APC

# APPLICATION NOTE #142

## InRow RC Environmental Control

**By Henry Jespersen**

### Abstract

The function of the InRow RC product is to cool air from the hot aisle and deliver it to the cold aisle at the temperature setpoint. The InRow RC controls the environment with a cooling function only. The control strategy employed depends upon the deployment strategy of the cooling group. For the InRow environment, the RC supplies constant-temperature supply air to the common cold aisle. The fan speed is modulated to ensure that the desired volume of air reaches the IT equipment. For Hot Aisle Containment (HACS) or Rack Air Containment (RACS) environment, the InRow RC neutralizes the heat accumulated in the common hot aisle and expels it back into the surrounding environmental space while maintaining the desired air temperature in the cold aisle. This document describes the control process for the InRow RC.

## Introduction

In order to provide environmental control, the InRow RC unit monitors the temperature of the return air, temperature of the supply air, and a remote rack inlet temperature (the remote temperature sensor is only used for In-Row mode). The InRow RC monitors the inlet fluid temperature, outlet fluid temperature, and fluid flow rate. The unit also monitors several other attributes to determine the health of the system and provide alarms under adverse conditions.

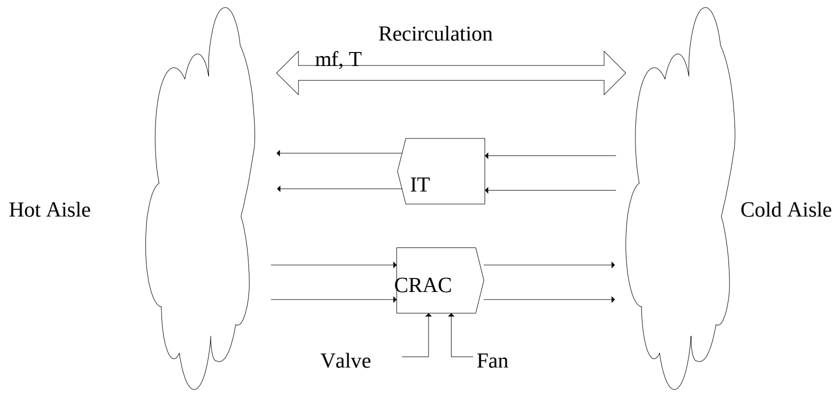
The InRow RC ensures proper server inlet temperatures by actively controlling cooling capacity. The unit adjusts cooling capacity in response to thermal changes within the row of IT equipment to maintain rack inlet temperatures 7 X 24. The Active Response Controls of the InRow RC ensures that servers consistently operate at the desired rack inlet setpoint, which can be configured to be between 68-77°F (20-25°C) as recommended by the Thermal Guidelines for Data Processing Environments provided by ASHRAE.

The InRow RC continually adjusts its cooling output to accommodate varying loads. It controls a fluid valve to modulate the fluid flow into the cooling coil. The cooling output is determined by the difference between the supply air temperature setpoint and the actual supply air temperature as well as the airflow (for each of the cooling units in the cooling group if more than one cooling unit is present).

# InRow RC Environmental Models

## InRow (open aisle) model

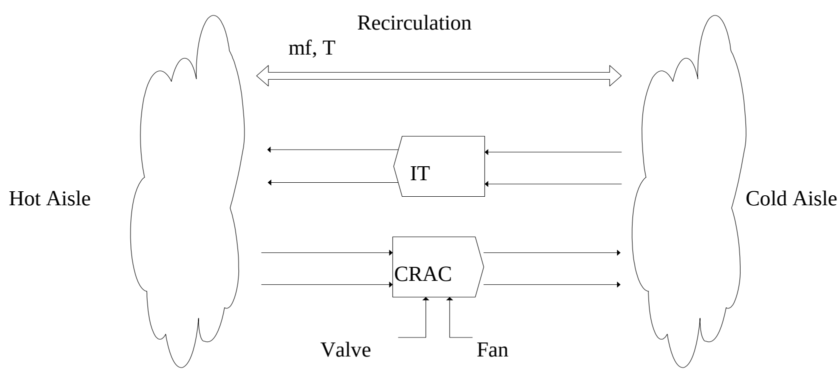
*Figure 1 – InRow (open aisle) environmental model*




The InRow (open aisle) model is characterized by the free circulation of air. The IT equipment draws in cool air from the cold aisle and rejects it to the hot aisle. The CRAC takes hot air from the hot aisle and supplies cool air to the cold aisle. There may be mixing of the cold and hot aisles over the top of the racks, around the sides, etc.

## Hot aisle containment system (HACS) model

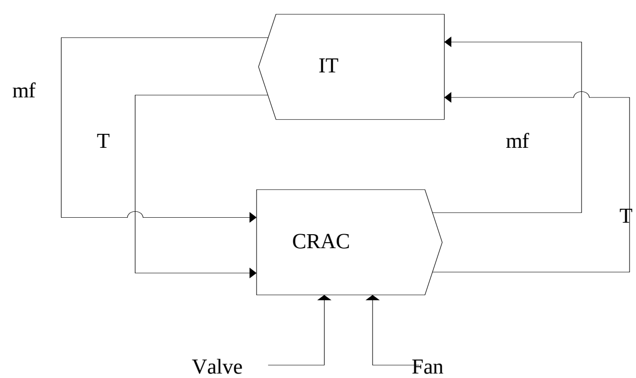
*Figure 2 – HACS environmental model*



The Hot Aisle Containment System (HACS) Model is similar to the InRow model, except that the amount of recirculation is drastically reduced.

## Rack air containment system (RACS) model

*Figure 3 – RACS environmental model*

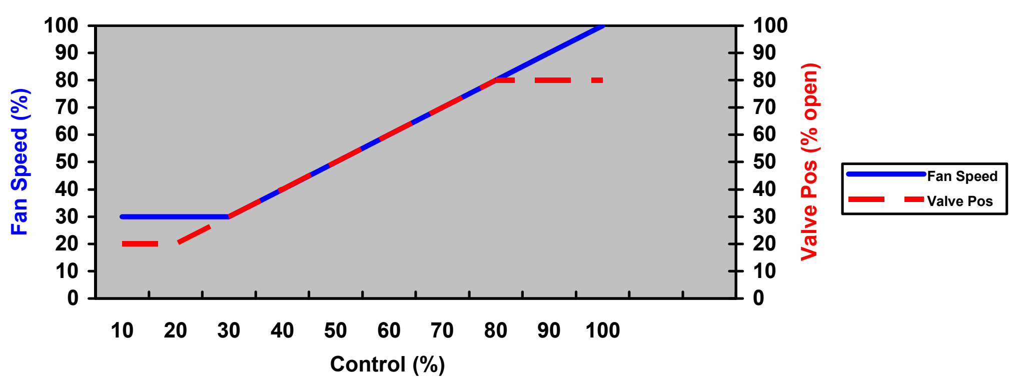



The Rack Air Containment System (RACS) model utilizes both front and rear containment and is characterized by the direct coupling of the CRAC supply and return to the IT equipment intake and exhaust respectively. The environment is semi-sealed such that mixing of cold and hot air is minimized.

# InRow RC Control Models

## InRow (open aisle) mode

*Figure 4 – InRow (open aisle) control response*



## Fan control

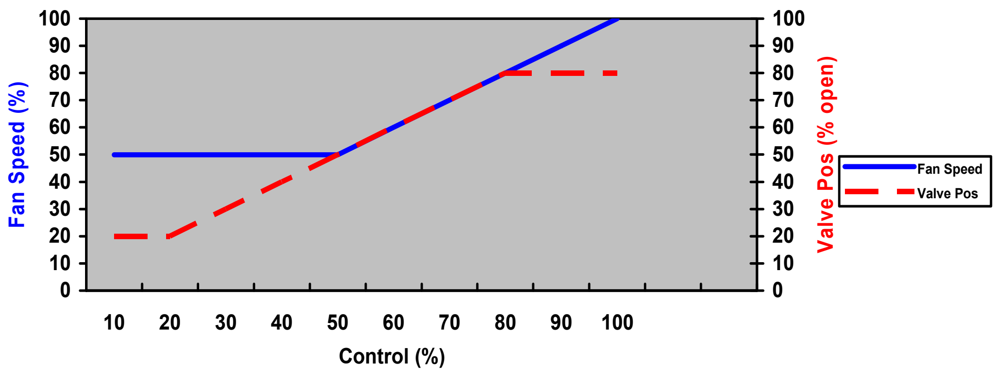
Mass airflow is determined by T (remote), and measured by the Remote Rack Inlet Temperature Sensor. The RC has a minimum fan speed of 30%. This speed was chosen to prevent fan bearing wear, as well as guarantee there is always some airflow over the temperature sensors to ensure accurate readings. Therefore when the fans are on, the actual fan speed will vary between 30% and 100% of the maximum fan speed, as shown in Figure 4.

## Chilled water valve control

The chilled water valve is controlled by the supply air temperature controller which is responsible for maintaining the leaving air temperature at the desired set point. When the unit is on, the actual valve position will vary between 20% open and 80% open, as shown in Figure 4. These valve positions correspond to zero fluid flow and maximum fluid flow respectively. The design of the supply temperature controller is the same for all rack configurations.

## HACS and RACS modes

*Figure 5 – HACS/RACS control response*




## Fan control

HACS and RACS environments are controlled by the same control strategy. In a HACS or RACS environment, the primary goal is to control the temperature and movement of the contained air by maintaining a temperature gradient across the unit. This temperature gradient (ΔT value) is the difference between the unit's return air temperature and its supply air temperature. The remote rack inlet sensor is not used in HACS or RACS mode. The following table describes how the user-specified Fan Speed Preference relates to a given ΔT value:

| Fan Speed Preference Setting | $\Delta T$ |
|---|---|
| High | 10 |
| Med High | 15 |
| Med | 20 |
| Med Low | 25 |
| Low | 30 |

The minimum fan speed is 50%. This speed was chosen to prevent fan bearing wear, as well as guarantee there is always some airflow over the temperature sensors to ensure accurate readings. This speed is slightly higher than the InRow minimum speed; the higher speed helps stabilize the supply temperature in lower load conditions. As a result, when the fans are on, the actual fan speed will vary between 50% and 100% of the maximum fan speed, as shown in Figure 5.

### Chilled water valve control

The chilled water valve is controlled by the supply air temperature controller which is responsible for maintaining the leaving air temperature at the desired set point. When the unit is on, the actual valve position will vary between 20% open and 80% open, as shown in Figure 5. These valve positions correspond to zero fluid flow and maximum fluid flow respectively. The design of the supply temperature controller is the same for all rack configurations.

## InRow RC Group Control

The goal of this model of group control is to stabilize unit interaction while still providing adequate cooling to control the environment. Independent of rack configuration, the units in a group operate in a master/slave relationship. One unit is elected to perform the duties of the group master without user intervention. In the event the master unit fails one of the slave units will become the new group master without any user intervention. If a temperature sensor on a unit fails, it will not be considered by the master unit's group control.

## InRow Mode

### Fan control

In an InRow configuration, all the units in the group control their fans to the output of the master unit's fan controller. The master unit uses its own and each slave unit's remote temperature sensor reading to determine the maximum group rack inlet temperature ($T_{MAX}$), and uses this value as the input to its fan controller. This approach assures even air distribution and circulation through the space rather than independent airflow patterns that would influence other units and cause instability.

### Chilled water valve control

Each unit controls their CW valve independently based on their own supply air temperature sensor readings. In a group configuration, the supply air setpoint is shared among all the units, with each unit managing its own CW valve based on supply air temperature. Thus there is no need for group control of the CW valve.

## HACS and RACS Modes

### Fan control

In a HACS or RACS configuration all the units in the group calculate their unit power demand based on their own return air temperature sensor readings. The demand from each unit is sent to the group master unit. The master unit uses the demand from all the units to calculate an average power demand. This average power demand is used by each unit to control its own fan speed. This approach assures even air distribution and circulation through the space rather than independent airflow patterns that would influence other units and create instability.

### Chilled water valve control

Each unit controls their CW valve independently based on their own supply air temperature sensor readings. In a group configuration the supply air setpoint is shared among all the units, with each unit managing its own CW valve based on its own supply air temperature. Thus there is no need for group control of the CW valve.

## InRow RC Control Setpoints (Mode Dependencies)

| Mode | Cooling Setpoint | Supply Air Setpoint | Fan Speed Preference |
|---|---|---|---|
| InRow | Set desired Maximum Rack Inlet Temperature | Set desired Supply Air Temperature | No Effect |
| HACS | No Effect | Set desired Supply Air Temperature | Set desired Delta-T (Return to Supply Air Temperature) |
| RACS | No Effect | Set desired Supply Air Temperature | Set desired Delta-T (Return to Supply Air Temperature) |

# InRow RC Startup Time

The unit startup time is the delay period from power-up until normal environmental control ensues. It determines the power outage recovery time once power is reactivated. During the delay period, the system performs self diagnostics and determines its state of health. The startup time is as follows:

Startup Time = Startup *Delay* + 15 seconds

*Startup Delay* is a user selectable unit configuration setting which provides a mechanism to restart multiple units sequentially.

# InRow RC Fault Handling Strategy

The primary failure mode strategy is that a unit should provide cooling if possible and that providing more cooling than needed is acceptable to ensure adequate cooling. When cooling is not possible, the dumping of hot air into the cold aisle is minimized by shutting off the fans.

## Alarms

When an abnormal condition or fault is detected, the unit will generate an alarm. When the condition no longer exists, the unit will clear the alarm without any user intervention. Alarms are categorized as either a warning or a critical alarm. If the condition causes the unit to shut down or otherwise results in impaired cooling, a critical alarm is generated; otherwise a warning alarm is generated. There are also informational events that do not have an associated alarm but that are created in the event log. For a detailed description of all the supported alarms and their recommended actions, refer to the InRow RC User Guide.

## Unit shutdown causes

The following failure conditions will shut down the unit, thereby changing the unit's operating state to Idle or Standby.

**Remote shutdown**

When the Remote Shutdown discrete input is active, the unit will go into Standby, ceasing all environmental control.

**Cooling failure**

This condition occurs when the supply temperature of the unit exceeds 77°F (25°C) and the cooling output is too low for a period of time. After a cooling failure occurs, the unit goes into the Idle state, the fans are turned Off, and the valve is completely closed. Periodically a cooling retry is initiated which turns the fans On (minimum speed) and activates the supply temperature controller. If the temperature still remains above 77° (25°C), the fans are again turned Off and the valve is completely closed. Once the temperature drops below 77°F (25°C) during the cooling retry, the unit can go into the On state and perform normal environmental control.

**Condensate pan full**

This condition occurs when the backup (upper) float of the condensate pan is tripped. It is cleared automatically when the backup float becomes inactive. When this fault condition occurs, the fans are turned Off, the CW valve is closed completely, and the unit goes into the Idle state. This prevents any further condensation which could cause the condensate pan to overflow. When this fault is cleared, the unit can go into the On state and perform normal environmental control.

**Leak detection shutdown**

This condition is active when a leak is detected at a unit, and the unit setting “Shutdown on Leak Detect” is set to enabled. It is automatically cleared when the leak is no longer detected. When this fault condition occurs, the fans are turned Off, the CW valve is closed completely, and the unit goes into the Idle state. When this fault is cleared the unit is allowed to go into the On state and perform normal environmental control.

**InRow RC faults which limit cooling capacity**

The DC Power Supply Fault will reduce the maximum airflow possible, thereby limiting the maximum cooling output of the unit. The RC has two DC supplies for powering the fans. In the event of a single DC supply failure, the controller will limit the maximum fan speed to 70% to prevent the fans from overloading the remaining DC supply.

## About the Author:

**Henry Jespersen** is a Senior Firmware Engineer for APC. He is responsible for designing and implementing embedded controls for IT equipment cooling products. Henry received a Bachelor’s degree in Electrical Engineering from Fairleigh Dickinson University in 1990.