COOL-VAPOR HUMIDIFICATION

DUCT-WETTING and ENERGY CONSERVATION

The humidification control problems and solutions presented in this paper are not the only way to approach AHU and duct wetting issues. Rather these recommendations have evolved and are presented as a successful design and control methodology that the author has proven to work in actual field applications.

-Jim Durkey – DURAL International, Inc.

1. TYPES OF HUMIDIFICATION - Steam vs. Ultrasonic

***STEAM (HOT VAPOR) – Isothermal Process**

ADVANTAGES:

- -Small Droplet Size (the smaller the droplet size the lower the surface tension: easier to atomize)
- -Provides Latent Heat (advantage if heating space)
- -Plentiful on larger projects
- -Single-wand distribution manifold

DISADVANTAGES:

- -Expensive to operate.
- -Provides Latent Heat (disadvantage if cooling).
- -It takes around 340 Watts to electrically generate 1 pound of vapor

***ULTRASONIC (COOL-VAPOR) – Adiabatic Cooling Process**

ADVANTAGES:

- -Small Droplet Size
- -Lowers Dry Bulb Temp
- -Economical to Operate
- -Provides Free Cooling
- -Electric Utility Rebates are often available
- -It only takes 25 Watts to generate 1# of vapor – this is one-tenth of the electrical energy compared to electric steam generators

DISADVANTAGES:

-Higher up-front cost than electric steam generators
-Requires Deionized Water (which adds to cost)
-Entire unit must be installed in ducts or AHUs
-Provides Cooling Effect (disadvantage if heating)

2. WETTING IN DUCTWORK: Reasons Why Central HVAC Humidifiers Cause Wetting in the AHU or ductwork

*Improper Humidifier Sizing (Maximum size to handle Maximum Load)
*Inability of Cold Entering Air (to humidifier) to hold enough vapor to satisfy space design Relative Humidity.
*Unspecified Dew Point Controller/High-Limit Humidistat Location
*Incorrect Dew Point/High-Limit Humidistat Setting.
*INCORRECT CONTROL STRATEGY

SOLUTIONS TO WETTING

REVIEW THE PSYCHROMETRIC CHART- Can the Mist Be Absorbed?

A. Calculate the Total Humidification Load (#/Hour) and the Ability of the Air to Absorb Moisture:

Total Humidification Load is the amount of moisture that needs to be introduced into the entering air to achieve the specified Space Relative Humidity set-point.

The question then is whether the incoming air at the humidifier can absorb all of the moisture being provided by the humidifier? If it cannot, then the AHU or ductwork will get wet and the designed space will not receive enough moisture to achieve the Relative Humidity set-point.

HOW TO USE THE PSYCH CHART (See chart on page 5)

1. First, on the Psychrometric Chart, locate the Dry Bulb Temperature and Relative Humidity Point of the Entering Air being introduced to the humidifiers. For example, use entering air conditions of 58DB/20%RH. *Label this as Point 1.*

2. Now, determine the amount of Grains of Moisture at that point. Follow the horizontal line over to the Humidity Ratio (Grains of moisture per pound of dry air.

The humidity ratio is also called Specific Humidity). In our example, 58DB/20%RH holds 15 grains. *Label this as X1.*

3. Next, locate the Dry Bulb temperature and RH point for the designed space condition. For example, use a standard room design of 72DB/40%RH. *Label this as Point 3.*

4. Then determine the amount of Grains of Moisture at that point by following the horizontal line over to the Humidity Ratio. In our example, 72DB/40%RH holds 47 grains. *Label this as X3.* 47 grains is the total grains of moisture required to reach the room's designed RH set-point.

5. Now comes the important part! Calculate the Grains of Moisture Differential between the Entering Air Condition [P1 & X1] and the maximum and highest level of Relative Humidity allowable in the air of the duct before it saturates and causes wetting. How do we do that?

We recommend using 75% as the highest level of RH in the AHU or ductwork. Call this the Maximum High Limit Load (Max H.L. Load). If the Grains at Max H.L. Load are equal to or higher than the Grains of moisture for the Design Space Condition (X4), then there is no problem--the air in the duct can absorb all of the mist being produced by the humidifier.

NOTE: Max H.L. Load is the capability of the Entering Air to absorb mist up to the High-Limit setting of a High-Limit Humidistat. This should be a Maximum of 75%RH.
(Setting the High Limit above 75%RH risks the momentum effect of the mist attaining saturation faster than the Humidifier Controls can respond as they try to back down the humidifier. This results in wetting.)

REMEMBER: When using a Psych Chart to find the Max H.L. Load, Steam humidification vertically tracks the dry bulb line (Isothermal); Cool-Vapor Ultrasonic humidification (Adiabatic Cooling) tracks the wet bulb line up to the left.

6. To find the Max H.L. Load point for ultrasonic humidifiers, follow the Wet Bulb line up to the left from Point 1 until you reach 75%RH. In our example, the Max H.L. Load point is at 46DB/75%RH. *Label this Point 2.*

7. Then determine the amount of Grains of Moisture at that point by following the horizontal line over to the Humidity Ratio. In our example, 46DB/75%RH holds 35 grains. *Label this as X2.*

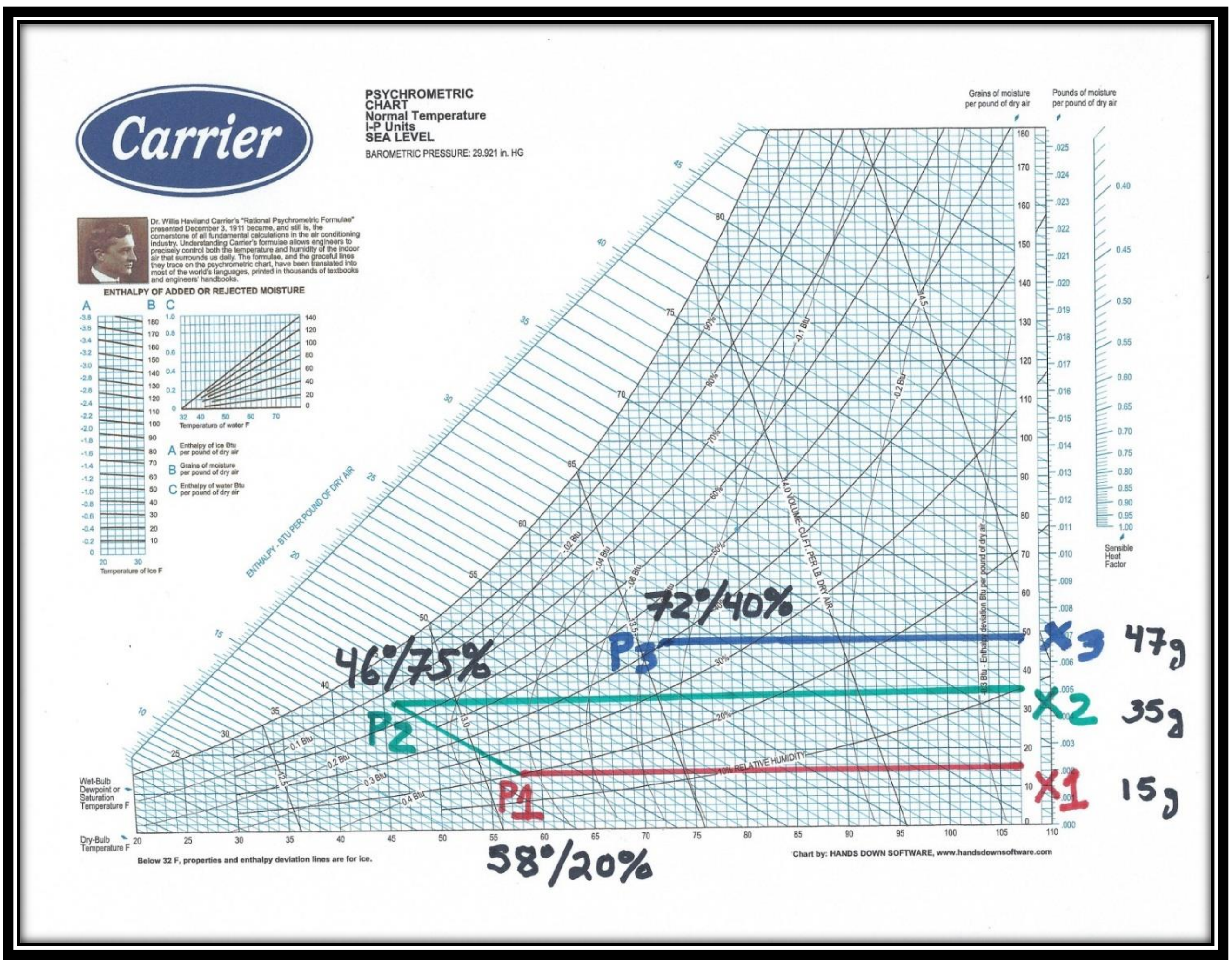
8. Now, compare the EAT Max H.L. Load Grains to the Total Humidification Grains required for the room. Here, the Max H.L. Load (X2) is 35 Grains, which is *less* than the Total Load (X4) of 47 Grains. This means that the entering air at

the humidifier cannot absorb the full amount of moisture necessary to achieve the designed space condition. The air can only hold 35 Grains of water so the remaining Grains – if supplied at Point 1 -- will fall out and wet the duct.

9. If the entering air cannot hold enough grains of moisture to achieve the Total Load conditions for the Space, then one of two procedures should be followed:

> 1. Increase the Entering Air Temperature (EAT) to the humidifier by using already-paid-for space or economizer air (Ex: heat wheel, runaround loop, etc.) This is preferable for Energy Savings versus using costly Reheat.
>
> OR
>
> 2. Supplement the Baseline humidification capacity by placing humidifiers in the Space.

Psychrometric Chart



HOW MUCH HEAT OR MOISTURE IS NEEDED?

First Let's Calculate the Various Loads in Our Example Using a 10,000 CFM Model with the Standard Specific Volume of Air-

***Assumptions:**

-Space Design Condition: 72DB/40%RH (Point #4 on Chart)
-EAT: 58DB/20%RH (Point #1 on Chart)
-Supply Air (100% OSA): 10,000 CFM
-Specific Volume of Air (Vs): 13.5 cf at 70DB/50%

(Note: 13.5 cf is a standard of design and can be used in most applications)

***Calculations:**

a.) REQUIRED HUMIDIFICATION LOAD

-TOTAL LOAD (#/Hour) = [CFM x 60 Minutes/Hour x (X_4 – X_1)] / [Vs x 7,000 grains/lb.]

--TOTAL LOAD (#/Hour) = [10,000 x 60 Minutes/Hour x (47 Grains–15 Grains at EAT)] / [13.5 x 7000]

---TOTAL LOAD = [600,000 x 32 Grains/ 94,500]

----TOTAL LOAD = 203 #/Hour

This means that the Space needs 203#/hr of moisture to meet its designed condition of 72DB/40%RH.

b.) MAX H.L. LOAD

-MAX H.L. LOAD (#/Hour) = [CFM x 60 Minutes/Hour x (X_2 – X_1)] / [Vs x 7,000 grains/lb.]

--MAX H.L. LOAD (#/Hour) = [10,000 x 60 (35 Grains-15 Grains)] / [13.5 x 7,000 grains/lb.]

---MAX H.L. LOAD = [600,000 x 20 Grains / 94,500]

----MAX H.L. LOAD = 127 #/Hour

This means that our entering air at the humidifiers can only absorb 127#/hr of moisture before wetting occurs. It also means it is impossible for the central HVAC humidifiers to provide the needed humidity to the Space unless changes are made to the system.

c.) DIFFERENTIAL LOAD

-DIFFERENTIAL LOAD = TOTAL LOAD minus MAX H.L. LOAD

--DIFFERENTIAL LOAD = 203 #/Hour – 127 #/Hour

--DIFFERENTIAL LOAD = 76 #/Hour

This means that the Differential Load must be made up either in the space with room humidifiers or by adding building heat to the EAT at the central HVAC humidifiers.

Let's Look at Adding Heat to the Air at the Humidifiers:

1. Go to Point 4 (the design condition)on the Psych Chart to find the Design Conditions for the Space. Draw a line from Point 4 along the Enthalpy Line -- down to the right -- until it intersects with the horizontal line that you previously drew from Point 1 (E.A. Condition). At that intersection, go straight down to find the required temperature for evaporating the Total Load of moisture. In our example, this is 90DB. Label this intersected point- Point 3. Now, how much heat is required to raise the EA temperature of 58DB up to 90DB?

BTUH = 1.085 x CFM (90DB – 58DB)
BTUH = 1.085 x 10,000 (90DB – 58DB)
BTUH = 347,200 BTUH (from existing building heat)

So if 347,200 BTUs/hr of heat is added to the entering air, then that air will be able to absorb all of the humidifier moisture needed to achieve the design conditions in the space.

As an Alternative, Let's Look Instead at Humidifiers in the Space:

If it is not feasible to introduce more heat into the EA, then the differential load of 76#/hr can be addressed by introducing 76#/hr of moisture directly into the space using wall mounted or free-standing humidifiers.

HUMIDIFIRST offers a variety of in-space misting and mist-free humidifiers for this type of application.

HUMIDIFIER DESIGN & SELECTION

1. Select an AHU/DUCT Ultrasonic Humidifier System that is large enough to meet the Max H.L. Humidification Requirement. To avoid wetting, never install more humidifiers than are necessary for this Max H.L. Load.

Several important factors should be considered at this point:

a.) Design the Ultrasonic Humidifier System to maximize the number of humidifier modules, bearing in mind space and cost limitations. The goal is to meter the vapor into the airstream without wetting.

b.) Locate the Ultrasonic Humidifier Modules in the center of the airflow to allow air to pass through and around the humidifiers.

c.) If the building has rooms or spaces that are controlled separately, each control zone must have its own Humidifier Control Panel to receive separate and distinct signals from the BAS.

d.) Optimal Air Velocity over the Ultrasonic Humidifiers is 800 Feet per Minute (FPM). Air speed should not exceed a Maximum of 1,200 FPM. Minimum Air Velocity over the humidifiers must not drop below 350-400 FPM as transducer damage may occur.

ACCESS DOORS WITH PLEXIGLAS VIEWPORTS

An access door with a Plexiglas Viewport should be installed at the humidifier section and also at the High-Limit Humidistat location. (Typically high limit RH sensors are located 15'-25' downstream of the humidifiers. Placement is dependent upon the design and performance of the AHU system)

If the Vapor is forming up and flowing past the high limit location, (i.e., the vapor is bypassing the sensing probes), then the High-Limit Humidistat must either be adjusted to read the vapor or moved to a new location.

View Ports are an excellent way to inspect real-time humidifier performance and vapor patterns. Without a View Port, an access door must be opened for inspection purposes, resulting in the disruption of normal air patterns inside the AHU system.

CONTROL SET-UP

In order to eliminate costly interfaces (such as BACNET, MODBUS, TECNET, etc.), the Building Automation System (BAS) should be the MASTER Humidification System Controller and the Ultrasonic Humidifier System becomes the SLAVE.

A SINGLE LOW-VOLTAGE PAIR of WIRES connects from the BAS to EACH of the Ultrasonic Humidifiers (or, in the case of humidifiers set up with individual stages, a pair of wires connects to each stage of a multi-stage humidifier).

ALL Sensors (space, high-limit, dew point) shall be provided by the Control Contractor. This allows for ease of interface to the BAS and less confusion during installation, plus streamlined trouble-shooting.

CONTROL METHODOLOGY

1. When the Space requires humidity, the BAS sends a 0-10 Volt signal to the Ultrasonic Humidifier Control Panel (UHCP). In turn, the UHCP sends a signal – depending on the strength of the voltage -- to control the Ultrasonic Humidifiers that are being activated by the BAS.

The BAS determines which Ultrasonic Humidifiers should operate (via an activation signal on the connected wire pair from the BAS). The BAS algorithms determine which humidifier stages, or combination of stages, need to be activated. For example, a humidifier system consisting of a rack of 4 humidifiers can be staged by the BAS so that only one humidifier operates, or two, or three, or four, as required.

2. Typically, after the BAS signals the first humidifier stage to come on, the BAS must then monitor the High-Limit RH Sensor to verify that the duct is dry, i.e., measuring less than the 75% Relative Humidity equivalent.

If the sensor is dry, a time delay of Fifteen Minutes should pass before the BAS sends an additional signal to activate the next humidifier stage.

After the BAS activates the second humidifier stage, it must again monitor the High Limit Sensor to make sure that the duct is dry and has not been overwhelmed with vapor. If dry, then another Fifteen Minute Delay should pass before an additional stage is activated. This Check-and-Wait process must be repeated before each additional stage is activated.

NOTE: EACH signal from the Space that calls on the BAS to send more humidity MUST BE SUBSERVIENT TO A DRY CONDITION AT THE HIGH LIMIT RH

SENSOR. (This is critical to maintaining space humidity requirements because once the High Limit Sensor gets wet, control of the humidifiers becomes very difficult-- the humidifiers start backing down while the space calls for more moisture!).

SUMMARY

1. It is very important that the Ultrasonic Humidification System is designed as a SLAVE to the BAS. Whenever the BAS sends a 0-10 Volt signal to the Ultrasonic Humidification Control Panel, the UHCP sends out a pulse-width modulation signal – depending on the strength of the 0-10 Volt signal – that will be sent to ONLY those humidifiers that have been selected to operate by the BAS.

2. The Consulting Engineer's Commissioning Agent must verify that the High Limit RH Sensor stays dry throughout the Humidification System's Operational Range. This may require additional jobsite visits during seasonal changes, especially on 100% Outside Air systems.

NOTE: Access doors with Plexiglas Viewports should be installed BOTH at the humidifier location and the High-Limit Humidistat location (or Dew Point Controller location) in order to observe mist flow without disturbing the airstream.

If mist is bypassing the High-Limit Sensor and precipitating out downstream (or upstream), the High-Limit Sensor should be moved to a place where it "sees" the mist and can back down the humidifiers before wetting occurs.

3. Finally, given the variety of designs, physical limitations and applications in the field, the methodology set forth in this paper cannot be considered foolproof. However, it has been proven to work, and it offers the consultant an approach that helps prevent expensive and frustrating trouble-shooting problems that result from trying to force too much humidification vapor into airstreams that simply cannot absorb it.