CAREL

Case Study

Automotive Paint Booth Humidification Using

humiFog

Photo from Nissan Motors website. Photo from ABB website.

THE CHALLENGE

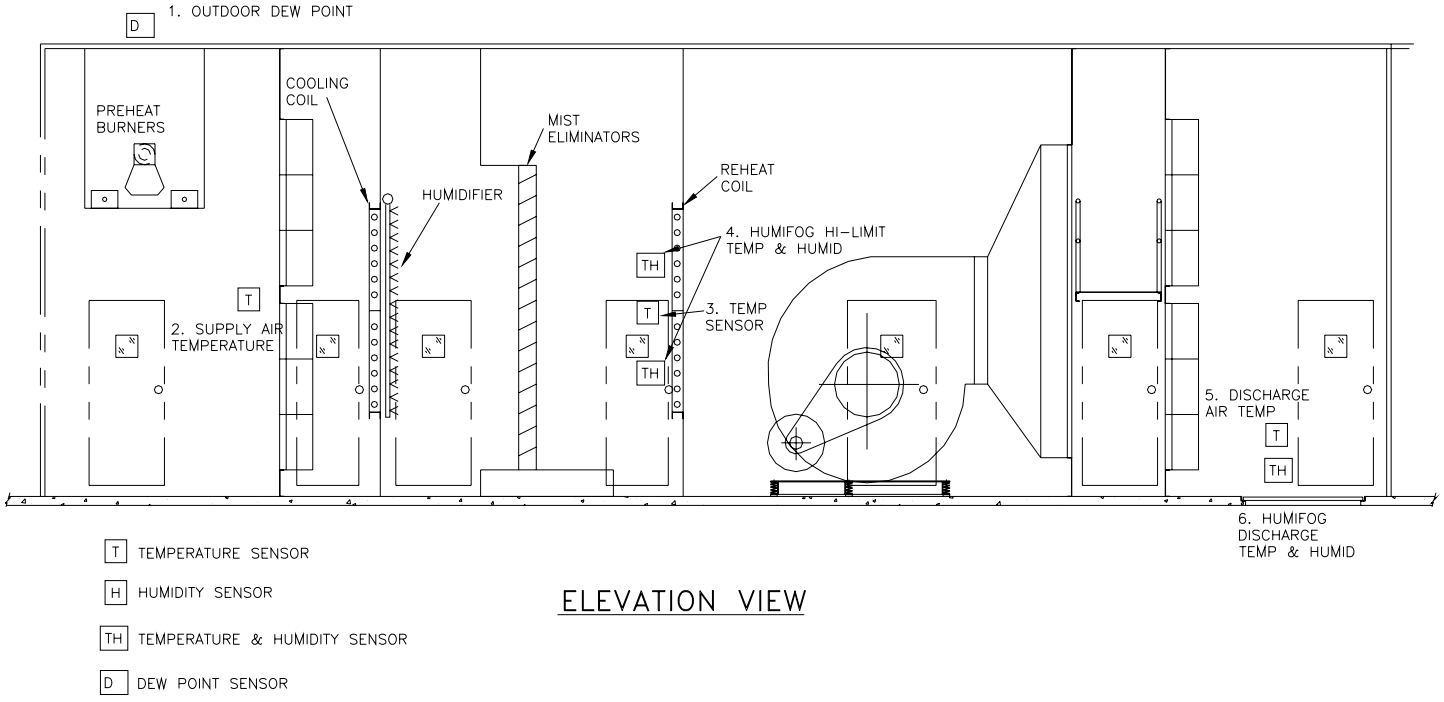
Humidification in most automotive paint booths has traditionally been accomplished by water spray coils or trickle-through paper media located in the air houses serving the paint booths. The leaders in the automotive industry are constantly looking to improve the quality of their paint and painting process, recently arriving at the need to maintain a higher degree of accuracy in the control of temperature and humidity.

The desired stable paint booth conditions are typically 70 to 75°F & 65 to 75%RH. In this case study, the automobile manufacturer contracted with Gallagher-Kaiser Corporation of Detroit, Michigan to rebuild their aging paint booth air handlers and provide a higher degree of control of the air quality delivered to the paint booths.

Only the blower would remain. The rest of the air house would be rebuilt in stainless steel with new preheat burners, coils, filters, walls and floors. Additionally, something better than a cardboard humidifier was desired – and necessary.

Air House Specifications:

Manufacturer:	Gallagher-Kaiser (custom built)
Air Volume:	90,000 CFM
Outside Air:	100%
Supply Air Specifications:	65 to 75°F & 65 to 75%RH
Water Supply:	Low Grade Deionized Water, 2 micromhos conductivity
Set Point Control:	From General Electric Fanuc controller
Preheat:	2 stage, modulating natural gas burner
Cooling:	2 bank chilled water coil – modulating
Reheat:	2 bank hot water coil – modulating
Filtration:	90% primary bag filters, 95% post bag filters
Controls:	General Electric Fanuc / variable frequency drive



ELEVATION VIEW

The new ***HumiFog*** humidification system was to be installed after the cooling coil and prior to the reheat coil.

THE CAREL HUMIDIFIER SOLUTION

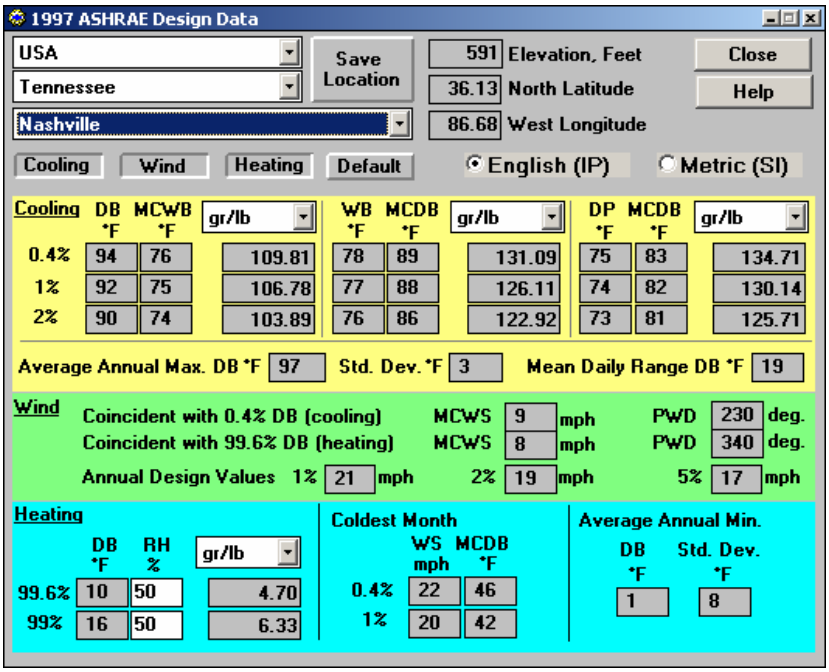
Gallagher-Kaiser reviewed several systems and settled on the CAREL ***HumiFog*** pressure atomizing system because:

- All stainless steel construction (pump, nozzles, manifolds, control cabinet, etc.)
- Cascading Sequential Staging (CSS) which gives excellent turn-down and overlapping staging
- Extensive diagnostics that protect the pump, motor, VFD, and monitor for leaks or clogs
- Connectivity: BacNET, ModBus, Lonworks, TCP/IP are all available
- CAREL's extensive technical background and history of successful atomizing installations
- 100% silicone free construction, able to operate with 18 meg-ohm deionized water.

It seemed that the ***HumiFog*** system would have the best chance of achieving the high level of humidity with the precision required (+- 5%RH).

CAREL USA then became involved and immediately conducted a full analysis of the system requirements versus the weather data for the Smyrna area. Since the air handlers were to be 100% outside air, the outdoor conditions would be the deciding factor both in the amount of humidification required, and the technology to be used to achieve the desired precision. In Smyrna, temperature and humidity can range from 25°F to 60°F in a single day. The humidifier system would have to accommodate these swings and provide a consistent 75°F & 65%RH to the paint booth at all times.

The weather data for Smyrna, TN shows a yearly temperature & humidity range of 10°F & 50%RH to 94°F & 50%RH.



The manufacturer desired stable paint booth conditions at 70 to 75°F & 65 to 75%RH. At the worst condition, which would be 75°F & 75%RH in the paint booth when the outside air conditions were at 10°F & 50%RH, the humidification system would be required to raise the moisture content of the final discharge air to the booth from 0.24 grains per cubic foot to 7.17 grains per cubic foot.

With 90,000 CFM of outside air per air house, the humidification load then worked out to 5,348 lbs/hr:

$$5{,}348 \text{ lbs/hr} = \frac{90{,}000 \text{ CFM} \times 60 \text{ min. per hour} \times 6.93 \text{ grain per CF}}{7000 \text{ grains per pound}}$$

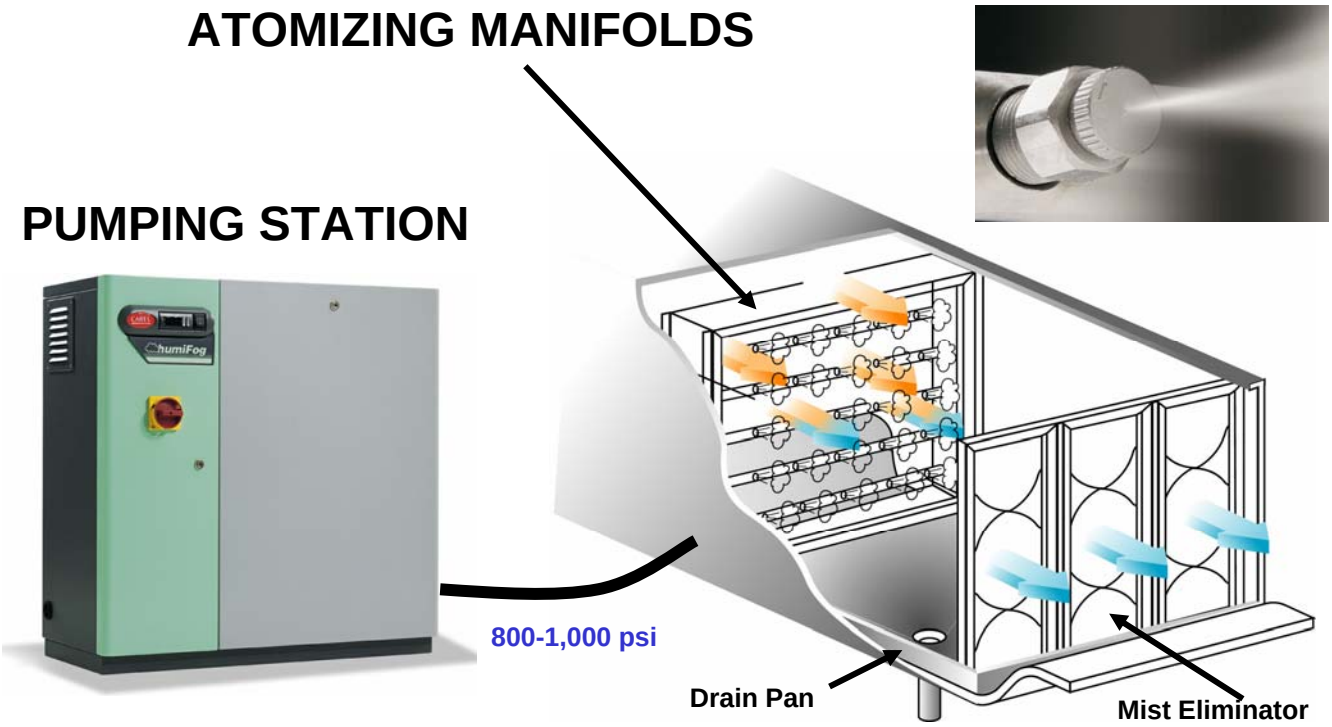
Using Smyrna weather data, it was determined that the humidification system would be in operation 2597 hours per year.

The technologies available were direct steam, electric steam, air/water atomization, or evaporative media. To humidify with steam would require over 6 million BTUs of energy at peak load. Electrically this would be 1,780 kW of power. Air/water atomizing would require a 200 hp compressor. Evaporative media could not provide the precision required and would have lengthy lead and lag operation. ***HumiFog*** seemed to be the logical choice.

CAREL then designed a ***HumiFog*** pressure atomizing system using 23 manifolds, interconnected to provide 18 active stages with 5,500 lbs/hr capacity and approximately 50:1 turn down.

HumiFog System Specifications:

System Capacity:	5,500 lbs/hr
Number of Atomizing Manifolds:	23, stainless steel
Number of Stages:	18, some interstaged
Number of Atomizing Nozzles:	667 @ 8 to 10 lbs/hr each
Mist Eliminators:	CAREL, non-hygroscopic, open mesh, low pressure drop, bacteriostatically treated media, 0.1" w.c. pressure drop @ 500 fpm
Pump Motor:	Toshiba high performance, 7.5 hp, TEFC, frame 213T
Pump:	CAT 1051 with prefilters
Electrical Characteristics:	460/3/60 Vac, 11 Full Load Amps
Variable Frequency Drive:	General Electric Fuji AF-300P11
System Turn-down:	50:1 Cascading Sequential Staging (CSS)
Controls:	CAREL pCO2 + pCOe expansion + pCOUMID
Control Inputs:	Set Point from General Electric Fanuc system, control to supply air, CAREL ASDC1 sensor. Carel temperature, pressure sensors used throughout.



The ***HumiFog*** system operates by boosting water pressure to 1,000 psi and feeding it to special atomizing nozzles that break the water up into 10 micron droplets that are then discharged into the surrounding air for evaporation. The advantage of the ***HumiFog*** over other types of atomizing systems for this application are that it produces very small droplets with very low energy consumption (1.8 Watts per pound of water per hour). In this case, the system uses only 7.5 hp for 5500 lbs/hr output versus and air/water system that would require at least a 200 hp air compressor. Assuming that ½ of the 2597 operating hours per year are at half load, at $0.08 per kW-hr, that means a savings of $14,900 per year using ***HumiFog*** instead of an air/water system.

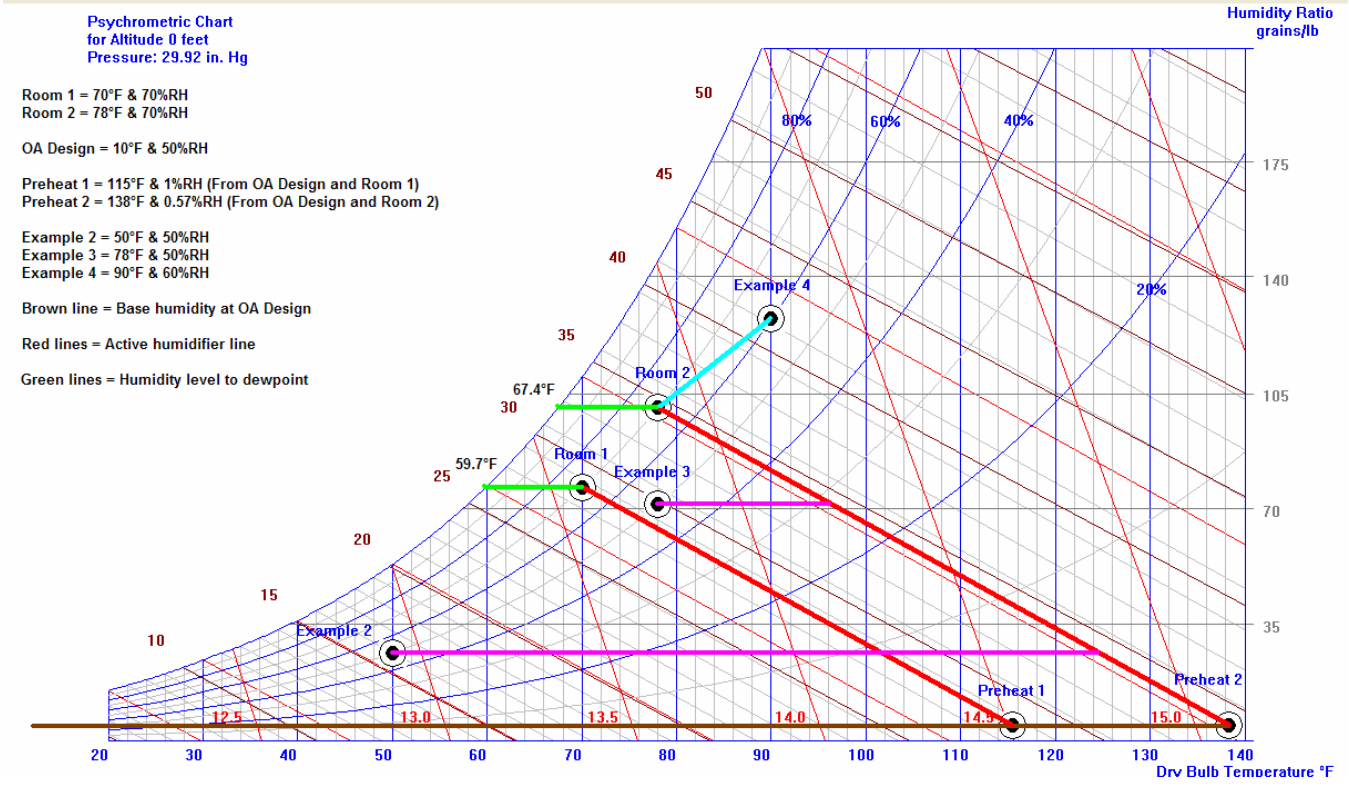
NOTE: Carel also manufactures air/water atomizing systems (***MC***), so the decision to use ***HumiFog*** was based purely on economics and required results.

HumiFog pumping station

Live mist raising the relative humidity of the air

In designing the ***HumiFog*** system for the project, Carel considered that all systems had to be integrated to work together, since ***HumiFog*** is an adiabatic type system that cools the air as it humidifies, at the rate of 970 BTU/lbs/hr of humidifcation. In fact, it requires 970 BTU to evaporate one pound of water, regardless of the technology. With steam (isothermic) humidifiers, there would be a heat gain to the air stream of about 180 BTU/lbs/hr of humidifier capacity. The overall enthalpy would increase by 1150 BTU/lbs/hr, increasing the load on the cooling system.

Adiabatic type humidifiers (atomizing) operate at “constant enthalpy” and thus follow the constant enthalpy line on the psychrometric chart. So, dry bulb temperature decreases and enthalpy (wet bulb) remains the same. On the following chart, the ***HumiFog*** atomizing system works on the red lines stretched from “Room 1” to “Preheat 1” for a set point of 70°F & 70%RH, and from “Room 2” to Preheat 2” for a set point of 78°F & 70%RH.



The brown line at the bottom is stretched from the minimum outside air condition of 10°F & 50%RH to the various starting preheat conditions. Accordingly, you can see that on the coldest day a preheat of 115°F would be needed to achieve 70°F & 70%RH, and a preheat of 138°F would be needed to achieve 78°F & 70%RH.

Example 2 shows an outside air condition of 50°F & 50%RH. Here you would need a preheat of about 101°F to achieve 70°F & 70%RH and 125°F to achieve 78°F & 70%RH. Just follow the purple line across page horizontally.

Example 3 shows an outside condition of 78°F & 70%RH. Here you would need to humidify and cool at the same time to reach a set point of 70°F & 70%RH. To reach a set point of 78°F & 70%RH, you would need to reheat to about 96°F and then humidify.

Example 4 shows an outside condition of 90°F & 60%RH. This condition would require you to cool and dehumidify to either set point.

The green lines show the dew points at either set point, ie: 59.7°F for 70°F & 70%RH, and 67.4°F for 78°F & 70%RH.

When atomization is used, control of the surrounding HVAC systems (preheat, cooling, reheat) becomes absolutely critical to the overall success and precision of the system, since the energy for evaporation must be provided by the air stream.

THE CAREL CONTROL SOLUTION

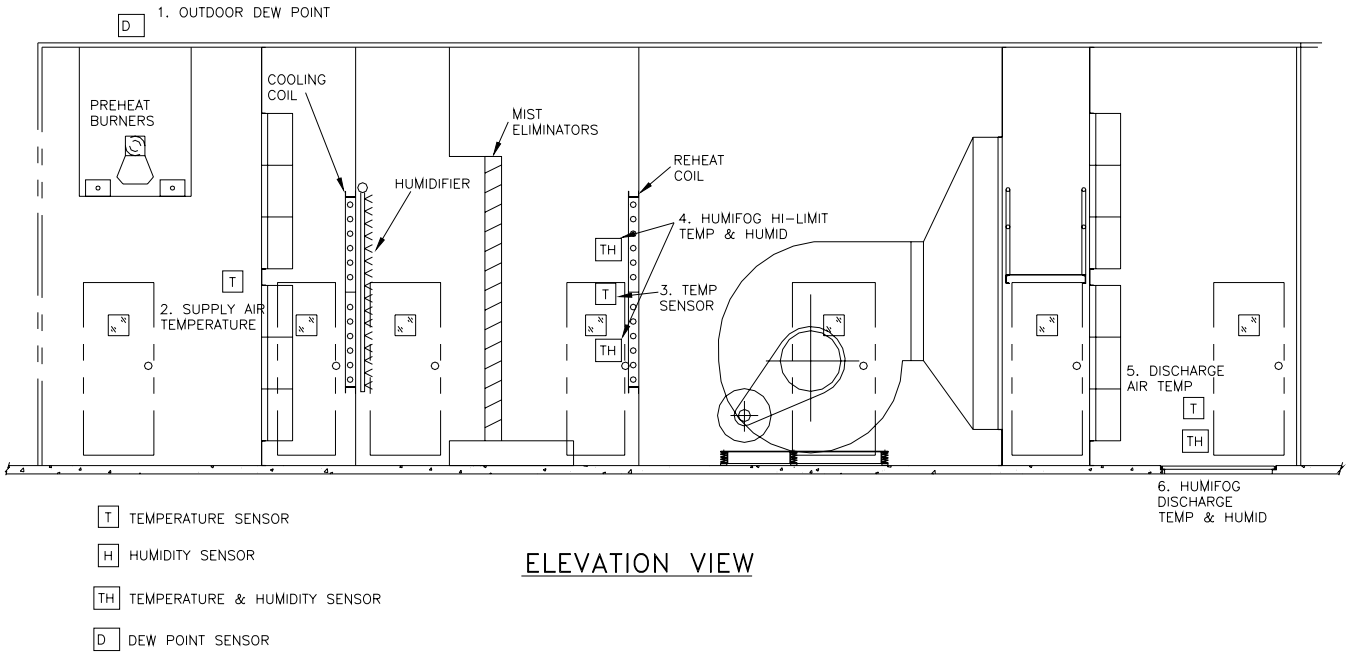
Carel used its own pCO2 series programmable controller so that the pumping station and atomizing manifolds could be fully integrated and monitored.

pCO2 is a high speed, precision controller with extensive connectivity capability (ModBus, BacNET, LonWorks, TCP/IP, etc.)

The software, written also by Carel, provides for full integration to the existing GE Fanuc control system.

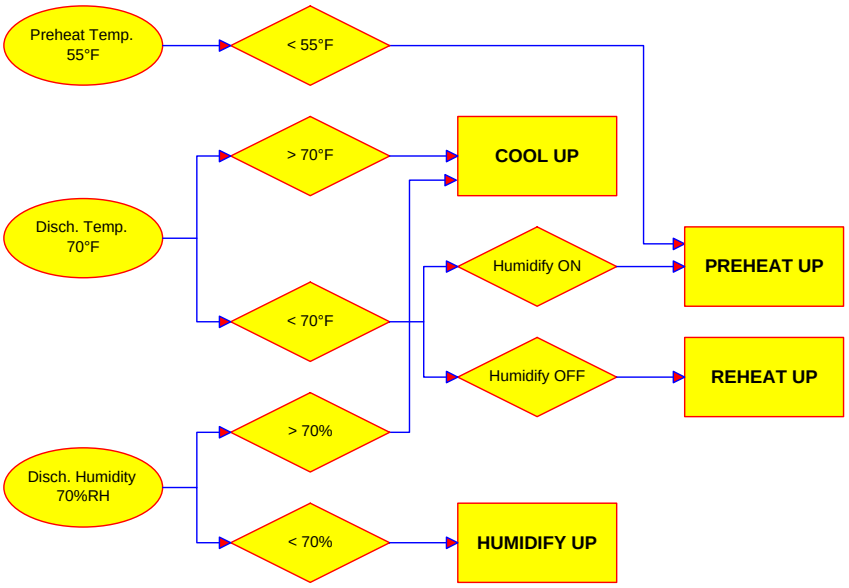
CONTROL SEQUENCE

The following sketch shows the location of all sensors. Sensors provided by CAREL are noted as "***HUMIFOG***" sensors.



ELEVATION VIEW

Graphically, the Sequence of Operation is as follows:



Written Sequence of Operation would be:

1. Preheat temperature set point of 55°F (at sensor # 2)
    a. If the preheat temperature falls below 55°F (sensor # 2), ramp the preheat burner UP to meet the set point (55°F).
    b. If the preheat temperature rises above 55°F (sensor # 2), ramp the preheat burner DOWN to meet the set point (55°F).
2. Discharge air temperature set point of 70°F (at sensor # 5)
    a. If the discharge air temperature rises above 70°F (sensor # 5), ramp the cooling UP to meet the set point (70°F).
    b. If the discharge air temperature falls below 70°F (sensor # 5)
        i. If the ***HumiFog*** system is **humidifying** (digital input closed to GE), ramp the preheat burner UP to meet the set point (70°F).
        ii. If the ***HumiFog*** system is **not humidifying** (digital input open to GE), ramp the reheat UP to meet the set point (70°F).
3. Discharge air humidity set point of 70%RH (sensor # 6)
    a. If the discharge air humidity falls below 70%RH (sensor # 6), the ***HumiFog*** system will begin to ramp up its stages and close a digital output to indicate to the GE system that it is in operation. The ***HumiFog*** system will automatically stage up as needed to achieve the 70%RH discharge condition (sensor # 6).
    b. If the discharge air humidity rises above 70%RH (sensor # 6), ramp the cooling UP to meet the set point (70%RH).

Of course there are a few proprietary things going on as well to insure high accuracy and extensive diagnostics of any system problems:

- High/Low water feed pressure
- High/Low water manifold pressure
- Variable Frequency Drive failure and auto reset
- High/Low discharge humidity
- Sensor failures
- Mircroprocessor self-diagnostics

Carel's OEM controls expertise is what makes the ***HumiFog*** more than just another high pressure system.

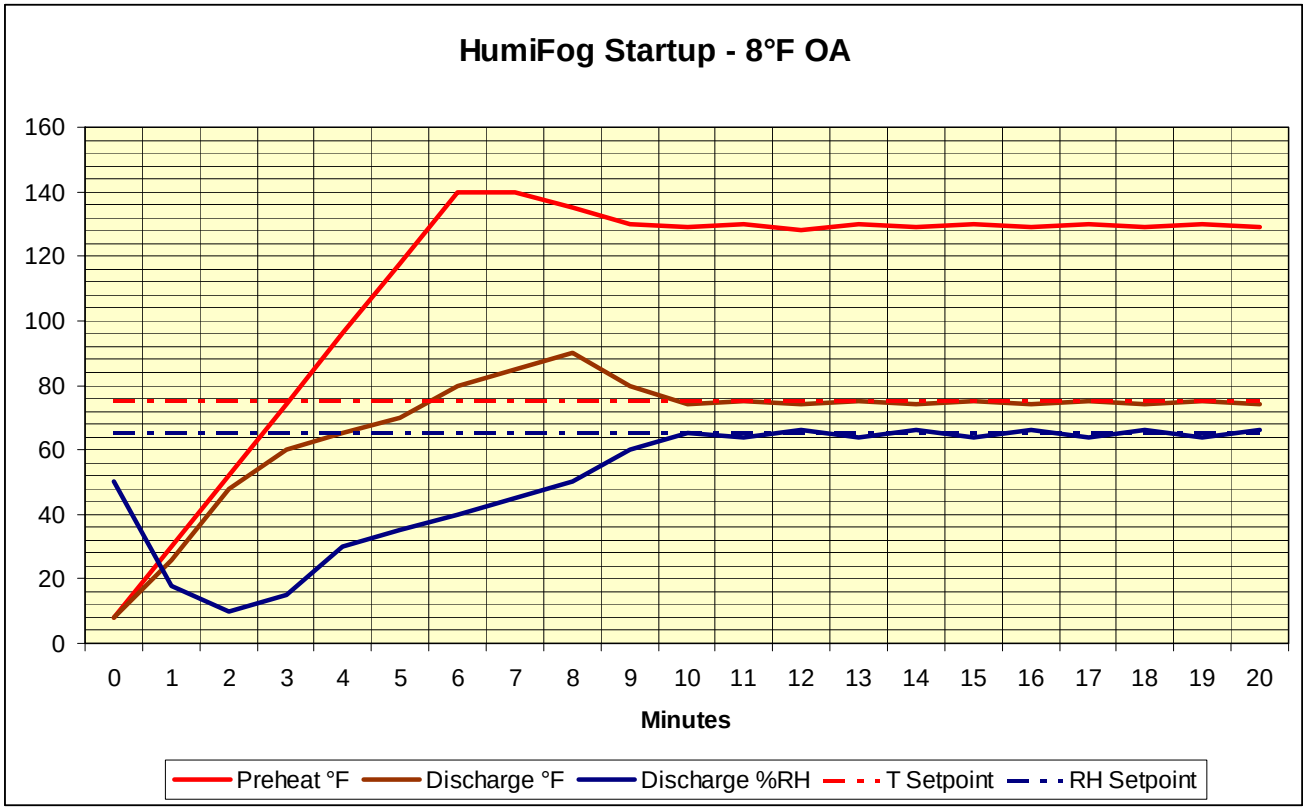
Remember, when it comes to humidifying paint booths, it truly is the *little* numbers that count:

- +-1%RH
- 1.8 Watts/lbs/hr

RESULTS +

The ***HumiFog*** system has operated with a precision previously unknown in this industry, achieving set point in 10 minutes from cold startup, and then maintaining +-1%RH control, with periods as close as +-0.6%RH. Temperature control is maintaining +-0.5°F at these times. Reaction to changes in outside air conditions is totally seamless without any deviation outside of the specified conditions.

From the actual performance graph, you can see that from a cold start, the system comes into specification within 10 minutes and then maintains +-1°F and +-2%RH. If the burner flames out, excursion outside of the specifications is for no more than a 5 minute period.



Starting conditions were 8°F & 50%RH outside air. The system is fully automatic and requires only periodic scheduled maintenance on the pump.

CONCLUSIONS

The CAREL ***HumiFog*** is the right solution at the right time. As more sophisticated paints are used (particularly water borne paints), more accurate humidity control systems are required. The old, simple cardboard pads will no longer provide the precision and reliability demanded.

The CAREL ***HumiFog*** will do for the painting industry, what fuel injection did for the automobile. The real winner will be the customer who buys a product with a perfect paint coating. Contact your local CAREL distributor today and switch to ***HumiFog*** precision humidity control for your paint booths!

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