[APPLICATION NOTE #142]

InRow RC Environmental Control

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PROJECT AT A GLANCE

Project Type

InRow Chilled Water Air Conditioner

CUSTOMER BENEFITS

- **Predictable cooling**
- **Rack inlet control**
- **Top and bottom chilled water connections**
- **Active response controls**

Abstract

The functions of the InRow RC product are to maintain a desired supply air temperature and to provide the required air flow to the Information Technology (IT) equipment. The InRow RC does not provide humidity control. The control strategy employed depends upon the deployment strategy of the cooling group. For the InRow or Cold Aisle Containment Systems (CACS) configurations, the InRow 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 Systems (HACS) or Rack Air Containment Systems (RACS) configurations, 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 InRow 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. The Active Response Controls of the InRow RC ensures that servers consistently operate at the desired rack inlet set point, which can be configured to be between 64.4-95°F (18-35°C). Recommended Thermal Guidelines for Data Processing Environments provided by ASHRAE suggest rack inlet temperatures to be maintained between 68-80.6°F (18-27°C).

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 set point 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) / CACS mode

The InRow model is an uncontained configuration where air can freely circulate. The CACS model is a configuration where the cold aisle is contained which results in reduced circulation. In either case, the control for these configurations is the same. The IT equipment draws in cool air from the cold aisle and rejects it to the hot aisle. The InRow RC (CRAC)pulls in hot air from the hot aisle and supplies cool air to the cold aisle.

HACS mode

The HACS model is a configuration where the hot aisle is contained which results in reduced circulation.

RACS mode

The RACS model utilizes both front and rear containment and is characterized by the direct coupling of the InRow RC (CRAC) supply and return to the IT equipment intake and exhaust respectively. Rear containment can be used with or without front containment; however front containment cannot be used without rear containment. The environment is semi-sealed such that mixing of cold and hot air is minimized.

InRow RC Control Models

InRow/CACS modes

Fan control

Mass airflow is determined by T (remote), and measured by the Remote Rack Inlet Temperature Sensor. The InRow RC adjusts its evaporator fans to match the airflow of the IT equipment. The InRow RC has a minimum fan speed of 30% for the standard model and 22% for the high temperature model. 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 linearly between the minimum and 100% of the maximum fan speed.

If you have purchased an Active Flow Controller (AFC), SKU # ACAC22000 an alternative fan control method can be utilized for the CACS configuration. In this method, mass airflow is measured by the AFC. This method provides more accurate control because the AFC provides a better measurement of airflow than the Remote Rack Inlet Temperature Sensor.

Table 1 – Fan Speed Preference Settings

Fan Speed Preference Setting	ΔT (°F)/(°C)
High	10/5.6
Medium High	15/8.3
Medium	20/11.1
Medium Low	25/13.9
Low	30/16.7

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 linearly between 20% open and 80% open for ACRC10X, 95% open for ACRC301S and 100% for ACRC301H. 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.

The ACRC301S and ACRC301H have the capability, when the unit's bypass valve is closed, to limit the flow of chilled water to a user defined value, Maximum Chilled Water Flow. This feature is available for all rack configurations.

HACS and RACS modes

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 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 in the ACRC10X products:
In the ACRC301S and ACRC301H products the setting is referred to as the Delta-T Set Point. In these products the range of set points has been expanded to included ΔT values of 35 °F (19.4 °C) and 40 °F (22.2 °C).

The minimum fan speed in the ACRC10X products 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 linearly between 50% and 100% of the maximum fan speed. In the ACRC301S and ACRC301H products the minimum fan speed is 30% and 22% respectively.

If you have purchased an Active Flow Controller (AFC), SKU # ACAC22000 an alternative fan control method can be utilized. In this method, mass airflow is measured by the AFC. This method provides more accurate control because the AFC provides a better measurement of airflow than a measurement of ΔT.

If you have purchased an Active Flow Controller (AFC), SKU # ACAC22000 an alternative fan control method can be utilized for the CACS configuration. In this method, mass airflow is measured by the AFC. This method provides more accurate control because the AFC provides a better measurement of airflow than the Remote Rack Inlet Temperature Sensor.

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 linearly between 20% open and 80% open for ACRC10X, 95% open for ACRC301S and 100% for ACRC301H. 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 mode 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 and CACS Modes

Fan control
In an InRow or CACS configuration, all the units in the group control their fans to the output of the master unit's fan controller. In the standard control method, the master unit uses its own and each slave unit's remote temperature sensor reading to determine the maximum group rack inlet temperature (TMAX), and uses this value as the input to its fan controller. For a CACS configuration, the AFC control method may be used. In this method the master uses the minimum differential pressure readings from all AFCs in the group as input to its fan controller. These approaches assure 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. The AFC control method may also be used. In this method the master uses the maximum differential pressure readings from all AFCs in the group as input to its fan controller. These approaches assure 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 chilled water 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 chilled water valve based on its own supply air temperature. Thus there is no need for group control of the chilled water valve.

Table 2 – RC Control Setpoints (Mode Dependencies)

Mode	Cooling Setpoint	Supply Air Setpoint	Fan Speed Preference (Delta-T Setpoint)
InRow/CACS	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)

Condensate Management in the ACRC301H

Because the ACRC301H operates at higher water temperatures, condensate management is not a concern in a typical application. However, the ACRC301H does provide controls to prevent the generation of condensate if the incoming water temperature falls below the dew point. The ACRC301H monitors the dew point of the environment using an onboard temperature/humidity sensor. If the chilled water inlet temperature falls below the dew point, then the ACRC301H monitors the Coil Inlet Temperature and keeps the chilled water inlet temperature at the dew point by adjusting the set point of the supply temperature control. The control is stopped when the chilled water inlet temperature rises 5 °F (2.8 °C) above the dew point.

Additionally, the ACRC301H may be optionally fitted with a circulation pump, ACAC10031. This pump circulates heated water from the coil back into the coil supply water to keep the coil temperature above the dew point. The pump is activated when the chilled water inlet temperature falls below the dew point. The pump is shut off when the chilled water inlet temperature rises 5 °F (2.8 °C) above the dew point.

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 90°F (32°C) and the cooling output is too low for a period of time and the unit setting “Idle on Cool Fail” is set to enabled. 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 90°F (32°C), the fans are again turned Off and the valve is completely closed. Once the temperature drops below 90°F (32°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 chilled water 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 “Idle on Leak Detect” is set to enabled. When the leak is no longer detected, the alarm is automatically cleared. When this fault condition occurs, the fans are turned Off, the chilled water 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% (ACRC10X), 75% (ACRC310S, ACRC301H) to prevent the fans from overloading the remaining DC supply.