R4 Ventures LLC

White Paper

Preliminary Temperature Performance Evaluation of New Cooling Technologies consisting of the Multistage Evaporative Cooling System (MECS) alone or combined with the Real Time Electronic Enclosure Cooling System (ISECS) in the Real Time Data Center Cooling System (RTDCCS) for Phoenix, AZ; Newark, DE; Houston, TX; and San Jose, CA.

Applications included in this evaluation include:

- ***Data Centers – Real Time Data Center Cooling System (MECS + ISECS)***
- ***Commercial/Industrial Buildings – MECS***
- ***Inlet Air Cooling for Nat Gas Turbines/CHP Systems – MECS***
- ***Process Cooling Water for Industrial & Food Processing Plants - MECS***

Patents

Mike Reytblat – Inventor and Chief Scientist - The first patented system is the Multistage Evaporative Cooling System (MECS). Notice of Allowance was issued by the USPTO in August 2014 on our Advanced Multi-Purpose, Multi-stage Evaporative Cold Water/Cold Air Generating and Supply System US Patent Application Number 13/624912 and a US Patent Number 8,899,061 published on December 2 2014. The second patented system is the Real Time Individual Electronic Enclosure Cooling System (hereinafter Individual Server Enclosure Cooling System or ISECS). Notice of Allowance was issued by the USPTO in August on our Real Time Individual Electronic Enclosure Cooling System – US Patent Application Number 13/748088 and US Patent Number 8,857,204 published on October 14, 2014. A Real Time Data Center Cooling System (RTDCCS) is created by combining ISECS with MECS.

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R4 Ventures LLC

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Executive Summary

R4V Ventures LLC (“R4V”) is using research, development, innovative technologies and the earth’s abundant natural and renewable resources to provide cooling to commercial and industrial buildings throughout the world. R4V’s first technology to be commercialized is the Real Time Data Center Cooling System focused on reducing the cooling costs and electrical usage in data centers worldwide. R4V is applying semi-conductor clean room process cooling methods to data center facilities through patent pending technologies providing significant cooling energy cost savings of 60 to 80% when compared to traditional mechanical cooling systems and technologies and significantly reducing green house gas (GHG) emissions. Data Centers (DCs) currently use 2.5% of the total electricity produced in the United States in the operation of DCs with 40% of this electricity being used for cooling. This equates to 1% of all the electricity produced in the United States.

In addition to data centers, R4V technologies are targeting extremely high energy use markets including process cooling requirements in industrial and manufacturing applications, high cooling energy using commercial and industrial buildings, natural gas turbine inlet air cooling, and large industrial compressor inlet air cooling. R4V patents, commercializes and brings to market these unique cooling technologies through continued R&D, strategic partnerships, contract manufacturing relationships and engineering knowhow licensing and system distribution relationships.

R4 Ventures LLC has evaluated the cooled water and cooled air temperature performance of our **compressor-less … refrigerant-less cooling system technologies** in this White Paper to provide engineering analysis of what temperatures can be attained in four major markets in the United States. The applications evaluated are:

- Data Centers – Real Time Data Center Cooling System (MECS + ISECS)
- Commercial/Industrial Buildings – MECS
- Inlet Air Cooling for Nat Gas Turbines/CHP Systems – MECS
- Process Cooling Water for Industrial & Food Processing Plants - MECS

Real Time Data Center Cooling System (RTDCCS) (Data Center Market) and the Multistage Evaporative Cooling System (MECS) (Commercial/Industrial Buildings, Turbine Inlet Air Cooling, and Process Cooling Water for Industrial & Food Processing Markets) for four (4) major cities in the United States, Phoenix, AZ; Newark (Wilmington), DE; Houston, TX; and San Jose, CA. The RTDCCS consists of patent pending technology including the Multistage Evaporative Cooling System (MECS) which generates cold water (and cold supply air for the above described markets) coupled with the Individual Server Enclosure Cooling System (ISECS) which provides process cooling of the heat load at the rack level based on the ASHRAE Summer Design Conditions for commissioning in a new or retro commissioned Data Centers. This white paper details the cooled water temperature performance of the RTDCCS (MECS + ISECS) in Data Center White Space and the cooled supply air temperature performance of the MECS for the above described markets based on ASHRAE published Summer Design Conditions of .4% for cooling applications, and the monthly Mean Dry Bulb and Wet Bulb Temperatures for each city’s closest airport (Phoenix, Wilmington and Houston) and monthly ASHRAE published Summer Design Conditions of .4% for cooling applications (San Jose).

The tables and charts below for each of the cities identified show the temperature performance of the RTDCCS and MECS. The RTDCCS performance is based on, first, the selected and operational components of the RTDCCS based on achieving the **maximum energy efficiency** while meeting the ASHRAE TC 9.9 Maximum Temperature Recommendations and second, the selected and operational components of the RTDCCS based on achieving the **lowest possible temperature** in the Data Center White Space. The MECS tables and charts show the temperature performance based on, first, the selected and operational components of the MECS based on achieving the **maximum energy efficiency** in meeting or approaching the desired comfort space temperatures in commercial and industrial buildings and second, the selected and operational components of the MECS based on achieving the **lowest possible space temperature** in commercial and industrial buildings. The MECS tables and charts designed to supply cold air for Turbine/Compressor Inlet Air applications show the temperature performance based on, first, the selected and operational components of the MECS based on achieving the **maximum energy efficiency** in meeting or approaching the desired inlet air temperatures of 59 °F (the temperature in which 100% name plate efficiency can be achieved) in natural gas turbine power generation systems and second, the selected and operational components of the MECS based on achieving the **lowest possible inlet air temperature** entering the turbine or compressor.

To begin putting the advantages and benefits of the RTDCCS together for this engineering analysis and perspective, let’s first look at the amount of potential energy savings available to Data Center Owners/Operators by comparing 11 different traditional data center mechanical cooling methods to the RTDCCS. These systems can be ranked from an energy usage standpoint by evaluating the energy required to operate the system in kilowatts (kW) versus the cooling capacity provided in tons of cooling

(12,000 BTU/Hr). The table following compares KW per ton of power usage of the Real Time Data Center Cooling System against these competitive systems.

Summary of Temperature Performance of R4 Ventures LLC's New Cooling Technologies

Data Centers – Real Time Data Center Cooling System (MECS + ISECS)

1. Phoenix AZ
    a. ASHRAE published Summer Design Conditions of .4% for cooling applications - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 63.45 °F completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 75 °F in the Data Center White Space.
    b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 68.94 °F in the hottest month of August completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 75 °F in the Data Center White Space.
2. Newark DE
    a. ASHRAE published Summer Design Conditions of .4% for cooling applications - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 75.65 °F completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 77 °F in the Data Center White Space.
    b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 75.80 °F in the hottest month of July completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 77 °F in the Data Center White Space.
3. Houston TX
    a. ASHRAE published Summer Design Conditions of .4% for cooling applications - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 76.16 °F completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Additional energy can be saved by maintaining a set point temperature of 79.5 °F in the Data Center White Space.
    b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 79.48°F in the hottest months of July and August completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Additional energy can be saved by maintaining a set point temperature of 79.5 °F in the Data Center White Space.
4. San Jose CA
    a. ASHRAE published Summer Design Conditions of .4% for cooling applications - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 61.97 °F completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 75 °F in the Data Center White Space.
    b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Data Center White Space temperature (for the entire compute space) can be maintained at a set point temperature of 67.60 °F in the hottest month of July completely eliminating hot aisles and cold aisles. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a set point temperature of 75 °F in the Data Center White Space.

Commercial/Industrial Buildings – MECS

1. Phoenix AZ
    a. ASHRAE published Summer Design Conditions of .4% for cooling applications – Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 54.80 °F plus adjustment for space heat gain. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building.
    b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 67.10 °F in the hottest month of August plus adjustment for space heat gain. No compressors and refrigerants

are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building.

2. Newark DE
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 73.20 °F plus adjustment for space heat gain. **An additional 5 °F to 10 °F set point temperature reduction can be obtained by adding dehumidification to the Make Up Air Handling Unit (MU AHU).** No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building when using dehumidification in Make Up Air Handling Unit (MU AHU).
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 70.10 °F in the hottest month of July plus adjustment for space heat gain. **An additional 5 °F to 10 °F set point temperature reduction can be obtained by adding dehumidification to the Make Up Air Handling Unit (MU AHU).** No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building when using dehumidification in Make Up Air Handling Unit (MU AHU).
3. Houston TX
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 73.70 °F plus adjustment for space heat gain. **An additional 5 °F to 10 °F set point temperature reduction can be obtained by adding dehumidification to the Make Up Air Handling Unit (MU AHU).** No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building when using dehumidification in Make Up Air Handling Unit (MU AHU).
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 77.40 °F in the hottest month of August plus adjustment for space heat gain. **An additional 5 °F to 10 °F set point temperature reduction can be obtained by adding dehumidification to the Make Up Air Handling Unit (MU AHU).** No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building when using dehumidification in Make Up Air Handling Unit (MU AHU).
4. San Jose CA
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 58.60 °F plus adjustment for space heat gain. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - Commercial and Industrial Building cold supply air temperatures provided to the entire space to be cooled can be maintained at a set point temperature of 63.80 °F in the hottest month of July plus adjustment for space heat gain. No compressors and refrigerants are used in the system. Significant additional energy can be saved by maintaining a cold supply air set point temperature of 72 °F in the Commercial and Industrial Building.

Inlet Air Cooling for Nat Gas Turbines/CHP Systems – MECS

Brief Introduction to Turbine Inlet Cooling (TIC) - The primary reason TIC is used to enhance the power output of combustion turbines (CTs) when ambient air dry bulb temperature if above 59 °F. The rated capacities of all CTs are based on the standard ambient conditions of 59 °F, 14.7 psia at sea level selected by the International Standards Organization (ISO). Example: for a typical aero derivative CT, as inlet air temperature increases from 59 °F to 100 °F on a hot summer day, its power output decreases to about 73 percent of its rated capacity. By cooling the inlet air from 100 °F to 59 °F, the 27% loss of rated generation capacity can be avoided. The engineering analysis provided in this White Paper shows the lowest Inlet Air Temperature available without dehumidification. **An additional 5 °F to 15 °F temperature reduction can be obtained by adding dehumidification to the MU AHU.**

1. Phoenix AZ
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 54.80 °F. No compressors and refrigerants are used in the system.

b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 67.10 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold air supply temperatures of between 52.10 °F and 62.10 °F can be maintained by adding dehumidification to the MU AHU.

2. Newark DE
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 73.20 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 70.10 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold air supply temperatures of between 55.10 °F and 65.10 °F can be maintained by adding dehumidification to the MU AHU.
3. Houston TX
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 73.70 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 77.40 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold air supply temperatures of between 62.40 °F and 72.40 °F can be maintained by adding dehumidification to the MU AHU.
4. San Jose CA
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 58.60 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Inlet Air Cooling for Nat Gas Turbines/CHP Systems, cold supply air temperatures provided to inlet of the combustion turbine can be maintained at an air temperature of 63.80 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold air supply temperatures of between 48.80 °F and 58.60 °F can be maintained by adding dehumidification to the MU AHU.

Process Cooling Water for Industrial & Food Processing Plants – MECS (Colder Water Temperatures can be achieved by consulting with R4 Ventures LLC on the specific application and client needs)

1. Phoenix AZ
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at a water temperature of 56.80 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at an air temperature of 68.84 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold water supply temperatures of between 53.84 °F and 63.84 °F can be maintained by adding dehumidification to the cooling system.
2. Newark DE
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at a water temperature of 73.55 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at an air temperature of 70.24 °F in the hottest month of July. No compressors and refrigerants are used in the system. Significantly lower cold water supply temperatures of between 55.24 °F and 65.24 °F can be maintained by adding dehumidification to the cooling system.
3. Houston TX
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application

   can be maintained at an water temperature of 74.06 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at an air temperature of 77.38 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold water supply temperatures of between 62.38 °F and 72.38 °F can be maintained by adding dehumidification to the cooling system.

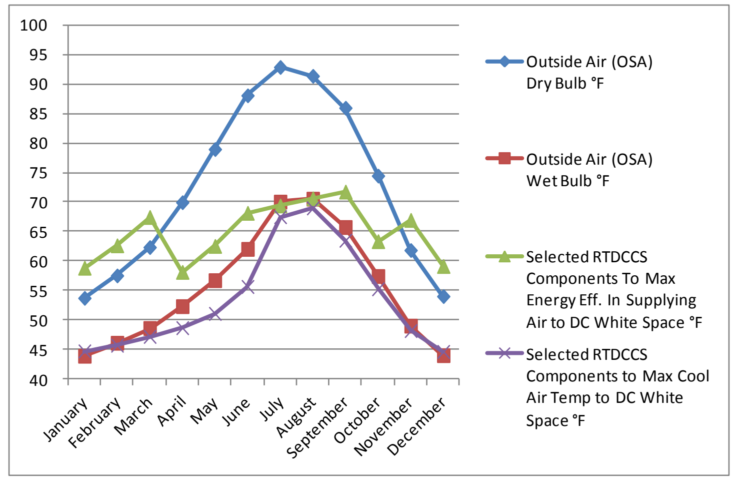
4. San Jose CA
   a. ASHRAE published Summer Design Conditions of .4% for cooling applications – For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at an water temperature of 59.87 °F. No compressors and refrigerants are used in the system.
   b. Based on the Monthly Mean Dry Bulb and Wet Bulb Temperatures - For Process Cooling Water for Industrial & Food Processing Plants, cold supply water temperatures provided to the process cooling application can be maintained at an air temperature of 64.57 °F in the hottest month of August. No compressors and refrigerants are used in the system. Significantly lower cold water supply temperatures of between 49.57 °F and 59.57 °F can be maintained by adding dehumidification to the cooling system.

Phoenix, AZ

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Phoenix AZ (www.weatherexplained.com)

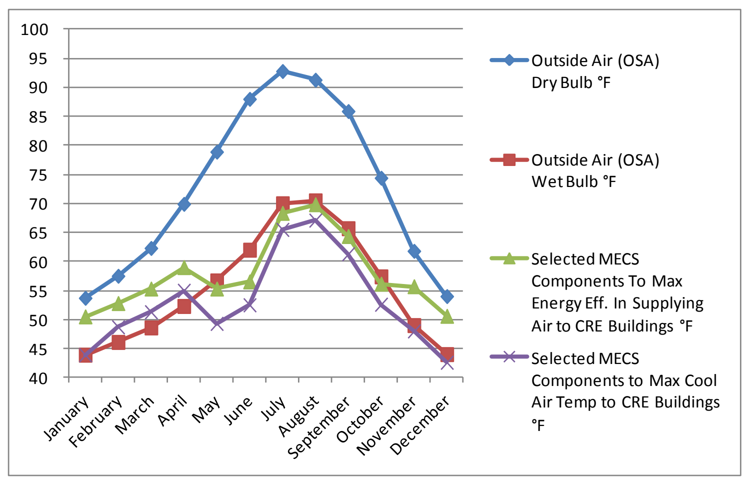
RTDDCS - Data Center White Space Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected RTDCCS Components To Max Energy Eff. In Supplying Air to DC White Space °F	Selected RTDCCS Components to Max Cool Air Temp to DC White Space °F
January	53.70	43.90	58.80	44.72
February	57.50	46.10	62.60	45.69
March	62.30	48.60	67.40	47.18
April	69.90	52.30	58.10	48.66
May	78.90	56.70	62.50	51.07
June	88.00	62.00	68.10	55.63
July	92.80	70.00	69.35	67.45
August	91.30	70.50	70.56	68.94
September	85.90	65.70	71.70	63.46
October	74.40	57.40	63.30	55.24
November	61.80	49.00	66.90	48.17
December	54.00	44.00	59.10	44.63



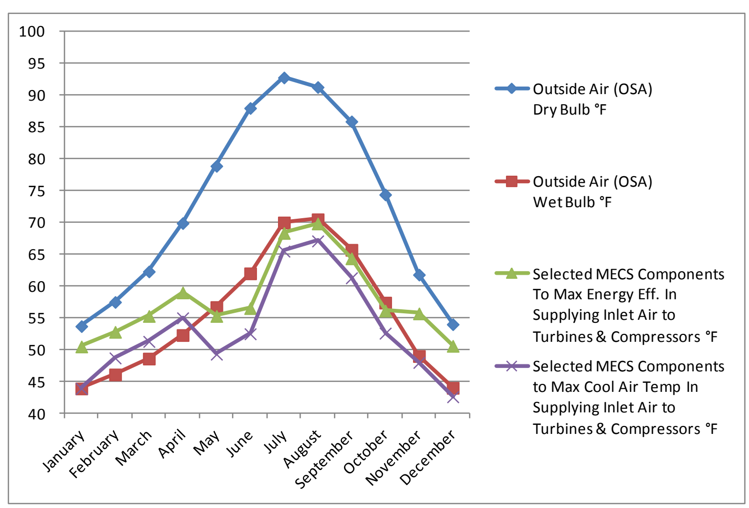
MECS - Comfort Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Air to CRE Buildings °F	Selected MECS Components to Max Cool Air Temp to CRE Buildings °F
January	53.70	43.90	50.50	43.90
February	57.50	46.10	52.80	48.70
March	62.30	48.60	55.30	51.30
April	69.90	52.30	59.00	55.00
May	78.90	56.70	55.30	49.30
June	88.00	62.00	56.53	52.50
July	92.80	70.00	68.35	65.50
August	91.30	70.50	69.84	67.10
September	85.90	65.70	64.36	61.30
October	74.40	57.40	56.14	52.60
November	61.80	49.00	55.70	48.00
December	54.00	44.00	50.60	42.60



MECS - Turbine Inlet Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Inlet Air to Turbines & Compressors °F	Selected MECS Components to Max Cool Air Temp In Supplying Inlet Air to Turbines & Compressors °F
January	53.70	43.90	50.50	43.90
February	57.50	46.10	52.80	48.70
March	62.30	48.60	55.30	51.30
April	69.90	52.30	59.00	55.00
May	78.90	56.70	55.30	49.30
June	88.00	62.00	56.53	52.50
July	92.80	70.00	68.35	65.50
August	91.30	70.50	69.84	67.10
September	85.90	65.70	64.36	61.30
October	74.40	57.40	56.14	52.60
November	61.80	49.00	55.70	48.00
December	54.00	44.00	50.60	42.60

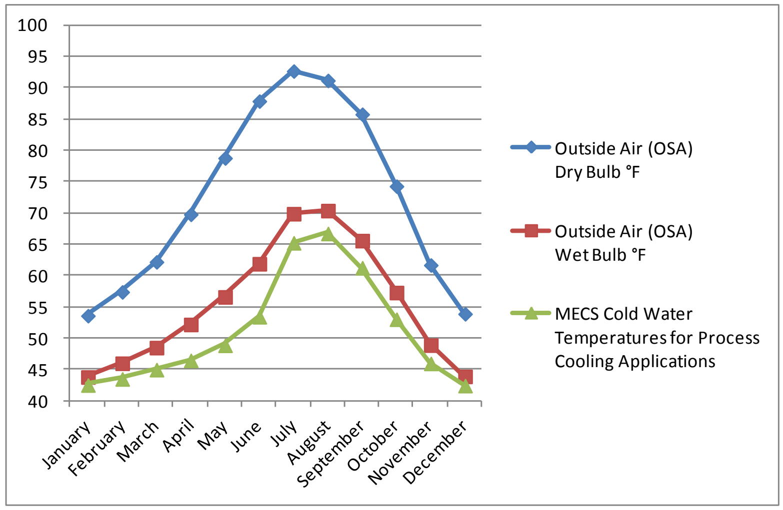


Phoenix, AZ Continued

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Phoenix AZ (www.weatherexplained.com)

MECS - Process Cooling Water Temps

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	MECS Cold Water Temperatures for Process Cooling Applications
January	53.70	43.90	42.62
February	57.50	46.10	43.59
March	62.30	48.60	45.08
April	69.90	52.30	46.56
May	78.90	56.70	48.97
June	88.00	62.00	53.53
July	92.80	70.00	65.35
August	91.30	70.50	66.84
September	85.90	65.70	61.36
October	74.40	57.40	53.14
November	61.80	49.00	46.07
December	54.00	44.00	42.53

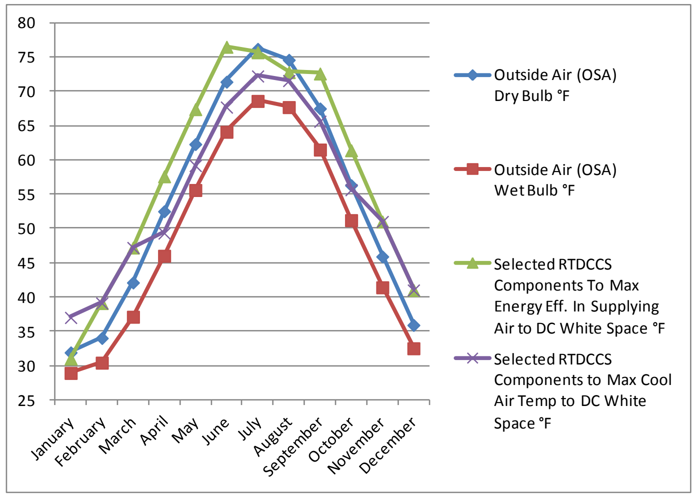


Newark (Wilmington), DE

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Wilmington DE (www.weatherexplained.com)

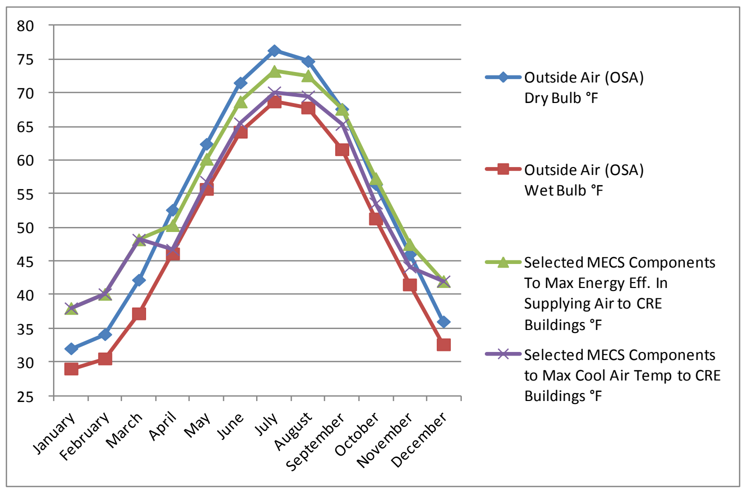
RTDDCS - Data Center White Space Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected RTDCCS Components To Max Energy Eff. In Supplying Air to DC White Space °F	Selected RTDCCS Components to Max Cool Air Temp to DC White Space °F
January	32.00	29.00	31.10	37.10
February	34.10	30.50	39.20	39.20
March	42.20	37.20	47.30	47.30
April	52.60	46.10	57.70	49.42
May	62.40	55.70	67.50	59.27
June	71.50	64.20	76.60	67.80
July	76.30	68.70	75.80	72.34
August	74.70	67.80	72.90	71.68
September	67.60	61.60	72.70	65.74
October	56.40	51.30	61.50	55.75
November	46.00	41.50	51.10	51.10
December	36.00	32.60	41.10	41.10



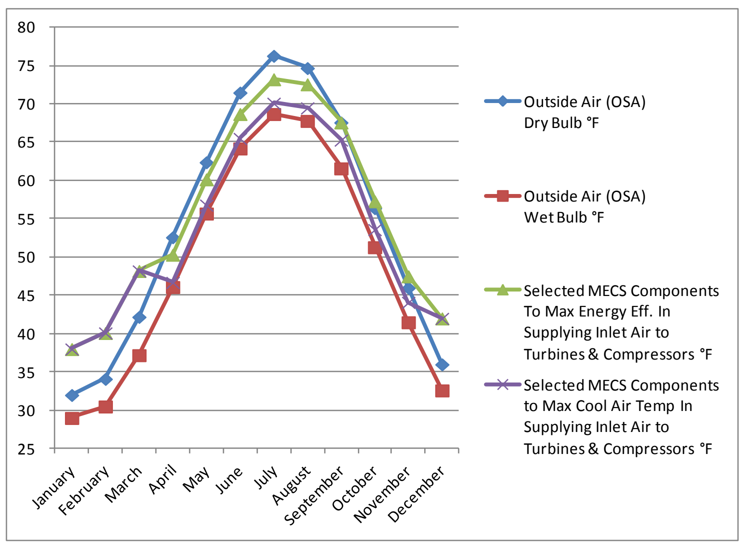
MECS - Comfort Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Air to CRE Buildings °F	Selected MECS Components to Max Cool Air Temp to CRE Buildings °F
January	32.00	29.00	38.00	38.00
February	34.10	30.50	40.10	40.10
March	42.20	37.20	48.20	48.20
April	52.60	46.10	50.32	46.70
May	62.40	55.70	60.17	56.80
June	71.50	64.20	68.70	65.50
July	76.30	68.70	73.24	70.10
August	74.70	67.80	72.58	69.50
September	67.60	61.60	67.60	65.30
October	56.40	51.30	57.30	53.60
November	46.00	41.50	47.50	44.10
December	36.00	32.60	42.00	42.00



MECS - Turbine Inlet Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Inlet Air to Turbines & Compressors °F	Selected MECS Components to Max Cool Air Temp In Supplying Inlet Air to Turbines & Compressors °F
January	32.00	29.00	38.00	38.00
February	34.10	30.50	40.10	40.10
March	42.20	37.20	48.20	48.20
April	52.60	46.10	50.32	46.70
May	62.40	55.70	60.17	56.80
June	71.50	64.20	68.70	65.50
July	76.30	68.70	73.24	70.10
August	74.70	67.80	72.58	69.50
September	67.60	61.60	67.60	65.30
October	56.40	51.30	57.30	53.60
November	46.00	41.50	47.50	44.10
December	36.00	32.60	42.00	42.00

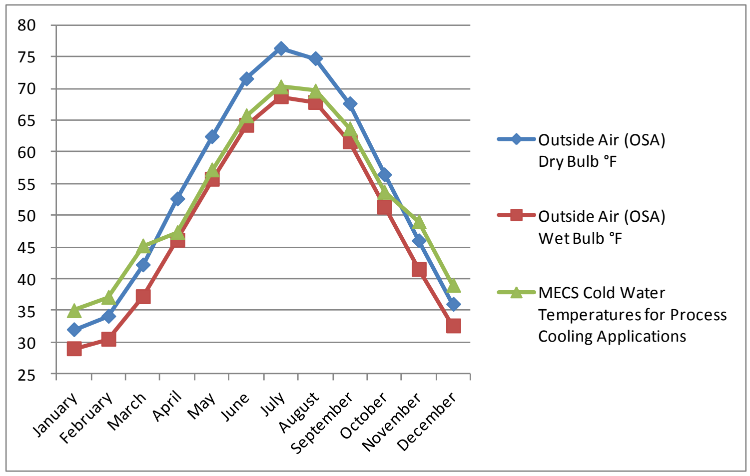


Newark (Wilmington), DE Continued

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Wilmington DE (www.weatherexplained.com)

MECS - Process Cooling Water Temps

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	MECS Cold Water Temperatures for Process Cooling Applications
January	32.00	29.00	35.00
February	34.10	30.50	37.10
March	42.20	37.20	45.20
April	52.60	46.10	47.32
May	62.40	55.70	57.17
June	71.50	64.20	65.70
July	76.30	68.70	70.24
August	74.70	67.80	69.58
September	67.60	61.60	63.64
October	56.40	51.30	53.65
November	46.00	41.50	49.00
December	36.00	32.60	39.00

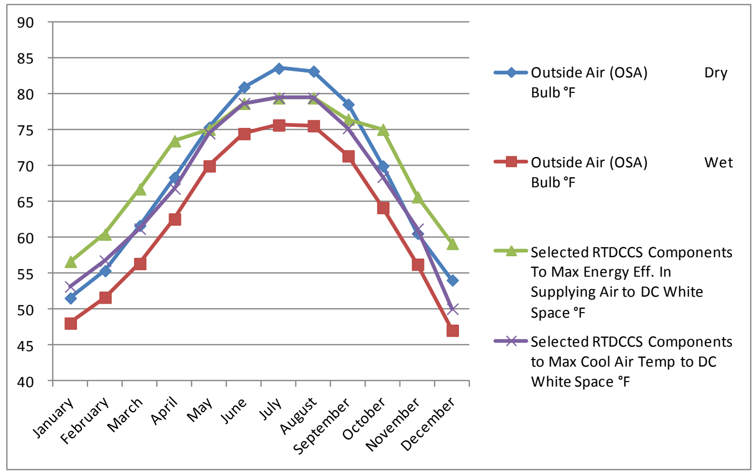


Houston, TX

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Houston, TX (www.weatherexplained.com)

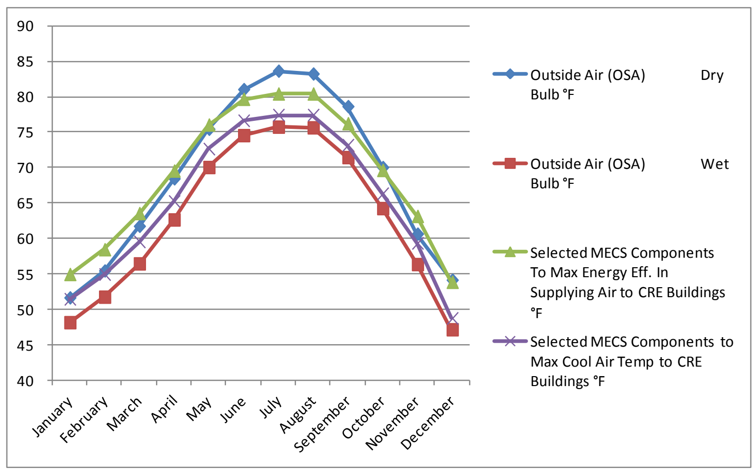
RTDDCS - Data Center White Space Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected RTDCCS Components To Max Energy Eff. In Supplying Air to DC White Space °F	Selected RTDCCS Components to Max Cool Air Temp to DC White Space °F
January	51.60	48.10	56.70	53.20
February	55.40	51.70	60.50	56.80
March	61.70	56.40	66.80	61.25
April	68.40	62.60	73.50	66.85
May	75.40	70.00	75.10	74.56
June	81.00	74.50	78.72	78.73
July	83.60	75.70	79.48	79.48
August	83.20	75.60	79.48	79.48
September	78.60	71.40	76.50	75.29
October	70.00	64.20	75.10	68.49
November	60.60	56.30	65.70	61.24
December	54.10	47.10	59.20	50.10



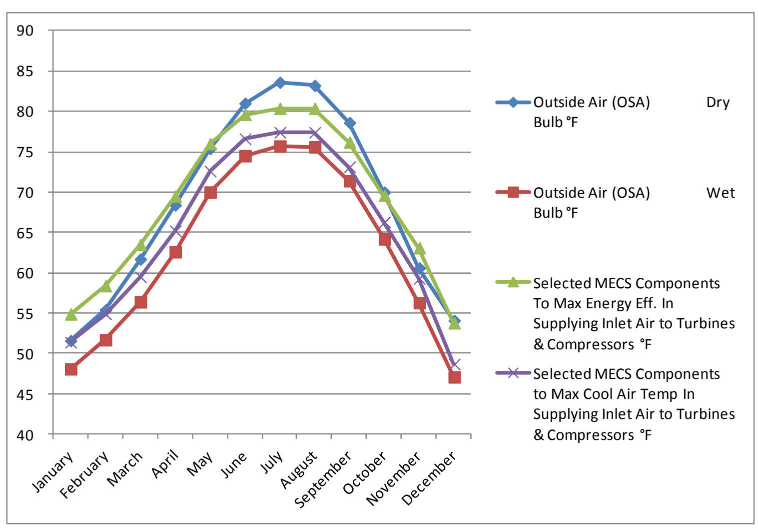
MECS - Comfort Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Air to CRE Buildings °F	Selected MECS Components to Max Cool Air Temp to CRE Buildings °F
January	51.60	48.10	54.90	51.40
February	55.40	51.70	58.40	54.90
March	61.70	56.40	63.50	59.50
April	68.40	62.60	69.50	65.20
May	75.40	70.00	76.00	72.60
June	81.00	74.50	79.63	76.60
July	83.60	75.70	80.38	77.40
August	83.20	75.60	80.38	77.40
September	78.60	71.40	76.19	73.15
October	70.00	64.20	69.59	66.30
November	60.60	56.30	63.10	59.30
December	54.10	47.10	53.80	48.70



MECS - Turbine Inlet Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Inlet Air to Turbines & Compressors °F	Selected MECS Components to Max Cool Air Temp In Supplying Inlet Air to Turbines & Compressors °F
January	51.60	48.10	54.90	51.40
February	55.40	51.70	58.40	54.90
March	61.70	56.40	63.50	59.50
April	68.40	62.60	69.50	65.20
May	75.40	70.00	76.00	72.60
June	81.00	74.50	79.63	76.60
July	83.60	75.70	80.38	77.40
August	83.20	75.60	80.38	77.40
September	78.60	71.40	76.19	73.15
October	70.00	64.20	69.59	66.30
November	60.60	56.30	63.10	59.30
December	54.10	47.10	53.80	48.70

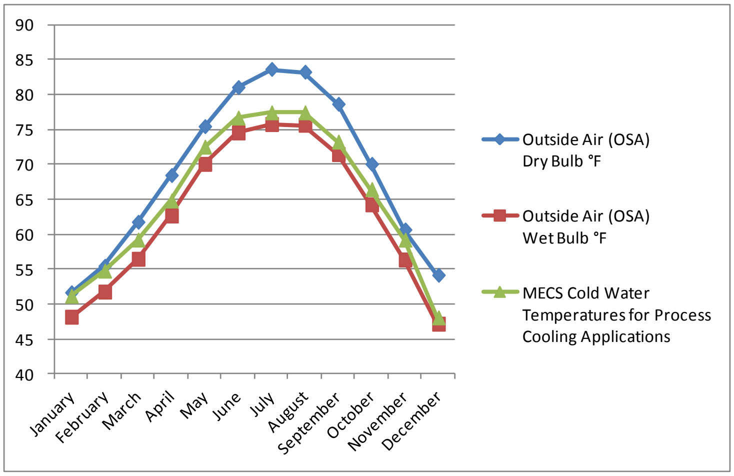


Houston, TX Continued

2001 Monthly Mean Dry Bulb and Wet Bulb Temperatures for Houston, TX (www.weatherexplained.com)

MECS - Process Cooling Water Temps

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	MECS Cold Water Temperatures for Process Cooling Applications
January	51.60	48.10	51.10
February	55.40	51.70	54.70
March	61.70	56.40	59.15
April	68.40	62.60	64.75
May	75.40	70.00	72.46
June	81.00	74.50	76.63
July	83.60	75.70	77.38
August	83.20	75.60	77.38
September	78.60	71.40	73.19
October	70.00	64.20	66.39
November	60.60	56.30	59.14
December	54.10	47.10	48.00

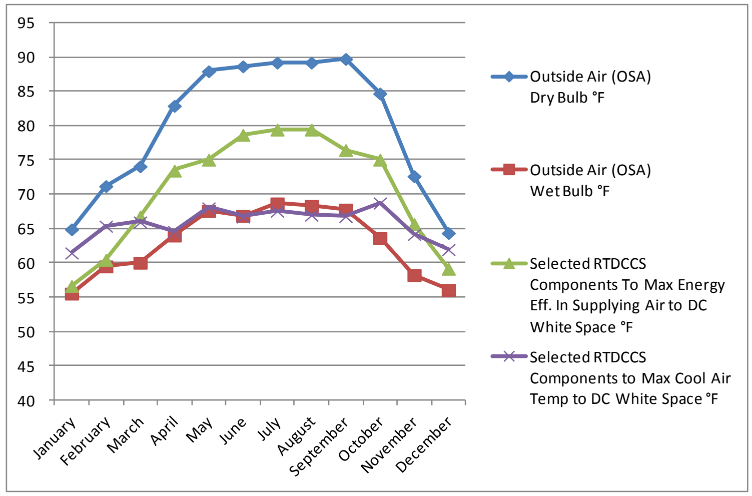


San Jose, CA

2005 ASHRAE Handbook - ASHRAE published Summer Design Conditions of .4% for cooling applications

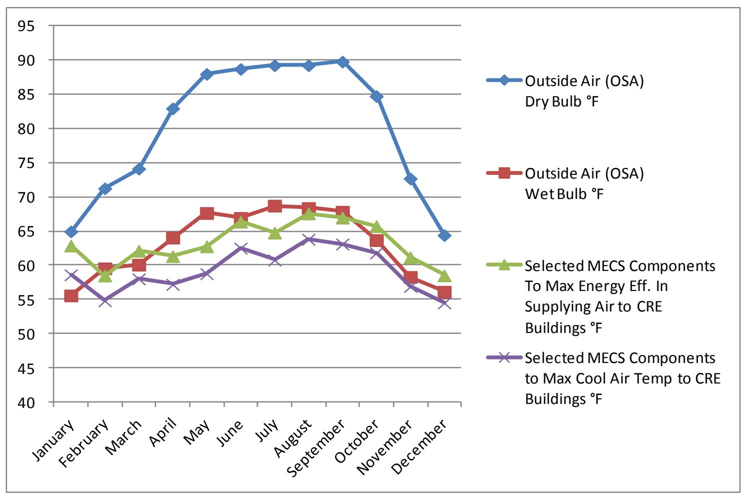
RTDDCS - Data Center White Space Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected RTDCCS Components To Max Energy Eff. In Supplying Air to DC White Space °F	Selected RTDCCS Components to Max Cool Air Temp to DC White Space °F
January	64.94	55.58	56.70	61.50
February	71.24	59.54	60.50	65.40
March	74.12	60.08	66.80	66.00
April	82.94	64.04	73.50	64.61
May	87.98	67.64	75.10	68.06
June	88.70	66.92	78.72	66.75
July	89.24	68.72	79.48	67.60
August	89.24	68.36	79.48	67.02
September	89.78	67.82	76.50	66.82
October	84.74	63.68	75.10	68.78
November	72.68	58.28	65.70	64.20
December	64.40	56.12	59.20	62.00



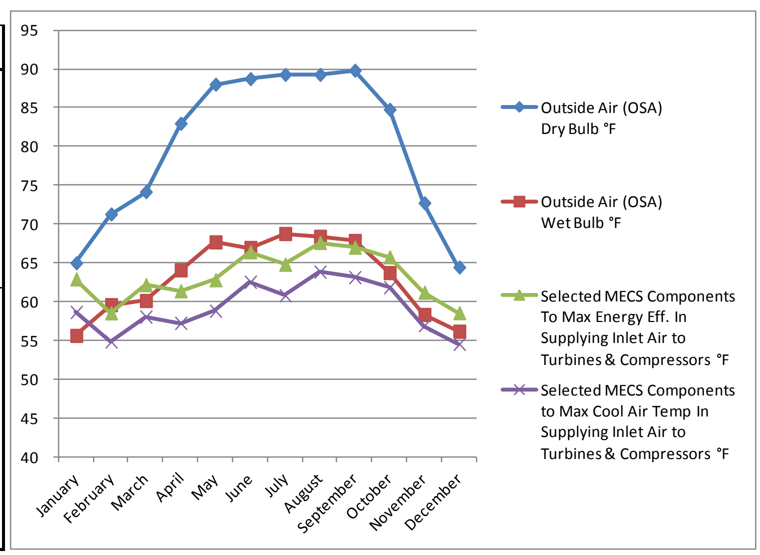
MECS - Comfort Cooling

	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Air to CRE Buildings °F	Selected MECS Components to Max Cool Air Temp to CRE Buildings °F
January	64.94	55.58	62.87	58.60
February	71.24	59.54	58.49	54.80
March	74.12	60.08	62.12	58.00
April	82.94	64.04	61.34	57.20
May	87.98	67.64	62.76	58.76
June	88.70	66.92	66.36	62.50
July	89.24	68.72	64.76	60.76
August	89.24	68.36	67.57	63.80
September	89.78	67.82	66.96	63.10
October	84.74	63.68	65.72	61.80
November	72.68	58.28	61.15	56.90
December	64.40	56.12	58.51	54.50



MECS - Turbine Inlet Cooling

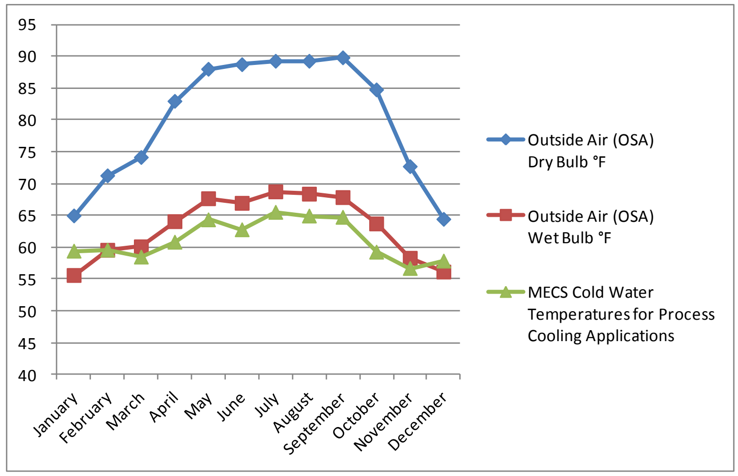
	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	Selected MECS Components To Max Energy Eff. In Supplying Inlet Air to Turbines & Compressors °F	Selected MECS Components to Max Cool Air Temp In Supplying Inlet Air to Turbines & Compressors °F
January	64.94	55.58	62.87	58.60
February	71.24	59.54	58.49	54.80
March	74.12	60.08	62.12	58.00
April	82.94	64.04	61.34	57.20
May	87.98	67.64	62.76	58.76
June	88.70	66.92	66.36	62.50
July	89.24	68.72	64.76	60.76
August	89.24	68.36	67.57	63.80
September	89.78	67.82	66.96	63.10
October	84.74	63.68	65.72	61.80
November	72.68	58.28	61.15	56.90
December	64.40	56.12	58.51	54.50



San Jose, CA Continued

2005 ASHRAE Handbook - ASHRAE published Summer Design Conditions of .4% for cooling applications

MECS - Process Cooling Water Temps	Outside Air (OSA) Dry Bulb °F	Outside Air (OSA) Wet Bulb °F	MECS Cold Water Temperatures for Process Cooling Applications
January	64.94	55.58	59.40
February	71.24	59.54	59.57
March	74.12	60.08	58.47
April	82.94	64.04	60.81
May	87.98	67.64	64.32
June	88.70	66.92	62.76
July	89.24	68.72	65.50
August	89.24	68.36	64.92
September	89.78	67.82	64.72
October	84.74	63.68	59.24
November	72.68	58.28	56.68
December	64.40	56.12	57.84



Technology Summary

Background

R4 Ventures LLC is applying semi-conductor clean room process cooling methods to Data Center / Mission Critical environments providing real time … load based process cooling at the Rack and eliminating hot isles and cold isles by combining the Multistage Evaporative Cooling System (MECS*),* Individual Server Enclosure Cooling System (ISECS), and Real Time Monitoring and Control System (RTMCS).

Multistage Evaporative Cooling System

- Scalable from 10 to over 1000 tons.
- Based on Phoenix AZ Summer Ambient Air Design Conditions for cooling applications are 110.2°FDB and 70°FWB, MECS delivers 57°F cool water, 53°F cold air, or both at the same time.
- Simple ... practical design provides ease of monitoring, control, and maintenance.
- 60 to 80% less power usage / energy savings compared to traditional mechanical refrigeration systems in Data Centers
- NO Compressors and NO Freon
- Process cooling approach leads to NO over sizing of Data Center cooling systems and therefore reduces up front capital requirements by 40% to 60% (over sizing is typically by 150% to 200% when cooling Data Centers with Air (Comfort cooling))

NEW ADVANCED MULTI-PURPOSE MULTISTAGE EVAPORATIVE COLD WATER/COLD AIR GENERATING AND SUPPLY SYSTEM
United States Patent 8,899,061
Published December 2, 2014

The Inventor has developed new methods and systems that provide evaporative cooling by combining multiple direct and indirect evaporative cooling stages into one multistage evaporative cooling system to achieve cooling media (air or water) temperatures that are much lower than the initial wet bulb temperature of the ambient air. The Inventor has named this cooling system the Multistage Evaporative Cooling System (MECS) This new approach and method of the combined multiple direct and indirect evaporative cooling processes fully complies with all laws of thermodynamics by properly sequencing components and actions to achieve maximum cooling at a minimal energy use. The MECS outperforms conventional refrigeration systems by using at least 60 - 80% less energy to operate. The MECS's resulting output is cold air, cold water, or both.

Individual Server Enclosure Cooling System

- Process Cooling Individual Racks with loads up to 35 KW on a Real Time basis
- Process Cooling adjusts cooling in Real Time to meet the actual load of the Rack as it varies between 3 KW to over 35 KW
- Provides 70°F to 80.6°F cool air back to Data Center white space
- Increases Data Center Floor Area and Capacity in White Space by eliminating perimeter CRACs and CRAHs in the Data Center white space
- Eliminates hot aisles and cold aisles
- Restores Lost Rack Capacity of the Data Center due to lack of cooling (cold air flow to individual racks) as rack load densities increase through the individual cooling high load density Racks
- Provides significant energy savings of 60 to 80%
- Eliminates the need for hot aisle / cold aisle containment equipment and systems thereby reducing capital costs
- Eliminates the need for air ducts in the Data Center White Space.
- Can be incorporated into raised floor designs or placed above the Racks over the aisles

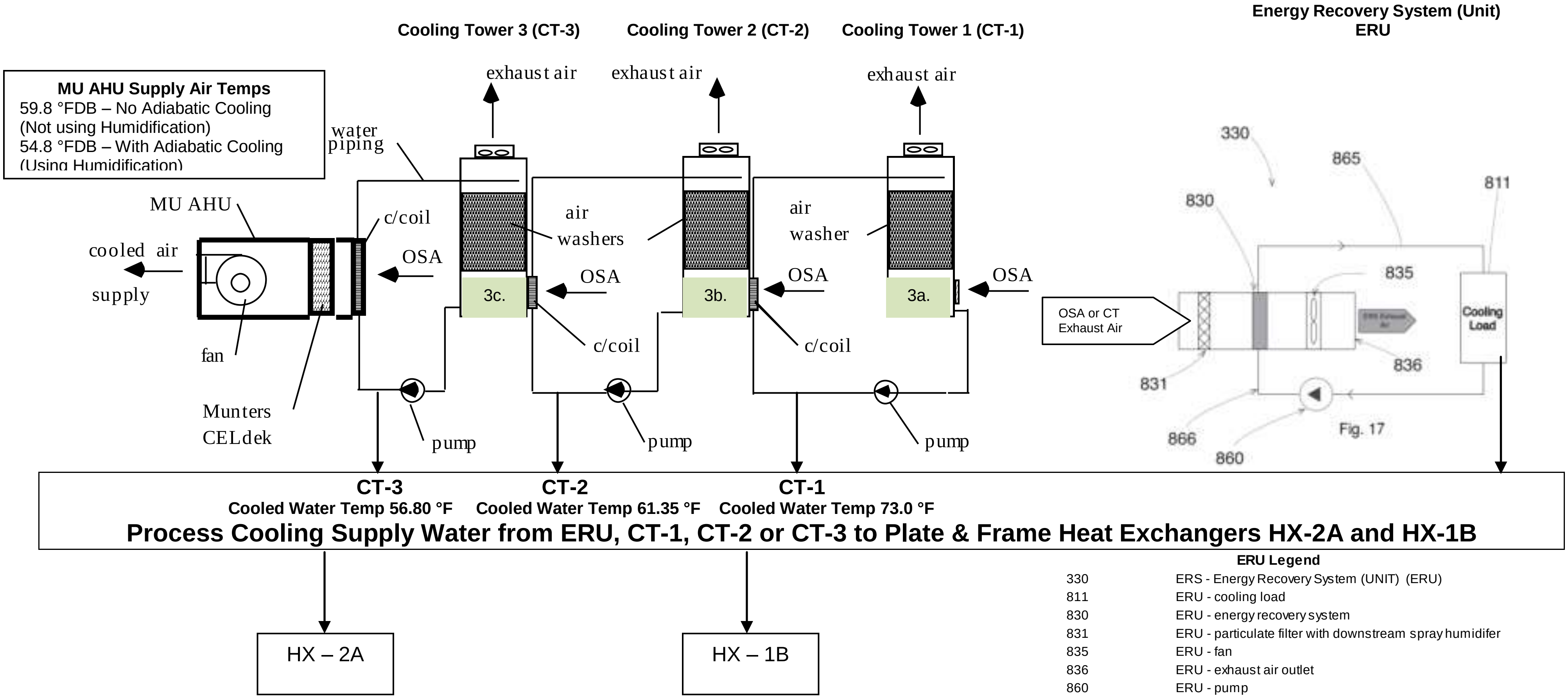
REAL TIME INDIVIDUAL ELECTRONIC ENCLOSURE COOLING SYSTEM
United States Patent 8,857,204
Published October 14, 2014

The Inventor is applying semi-conductor clean room process cooling methods to Data Center / Mission Critical environments providing real time … load based process cooling at the Rack or Electronic Enclosure as loads fluctuate between 3 KW and 50 KW. Process cooling the heat loads of Racks or Electronic Enclosures eliminates hot isles and cold isles typically found in today's Data Centers by combining the Multistage Evaporative Cooling System (MECS), Real Time Individual Electronic Enclosure Cooling System, or hereinafter, Individual Server Enclosure Cooling System (ISECS), and Real Time Monitoring and Control System (RTMCS). The various ISECS apparatus options (ISECS units) provide for cooling individual server racks or electrical enclosures. These ISECS units maintain target exiting (discharge) air temperatures, i.e. supply air to the Data Center white space, equal to or colder than room temperature within a tolerance of plus or minus 1 or 2 degrees F. The ISECS units employ industrial cooling using the staged cooling towers of the Multistage Evaporative Cooling System (MECS) to evaporatively provide cold water to the ISECS units.

Preliminary Performance Analysis for Phoenix AZ of the Real Time Data Center Cooling System consisting of the Multistage Evaporative Cooling System (MECS - Patent Pending) and the Individual Server Enclosure Cooling System (ISECS - Patent Pending)

Parameters:

1. Phoenix, AZ Summer Ambient Air Design Conditions (ASHRAE .4% for cooling applications Phoenix AZ (PHX) are 110.2 °FDB and 70.0 °FWB for the Energy Recovery System (Unit) or ERU, all three CTs and the Makeup Air Handling Unit (MU AHU)
2. OSA is the inlet air at above design parameters to all stages.
3. Entered Air Conditions entering the Fill at each stage:
    a. CT1 – 110.2°FDB and 70°FWB
    b. CT2 – 74.0°FDB and 58.35°FWB
    c. CT3 – 62.35°FDB and 53.80°FWB
4. Entered Air Conditions to the MU AHU is 110.2 °FDB and 70.0°FWB
5. Entered Air Conditions to the ERU is 110.2 °FDB and 70.0 °FWB



ERU Legend

330	ERS - Energy Recovery System (UNIT) (ERU)
811	ERU - cooling load
830	ERU - energy recovery system
831	ERU - particulate filter with downstream spray humidifer
835	ERU - fan
836	ERU - exhaust air outlet
860	ERU - pump
865	ERU - cold water outlet pipe
866	ERU - warm water inlet pipe

Plate & Frame Heat Exchanger – HX-2A serving Pre-Cooling Coils of ISECS

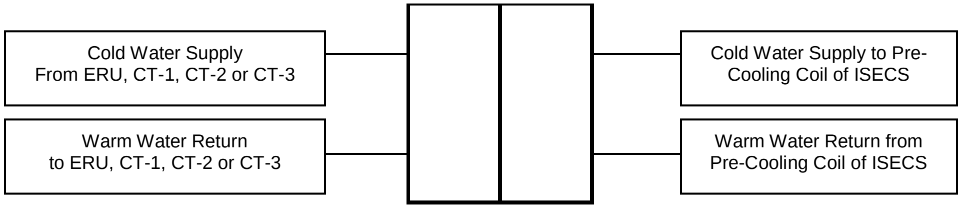
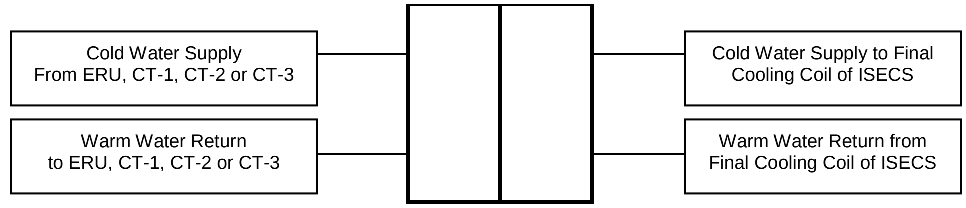
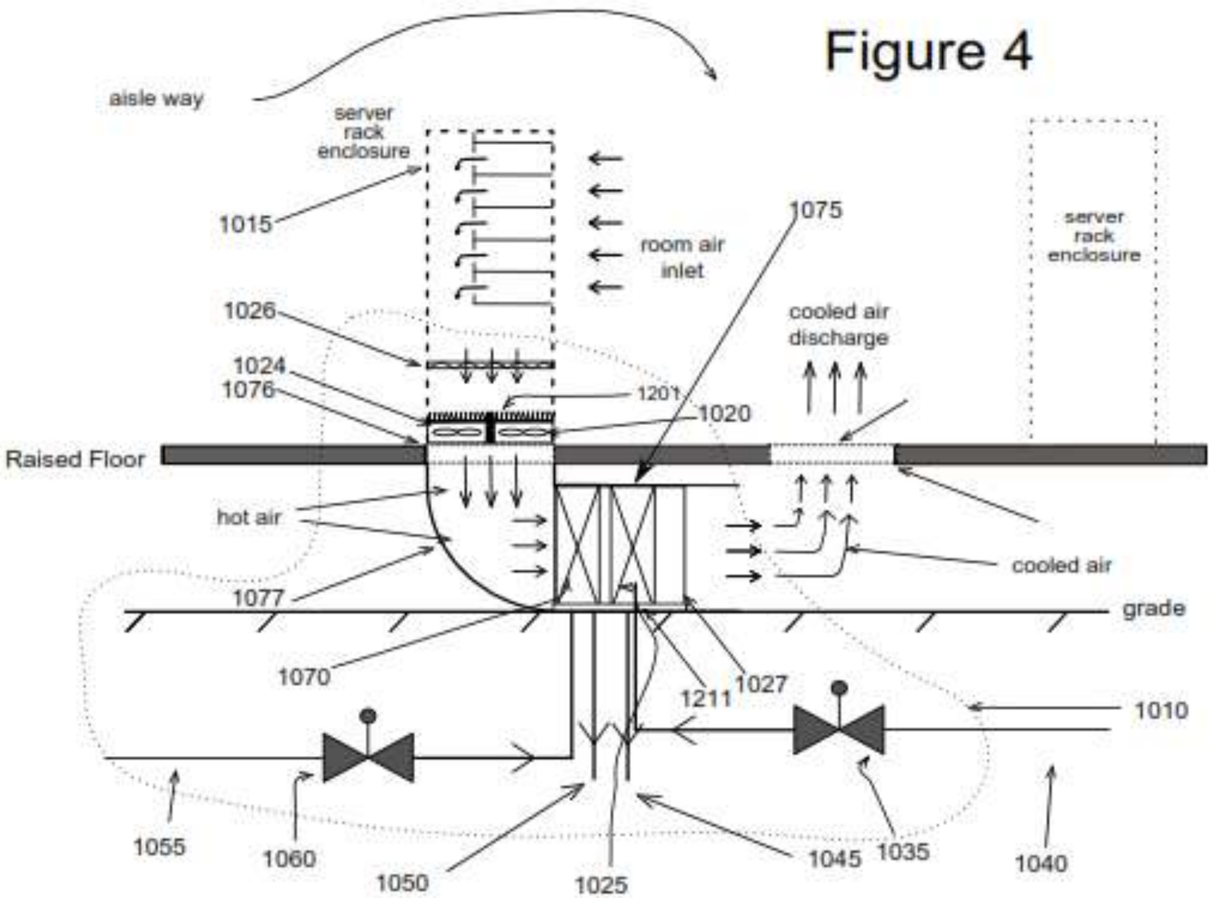


Plate & Frame Heat Exchanger – HX-1B serving Final Cooling Coils of ISECS



Individual Server Enclosure Cooling System (ISECS)



ISECS Legend

1010	ISECS
1015	server rack enclosure
1017	cold air dischage grill
1020	fan(s)
1024	fan rack
1025	final cooling coil
1026	air filter
1027	cooling coil unit
1035	final cooling coil water flow control valve
1040	final cooling coil cold water inlet pipe
1045	final cooling coil water outlet pipe
1050	pre-cooling coil water outlet pipe
1055	Not Defined (pre-cooling coil cold water Supply Pipe)
1060	pre-cooling coil water flow control valve
1070	pre-cooling coil
1074	"air duct elbow"
1075	housing
1076	hot air inlet
1077	hot air duct elbow
1201	Change from automatic louvers to automatic air damper
1202	louver door (safety door tied to fan motor automatic shutoff)
1211	condensate catch pan

Real Time Data Center Cooling System (RTDCCS) consisting of the Multistage Evaporative Cooling System (MECS) and Individual Server Enclosure Cooling Systems for each Rack (ISECS)

Cold Water & DC White Space Temp Performance in Phoenix AZ ASHRAE Summer Design and Mean Monthly Temperatures in °F

Phoenix International Airport (PHX)

Energy Recovery Unit and / or Cooling Towers of the MECS Serving the RTDCCS

- RTDCCS commissioned in Phoenix AZ can be served by an ERU & 3 Cooling Towers (CT-1,CT-2, CT-3)
- Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps - Redundant Backup CTs
- Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the RTDCCS

					Energy Recovery Unit (ERU) Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		Multistage Evaporative Cooling System Cold Water Temp Leaving Cooling Towers (CT), °F			Real Time Data Center Cooling System Performance within the Data Center White Space			
	DB °F	WB °F	Calculated Dew Pt °F	Calculated Humidity Ratio grains/lb	ERU without OSA Humidification	ERU with OSA Humidification to 95% RH (Adiabatic Cooling)	CT-1	CT-2	CT-3	Estimated Cold Water Temp Leaving Plate & Frame HX	Estimated Cold Water Temp Entering Fan Coil Unit serving each rack (ISECS)	Estimated Cold Air Temp Leaving Fan Coil Unit serving each rack (ISECS)	Lowest Data Center White Space Temperature (Temp can be set to ±75 °F in cooler months to save significant energy costs)
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	110.20	70.00	47.47	50.90	113.20	73.70	73.00	61.35	56.80	62.35	62.45	63.45	**63.45**
January	53.70	43.90	33.10	28.86	56.70	47.50	46.90	44.07	42.62	57.70	57.80	58.80	**58.80**
February	57.50	46.10	34.15	30.22	60.50	49.80	49.10	45.17	43.59	61.50	61.60	62.60	**62.60**
March	62.30	48.60	35.07	31.36	65.30	52.30	51.60	47.22	45.08	66.30	66.40	67.40	**67.40**
April	69.90	52.30	36.38	33.03	72.90	56.00	55.30	49.36	46.56	57.00	57.10	58.10	**58.10**
May	78.90	56.70	38.83	36.41	81.90	60.40	59.70	52.30	48.97	61.40	61.50	62.50	**62.50**
June	88.00	62.00	44.49	45.41	91.00	66.00	65.00	56.88	53.53	67.00	67.10	68.10	**68.10**
July	92.80	70.00	59.19	78.73	95.80	73.90	73.00	67.25	65.35	68.25	68.35	69.35	**69.35**
August	91.30	70.50	60.97	83.98	94.30	74.40	73.50	68.46	66.84	69.46	69.56	70.56	**70.56**
September	85.90	65.70	54.72	66.83	88.90	69.60	68.70	63.30	61.36	70.60	70.70	71.70	**71.70**
October	74.40	57.40	45.11	46.51	77.40	61.20	60.40	55.29	53.14	62.20	62.30	63.30	**63.30**
November	61.80	49.00	36.79	33.58	64.80	52.70	52.00	47.99	46.07	65.80	65.90	66.90	**66.90**
December	54.00	44.00	32.68	28.71	57.00	47.60	47.00	44.04	42.53	58.00	58.10	59.10	**59.10**

****** 1. Year round operation of RTDCCS incorporating MECS and ISECS together (Process Cooling) can provide the required cooling for the IT equipment (server racks). 2. Building HVAC system is serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system. ASHRAE TC 9.9 increased ambient data center termperatures to 80.6 degrees.***

Phoenix International Airport (PHX)

http://www.weatherexplained.com/Vol-2/2001-Phoenix-Arizona-PHX.html#ixzz2XMUi3ldJ

	Jan	Feb	Mar	Apr	May	Jun	
MEAN DRY BULB	53.7	57.5	62.3	69.9	78.9	88.0	
MEAN WET BULB	43.9	46.1	48.6	52.3	56.7	62.0	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Mean**
MEAN DRY BULB	92.8	91.3	85.9	74.4	61.8	54.0	72.5
MEAN WET BULB	70.0	70.5	65.7	57.4	49.0	44.0	55.5

Comfort Space and Natural Gas Turbine Inlet Air Cooling "cold supply air" provided by the Multistage Evaporative Cooling System (MECS) serving Commercial and Industrial facilities and plants

Temp Performance for Cold Supply Air for Commercial & Industrial Applications in Phoenix AZ ASHRAE Summer Design and Mean Monthly Temperatures in °F

MECS Including ERU, Cooling Towers and Makeup Air Handling Unit (MU AHU) Supplying Cold Fresh Air

ERU, Cooling Towers (CT-1,CT-2, CT-3) and MU AHU commissioned to provide Cold Supply Air

Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps to generate cold makeup air

Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the MU AHU

Phoenix International Airport (PHX)

					Multistage Evaporative Cooling System (MECS)									
					Energy Recovery Unit (ERU) Stage Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		**Cooling Tower Stage** Cold Water Temp Leaving Cooling Towers (CT), °F			**Make Up Air Handling Unit (MU AHU) Stage** Cold AIR Temp Leaving MU AHU, °F				
	OSA DB °F	**WB °F**	**Calculated Dew Pt °F**	**Calculated Humidity Ratio grains/lb**	**ERU-1A without OSA Humidification**	**ERU-1B with OSA Humidification to 95% RH (Adiabatic Cooling)**	**CT-1**	**CT-2**	**CT-3**	**MU AHU Pre-Cooling Coil Water Temp from ERU or CT-1, CT-2 or CT-3 (Source shown in RED)**	**MU AHU Cold Supply Air to space without OSA Humidification (No Adiabatic Cooling) includes 2 °F for fan heat**	**MU AHU Cold Supply Air to space with OSA Humidification to 95% RH (Adiabatic Cooling) includes 2 °F for fan heat**	**TEMPERATURE OF INLET AIR ENTERING NATURAL GAS TURBINES (TARGET TEMP IS 59 °F OR LOWER)**	**Commercial & Industrial Office Space Cold Supply Air Temperature Range**
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	110.20	70.00	47.47	50.90	113.20	73.70	73.00	61.35	56.80	56.80 / CT-3	59.80	54.80	54.80	54.80 - 59.80
January	53.70	43.90	33.01	28.86	56.70	47.50	46.90	44.07	42.62	47.50 / ERU-1B	50.50	43.90	43.90	43.90 - 50.50
February	57.50	46.10	34.15	30.22	60.50	49.80	49.10	45.17	43.59	49.80 / ERU-1B	52.80	48.70	48.70	48.70 - 52.80
March	62.30	48.60	35.07	31.36	65.30	52.30	51.60	47.22	45.08	52.30 / ERU-1B	55.30	51.30	51.30	51.30 - 55.30
April	69.90	52.30	36.38	33.03	72.90	56.00	55.30	49.36	46.56	56.00 / ERU-1B	59.00	55.00	55.00	55.00 - 59.00
May	78.90	56.70	38.83	36.41	81.90	60.40	59.70	52.30	48.97	52.30 / CT-2	56.16	49.30	49.30	49.30 - 56.16
June	88.00	62.00	44.49	45.41	91.00	66.00	65.00	56.88	53.53	53.53 / CT-3	57.71	52.50	52.50	52.50 - 57.71
July	92.80	70.00	59.19	78.73	95.80	73.90	73.00	67.25	65.35	65.35 / CT-3	69.24	65.50	65.50	65.50 - 69.24
August	91.30	70.50	60.97	83.98	94.30	74.40	73.50	68.46	66.84	66.84 / CT-3	70.69	67.10	67.10	67.10 - 70.69
September	85.90	65.70	54.72	66.83	88.90	69.60	68.70	63.30	61.36	61.36 / CT-3	65.34	61.30	61.30	61.30 - 65.34
October	74.40	57.40	45.11	46.51	77.40	61.20	60.40	55.29	53.14	53.14 / CT-3	57.34	52.60	52.60	52.60 - 57.34
November	61.80	49.00	36.79	33.58	64.80	52.70	52.00	47.99	46.07	52.70/ ERU-1B	55.70	48.00	48.00	48.00 - 55.70
December	54.00	44.00	32.88	28.71	57.00	47.60	47.00	44.04	42.53	47.60 / ERU-1B	50.60	42.60	42.60	42.60 - 50.60

***** NOTE *** If the negative pressure at the turbine compressor inlet allows for the elimination of the fan in the MU AHU, the temperature can be reduced by an additional 2 °F.**

***** 1. Year round operation of MECS and MU AHU together (Comfort Cooling) can provide the required spacecooling for Commercial & Industrial Office Spaces and Natural Gas and Industrial Compressor Inlet Air Cooling. 2. System is tied into the HVAC system serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system.**

Phoenix International Airport (PHX)

http://www.weatherexplained.com/Vol-2/2001-Phoenix-Arizona-PHX.html#ixzz2XMUi3ldJ

	Jan	Feb	Mar	Apr	May	Jun	
MEAN DRY BULB	53.7	57.5	62.3	69.9	78.9	88.0	
MEAN WET BULB	43.9	46.1	48.6	52.3	56.7	62.0	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Mean**
MEAN DRY BULB	92.8	91.3	85.9	74.4	61.8	54.0	72.5
MEAN WET BULB	70.0	70.5	65.7	57.4	49.0	44.0	55.5

Phoenix, AZ
Preliminary Temperature Performance Evaluation – Summer Design Conditions

Estimating temperature performance of the Real Time Data Center Cooling System (MECS + ISECS) for Data Center to be located in city of Phoenix AZ.

General

Below are calculations for the ASHRAE published Summer Design Conditions of .4% for cooling applications showing the ambient air design dry bulb and wet bulb temperatures for Phoenix AZ (PHX) of 110.2 ˚FDB and 70.0 ˚FWB.

Engineering Analysis

Given Data

- DC site Location: Phoenix AZ (PHX)
- Site Elevation: 1200 ft.
- OSA 0.4% design conditions: 110.2 ˚FDB / 70.0 ˚FWB

Assumed the following approach temperatures for:

- All Cooling Towers & ERUs: 3˚F
- All pre-cooling coils for Cooling Towers: 1˚F
- Fluid-fluid Plate HX: 1˚F
- Pre-cooling coil of FCU: 1˚F
- Final cooling coil of FCU: 1˚F

Design parameters of the OSA are:

- Relative humidity: 12.61%
- Dew point temperature, 47.47 ˚F
- Humidity ratio: 50.90 gr/lb
- Enthalpy: 34.52 btu/lb
- Specific volume: 15.18 ft^3/lb

Calculation

Estimated temperature of the cold water leaving the Cooling Tower CT-1 and entering the ambient air pre-cooling coils of the cooling tower CT-2 is:

70.0+ 3 = 73.0 ˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-2:

73.0 +1 = 74.0 ˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-2A:

- Dry Bulb temperature: 74.0 ˚F
- Wet Bulb Temperature: 58.35 ˚F
- Relative humidity: 38.94%

- Dew point temperature, 47.47 ˚F
- Humidity ratio: 50.90 gr/lb
- Enthalpy: 25.70 btu/lb
- Specific volume: 14.21 ft^3/lb

Estimated temperature of the cold water leaving the Cooling Tower CT-2 and entering the ambient air pre-cooling coils of the cooling tower CT-3 is:

58.35 + 3 = 61.35˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-3:

61.35 +1 = 62.35˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-3:

- Dry Bulb temperature: 62.35˚F
- Wet Bulb Temperature: 53.80˚F
- Relative humidity: 58.31%
- Dew point temperature, 47.47˚F
- Humidity ratio: 50.90 gr./lb.
- Enthalpy: 22.85 btu / lb.
- Specific volume: 13.90 ft^3/lb.

Estimated temperature of the cold water leaving the Cooling Tower CT-3 and entering into primary loop of the liquid-liquid plate and frame HX:

53.80 + 3 = 56.80˚F

Estimated temperature of the secondary loop supply cooling water leaving plate and frame HX and entering into the final cooling coils of the FCUs:

56.80 + 1 = 57.80˚F

Estimated temperature of the cooled air leaving final cooling coil of the FCU serving and individual electronics enclosure*:

57.80 + 1.1 = 58.90 ˚F < 80.6˚F (ASHRAE TC 9.9 Maximum Recommended)

*Notes:

- The FCU is configured the way that its fan is located upstream of the pre-cooling and final cooling coils.

Preliminary Temperature Performance Evaluation – Monthly Mean Temperature Conditions

Projected Monthly Temperature Performance of the Real Time Data Center Cooling System

The Engineering Analysis shown in the above spreadsheet estimating mean monthly thermal performance of the Real Time Data Center Cooling System consisting of Multistage Evaporative Cooling System (MECS) generating cold water and the Individual Server Enclosure Cooling Systems (ISECS) for use in process cooling of the Server Racks located in the white space of the Data Center. The analysis is for a data center project that would be located in Phoenix AZ. This analysis uses the ASHRAE Design Conditions for Selected Locations table and specifically the Phoenix International Airport (PHX) area and the monthly mean dry bulb and wet bulb temperatures for the Phoenix International Airport (PHX). http://www.weatherexplained.com/Vol-2/2001-Phoenix-Arizona-PHX.html#ixzz2XMUi3IdJ

Given conditions

- Site elevation, ft.: 1200

Preliminary Assumptions:

- Preliminary assumption - MECS consists of three cooling towers: CT-1, CT-2 and CT-3.
- An assumed approach temperature for all cooling tower CT-1, CT-2 and CT-3 is 3.0 ˚F.
- An assumed approach temperature for ambient air pre-cooling coils for the mentioned cooling towers is 1.0 ˚F.
- Humidity and partial temperature control of the Data Center's White Space should be provided by the building comfort HVAC Systems.
- A combination of the MECS + ISECS provides process sensible cooling of the Data Center Server Racks.
- Each cooling coil in the Fan Coil Unit (Pre-Cooling Coil and Final Cooling Coil) assumes a 1.0 ˚F approach temperature plus a 0.1 ˚F adjustment for cooling water heat (temperature) gain (Totaling 2.1 °F).

An Executive Summary of the Engineering Analysis

The Engineering Analysis conducted below is based on the R4 Ventures LLC - Real Time Data Center Cooling System and its patent-pending cooling technologies consisting of the Multi-stage Evaporative Cooling System (MECS) combined with the Individual Server Enclosure Cooling System (ISECS), also described herein as Fan Coil Unit (FCU), operating in Phoenix, AZ, would provide year round required cooling of the Server Racks in the Data Center and returning cold supply air back to the Data Center While Space (See Individual Server Enclosure Cooling System (ISECS) Figure 4). Depending on the ambient conditions, in the majority of cases, the Energy Recovery Unit (ERU) operating alone would be able to satisfy the all cooling needs of the Data Center's IT Equipment (See attached Engineering Analysis spread sheet document). In some ambient conditions and depending on the customer's set point temperature requirements for the Data Center White Space, Cooling Tower CT-1, Cooling Tower CT-2, and Cooling Tower CT-3 may be operational. The sequence of operations would be CT-1 alone, CT-1 and CT-2, or CT-1, CT-2 and CT-3. All 3 Cooling Towers can be used to provide redundant back up the Energy Recovery Units (ERU 1A and ERU 1B). This analysis results in a very economical and cost effective cooling solution providing significant energy savings as compared to traditional data center mechanical refrigeration systems.

Phoenix AZ Conclusions – RTDCCS Temperature Performance

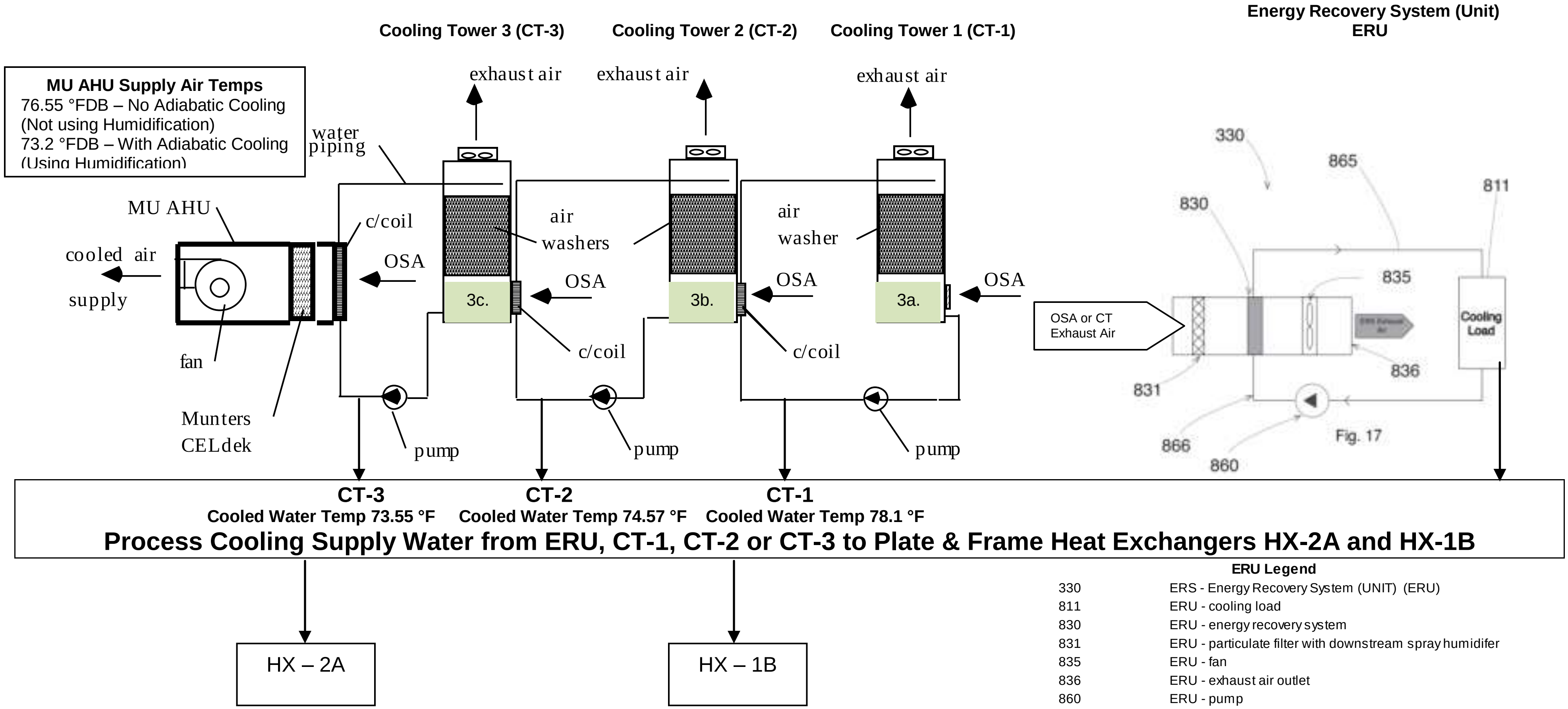
A Real Time Data Center Cooling System applied to a Data Center in Phoenix AZ can meet ASHRAE TC 9.9 data center white space maximum temperature set point of 80.6 °F or below for both the ASHRAE published ambient air Summer Design Conditions of .4% for cooling applications; and the monthly Mean Temperatures for Phoenix International Airport (PHX) (highest temperature of the process cooled air entering the white space is 71.7 °F in September) (See Engineering Analysis spreadsheet).

Therefore, the RTDCCS can provide a temperature of process cooled air (process cooling of the rack heat loads) entering the white space of between 58.8 °F and 71.7 °F meeting the guidelines established by ASHRAE TC 9.9. The Real Time Monitoring and Control System can maintain customer desires set point temperatures within the data center white space of customer selected temperature within a ± 1 °F control tolerance.

Preliminary Performance Analysis for Newark DE of the Real Time Data Center Cooling System consisting of the Multistage Evaporative Cooling System (MECS - Patent Pending) and the Individual Server Enclosure Cooling System (ISECS - Patent Pending)

Parameters:

1. Newark, Delaware Summer Ambient Air Design Conditions (ASHRAE .4% for cooling applications Wilmington DE (ILG)) are 91.9°FDB and 75.1°FWB for the Energy Recovery System (Unit) or ERU, all three CTs and the Makeup Air Handling Unit (MU AHU)
2. OSA is the inlet air at above design parameters to all stages.
3. Entered Air Conditions entering the Fill at each stage:
    a. CT-1 – 91.9 °FDB and 75.1 °FWB
    b. CT-2 – 79.1 °FDB and 71.57 °FWB
    c. CT-3 – 75.57 °FDB and 70.55 °FWB
4. Entered Air Conditions to the MU AHU is 91.9 °FDB and 75.1.°FWB
5. Entered Air Conditions to the ERU is 91.9 °FDB and 75.1 °FWB



ERU Legend

330	ERS - Energy Recovery System (UNIT) (ERU)
811	ERU - cooling load
830	ERU - energy recovery system
831	ERU - particulate filter with downstream spray humidifer
835	ERU - fan
836	ERU - exhaust air outlet
860	ERU - pump
865	ERU - cold water outlet pipe
866	ERU - warm water inlet pipe

Plate & Frame Heat Exchanger – HX-2A serving Pre-Cooling Coils of ISECS

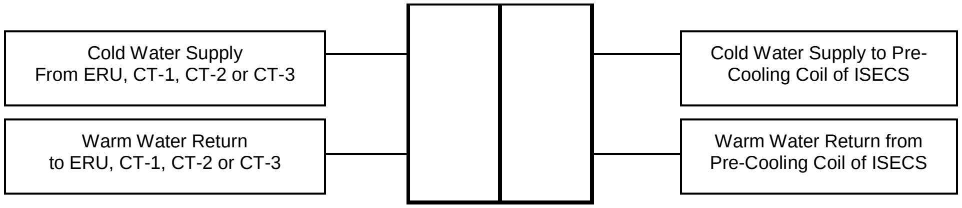
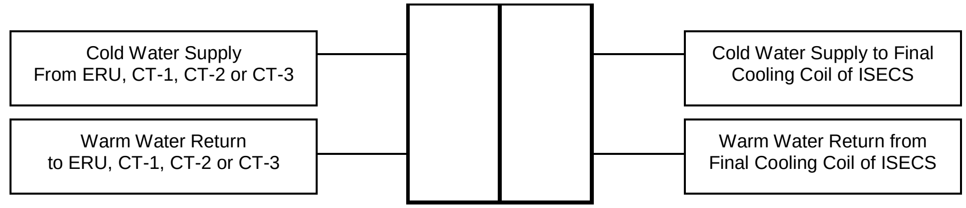
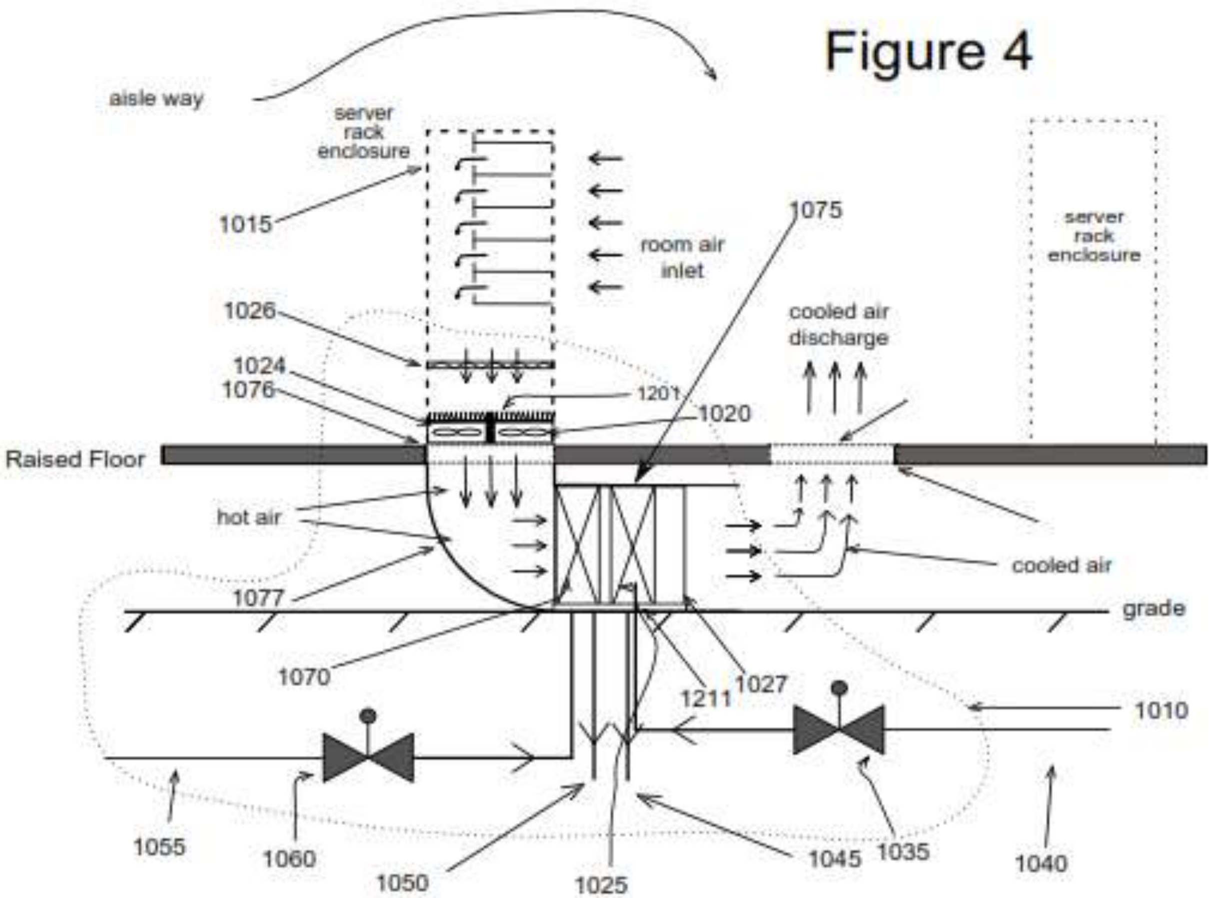


Plate & Frame Heat Exchanger – HX-1B serving Final Cooling Coils of ISECS



Individual Server Enclosure Cooling System (ISECS)



ISECS Legend

1010	ISECS
1015	server rack enclosure
1017	cold air dischage grill
1020	fan(s)
1024	fan rack
1025	final cooling coil
1026	air filter
1027	cooling coil unit
1035	final cooling coil water flow control valve
1040	final cooling coil cold water inlet pipe
1045	final cooling coil water outlet pipe
1050	pre-cooling coil water outlet pipe
1055	Not Defined (pre-cooling coil cold water Supply Pipe)
1060	pre-cooling coil water flow control valve
1070	pre-cooling coil
1074	"air duct elbow"
1075	housing
1076	hot air inlet
1077	hot air duct elbow
1201	Change from automatic louvers to automatic air damper
1202	louver door (safety door tied to fan motor automatic shutoff)
1211	condensate catch pan

Real Time Data Center Cooling System (RTDCCS) consisting of the Multistage Evaporative Cooling System (MECS) and Individual Server Enclosure Cooling Systems for each Rack (ISECS)

Cold Water & DC White Space Temp Performance in Wilmington DE ASHRAE Summer Design and Mean Monthly Temperatures in °F

Wilmington New Castle County Airport (ILG)

Energy Recovery Unit and / or Cooling Towers of the MECS Serving the RTDCCS

- RTDCCS commissioned in Wilmington DE can be served by an ERU & 3 Cooling Towers (CT-1,CT-2, CT-3)
- Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps - Redundant Backup CTs
- Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the RTDCCS

	DB °F	WB °F	Calculated Dew Pt °F	Calculated Humidity Ratio grains/lb	Energy Recovery Unit (ERU) Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification: ERU without OSA Humidification	ERU with OSA Humidification to 95% RH (Adiabatic Cooling)	Multistage Evaporative Cooling System Cold Water Temp Leaving Cooling Towers (CT), °F: CT-1	CT-2	CT-3	Real Time Data Center Cooling System Performance within the Data Center White Space: Estimated Cold Water Temp Leaving Plate & Frame HX	Estimated Cold Water Temp Entering Fan Coil Unit serving each rack (ISECS)	Estimated Cold Air Temp Leaving Fan Coil Unit serving each rack (ISECS)	Lowest Data Center White Space Temperature (Temp can be set to ±75 °F in cooler months to save significant energy costs)
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) **for Cooling Applications** (35 hours per year)	91.90	75.10	68.41	105.28	94.90	79.10	78.10	74.57	73.55	74.55	74.65	75.65	**75.65**
January	32.00	29.00	24.18	18.49	35.00	n/a	n/a	n/a	n/a	36.00	36.10	37.10	**37.10**
February	34.10	30.50	24.99	19.22	37.10	n/a	n/a	n/a	n/a	38.10	38.20	39.20	**39.20**
March	42.20	37.20	30.57	24.95	45.20	n/a	n/a	n/a	n/a	46.20	46.30	47.30	**47.30**
April	52.60	46.10	39.62	36.12	55.60	49.80	49.10	47.91	47.32	56.60	56.70	57.70	**57.70**
May	62.40	55.70	50.97	55..86	65.40	59.50	58.70	57.62	57.17	66.40	66.50	67.50	**67.50**
June	71.50	64.20	60.31	78.84	74.50	68.10	67.20	66.09	65.70	75.50	75.60	76.60	**76.60**
July	76.30	68.70	65.19	93.95	79.30	72.70	73.70	70.58	70.24	74.70	74.80	75.80	**75.80**
August	74.70	67.80	64.54	91.79	77.70	71.80	70.80	69.82	69.58	71.80	71.90	72.90	**72.90**
September	67.60	61.60	58.16	72.90	70.60	67.00	64.60	63.89	63.64	71.60	71.70	72.70	**72.70**
October	56.40	51.30	47.18	48.41	59.40	55.10	54.30	53.85	53.65	60.40	60.50	61.50	**61.50**
November	46.00	41.50	36.37	31.76	49.00	45.10	n/a	n/a	n/a	50.00	50.10	51.10	**51.10**
December	36.00	32.60	27.83	21.98	39.00	n/a	n/a	n/a	n/a	40.00	40.10	41.10	**41.10**

NOTE: The reason n/a is in some columns is because the system component at this stage would either create ice or is uneconomical. (Example: Wet Bulb temperature in Januaray and February in below freezing and no benefit can be derived) The RTDCCS is designed to maximize cooling at the lowest possible energy usage and cost.

****** 1. Year round operation of RTDCCS incorporating MECS and ISECS together (Process Cooling) can provide the required cooling for the IT equipment (server racks). 2. Building HVAC system is serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system. ASHRAE TC 9.9 increased ambient data center termperatures to 80.6 degrees.***

Wilmington New Castle County Airport (ILG)

http://www.weatherexplained.com/Vol-2/2001-Wilmington-Delaware-ILG.html

	Jan	Feb	Mar	Apr	May	Jun
MEAN DRY BULB	32.0	34.1	42.2	52.6	62.4	71.5
MEAN WET BULB	29.0	30.5	37.2	46.1	55.7	64.2

	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Mean
MEAN DRY BULB	76.3	74.7	67.6	56.4	46.0	36.0	54.3
MEAN WET BULB	68.7	67.8	61.6	51.3	41.5	32.6	48.8

Comfort Space and Natural Gas Turbine Inlet Air Cooling "cold supply air" provided by the Multistage Evaporative Cooling System (MECS) serving Commercial and Industrial facilities and plants

Temp Performance for Cold Supply Air for Commercial & Industrial Applications in Wilmington DE
ASHRAE Summer Design and Mean Monthly Temperatures in °F

Wilmington New Castle County Airport (ILG)

MECS Including ERU, Cooling Towers and Makeup Air Handling Unit (MU AHU) Supplying Cold Fresh Air

ERU, Cooling Towers (CT-1,CT-2, CT-3) and MU AHU commissioned to provide Cold Supply Air

Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps to generate cold makeup air

Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the MU AHU

					Multistage Evaporative Cooling System (MECS)									
					Energy Recovery Unit (ERU) Stage Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		**Cooling Tower Stage** Cold Water Temp Leaving Cooling Towers (CT), °F			**Make Up Air Handling Unit (MU AHU) Stage** Cold AIR Temp Leaving MU AHU, °F				
	OSA DB °F	**WB °F**	**Calculated Dew Pt °F**	**Calculated Humidity Ratio grains/lb**	**ERU-1A without OSA Humidification**	**ERU-1B with OSA Humidification to 95% RH (Adiabatic Cooling)**	**CT-1**	**CT-2**	**CT-3**	**MU AHU Pre-Cooling Coil Water Temp from ERU or CT-1, CT-2 or CT-3 (Source shown in RED)**	**MU AHU Cold Supply Air to space without OSA Humidification (No Adiabatic Cooling) includes 2 °F for fan heat**	**MU AHU Cold Supply Air to space with OSA Humidification to 95% RH (Adiabatic Cooling) includes 2 °F for fan heat**	**TEMPERATURE OF INLET AIR ENTERING NATURAL GAS TURBINES (TARGET TEMP IS 59 °F OR LOWER)**	**Commercial & Industrial Office Space Cold Supply Air Temperature Range**
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) **for Cooling Applications** (35 hours per year)	91.90	75.10	68.41	105.28	94.90	79.10	78.10	74.57	73.55	73.55 / CT-3	76.55	73.20	73.20	73.20 - 76.55
January	32.00	29.00	24.18	18.49	35.00	n/a	n/a	n/a	n/a	35.00 / ERU-1A	38.00	n/a	38.00	38.00 - 38.00
February	34.10	30.50	24.99	19.22	37.10	n/a	n/a	n/a	n/a	37.10 / ERU-1A	40.10	n/a	40.10	40.10 - 40.10
March	42.20	37.20	30.57	24.95	45.20	n/a	40.20	n/a	n/a	45.20 / ERU-1A	48.20	n/a	48.20	48.20 - 48.20
April	52.60	46.10	39.62	36.12	55.60	49.80	49.10	47.91	47.32	47.32 / CT-3	50.32	46.70	46.70	46.70 - 50.32
May	62.40	55.70	50.97	55.86	65.40	59.50	58.70	57.62	57.17	57.17 / CT-3	60.17	56.80	56.80	56.80 - 60.17
June	71.50	64.20	60.31	78.84	74.50	68.10	67.20	66.09	65.70	65.70 / CT-3	68.70	65.50	65.50	65.50 - 68.70
July	76.30	68.70	65.19	93.95	79.30	72.70	71.70	70.58	70.24	70.24 / CT-3	73.24	70.10	70.10	70.10 - 73.24
August	74.70	67.80	65.54	91.79	77.70	71.80	70.80	69.82	69.58	69.58 / CT-3	72.58	69.50	69.50	69.50 - 72.58
September	67.60	61.60	58.16	79.90	70.60	67.00	64.60	63.89	63.64	64.60 / CT-1	67.60	65.30	65.30	65.30 - 67.60
October	56.40	51.30	47.18	48.49	59.40	55.10	54.30	53.85	53.65	54.3 0/ CT-1	57.30	53.60	53.60	53.60 - 57.30
November	46.00	41.50	36.37	31.76	49.00	45.10	44.50	n/a	n/a	44.50 / CT-1	47.50	44.10	44.10	44.10 - 47.50
December	36.00	32.60	27.83	21.96	39.00	n/a	35.60	n/a	n/a	39.00 /ERU-1A	42.00	n/a	42.00	42.00 - 42.00

***** NOTE *** If the negative pressure at the turbine compressor inlet allows for the elimination of the fan in the MU AHU, the temperature can be reduced by an additional 2 °F.**

NOTE: The reason n/a is in some columns is because the system component at this stage would either create ice or is uneconomical. (Example: Wet Bulb temperature in Januaray and February in below freezing and no benefit can be derived) The RTDCCS is designed to maximize cooling at the lowest possible energy usage and cost.

***** 1. Year round operation of MECS and MU AHU together (Comfort Cooling) can provide the required spacecooling for Commercial & Industrial Office Spaces and Natural Gas and Industrial Compressor Inlet Air Cooling. 2. System is tied into the HVAC system serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system.**

Wilmington New Castle County Airport (ILG) http://www.weatherexplained.com/Vol-2/2001-Wilmington-Delaware-ILG.html

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	
MEAN DRY BULB	32	34.1	42.2	52.6	62.4	71.5	
MEAN WET BULB	29	30.5	37.2	46.1	55.7	64.2	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Mean**
MEAN DRY BULB	76.3	74.7	67.6	56.4	46	36	54.3
MEAN WET BULB	68.7	67.8	61.6	51.3	41.5	32.6	48.8

Preliminary Temperature Performance Evaluation – Summer Design Conditions

Estimating temperature performance of the Real Time Data Center Cooling System (MECS + ISECS) for the future Delaware Data Center to be located in city of Newark, DE

General

Below are calculations for the ASHRAE published Summer Design Conditions of .4% for cooling applications showing the ambient air design dry bulb and wet bulb temperatures for Newark, DE (Wilmington New Castle County Airport (ILG) of 91.9 ˚FDB and 75.1 ˚FWB.

Engineering Analysis

Given Data

- DC site Location: Wilmington DE (Near the Newark, DE DC location)
- Site Elevation: 125 ft.
- OSA 0.4% design conditions: 91.9 ˚FDB / 75.1 ˚FWB

Assumed the following approach temperatures for:

- All Cooling Towers &ERUs: 3˚F
- All pre-cooling coils for Cooling Towers: 1˚F
- Fluid-fluid Plate HX: 1˚F
- Pre-cooling coil of FCU: 1˚F
- Final cooling coil of FCU: 1˚F

Design parameters of the OSA are:

- Relative humidity: 46.37%
- Dew point temperature, 68.41 ˚F
- Humidity ratio: 105.28 gr/lb
- Enthalpy: 38.62 btu/lb
- Specific volume: 14.31 ft^3/lb

Calculation

Estimated temperature of the cold water leaving the Cooling Tower CT-1 and entering the ambient air pre-cooling coils of the cooling tower CT-2 is:

75.1+ 3 = 78.1 ˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-2:

78.1 +1 = 79.1 ˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-2A:

- Dry Bulb temperature: 79.1 ˚F
- Wet Bulb Temperature: 71.57 ˚F
- Relative humidity: 69.8%
- Dew point temperature, 68.41 ˚F
- Humidity ratio: 105.24 gr/lb

- Enthalpy: 35.45 btu/lb
- Specific volume: 13.97 ft^3/lb

Estimated temperature of the cold water leaving the Cooling Tower CT-2 and entering the ambient air pre-cooling coils of the cooling tower CT-3 is:

71.57 + 3 = 74.57˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-3:

74.57 +1 = 75.57˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-3:

- Dry Bulb temperature: 75.57˚F
- Wet Bulb Temperature: 70.55 ˚F
- Relative humidity: 78.45%
- Dew point temperature, 68.40˚F
- Humidity ratio: 105.24 gr./lb.
- Enthalpy: 34.58 btu / lb.
- Specific volume: 13.88 ft^3/lb.

Estimated temperature of the cold water leaving the Cooling Tower CT-3 and entering into primary loop of the liquid-liquid plate and frame HX:

70.55 + 3 = 73.55˚F

Estimated temperature of the secondary loop supply cooling water leaving plate and frame HX and entering into the final cooling coils of the FCUs:

73.55 + 1.1 = 74.65˚F

Estimated temperature of the cooled air leaving final cooling coil of the FCU serving and individual electronics enclosure*:

74.65 + 1 = 75.65 ˚F < 80.6˚F (ASHRAE TC 9.9 Maximum Recommended)

*Notes:

- The FCU is configured the way that its fan is located upstream of the pre-cooling and final cooling coils.
- In this case, the booster mechanical refrigeration cooling system is not required, because the MECS generated cold enough water allowing the FCUs discharge into the white space the cooled air at dry bulb temperature of 75.65 ˚FDB. If fan of the FCUs locate downstream of the final cooling coil, the anticipated dry bulb temperature of the cooled air entering into the white space would be within 76 ±1 ˚F.

Preliminary Temperature Performance Evaluation – Monthly Mean Temperature Conditions

Projected Monthly Temperature Performance of the Real Time Data Center Cooling System

This is an engineering analysis estimating mean monthly thermal performance of the Real Time Data Center Cooling System consisting of Multistage Evaporative Cooling System (MECS) generating cold water and the Individual Server Enclosure Cooling Systems (ISECS) for use in process cooling of the Server Racks located in the white space of the Data Center. The analysis is for a data center project to be built on the University of Delaware's Science, Technology and Advanced Research (STAR) Campus by The Data Centers LLC in Newark, DE. This analysis uses the ASHRAE Design Conditions for Selected Locations table and specifically the Wilmington New Castle Airport (ILG) area and the monthly mean dry bulb and wet bulb temperatures for the Wilmington New Castle Airport (ILG). http://www.weatherexplained.com/Vol-2/2001-Wilmington-Delaware-ILG.html

Given conditions

- Site elevation, ft.: 125

Preliminary Assumptions:

- Preliminary assumption - MECS consists of three cooling towers: CT-1, CT-2 and CT-3.
- An assumed approach temperature for all cooling tower CT-1, CT-2 and CT-3 is 3.0 ˚F.
- An assumed approach temperature for ambient air pre-cooling coils for the mentioned cooling towers is 1.0 ˚F.
- Humidity and partial temperature control of the Data Center's White Space should be provided by the building comfort HVAC Systems.
- A combination of the MECS + ISECS provides process sensible cooling of the Data Center Server Racks.
- Each cooling coil in the Fan Coil Unit (Pre-Cooling Coil and Final Cooling Coil) assumes a 1.0 ˚F approach temperature plus a 0.1 ˚F adjustment for cooling water heat (temperature) gain (Totaling 2.1 °F).

An Executive Summary of the Engineering Analysis

The Engineering Analysis conducted below is based on the R4 Ventures LLC - Real Time Data Center Cooling System and its patent-pending cooling technologies consisting of the Multi-stage Evaporative Cooling System (MECS) combined with the Individual Server Enclosure Cooling System (ISECS), also described herein as Fan Coil Unit (FCU), operating in Wilmington, DE (closest location identified in the ASHRAE table) would provide year round required cooling of the Server Racks in the Data Center and returning cold supply air back to the Data Center While Space (See Individual Server Enclosure Cooling System (ISECS) Figure 4). Depending on the ambient conditions, in the majority of cases, the Energy Recovery Unit (ERU) operating alone would be able to satisfy the all cooling needs of the Data Center's IT Equipment (See attached Engineering Analysis spread sheet document). In some ambient conditions and depending on the customer's set point temperature requirements for the Data Center White Space, Cooling Tower CT-1, Cooling Tower CT-2, and Cooling Tower CT-3 may be operational. The sequence of operations would be CT-1 alone, CT-1 and CT-2, or CT-1, CT-2 and CT-3. All 3 Cooling Towers can be used to provide redundant back up the Energy Recovery Units (ERU 1A and ERU 1B). This analysis results in a very economical and cost effective cooling solution providing significant energy savings as compared to traditional data center mechanical refrigeration systems.

Wilmington DE Conclusions – RTDCCS Temperature Performance

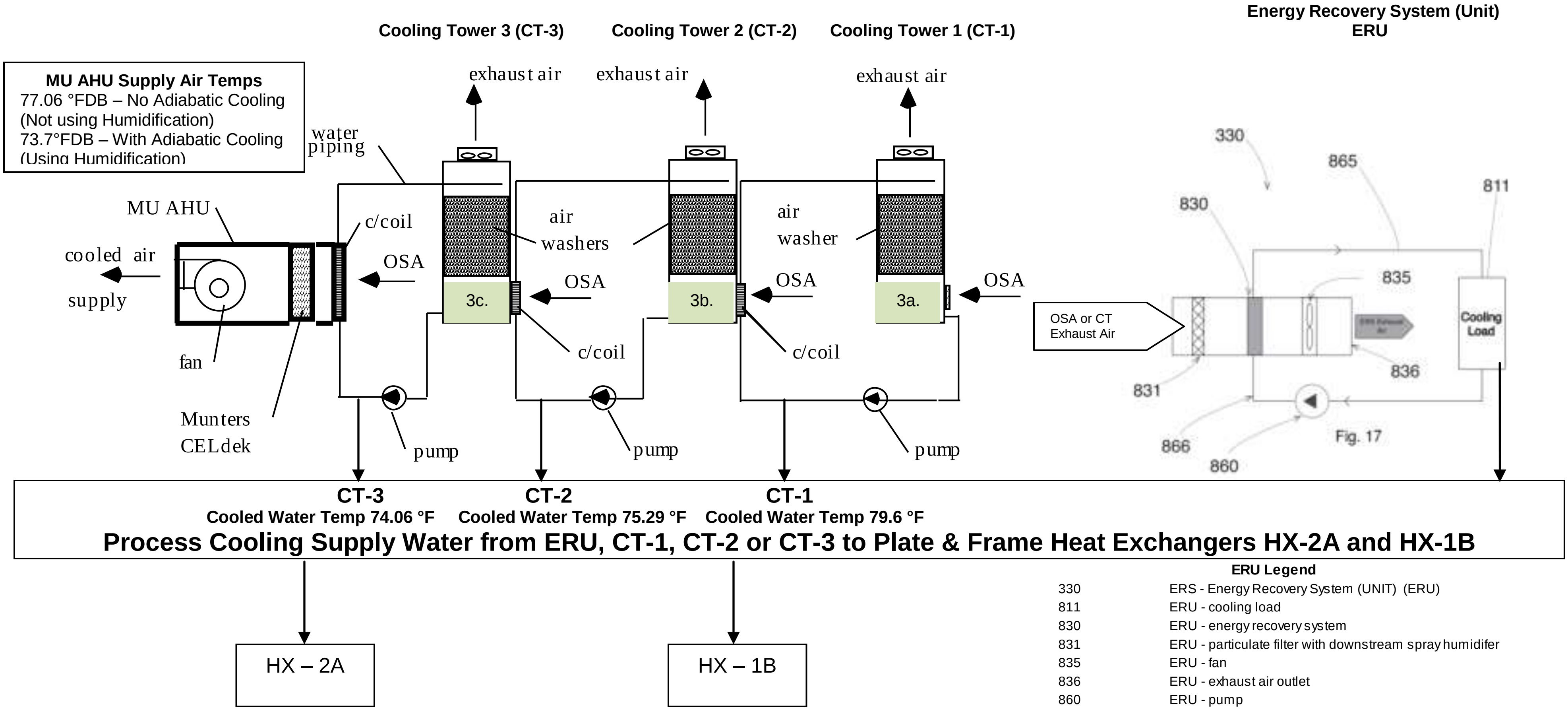
A Real Time Data Center Cooling System applied to a Data Center in Wilmington DE can meet ASHRAE TC 9.9 data center white space maximum temperature set point of 80.6 °F or below for both the ASHRAE published ambient air Summer Design Conditions of .4% for cooling applications; and the monthly Mean Temperatures for Wilmington New Castle County Airport (ILG) (highest temperature of the process cooled air entering the white space is 76.6 °F in June) (See Engineering Analysis spreadsheet).

Therefore, the RTDCCS can provide a temperature of process cooled air (process cooling of the rack heat loads) entering the white space of between 37.1 °F and 76.6 °F meeting the guidelines established by ASHRAE TC 9.9. The Real Time Monitoring and Control System can maintain customer desires set point temperatures within the data center white space of customer selected temperature within a ± 1 °F control tolerance.

Preliminary Performance Analysis for Houston TX of the Real Time Data Center Cooling System consisting of the Multistage Evaporative Cooling System (MECS - Patent Pending) and the Individual Server Enclosure Cooling System (ISECS - Patent Pending)

Parameters:

1. Houston TX Summer Ambient Air Design Conditions (ASHRAE .4% for cooling applications George Bush Intercontinental Airport (IAH)) are 96.8°FDB and 76.6°FWB for the Energy Recovery System (Unit) or ERU, all three CTs and the Makeup Air Handling Unit (MU AHU)
2. OSA is the inlet air at above design parameters to all stages.
3. Entered Air Conditions entering the Fill at each stage:
    a. CT-1 – 96.8 °FDB and 76.6 °FWB
    b. CT-2 – 80.6 °FDB and 72.29 °FWB
    c. CT-3 – 76.29 °FDB and 71.06 °FWB
4. Entered Air Conditions to the MU AHU is 96.8 °FDB and 76.6 °FWB
5. Entered Air Conditions to the ERU is 96.8 °FDB and 76.6 °FWB



ERU Legend

330	ERS - Energy Recovery System (UNIT) (ERU)
811	ERU - cooling load
830	ERU - energy recovery system
831	ERU - particulate filter with downstream spray humidifer
835	ERU - fan
836	ERU - exhaust air outlet
860	ERU - pump
865	ERU - cold water outlet pipe
866	ERU - warm water inlet pipe

Plate & Frame Heat Exchanger – HX-2A serving Pre-Cooling Coils of ISECS

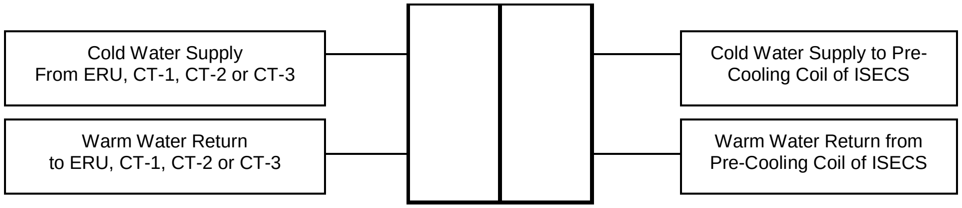
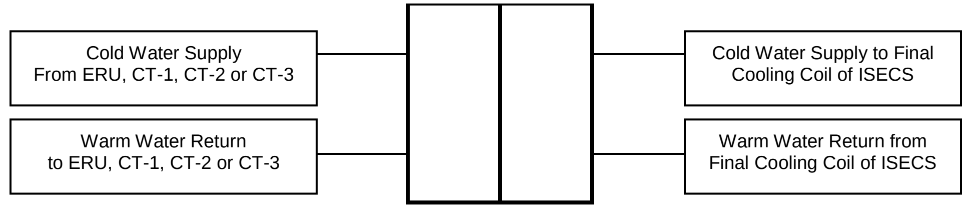
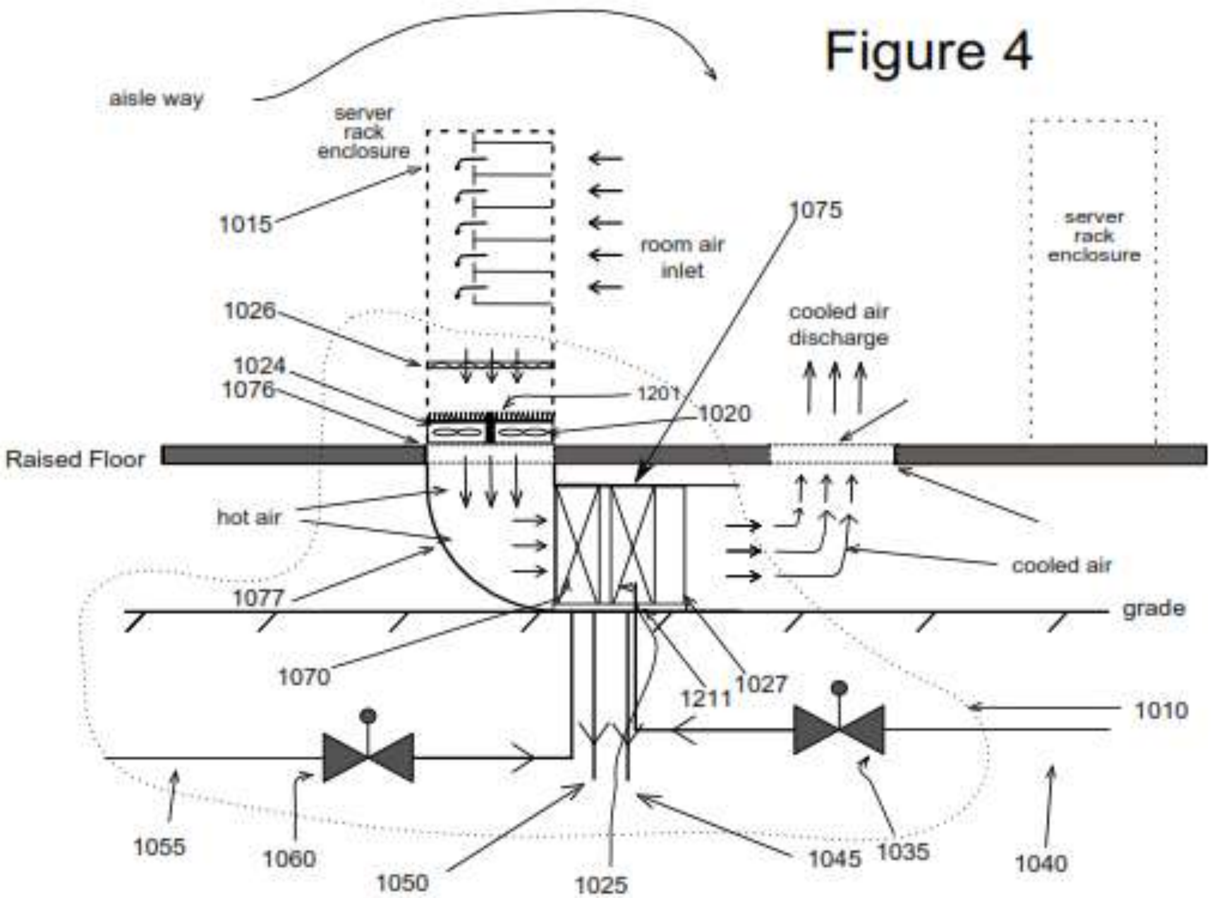


Plate & Frame Heat Exchanger – HX-1B serving Final Cooling Coils of ISECS



Individual Server Enclosure Cooling System (ISECS)



ISECS Legend

1010	ISECS
1015	server rack enclosure
1017	cold air dischage grill
1020	fan(s)
1024	fan rack
1025	final cooling coil
1026	air filter
1027	cooling coil unit
1035	final cooling coil water flow control valve
1040	final cooling coil cold water inlet pipe
1045	final cooling coil water outlet pipe
1050	pre-cooling coil water outlet pipe
1055	Not Defined (pre-cooling coil cold water Supply Pipe)
1060	pre-cooling coil water flow control valve
1070	pre-cooling coil
1074	"air duct elbow"
1075	housing
1076	hot air inlet
1077	hot air duct elbow
1201	Change from automatic louvers to automatic air damper
1202	louver door (safety door tied to fan motor automatic shutoff)
1211	condensate catch pan

Real Time Data Center Cooling System (RTDCCS) consisting of the Multistage Evaporative Cooling System (MECS) and Individual Server Enclosure Cooling Systems for each Rack (ISECS)

Cold Water & DC White Space Temp Performance in Houston TX
ASHRAE Summer Design and Mean Monthly Temperatures in °F

George Bush Intercontinental Airport (IAH)

Energy Recovery Unit and / or Cooling Towers of the MECS Serving the RTDCCS

RTDCCS commissioned in Houston TX can be served by an ERU & 3 Cooling Towers (CT-1,CT-2, CT-3)

Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps - Redundant Backup CTs

Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the RTDCCS

					Energy Recovery Unit (ERU) Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		Multistage Evaporative Cooling System Cold Water Temp Leaving Cooling Towers (CT), °F			Real Time Data Center Cooling System Performance within the Data Center White Space			
	DB °F	WB °F	Calculated Dew Pt °F	Calculated Humidity Ratio grains/lb	ERU without OSA Humidification	ERU with OSA Humidification to 95% RH (Adiabatic Cooling)	CT-1	CT-2	CT-3	Estimated Cold Water Temp Leaving Plate & Frame HX	Estimated Cold Water Temp Entering Fan Coil Unit serving each rack (ISECS)	Estimated Cold Air Temp Leaving Fan Coil Unit serving each rack (ISECS)	Lowest Data Center White Space Temperature (Temp can be set to ±75 °F in cooler months to save significant energy costs)
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	96.80	76.60	68.75	106.04	99.80	80.50	79.60	75.29	74.06	75.06	75.16	76.16	**76.16**
January	51.60	48.10	45.00	44.32	54.60	51.90	51.10	n/a	n/a	55.60	55.70	56.70	**56.70**
February	55.40	51.70	48.80	51.24	58.40	55.40	54.70	n/a	n/a	59.40	59.50	60.50	**60.50**
March	61.70	56.40	53.34	60.76	64.70	60.50	59.70	59.31	59.15	65.70	65.80	66.80	**66.80**
April	68.40	62.60	59.37	75.84	71.40	66.50	65.60	64.96	64.75	72.40	72.50	73.50	**73.50**
May	75.40	70.00	67.63	101.97	78.40	74.00	73.00	72.58	72.46	74.00	74.10	75.10	**75.10**
June	81.00	74.50	72.01	118.85	84.00	78.60	77.50	76.82	76.63	77.63	77.73	78.73	**78.73**
July	83.60	75.70	72.76	121.98	86.60	79.80	78.70	77.66	77.38	78.38	78.48	79.48	**79.48**
August	83.20	75.60	72.77	122.02	86.20	79.70	78.60	77.64	77.38	78.38	78.48	79.48	**79.48**
September	78.60	71.40	68.35	104.56	81.60	75.40	74.40	73.47	73.19	75.40	75.50	76.50	**76.50**
October	70.00	64.20	61.13	80.85	73.00	68.10	67.20	66.59	66.39	74.00	74.10	75.10	**75.10**
November	60.60	56.30	53.39	60.88	63.60	60.10	59.30	59.18	59.14	64.60	64.70	65.70	**65.70**
December	54.10	47.10	40.28	36.91	57.10	50.80	50.10	48.68	48.00	58.10	58.20	59.20	**59.20**

NOTE: The reason n/a is in some columns is because the system component at this stage would either create ice or is uneconomical. (Example: Wet Bulb temperature in Januaray and February in below freezing and no benefit can be derived) The RTDCCS is designed to maximize cooling at the lowest possible energy usage and cost.

****** 1. Year round operation of RTDCCS incorporating MECS and ISECS together (Process Cooling) can provide the required cooling for the IT equipment (server racks). 2. Building HVAC system is serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system. ASHRAE TC 9.9 increased ambient data center termperatures to 80.6 degrees.***

George Bush Intercontinental Airport (IAH)

http://www.weatherexplained.com/Vol-6/2001-Houston-Texas-IAH.html#ixzz2V5Qe40Ob

	Jan	Feb	Mar	Apr	May	Jun	
MEAN DRY BULB	51.6	55.4	61.7	68.4	75.4	81.0	
MEAN WET BULB	48.1	51.7	56.4	62.6	70.0	74.5	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Mean**
MEAN DRY BULB	83.6	83.2	78.6	70.0	60.6	54.1	68.6
MEAN WET BULB	75.7	75.6	71.4	64.2	56.3	47.1	62.8

Comfort Space and Natural Gas Turbine Inlet Air Cooling "cold supply air" provided by the Multistage Evaporative Cooling System (MECS) serving Commercial and Industrial facilities and plants

Temp Performance for Cold Supply Air for Commercial & Industrial Applications in Houston TX
ASHRAE Summer Design and Mean Monthly Temperatures in °F

MECS Including ERU, Cooling Towers and Makeup Air Handling Unit (MU AHU) Supplying Cold Fresh Air

George Bush Intercontinental Airport (IAH)

ERU, Cooling Towers (CT-1,CT-2, CT-3) and MU AHU commissioned to provide Cold Supply Air

Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps to generate cold makeup air

Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the MU AHU

					Multistage Evaporative Cooling System (MECS)									
					Energy Recovery Unit (ERU) Stage Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		**Cooling Tower Stage** Cold Water Temp Leaving Cooling Towers (CT), °F			**Make Up Air Handling Unit (MU AHU) Stage** Cold AIR Temp Leaving MU AHU, °F				
	OSA DB °F	WB °F	Calculated Dew Pt °F	Calculated Humidity Ratio grains/lb	ERU-1A without OSA Humidification	ERU-1B with OSA Humidification to 95% RH (Adiabatic Cooling)	CT-1	CT-2	CT-3	MU AHU Pre-Cooling Coil Water Temp from ERU or CT-1, CT-2 or CT-3 (Source shown in RED)	MU AHU Cold Supply Air to space without OSA Humidification (No Adiabatic Cooling) includes 2 °F for fan heat	MU AHU Cold Supply Air to space with OSA Humidification to 95% RH (Adiabatic Cooling) includes 2 °F for fan heat	TEMPERATURE OF INLET AIR ENTERING NATURAL GAS TURBINES (TARGET TEMP IS 59 °F OR LOWER)	Commercial & Industrial Office Space Cold Supply Air Temperature Range
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	96.80	76.60	68.75	106.04	99.80	80.50	79.60	75.29	74.06	74.34 / CT-3	77.06	73.70	73.70	73.70 - 77.06
January	51.60	48.10	45.00	44.32	54.60	51.90	51.10	n/a	n/a	51.90 / ERU-1B	54.90	51.40	51.40	51.40 - 54.90
February	55.40	51.70	48.80	51.24	58.40	55.40	54.70	n/a	n/a	55.40 / ERU-1B	58.40	54.90	54.90	54.90 - 58.40
March	61.70	56.40	52.79	59.52	64.70	60.50	59.70	59.31	59.15	60.50 / ERU-1B	63.50	59.50	59.50	59.50 - 63.50
April	68.40	62.60	59.37	75.84	71.40	66.50	65.60	64.96	64.75	66.50 / ERU-1B	69.50	65.20	65.20	65.20 - 69.50
May	75.40	70.00	67.63	101.97	78.40	74.00	73.00	72.58	72.46	73.00 / CT-1	76.00	72.60	72.60	72.60 - 76.00
June	81.00	74.50	72.01	118.85	84.00	78.60	77.50	76.82	76.63	76.63 / CT-3	79.63	76.60	76.60	76.60 - 79.63
July	83.60	75.70	72.76	121.98	86.60	79.80	78.70	77.66	77.38	77.38 / CT-3	80.38	77.40	77.40	77.40 - 80.38
August	83.20	75.60	72.77	122.02	86.20	79.70	78.60	77.64	77.38	77.38 / CT-3	80.38	77.40	77.40	77.40 - 80.38
September	78.60	71.40	68.35	104.56	81.60	75.40	74.40	73.47	73.19	73.19 / CT-3	76.19	73.15	73.15	73.15 - 76.19
October	70.00	64.20	61.13	80.85	73.00	68.10	67.20	66.59	66.39	66.59 / CT-2	69.59	66.30	66.30	66.30 - 69.59
November	60.60	56.30	53.39	60.88	63.60	60.10	59.30	59.18	59.14	60.10 / ERU-1B	63.10	59.30	59.30	59.30 - 63.10
December	54.10	47.10	40.28	36.91	57.10	50.80	50.10	48.68	48.00	50.80 / ERU-1B	53.80	48.70	48.70	48.70 - 53.80

***** NOTE *** If the negative pressure at the turbine compressor inlet allows for the elimination of the fan in the MU AHU, the temperature can be reduced by an additional 2 °F.**

***** 1. Year round operation of MECS and MU AHU together (Comfort Cooling) can provide the required spacecooling for Commercial & Industrial Office Spaces and Natural Gas and Industrial Compressor Inlet Air Cooling. 2. System is tied into the HVAC system serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system.**

George Bush Intercontinental Airport (IAH)

http://www.weatherexplained.com/Vol-6/2001-Houston-Texas-IAH.html

	Jan	Feb	Mar	Apr	May	Jun	
MEAN DRY BULB	51.6	55.4	61.7	68.4	75.4	81	
MEAN WET BULB	48.1	51.7	56.4	62.6	70	74.5	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly Mean**
MEAN DRY BULB	83.6	83.2	78.6	70	60.6	54.1	68.6
MEAN WET BULB	75.7	75.6	71.4	64.2	56.3	47.1	62.8

Houston, TX
Preliminary Temperature Performance Evaluation – Summer Design Conditions

Estimating temperature performance of the Real Time Data Center Cooling System (MECS + ISECS) for Data Center to be located in city of Houston TX.

General

Below are calculations for the ASHRAE published Summer Design Conditions of .4% for cooling applications showing the ambient air design dry bulb and wet bulb temperatures for George Bush Intercontinental Airport (IAH) of 96.8 ˚FDB and 76.6 ˚FWB.

Engineering Analysis

Given Data

- DC site Location: Houston TX (IAD)
- Site Elevation: Sea Level
- OSA 0.4% design conditions: 96.8 ˚FDB / 76.6 ˚FWB

Assumed the following approach temperatures for:

- All Cooling Towers & ERUs: 3˚F
- All pre-cooling coils for Cooling Towers: 1˚F
- Fluid-fluid Plate HX: 1˚F
- Pre-cooling coil of FCU: 1˚F
- Final cooling coil of FCU: 1˚F

Design parameters of the OSA are:

- Relative humidity: 40.33%
- Dew point temperature, 68.75 ˚F
- Humidity ratio: 106.04 gr/lb
- Enthalpy: 39.95 btu/lb
- Specific volume: 14.37 ft^3/lb

Calculation

Estimated temperature of the cold water leaving the Cooling Tower CT-1 and entering the ambient air pre-cooling coils of the cooling tower CT-2 is:

76.6+ 3 = 79.6 ˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-2:

79.6 +1 = 80.6 ˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-2A:

- Dry Bulb temperature: 80.6 ˚F
- Wet Bulb Temperature: 72.23 ˚F
- Relative humidity: 67.25%

- Dew point temperature, 68.75 ˚F
- Humidity ratio: 106.04 gr/lb
- Enthalpy: 35.95 btu/lb
- Specific volume: 13.95 ft^3/lb

Estimated temperature of the cold water leaving the Cooling Tower CT-2 and entering the ambient air pre-cooling coils of the cooling tower CT-3 is:

72.23 + 3 = 75.23˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-3:

75.23 +1 = 76.23˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-3:

- Dry Bulb temperature: 76.23 ˚F
- Wet Bulb Temperature: 70.97 ˚F
- Relative humidity: 77.67%
- Dew point temperature, 68.75˚F
- Humidity ratio: 106.04 gr./lb.
- Enthalpy: 34.86 btu / lb.
- Specific volume: 13.83 ft^3/lb.

Estimated temperature of the cold water leaving the Cooling Tower CT-3 and entering into primary loop of the liquid-liquid plate and frame HX:

70.97 + 3 = 73.97 ˚F

Estimated temperature of the secondary loop supply cooling water leaving plate and frame HX and entering into the final cooling coils of the FCUs:

73.97 + 1 = 74.97 ˚F

Estimated temperature of the cooled air leaving final cooling coil of the FCU serving and individual electronics enclosure*:

74.97 + 1.1 = 76.07 ˚F < 80.6˚F (ASHRAE TC 9.9 Maximum Recommended)

*Notes:

- The FCU is configured the way that its fan is located upstream of the pre-cooling and final cooling coils.

Preliminary Temperature Performance Evaluation – Monthly Mean Temperature Conditions

Projected Monthly Temperature Performance of the Real Time Data Center Cooling System

The Engineering Analysis shown in the above spreadsheet estimating mean monthly thermal performance of the Real Time Data Center Cooling System consisting of Multistage Evaporative Cooling System (MECS) generating cold water and the Individual Server Enclosure Cooling Systems (ISECS) for use in process cooling of the Server Racks located in the white space of the Data Center. The analysis is for a data center project that would be located in Houston TX. This analysis uses the ASHRAE Design Conditions for Selected Locations table and specifically the George Bush Intercontinental Airport (IAH) area and the monthly mean dry bulb and wet bulb temperatures for the George Bush Intercontinental Airport (IAH). http://www.weatherexplained.com/Vol-6/2001-Houston-Texas-IAH.html#ixzz2V5Qe40Ob

Given conditions

- Site elevation, ft.: Sea Level

Preliminary Assumptions:

- Preliminary assumption - MECS consists of three cooling towers: CT-1, CT-2 and CT-3.
- An assumed approach temperature for all cooling tower CT-1, CT-2 and CT-3 is 3.0 ˚F.
- An assumed approach temperature for ambient air pre-cooling coils for the mentioned cooling towers is 1.0 ˚F.
- Humidity and partial temperature control of the Data Center's White Space should be provided by the building comfort HVAC Systems.
- A combination of the MECS + ISECS provides process sensible cooling of the Data Center Server Racks.
- Each cooling coil in the Fan Coil Unit (Pre-Cooling Coil and Final Cooling Coil) assumes a 1.0 ˚F approach temperature plus a 0.1 ˚F adjustment for cooling water heat (temperature) gain (Totaling 2.1 °F).

An Executive Summary of the Engineering Analysis

The Engineering Analysis conducted below is based on the R4 Ventures LLC - Real Time Data Center Cooling System and its patent-pending cooling technologies consisting of the Multi-stage Evaporative Cooling System (MECS) combined with the Individual Server Enclosure Cooling System (ISECS), also described herein as Fan Coil Unit (FCU), operating in Houston, TX, would provide year round required cooling of the Server Racks in the Data Center and returning cold supply air back to the Data Center While Space (See Individual Server Enclosure Cooling System (ISECS) Figure 4). Depending on the ambient conditions, in the majority of cases, the Energy Recovery Unit (ERU) operating alone would be able to satisfy the all cooling needs of the Data Center's IT Equipment (See attached Engineering Analysis spread sheet document). In some ambient conditions and depending on the customer's set point temperature requirements for the Data Center White Space, Cooling Tower CT-1, Cooling Tower CT-2, and Cooling Tower CT-3 may be operational. The sequence of operations would be CT-1 alone, CT-1 and CT-2, or CT-1, CT-2 and CT-3. All 3 Cooling Towers can be used to provide redundant back up the Energy Recovery Units (ERU 1A and ERU 1B). This analysis results in a very economical and cost effective cooling solution providing significant energy savings as compared to traditional data center mechanical refrigeration systems.

Houston TX Conclusions – RTDCCS Temperature Performance

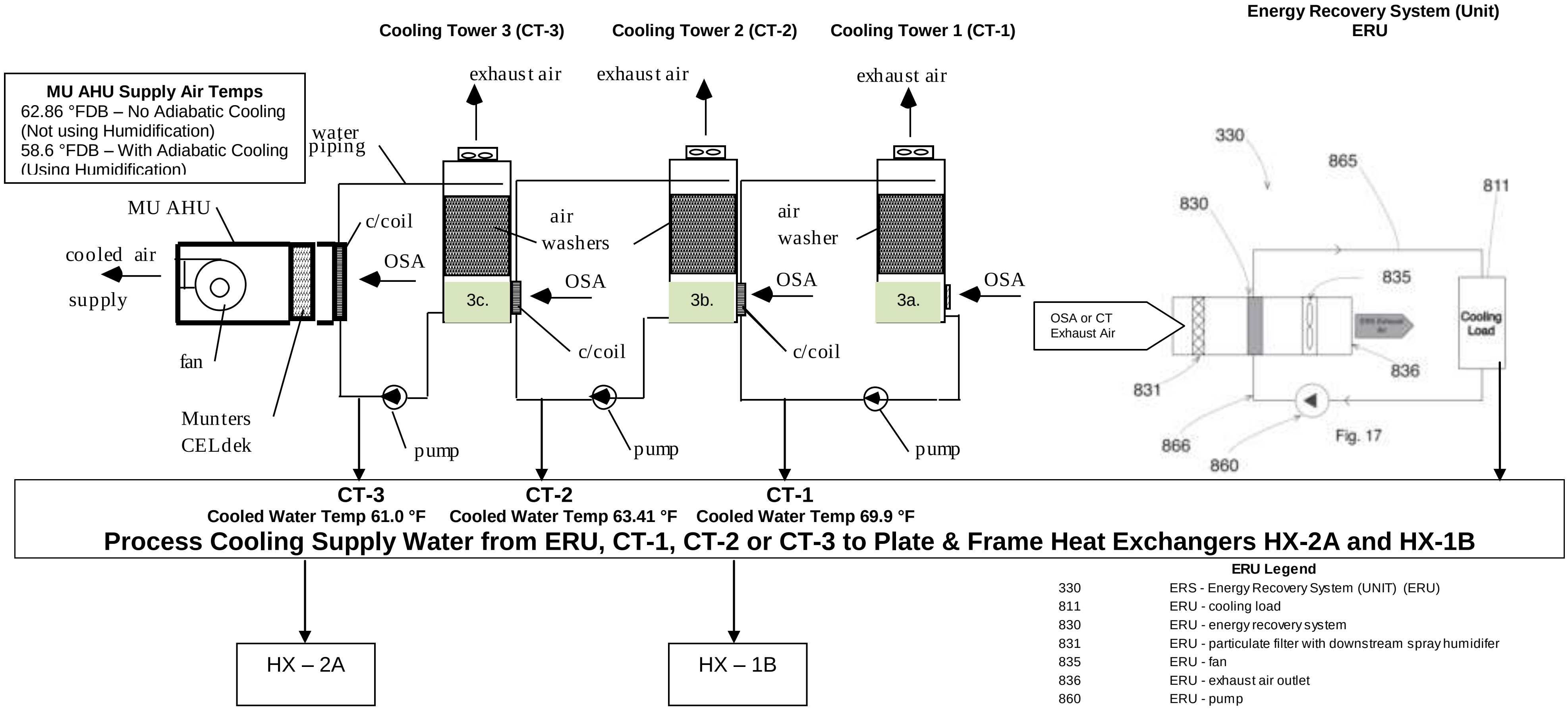
A Real Time Data Center Cooling System applied to a Data Center in Houston TX can meet ASHRAE TC 9.9 data center white space maximum temperature set point of 80.6 °F or below for both the ASHRAE published ambient air Summer Design Conditions of .4% for cooling applications; and the monthly Mean Temperatures for Bush Intercontinental Airport (IAH) (highest temperature of the process cooled air entering the white space is 80.03 °F in July) (See Engineering Analysis spreadsheet).

Therefore, the RTDCCS can provide a temperature of process cooled air (process cooling of the rack heat loads) entering the white space of between 56.7 °F and 80.03 °F meeting the guidelines established by ASHRAE TC 9.9. The Real Time Monitoring and Control System can maintain customer desires set point temperatures within the data center white space of customer selected temperature within a ± 1 °F control tolerance.

Preliminary Performance Analysis for San Jose CA of the Real Time Data Center Cooling System consisting of the Multistage Evaporative Cooling System (MECS - Patent Pending) and the Individual Server Enclosure Cooling System (ISECS - Patent Pending)

Parameters:

1. San Jose CA Summer Ambient Air Design Conditions (ASHRAE .4% for cooling applications San Jose CA(SJC)) are 92.3°FDB and 66.9°FWB for the Energy Recovery System (Unit) or ERU, all three CTs and the Makeup Air Handling Unit (MU AHU)
2. OSA is the inlet air at above design parameters to all stages.
3. Entered Air Conditions entering the Fill at each stage:
    a. CT-1 – 92.3 °FDB and 66.9 °FWB
    b. CT-2 – 70.9 °FDB and 60.41 °FWB
    c. CT-3 – 64.41 °FDB and 58.0 °FWB
4. Entered Air Conditions to the MU AHU is 92.3 °FDB and 66.9 °FWB
5. Entered Air Conditions to the ERU is 92.3 °FDB and 66.9 °FWB



ERU Legend

330	ERS - Energy Recovery System (UNIT) (ERU)
811	ERU - cooling load
830	ERU - energy recovery system
831	ERU - particulate filter with downstream spray humidifer
835	ERU - fan
836	ERU - exhaust air outlet
860	ERU - pump
865	ERU - cold water outlet pipe
866	ERU - warm water inlet pipe

Plate & Frame Heat Exchanger – HX-2A serving Pre-Cooling Coils of ISECS

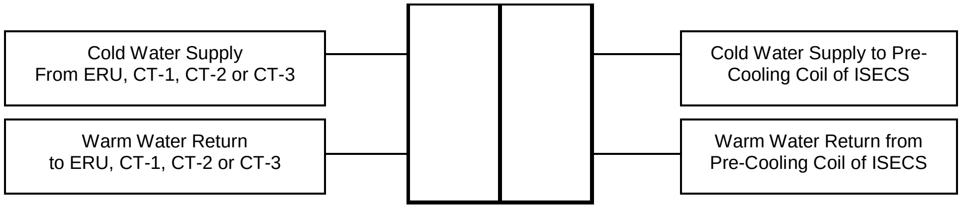
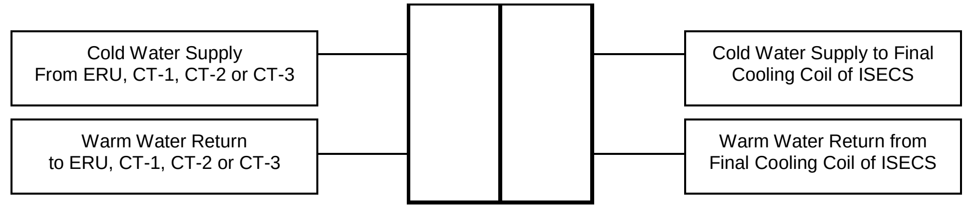


Plate & Frame Heat Exchanger – HX-1B serving Final Cooling Coils of ISECS



Individual Server Enclosure Cooling System (ISECS)

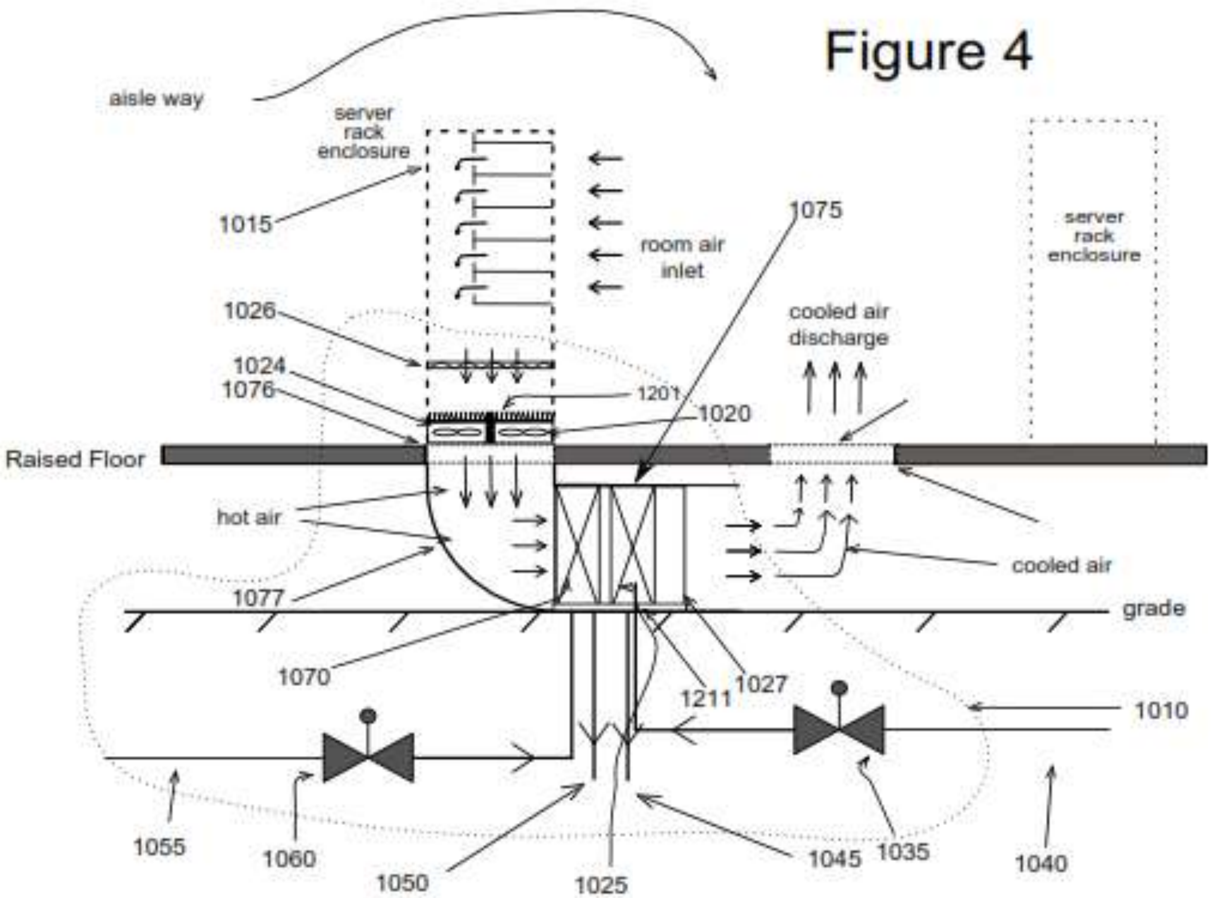


Figure 4

ISECS Legend

1010	ISECS
1015	server rack enclosure
1017	cold air dischage grill
1020	fan(s)
1024	fan rack
1025	final cooling coil
1026	air filter
1027	cooling coil unit
1035	final cooling coil water flow control valve
1040	final cooling coil cold water inlet pipe
1045	final cooling coil water outlet pipe
1050	pre-cooling coil water outlet pipe
1055	Not Defined (pre-cooling coil cold water Supply Pipe)
1060	pre-cooling coil water flow control valve
1070	pre-cooling coil
1074	"air duct elbow"
1075	housing
1076	hot air inlet
1077	hot air duct elbow
1201	Change from automatic louvers to automatic air damper
1202	louver door (safety door tied to fan motor automatic shutoff)
1211	condensate catch pan

Real Time Data Center Cooling System (RTDCCS) consisting of the Multistage Evaporative Cooling System (MECS) and Individual Server Enclosure Cooling Systems for each Rack (ISECS)

Cold Water & DC White Space Temp Performance in San Jose CA
ASHRAE Summer Design and .4% Mean Coincident Monthly Temperatures in °F

San Jose International Airport (SJC)

Energy Recovery Unit and / or Cooling Towers of the MECS Serving the RTDCCS

- RTDCCS commissioned in San Jose CA can be served by an ERU & 3 Cooling Towers (CT-1,CT-2, CT-3) (green)
- Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps - Redundant Backup CTs (red)
- Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the RTDCCS (yellow)

					Energy Recovery Unit (ERU) Cold Water Temp Leaving ERU, °F Without Outside Air (OSA) Humidification and With OSA Humidification		**Multistage Evaporative Cooling System** Cold Water Temp Leaving Cooling Towers (CT), °F			**Real Time Data Center Cooling System Performance within the Data Center White Space**			
	DB °F	**WB °F**	**Calculated Dew Pt °F**	**Calculated Humidity Ratio grains/lb**	**ERU without OSA Humidification**	**ERU with OSA Humidification to 95% RH (Adiabatic Cooling)**	**CT-1**	**CT-2**	**CT-3**	Estimated Cold Water Temp Leaving Plate & Frame HX	Estimated Cold Water Temp Entering Fan Coil Unit serving each rack (ISECS)	Estimated Cold Air Temp Leaving Fan Coil Unit serving each rack (ISECS)	**Lowest Data Center White Space Temperature (Temp can be set to ±75 °F in cooler months to save significant energy costs)**
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	92.30	66.90	52.28	58.54	95.30	70.70	69.90	62.62	59.87	60.87	60.97	61.97	**61.97**
January	64.94	55.58	48.70	51.16	67.94	59.40	58.58	57.23	56.67	60.40	60.50	61.50	**61.50**
February	71.24	59.54	51.87	57.66	74.24	63.30	62.54	60.40	59.57	64.30	64.40	65.40	**65.40**
March	74.12	60.08	50.82	55.42	77.12	63.90	63.08	59.02	58.47	64.90	65.00	66.00	**66.00**
April	82.94	64.04	52.69	59.45	85.94	67.80	67.04	62.51	60.81	63.51	63.61	64.61	**64.61**
May	87.98	67.64	56.82	69.25	90.98	71.50	70.64	65.96	64.32	66.96	67.06	68.06	**68.06**
June	88.70	66.92	54.85	64.41	91.70	70.70	69.92	64.65	62.76	65.65	65.75	66.75	**66.75**
July	89.24	68.72	58.21	72.87	92.24	72.60	71.72	67.02	65.50	66.50	66.60	67.60	**67.60**
August	89.24	68.36	57.49	70.98	92.24	72.20	71.36	66.57	64.92	65.92	66.02	67.02	**67.02**
September	89.78	67.82	56.04	67.29	92.78	71.70	70.82	68.29	64.72	65.72	65.82	66.82	**66.82**
October	84.74	63.68	50.55	54.86	87.74	67.50	66.68	61.31	59.24	67.68	67.78	68.78	**68.78**
November	72.68	58.28	48.06	49.95	75.68	62.10	61.28	58.01	56.68	63.10	63.20	64.20	**64.20**
December	64.40	56.12	50.23	54.21	67.40	59.90	59.12	58.21	57.84	60.90	61.00	62.00	**62.00**

****** 1. Year round operation of RTDCCS incorporating MECS and ISECS together (Process Cooling) can provide the required cooling for the IT equipment (server racks). 2. Building HVAC system is serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system. ASHRAE TC 9.9 increased ambient data center termperatures to 80.6 degrees.***

San Jose International Airport (SJC)

http://cms.ashrae.biz/weatherdata/STATIONS/724945_s.pdf

°C x 9/5 + 32

°F	Jan	Feb	Mar	Apr	May	Jun
MCDB	64.94	71.24	74.12	82.94	87.98	88.70
MCWB	55.58	59.54	60.08	64.04	67.64	66.92
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
MCDB	89.24	89.24	89.78	84.74	72.68	64.40
MCWB	68.72	68.36	67.82	63.68	58.28	56.12

San Jose International Airport

°C	Jan	Feb	Mar	Apr	May	Jun
MCDB	18.30	21.80	23.40	28.30	31.10	31.50
MCWB	13.10	15.30	15.60	17.80	19.80	19.40
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
MCDB	31.80	31.80	32.10	29.30	22.60	18.00
MCWB	20.40	20.20	19.90	17.60	14.60	13.40

Comfort Space and Natural Gas Turbine Inlet Air Cooling "cold supply air" provided by the Multistage Evaporative Cooling System (MECS) serving Commercial and Industrial facilities and plants

Temp Performance for Cold Supply Air for Commercial & Industrial Applications in San Jose CA
ASHRAE Summer Design and Mean Monthly Temperatures in °F

San Jose International Airport (SJC)

MECS Including ERU, Cooling Towers and Makeup Air Handling Unit (MU AHU) Supplying Cold Fresh Air

ERU, Cooling Towers (CT-1,CT-2, CT-3) and MU AHU commissioned to provide Cold Supply Air

Cooling Towers that are not necessary to meet Mean Monthly Ambient Air Temps to generate cold makeup air

Selected Cold Water Temperatures from Energy Recvery Unit or Cooling Towers serving the MU AHU

					Multistage Evaporative Cooling System (MECS)									
					Energy Recovery Unit (ERU) Stage Cold Water Temp Leaving ERU, °F **Without Outside Air (OSA) Humidification and With OSA Humidification**		**Cooling Tower Stage** Cold Water Temp Leaving Cooling Towers (CT), °F			**Make Up Air Handling Unit (MU AHU) Stage** Cold AIR Temp Leaving MU AHU, °F				
	OSA DB °F	**WB °F**	**Calculated Dew Pt °F**	**Calculated Humidity Ratio grains/lb**	**ERU-1A without OSA Humidification**	**ERU-1B with OSA Humidification to 95% RH (Adiabatic Cooling)**	**CT-1**	**CT-2**	**CT-3**	**MU AHU Pre-Cooling Coil Water Temp from ERU or CT-1, CT-2 or CT-3 (Source shown in RED)**	**MU AHU Cold Supply Air to space without OSA Humidification (No Adiabatic Cooling) includes 2 °F for fan heat**	**MU AHU Cold Supply Air to space with OSA Humidification to 95% RH (Adiabatic Cooling) includes 2 °F for fan heat**	**TEMPERATURE OF INLET AIR ENTERING NATURAL GAS TURBINES (TARGET TEMP IS 59 °F OR LOWER)**	**Commercial & Industrial Office Space Cold Supply Air Temperature Range**
ASHRAE Coincident Summer Design DB & WB Temps at .4% (Annual) for Cooling Applications (35 hours per year)	92.30	66.90	52.28	58.54	95.30	70.70	69.90	62.62	59.87	59.87 / CT-3	62.87	58.60	58.60	58.60 - 62.86
January	64.94	55.58	48.70	51.16	67.94	59.40	58.58	56.40	55.49	55.49 / CT-3	58.49	54.80	54.80	54.80 - 58.49
February	71.24	59.54	51.87	57.66	74.24	63.30	62.54	60.08	59.12	59.12 / CT-3	62.12	58.00	58.00	58.00 - 62.12
March	74.12	60.08	50.82	55.42	77.12	63.90	63.08	60.78	58.34	58.34 / CT-3	61.34	57.20	57.20	57.20 - 61.34
April	82.94	64.04	52.69	59.45	85.94	67.80	67.04	61.77	59.76	59.76 / CT-3	62.76	58.76	58.76	58.76 - 62.76
May	87.98	67.64	56.82	69.25	90.98	71.50	70.64	65.26	63.36	63.36 / CT-3	66.36	62.50	62.50	62.50 - 66.36
June	88.70	66.92	54.85	64.41	91.70	70.70	69.92	63.94	61.76	61.76 / CT-3	64.76	60.76	60.76	60.76 - 64.76
July	89.24	68.72	58.21	72.87	92.24	72.60	71.72	66.40	64.57	64.57 / CT-3	67.57	63.80	63.80	63.80 - 67.57
August	89.24	68.36	57.49	70.98	92.24	72.20	71.36	65.88	63.96	63.96 / CT-3	66.96	63.10	63.10	63.10 - 66.96
September	89.78	67.82	56.04	67.29	92.78	71.70	70.82	64.85	62.72	62.72 / CT-3	65.72	61.80	61.80	61.80 - 65.72
October	84.74	63.68	50.55	54.86	87.74	67.50	66.68	60.55	58.15	58.15 / CT-3	61.15	56.90	56.90	56.90 - 61.15
November	72.68	58.28	48.06	49.95	75.68	62.10	61.28	57.20	55.51	55.51 / CT-3	58.51	54.50	54.50	54.50 - 58.51
December	64.40	56.12	50.23	54.21	67.40	59.90	59.12	57.40	56.70	56.70 / CT-3	59.70	56.20	56.20	56.20 - 59.70

***** NOTE *** If the negative pressure at the turbine compressor inlet allows for the elimination of the fan in the MU AHU, the temperature can be reduced by an additional 2 °F.**

***** 1. Year round operation of MECS and MU AHU together (Comfort Cooling) can provide the required spacecooling for Commercial & Industrial Office Spaces and Natural Gas and Industrial Compressor Inlet Air Cooling. 2. System is tied into the HVAC system serving the entire building and is providing comfort conditions ("Comfort Cooling"; heating, cooling, humidification, dehumidification) as required. The column on the right in green does not take into consideration any positive or negative affects of the HVAC system.**

San Jose International Airport (SJC)

http://cms.ashrae.biz/weatherdata/STATIONS/724945_s.pdf

°F	Jan	Feb	Mar	Apr	May	Jun
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MCDB	89.24	89.24	89.78	84.74	72.68	64.40
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	Jul	Aug	Sep	Oct	Nov	Dec
MCDB	31.80	31.80	32.10	29.30	22.60	18.00
MCWB	20.40	20.20	19.90	17.60	14.60	13.40

San Jose, CA
Preliminary Temperature Performance Evaluation – Summer Design Conditions

Estimating temperature performance of the Real Time Data Center Cooling System (MECS + ISECS) for Data Center to be located in city of San Jose CA.

General

Below are calculations for the ASHRAE published Summer Design Conditions of .4% for cooling applications showing the ambient air design dry bulb and wet bulb temperatures for San Jose (SJC) of 92.3 ˚FDB and 66.9 ˚FWB.

Engineering Analysis

Given Data

- DC site Location: San Jose (SJC)
- Site Elevation: 62 ft.
- OSA 0.4% design conditions: 92.3 ˚FDB / 66.9 ˚FWB

Assumed the following approach temperatures for:

- All Cooling Towers & ERUs: 3˚F
- All pre-cooling coils for Cooling Towers: 1˚F
- Fluid-fluid Plate HX: 1˚F
- Pre-cooling coil of FCU: 1˚F
- Final cooling coil of FCU: 1˚F

Design parameters of the OSA are:

- Relative humidity: 25.79%
- Dew point temperature, 52.28 ˚F
- Humidity ratio: 58.54 gr/lb
- Enthalpy: 31.36 btu/lb
- Specific volume: 14.13 ft^3/lb

Calculation

Estimated temperature of the cold water leaving the Cooling Tower CT-1 and entering the ambient air pre-cooling coils of the cooling tower CT-2 is:

66.9+ 3 = 69.9 ˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-2:

69.9 +1 = 70.9 ˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-2A:

- Dry Bulb temperature: 70.9 ˚F
- Wet Bulb Temperature: 59.62 ˚F
- Relative humidity: 51.73%

- Dew point temperature, 52.28 ˚F
- Humidity ratio: 58.54 gr/lb
- Enthalpy: 26.14 btu/lb
- Specific volume: 13.59 ft^3/lb

Estimated temperature of the cold water leaving the Cooling Tower CT-2 and entering the ambient air pre-cooling coils of the cooling tower CT-3 is:

59.62 + 3 = 62.62˚F

Estimated dry bulb temperature of the pre-cooled ambient air leaving pre-cooling coils of the Cooling Tower CT-3:

62.62 +1 = 63.62˚F

Estimated parameters of the pre-cooled ambient air entering wet media of the cooling tower CT-3:

- Dry Bulb temperature: 63.62˚F
- Wet Bulb Temperature: 56.87˚F
- Relative humidity: 66.51%
- Dew point temperature, 52.28˚F
- Humidity ratio: 58.54 gr./lb.
- Enthalpy: 24.36 btu / lb.
- Specific volume: 13.40 ft^3/lb.

Estimated temperature of the cold water leaving the Cooling Tower CT-3 and entering into primary loop of the liquid-liquid plate and frame HX:

56.87 + 3 = 59.87 ˚F

Estimated temperature of the secondary loop supply cooling water leaving plate and frame HX and entering into the final cooling coils of the FCUs:

59.87 + 1 = 60.87 ˚F

Estimated temperature of the cooled air leaving final cooling coil of the FCU serving and individual electronics enclosure*:

60.87 + 1.1 = 61.97 ˚F < 80.6˚F (ASHRAE TC 9.9 Maximum Recommended)

*Notes:

- The FCU is configured the way that its fan is located upstream of the pre-cooling and final cooling coils.

Preliminary Temperature Performance Evaluation – Monthly Mean Temperature Conditions

Projected Monthly Temperature Performance of the Real Time Data Center Cooling System

The Engineering Analysis shown in the above spreadsheet estimating mean monthly thermal performance of the Real Time Data Center Cooling System consisting of Multistage Evaporative Cooling System (MECS) generating cold water and the Individual Server Enclosure Cooling Systems (ISECS) for use in process cooling of the Server Racks located in the white space of the Data Center. The analysis is for a data center project that would be located in San Jose CA. This analysis uses the ASHRAE Design Conditions for Selected Locations table and specifically the San Jose International Airport (SJC) area and the monthly mean dry bulb and wet bulb temperatures for the San Jose International Airport (SJC). http://cms.ashrae.biz/weatherdata/STATIONS/724945_s.pdf

Given conditions

- Site elevation, ft.: 62

Preliminary Assumptions:

- Preliminary assumption - MECS consists of three cooling towers: CT-1, CT-2 and CT-3.
- An assumed approach temperature for all cooling tower CT-1, CT-2 and CT-3 is 3.0 ˚F.
- An assumed approach temperature for ambient air pre-cooling coils for the mentioned cooling towers is 1.0 ˚F.
- Humidity and partial temperature control of the Data Center's White Space should be provided by the building comfort HVAC Systems.
- A combination of the MECS + ISECS provides process sensible cooling of the Data Center Server Racks.
- Each cooling coil in the Fan Coil Unit (Pre-Cooling Coil and Final Cooling Coil) assumes a 1.0 ˚F approach temperature plus a 0.1 ˚F adjustment for cooling water heat (temperature) gain (Totaling 2.1 °F).

An Executive Summary of the Engineering Analysis

The Engineering Analysis conducted below is based on the R4 Ventures LLC - Real Time Data Center Cooling System and its patent-pending cooling technologies consisting of the Multi-stage Evaporative Cooling System (MECS) combined with the Individual Server Enclosure Cooling System (ISECS), also described herein as Fan Coil Unit (FCU), operating in San Jose, CA would provide year round required cooling of the Server Racks in the Data Center and returning cold supply air back to the Data Center While Space (See Individual Server Enclosure Cooling System (ISECS) Figure 4). Depending on the ambient conditions, in the majority of cases, the Energy Recovery Unit (ERU) operating alone would be able to satisfy the all cooling needs of the Data Center's IT Equipment (See attached Engineering Analysis spread sheet document). In some ambient conditions and depending on the customer's set point temperature requirements for the Data Center White Space, Cooling Tower CT-1, Cooling Tower CT-2, and Cooling Tower CT-3 may be operational. The sequence of operations would be CT-1 alone, CT-1 and CT-2, or CT-1, CT-2 and CT-3. All 3 Cooling Towers can be used to provide redundant back up the Energy Recovery Units (ERU 1A and ERU 1B). This analysis results in a very economical and cost effective cooling solution providing significant energy savings as compared to traditional data center mechanical refrigeration systems.

San Jose CA Conclusions – RTDCCS Temperature Performance

A Real Time Data Center Cooling System applied to a Data Center in San Jose CA can meet ASHRAE TC 9.9 data center white space maximum temperature set point of 80.6 °F or below for both the ASHRAE published ambient air Summer Design Conditions of .4% for cooling applications; and the monthly ASHRAE published ambient air Summer Design Conditions of .4% for cooling applications San Jose International Airport (SJC) (highest temperature of the process cooled air entering the white space is 68.78 °F in October) (See Engineering Analysis spreadsheet).

Therefore, the RTDCCS can provide a temperature of process cooled air (process cooling of the rack heat loads) entering the white space of between 61.5 °F and 68.78 °F meeting the guidelines established by ASHRAE TC 9.9. The Real Time Monitoring and Control System can maintain customer desires set point temperatures within the data center white space of customer selected temperature within a ± 1 °F control tolerance.