



Digital Precise Air Control System
D-PACTM



Functionality

Factory Testing

Ease of Installation

Ease of Maintenance

Energy Efficiency

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Total Control

Indoor Air Quality and Comfort

Indoor air quality (IAQ) and occupant comfort are two of the most important factors to consider with any HVAC system design. One of the leading causes of poor IAQ and occupant discomfort is too much moisture in the air, commonly referred to as high humidity. IAQ problems associated with high humidity include mold growth, condensation and increased sickness and allergic reactions. As for occupant comfort, the saying goes “It’s not the heat, it’s the humidity”. Improving indoor air quality and occupant comfort by controlling the humidity and the temperature will help with these problems, boost productivity, and even improve the general well-being of the occupants.

One way to improve IAQ and occupant comfort is with uniform humidity and temperature control. Ideally indoor conditions should remain consistently around 75°F dry bulb and 45% relative humidity. This will keep the occupants comfortable and decrease the likelihood of IAQ issues.

Energy Use

Controlling both temperature and humidity can be very energy intensive. This is because both the sensible (temperature) and latent (humidity) loads require energy from the HVAC equipment to be controlled. With a conventional rooftop unit extra energy is used to satisfy the sensible load during part load conditions because cooling is staged with only a few compressors which will not always match the load. To satisfy the latent load the system must either satisfy the latent load while satisfying the sensible load, include an energy recovery wheel to reduce the outside air load, or there must some form of cooling and reheating to dehumidify the air and avoid over cooling the space. Satisfying the latent load while satisfying the sensible load and including an energy recovery wheel will not control the humidity at all conditions. Cooling and reheating will control the humidity at all conditions, however, it uses extra energy.

The Solution

AAON’s energy efficient rooftop unit solution to improving indoor air quality and occupant comfort

by controlling both temperature and humidity is the patented digital precise air control system, D-PAC™ (Patent No. 6,792,767).

The system uses a digital scroll compressor for energy efficient load matching temperature control. For humidity control the system uses a combination of the digital scroll compressor, return air bypass, and modulating hot gas reheat for energy efficient load matching humidity control. An AAON D-PAC controller is also factory installed to provide optimum performance of the system. **Thus the D-PAC system provides an energy efficient, cost effective solution to temperature and humidity control.**

The Competition

A misconception in the HVAC industry is that as the dry bulb temperature is being controlled the humidity will be controlled as well. This, however, is not true at many ambient conditions and space loads with higher humidity. Humidity is also especially uncontrollable when in ventilation mode, when the mechanical cooling is off and outside air is being introduced into the system.

Previously there have been only a few methods for controlling both temperature and humidity.

One method is to have a chiller and boiler system with air handlers. This method allows modulation of both cooling and reheating for tight control of temperature and humidity. The problems with this system are that it is large, expensive to implement, and energy is wasted controlling the humidity because both the chillers and boilers must be running.

A second method is a conventional rooftop unit with on/off hot gas reheat. The problems with this system are there is poor control of the amount of reheat, there will be uncomfortable discharge air temperature swings during operation, especially in make up air applications, and finally the temperature is still only controlled by a few compressor stages.

A third method is to use an energy recovery wheel to control humidity. This, however, is not a total solution because at higher latent loads humidity will still be an issue.

The D-PAC™ System

What is D-PAC™?

The D-PAC control system consists of a digital scroll compressor, modulating hot gas reheat, an economizer with three independently controlled sections, outside air, return air, and return air bypass, and an AAON D-PAC controller.

The **Digital Scroll Compressor™** varies the volume of refrigerant that flows through the cooling system. This allows the compressor to match the load needed by the unit. The compressor can modulate from 10-100% of its cooling capacity. This allows the unit to have tighter temperature control than a conventional unit. The compressor will also run for a longer period of time, thus dehumidifying the air more and cycling the compressor on and off less.

The compressor operates in two states, loaded (Figure 1) and unloaded (Figure 2), to be able to modulate from 10-100%. The loaded state is the standard scroll compressor operation. During the unloaded state a solenoid valve opens and the top of the scroll moves up separating from the bottom of the scroll allowing refrigerant to circulate back to the suction line and keeping it from leaving out the discharge line. There is a power reduction during this unloaded state that allows the compressor to save energy at part load conditions (Figure 3). So, by pulsing between the loaded and unloaded states the capacity of the compressor can be varied for energy saving load matching capability.



Digital Scroll Compressor

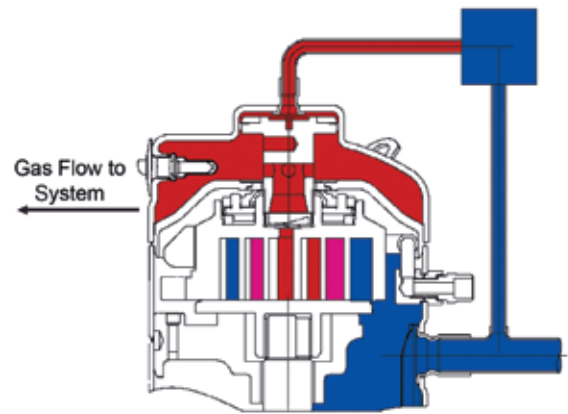


Figure 1: Loaded State

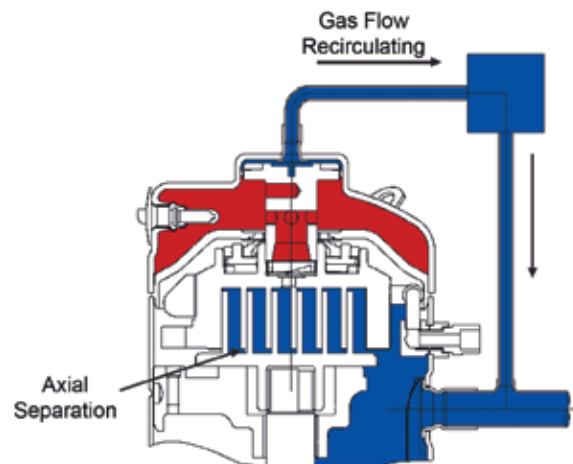


Figure 2: Unloaded State

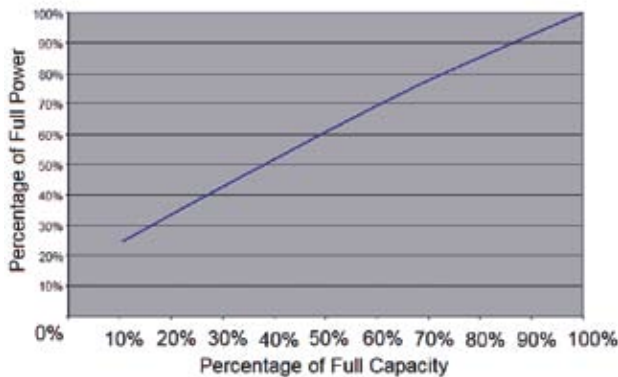


Figure 3: Typical Digital Scroll Compressor Modulated Power Reduction

Return Air Bypass consists of an economizer with an independently controlled outside air damper for ventilation, an independently controlled return air damper to allow return air to pass through the evaporator coil, and an independently controlled return air bypass damper to allow return air to bypass around the evaporator coil. The economizer routes all of the outside air across the evaporator coil and the return air either through or around the evaporator coil. Up to 50% of the return air can be bypassed around the evaporator coil. This allows the mixed return and outside air to be dehumidified by the evaporator coil and then reheated by the return air bypassed around the coil. Return air bypass is an energy efficient solution to controlling light humidity loads.

Modulating Hot Gas Reheat consists of a reheat coil downstream of the evaporator coil, a modulating reheat hot gas valve, a modulating condenser hot gas valve, and a reheat controller. To minimize energy usage, reheat begins after the return air bypass damper is fully open. The evaporator coil can then cool and dehumidify the mixed air even more and then reheat the air with the reheat coil. The modulating valves allow only the needed amount of reheat to be used, creating a consistent supply air temperature. Modulating hot gas reheat is an energy efficient solution to controlling high humidity loads.



Modulating Control Valve

The **AAON D-PAC™ Controller** controls the fans, outside air, return air, and return air bypass actuators, modulating hot gas reheat, compressor, heating, and optional AAONAIRE energy recovery wheel. Using these pieces, the controller controls the temperature and humidity

of the space under all conditions in the most energy efficient manner. The controller is factory installed and tested to ensure correct operation. Use of either the Wattmaster VCM controller or the Lynxspring JENEsys™ controller as the D-PAC controller is available to meet all of your controls needs. With a choice of factory installed controllers the D-PAC unit can be used as a stand alone unit or integrated into an existing building automation system. The factory installed and tested D-PAC unit controller optimizes performance of the complete D-PAC unit.



Wattmaster VCM Controller

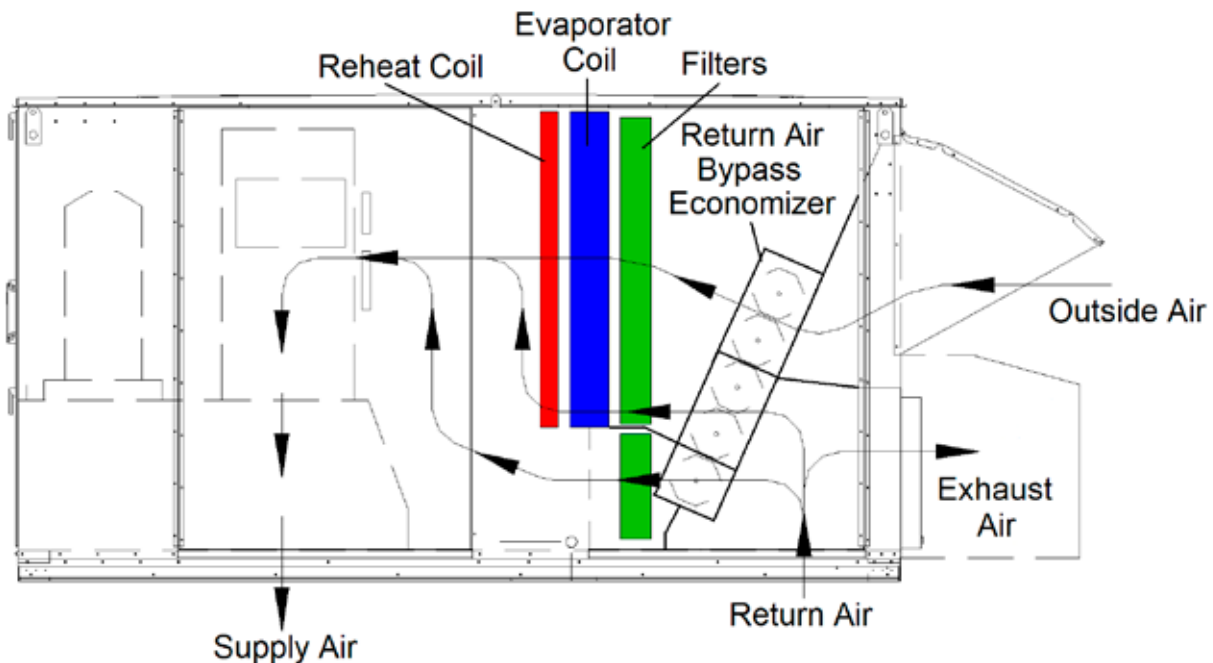


Lynxspring JENEsys™ Controller

Sequence of Operation

As the space temperature increases or decreases, the controller modulates the compressor's capacity to maintain the space temperature setpoint.

As the space humidity rises, the controller modulates the compressors capacity to maintain a low evaporator coil temperature to maximize dehumidification and meet the space latent load. The controller then modulates the return air damper closed and the return air bypass damper open, diverting return air around the evaporator coil to maintain the space temperature. Finally after the return air bypass damper is fully open, the controller uses modulating hot gas reheat to increase the dehumidification capacity of the unit while still maintaining the space temperature. Thus the humidity setpoint and temperature setpoint will be maintained with minimum energy usage.



D-PAC™ Airflow

Why Use a Digital Scroll Compressor?

There are four common ways to modulate the refrigerant capacity of a cooling system: hot gas bypass, multiple compressors, an inverter driven compressor, and a digital scroll compressor.

A hot gas bypass system mixes hot refrigerant gas from the compressor with cool refrigerant liquid at the evaporator to control the amount of cooling supplied. Hot gas bypass, however, is an inefficient modulation technique because it is adding a false load that the system must satisfy.

A multiple compressor system stages the compressors on and off to control the amount of cooling supplied. The problem with this system is that it has

a finite number of capacity steps for modulation thus will have inefficient operation at many part load conditions. Another issue is at smaller tonnages multiple compressors are often not available.

An inverter driven compressor system varies the speed of the compressor motor to varying the amount of cooling supplied. This system, however, has oil return issues and the modulation range is limited by the motor speed range.

A digital scroll compressor system modulates the volume of refrigerant that flows through the cooling system. It is a simple, reliable, energy efficient system with a broad modulation capability.

System Comparison

Example 1: Full Load Example - 40 MBH Sensible Load, 10 MBH Latent Load

Assume the ambient conditions of 95°F DB and 75°F WB with 2800 CFM of supply air, 700 CFM of which is outside air. The unit is attempting to control to 75°F space temperature and if the unit includes humidity control options 45% space relative humidity. The space full load conditions are 40 MBH sensible load and 10 MBH latent load for a sensible heat ratio of 0.8. Supply fan motor heat is neglected.

Full Load Steady State Conditions						
	Space DB	Space RH	Supply Air DB	Compressor Load	Reheat Amount	Return Air Bypass Amount
Controlling Temperature Only						
Conventional System	75°F	65%	62°F	6.0 Tons	NA	NA
Controlling Temperature and Humidity						
With Only Return Air Bypass (RAB)	75°F	46%	62°F	7.0 Tons	NA	1400 CFM
With Only Modulating Hot Gas Reheat (MHGR)		45%		9.8 Tons	33100 BTU/H	NA
With a Digital Scroll, RAB and MHGR (D-PAC™)				7.1 Tons	800 BTU/H	1400 CFM
D-PAC™ with Sensible Energy Recovery Wheel				6.0 Tons		
D-PAC™ with Total (Enthalpy) Energy Recovery Wheel				5.6 Tons		

System Conclusion

The first comparison is the space full load conditions of 40 MBH sensible load and 10 MBH latent load. An example of this would be a large well lit conference room with people, laptops, projectors, and other sensible heat sources.

Conventional Rooftop Unit

With no humidity control the conventional rooftop unit can control to 75°F space temperature with and uncontrolled 65% space relative humidity. The load on the compressor is 6.0 tons, thus the rooftop unit will be a single stage, 6 ton unit.

Rooftop Unit with Return Air Bypass

With the addition of return air bypass the unit can control to the conditions of 75°F space temperature and 46% space relative humidity.

The load on the compressor is 7.0 tons, thus the rooftop unit will be a return air bypass, 7 ton unit. Controlling the humidity with return air bypass alone required an extra 1.0 ton of load. Return air bypass alone, however, cannot control to 45% relative humidity because only up to 50% of the return air can be bypassed around the evaporator coil.

Rooftop Unit with Modulating Hot Gas Reheat

With the addition of modulating hot gas reheat the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 9.8 tons, thus the rooftop unit will be a modulating hot gas reheat, 10 ton unit. Controlling the humidity with modulating hot gas reheat alone required an extra 3.8 tons of load.

Rooftop Unit with a Digital Scroll Compressor, Return Air Bypass and Modulating Hot Gas Reheat (D-PAC™)

With the addition of a digital scroll compressor, return air bypass and modulating hot gas reheat the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 7.1 tons, thus the rooftop unit will be a D-PAC, 8 ton unit. Controlling the humidity with the D-PAC unit required an extra 1.1 tons of load. **Therefore, the D-PAC unit requires 2.7 tons load less than the modulating hot gas reheat only unit and unlike the return air bypass only unit can control to 45% relative humidity.**

D-PAC™ with an AAONAIRE® Sensible Energy Recovery Wheel

With the addition of an AAONAIRE sensible energy recovery wheel the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 6.0 tons, thus the rooftop unit will be a sensible AAONAIRE, D-PAC, 6 ton unit. The addition of the sensible energy recovery wheel reduced the entering outside air conditions to 77°F DB and 70°F WB. **Therefore, the D-PAC unit with an AAONAIRE sensible energy recovery wheel requires 1.1 tons less than a D-PAC unit alone. It requires the same tonnage as the conventional unit and controls both temperature and humidity.**

D-PAC™ with an AAONAIRE® Total (Enthalpy) Energy Recovery Wheel

With the addition of an AAONAIRE total energy recovery wheel the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 5.6 tons, thus the rooftop unit will be an enthalpy AAONAIRE, D-PAC, 6 ton unit. The addition of the total energy recovery wheel reduced the entering

outside air conditions to 77°F DB and 68°F WB. **Therefore, the D-PAC unit with an AAONAIRE total energy recovery wheel requires 1.5 tons less than a D-PAC unit alone. It requires less tonnage than the conventional unit and controls both temperature and humidity.**

System Comparison Summary

Return Air Bypass alone can control humidity at high sensible heat ratio loads.

Modulating Hot Gas Reheat alone can control humidity at a majority of load conditions, however, a larger unit with more capacity may be needed.

D-PAC™ (Digital Scroll Compressor, Return Air Bypass and Modulating Hot Gas Reheat) can control humidity and temperature at all load conditions. It can also control humidity at those conditions with less compressor work than modulating hot gas reheat alone.

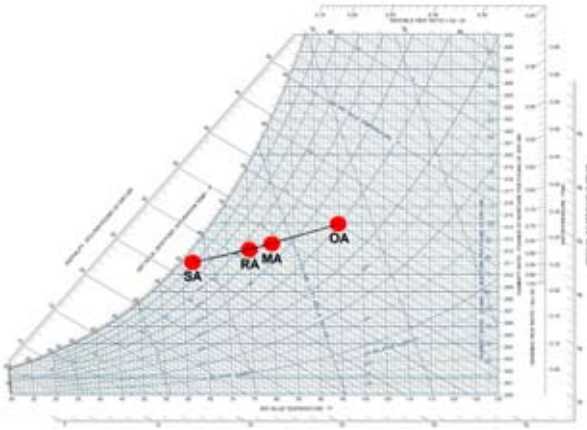
AAONAIRE® Energy Recovery Wheel can greatly reduce the compressor work at all load conditions. Thus, the overall size of the unit can be reduced resulting in lower operating costs.

Psychrometric Chart Comparisons

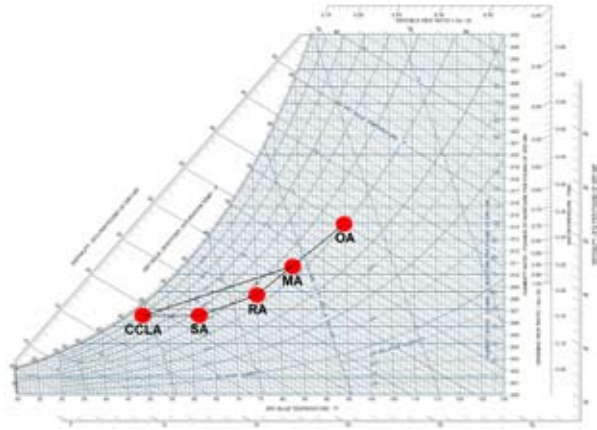
To see how each of these systems is controlling the temperature and humidity, psychrometric charts for each system are shown on the next page.

- OA** Outside Air introduced into the unit or for energy recovery wheel units outside air after going through the wheel.
- RA** Return Air from the space.
- MA** Mixed Air (Return and outside air)
- CCLA** Cooling Coil Leaving Air before mixing with bypassed return air or before reheat coil.
- SA** Supply Air

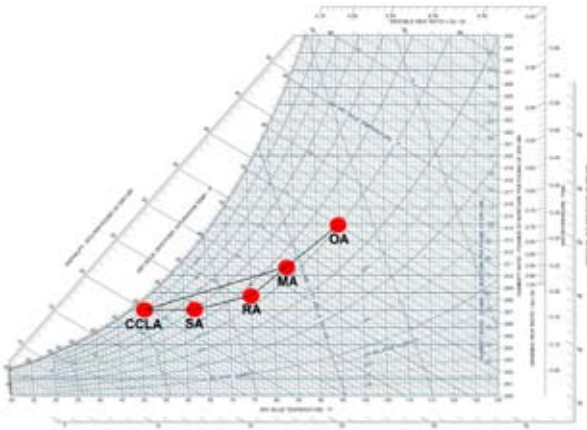
Psychrometric Chart Comparisons



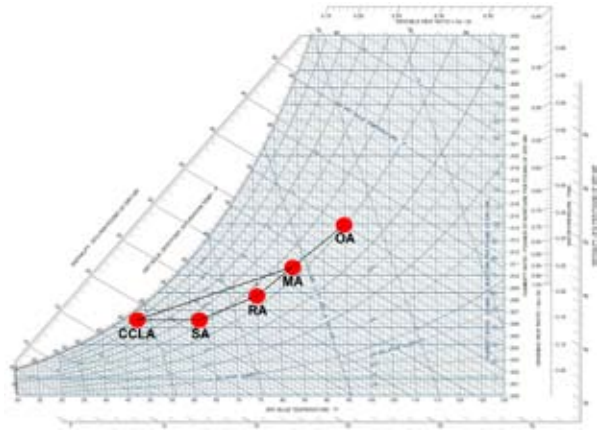
Full Load Conventional



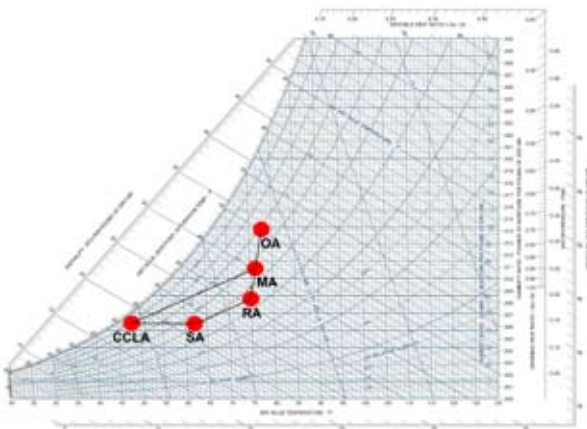
Full Load with Return Air Bypass



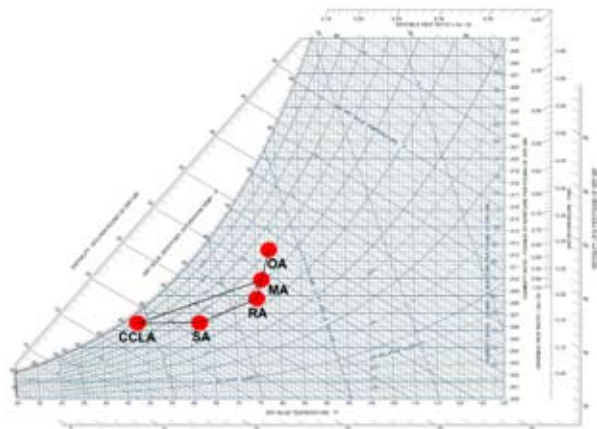
Full Load with Modulating Hot Gas Reheat



Full Load D-PAC™



Full Load D-PAC™ with Sensible Heat Wheel



Full Load D-PAC™ with Total Heat Wheel

Example 2: Part Load Example - 10 MBH Sensible Load, 10 MBH Latent Load

Assume the ambient conditions of 95°F DB and 75°F WB with 2800 CFM of supply air, 700 CFM of which is outside air. The unit is attempting to control to 75°F space temperature and if the unit includes humidity control options 45% space relative humidity. The space part load conditions are 10 MBH sensible load and 10 MBH latent load for a sensible heat ratio of 0.5. Supply fan motor heat is neglected.

Part Load Steady State Conditions						
	Space DB	Space RH	Supply Air DB	Compressor Load	Reheat Amount	Return Air Bypass Amount
Controlling Temperature Only						
Conventional System	75°F	89%	72°F	2.2 Tons	NA	NA
Controlling Temperature and Humidity						
With Only Return Air Bypass (RAB)	75°F	84%	72°F	2.5 Tons	NA	1400 CFM
With Only Modulating Hot Gas Reheat (MHGR)				9.8 Tons	63100 BTU/H	NA
With a Digital Scroll, RAB and MHGR (D-PAC™)		45%		7.1 Tons	30800 BTU/H	1400 CFM
D-PAC™ with Sensible Energy Recovery Wheel		6.0 Tons				
D-PAC™ with Total (Enthalpy) Energy Recovery Wheel		5.6 Tons				

System Conclusion

The second comparison is the space part load conditions of 10 MBH sensible load and 10 MBH latent load. An example of this would be the same conference room with the lights and electronics turned off while the people are watching video on a projection screen.

Conventional Rooftop Unit

With no humidity control the conventional rooftop unit can control to 75°F space temperature with an uncontrolled 89% space relative humidity. The load on the compressor is 2.2 tons.

Note: By adding a digital scroll compressor to a conventional rooftop unit the compressor work will be greatly reduced at part load conditions because the compressor can match the required load. The digital scroll compressor will also cycle on and off less resulting in less compressor wear, tighter temperature control, more dehumidification, and longer compressor life.

Rooftop Unit with Return Air Bypass

With the addition of return air bypass the unit can control to the conditions of 75°F space temperature and 84% space relative humidity. The load on the compressor is 2.5 tons. Controlling the humidity with return air bypass alone required an extra 0.3 ton of load. Return air bypass alone, however, cannot control to 45% relative humidity because only up to 50% of the return air can be bypassed around the evaporator coil.

Rooftop Unit with Modulating Hot Gas Reheat

With the addition of modulating hot gas reheat the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 9.8 tons. Controlling the humidity with modulating hot gas reheat alone required an extra 7.6 tons of load.

Rooftop Unit with a Digital Scroll Compressor, Return Air Bypass and Modulating Hot Gas Reheat (D-PAC™)

With the addition of a digital scroll compressor, return air bypass and modulating hot gas reheat the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 7.1 tons. Controlling the humidity with the D-PAC unit required an extra 4.9 tons of load. **Therefore, the D-PAC unit requires 2.7 tons load less than the modulating hot gas reheat only unit and unlike the return air bypass only unit can control to 45% relative humidity.**

D-PAC™ with an AAONAIRE® Sensible Energy Recovery Wheel

With the addition of an AAONAIRE sensible energy recovery wheel the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 6.0 tons. The addition of the sensible energy recovery wheel reduced the entering outside air conditions to 78°F DB and 70°F WB. **Therefore, the D-PAC unit with an AAONAIRE sensible energy recovery wheel requires 1.1 tons less than a D-PAC unit alone.**

D-PAC™ with an AAONAIRE™ Total (Enthalpy) Energy Recovery Wheel

With the addition of an AAONAIRE total energy recovery wheel the unit can control to the desired conditions of 75°F space temperature and 45% space relative humidity. The load on the compressor is 5.6 tons. The addition of the total energy recovery wheel reduced the entering outside air conditions to 78°F DB and 68°F WB. **Therefore, the D-PAC unit with an**

AAONAIRE total energy recovery wheel requires 1.5 tons less than a D-PAC™ unit alone.

System Comparison Summary

Return Air Bypass alone can control humidity only at high sensible heat ratio loads.

Modulating Hot Gas Reheat alone can control humidity at a majority of load conditions, however, a larger unit with more capacity may be needed.

D-PAC™ (Digital Scroll Compressor, Return Air Bypass and Modulating Hot Gas Reheat) can control humidity and temperature at all load conditions. It can also control humidity at those conditions with less compressor work than modulating hot gas reheat alone.

AAONAIRE Energy Recovery Wheel can greatly reduce the compressor work at all load conditions. Thus, the overall size of the unit can be reduced resulting in less initial and running cost.

Psychrometric Chart Comparisons

To see how each of these systems is controlling the temperature and humidity psychrometric charts for each system are shown on the next page.

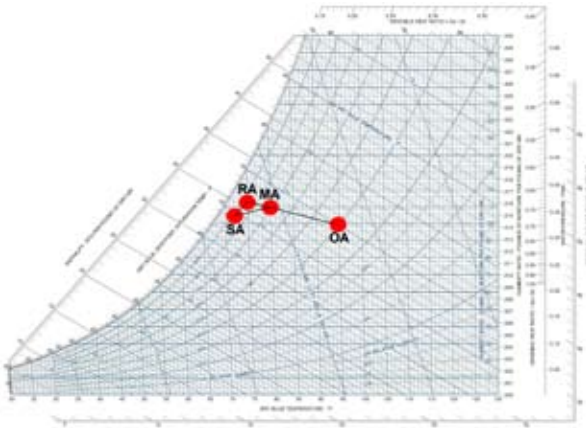
- OA** **Outside Air** introduced into the unit or for energy recovery wheel units outside air after going through the wheel.
- RA** **Return Air** from the space.
- MA** **Mixed Air** (Return and outside air)
- CCLA** **Cooling Coil Leaving Air** before mixing with bypassed return air or before reheat coil.
- SA** **Supply Air**

Conclusion

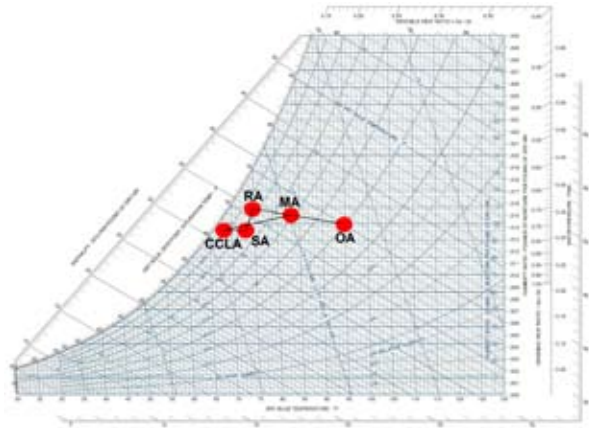
The D-PAC control system uses a digital scroll compressor, return air bypass, and modulating hot gas reheat to control both temperature and humidity. With the combination of these components and an AAON D-PAC controller to optimize them the system can control temperature and humidity as efficiently as possible. Thus, the D-PAC control system is an energy efficient system providing total temperature and humidity control under all conditions.

Contact your local AAON sales representative to learn more about the AAON D-PAC features and many more ways AAON can provide HVAC solutions to your applications.

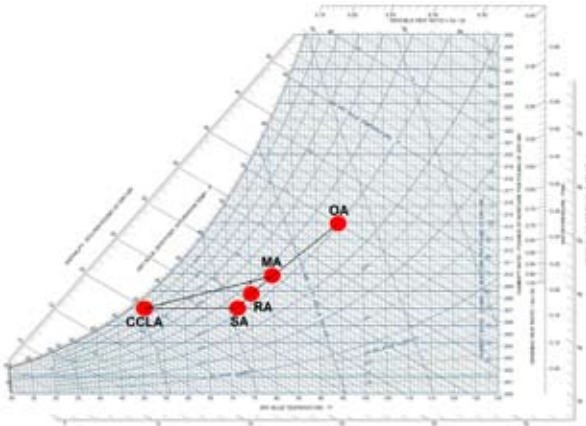
Psychrometric Chart Comparisons



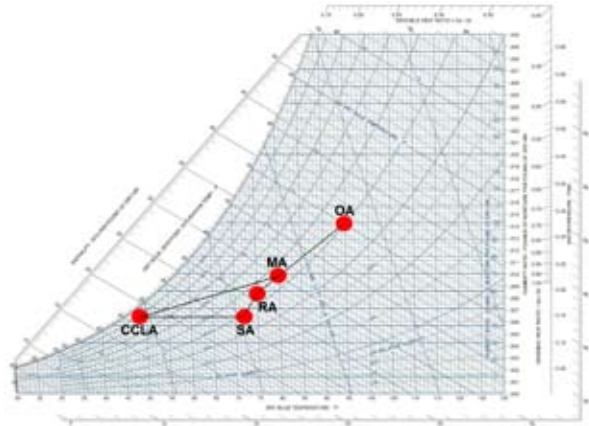
Part Load Conventional



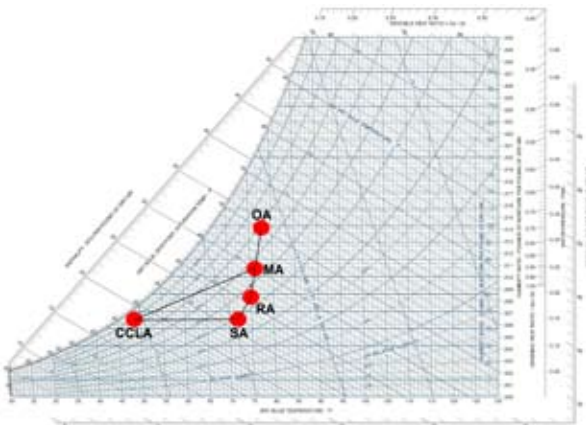
Part Load with Return Air Bypass



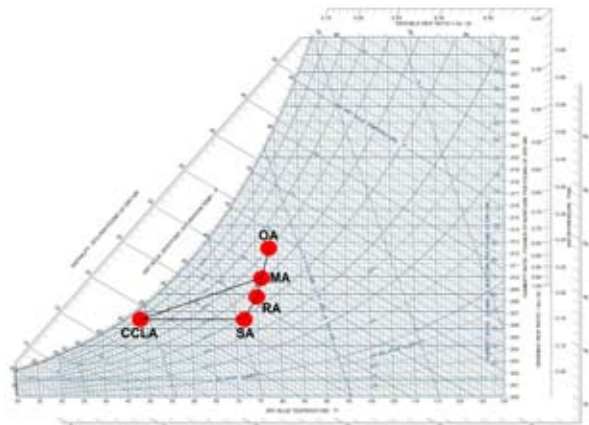
Part Load with Modulating Hot Gas Reheat



Part Load D-PAC™



Part Load D-PAC™ with Sensible Heat Wheel



Part Load D-PAC™ with Total Heat Wheel



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Functionality

Factory Testing

Ease of Installation

Ease of Maintenance

Energy Efficiency

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