[APPLICATION NOTE #183]

Active Flow Control (AFC)

By Nick Schweissguth

PRODUCT AT A GLANCE

Product Type

Data center airflow controller for thermal containment applications

Applications

Small to Large Data Centers
EcoAisle Thermal Containment
Rack Air Containment (RACS)

Availability

Worldwide

CUSTOMER BENEFITS

- **Potential for energy savings**
- **Prevents hot and cold aisle mixing**
- **Use of existing network resources**
- **Ease of use and maintenance**

ZERO-POINT DEFAULTS

- **Positive = 0.004 in-H2O**
- **Slightly Positive = 0.002 in-H2O**
- **Zero = 0 in-H2O**
- **Slightly Negative = -0.002 in-H2O**
- **Negative = -0.004 in-H2O**

The zero-point accuracy is +/-0.0004 inches WC. The accuracy over the entire span of the sensor is 3% of the measurement, or +/- 0.003 inches WC maximum at full scale.

Abstract

The function of the Active Flow Control (AFC) product is to improve the balance of airflow between the cooling structure and IT equipment when placed in an aisle containment system. It is a ΔP controller – an alternative to traditional data center ΔT control. The device samples pressure inside and outside the thermal containment system and communicates with the cooling units to right-size airflow. The controller accomplishes this by adjusting the cooling units' fan speed to ensure the desired volume of air reaches the IT equipment. It is compatible with EcoAisle Thermal Containment and Rack Air Containment (RACS); as well as firmware compatible with many of Schneider Electric cooling products.

Introduction

In a traditional data center desired cooling is dictated by the required ΔT (or CFM/kW values) of the IT equipment. The ΔT is typically constant for all servers and racks; however, modern day data centers now utilize high density servers and experience off-peak hour conditions that can result in an overall dynamic ΔT. Dynamic ΔT control in a data center can present complexity for the IT manager. By using Active Flow Control, a ΔP based control scheme, the complexity regarding ΔT control can become an issue of the past. This document describes the control process for the Active Flow Controller as well as the benefits of a ΔP control scheme.

"The ΔP-based Active Flow Controller alleviates the complexity, unpredicability, and limitations of traditional ΔT control within my data center."

Facilities Manager

ΔT and CFM/kW Explained

Table 1 (below) represents the relationship between ΔT and CFM/kW. The two terms are interchangeable in their inverse sense.

Table 1: InRow RC 300mm Cooling Presets

Fan Speed Preference	ΔT	CFM/kW
High	10	315
Med High	15	210
Med	20	160
Med Low	25	125
Low	30	105

The table above uses the InRow RC 300mm unit as an example to show how various ΔT setpoints are obtained via presets. The five low to high ranges represent the five presets available on the InRow RC units and each corresponding ΔT. The IT equipment ΔT dictates the preset; only one preset can be selected at a time

CFM/kW Variation – Rack Level

Observe an example data center in Figure 1. Notice how all servers are identical and designed for 160 CFM/kW, thus the InRow RC 300mm cooling units can be configured for the 20°F ΔT mode. This means that the cooling units will provide the exact amount of airflow required for the IT equipment. There is no need for an Active Flow Controller in this scenario.

Conversely, IT equipment in modern data centers is mixed with high density equipment that can require various airflow requirements (i.e. the CFM/kW is no longer the same for each server). An example of a rack equipped with various types of servers is shown in Table 2. Notice the total airflow requirement of the rack is the average airflow of each server.

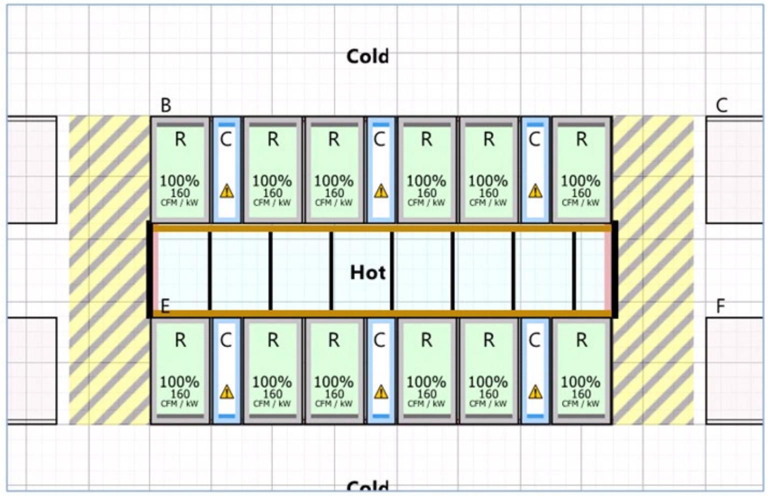

Figure 1: Traditional Pod

Table 2: Example of Server Layout in a Rack

Example of Individual Airflow Requirements of a Server Rack in Data Center	
Server 1	160 CFM/kW
Server 2	105 CFM/kW
Server 3	80 CFM/kW
Server 4	115 CFM/kW
Server 5	210 CFM/kW
Server 6	160 CFM/kW
Server 7	80 CFM/kW
	130 CFM/kW

Notice that the average airflow requirement comes out to be an irregular CFM/kW. 130 CFM/kW is not one of five InRow RC 300 presets. The cooling units are limited to five cooling presets – 105 CFM/kW, 125 CFM/kW, 160 CFM/kW, 210 CFM/kW, 315 CFM/kW. This presents a dilemma for the IT manager. The 125 CFM/kW preset would not be enough cooling while the 160 CFM/kW would be overcooling. Thus the InRow RC 300mm preset must be 160 CFM/kW and the units must be continuously overcooling.

The Dilemma of ΔT Control

Observe the example data center in Figure 2. This example will demonstrate the need for the Active Flow Controller as well as its potential cost benefit.

Suppose we are faced with the above configuration. There are 12 racks and 6 cooling units. We will assume each InRow RC 300mm unit supplies enough air for two racks. Let us assume each rack contains servers with varying CFM/kW requirements; however, the average airflow requirement for each rack comes out to be 130 CFM/kW. Each rack operates at a load of 9 kW. Each cooling unit is operating at max airflow (2,900 CFM) and outputs 18 kW (9 kW per rack) of cooling. The InRow RC 300mm unit operates at five preset options: 105 CFM/kW, 125 CFM/kW, 160 CFM/kW, 210 CFM/kW, or 315 CFM/kW. In order to supply enough air to each rack, the cooling units must be configured for the 160 CFM/kW preset, since 125 CFM/kW would be too little. Adding the total airflows for both the cooling units and racks we obtain the following values:

Rack:

130 CFM/kW × 9 kW = 1,200 CFM/rack

1,200 CFM/rack × 12 racks = 14,400 CFM/pod

Cooling Units:

2,900 CFM × 6 units = 17,400 CFM/pod

Notice that together, the cooling units are supplying 17,400 CFM while the racks are discharging 14,400 CFM. How is this possible? Since the cooling units cannot be configured to exactly 130 CFM/kW, but are rather set at 160 CFM/kW, they are forced to draw air from cracks and leaks within the containment. In other words, the cooling units are supplying 14,400 CFM from the racks and another 3,000 CFM from cracks and leaks. This extra 3,000 CFM is extra work for the cooling units. The Active Flow Controller alleviates this extra work by allowing the InRow RC to operate at any CFM/kW (in this case 130 CFM/kW).

Fan power for an InRow RC operating at 2,900 CFM without the AFC is 0.525 kW/unit,

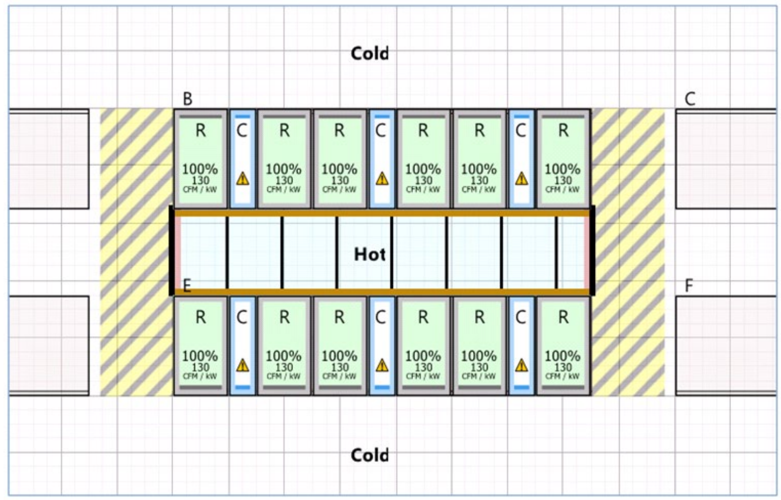

Figure 2: Peak Hours Pod

or 3.2 kW altogether. Fan power for an InRow RC operating at 2,400 CFM with the AFC is 0.430 kW/unit, or 2.6 kW altogether. The Active Flow Controller saves 0.6 kW.

If a kilowatt-hour costs 0.1€, this saving becomes an extra 262€ per year (based off 12 hours of operation per day).

CFM/kW Fluctuation: Off-peak Hours

The Active Flow Controller is also useful in situations where a rack's CFM/kW fluctuates throughout the day. Consider the

Table 3: Example of Reduced CFM/kW in Rack During Off-peak Hours

Peak Hours	
Server 1	160 CFM/kW
Server 2	210 CFM/kW
Server 3	80 CFM/kW
Server 4	100 CFM/kW
Server 5	315 CFM/kW
Server 6	160 CFM/kW
Server 7	80 CFM/kW
	158 CFM/kW

Off-peak Hours	
Server 1	160 CFM/kW
Server 2	~~210 CFM/kW~~
Server 3	80 CFM/kW
Server 4	100 CFM/kW
Server 5	~~315 CFM/kW~~
Server 6	~~160 CFM/kW~~
Server 7	80 CFM/kW
	105 CFM/kW

tables below.

During peak hours the combined average CFM/kW of some servers within a rack is 158 CFM/kW; however, during off-peak hours the 315 CFM/kW, 210 CFM/kW, and there is less IT load) while servers 1, 3, 4, & 7 keep operating. Thus, the new combined average CFM/kW becomes 105 CFM/kW. In order for the InRow RC units to provide 158 CFM/kW cooling they are configured for the 160 CFM/kW preset; however, during off-peak hours the airflow requirement is reduced to 105 CFM/kW. In this situation the cooling units cannot adjust as they are still configured on the 160 CFM/kW preset and will overcool considerably.

Now let us revisit the previous example, this time at off-peak hours. Refer to the layout in Figure 3. Suppose we are faced with the above situation at off-peak hours. There are 12 racks and 6 cooling units. We will again assume each InRow RC 300mm unit supplies enough air for two racks. Let us assume each rack contains servers with varying CFM/kW requirements; however, the average airflow requirement for each rack changes from 158 CFM/kW to 90 CFM/kW. Each cooling unit is operating at a reduced airflow (1260 CFM) and outputs a total of 8 kW (4 kW per rack). Since the InRow RC preset is configured for 160 CFM/kW at peak load, it continues to operate at 160 CFM/kW even though the overall airflow requirement is only 90 CFM/kW during off-peak hours. Adding the total airflows for both the cooling units and racks we obtain the following values:

Rack:

90 CFM/kW × 4 kW = 360 CFM/rack

360 CFM/rack × 12 racks = 4320 CFM/pod

Cooling Units:

1,260 CFM × 6 units = 7,560 CFM/pod

Together the cooling units are supplying 7,560 CFM while the racks are discharging a total of 4,320 CFM. Since the cooling units cannot be automatically configured to adjust from 160 CFM/kW to 90 CFM/kW, they are forced to draw air from cracks and leaks within the containment. In other words, the cooling units are supplying 4,320 CFM from the racks and another 3,240 CFM from cracks and leaks. This extra 3,240 CFM creates considerable additional work for the cooling units. The Active Flow Controller alleviates this additional work by allowing the InRow RC to operate at any CFM/kW (in this case 90 CFM/kW).

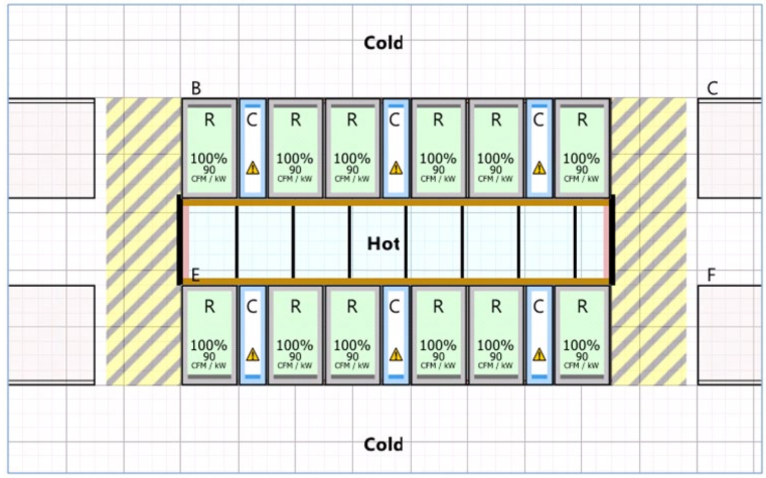

Figure 3: Off-peak Hours Pod

Fan power for an InRow RC operating at 1,260 CFM without the AFC is 0.211 kW/unit, or 1.266 kW altogether. Fan power for an InRow RC operating at 720 CFM with the AFC is 0.122 kW/unit, or 0.732 kW altogether. The Active Flow Controller saves 3.2 kW. If a kilowatt-hour costs 0.1€, this saving becomes an additional 1,400€ per year (based off 12 off-peak hours per day). In total then, savings become: 262€ (peak hours) + 1,400€ (off-peak hours) = 1662€ (42% fan energy savings)

NOTE: The AFC also works in reverse. If IT demands exceed the cooling unit presets, the AFC will automatically sense the under-cooling and adjust fan speed to compensate.

In summary, the AFC will rightsize the data center airflow by continuously adjusting the cooling units to the necessary CFM/kW requirement. The following graph demonstrate how the InRow RC 300 cooling units respond with and without the Active Flow Controller as CFM/kW varies throughout the day.

How the AFC Works

The Active Flow Controller works in two ways – first as a pressure indicator and then a controller.

The AFC has ports for measuring the pressure on the inside and outside of the aisle. If it senses a positive pressure inside the aisle and is configured for hot aisle containment, the indicator on the front panel will illuminate red (undercooling). If it senses a negative pressure inside the aisle, the indicator will illuminate blue (overcooling). If the cooling units possess the necessary firmware/compatibility with the AFC, the AFC will send a signal instructing the cooling units to adjust fan speed. These adjustments will balance airflow to match that of the IT equipment and change the indicator back to green. This all happens automatically.

HACS, CACS, and RACS Modes

The AFC is compatible with both Hot Aisle Containment and Cold Aisle Containment. For Hot Aisle Containment the Active Flow Controller represents the following:

When there is insufficient airflow from the cooling units, the pressure inside the aisle will be positive (negative for cold aisle containment). The AFC will sense this and the indicator will display red. When the cooling units are overcooling the pressure inside the aisle becomes negative (positive for cold aisle containment). The AFC will sense this and the indicator will display blue. If the AFC is configured for indication AND control, it will automatically ramp up or ramp down the cooling units fan speeds. When the pressure is balanced, the indicator should display green and thus the airflow for both the cooling units and the IT equipment should be balanced.

Chilled Water Valve Control

The AFC effectively decouples the fan from the chilled water valve. This allows fan speeds to ramp up and down without affecting valve position. When the cooling unit is equipped with the AFC firmware, the unit no longer controls based off fan speed and valve position presets. Rather, fan speed is adjusted to match the IT airflow while the chilled water valve is adjusted to match the desired set point.

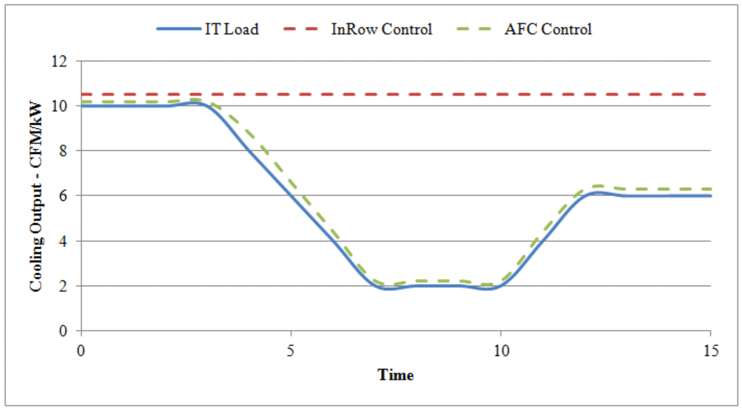

Figure 4: Control Strategy – Active Flow Control versus InRow Mode

InRow Group Control

Typically two or more Active Flow Controllers are used within each pod to improve measurements and for redundancy. All the controllers in a single pod can be combined into "group-mode" to share the worst-case readings. This will send controls based off first indication readings while also grouping all LED indicators.

For multiple pods, each group of AFC can be clustered to share readings among all pods. This is useful for EcoBreeze installations where air starvation might be more common on distant pods (pods located furthest away from the EcoBreeze).

InRow RC Fault Handling Strategy

InRow RC Fault Handling Strategy

The primary failure mode strategy is to allow an AFC to be overridden so that the cooling unit can provide more cooling than needed in certain situations. If an Active Flo Control unit fails, or if the communication is broken, the cooling systems will automatically revert back to dT control. This ensures adequate cooling at