Digital Precise Air Control System

D-PAC

Functionality  Factory Testing  Ease of Installation  Ease of Maintenance  Energy Efficiency

AAON  •  2425 South Yukon Avenue  •  Tulsa, Oklahoma 74107  •  (918) 583-2266  •  Fax (918) 583-6094  •  www.aaon.com
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 be some form of cooling and reheating to dehumidify the air and avoid overcooling 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

The AAON 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, 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 for temperature and humidity control.

The Competition

Some in the HVAC industry assume 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 solutions for controlling both temperature and humidity.

One method is to have a chiller and boiler system with air handling units. This method allows modulation of both cooling and reheating for tight control of temperature and humidity.
The D-PAC System

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.

The second solution 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.

The last solution 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.

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, dehumidifying the air more and cycling the compressor on and off less.

The compressor operates in two states, loaded and unloaded, to be able to modulate from 10-100% (Figure 1 and 2). 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 and unit to save energy at part load conditions (Figure 3). By pulsing between the loaded and unloaded states the capacity of the compressor can be varied for energy saving load matching capability.
The **Return Air Bypass** feature consists of an economizer with three independently controlled sections - outside air, return air, and return air bypass (Figure 4). The outside air damper routes all of the ventilation air through the evaporator coil. The return air damper routes return air through the evaporator coil. The return air bypass damper routes up to 50% of the return air 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. The cooling load is increased when return air is bypassed because the mixed air entering the evaporator coil contains a greater percentage of outside air; the mixed air is not pre-cooled by the bypassed return air. Return air bypass is an energy efficient solution to controlling light humidity loads.

The **Modulating Hot Gas Reheat** feature 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 (Figure 5). The evaporator coil cools the mixed air to below the dew point and then reheats the air with the reheat coil. The modulating valves allow only the needed amount of reheat to be used, creating consistent supply air temperature. To minimize energy usage, reheat begins only after the return air bypass damper is fully open with the D-PAC System. Modulating hot gas reheat is an energy efficient solution to controlling high humidity loads.

The **AAON D-PAC Controller** controls the fans, outside air, return air, and return air bypass actuators, modulating hot gas reheat, compressors, heating, and optional AAONAI® energy recovery wheel. Using these components, 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 proper operation. The WattMaster VCM-X controller and the AAON JENEsys controller are available for the D-PAC system to meet any controls application. With a choice of these factory installed controllers a D-PAC unit can 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 system.
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 cooling capacity. Hot gas bypass 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 cooling capacity. The problem with this system is that it has a finite number of capacity steps for modulation and 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 control the cooling capacity. 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 to control the cooling capacity. It is a simple, reliable, energy efficient system with wide modulation capability.

**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. 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.

**Figure 5: Modulating Hot Gas Reheat**
**System Comparison**

**Example 1:** Full load example consisting of a large well lit conference room with occupants, laptops, projectors and other sensible heat sources.

Ambient conditions are 95°F DB and 75°F WB with 2,800 cfm of supply air, 700 cfm of outside air and 700 cfm of exhaust air. A packaged rooftop unit is attempting to control to 75°F DB space temperature and 45% space relative humidity. The space full load conditions are 40 MBtu/h sensible load and 10 MBtu/h latent load for a sensible heat ratio of 0.8. Supply fan motor heat is neglected. Psychrometric charts match with the descriptions. Calculations can be recreated using your specific ambient and loading conditions within the AAONEcat32™ software.

**Conventional Rooftop Unit**
With no humidity control the conventional rooftop unit can control to 75°F DB space temperature with an uncontrolled 65% space relative humidity. The load on the compressor is 6.0 tons, thus a 6 ton rooftop unit is required.

**Rooftop Unit with Return Air Bypass**
With the addition of return air bypass the unit can control to the conditions of 75°F DB space temperature and 53% space relative humidity. Return air bypassed around the evaporator coil is 1.050 cfm. The load on the compressor increased to 6.7 tons because the mixed air entering the evaporator coil is not pre-cooled by the bypassed return air, thus a return air bypass 7 ton rooftop unit is required. Controlling the humidity with return air bypass alone required an extra 0.7 tons of load, however, the unit cannot control to 45% relative humidity because only up to 50% of the total return air can be bypassed.

**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 DB space temperature and 45% space relative humidity. The amount of reheat required is 33.1 MBtu/h. The load on the compressor is 9.8 tons, thus a modulating hot gas reheat, 10 ton rooftop unit is required. 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 DB space temperature and 45% space relative humidity. The load on the compressor is 7.8 tons, thus a D-PAC, 8 ton rooftop unit is required. Controlling the humidity with the D-PAC unit required an extra 1.8 tons of load, over the conventional rooftop with uncontrolled humidity.

The D-PAC unit can control to 45% space relative humidity and requires 2 tons less load than the modulating hot gas reheat only unit.

**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 DB space temperature and 45% space relative humidity. The addition of the sensible energy recovery wheel reduced the entering outside air conditions to 79°F DB and 70°F WB. The load on the compressor is 6.7 tons, thus a sensible AAONAIRE, D-PAC, 7 ton rooftop unit is required. 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 DB space temperature and 45% space relative humidity. The addition of the total energy recovery wheel reduced the entering outside air conditions to 79°F DB and 65°F WB. The load on the compressor is 5.6 tons, thus a total AAONAIRE, D-PAC, 6 ton rooftop unit is required. Therefore, the D-PAC unit with an AAONAIRE total energy recovery wheel requires 2.2 tons less than a D-PAC unit alone. It requires the same tonnage as the conventional unit and controls both temperature and humidity!
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 Energy Recovery Wheel**

**Full Load D-PAC with Total Energy Recovery Wheel**

**OA** = Outside Air or outside air after going through the wheel; **S-ERW** = Preconditioned outside air downstream of the Sensible Energy Recovery Wheel; **T-ERW** = Preconditioned outside air downstream of the Total Energy Recovery Wheel; **RA** = Return Air; **MA** = Mixed Air (Return and outside air); **CCLA** = Cooling Coil Leaving Air before mixing with bypassed return air and before reheat coil; **SA** = Supply Air
Example2: Part load example consisting of the same conference room in the full load example with the lights and electronics turned off while the occupants are watching a video on a projection screen.

Ambient conditions are 95°F DB and 75°F WB with 2,800 cfm of supply air, 700 cfm of outside air and 700 cfm of exhaust air. A packaged rooftop unit is attempting to control to 75°F DB space temperature and 45% space relative humidity. The space part load conditions are 10 MBtu/h sensible load and 10 MBtu/h latent load for a sensible heat ratio of 0.5. Supply fan motor heat is neglected. Psychrometric charts match with the descriptions. Calculations can be recreated using your specific ambient and loading conditions within the AAONEcat32™ software.

Conventional Rooftop Unit
With no humidity control the conventional rooftop unit can control to 75°F DB 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 DB space temperature and 86% space relative humidity. Return air bypassed around the evaporator coil is 1,050 cfm. The load on the compressor increased to 2.4 tons because the mixed air entering the evaporator coil is not pre-cooled by the bypassed return air. Controlling the humidity with return air bypass alone required an extra 0.2 tons of load, however, the unit cannot control to 45% relative humidity because only up to 50% of the total return air can be bypassed.

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 DB space temperature and 45% space relative humidity. The amount of heat required is 63.1 MBtu/h. The load on the compressor increased to 9.8 tons because the mixed air is cooled to below the dew point and then reheated. 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 DB space temperature and 45% space relative humidity. The load on the compressor is 7.8 tons. Controlling the humidity with the D-PAC unit required an extra 5.6 tons of load. The D-PAC unit can control to 45% space relative humidity and requires 2 tons less load than the modulating hot gas reheat only unit.

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 DB space temperature and 45% space relative humidity. The addition of the sensible energy recovery wheel reduced the entering outside air conditions to 79°F DB and 70°F WB. The load on the compressor is 6.7 tons. 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 DB space temperature and 45% space relative humidity. The addition of the total energy recovery wheel reduced the entering outside air conditions to 79°F DB and 65°F WB. The load on the compressor is 5.6 tons. Therefore, the D-PAC unit with an AAONAIRE total energy recovery wheel requires 2.2 tons less than a D-PAC unit alone.
OA = Outside Air or outside air after going through the wheel; S-ERW = Preconditioned outside air downstream of the Sensible Energy Recovery Wheel; T-ERW = Preconditioned outside air downstream of the Total Energy Recovery Wheel; RA = Return Air; MA = Mixed Air (Return and outside air); CCLA = Cooling Coil Leaving Air before mixing with bypassed return air and before reheat coil; SA = Supply Air
**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 is less initial and running cost.

### Full Load Steady State Conditions

<table>
<thead>
<tr>
<th></th>
<th>Space DB</th>
<th>Supply Air DB</th>
<th>Compressor Load</th>
<th>Reheat Amount</th>
<th>Return Air Bypass Amount</th>
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<tr>
<td><strong>Controlling Temperature Only</strong></td>
<td></td>
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<tr>
<td>Conventional System</td>
<td>75°F</td>
<td>62°F</td>
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<td>NA</td>
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<td><strong>Controlling Temperature and Humidity</strong></td>
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<tr>
<td>With Only Return Air Bypass (RAB)</td>
<td>53°F</td>
<td>62°F</td>
<td>6.7 tons</td>
<td>NA</td>
<td>1,050 cfm</td>
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<td>With Only Modulating Hot Gas Reheat (MHGR)</td>
<td>45°F</td>
<td>75°F</td>
<td>9.8 tons</td>
<td>33,100 Btu/h</td>
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<td>With a Digital Scroll, RAB and MHGR (D-PAC)</td>
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<td>62°F</td>
<td>7.8 tons</td>
<td></td>
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<tr>
<td>D-PAC with Sensible Energy Recovery Wheel</td>
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<td></td>
<td>6.7 tons</td>
<td>8,800 Btu/h</td>
<td>1,050 cfm</td>
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<tr>
<td>D-PAC with Total (Enthalpy) Energy Recovery Wheel</td>
<td></td>
<td></td>
<td>5.6 tons</td>
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### Part Load Steady State Conditions

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<th>Compressor Load</th>
<th>Reheat Amount</th>
<th>Return Air Bypass Amount</th>
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<tr>
<td>Conventional System</td>
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<td>72°F</td>
<td>2.2 tons</td>
<td>NA</td>
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<tr>
<td>With Only Return Air Bypass (RAB)</td>
<td>84°F</td>
<td>72°F</td>
<td>2.4 tons</td>
<td>NA</td>
<td>1,050 cfm</td>
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<tr>
<td>With Only Modulating Hot Gas Reheat (MHGR)</td>
<td>45°F</td>
<td>75°F</td>
<td>9.8 tons</td>
<td>63,100 Btu/h</td>
<td>NA</td>
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<tr>
<td>With a Digital Scroll, RAB and MHGR (D-PAC)</td>
<td>75°F</td>
<td>72°F</td>
<td>7.8 tons</td>
<td></td>
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<tr>
<td>D-PAC with Sensible Energy Recovery Wheel</td>
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<td></td>
<td>6.7 tons</td>
<td>38,800 Btu/h</td>
<td>1,050 cfm</td>
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<tr>
<td>D-PAC with Total (Enthalpy) Energy Recovery Wheel</td>
<td></td>
<td></td>
<td>5.6 tons</td>
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Conclusion

The D-PAC control system combines a Digital Scroll compressor, return air bypass, and modulating hot gas reheat to control both space temperature and space 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. The system can accurately control the temperature to +/- 1°F and the relative humidity to +/- 5%. The patented sequence of operation allows the unit to have reduced energy costs when compared to conventional temperature and humidity control systems.

Applications for the D-PAC system, which require both temperature and humidity control, include supermarkets, convenience stores, schools, office buildings, restaurants, cafes, churches, auditoriums, health clubs, healthcare facilities, lodgings, museums and libraries.

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.

Winners of...
The D-PAC control system was recognized as the 2008 Product of the Year, in the HVAC category, and the Most Valuable Product (MVP), in the overall competition, by Consulting-Specifying Engineer Magazine as well as the 2009 Product of the Year by the National Society of Professional Engineers (NSPE).
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