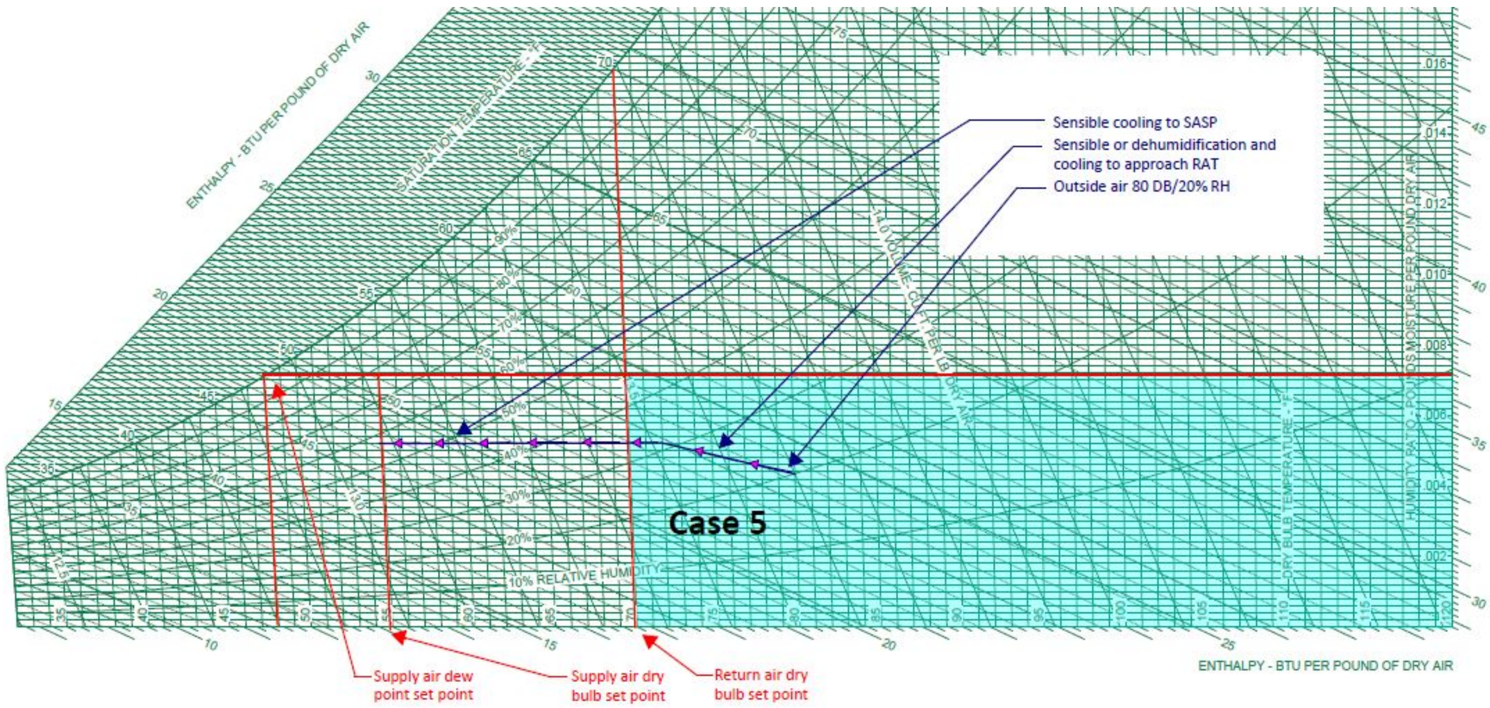
3. **Warm and dry** (OAT < RAT and OAT > SASP and OADP < SADP): This case sees the outdoor air temperature between the supply air set point and the return air temperature. Because the dew point is sufficiently low, dehumidification is not required, the heat pipe and air-to-air heat exchanger can be turned off, and the cooling coil brings the entering air down to the supply air set point.



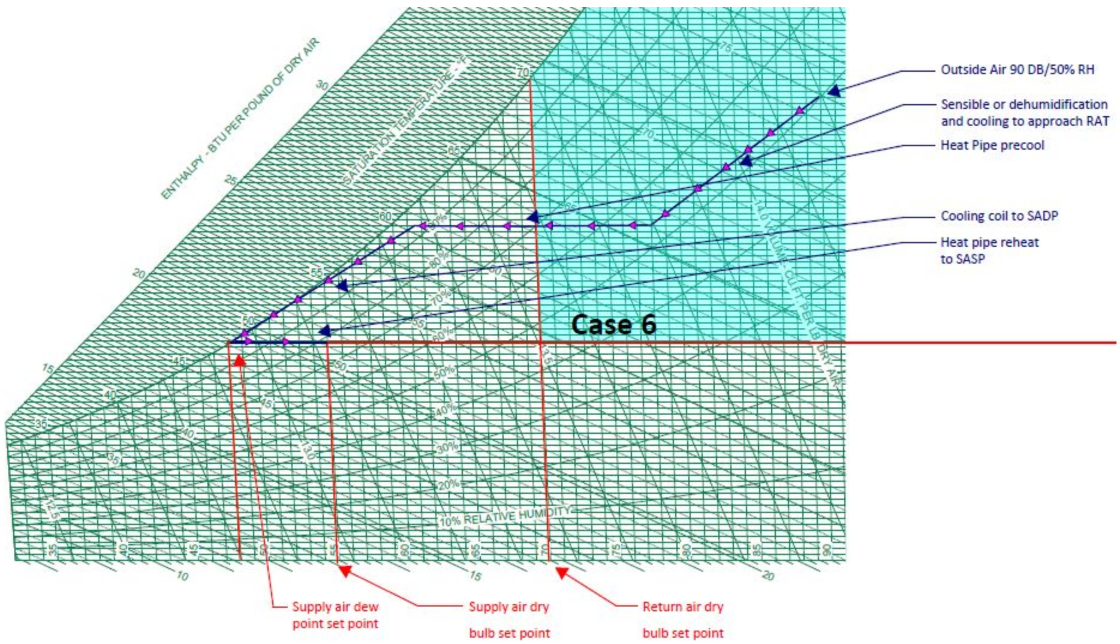
4. **Cool to warm, but humid** (OAT< RAT and OAT > SADP and OADP > SADP): The outdoor air temperature is between the return air temperature and the supply air dew point set point, but contrary to cases 2 and 3, the entering dew point temperature is sufficiently high to require dehumidification. In this scenario, cooling mode is enabled, but the air-to-air heat exchanger operates to bring the entering air temperature as close as possible to the return air temperature to maximize reheat effectiveness. Though this increases the cooling load, the additional reheat savings will outweigh that additional cooling penalty. The cooling coil will work to cool/dehumidify, and the heat pipe can be staged to meet the supply air dry bulb set point.



5. **Hot and dry** (If OAT > RAT and OADP < SADP): The outdoor air temperature is greater than the return air temperature, but because the outdoor air dew point is below the supply air dew point set point, dehumidification is not required. Cooling mode is enabled and the air-to-air heat exchanger precools outdoor air. The heat pipe can be staged off and the cooling coil is used to cool down the air to the supply air dry bulb set point.



6. **Hot and humid** (If OAT > RAT and OADP > SADP): This scenario is for a typical summer day, when full cooling mode is enabled. The air-to-air heat exchanger precools outdoor air and the heat pipe/cooling coil work to cool/dehumidify/reheat supply air. Stage heat pipe solenoid valves closed as required to maintain supply air dry bulb set point.



Conclusions:

With proper application and control of wrap-around heat pipe systems, the example illustrated can be expanded to nearly any system with strict space humidity requirements. Even more common systems where humidity requirements aren't as strict can be accomplished the same way by simply raising the dew point line that separates Cases 1-2-3 from Cases 4-5-6. Although the example did not include mention of humidification requirements, the system can be used in conjunction with a humidification system to effectively raise the humidity in the airstream and space as required. Furthermore, it is worth noting that the larger the outdoor air (ventilation) requirement for the particular air handling system, the more effective the controllable wrap-around heat pipe system will be, as less return air means less opportunity to condition the air by mixing.

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