

## Best Practices for Designing Data Centers with the InfraStruXure InRow RC

By John Niemann

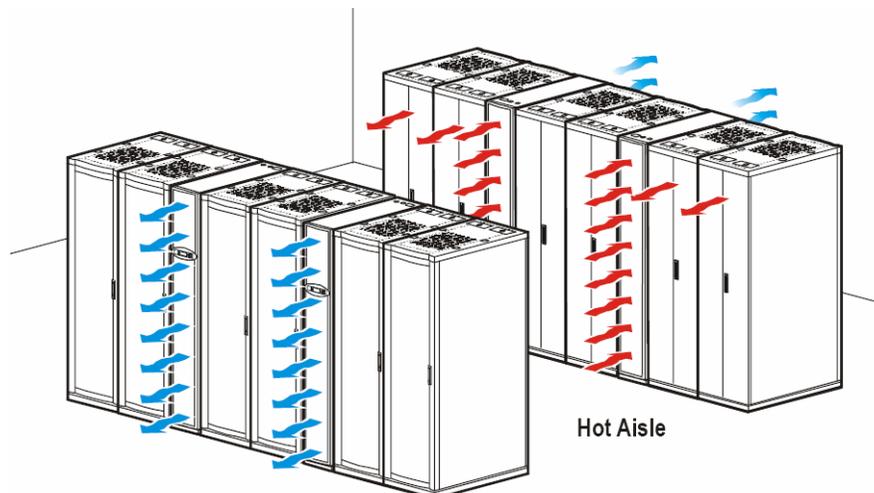
### Abstract

The InfraStruXure® InRow RC is designed to provide cooling at the row and rack level of a data center for rack based IT equipment with front to back airflow. When designing data centers with this product, there are some best practices that should be followed to ensure the InRow RC is cooling as designed. This paper presents the best practices that should be followed when designing a data center with the InRow RC, and provides some additional guidelines to follow when some of these best practices can not be adopted as part of the data center layout.

### Introduction

In-Row cooling architecture is a new approach to data center cooling that provides a predictable way of addressing the heat generated by IT equipment within a data center or small server room. The fundamental purpose of in-row cooling is to capture heat from the IT equipment in the hot aisle and neutralize the heat before it mixes in the room. Hot air mixing within the data center is the fundamental cause of thermal issues. With heat removal being the key driver with in-row cooling, there are some fundamental design practices that should be followed to ensure the design of the system is maximized to remove the heat being generated.

*Figure 1 – InfraStruXure InRow RC cooling unit removes heat before it mixes in the room*



The latest in-row cooling product released by APC is the InfraStruXure InRow RC shown in **Figure 1**. The InRow RC is designed to go into a row of IT equipment racks. The design is based on a half rack foot print and can provide up to 30 kW of cooling.

To ensure the unit properly captures the hot air from the IT equipment, the room must be designed with a hot aisle / cold aisle arrangement or containment systems. This is a fundamental data center design criteria that must be met in order for the InRow RC to provide effective cooling.

To better understand the influence the InRow RC has on the heat load of neighboring IT racks within the row, APC has done extensive testing and analysis to determine the ability each cooling unit has to capture hot air. The effect an InRow RC unit has on neighboring IT racks within the row is known as the sphere of influence. The sphere of influence is affected by the distance between the rack and cooling unit, the heat density of the rack, and the airflow of the rack. Knowing the design criteria for rack density as well as the cfm / kW is important to effectively designing the data center using the InRow RC. Using this information, APC has developed algorithms that accurately predict the ability of the RC units to capture air from the racks within the row (known as the capture index). The algorithms have been validated through CFD analysis and empirical data gathered through testing, and are incorporated into APC's ISX Designer for validation of data center configurations. This tool must be used in conjunction with following best practices when designing the data center with the InfraStruXure InRow RC. The best practices that should be followed are categorized as: placement of RC Units, row layout, hot aisle containment, and rack air containment.

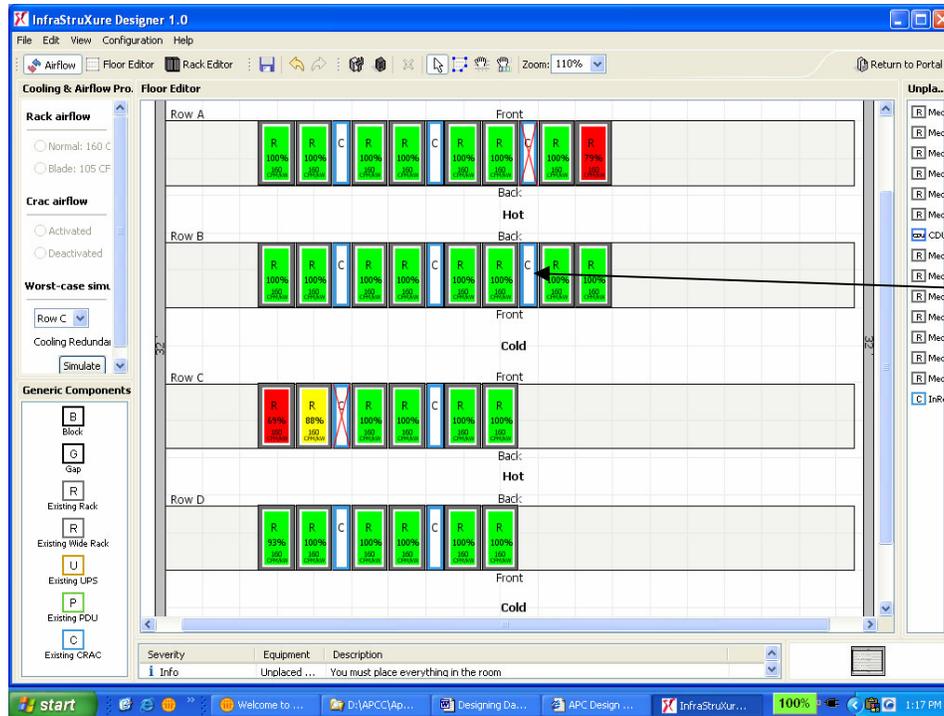
## Placement of InRow RC Units

Placement best practices to follow:

1. Even spacing of InRow RC Units throughout the row of IT equipment.
2. Use the ISX Designer Airflow calculation to ensure that hot air from IT equipment is being captured.
3. Do not place units at the end of a row in either open hot aisle or contained hot aisle configurations.
4. InRow RC units should be placed directly across the cold aisles from each other.
5. Calculate the capacity of the InRow RC (See Technical Data Manual for performance conditions).

APC's ISX™ Designer is available for APC employees or partners to use when configuring and pricing APC InfraStruXure Solutions. When configuring a given data center layout in ISX Designer, information about the density of the racks is selected by the user before configuring the layout of the data center. Using this information along with the sphere of influence algorithms for the InRow RC, ISX Designer has the capability to display the capture index of each rack in the row. The capture index is displayed on each rack along with a red, yellow, or green status showing whether or not the hot air from that rack will have an impact on increasing room temperature, which could lead to hot spots and unpredictable cooling behavior. **Figure 2** on page 3 shows an example layout in ISX Designer with the Capture Index displayed.

Figure 2 – Display showing Capture Index in ISX Designer. Four Rows of IT Racks



InRow RC Units x10

InRow RC units must be placed evenly in the row to maximize the capture index on each of the racks, and should be placed such that the capture index status of each rack is green. The red and yellow racks, shown in **Figure 2**, indicate that a large percentage of hot air is escaping into the room, which could increase overall room temperature or cause hot spots to occur. To maximize the sphere of influence of the system, it is best to evenly space the InRow RC throughout the row. By evenly spreading units throughout the row, air is more evenly captured and neutralized. For best performance, the InRow RC should also be placed at least one rack position in from the end of the row. The only exception to this rule is if you are using a rack air containment system.

When more than two rows of racks are configured, InRow RC units should be placed directly across the aisle from each other. This placement ensures that the cold air being discharged from the cooling unit is not blowing directly on the rack across the aisle. Having cold air blowing directly on a rack could influence the rack inlet probe of an InRow RC unit in that row. This could result in false readings causing the unit to provide less cooling than required by the row. **Figure 2** also shows proper placement of the InRow RC units across the cold aisles from each other in the data center

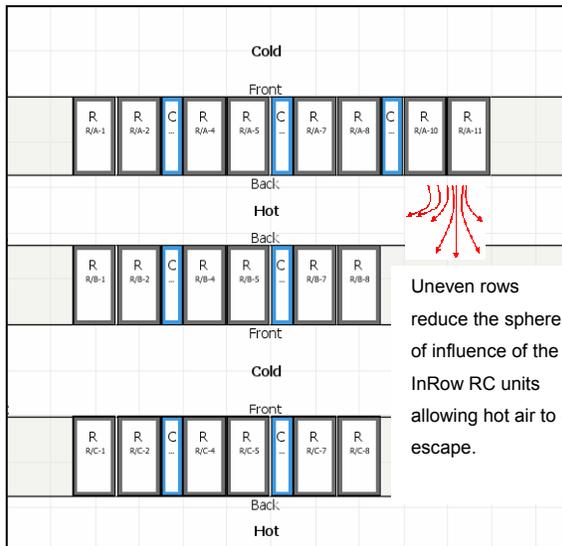
## Row Layout

Row layout best practices to Follow:

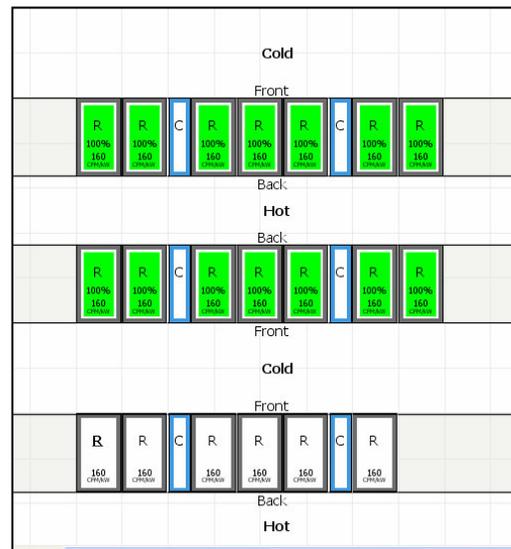
1. Rows that share a common hot aisle must be the same length.
2. Minimum Hot Aisle width – 3'
3. Maximum Hot Aisle width – 6'
4. Rows should be kept parallel to each other throughout the data center.

Layout of the rows within the data center is another design consideration that can impact the operation of an in-row cooling system. The two continuous rows of racks that make up the hot aisle (rack clusters) should be kept the same length. By keeping these rows equal length, the InRow RC is best able to capture the air that is exhausted from IT equipment. When two rows within a given cluster are not of equal length, the sphere of influence of the InRow RC is greatly dissipated and the exhaust air from the IT equipment can escape into the room. **Figure 3a** illustrates an uneven set of rows and represents an unfavorable layout for the InRow RC. **Figure 3b** shows a possible solution for this using the same amount of cooling and rack positions.

**Figure 3a-** Uneven rows reduce sphere of influence of the InRow RC allowing hot air to mix in the room.



**Figure 3b –** Rows should be equal length to ensure hot air is captured by the InRow RC's.



Another factor that needs to be considered when laying out the rows of racks with the InRow RC is the distance of the hot aisle. Keeping the hot aisle width between 3 and 6 ft will ensure the sphere of influence of the in-row cooling units is not significantly impacted. A single row of racks can be utilized with in-row cooling provided the row backs to a wall, and the rule for hot aisle distance is followed. **Figure 4a** shows a pair of racks with the hot aisle dimension shown, **Figure 4b** shows a sample layout with a single row of racks using a wall to create the hot aisle.

Figure 4a- Hot aisle width = 3 ft min, 6 ft max

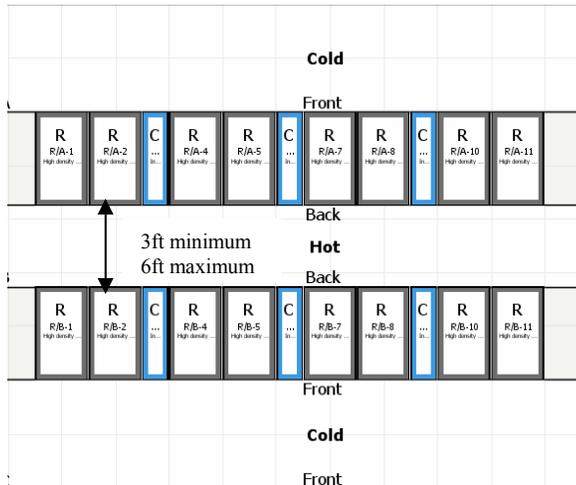
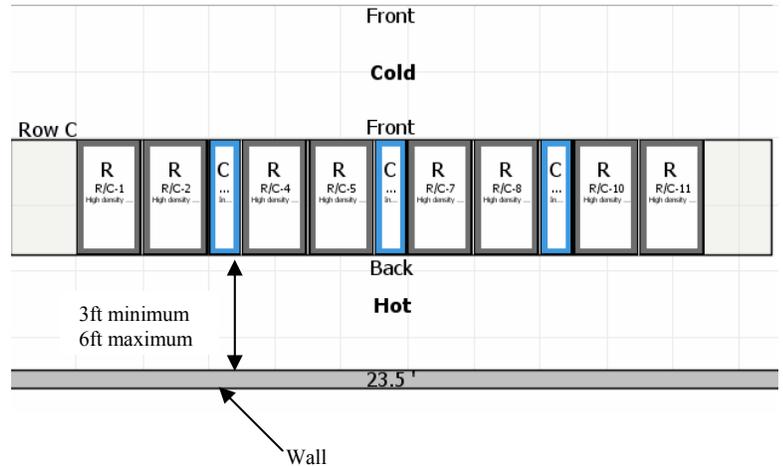


Figure 4b – Single rows without containment should follow the same hot aisle rules.



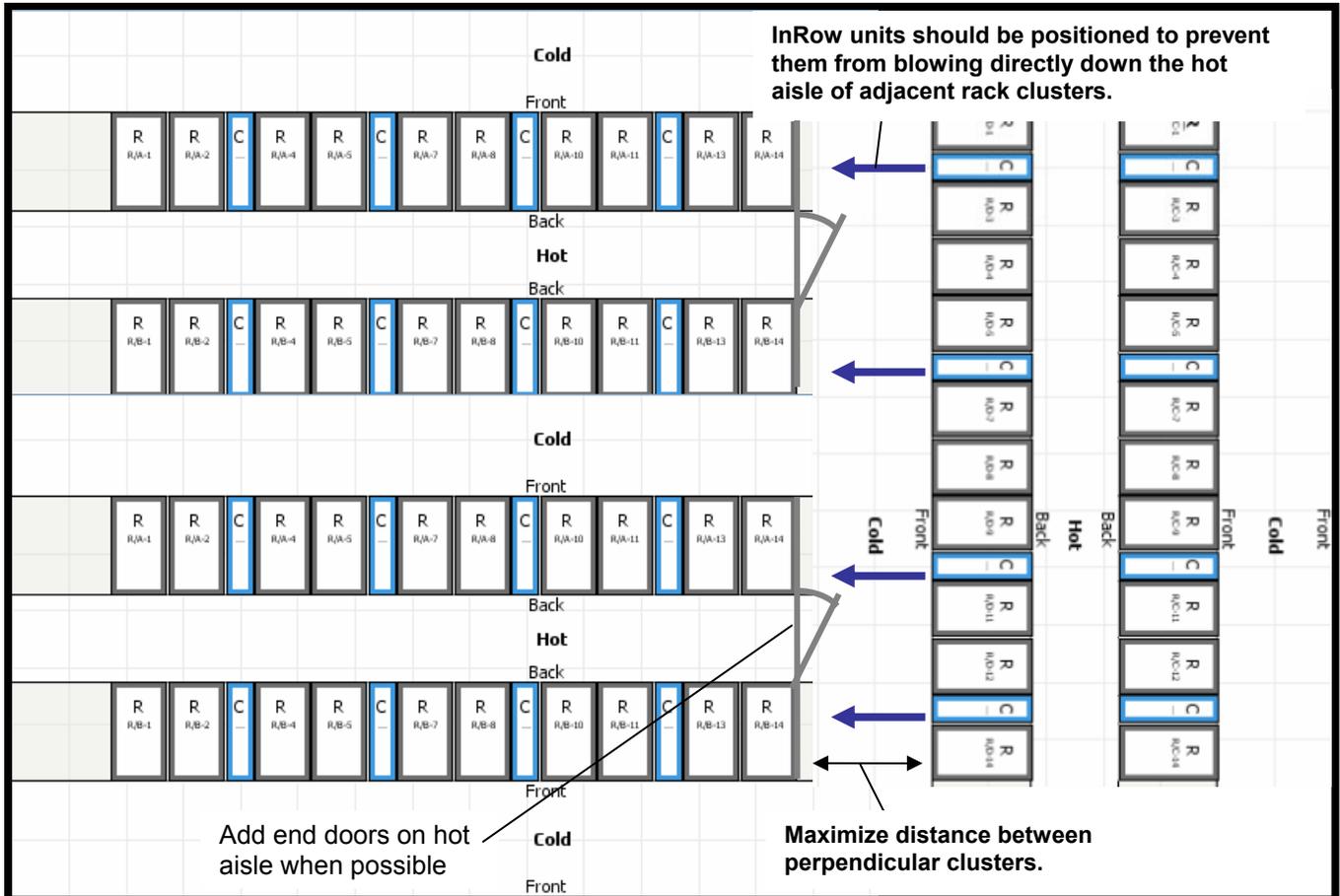
If the hot aisle becomes larger than 6 ft, it is recommended that rear rack air containment be used to ensure hot air is captured by the InRow RC. Rules for application of the Rack Air Containment can be found in the Rack Air Containment Section of this paper on page 8 and in Application Note #90.

A final best practice for row layout that should be followed when designing the data center with the InRow RC is the positioning of the rows in relation to each other in the room. As previously mentioned, rows must be arranged to achieve a hot and cold aisle, which effectively creates clusters in the room. When configuring these clusters in the room, it is recommended to keep them oriented in the same direction such that the rows are parallel to each other. Orienting clusters perpendicular to each other could possibly introduce unknown airflow patterns in the hot aisle affecting the sphere of influence of the InRow RC.

There will be some cases where this configuration is required to support the shape of the room. Even though APC does not recommend this approach, the following are some guidelines to follow if configuring a room with rows perpendicular to each other is required:

- **Maximize the distance between the clusters of racks that are perpendicular to each other.**
- **Arrange RC units to prevent air from blowing down the hot aisle of adjacent clusters.**
- **Recommend use of Hot Aisle Containment to prevent air from entering the hot aisle, or the use of the Hot Aisle Containment Doors at the end of aisle.**

Figure 5– Perpendicular rack cluster configuration

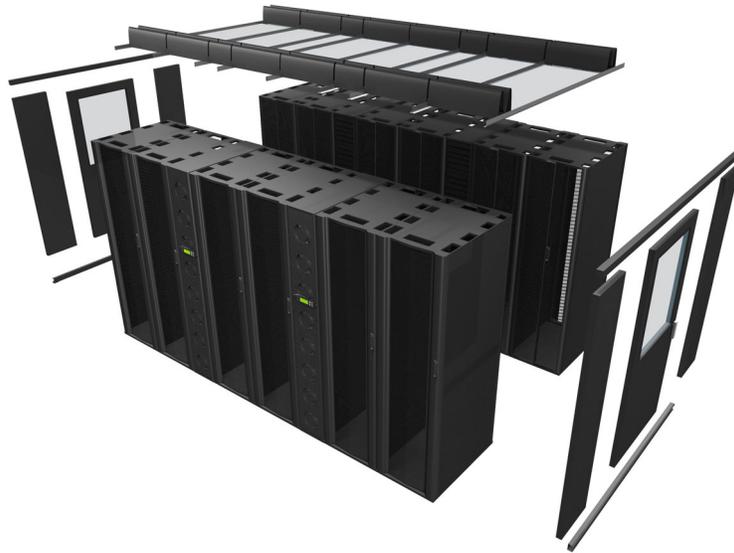


## Hot Aisle Containment Systems

To improve the predictability of an in-row cooling system, a containment system can be added to the hot aisle. This further reduces the opportunity for the hot air to mix with the room, and improves the sphere of influence of the InRow RC cooling unit. The hot aisle containment system is made up of a series for roof panels and door kits to accommodate a variety of configurations using APC racks, UPSs, and power distribution units (PDU). When designing a system with hot aisle containment, all the rules for an open aisle configuration apply with the exception of the rules discussed for perpendicular rows. It is best to design the rack cluster as if it were an open aisle, and then add containment to further improve the predictability of the system. Installations for high density applications that will rely on redundancy to ensure maximum uptime will benefit the

most from hot aisle containment. Cooling failures that may yield unacceptable performance, based on the airflow calculation that is performed, can be improved by adding a containment system. **Figure 5** shows an example hot aisle containment system with InRow RC units.

*Figure 6– InfraStruXure HD – APC Symmetra UPS, PDU, NetShelter SX Racks, and InRow RC Cooling Units*



To support hot aisle containment the InRow RC units must be placed directly across the hot aisle from each other. This allows for a half width ceiling panel to be installed across the hot aisle from InRow RC to InRow RC.

When designing a solution with hot aisle containment, three important factors to consider are:

- 1) The capacity of the RC units should be greater than or equal to the total power capacity of all the racks within the containment system.
- 2) The total amount of air provided by the InRow RC units should be greater than or equal to the airflow of the racks within the containment system.
- 3) The InRow RC units should be placed directly across the hot aisle from each other in the row.

To ensure there is adequate cooling capacity for the containment system see the technical data manual for the InRow RC unit to determine capacity of the unit under various operating conditions. The total cooling capacity of the RC's within the containment system must be greater than or equal to the total power in the row. In addition Total airflow of the IT equipment in the containment system must not exceed the total airflow of the InRow RC units.

## Rack Air Containment Systems

In smaller applications that require high density or improved overall system predictability the Rack Air Containment System (RACS) can be used. RACS consists of a set of front and rear plenum sections that mount to an APC NetShelter® SX Enclosure and InRow RC unit in various configurations to provide flexibility in deployment of high density cooling. Application Note #90 provides the various configurations that are supported within a rack air containment system. **Figure 7** illustrates one example of a rack air containment system with a single NetShelter SX enclosure and a single InRow RC unit.

*Figure 7– APC Rack Air Containment System configured with a Single InRow RC unit and NetShelter SX Enclosure*



There are several different configurations that are supported within a Rack Air Containment System and there are two levels of containment that can be configured. The first level is rear containment of the cooling and enclosure. This level of containment ensures that all the heat from the racks is captured by the InRow RC units. Front containment can be added for those applications that may be more sensitive for noise and airflow considerations in the space it is installed. **Table 1** on page 9 lists the various cases where rack air containment should be considered to ensure best practices are followed.

*Table 1– RACS solutions to address various data center design cases*

Design Case	RACS Solution
<b>Single rows with large hot aisle distances</b>	Rear containment improves the capture index and overall system predictability. For those applications that have larger distances (over 6ft) it is recommended to use rear containment.
<b>Single high density racks in rows within an existing data center</b>	When installing a single high density rack in an existing row, best practice dictates that all the hot air from that rack is captured by the InRow RC unit. Rear containment is recommended.
<b>Small high density applications</b>	When deploying smaller clusters of high density equipment (one to five racks), RACS is recommended. Rear containment is a minimum. However, for installations that will be sensitive to sound or air blowing in the space, front containment is recommended. Larger deployments of high density equipment should consider hot aisle containment.
<b>Uneven rows</b>	Containment can be used on the longer row to ensure hot air does not mix with the room.

The RACS is not a completely sealed system and is designed to go into a temperature and humidity controlled space such as a small server room or large data center. For recommended RACS configurations refer to Application Note #90.

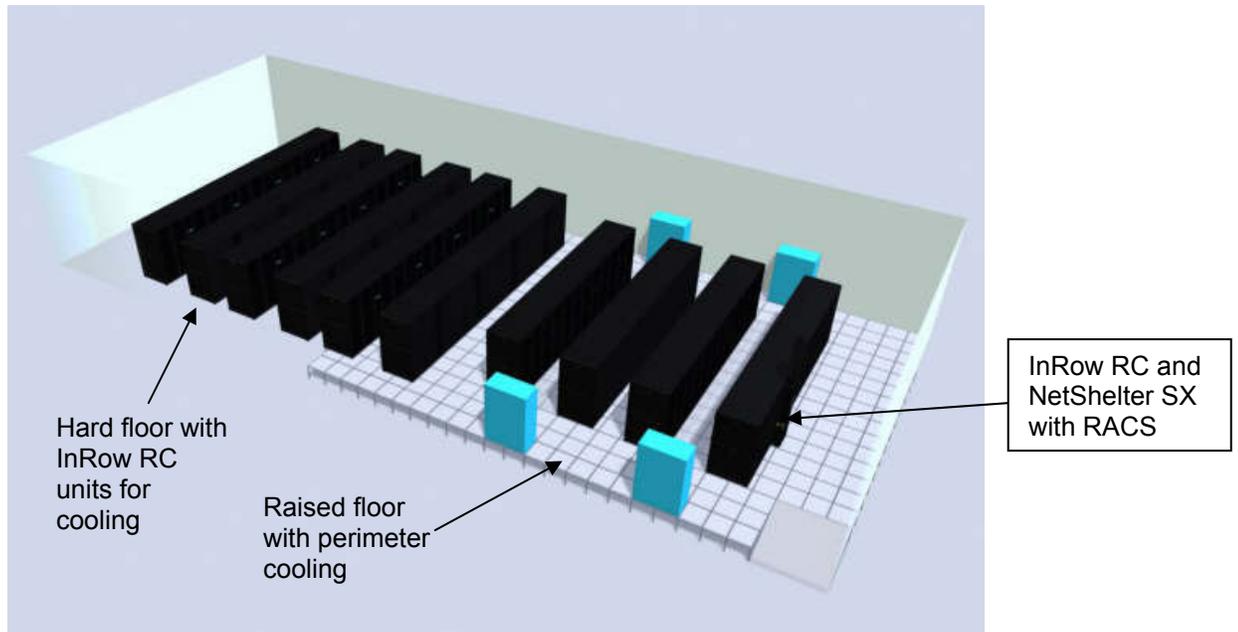
## Hybrid Environments

Best practices for hybrid environments:

1. Follow the fundamental best practices for row layout and InRow RC cooling unit placement.
2. Prevent airflow disruptions within the hot aisle.
3. Follow best practices for raised floor cooling applications where applicable.

Many data centers today are evolving into hybrid environments where there is a mixture of cooling architectures in the room. There are many types of cooling architectures that can control temperature at the rack, row, and room level. APC White Paper #130 discusses these architectures and the advantages that both rack and row level cooling have over other approaches. When designing a hybrid data center with the InRow RC, all of the previous considerations discussed in this paper should be followed. One example of a hybrid data designed with InRow RC units is shown in **Figure 8** on Page 10.

**Figure 8**– Example of a hybrid data center environment



Most data centers that exist today were designed around a traditional cooling approach. This approach implements perimeter down flow CRAC units with a raised floor for cold air distribution to the racks. When looking at deploying InRow RC units in an existing or new data center that will be a hybrid environment, it is best to follow traditional cooling architecture best practices as well. APC White Paper #40 discusses how to determine the health of cooling in an existing data center environment and best practices to follow to ensure the system is properly designed.

Other data center designs may use alternative means to provide cooling to the data center such as specialized ducting or other means of air distribution such as a bowling alley design. When looking at these applications in conjunction with the InRow RC, it is important to ensure that air from the hot aisle is disrupted as little as possible. Since the InRow RC is focused on capturing the hot air and removing the heat, any disruptive airflow patterns in the hot aisle will reduce the overall sphere of influence of the InRow RC cooling units. To minimize this disruption, either hot aisle containment or rack air containment can be deployed as a best practice for hybrid environments, especially for high density applications. When containment of the hot air is not an option for a hybrid environment, any sources of air blowing into the hot aisle should be eliminated. The design should restrict any air from being blown directly into the hot aisle.

## Conclusions

There are many different design options for today's data center. Deploying the InRow RC requires that some fundamental best practices are followed to ensure proper performance of the in-row cooling system. These best practices are as follows:

1. Evenly space InRow RC Units through out the row of IT equipment.
2. Use the ISX Designer airflow calculation to ensure that hot air from IT equipment is being captured.
3. Do not place units at the end of a row in either open hot aisle or contained hot aisle configurations.
4. InRow RC units should be placed directly across the cold aisles from each other.
5. Verify the capacity of the InRow RC (See Technical Data Manual for performance conditions).
6. Ensure that rows sharing a common hot aisle are the same length.
7. Minimum hot aisle width – 3'
8. Maximum hot aisle width – 6'
9. When possible, rows should be kept parallel to each other throughout the data center.
10. When using hot aisle containment, follow the same rules for placement of units in the row.
11. When using hot aisle containment, the airflow of the InRow RC units must be greater than or equal to the air being put into the hot aisle by IT equipment.
12. When using hot aisle containment InRow RC units should be placed directly across the hot aisle from each other. This requires an even number of RC units to be placed within a single hot aisle containment system.
13. Capacity of the InRow RC cooling units must be at least equal to the power of the racks in that row.
14. Prevent air from being blown directly into the hot aisle.
15. Hybrid environments should follow design best practices as outlined in APC White Paper #40.

Adhering to the best practices outlined in this paper will ensure worry free data center designs using the InfraStruXure InRow RC. While these guidelines will not lend themselves to all data centers they should prove useful for the majority of designs. When in doubt of the application of the InRow RC or any cooling application, there are tools and resources available in the market to do a more thorough analysis of the data center. APC is striving to provide more automated tools such as ISX Designer to incorporate these best practices into a data center design tool, as well as provide validation of the design using algorithms such as those created to calculate the capture index. When in doubt about a particular design or application that is not supported, following these best practices will prevent heat issues from occurring in the data center. For further validation of a given data center design, Computation Fluid Dynamic (CFD) analysis can be done to provide a complete validation of the cooling capabilities of a given data center design.

**About the Author:**

**John Niemann** is the Product Manager for In-Row Cooling Solutions for American Power Conversion. At APC, John is responsible for managing the products focused on applications greater than 16 kW for in-row cooling architecture. He has 10 years experience in design, sales, and support of both complex cooling solutions and IT technologies. John received a Bachelors degree in Mechanical Engineering from Washington University, St. Louis, MO in 1994.