APC

APPLICATION NOTE #126

Selection Procedure for InRow® Chilled Water Products

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Abstract

Proper selection of InRow chilled water cooling systems requires an engineer or technical salesperson to assess a number of variables to ensure customer satisfaction. These variables include but are not limited to the room layout, load profile of the servers and IT equipment, user's desired cold aisle temperature, and available or desired chilled water temperatures.

Introduction

With new APC InRow products, a number of variables are needed to be calculated. Among those variables are the entering water temperature, expected water side temperature difference, expected hot aisle temperature, chiller capacity, and Cooling Distribution Units in use. All of these factors must also be factored in with the overall data center layout as this will also have significant effect on how the cooling units perform. For information about best practice of data center layout, refer to Application Note 92, Best Practices for Designing Data Centers with the InRow RC.

Calculation of Hot Aisle Temperature

The biggest and most complex variable is the hot aisle temperature calculation. Generally, servers are rated for typical power and airflow draw. This makes it simple to calculate a temperature difference for the air through the server.

$$\Delta T_{air} = \frac{3162}{(CFM / kW)}$$

In addition to server loads, InRow Power must be considered. Inefficiencies inherent in the transformers, rectifiers, power distribution units, and UPS units lead to an increased heat load that must be accounted for and neutralized by the cooling units.

Table 1 – Symmetra PX Thermal Characteristics

Product	Heat Output (kW)	Air Flow (SCFM) [m^3/hr]
Symmetra PX40	3.5	180 [306]
Symmetra PX80	7.0	420 [714]

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Then, for a given cell (probably a set of rows forming a common hot aisle), the hot aisle temperature can be taken as the users desired cold aisle temp plus the average weighted ΔT . While there is some error associated with using this on a larger scale, it can be sized down to smaller groups of equipment to provide a good estimate of peak local hot aisle temperatures.

$$\Delta T_{average} = \frac{\sum (CFM \times \Delta T_{air})}{\sum CFM}$$

$$\left[\Delta T_{average} = \frac{\sum (CMH \times \Delta T_{air})}{\sum CMH} \right]$$

or its analog

$$\Delta T_{average} = 3162 \times \frac{\sum kW}{\sum CFM}$$

$$\left[\Delta T_{average} = 1861 \times \frac{\sum kW}{\sum CMH} \right]$$

The Cooling Correction Multiplier (CCM) found in Table 2, accounts for extra room temperature air that is mixed with the hot air leaving the servers before being conditioned in the air-conditioner.

Table 2 – Cooling Correction Multiplier

Configuration	Multiplier, CCM
Open Aisle	.70
HACS	.95
RACS	.95

The hot aisle temperature can then be calculated as

$$T_{hot} = \Delta T_{average} \times CCM + T_{cold}$$

This T_{hot} is then used as the entering air temp for the air conditioner.

Water Variables

The water variables are almost entirely dependent on user preferences, or in the case that the user is connecting to a building chilled water system, building system design and operation. The ACRC and ACRP products can tolerate a wide variety of entering water temperatures, currently cataloged as 42°F to 60°F [5.6°C to 15.6°C]. If building chilled water is available in sufficient quantity, it can be used. In that scenario, the entering water temperature would be the chilled water system's low temperature main. A facility engineer would need to be consulted to determine what water side temperature rise is acceptable for smooth and efficient operation of the building system. Also, the facility engineer would need to be consulted to ensure that the building chilled water system does not go into a "setback" mode during non-occupied hours, as that would adversely effect the data center operation. Available pump head will also determine the amount of water flow that can be obtained. The maximum available flow for an ACRC can be back solved by the pressure loss equation:

$$\Delta P = \frac{(.0762 \times \dot{V}^2 + .1669 \times \dot{V})}{2.31}$$

$$\left[\Delta P = (.9053 \times \dot{V}^2 + 31.43 \times \dot{V})\right]$$

where ΔP is in psi [Pa] and $\dot{V}$ is in Gallons per minute [L/s]. The maximum available flow for an ACRP500 series can be back solved by the pressure loss equation:

$$\Delta P = \frac{(.0306 \times \dot{V}^2 + .0537 \times \dot{V})}{2.31}$$

$$\left[\Delta P = (.3635 \times \dot{V}^2 + 10.112 \times \dot{V})\right]$$

where ΔP is in psi [Pa] and $\dot{V}$ is in Gallons per minute [L/s].

For dedicated chiller loops that are designed to meet the datacenter's cooling load only, one should consult the published Technical Data Manual for performance specifications, water flow rates, and pressure drops. If the user is setting up a dedicated loop to their datacenter, then nearly any temperature is attainable in the given range. APC recommends use of 45°F [7.2°C] entering water temperature and a 10°F [5.6°C] temperature rise for optimal performance and minimal latent capacity waste. For increased electrical efficiency, entering water temperature leaving the chiller can be increased, however the user must consider the capacity loss of the RC/RP and adjust the datacenter design accordingly if high enough densities are present. Pumps should be sized to ensure that the pressure drop of not only the air conditioner are included, but also any building piping, CDU pressure drop (APC Skus ACFD12-T and ACFD12-B), or pex piping pressure loss. CDU pressure loss is given by :

$$\Delta P = \frac{(.0498 \times \dot{V}^2 + .0313 \times \dot{V})}{2.31}$$

$$\left[\Delta P = (.5916 \times \dot{V}^2 + 5.8940 \times \dot{V})\right]$$

And pressure loss through the pex piping is given by:

$$\frac{\Delta P}{L_{eq}} = \frac{(.0542 \times \dot{V}^2 + .1705 \times \dot{V})}{2.31}$$

$$\left[\frac{\Delta P}{L_{eq}} = (2.1249 \times \dot{V}^2 + 105.95 \times \dot{V}) \right]$$

There also can be flexible hoses used for vibration isolation and ease of installation and placement. Table 3 shows the pressure drop induced by the stainless hoses.

Table 3 – Stainless Steel Hose Cv

Length	D=1.00" [DN25]	D=1.25" [DN30]
36"[914mm]	35	57
72"[1829mm]	24	38

Glycols

Frequently, in areas where freeze protection is required or desired for safety of system integrity, glycol solutions are used to depress the freezing point to prevent pipe freezing. Either ethylene or propylene glycol can be used at any proportion, however, ASHRAE recommends a maximum of 30% ethylene glycol or 35% propylene glycol due to the decrease heat carrying capacity and higher viscosity of glycol mixtures (ASHRAE Fundamentals Handbook 2001 p. 21.5). Table 4 lists the derating factors used for glycols.

Table 4 – Glycol Adjustment Multiplier

Percentage Glycol (%)	Capacity Multiplier Ethylene Glycol	Capacity Multiplier Propylene Glycol	Pressure Drop Multiplier Ethylene Glycol	Pressure Drop Multiplier Propylene Glycol
0	1.00	1.00	1.00	1.00
10	.97	.96	1.04	1.09
20	.93	.90	1.13	1.20
30	.88	.82	1.21	1.35
40	.81	.77	1.31	1.52

The above factors assume a constant flow rate as rated for the given conditions in the technical data manual.

Altitude

In properly estimating the capacity of a chilled water unit, many locations may require use of an altitude correction factor. All values found in APC Technical Data manuals are based on sea level performance. Table 5 gives the Altitude Correction Factors. Note that while APC can adequately predict cooling equipment performance, we cannot predict how a user's servers will perform in high altitude applications. Although, it is generally a fair assumption that as altitude increases, the server outlet temperature, for a given server, will increase and as a result the hot aisle temperature will slightly increase.

Table 5 –Altitude Correction Factors (ACF)

Altitude (ft [m])	ACF (-)
0 [0]	1.00
1000 [305]	.98
2000 [610]	.96
3000 [914]	.93
4000 [1219]	.91
5000 [1524]	.88
6000 [1829]	.86
7000 [2134]	.85
8000 [2438]	.83

Chilled Water InRow CRACs

ACRC 100 series

The ACRC is a sensible-only half rack wide InRow cooling product. It has a nominal capacity of 17 kW at 85°F [29.4°C] Entering Air Temperature and 45°F [7.2°C] EWT with a 10° F [5.6°C] temperature rise on the water side and running its full capacity, 2900 SCFM [4900 CMH], of air. The actual capacity can be modulated from 0 to 30 kW depending on actual conditions. The unit is fully capable of modulating both airflow and water flow rate to maintain leaving air temperature and cold aisle temperatures within a user defined range.

ACRP 500 series

The ACRP is a precision, full rack wide InRow cooling product. It has a nominal capacity of 37 kW at 85°F [29.4°C] EAT and 45°F [7.2°C] EWT with a 10°F [5.6°C] temperature rise on the water side and running its full capacity, 6900 SCFM [11,700 CMH], of air. The actual capacity can be modulated from 0 to 70 kW depending on actual conditions. The unit is fully capable of modulating both airflow and water flow rate to maintain leaving air temperature and cold aisle temperatures within a user defined range. Furthermore, the unit is capable of reheat and humidification for precision room control.

ACRC 500 series

The ACRC500 series is alike is capacities to the ACRP, however has no humidity control or reheat ability and therefore is not precision air conditioning.

Checking a Solution

Three checks must be run to make sure that the system will satisfy all needs and redundancy requirements: a capacity check, an airflow check, and a supply air temperature check. If any of these fail, application engineering must determine what must be done to make the system operate as planned or determine whether the other variables are enough to compensate.

The capacity check verifies that the unit performance is adequate to meet the user requirements. If a user requires N redundancy on a row basis, the engineer must ensure each row has more cooling than power input. If the user requires N+1, one more unit than is required to meet the cooling needs must be installed. In mixed mode applications, it must be assumed that the redundant unit is always the highest capacity unit.

The airflow check ensures that the cooling units are drawing at least as much air as required to maintain the calculated entering air temperature. Therefore, for N redundancy

$$\sum_{CRAC} CFM * CCM > \sum_{Servers} CFM$$

If this is not true, then additional cooling units must be added to ensure all air is captured by the cooling units and hot air is not recycled into the servers. To define N+1 or greater redundancy, particularly in mixed mode applications, assume a loss of the highest flow unit and ensure,

$$\sum_{CRAC} CFM * CCM - CFM_{highestflowunit} > \sum_{Servers} CFM$$

Finally, an inlet air temperature check should be run. This ensures that at the maximum air flow rate, the cooling units have adequate cooling to maintain a sufficient inlet air temperature to the servers. To perform this check,

$$T_{hot} - \frac{3415 \times \sum kW}{1.08 \times \sum CFM} = T_{outlet}$$

$$\left[T_{hot} - \frac{3415 \times \sum kW}{1.84 \times \sum CMH} = T_{outlet} \right]$$

Verify that T_{outlet} is less than the cold aisle setpoint.

Sample Procedure

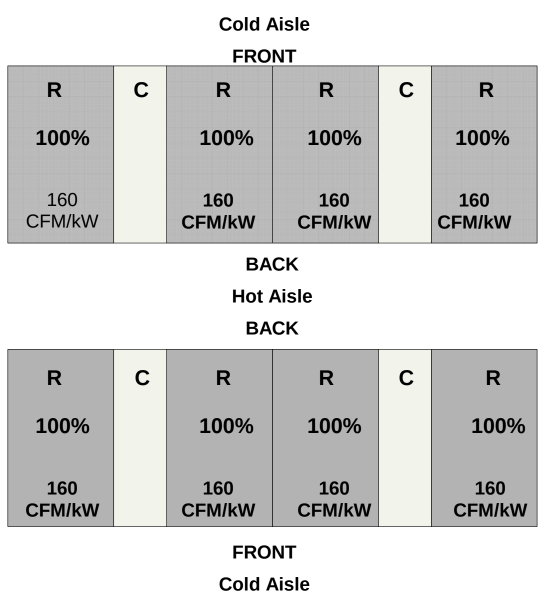
Take Figure 1 as our example data center located in Denver. Each rack is loaded to 5 kW and each have an associated minimum airflow per kW. User assigns the cold aisle temperature to be 70°F. Four ACRC 100 units are placed in the space with open aisle configuration, as shown, and supplied with 45°F ethylene glycol at 20% solution and a desired water temperature rise of 10°F. Determine the cooling system characteristics and redundancy.

Total rack airflow is shown in Table 6.

Table 6 – Rack Power Table

		Power Draw (kW)	CFM/KW	Airflow (CFM)
Row A	Rack 1	5	160	800
	Rack 2	5	160	800
	Rack 3	5	105	525
	Rack 4	5	160	800
Row B	Rack 5	5	160	800
	Rack 6	5	105	525
	Rack 7	5	160	800
	Rack 8	5	160	800
totals		40		5850

Figure 1 – Sample Datacenter Cluster



Therefore, by calculating, the temperature rise can be determined,

$$\Delta T_{average} = 3162 \times \frac{\sum kW}{\sum CFM} = 3162 \times \frac{40}{5850} = 21.62^{o} F$$

and

$$T_{hot} = \Delta T_{average} \times CCM + T_{cold} = 21.62 \times .70 + 70 = 85.1^{o} F$$

From there, the capacity and performance specifications of the chilled water air-conditioner can be determined. Look up tables from the technical data manual for *pure water at sea level* and interpolation indicates a sensible performance of 62,000 BTU/hr. Water flow required is found as 13.2 GPM. Adjusting for the altitude in Denver (5280 ft ASL) yields an altitude correction factor of .875, and the adjustment for 20% ethylene glycol yields a correction factor of .93. Therefore the actual capacity is

$$62{,}000 BTU / hr \times .93 \times .875 = 50{,}400 BTU / hr = 14.8 kW$$

From here a number of checks must be run. First is the airflow check. The racks require 5850 SCFM. Each ACRC unit produces 2900 SCFM. In order to achieve the required airflow, the use of 3 ACRC units is required, however, the overage will be 1390 SCFM taking into account the CCM. Therefore, the system, as designed with four RC units, is N+1 from the airflow vantage. Thermally, the system requires 40 kW of cooling capacity. At 50,400 BTU/hr, the converted capacity is 14.8 kW.

Therefore, from the thermal standpoint, the system is also N+1. Finally, we must check the leaving air temperature. Maximum supply temperature will be attained at full airflow rate, therefore, the maximum supply temp is found to be 68.9°F. This value is below the desired setpoint of 70°F, so the third check is satisfied. The system can be declared to be N+1.

At this point any room or partial room layout needs to be looked at from the perspective of the actual physical configuration. The proximity of heat loads relative to coolers is critical in an InRow configuration. It is possible that the total cooling capacity is sufficient to handle the total heat load and yet can not be configured in such a manner that all of the heat will be captured by the necessary coolers. Please refer to Application Note 92, Best Practices for Designing Data Centers with the InRow RC for more information.

About the Authors:

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