APC

APPLICATION NOTE #113

# Configuration Types and Sequence of Operations for the InfraStruXure InRow SC

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## Abstract

The InfraStruXure® InRow™ SC (ACSC100 and ACSC101) is a self-contained air conditioner for server rooms and wiring closets. This application note outlines various operating modes and the impact of user configurable setting on unit component behavior.

## Introduction

The InfraStruXure InRow SC is an air-cooled, self-contained, cooling-only air conditioner designed to be placed in-row, between equipment racks. The in-row design allows the SC to capture waste heat from the IT equipment in the hot aisle and neutralize it before it mixes with the room air. Conditioned air is then discharged into the cold aisle, ready for immediate use by the equipment in the adjacent racks.

The unit has a microprocessor controller, the easy-to-use display allows the operator to select options from the device's menu-driven interface to control and monitor the air conditioning system. The user can adjust set points, change operating modes, view events logs, alarm conditions and components run times. The SC also has a Network Management Card (NMC) that allows for remote monitoring and control via a web browser, SNMP or Telnet.

When the SC is not in Standby, the fan, compressor, and hot gas bypass valve behavior is determined by the Configuration Type and Capacity Control settings. These behaviors are described below based on the specific Configuration Type as well as common behaviors that work across all configurations. The unit has three primary configurations: Spot Cooling, In-row, and Rack Air Containment System (RACS).

## Set Points and Thresholds

The InRow SC has several set points and thresholds that are user defined. The set points affect the behavior of the unit as it responds to the environmental conditions within the room. Depending on the configuration of the unit, these set points may or may not impact the control of the unit. **Table 1** provides a quick summary of the relevance between the four major settings and the configuration of the unit. A check mark indicates that the set point impacts unit behavior in that operating mode, N/A means

it has no effect. The specific effects of the Cool Setpoint, Cool Deadband, Supply Air Setpoint and Fan Speed Preference settings are described in each of the configuration sections below.

There are three additional settings the user should be aware of: altitude, start up delay and temperature thresholds. Altitude should be entered to allow the output power calculation to be more accurate. The closer this setting is to the true altitude above sea level the better, however within 1000 feet (305m) will be adequate. The Startup Delay is the number of seconds after the unit is powered on before it will resume operations. This setting can be useful to stagger the units after a power outage if there is a concern regarding generator loads. If the Idle on Leak Detect settings is changed to "Yes" the unit will go to Idle when water is detected. The unit must be equipped with a cable water sensor (AP9325) for this feature to be used. Finally, the user can also set temperature thresholds, above which the unit will signal an appropriate high temperature alarm. Available alarm settings are Rack Inlet Temperature, Supply Air Temperature and Return Air Temperature. Thresholds can be set in the range of 32 – 212°F (0 – 100°C).

*Table 1 – Setting relevance per configuration type*

| Setting | Configuration Type | | | |
|---|---|---|---|---|
| | Spot Discrete | Spot Proportional | In-row | RACS |
| Cool Set Point | √ | √ | √ | N/A |
| Cool Deadband | √ | √ | √ | √ |
| Supply Air Set Point | N/A | √ | √ | N/A |
| Fan Speed Preference | √ | N/A | N/A | N/A |

# Common Behaviors

The SC has several behaviors that are generally not affected by the unit configuration or the set points. The user should expect to see these control sequences any time the unit is not in Standby.

## Condenser fan control

In all modes of operation, the condenser fans will run when the compressor is active. The speed of the fans will change based on the discharge pressure of the compressor. The unit will attempt to maintain a nominal discharge pressure of 425 psi (2930 kPa). If the discharge pressure falls below this set point the speed of the fans will decrease to allow the discharge pressure to rise. If the discharge pressure rises above this set point the speed of the fans will increase in an attempt to reduce the discharge pressure; this functionality is detailed below.

## Compressor control

The compressor is activated or deactivated based on the environmental conditions and the unit's currently configured mode of operation, as described below. When a demand for cooling exists, the unit will activate the compressor when the following conditions are met: the compressor has been deactivated for a least two minutes, the refrigerant suction pressure is greater than or equal to 92 psi (634 kPa), and the pressure difference between the refrigerant suction and discharge lines is less than or equal to 7 psi (48 kPa). Once activated, the compressor will remain on for a minimum time of seven minutes, provided there are no abnormal conditions that prevent the unit from running safely. During the first two minutes of operation, the fan speed and Hot Gas Bypass Valve (HGBV) position are held constant to allow the refrigerant line pressures to stabilize. The next five minutes allows time for the unit's controls to bring the temperatures to their set points. After that delay, the unit will continuously monitor the system temperatures to see if the cooling demand has been satisfied; if so, the compressor will be deactivated.

## Hot gas bypass valve control

The SC utilizes a HGBV to help control the capacity of the unit. The position of this valve is based on environmental conditions and the operating mode selected. In all modes, the HGBV is fully open when the compressor is inactive, to equalize compressor line pressures.

## High head pressure protection

The condenser fans modulate from 30% to 100% to control the compressor discharge pressure, targeting a nominal value of 425 psi (2930 kPa). However, it is possible that the discharge pressure could continue to rise above this value even with the condenser fans running at 100%. Thus, additional safeguards are built-in to the control algorithm.

In Spot Cooling configuration with discrete capacity control, if the discharge pressure exceeds 520 psi (3585 kPa), the HGBV will be opened up to 50% in an attempt to reduce the pressure. In all other configurations, if the refrigerant discharge pressure exceeds 535 psi (3690 kPa), the HGBV will be opened up an additional 35% from its current position. This safeguard will reduce the unit's cooling capacity, which is preferable to a total loss of cooling.

If the discharge pressure reaches approximately 550 psi (3790 kPa), the compressor will automatically shutdown, and a High Discharge Pressure alarm will be generated. The compressor will re-start automatically after its normal minimum off time of two minutes, if a cooling demand is present. The High Discharge Pressure alarm will automatically be cleared at this time. If three high discharge pressure alarms occur within a 30 minute window, then unit requires that the user to manually clear the alarm condition before the unit will attempt to restart.

# Spot Cooling Configuration

In a Spot Cooling configuration, the unit attempts to maintain the measured Return Air Temperature at the user-specified Cooling Setpoint; this configuration is best suited for controlling the environment of a small room. If the Return Air Temperature rises above the Cooling Setpoint plus the Cooling Deadband, the compressor will be activated. The condition under which the compressor is shut off is dependent on which capacity control methods chosen. The Spot Cooling configuration has two capacity control modes: Discrete and Proportional; each mode is described in detail below. The Rack Inlet Air Temperature sensor is used for monitoring purposes only; it does not affect the behavior of the unit.

The evaporator fans of the SC in Spot Cooling configuration will run continually even when the compressor is off. This is to provide adequate airflow to the Return Air Temperature sensor so the temperature may be accurately measured. The speed of the fans both when the compressor is active and when it is off is also dependent on the choice of Discrete versus Proportional as described below.

# Spot Cooling – Discrete Capacity Control

In a Spot Cooling configuration with discrete capacity control selected, the SC keeps the evaporator fan speed constant and does not regulate the capacity of the compressor. The Supply Air Setpoint setting has no effect in this mode.

## Evaporator fan control

The evaporator fan speed is based on the Fan Speed Preference selected by the user. **Table 2** shows the settings as a percentage of the maximum speed. Should the refrigerant suction temperature begin to exceed 68°F (20°C), the evaporator fan speed will automatically be scaled down to 50% of the selected fan speed to prolong compressor life.

## Compressor control

The condition necessary for the compressor to activate is as described above. The compressor will deactivate when the Return Air Temperature is equal to or less than the Cooling Setpoint.

## Hot gas bypass valve control

Normally, the HGBV will be fully closed during compressor operation in the mode to provide maximum cooling capacity. Should the refrigerant discharge pressure begin to exceed 520 psi (3585 kPa), the HGBV will be opened to a maximum of 50% to prevent a high head pressure shutdown.

*Table 2 – Discrete capacity control fan speed settings*

| Fan Speed Preference | Evaporator Fan Speed |
|---|---|
| High | 100% |
| Med-High | 90% |
| Medium | 80% |
| Med-Low | 70% |
| Low | 60% |

# Spot Cooling – Proportional Capacity Control

In this mode, the unit not only changes the speed of the evaporator fans in response to the environment, but also attempts to control the temperature of the air leaving the unit. This allows the unit to reduce its capacity and keep the compressor running as long as possible, reducing cycling.

## Evaporator fan control

When the compressor is inactive, the speed of the evaporator fans is fixed at 50%. When the compressor is active, the speed of the evaporator fans is based on the Return Air Temperature and the user-specified Cooling Setpoint. If the Return Air Temperature is above the Cooling Setpoint, the unit will increase the fan speed. If the Return Air Temperature is below the Cooling Setpoint, the unit will decrease the fan speed. In this mode, the evaporator fans have a minimum speed of 50% and the Fan Speed Preference setting has no effect. Should the refrigerant suction temperature begin to exceed 68°F (20°C), the evaporator fan speed will be scaled down to a minimum of 30% to prolong compressor life.

## Compressor control

The compressor will remain active until the Return Air Temperature falls below the set point minus 1°F (0.5°C). If the evaporator fans are near their minimum speed, a timer will be set. If the Return Air Temperature does not rise to be at least equal to the set point minus 1°F (0.5°C) within a calculated period of time, the compressor will be deactivated. The amount of time that needs to elapse is based on the difference between the Return Air Temperature and the set point; the greater this difference, the shorter the amount of time before the compressor is deactivated.

## Hot gas bypass valve control

When the compressor is active, the position of the HGBV is dependent on the measured Supply Air Temperature and the user-specified Supply Air Setpoint. In general, the HGBV will open when the Supply Air Temperature falls below the set point, and

will close when the Supply Air Temperature rises above the set point. However, there is the additional constraint that the evaporator temperature must be held between 38°F and 56°F (3.3°C and 13.3°C), a range which keeps the evaporator from freezing or overheating. Should the refrigerant discharge pressure begin to exceed 535 psi (3690 kPa), the HGBV will be opened up to an additional 35% to prevent a high head pressure shutdown.

# In-row Configuration

In an In-row configuration, the unit attempts to maintain the measured Rack Inlet Air Temperature at the user-specified Cooling Setpoint. It will change the speed of the evaporator fans in response to the environment, and also attempt to control the temperature of the air leaving the unit. This allows the unit to reduce its capacity and keep the compressor running as long as possible, reducing cycling.

This configuration is best suited for a hot-aisle/cold-aisle environment, where the unit is situated such that the return side of the unit is facing into the hot-aisle, and the supply side of the unit is facing into the cold-aisle. The rack inlet sensor should be placed on the air intake of adjacent server equipment.

## Evaporator fan control

When the compressor is inactive, the evaporator fans will be turned off. The speed of the evaporator fans when the compressor is active is based on the Rack Inlet Air Temperature and the user-specified Cooling Setpoint. If the Rack Inlet Air Temperature is above the Cooling Setpoint, the unit will increase the fan speed. If the Rack Inlet Air Temperature is below the Cooling Setpoint, the unit will decrease the fan speed. In this mode, the evaporator fans have a minimum speed of 30% and the Fan Speed Preference setting has no effect. Should the suction temperature begin to exceed 68°F (20°C), the evaporator fan speed will be scaled down to a minimum of 30% to prolong compressor life.

## Compressor control

The compressor is activated when the Rack Inlet Air Temperature rises above the Cooling Setpoint plus the Cooling Deadband. The compressor will remain active until the Rack Inlet Air Temperature falls below the set point minus 1°F (0.5°C). If the evaporator fans are near their minimum speed, a timer will be set. If the Rack Inlet Air Temperature does not rise to be at least equal to the set point minus 1°F (0.5°C) within a calculated period of time, the compressor will be deactivated. The amount of time that needs to elapse is based on the difference between the Rack Inlet Temperature and the set point; the greater this difference, the shorter the amount of time before the compressor is deactivated.

## Hot gas bypass valve control

When the compressor is active, the position of the HGBV is dependent on the measured Supply Air Temperature and the user-specified Supply Air Setpoint. In general, the HGBV will open when the Supply Air Temperature falls below the set point, and will close when the Supply Air Temperature rises above the set point. However, there is the additional constraint that the

evaporator temperature must be between 38°F and 56°F (3.3°C and 13.3°C), a range which keeps the evaporator from freezing or overheating. Should the refrigerant discharge pressure begin to exceed 535 psi (3690 kPa), the HGBV will be opened up to an additional 35% to prevent a high head pressure shutdown.

# RACS Configuration

In Rack Air Containment System (RACS) configuration, the unit attempts to remove and neutralize heat from the hot side of the containment, maintaining a temperature differential between the intake and outlet of the server equipment. The Rack Inlet Air Temperature sensor has no effect on unit behavior in a RACS configuration. This mode is intended for use only when a RACS is utilized; undesired behavior will result if this condition is not met. Careful attention to applying the SC with RACS must be undertaken to prevent the compressor from cycling off during low load conditions. If the compressor cycles off, there is a minimum off time delay period of 2-minutes where no cooling is provided and the desired rack inlet temperatures may be exceeded. Refer to Application Notes AN-90 and AN-114 for a thorough discussion on RACS usage.

## Evaporator fan control

When the compressor is active, the fan speed is set such that a temperature differential of 10°F (5.5°C) is maintained between the unit's Return Air Temperature and Supply Air Temperature Setpoint. The Cooling Setpoint and Fan Speed Preference settings have no effect in RACS configuration. Should the suction temperature begin to exceed 68°F (20°C), the evaporator fan speed will be scaled down to a minimum of 30% to prolong compressor life. When the compressor is inactive, the evaporator fans maintain a constant speed of 30% to maintain a minimal amount of airflow through the unit so the system temperatures may be accurately monitored.

## Compressor control

The compressor is activated when the Supply Air Temperature rises above the Supply Air Setpoint (fixed at 64°F (17.8°C)) plus the Cooling Deadband. The compressor will remain active until the Supply Air Temperature falls below the set point minus 1°F (0.5°C). If the Supply Air Temperature does not rise to be at least equal to the set point minus 1°F (0.5°C) within a calculated period of time, the compressor will be deactivated. The amount of time that needs to elapse is based on the difference between the Supply Air Temperature and the set point; the greater this difference, the shorter the amount of time before the compressor is deactivated.

## Hot gas bypass valve control

When the compressor is active, the position of the HGBV is dependent on the measured Supply Air Temperature. The Supply Air Setpoint is fixed at 64°F (17.8°C) in RACS configuration. In a RACS enclosure, this will provide the rack with an intake air temperature of approximately 68°F (20°C). This temperature set point is fixed because it allows the unit to perform optimally across the heat load range supported by the unit. In general, the HGBV will open when the Supply Air Temperature falls below the set point, and will close when the temperature rises above the set point. However, there is the additional constraint that the

evaporator temperature must be held between 38°F and 56°F (3.3°C and 13.3°C), a range which keeps the evaporator from freezing or overheating. Should the refrigerant discharge pressure begin to exceed 535 psi (3690 kPa), the HGBV will be opened up to an additional 35% to prevent a high head pressure shutdown.

# Conclusions

The InRow SC has multiple control configurations that the user can select. Spot Cooling mode is best used for small spaces with a limited number of racks and modest IT loads. InRow mode is better for larger configurations with one or more rows of racks with SC units included. RACS mode should only be used in conjunction with a Rack Air Containment System.

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