

# **POTENTIAL BENEFITS OF SMART REFRIGERANT DISTRIBUTORS**

Final Report

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## EXECUTIVE SUMMARY

The main goal of this study was to investigate the benefits possible for finned tube refrigerant evaporators when refrigerant distribution was precisely controlled to produce a desired equal superheat in each circuit. This goal was accomplished by examining three different finned tube evaporators; a wavy fin, wavy-lanced fin, and a wavy-lanced fin evaporator with tube sheets separated. The effects of non-uniform airflow on capacity were also examined while superheat was controlled in each evaporator circuit. In parallel with the experimental effort, a modeling program was implemented and validated with the experimental results and then used to determine the savings in evaporator core volume possible if refrigerant distribution was controlled by a smart distributor. In extreme cases, the savings in core volume could be as much as 40 %.

Within the experimental part of this study, all three evaporators could avoid significant performance degradation using the ability to control superheat within each of the three finned tube circuits. As an example, with cross-counter flow configuration, uniform airflow, and exit manifold superheat fixed at 5.6 °C (10.0 °F), the wavy fin and wavy-lanced fin evaporator's capacity dropped by as much as 41 % and 32 %, respectively, as the superheat was allowed to vary between the circuits. Control of superheat was shown to be even more important during cross-parallel refrigerant flow due to the rapid pinching of the refrigerant and air temperatures. For the wavy and lanced finned evaporators in cross-parallel flow, capacity dropped by 85 % and 78 % as superheat changed from 5.6 °C (10.0 °F) to 16.7 °C (30.0 °F). As the coil faces were blocked to produce a non-uniform airflow, pressure drop through the coils increased

substantially and control of superheat was shown to restore performance. The non-uniform airflow tests showed that when airflow rate was held constant, the losses in capacity due to low airflow over a portion of the coil could be recovered to within 2% of the original uniform airflow capacity by controlling superheat. The more non-uniform the airflow over the coil, the more capacity was improved by controlling superheat.

A combination of results obtained from laboratory testing and simulations indicate the influence of tube-to-tube heat transfer on capacity degradation. The impact of tube-to-tube heat transfer was negligible in tests with a uniform 5.6 °C (10 °F) superheat, but it was significant in tests involving 16.7 °C (30 °F) superheat. Between the two possible conduction mechanisms of heat transfer that may occur, longitudinal fin conduction is responsible for degraded performance rather than longitudinal tube conduction, which has insignificant impact. The upgraded version of the EVAP5 evaporator model, which accounts for tube-to-tube heat transfer based on tube temperatures, was able to predict key return bend temperatures which indicated the occurrence of tube-to-tube heat transfer. However, the study also confirmed that longitudinal heat conduction is affected by the fin design, air-side heat transfer coefficient, and moisture removal process.

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## NOMENCLATURE

- $A_f$  = finned surface area,  $m^2$  ( $ft^2$ )
- $A_o$  = outside tube and fin area,  $m^2$  ( $ft^2$ )
- $A_{pm}$  = pipe mean surface area,  $m^2$  ( $ft^2$ )
- $A_{po}$  = pipe outside surface area,  $m^2$  ( $ft^2$ )
- $A_w$  = cross sectional area of the tube available for axial heat conduction,  $m^2$  ( $ft^2$ )
- $C_{min}$  = minimum of mass flow rate times heat capacity for either fluid, W/K  
(Btu/(h·°F))
- $C_{max}$  = maximum of the mass flow rate times the heat capacity for either fluid, W/K  
(Btu/(h·°F))
- $C_{pa}$  = specific heat at constant pressure for air, kJ/(kg·K) (Btu/(lb·°F))
- cfm = airflow in cubic feet per minute,  $ft^3/min$
- COP = coefficient of performance
- fpm = velocity in feet per minute, ft/min
- $h_i$  = inside-tube heat-transfer coefficient, W/( $m^2 \cdot K$ ), (Btu/( $ft^2 \cdot h \cdot °F$ ))
- $h_l$  = heat-transfer coefficient for condensate layer, W/( $m^2 \cdot K$ ) (Btu/( $ft^2 \cdot h \cdot °F$ ))
- $h_{pf}$  = heat-transfer coefficient for tube/fin contact, W/( $m^2 \cdot K$ ) (Btu/( $ft^2 \cdot h \cdot °F$ ))
- $h_o$  = air-side heat transfer coefficient, W/( $m^2 \cdot K$ ) (Btu/( $ft^2 \cdot h \cdot °F$ ))
- $i_{fg}$  = latent heat of evaporation, kJ/(kg·K) (Btu/(lb·°F))
- in WG = inches of water in gage pressure
- IP = inch-pound or English system of units
- K = material thermal conductivity, W/(m·K) (Btu/(ft·h·°F))
- L = length,  $m^2$  ( $ft^2$ )
- $m_a$  = air mass flow rate, kg/s (lb/h)
- NTU = number of transfer units for the heat exchanger, dimensionless
- Q = capacity or heat transferred, W (Btu/h)
- scfm = airflow in standard cubic feet per minute where flowrate is taken at the air standard density of 0.075 lbm/ $ft^3$  (ANSI/ASHRAE 51-1985)
- SI = international system of units or metric system of units

- T = temperature, K (°F)
- t = thickness, m (ft)
- TXV = thermostatic expansion valve
- U = overall heat-transfer coefficient, W/(m<sup>2</sup>·K) (Btu/(ft<sup>2</sup>·h·°F))
- W = width, m (ft)
- X<sub>p</sub> = thickness of the tube wall, m (ft)
- $\alpha$  =  $i_{fgw}(\omega_a - \omega_w)/(C_{pa}(T_a - T_w))$
- $\epsilon$  = heat-transfer effectiveness, fraction
- $\phi$  = fin efficiency, fraction
- $\lambda$  = longitudinal heat conduction parameter, dimensionless
- $\tau$  = tube longitudinal conduction effect factor, fraction
- $\omega_a$  = humidity ratio of air at tube inlet, kg<sub>w</sub>/kg<sub>a,dry</sub> (lb<sub>w</sub>/lb<sub>a,dry</sub>)
- $\omega_w$  = humidity ratio of saturated air at temperature of condensate wetting the tube, kg<sub>w</sub>/kg<sub>a,dry</sub> (lb<sub>w</sub>/lb<sub>a,dry</sub>)

#### Subscripts

- a = air
- f = fin
- i = inlet, inside, or tube numbering index
- j = tube numbering index
- nc = no longitudinal conduction effects
- wc = considering longitudinal conduction effects
- r = refrigerant
- sim = simulation
- w = tube wall or water

## **1. SCOPE OF THE STUDY**

Typically, finned tube evaporators employ parallel refrigerant circuits to obtain an optimal refrigerant mass flux, which affects refrigerant heat transfer coefficient and pressure drop. Each circuit performs optimally when the superheat at its exit matches the desired overall superheat in the exit manifold. Circuit superheat is affected by the refrigerant mass flowrate and the air flowrate associated with each tube.

Most evaporators use an inlet expansion valve with a flow distributor to control the bulk superheat at the evaporator exit manifold. The current practice does not embody means for adjusting refrigerant distribution between different circuits as needed. This means that non-uniform airflow or unintended pressure drops could cause some circuits to have excessive superheat while others may remain two-phase at the evaporator exit. In such situations, some circuits are inefficiently using coil area by transferring heat with superheated vapor instead of two-phase refrigerant. There are also mixing losses associated with reaching the final superheat as two-phase and superheated refrigerant mix in the evaporator exit manifold.

The advances in micro electro-mechanical systems (MEMS) offers the opportunity to develop and place inexpensive flow control valves on each circuit of an evaporator. This would allow control of the refrigerant superheat at the exit of each circuit. This experimental investigation examines the benefits of controlling superheat by placing individual needle valves on each circuit of the evaporators. The study involves three evaporators containing three parallel refrigerant circuits in identical configurations. Two

of these evaporators equipped with enhanced (wavy-lanced) fins, respectively, were tested to examine the benefits of maintaining even superheat when compared to three different scenarios of excessive superheat. The third evaporator with wavy-lanced fins and separated (cut) depth rows facilitates documenting the impact of tube-to-tube heat conduction. Non-uniform superheats are imposed and compared to uniform superheats of 5.6 °C (10.0 °F) and 16.7 °C (30.0 °F). Non-uniform airflow is also imposed while superheats are allowed to adjust naturally, and while superheats are controlled by the individual expansion valves. The NIST tube-by-tube evaporator model, EVAP5, is also modified and used to simulate the experimental results.

The modeling part of the study discusses longitudinal tube and fin conduction and presents a scheme for including tube-to-tube heat transfer into a tube-by-tube simulation model. Validated results for an upgraded evaporator model are presented.

## **2. BACKGROUND AND LITERATURE REVIEW**

Refrigerant incurs a phase change from the two-phase to the superheat zone in the evaporator. Large refrigerant mass flux not only increases the heat transfer rate, but also increases the pressure drop. Therefore, most refrigerant evaporators employ parallel circuits to provide a balanced effect on the evaporator capacity between the negative effect of refrigerant pressure drop and the positive effect of improved inside-tube heat transfer coefficient.

Even though all refrigerant circuits have the same inlet and outlet conditions, the refrigerant distribution is not uniform; the staggered tube arrangement can cause different heat transfer rates. Non-uniform refrigerant distribution is also due to the thermal resistance in the superheat region increasing more rapidly than in the two-phase region. Superheated vapor at the evaporator exit is necessary to prevent liquid compression and subsequent damage to the compressor, even though superheat reduces the performance of the system.

Refrigerant superheat in a given circuit is affected by the refrigerant mass flow rate and the airflow rate over the coil area associated with that circuit. For a given air distribution there is one refrigerant flow rate that results in a desired superheat at the individual circuit exit. When circuits are not well balanced, the target overall superheat is a result of mixing a highly superheated refrigerant and two-phase refrigerant leaving different circuits. This causes significant degradation in evaporator capacity because the circuit with superheated refrigerant transfers less heat.

Liang et al.(2001) conducted a numerical study of the refrigerant circuit. The governing equations and control volumes were presented with the simulation procedure for branches, tubes, and control volumes of a coil. Using the model, the heat transfer and fluid flow characteristics of the coils were studied. Compared to a common coil, the researchers found that using a complex refrigerant circuit arrangement where the refrigerant circuits are properly branched or joined may reduce the heat transfer area by around 5 % while maintaining constant capacity. The investigators experimentally validated 6 different refrigerant circuiting arrangements while maintaining the evaporators inlet and exit states. They used an R134a expansion valve inlet condition of 40 °C (104 °F) saturated liquid with 5.0 °C (2.8 °F) of subcooling and an evaporator exit saturation temperature of 10 °C (50 °F) with 5.0 °C (2.8 °F) of superheat. Liang et al. noted that for a given evaporator load, designers must design the refrigerant circuitry to produce a refrigerant mass velocity that produces a maximum heat flux. Maximum heat fluxes vary with refrigerant circuiting due to varying levels of refrigerant pressure drop. Their model was able to predict evaporator capacity within 5 % on four of the six coils while predicting refrigerant pressure drop to within 25 %.

Kirby et al. (1998) experimentally investigated the performance of a 5275 W (18 000 Btu/h) window air conditioner under wet and dry coil conditions with non-uniform airflow over the evaporator. The velocity variation over the evaporator varied by as much as a factor of 3, but upon correcting the non-uniformity of airflow, the investigators saw only a minor improvement in performance. This was a system study

with no attempt to maintain constant refrigerant states at the inlet and exit of the evaporator. A round disk was used to block 16 % of the central area of the evaporator while maintaining the original airflow. Tests were conducted with this blockage against the evaporator face and then moved in steps in the upstream direction. They found no capacity degradation greater than 2 %. The authors noted that the blockage caused more of the evaporating refrigerant to exist in the two-phase state; thereby reducing the superheated area of the evaporator and offsetting the inability of the air velocity to compensate for the loss of heat transfer area. Wet-coil tests also showed very little difference in the sensible heat ratio with non-uniform airflow. The authors noted that any non-uniformity in airflow must be noted by designers and used to intelligently circuit the refrigerant to equalize exposure of the evaporating refrigerant to airflow.

Chwalowski et al. (1989) examined computer models and performed experiments using three different evaporators; two V-shaped evaporators with upflow and one vertical slab evaporator with horizontal and angled flow with respect to the approaching airstream. These were evaporator tests with fixed evaporator saturation pressures; therefore, these tests parallel the technique used in the current experimental investigation. The investigators determined coil face velocity for several of the configurations and noted non-uniformity of the airflow. Generally, the evaporator capacity varied with the configuration mainly as a function of the exit superheats at the two evaporator exits. As the coil angle with respect to the approaching airstream was varied, capacity degradations on the order of 20 % were noted. Non-uniformities in superheat were produced by non-uniform airflow that produced differences in heat transfer and pressure drops within the

heat exchangers. The design of the circuitry and various splitting points within the evaporator produced differing capacities as a function of the coil orientation with the airstream. The investigators noted that none of the three evaporator models they considered could accurately predict capacity without some knowledge of the air velocity profile and refrigerant maldistribution.

### 3. LABORATORY EXPERIMENT

#### 3.1 Experimental Setup

Figure 3.1.1 shows a schematic diagram of the experimental setup. The test rig consisted of three major flow loops: (1) a refrigerant flow loop containing a detachable test section, (2) a water flow loop used for the condensation heat exchanger and (3) an air flow loop used for the evaporation heat exchanger. The design of the rig allowed easy control of operating parameters such as condensing pressure and subcooling at the inlet of the expansion valve (evaporator inlet enthalpy), evaporating pressure at the exit of the evaporator, and superheat at the exit of the evaporator.

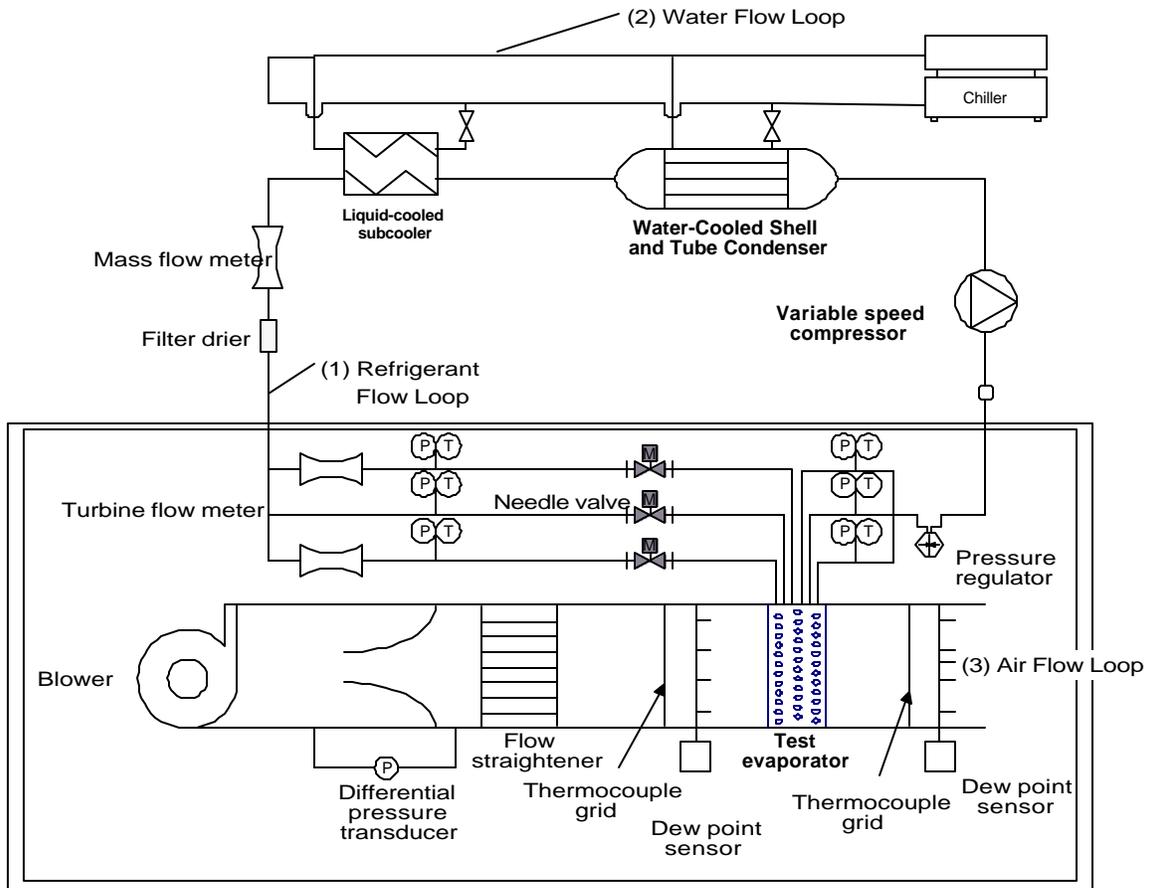


Figure 3.1.1: Schematic diagram of the experimental setup

Figure 3.1.2 is a photo of the specially designed and constructed R22 condensing unit. The design of this condensing unit allowed complete control of the subcooled R22 liquid conditions.



Figure 3.1.2: Condensing unit used to precisely control refrigerant conditions

An open-drive compressor with a variable speed motor provided refrigerant mass flow, set the enthalpy entering the test section, set the condensing pressure, and set the subcooling at the inlet of the expansion valves. We controlled condensing pressure by adjusting cooling water flow using a hand-operated needle valve. To provide additional pressure control for the condenser, we also controlled the entering temperature of the cooling water. Water flow rate and temperature through the subcooler plate type heat

exchanger controlled the refrigerant subcooling at the inlet of the expansion valve. A loop supplying water to the condensing heat exchanger and subcooler consisted of a refrigerator, water storage tank, and a pump. The controls combined to produce evaporator inlet quality of  $25 \% \pm 1 \%$  (using a 95 % confidence interval).

The test section has three parallel refrigerant paths. The exit pressure of the evaporator was adjusted by a pressure regulating valve which was installed in the refrigerant line. The superheats of the three circuits of the evaporator were adjusted by three manual expansion valves. The design of the test section allowed easy installation and replacement of the evaporators. The pressure and temperature were measured upstream and downstream of the test rig. Flow conditions were also monitored using a sight glass at the inlet of the compressor and expansion valves.

The total refrigerant flow rate was measured by a coriolis-type mass flow meter in the liquid line between the subcooler and the expansion valves. Two turbine flow meters were installed to measure flow rate in two of the circuits. Flow through the third circuit was calculated by subtracting the flow through two of the circuits from the total mass flow.

Air flow rate was measured in the air flow chamber according to ANSI/ASHRAE 51-1985. Evaporator capacity was calculated using the air enthalpy method and refrigerant enthalpy method following procedures specified in ASHRAE Standard 37 (1998). In the present experiments, the maximum difference between the air and refrigerant side capacity was less than 5 %. Air velocity at the face of the evaporator was measured with a hot wire anemometer.

Table 3.1.1 lists the parameters controlled to produce a successful evaporator test. The parameters are listed in the order they were set to produce a controlled test.

Table 3.1.1: Essential Control Parameters

| Parameter                              | Setpoint  |
|--|---|
| Upstream Liquid Saturation Temperature | 40.6 °C (105.0 °F): controlled by condenser water flowrate and compressor speed   |
| Liquid Line Subcooling                 | 8.3 °C (15.0 °F): controlled by upstream pressure and refrigerant charge  |
| Evaporator Circuit Superheats          | 5.6 °C or 16.7 °C (10.0 °F or 30.0 °F): controlled by expansion/needle valve opening and evaporator exit pressure   |
| Evaporator Exit Saturation Temperature | 7.2 °C (45.0 °F): controlled by evaporator pressure regulator valve and compressor speed  |
| Evaporator Inlet Liquid Enthalpy       | Corresponds to the saturated liquid temperature of 40.6 °C (105.0 °F): when inlet pressures were increased, the inlet enthalpy was always monitored to produce an enthalpy equal to the saturated liquid enthalpy at 40.6 °C (105.0 °F) ± 1.4 °C (2.5 °F) |

### **3.2 Evaporators Selected for Testing**

We used three finned tube heat exchangers of the same outside dimensions, tube spacing, and circuitry as the test evaporators: (1) COIL-W with wavy fins, (2) COIL-E with wavy-lanced (enhanced) fins, and (3) COIL-EC (Figure 3.2.1) with wavy-lanced (enhanced) fins and the tube rows separated to inhibit tube-to-tube heat transfer (enhanced-cut). Figures 3.2.2, 3.2.3, and 3.2.4 show the side views of the refrigerant circuits. The following are the main design parameters:

- (a) 3 depth rows with 25.4 mm (1 in) face spacing and 22.0 mm (0.866 in) row spacing
- (b) 3 refrigerant circuits as shown in Figures 3.2.1 and 3.2.2
- (c) 9.53 mm (0.375 in) diameter round copper tubes, smooth walls, 0.254 mm (0.010 in) wall thickness
- (d) 0.1143 mm (0.0045 in) thick aluminum fins; wavy fins for COIL-W and louvered or slit fins for COIL-E and COIL-EC



Figure 3.2.1: COIL-EC showing separated tube depth rows

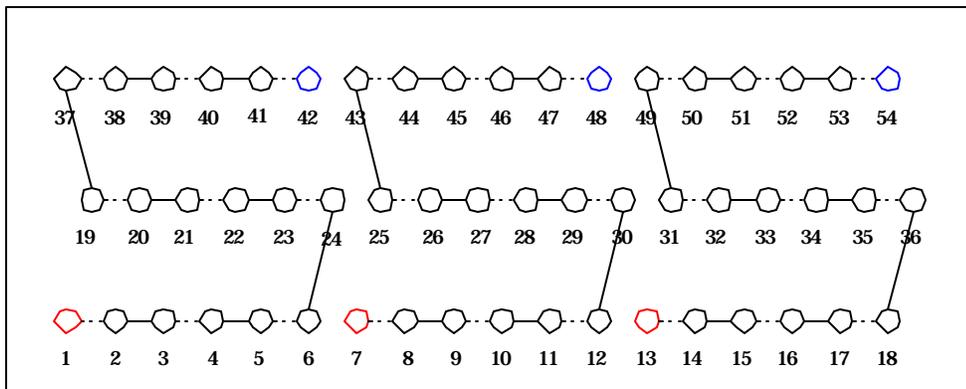


Figure 3.2.2: A schematic side view of refrigerant circuitry

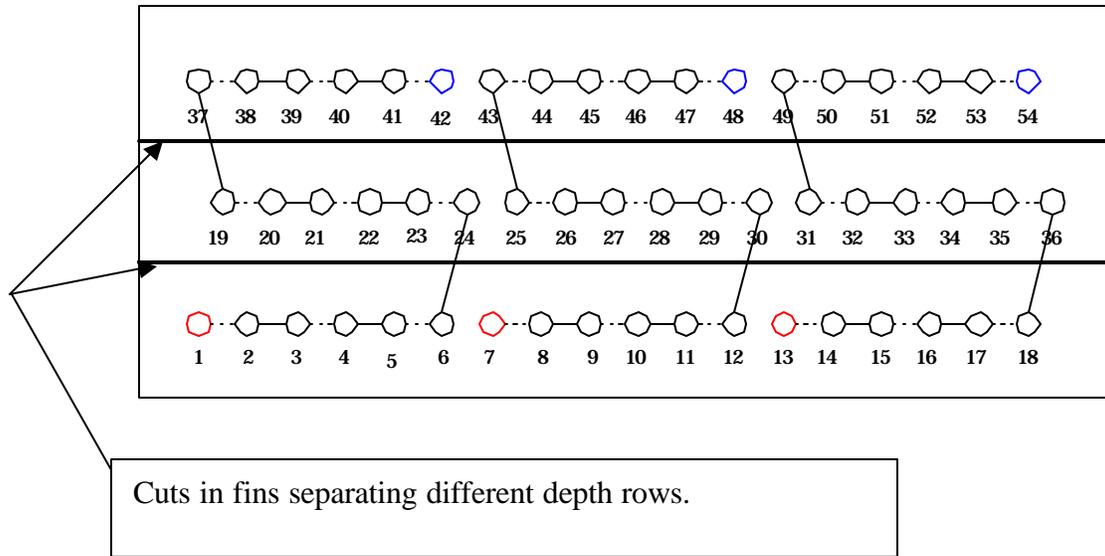


Figure 3.2.3: A schematic side view of refrigerant circuitry for COIL-EC

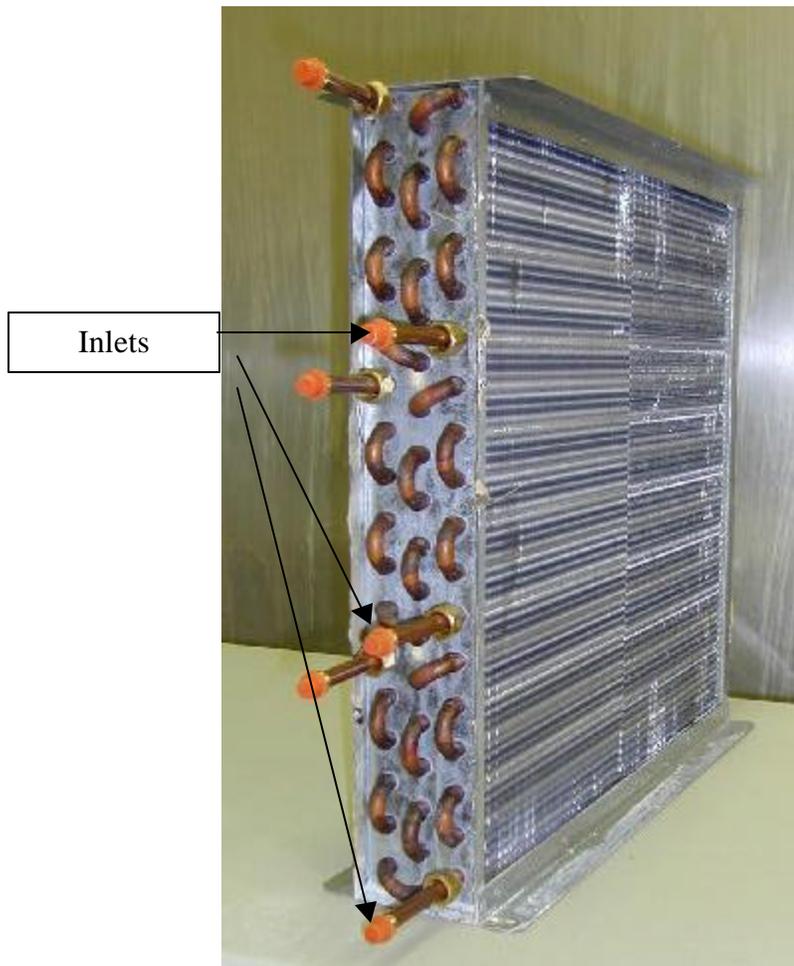


Figure 3.2.4: Circuiting of all three evaporators

### 3.3 Test Conditions and Experimental Procedure

Table 3.3.1 lists the test parameters and environmental chamber conditions for tests on the three evaporators. All tests were conducted at the same 26.7 °C (80.0 °F) indoor dry-bulb with dew-point varying for wet-coil tests and dry-coil tests. Refrigerant R22 conditions at the inlet to the expansion valves were controlled to maintain an enthalpy equivalent to a 48.9 °C (120.0 °F) saturation temperature with a subcooling of 8.3 °C (15.0 °F)  $\pm$  1.4 °C (2.5 °F). Some tests required increasing the inlet pressure to produce the required superheats at the evaporator circuit exits. When the pressure was increased, the enthalpy and subcooling were adjusted to keep a constant enthalpy at the evaporator inlet.

Table 3.3.1: Experimental Test Conditions

| Variable  | Value              | Tolerance        |
|---|--------------------|------------------|
| Indoor Dry-Bulb   | 26.7 °C (80.0 °F)  | 0.28 °C (0.5 °F) |
| Indoor Dew-Point for Wet-Coil Tests                     | 15.8 °C (60.4 °F)  | 0.28 °C (0.5 °F) |
| Evaporator Exit Saturation Temperature                  | 7.2 °C (45.0 °F)   | 0.28 °C (0.5 °F) |
| Evaporator/Expansion Valve Inlet Saturation Temperature | 48.9 °C (120.0 °F) | 1.4 °C (2.5 °F)  |
| Evaporator/Expansion Valve Inlet Subcooling             | 8.3 °C (15.0 °F)   | 1.4 °C (2.5 °F)  |

Once an evaporator coil was mounted in the airflow chamber, indoor dry-bulb and dew-point were stabilized for at least 1 h. While indoor psychrometric conditions stabilized, the evaporator inlet R22 pressure and temperature were set by adjusting the flow control

valves on the condensing unit. Water flow to the condenser and subcooler plate heat exchangers was adjusted to establish the evaporator expansion valves inlet pressure and temperature. The evaporator exit saturation temperature was set by adjusting the evaporator pressure regulating valve at the exit of the evaporator. Superheat conditions in the individual circuits were set by adjusting R22 mass flow through each circuit. Airflow rate over the evaporator was adjusted using the variable speed drive on the airflow chamber's pull-thru fan.

Table 3.3.2 and 3.3.3 list the tests performed for the evaporators. Capacity specific airflow rate was initially established at  $193 \text{ m}^3/\text{kW h}$  ( $400 \text{ scfm/ton}$ ) for test 9. Test 9 required manipulating superheats and airflow rate to obtain the desired airflow to capacity ratio. Test 9 capacity was then used to calculate the airflow rate for the  $169 \text{ m}^3/\text{kW h}$  ( $300 \text{ scfm/ton}$ ) and  $242 \text{ m}^3/\text{kW h}$  ( $500 \text{ scfm/ton}$ ) tests. Tests with a cross-parallel flow configuration were performed by switching the refrigerant flow.

Non-uniform airflow tests were performed with COIL-W and COIL-E. We established non-uniform air distribution by attaching a series of metal mesh plates to the upper half of the coil.

A hot wire anemometer was used to measure airflow rate by traversing the coil at a minimum of 25 equally spaced points at the face of the coil. This measurement agreed with the chamber airflow within 2 %.

Table 3.3.2: Evaporator Tests

| Evaporator                                      | Tests Performed  |
|---|--|
| COIL-W (wavy fins), cross-counter flow          | 1, 5-13 (10 tests)   |
| COIL-W (wavy fins), cross-parallel flow         | 9-12 (4 tests)   |
| COIL-E (lanced fins), cross-counter flow        | 1, 2, 5-14 (12 tests)  |
| COIL-E (lanced fins), cross-parallel flow       | 9-12 (4 tests)   |
| COIL-EC, cross-counter flow                     | 1, 2, 5, 6, 9, 10, 13, 14 (8 tests)  |
| COIL-W, cross-counter flow, non-uniform airflow | 9 (1/2 profile, no superheat adjustment), 9 (1/2 profile, superheat adjusted), 9 (1/3 profile, no superheat adjustment), 9 (1/3 profile, superheat adjusted) [4 tests] |
| COIL-E, cross-counter flow, non-uniform airflow | 9 (1/2 profile, no superheat adjustment), 9 (1/2 profile, superheat adjusted), 9 (1/3 profile, no superheat adjustment), 9 (1/3 profile, superheat adjusted) [4 tests] |

Table 3.3.3: Test Number and Conditions for Each Evaporator Test

| Test # | Volumetric Flowrate of Air m <sup>3</sup> /h (scfm) |                               |                               | Coil Surface |     | Overall Superheat                 |                              |                        |                        |
|--------|---|-------------------------------|-------------------------------|--------------|-----|-----------------------------------|------------------------------|------------------------|------------------------|
|        |   |                               |                               |              |     | Superheats in Individual Circuits |                              |                        |                        |
|        | 145·Q <sup>1</sup><br>(300·Q)                       | 193·Q <sup>1</sup><br>(400·Q) | 242·Q <sup>1</sup><br>(500·Q) | Dry          | Wet | 5.6 °C<br>(10.0 °F)               | 16.7 °C<br>(30.0 °F)         | 5.6 °C<br>(10.0 °F)    | 5.6 °C<br>(10.0 °F)    |
|        |   |                               |                               |              |     | 5.6/5.6/5.6<br>(10/10/10)         | 16.7/16.7/16.7<br>(30/30/30) | 16.7*/16.7<br>(30*/30) | *16.7/16.7<br>(*30/30) |
| 1      | x   |                               |                               |              | x   |                                   | 1                            |                        |                        |
| 2      | x   |                               |                               |              | x   |                                   |                              | 2                      |                        |
| 3      | x   |                               |                               |              | x   |                                   |                              |                        | 3                      |
| 4      | x   |                               |                               |              | x   |                                   |                              |                        | 4                      |
| 5      |   | x                             |                               | x            |     |                                   | 5                            |                        |                        |
| 6      |   | x                             |                               | x            |     |                                   |                              | 6                      |                        |
| 7      |   | x                             |                               | x            |     |                                   |                              |                        | 7                      |
| 8      |   | x                             |                               | x            |     |                                   |                              |                        | 8                      |
| 9      |   | x                             |                               |              | x   |                                   | 9                            |                        |                        |
| 10     |   | x                             |                               |              | x   |                                   |                              | 10                     |                        |
| 11     |   | x                             |                               |              | x   |                                   |                              |                        | 11                     |
| 12     |   | x                             |                               |              | x   |                                   |                              |                        | 12                     |
| 13     |   |                               | x                             |              | x   |                                   | 13                           |                        |                        |
| 14     |   |                               | x                             |              | x   |                                   |                              | 14                     |                        |
| 15     |   |                               | x                             |              | x   |                                   |                              |                        | 15                     |
| 16     |   |                               | x                             |              | x   |                                   |                              |                        | 16                     |

\* Superheat to be controlled such that the desired overall level of superheat is obtained

1) SI units of m<sup>3</sup>/kW h multiplied by capacity (Q) in kW to determine airflow, (IP units of cfm/ton multiplied by capacity (Q) in tons).

In total we performed 54 tests with uniform airflow and 28 tests with imposed non-uniform distribution of air. We conducted a total of 90 tests including repeats and tests that were excluded due to unsteady or non-standard conditions.

The capacity characteristics of the three evaporators are shown below. Figure 3.3.1 shows the capacity ratio at different test conditions to the capacity at test 9 for the wavy coil. Tests 1, 9, and 13 are wet coil tests, and test 5 is a dry coil test. COIL-E and COIL-EC evaporators represented higher capacity than that of the COIL-W evaporator for the wet coil tests. Even though the air-side sensible heat transfer coefficient is much lower than the refrigerant side, the air-side thermal resistance is reduced due to the enhancement of moisture condensation and large finned area. For wet coil tests (tests 1, 9, 13), the capacity of COIL-E and COIL-EC was larger than that of COIL-W. The COIL-EC produced higher capacity than COIL-E possibly because of the added fin leading edges agitating the boundary layer and increasing the air-side heat transfer coefficient even further in addition to eliminating some tube-to-tube heat transfer.

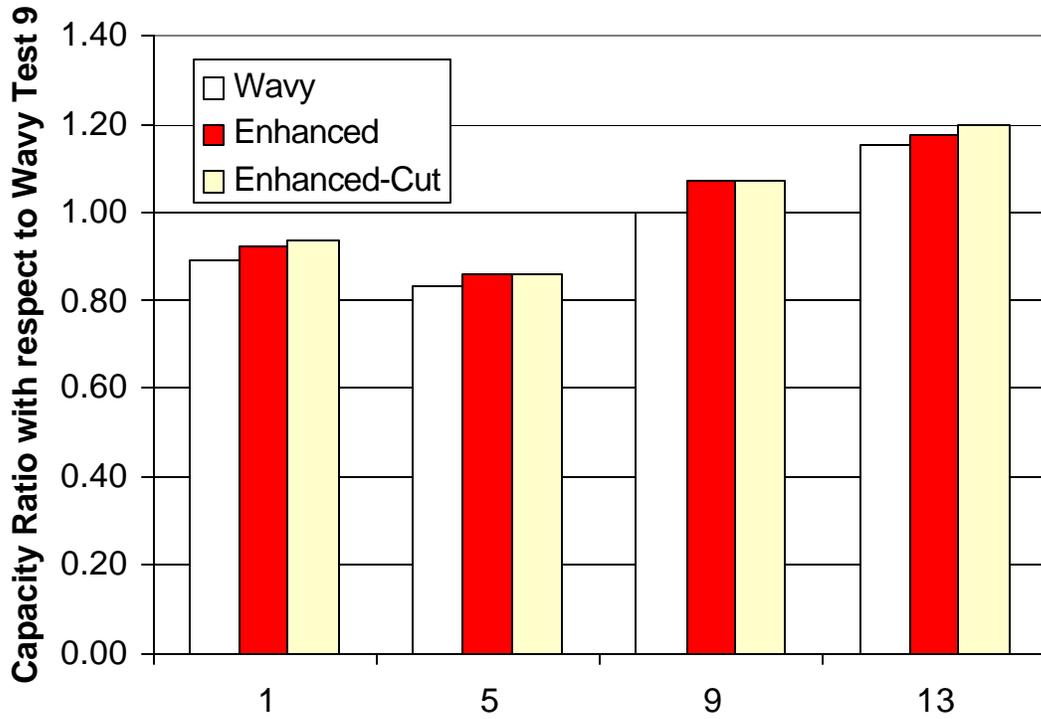


Figure 3.3.1: Capacity ratio for different shape fins relative to the capacity at test 9 for the wavy coil (Test 1: low airflow, wet coil, Test 5: median airflow, dry coil, Test 9: median airflow, wet coil, Test 13: high airflow, wet coil). All tests have a 5.6 °C (10.0 °F) uniform superheat.

## 3.4 Experimental Results

### 3.4.1 Cross-Counter Air/Refrigerant Flow Configuration Tests

#### *3.4.1.1 Non-Uniform Superheat Tests*

Figure 3.4.1.1.1 shows capacity at different superheat test conditions. These data are shown in Table 3.4.1.1.1. All of the coils showed a rapid decrease in capacity when individual circuit superheat was increased with the overall superheat maintained at 5.6 °C (10 °F). Figure 3.4.1.1.2 shows the relative capacity of COIL-W tests 10 and 12 with respect to test 9. Even though the overall superheat was held at 5.6 °C (10 °F), the non-uniformity of superheat in cases 11 and 12 produced a 41 % loss in capacity. This was almost as severe as the 43 % loss in capacity seen when overall superheat was held at 16.7 °C (30.0 °F).

Test 12 showed similar capacity as test 10 even though overall superheat was lower. At test condition 12, the mass flow rate through the top circuit was much higher than that at test 10. Therefore, the inlet refrigerant temperature of the evaporator for test 10 was higher than test 12 because exit pressure was the same. This means that the temperature difference between air and refrigerant for test 12 was higher than for test 10. This allowed test 12 to have a higher capacity than test 10.

Table 3.4.1.1.1: Non-Uniform Superheat Test Data for COIL-W and COIL-E

| Test Name                                 | Test # | Coil Designation                   | Volumetric Flowrate of Air m <sup>3</sup> /h (cfm) |                              |    | Coil Surface                       |    | Overall Superheat            |              |                                    |              |                           |              |                     |              |                       |  |
|---|--------|------------------------------------|--|------------------------------|----|------------------------------------|----|------------------------------|--------------|------------------------------------|--------------|---------------------------|--------------|---------------------|--------------|-----------------------|--|
|   |        |                                    | 10   | 11                           | 12 | 13                                 | 14 | 15                           | 16           | Superheats in Individual Circuits  |              |                           |              |                     |              |                       |  |
|   |        |                                    |  |                              |    |                                    |    |                              |              | 5.6 °C (10.0 °F)                   |              | 16.7 °C (30.0 °F)         |              | 5.6 °C (10.0 °F)    |              | 5.6 °C (10.0 °F)      |  |
|   |        |                                    |  |                              |    |                                    |    |                              |              | 5.6/5.6/5.6 (10/10/10)             |              | 16.7/16.7/16.7 (30/30/30) |              | 16.7*/16.7 (30*/30) |              | */16.7/16.7 (*/30/30) |  |
| Q <sub>test</sub> /W (Btu/h)              |        | Q <sub>test</sub> /Q <sup>1b</sup> |  | Q <sub>test</sub> /W (Btu/h) |    | Q <sub>test</sub> /Q <sup>1b</sup> |    | Q <sub>test</sub> /W (Btu/h) |              | Q <sub>test</sub> /Q <sup>1b</sup> |              |                           |              |                     |              |                       |  |
| <b>Cross-Counter Air/Refrigerant Flow</b> |        |                                    |  |                              |    |                                    |    |                              |              |                                    |              |                           |              |                     |              |                       |  |
| W020225B                                  | 5      | W                                  |  | X                            |    |                                    | X  |                              | 5428 (18519) | 1                                  |              |                           |              |                     |              |                       |  |
| W020228A                                  | 6      | W                                  |  | X                            |    |                                    | X  |                              |              |                                    | 3569 (12177) | 0.66                      |              |                     |              |                       |  |
| W020221A                                  | 7      | W                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           | 3910 (13341) | 0.72                |              |                       |  |
| W020225A                                  | 8      | W                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           |              |                     | 3888 (13266) | 0.72                  |  |
| W020207B                                  | 9      | W                                  |  | X                            |    |                                    | X  |                              | 6507 (22203) | 1                                  |              |                           |              |                     |              |                       |  |
| W020530A                                  | 10     | W                                  |  | X                            |    |                                    | X  |                              |              |                                    | 3722 (12701) | 0.57                      |              |                     |              |                       |  |
| W020531A                                  | 11     | W                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           | 3837 (13091) | 0.59                |              |                       |  |
| W020215B                                  | 12     | W                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           |              |                     | 3830 (13067) | 0.59                  |  |
| W020322A                                  | 5      | E                                  |  | X                            |    |                                    | X  |                              | 5602 (19115) | 1                                  |              |                           |              |                     |              |                       |  |
| W020321B                                  | 6      | E                                  |  | X                            |    |                                    | X  |                              |              |                                    | 4301 (14677) | 0.77                      |              |                     |              |                       |  |
| W020322C                                  | 7      | E                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           | 4797 (16367) | 0.86                |              |                       |  |
| W020322B                                  | 8      | E                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           |              |                     | 4700 (16037) | 0.84                  |  |
| E020607A                                  | 9      | E                                  |  | X                            |    |                                    | X  |                              | 6955 (23733) | 1                                  |              |                           |              |                     |              |                       |  |
| W020318A                                  | 10     | E                                  |  | X                            |    |                                    | X  |                              |              |                                    | 4865 (16599) | 0.70                      |              |                     |              |                       |  |
| W020318B                                  | 11     | E                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           | 5485 (18715) | 0.79                |              |                       |  |
| W020319A                                  | 12     | E                                  |  | X                            |    |                                    | X  |                              |              |                                    |              |                           |              |                     | 4735 (16157) | 0.68                  |  |

\* Superheat to be controlled such that the desired overall level of superheat is obtained

1a) SI units of m<sup>3</sup>/kW h multiplied by capacity (Q) in kW to determine airflow, (IP units of cfm/ton multiplied by capacity (Q) in tons).

1b) Capacity relative to the 5.6 °C (10.0 °F) tests noted by a ratio of 1 in the row above.

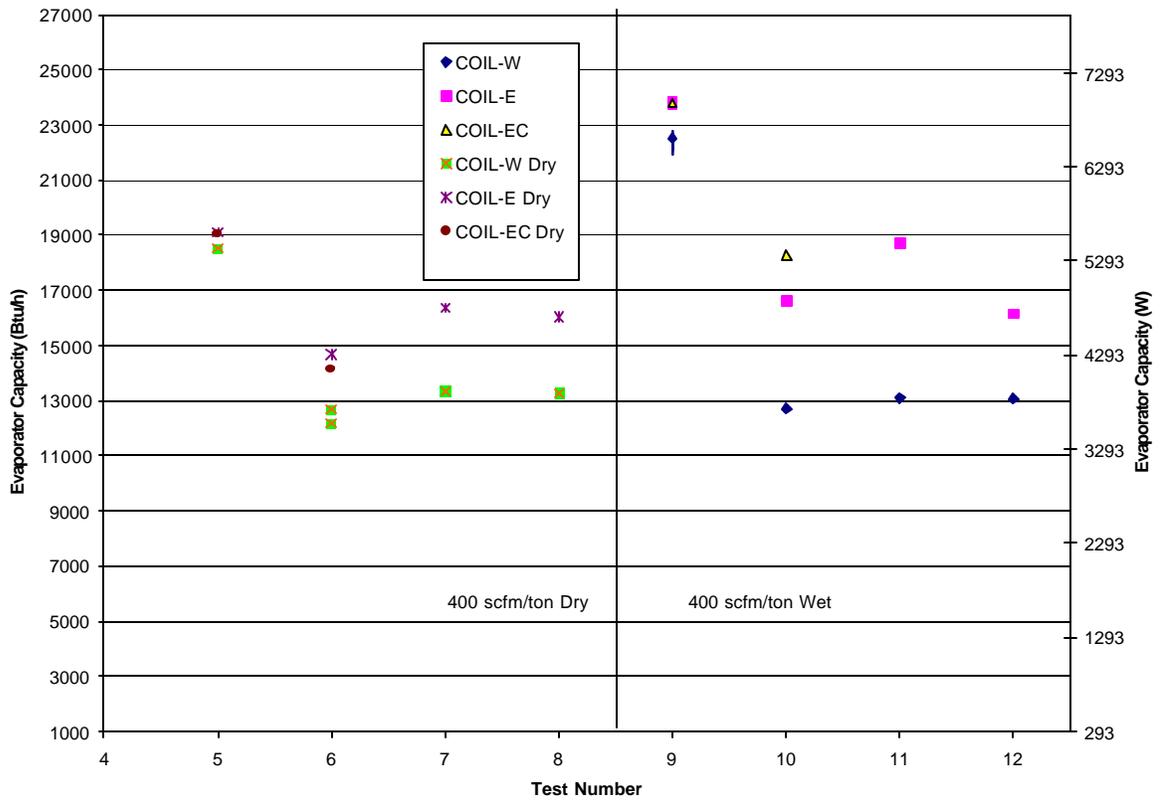


Figure 3.4.1.1.1: Capacity of evaporators for tests 5 through 12

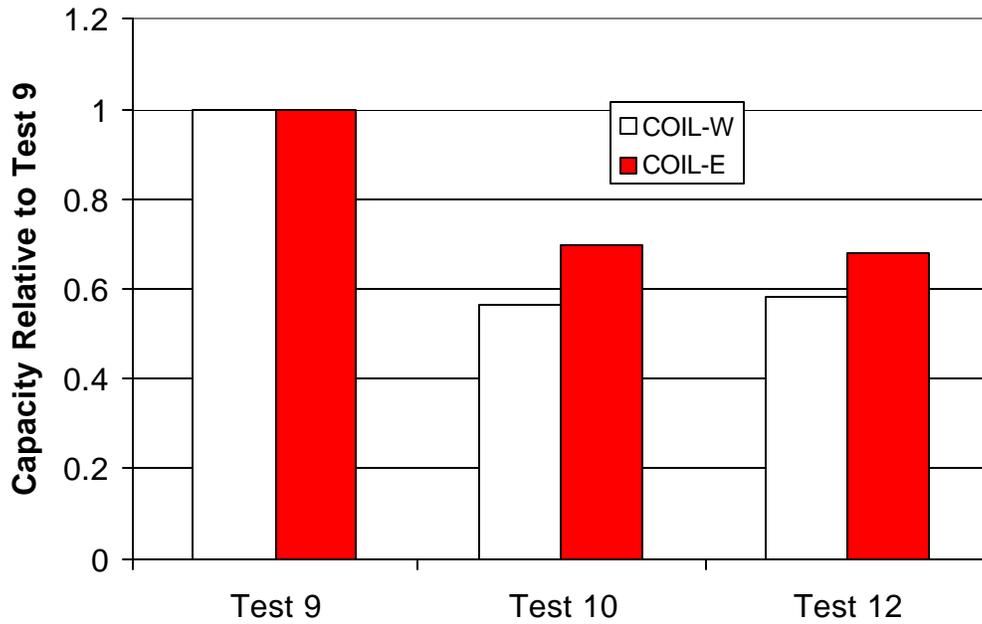


Figure 3.4.1.1.2: Capacity ratio at different superheat conditions relative to test 9 for COIL-W and COIL-E (superheat cases follow Table 3.4.1.1.1).

For COIL-E, the reduction in capacity due to an increase in superheat was lower than COIL-W (Figure 3.4.1.1.1 and 3.4.1.1.2). COIL-E seemed to show a preference as to which flooded circuit (test 11 or 12) produced the higher capacity. When the middle circuit was flooded, the capacity decreased by 21 % compared to 32 % when the top circuit was flooded.

Figure 3.4.1.1.3 shows the relative capacity of COIL-W for tests 10 and 12 with respect to test 9 and for tests 6 and 8 with respect to test 5. The capacity of the dry coil decreased by 28 % with non-uniform circuit superheats with overall superheat fixed at 5.6 °C (10 °F). COIL-E capacity (Figure 3.4.1.1.4) dropped by 16 % with non-uniform superheat under dry conditions; again COIL-E showed that flooding the middle circuit produced a smaller capacity drop than flooding the top circuit while holding overall superheat constant at 5.6 °C (10 °F).

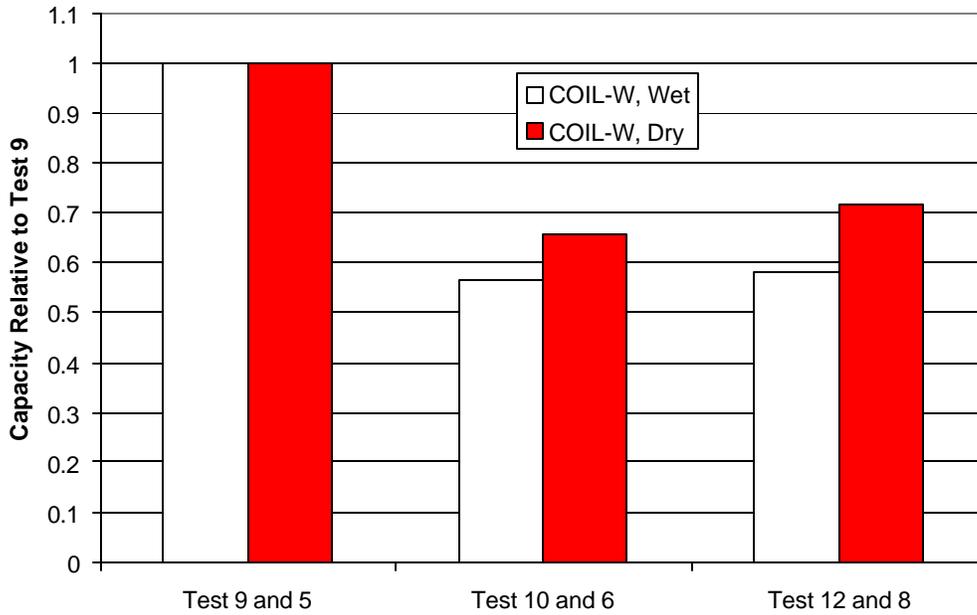


Figure 3.4.1.1.3: Capacity ratio for COIL-W relative to test 9 for wet and test 5 for dry conditions

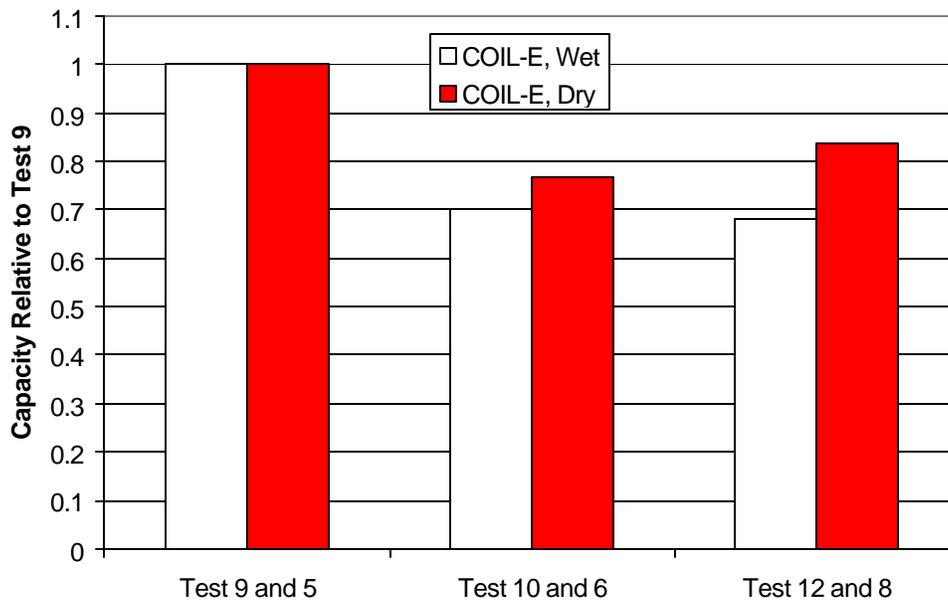


Figure 3.4.1.1.4: Capacity ratio for COIL-E relative to test 9 for wet and test 5 for dry conditions

The experimental investigation was designed to reveal some of the effects of tube-to-tube heat transfer by heat conduction through the fin material. The comparison was done by

examining COIL-E and COIL-EC and comparing their capacity at different levels of superheat. In addition to the capacity comparison between COIL-E and COIL-EC, direct evidence of conduction between tubes was noted from the thermocouple bend temperature data for COIL-W.

Figures 3.4.1.1.5 and 3.4.1.1.6 show bend temperature data for test 9 (6.7 °C (10 °F) superheat on all circuits) and test 12 (flooded top circuit with 16.7 °C (30.0 °F) superheat on the other two circuits). The figure for test 9 shows a uniform temperature distribution between comparable bends in the three refrigerant circuits. The noticeable difference occurs for test 12 where the low temperature, flooded top circuit shows some thermal communication with the final tube passes of the middle circuit. The top circuit is showing an average surface temperature of approximately 9.4 °C (49 °F) throughout all of its tubes, while the middle circuit shows definite superheat at the third and fourth final tube bend with a temperature of 24.0 °C (75.2 °F). This is where the conduction between circuits was obvious; the surface temperature on the final two tubes bend was 22.3 °C (72.2 °F). This is a decrease in temperature due to conduction between the top circuit's tube and the middle circuit's tubes.

The conduction effects were quantified in the tests conducted with COIL-E and COIL-EC; by separating the tube sheets in COIL-EC and thereby removing a majority of the conduction path between tubes. Figure 3.4.1.1.7 shows the capacity of COIL-E and COIL-EC relative to test 9 for COIL-E during cross-counter flow for tests 9, 10, 13, and 14. These two coils used identical fin material and fin type; the only difference was the

tube sheets of COIL-EC were separated. Figure 3.4.1.1.8 shows that for test 9, COIL-E and COIL-EC have very similar bend temperatures. Figure 3.4.1.1.9 shows the same coils with the superheat increased to 16.7 °C (30.0 °F) at the coil exit (test 10). COIL-EC shows lower inlet temperatures than COIL-E even though expansion valve inlet and coil exit conditions are almost identical for both tests. The differences in temperatures seen with tests 9 and 10 are more pronounced for tests 13 and 14 at the higher airflow rate.

These differences in temperatures could have produced the differences in capacity seen between COIL-E and COIL-EC. As noted above, the inlet and exit conditions for these coils were nearly identical, but COIL-EC always showed lower bend temperatures than COIL-E. This would mean that COIL-EC was operating at a higher average temperature difference with respect to the air than COIL-E. The greater average temperature difference for COIL-EC could translate to higher capacity than COIL-E. The test results showed that both coils produced very similar capacities when the overall superheat was at 5.6 °C (10.0 °F). As the superheat was increased to 16.7 °C (30.0 °F), COIL-EC capacity was 10 % higher than COIL-E. As the airflow increased for tests 13 and 14, COIL-E and COIL-EC still produced nearly equal capacities at 5.6 °C (10.0 °F) superheat, but when superheat was increased to 16.7 °C (30.0 °F), COIL-EC had a 23 % higher capacity than COIL-E (Figures 3.4.1.1.10 and 3.4.1.1.11). This tends to lend more evidence to conduction effects between the tube sheets; eliminating some conduction paths improved the performance of the enhanced fin coil.

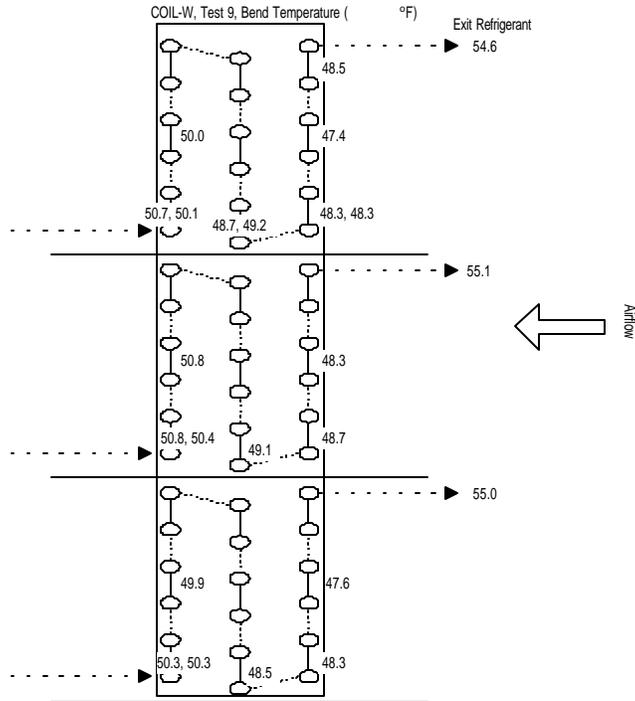


Figure 3.4.1.1.5: COIL-W, test 9, circuit bend temperatures for cross-counter flow (All circuits with 6.7 °C (10.0 °F) superheat; refrigerant exit manifold saturation temperature set to 7.2 °C (45.0 °F))

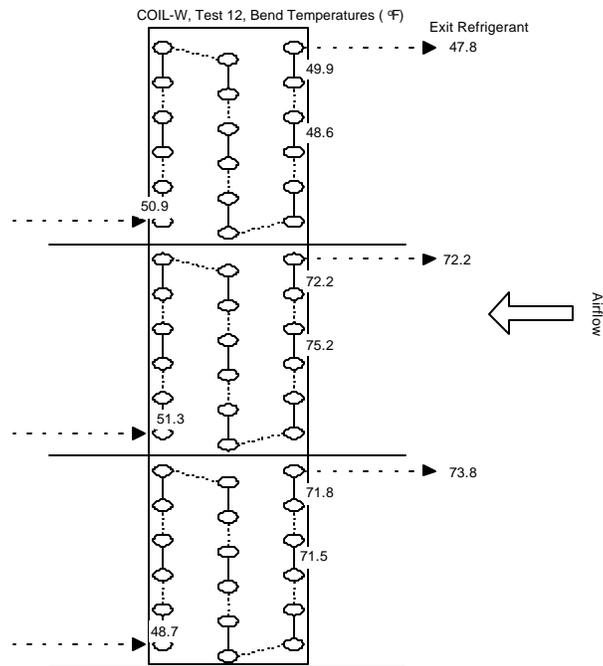


Figure 3.4.1.1.6: COIL-W, test 12, circuit bend temperatures for cross-counter flow (Top circuit flooding with 16.7 °C (30.0 °F) superheat on bottom two circuits to yield overall exit superheat of 5.6 °C (10.0 °F); refrigerant exit manifold saturation temperature set to 7.2 °C (45.0 °F))

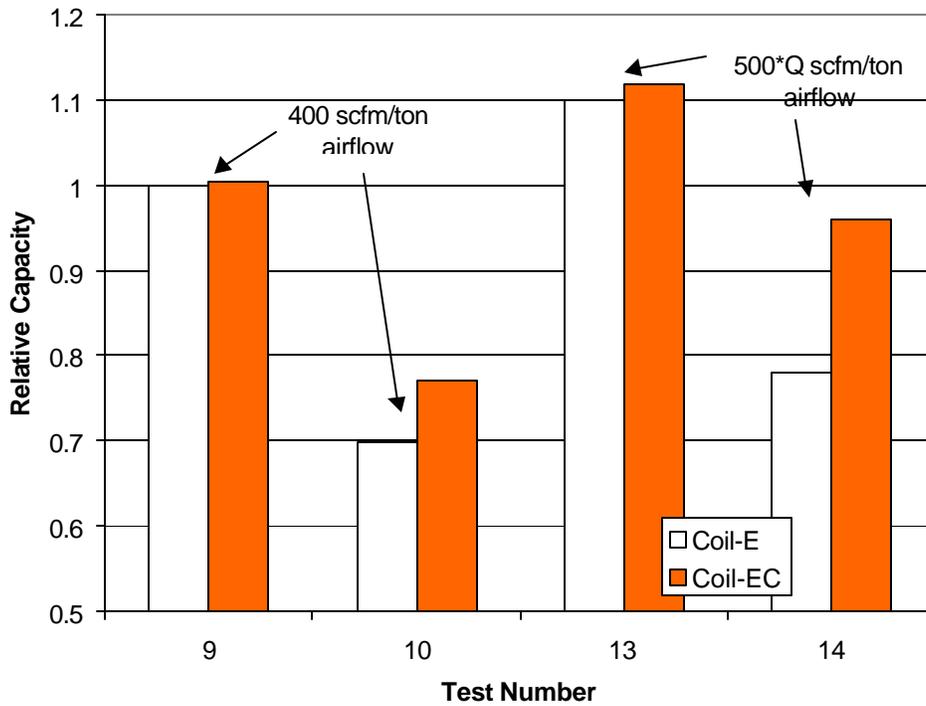


Figure 3.4.1.1.7: Capacity of COIL-E and COIL-EC relative to COIL-E, test 9 at two different airflow rates

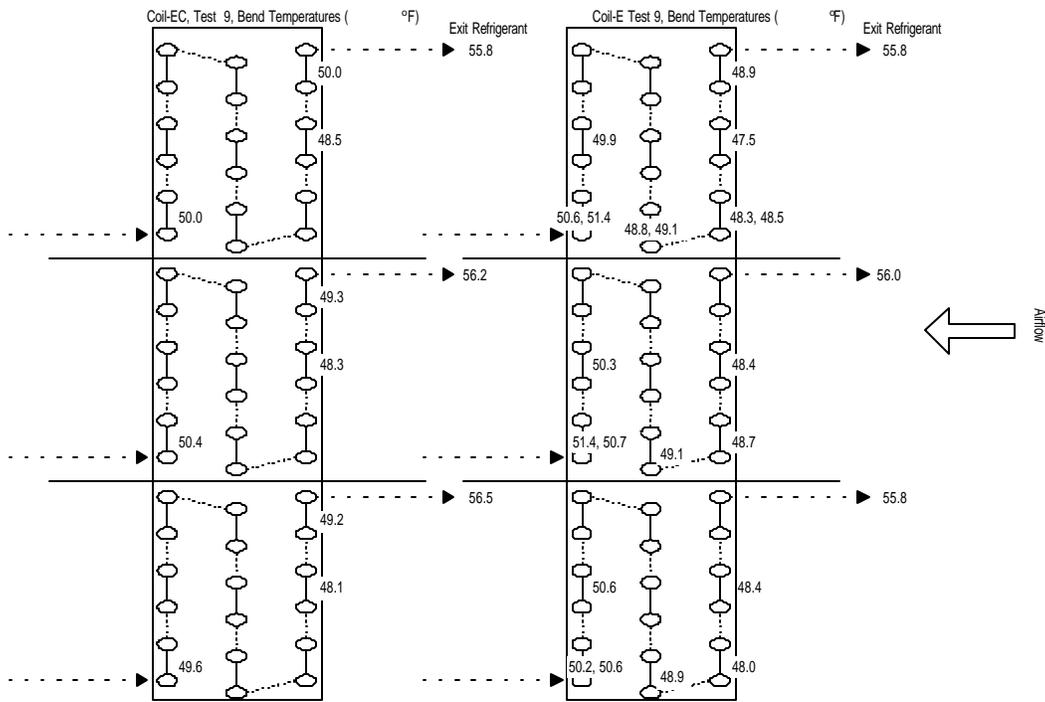


Figure 3.4.1.1.8: COIL-EC and COIL-E bend temperatures for test 9 (cross-counter flow, wet coil, 5.6 °C (10.0 °F) superheat on all circuits)

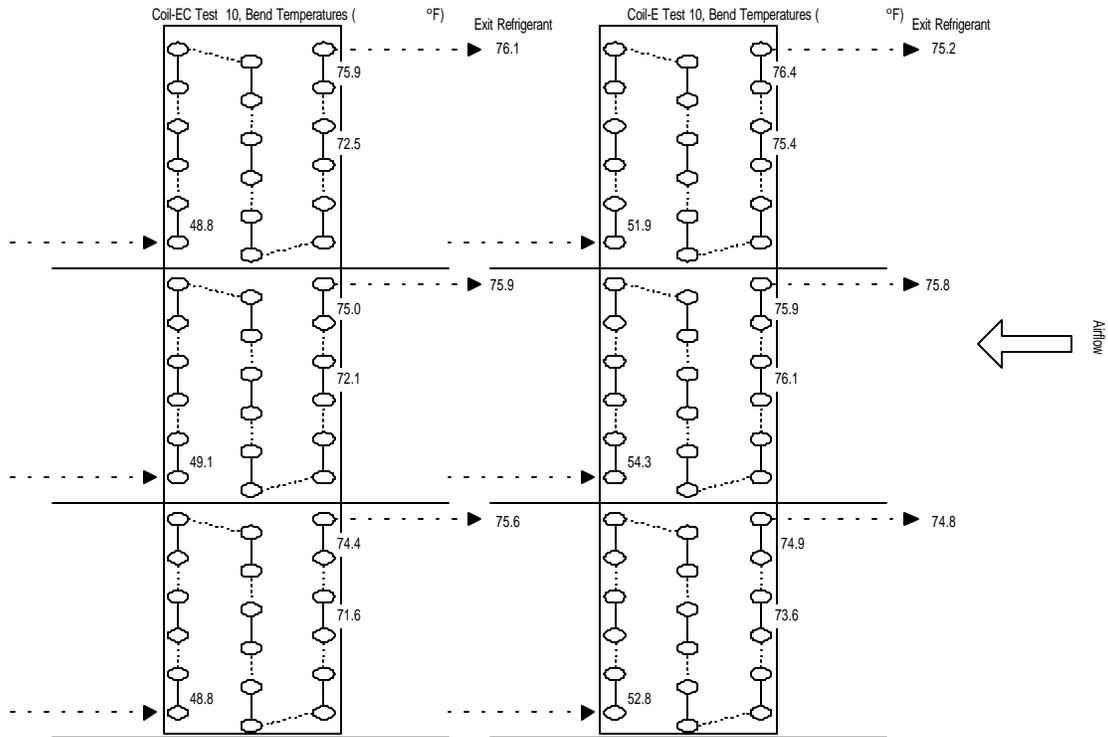


Figure 3.4.1.1.9: COIL-EC and COIL-E bend temperatures for test 10 (cross-counter flow, wet coil, 16.7 °C (30.0 °F) superheat on all circuits)

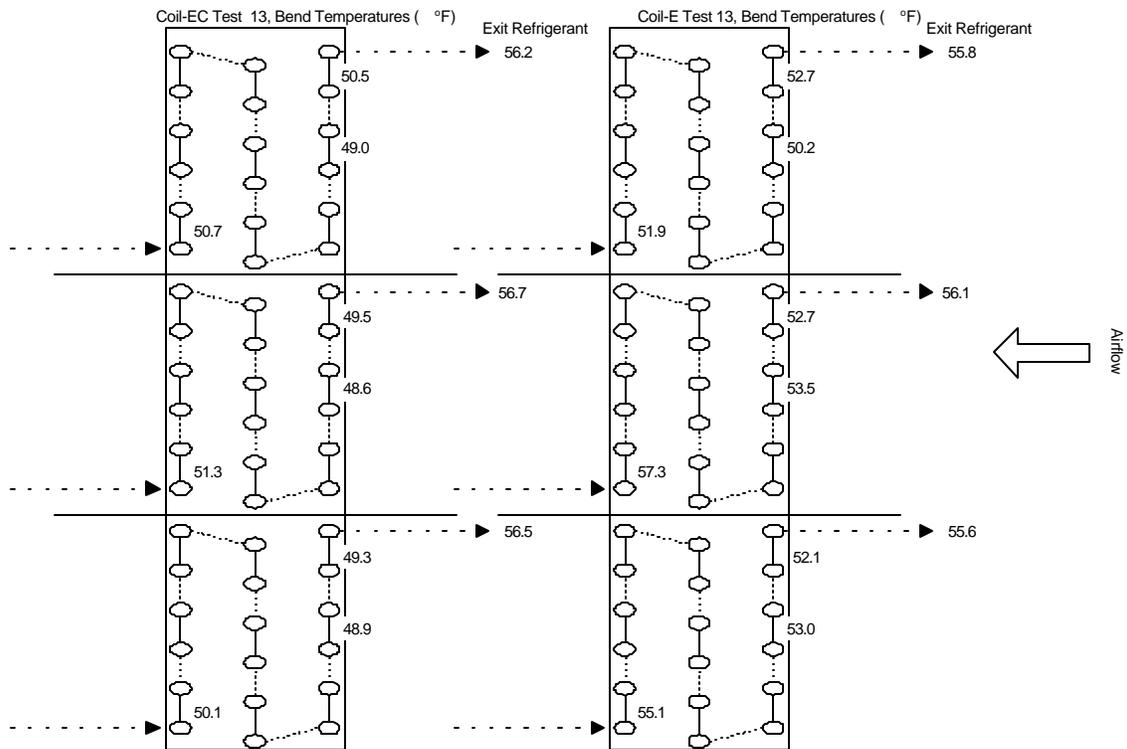


Figure 3.4.1.1.10: COIL-EC and COIL-E bend temperatures for test 13 (cross-counter flow, wet coil, 5.6 °C (10.0 °F) superheat on all circuits)

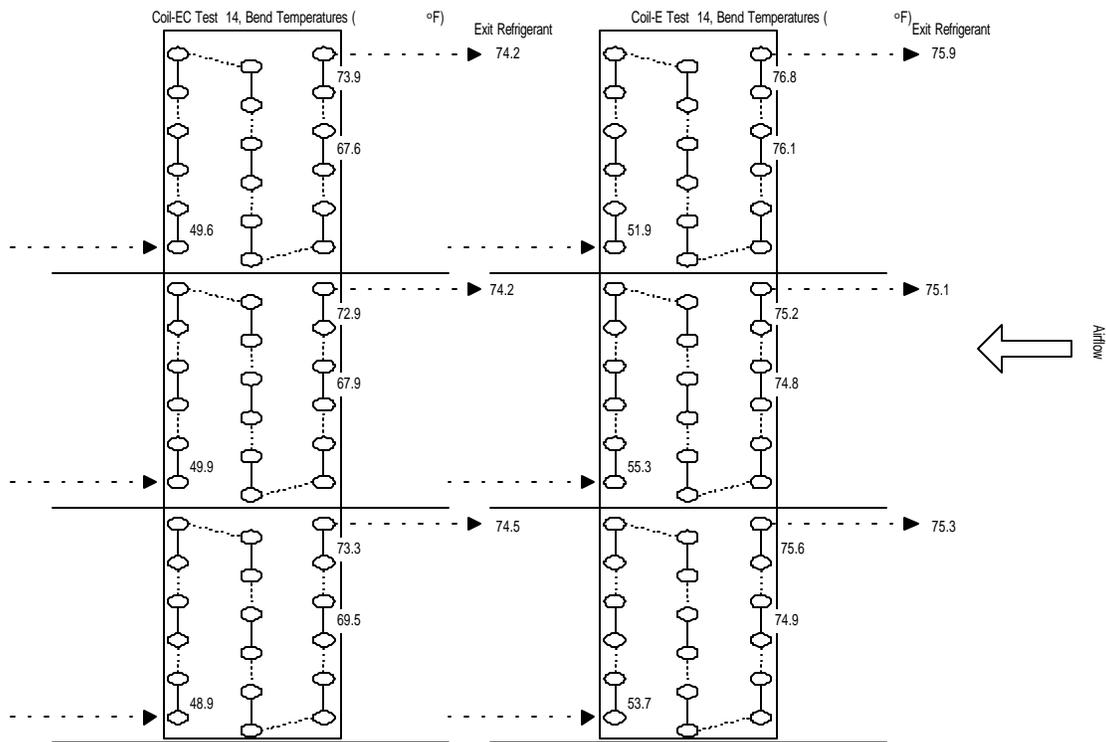


Figure 3.4.1.1.11: COIL-EC and COIL-E bend temperatures for test 14 (cross-counter flow, wet coil, 16.7 °C (30.0 °F) superheat on all circuits)

### 3.4.1.2 Effects of Airflow Rate on Coil Capacity

Air flow rate through the evaporator plays an important role in the capacity. When air flow rate is higher than the optimum quantity, the COP of the system decreases due to an increase in the air pressure drop and accompanying fan power consumption. But higher airflow enhances the heat transfer rate of the evaporator on the air-side due to the higher Reynolds number. Table 3.4.1.2.1 and figure 3.4.1.2.1 show the capacity variation of the tested evaporators as a function of air flow rate. As the air flow rate increased, total capacity increased due to the increased air mass flow rate. The latent heat transfer rate changed a little due to the constant evaporator pressure set by the evaporator pressure regulating valve. Other reasons that could play a small part in the constant latent



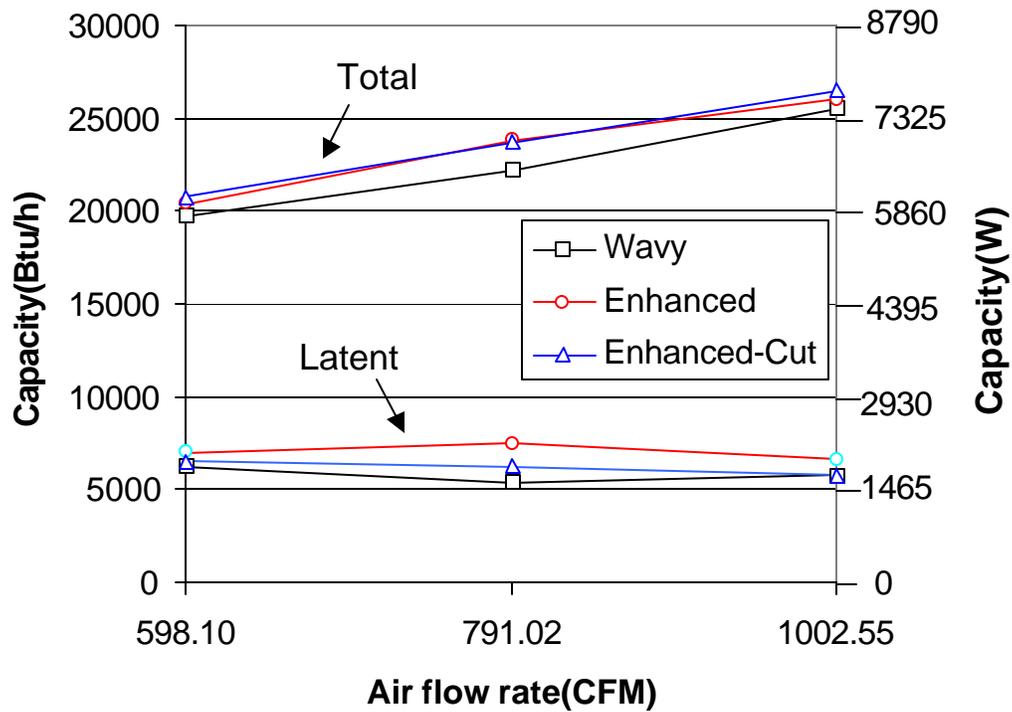


Figure 3.4.1.2.1: Capacity as a function of air flow rate for wet coil conditions

### 3.4.1.3 Effects of Non-Uniform Airflow on Coil Capacity

The combined effects of non-uniform airflow and evaporator superheat were examined by blocking the upper portion of the test evaporator on COIL-W and COIL-E during cross-counter flow operation for wet coil conditions. Figure 3.4.1.3.1 shows an idealized non-uniform velocity profile for a test coil with the upper half of the coil partially blocked. The velocity ratio was calculated by taking the average of the 15 velocity points on the top half divided by the average of the 15 velocity points on the lower half of the test evaporator. Test 9 conditions of 5.6 °C (10.0 °F) superheat were first performed, then the blockage was applied with no expansion valve adjustment (test 9A), and finally the expansion valves were adjusted to yield 5.6 °C (10.0 °F) superheat on all circuits (test 9B). During these tests the standard airflow rate was held constant; the airflow was not

allowed to drop when the blockage was added regardless of the significantly higher pressure drop. Table 3.4.1.3.1 shows the performance of the coils with varying degrees of airflow blockage.

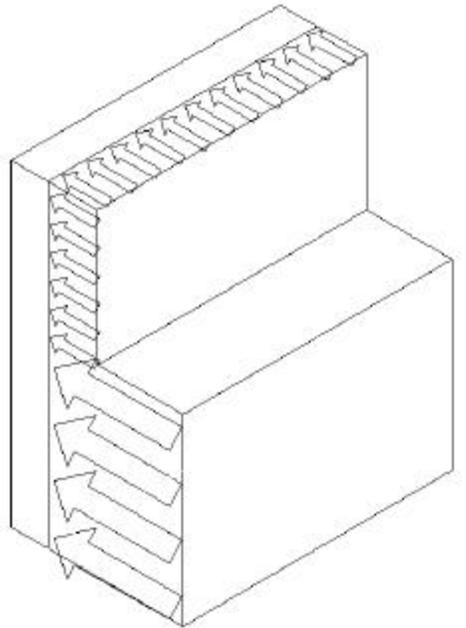


Figure 3.4.1.3.1: Idealized velocity profile over evaporator with upper half partially blocked

Table 3.4.1.3.1: COIL-W Performance with Non-Uniform Airflow

| Velocity Ratio<br>(see Figure #) | Test name    | Test type <sup>1</sup> | Coil | Airflow,<br>m <sup>3</sup> /h (scfm) | Air-side<br>Capacity, W<br>(Btu/h) | Capacity<br>Ratio,<br>Q/Q <sub>Test 9</sub> | Coil Air<br>Pressure<br>Drop, Pa<br>(in WG) |
|----------------------------------|--------------|------------------------|------|--------------------------------------|------------------------------------|---|---|
| 1:1<br>(Fig. 3.4.1.3.2)          | W020522<br>A | 9                      | W    | 1244 (732)                           | 6598 (22515)                       | 1   | 37.9<br>(0.152)                             |
| 1:1.5<br>(Fig. 3.4.1.3.3)        | W020523<br>A | 9A                     | W    | 1252 (737)                           | 6351 (21670)                       | 0.96  | 49.6<br>(0.199)                             |
| 1:1.5                            | W020524<br>A | 9B                     | W    | 1249 (735)                           | 6535 (22298)                       | 0.99  | 49.8<br>(0.200)                             |
| 1:1                              | W020528<br>B | 9                      | W    | 1245 (733)                           | 6636 (22644)                       | 1   | 38.1<br>(0.153)                             |
| 1:2<br>(Fig. 3.4.1.3.4)          | W020528<br>C | 9A                     | W    | 1239 (729)                           | 6179 (21085)                       | 0.93  | 53.3<br>(0.214)                             |
| 1:2                              | W020529<br>A | 9B                     | W    | 1237 (728)                           | 6307 (21521)                       | 0.95  | 58.8<br>(0.236)                             |

1) Test 9: uniform airflow with superheat on all circuits of 5.6 °C (10.0 °F), 9A: same expansion valve setting as test 9 but with non-uniform airflow and no superheat adjustment, 9B: expansion valves adjusted to yield 5.6 °C (10.0 °F) superheat on all circuits with non-uniform airflow.

Table 3.4.1.3.2: COIL-E Performance with Non-Uniform Airflow

| Velocity Ratio<br>(see Figure #) | Test name    | Test<br>type <sup>1</sup> | Coil | Airflow,<br>m <sup>3</sup> /h (scfm) | Air-side<br>Capacity, W<br>(Btu/h) | Capacity<br>Ratio,<br>Q/Q <sub>Test9</sub> | Coil Air<br>Pressure<br>Drop, Pa<br>(in WG) |
|----------------------------------|--------------|---------------------------|------|--------------------------------------|------------------------------------|--|---|
| 1:1<br>(Fig. 3.4.1.3.6)          | E020604<br>A | 9                         | E    | 1276 (751)                           | 6985 (23833)                       | 1  | 92.7<br>(0.372)                             |
| 1:1.26<br>(Fig. 3.4.1.3.7)       | E020604<br>B | 9A                        | E    | 1281 (754)                           | 6933 (23655)                       | 0.99                                       | 108.4<br>(0.435)                            |
| 1:1.26                           | E020605<br>A | 9B                        | E    | 1281 (754)                           | 7029 (23984)                       | 1.01                                       | 106.6<br>(0.428)                            |
| 1:1                              | E020607<br>A | 9                         | E    | 1293 (761)                           | 6955 (23733)                       | 1  | 84.7<br>(0.340)                             |
| 1:1.36<br>(Fig. 3.4.1.3.8)       | E020607<br>B | 9A                        | E    | 1291 (760)                           | 6797 (23192)                       | 0.98                                       | 102.9<br>(0.413)                            |
| 1:1.36                           | E020610<br>A | 9B                        | E    | 1286 (757)                           | 6807 (23226)                       | 0.98                                       | 101.9<br>(0.409)                            |
| 1:1.62<br>(Fig. 3.4.1.3.9)       | E020611<br>A | 9A                        | E    | 1290 (759)                           | 6751 (23034)                       | 0.97                                       | 101.1<br>(0.406)                            |
| 1:1.62                           | E020612<br>A | 9B                        | E    | 1274 (750)                           | 6914 (23591)                       | 0.99                                       | 101.4<br>(0.407)                            |
| 1:1.75<br>(Fig. 3.4.1.3.10)      | E020613<br>A | 9A                        | E    | 1288 (758)                           | 6654 (22705)                       | 0.96                                       | 105.4<br>(0.423)                            |
| 1:1.75                           | E020620<br>A | 9B                        | E    | 1288 (758)                           | 6877 (23465)                       | 0.99                                       | 103.4<br>(0.415)                            |
| 1:2.59<br>(Fig. 3.4.1.3.11)      | E020621<br>A | 9A                        | E    | 1299 (764)                           | 6575 (22435)                       | 0.95                                       | 98.9<br>(0.397)                             |
| 1:2.59                           | E020624<br>A | 9B                        | E    | 1290 (759)                           | 6874 (23456)                       | 0.99                                       | 101.9<br>(0.409)                            |

1) Test 9: uniform airflow with superheat on all circuits of 5.6 °C (10.0 °F), 9A: same expansion valve setting as test 9 but with non-uniform airflow and no superheat adjustment, 9B: expansion valves adjusted to yield 5.6 °C (10.0 °F) superheat on all circuits with non-uniform airflow.

Figure 3.4.1.3.2 shows the air velocity contour map for COIL-W with no obstructions present. The volumetric flowrate for this test was 1244 m<sup>3</sup>/h (732 scfm) with an average velocity of 6437 m/h (352 fpm) and standard deviation of 512 m/h (28 fpm). Any non-uniformity in the unobstructed evaporator's entrance region airflow was due to the dewpoint sampling tree, thermocouple grid, and fin angles. Figure 3.4.1.3.3 shows the

non-uniform velocity contour map for COIL-W when the flow was obstructed to the upper half of the coil. An average of the top half air velocity was compared to the bottom half average air velocity to yield the velocity ratio of 1 to 1.5. The volumetric flowrate for this test was 1252 m<sup>3</sup>/h (737 scfm) with a 4097 m/h (224 fpm) and 6163 m/h (337 fpm) average velocity on the upper and lower halves of the coil, respectively. Further obstruction was added to produce the velocity contours seen in Figure 3.4.1.3.4 at a velocity ratio of 1 to 2. The average velocities in this case were 4005 m/h (219 fpm) and 8211 m/h (449 fpm) over the upper and lower halves of the coil, respectively.

The imposed airflow blockage in the case of the 1 to 1.5 velocity ratio would have increase fan power by more then 30 %. For the 1 to 2 velocity ratio case, the fan power would have increased by at least 54 % relative to the uniform airflow case.

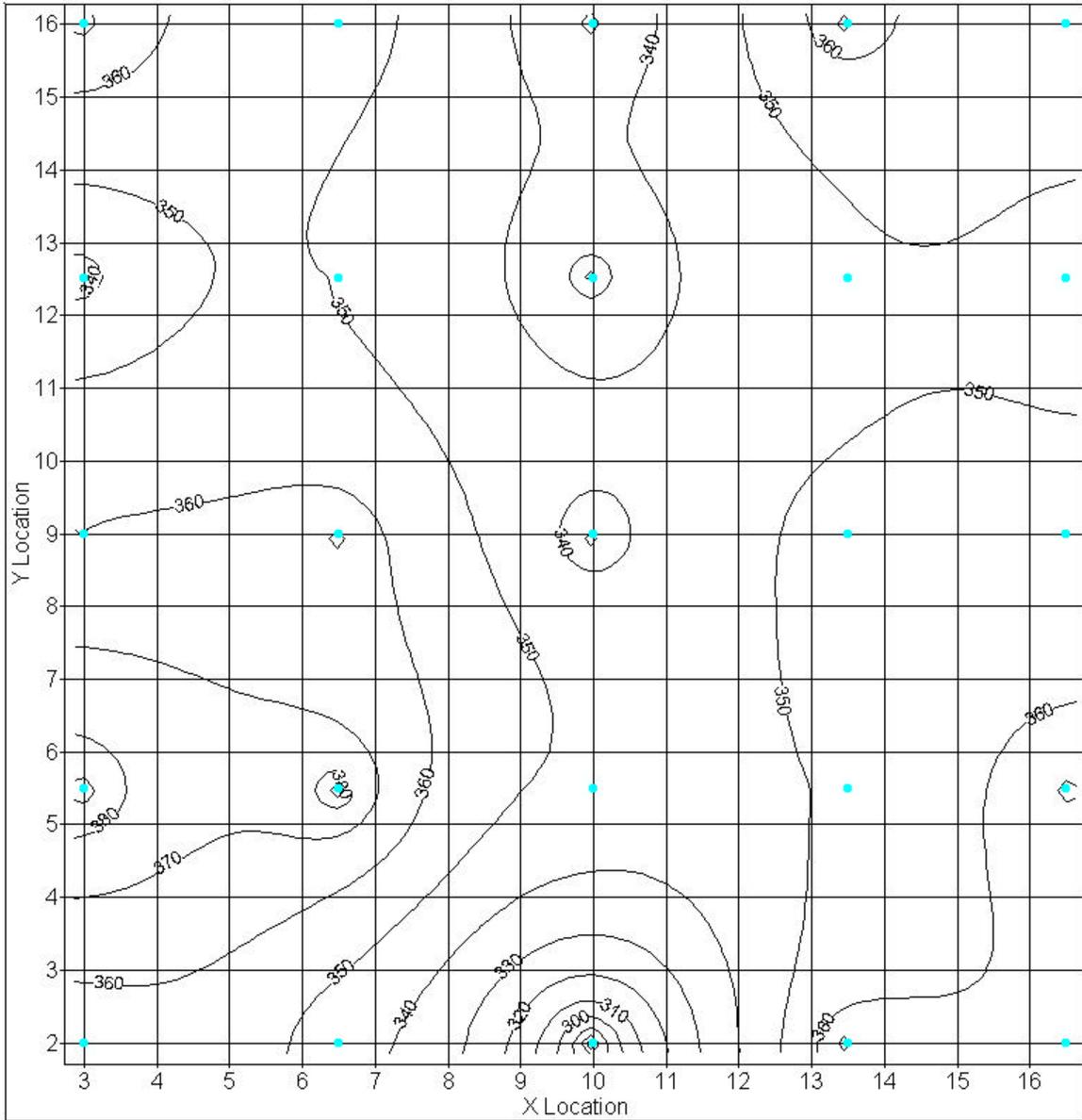


Figure 3.4.1.3.2: Uniform airflow velocity (ft/min) contour map for COIL-W

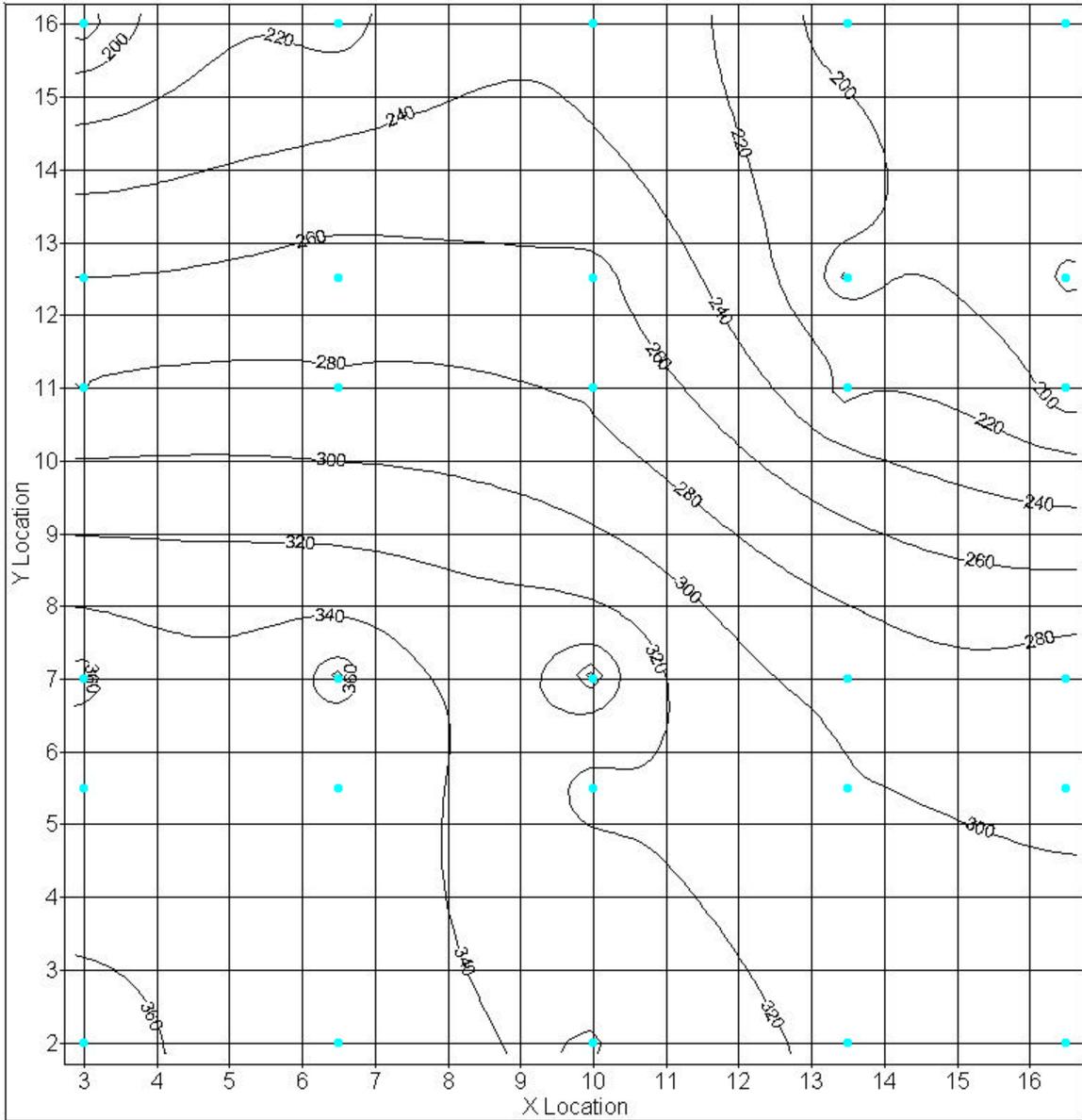


Figure 3.4.1.3.3: Non-uniform velocity (1:1.5) (ft/min) contour map for COIL-W

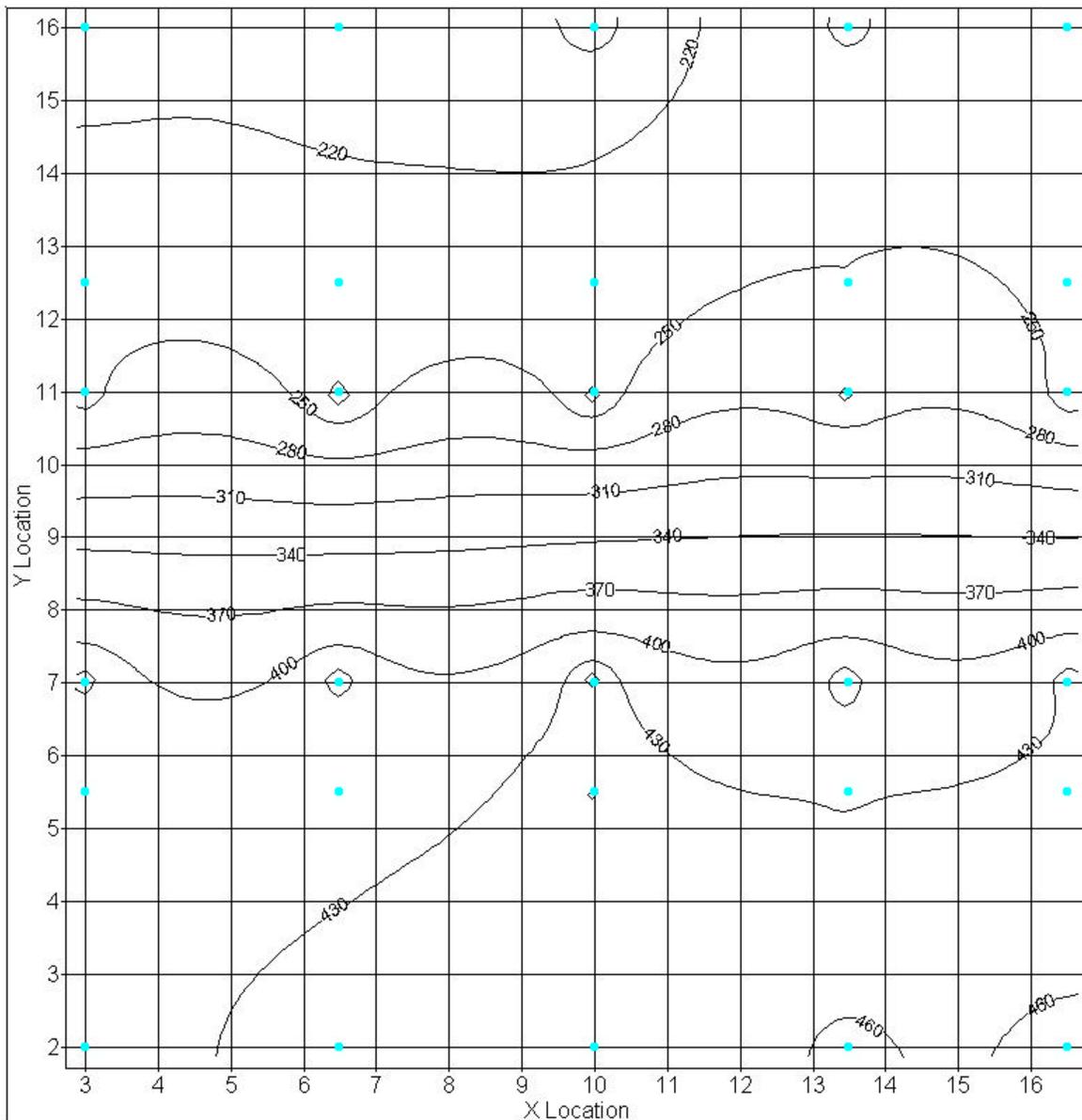


Figure 3.4.1.3.4: Non-uniform velocity (1:2) (ft/min) contour map for COIL-W

Figure 3.4.1.3.5 shows the non-uniform air velocity evaporator capacity relative to the uniform air velocity capacity. The first case shows the effects of an imposed obstruction with a fixed area expansion device. The expansion device would not be able to correct superheat and capacity would drop by 4 % in the 1:1.5 velocity ratio case and by 6.5 % in the 1:2 velocity ratio case. If the expansion device were able to correct each circuit, then the performance would improve closer to pre-obstruction, but for both cases the capacity

still decreased by 1.2 % and 4.5 %, respectively. The COIL-W non-uniform velocity results show that a more non-uniform velocity ratio produced a higher drop in capacity; and superheat correction still could not alleviate the entire penalty.

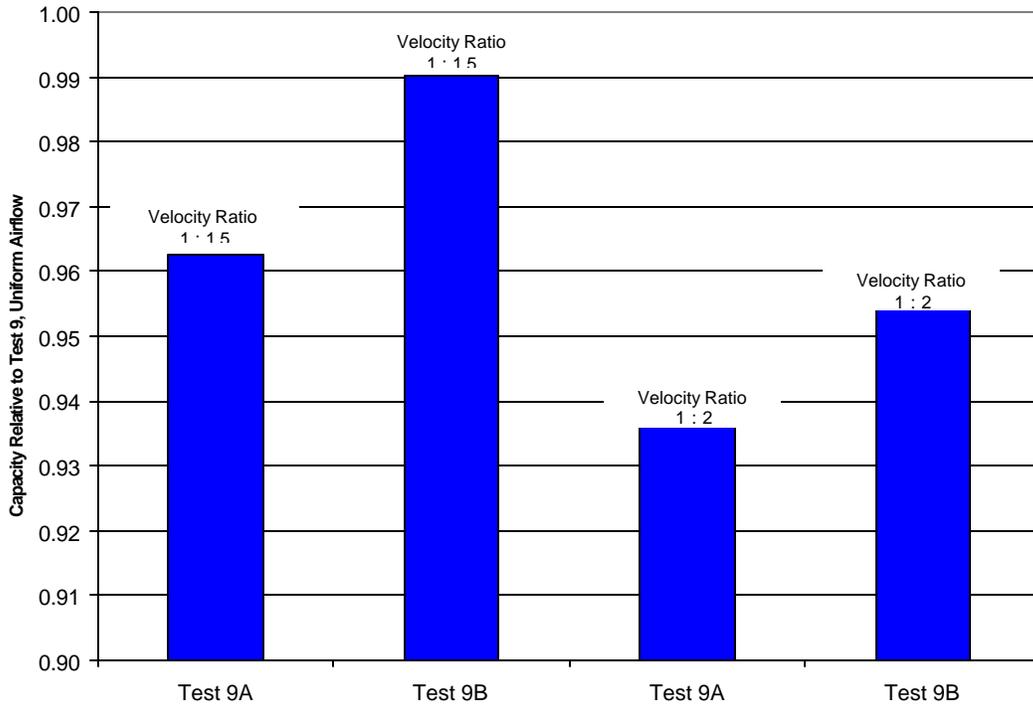


Figure 3.4.1.3.5: Relative capacities for COIL-W non-uniform airflow (refer to Table 3.4.1.3.1 for a description of the actual tests)

Figure 3.4.1.3.6 shows the air velocity contour map for COIL-E with no obstructions present. The volumetric flowrate for this test was 1276 m<sup>3</sup>/h (751 scfm) with an average velocity of 6108 m/h (334 fpm) and standard deviation of 512 m/h (28 fpm). Any non-uniformity in the unobstructed evaporator's entrance region airflow was due to the dewpoint sampling tree, thermocouple grid, and fin angles. Figure 3.4.1.3.7 shows the non-uniform velocity contour map for COIL-E when the flow was obstructed to the upper half of the coil. An average of the top half air velocity was compared to the bottom half

average air velocity to yield the velocity ratio of 1 to 1.26. The volumetric flowrate for this test was 1281 m<sup>3</sup>/h (754 scfm) with a 5340 m/h (292 fpm) and 6748 m/h (369 fpm) average velocity on the upper and lower halves of the coil, respectively. Further obstruction was added to produce the velocity contours seen in Figure 3.4.1.3.8 at a velocity ratio of 1 to 1.36. The average velocities in this case were 5340 m/h (292 fpm) and 7279 m/h (398 fpm) over the upper and lower halves of the coil, respectively. More obstruction was added to produce a 1 to 1.62 average velocity ratio seen in Figure 3.4.1.3.9. Average velocities in this case were 4609 m/h (252 fpm) and 7498 m/h (410 fpm) over the upper and lower halves of the coil, respectively. Again, obstruction was added to produce a 1 to 1.75 average velocity ratio seen in Figure 3.4.1.3.10. Average velocities in this case were 3621 m/h (198 fpm) and 6346 m/h (347 fpm) over the upper and lower halves of the coil, respectively. The final obstruction was then added to produce a velocity ratio of 1 to 2.59. Average velocities in this case were 3219 m/h (176 fpm) and 8358 m/h (457 fpm) over the upper and lower halves of the coil, respectively.

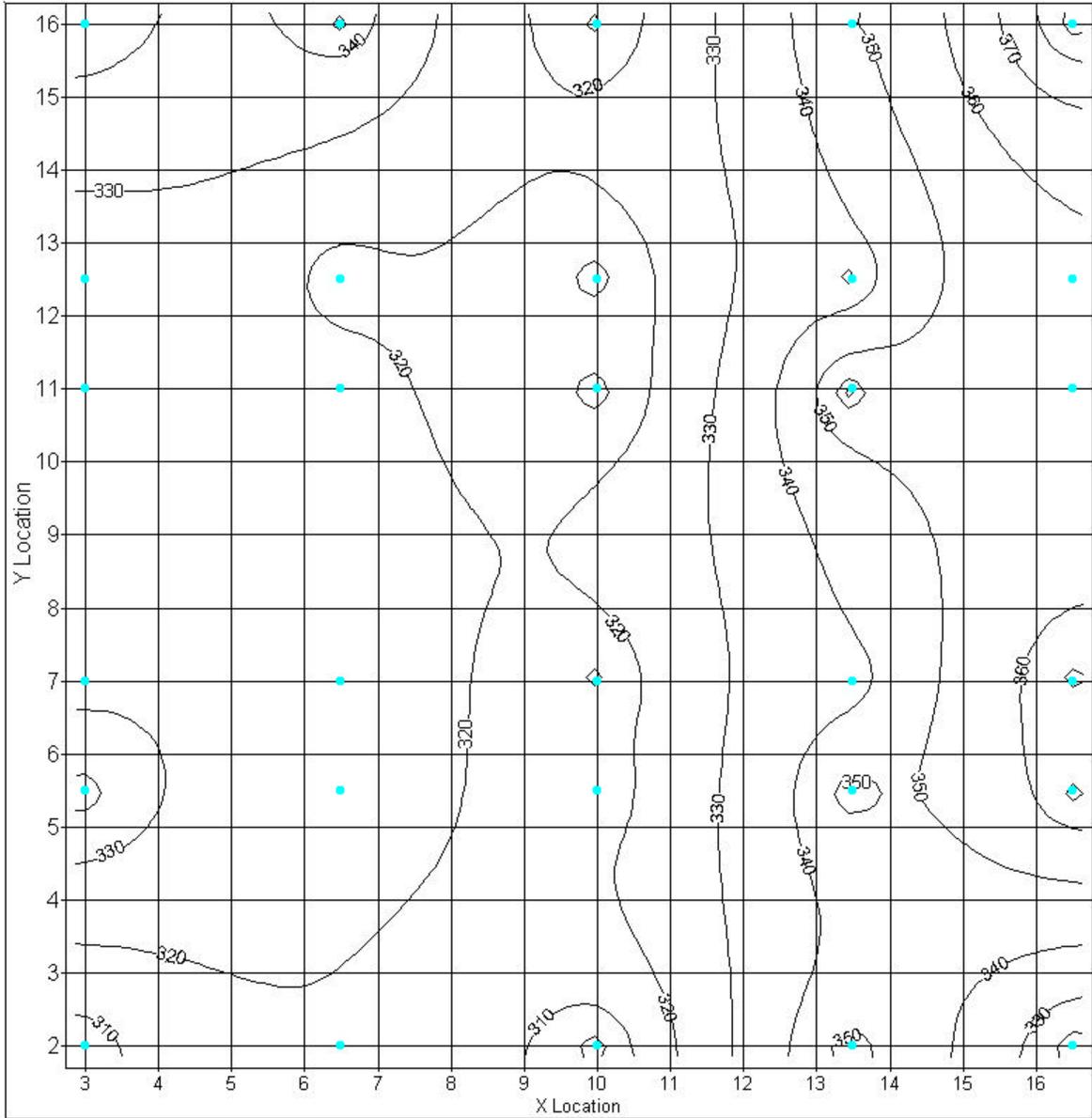


Figure 3.4.1.3.6: Uniform velocity (ft/min) contour map for COIL-E

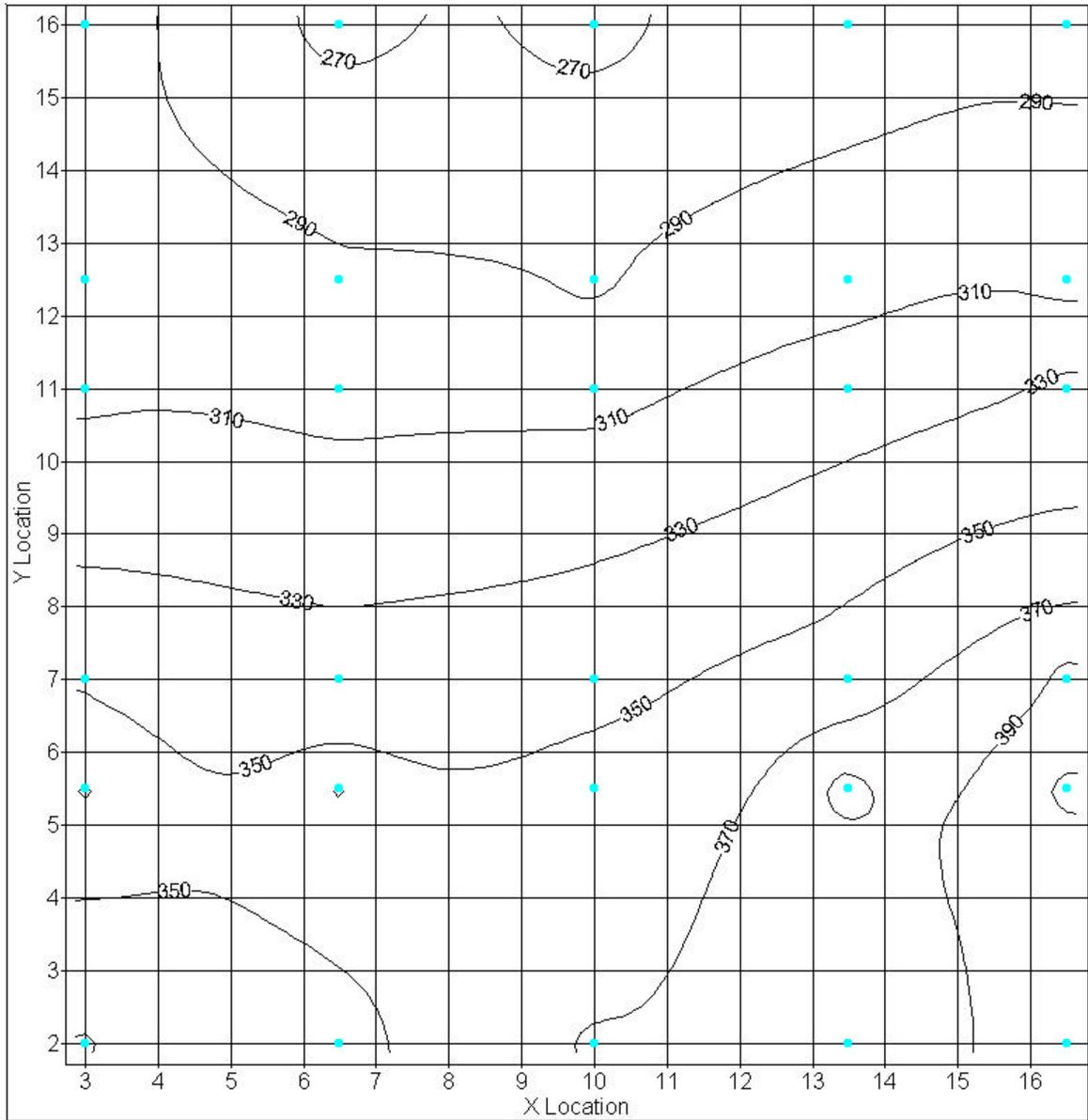


Figure 3.4.1.3.7: Non-uniform velocity (1:1.26) (ft/min) contour map for COIL-E

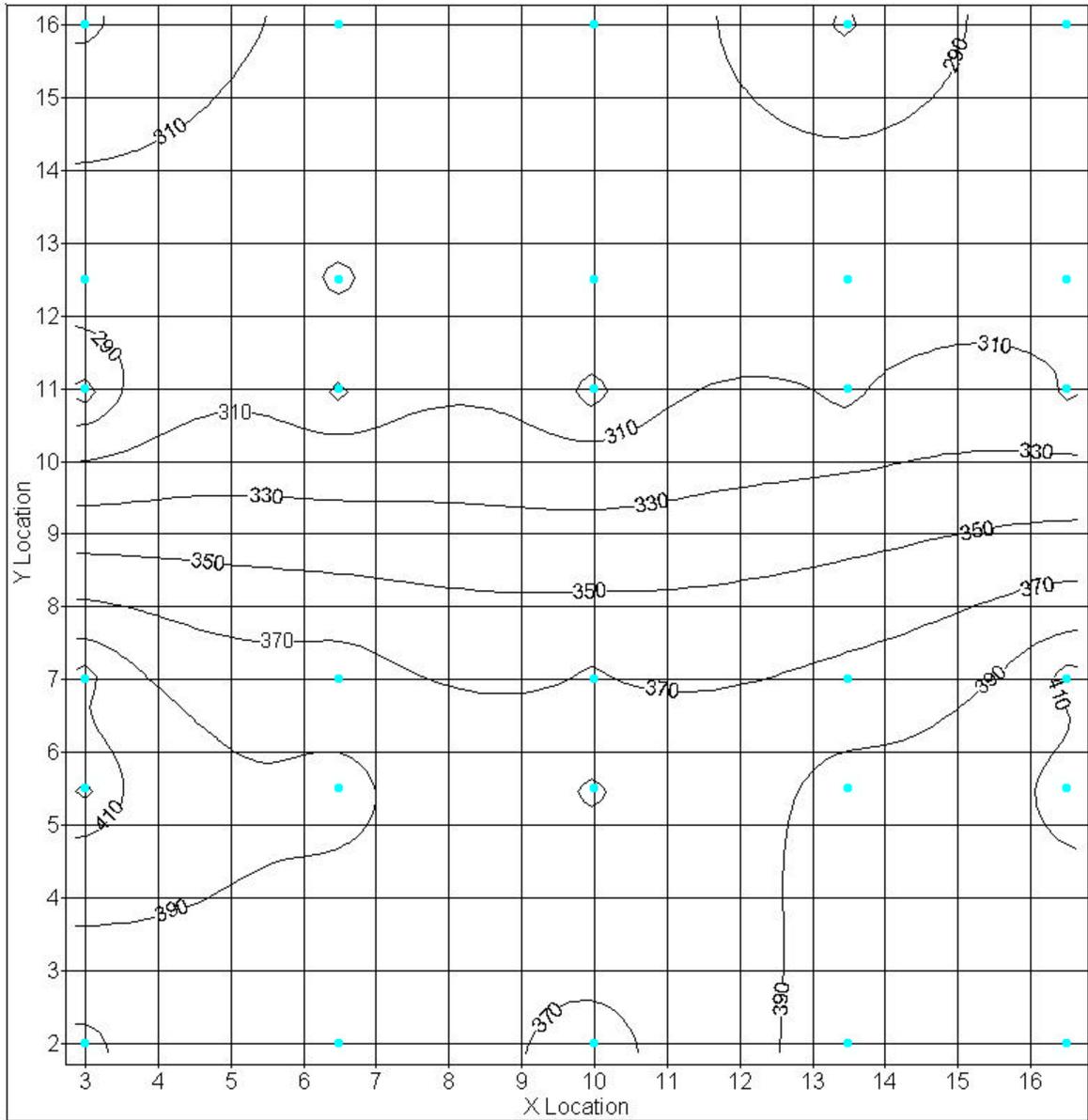


Figure 3.4.1.3.8: Non-uniform velocity (1:1.36) (ft/min) contour map for COIL-E

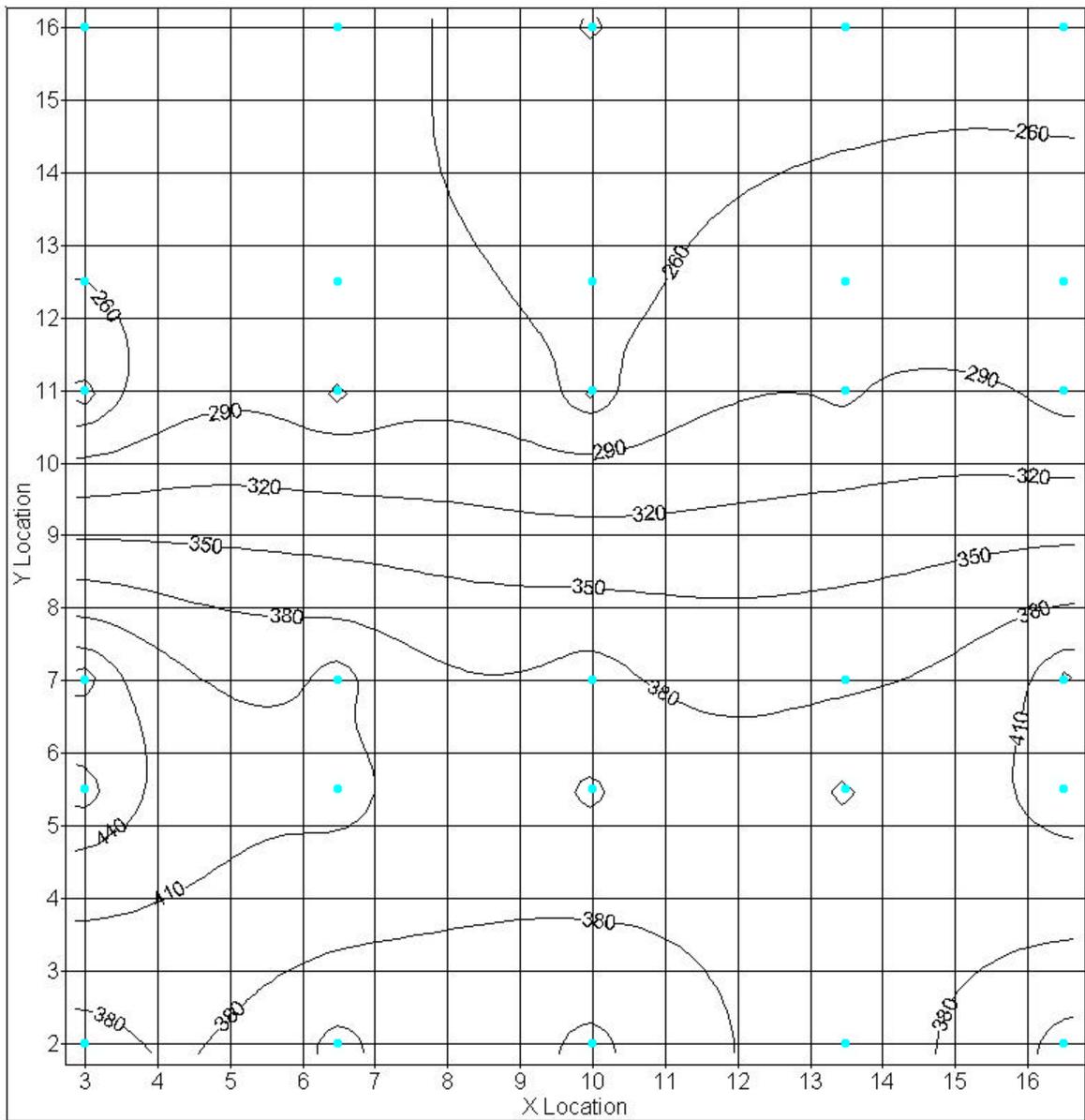


Figure 3.4.1.3.9: Non-uniform velocity (1:1.62) (ft/min) contour map for COIL-E

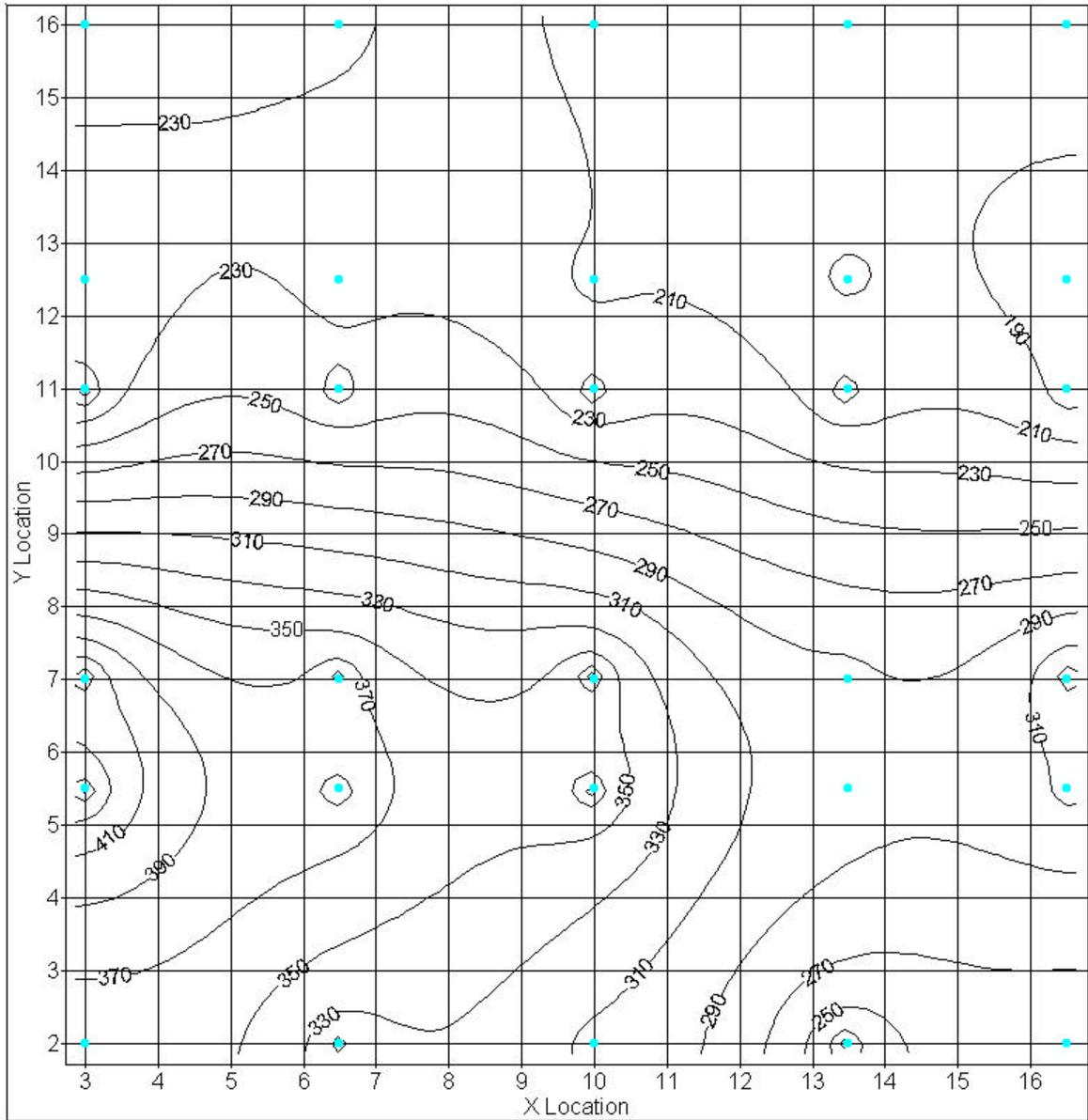


Figure 3.4.1.3.10: Non-uniform velocity (1:1.75) (ft/min) contour map for COIL-E

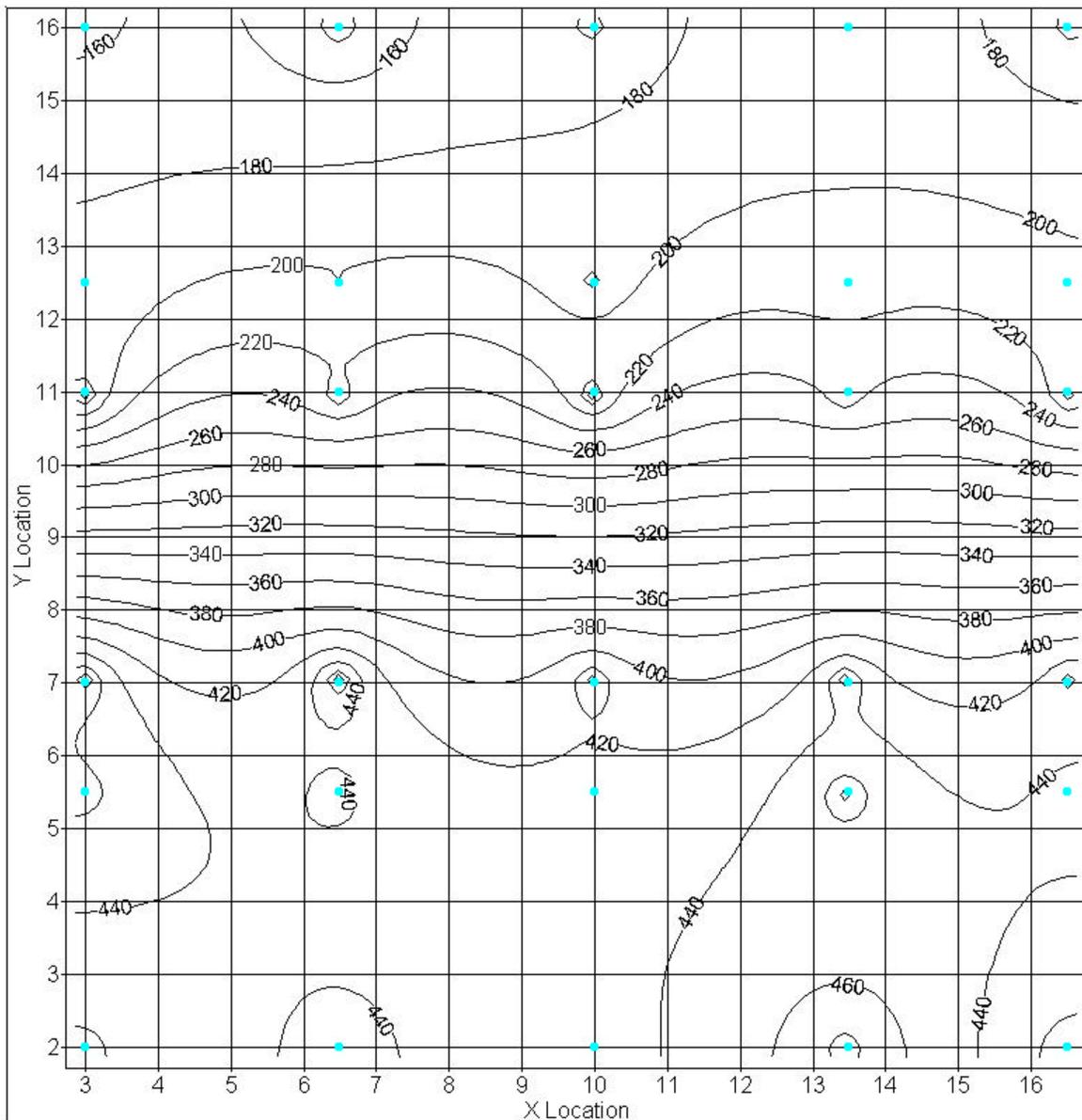


Figure 3.4.1.3.11: Non-uniform velocity (1:2.59) (ft/min) contour map for COIL-E

Figure 3.4.1.3.12 shows the non-uniform air velocity evaporator capacity relative to the uniform air velocity capacity for all COIL-E tests represented above and shown in Table 3.4.1.3.2. The cases labeled “Test 9A” show the effects of an imposed obstruction with a fixed area expansion device. Cases labeled “Test 9B” have the superheat adjusted back to 5.6 °C (10.0 °F) on each circuit. The first case had a velocity ratio of 1 to 1.26 and a capacity specific airflow of 183 m<sup>3</sup>/kW h (378 scfm/ton). Less than 1 % in capacity was

lost due to the obstruction, and this lost capacity was recovered when superheat was corrected (capacity was corrected within the uncertainty of our measurement at approximately 3.5 %). At a higher absolute airflow of 186 m<sup>3</sup>/kW h (385 scfm/ton), the losses in capacity with the obstruction were greater.

The losses in capacity with no superheat correction ranged from slightly more than 2 % at the 1 to 1.36 velocity ratio to approximately 5.5 % at the 1 to 2.59 velocity ratio. When the superheat was corrected, much of the loss in capacity was recovered. Please note that all of these tests were performed at a constant airflow rate. As shown in Table 3.4.1.3.1 and 3.4.1.3.2, the air pressure drop across the evaporator increased substantially when the blockage was imposed. This would translate into much higher fan power requirements and a subsequently lower COP. In the case of the 1 to 1.36 velocity profile, fan power would have increased by 21 % with the imposed blockage (power equals flowrate times the pressure drop). For the 1:1.62 velocity profile, fan power would have increased by 19 %. For the 1:1.75 velocity ratio, fan power would have increased by 24 %. For the highest blockage test with a velocity ratio of 1:2.59, the fan power would have increased by at least 20 %.

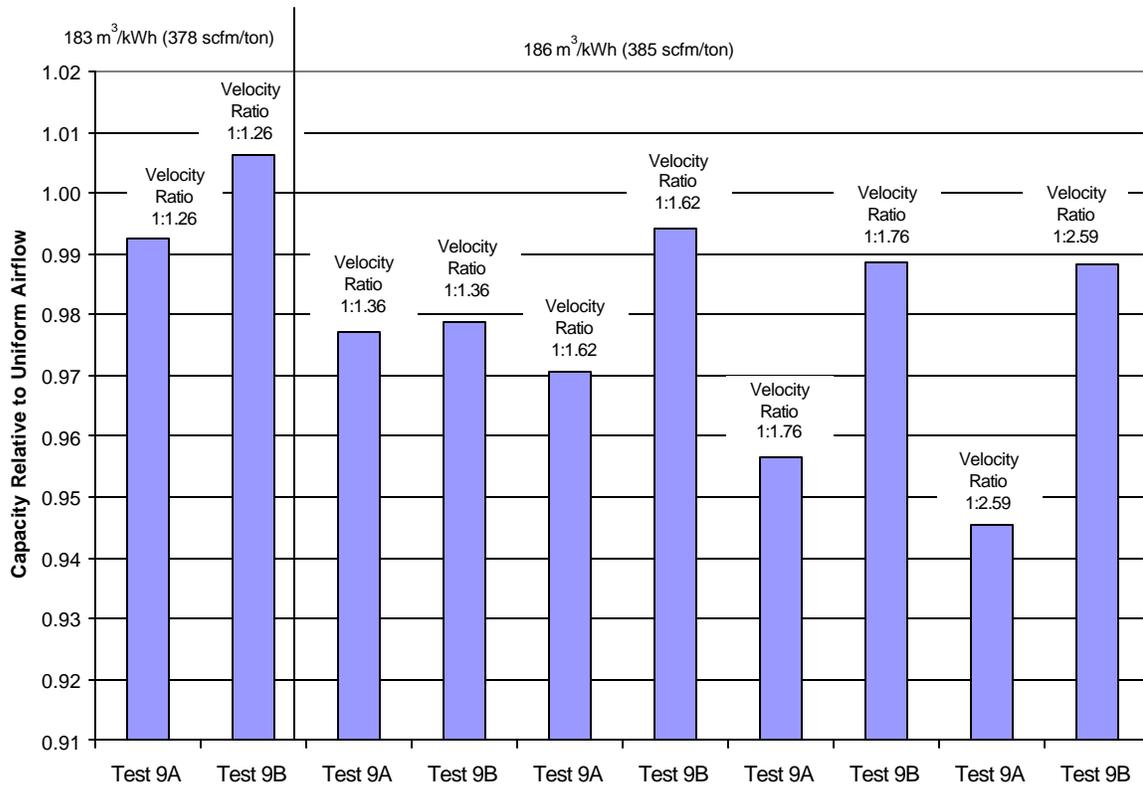


Figure 3.4.1.3.12: Capacity relative to uniform airflow for COIL-E (refer to Table 3.4.1.3.2 for a description of the tests)

### 3.4.2 Cross-Parallel Air/Refrigerant Flow Configuration Tests

Table 3.4.2.1 shows the performance of COIL-W and COIL-E with refrigerant circuited in cross-counter flow and cross-parallel flow with a capacity specific airflow rate of 193 m<sup>3</sup>/h (400 scfm/ton). COIL-W airflow rates for parallel flow and counter flow were 912 m<sup>3</sup>/h (537 scfm) and 1240 m<sup>3</sup>/h (730 scfm), respectively. COIL-E airflow rates for parallel flow and counter flow were 895 m<sup>3</sup>/h (527 scfm) and 1288 m<sup>3</sup>/h (758 scfm), respectively. The main information to be gained from this comparison is the rapid reduction in capacity that follows any increase in superheat during parallel flow (Figure 3.4.2.1). This was evident for both coils tested under parallel flow conditions.

As the superheat increased from 5.6 °C (10.0 °F) to 16.7 °C (30.0 °F), the refrigerant and air temperatures became pinched very quickly. During all tests the evaporator pressure was fixed to give an evaporating saturation temperature of 7.2 °C (45.0 °F). When superheat was increased to 16.7 °C (30.0 °F), the exiting refrigerant temperature approached 23.9 °C (75.0 °F); pinching of the two streams occurred rapidly. This is evident from examining the capacity of test 10 in parallel flow.

Figure 3.4.2.1 shows that COIL-W capacity in parallel flow decreased by 84.8 % as the superheat increased from 5.6 °C (10.0 °F) to 16.7 °C (30.0 °F); test 9 to test 10. Tests 11 and 12 also produced very low capacity due to two of the three circuits having a 16.7 °C (30.0 °F) superheat. Although tests with the center circuit flooding produced higher capacity than the top circuit flooding for both COIL-W and COIL-E.

Table 3.4.2.1: Counter and Parallel Flow Performance of COIL-W and COIL-E

| Test Name                                  | Test # | Coil Designation | Volumetric Flowrate of Air m <sup>3</sup> /h (cfm) |                                |                                | Coil Surface |    | Overall Superheat<br>Superheats in Individual Circuits |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
|--|--------|------------------|--|--------------------------------|--------------------------------|--------------|----|--|-----------------|-----|-----|------------------|------|-------------------|------|------------------|--|------------------|------|--|
|  |        |                  | 10   | 11                             | 12                             | 13           | 14 | 15   | 16              | Dry | Wet | 5.6 °C (10.0 °F) |      | 16.7 °C (30.0 °F) |      | 5.6 °C (10.0 °F) |  | 5.6 °C (10.0 °F) |      |  |
|  |        |                  | 145-Q <sup>1a</sup><br>(300-Q)                     | 193-Q <sup>1a</sup><br>(400-Q) | 242-Q <sup>1a</sup><br>(500-Q) |              |    |  |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
|  |        |                  |  |                                |                                |              |    |  |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
|  |        |                  |  |                                |                                |              |    |  |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
| <b>Cross-Counter Air/Refrigerant Flow</b>  |        |                  |  |                                |                                |              |    |  |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
| W020207B                                   | 9      | W                |  | X                              |                                |              |    | X  | 6507<br>(22203) | 1   |     |                  |      |                   |      |                  |  |                  |      |  |
| W020530A                                   | 10     | W                |  | X                              |                                |              |    | X  |                 |     |     | 3722<br>(12701)  | 0.57 |                   |      |                  |  |                  |      |  |
| W020531A                                   | 11     | W                |  | X                              |                                |              |    | X  |                 |     |     |                  |      | 3837<br>(13091)   | 0.59 |                  |  |                  |      |  |
| W020215B                                   | 12     | W                |  | X                              |                                |              |    | X  |                 |     |     |                  |      |                   |      |                  |  | 3830<br>(13067)  | 0.59 |  |
| E020607A                                   | 9      | E                |  | X                              |                                |              |    | X  | 6955<br>(23733) | 1   |     |                  |      |                   |      |                  |  |                  |      |  |
| W020318A                                   | 10     | E                |  | X                              |                                |              |    | X  |                 |     |     | 4865<br>(16599)  | 0.70 |                   |      |                  |  |                  |      |  |
| W020318B                                   | 11     | E                |  | X                              |                                |              |    | X  |                 |     |     |                  |      | 5485<br>(18715)   | 0.79 |                  |  |                  |      |  |
| W020319A                                   | 12     | E                |  | X                              |                                |              |    | X  |                 |     |     |                  |      |                   |      |                  |  | 4735<br>(16157)  | 0.68 |  |
| <b>Cross-Parallel Air/Refrigerant Flow</b> |        |                  |  |                                |                                |              |    |  |                 |     |     |                  |      |                   |      |                  |  |                  |      |  |
| W020304A                                   | 9      | W                |  | X                              |                                |              |    | X  | 4732<br>(16146) | 1   |     |                  |      |                   |      |                  |  |                  |      |  |
| W020311B                                   | 10     | W                |  | X                              |                                |              |    | X  |                 |     |     | 721<br>(2461)    | 0.15 |                   |      |                  |  |                  |      |  |
| W020306A                                   | 11     | W                |  | X                              |                                |              |    | X  |                 |     |     |                  |      | 2605<br>(8887)    | 0.55 |                  |  |                  |      |  |
| W020307A                                   | 12     | W                |  | X                              |                                |              |    | X  |                 |     |     |                  |      |                   |      |                  |  | 2143<br>(7311)   | 0.45 |  |
| E020403A                                   | 9      | E                |  | X                              |                                |              |    | X  | 4549<br>(15523) | 1   |     |                  |      |                   |      |                  |  |                  |      |  |
| E020404A                                   | 10     | E                |  | X                              |                                |              |    | X  |                 |     |     | 1017<br>(3470)   | 0.22 |                   |      |                  |  |                  |      |  |
| E020408A                                   | 11     | E                |  | X                              |                                |              |    | X  |                 |     |     |                  |      | 3373<br>(11508)   | 0.74 |                  |  |                  |      |  |
| E020409A                                   | 12     | E                |  | X                              |                                |              |    | X  |                 |     |     |                  |      |                   |      |                  |  | 2797<br>(9543)   | 0.61 |  |

1a : capacity determined at 193 m<sup>3</sup>/h (400 scfm/ton)

1b : capacity at test 9 for the coil specified.

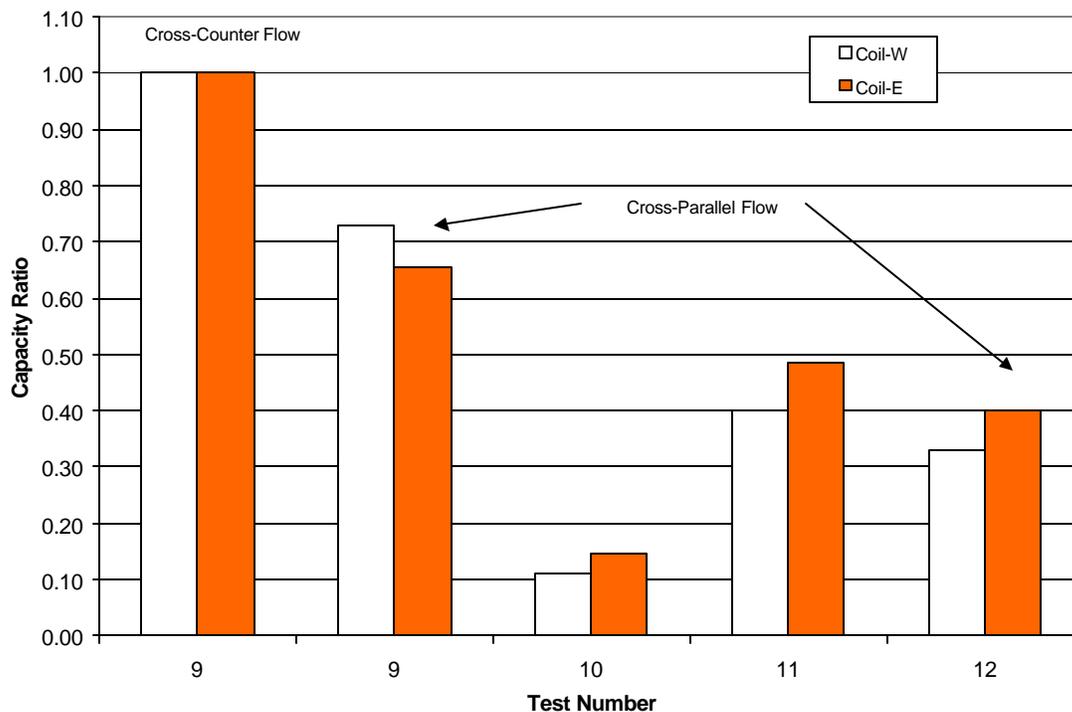


Figure 3.4.2.1: Cross-parallel flow capacity comparison for COIL-W and COIL-E relative to their performance at test 9 with cross-counter flow

COIL-E capacity in parallel flow was 3.9 % less than COIL-W at the test 9 condition of  $193 \text{ m}^3/\text{kW h}$  (400 scfm/ton). This is the opposite of the counter flow capacity results where COIL-E had a 5.4 % greater capacity than COIL-W. COIL-E produced a slightly lower capacity than COIL-W at the test 9 parallel flow conditions. This was mainly due to the  $196 \text{ m}^3/\text{kW h}$  (406 scfm/ton) for COIL-W and the  $193 \text{ m}^3/\text{kW h}$  (399 scfm/ton) for COIL-E. The ideal airflow would have produced  $193 \text{ m}^3/\text{kW h}$  (400 scfm/ton) for both coils, but COIL-W airflow was high while COIL-E airflow was slightly low. These differences in airflow produced the accompanying difference in capacity. Also, a secondary factor in the lower capacity of COIL-E than COIL-W may be due to the more rapid pinching of COIL-E than COIL-W due to the higher air-side heat transfer of the enhanced fins.

COIL-E capacity in parallel flow decreased by 77.6 % as the superheat increased from 5.6 °C (10.0 °F) to 16.7 °C (30.0 °F); test 9 to test 10. Again, rapid pinching of the two fluid streams reduced capacity.

## **4 EVAPORATOR MODELING AND SIMULATIONS**

### **4.1 Background on Evaporator Model EVAP5**

Modeling of finned tube heat exchangers started at NIST with a tube-by-tube simulation model originally formulated by Chi (1979). Over the years, the model underwent significant upgrades, which are documented in Domanski and Didion (1983), Domanski (1991), Lee and Domanski (1997), and Domanski (1999b). These upgrades included the capability to account for air maldistribution and its interaction with refrigerant distribution, the extension to zeotropic mixtures, the extension to new refrigerant property representations, and implementations of new simulation correlations. The 1999 upgrade equipped the evaporator model with a graphical user interface (GUI). The GUI serves as a pre- and post-processor; it facilitates preparation of simulation input data, including the layout of refrigerant circuitry, and allows the user to display detailed performance results for individual tubes after a simulation run is completed. In 2002 under a parallel ARTI-21CR/605-500100 project (Domanski and Payne, 2002), the EVAP-COND simulation package was developed that included the evaporator and condenser models, EVAP5 and COND5, working under the same GUI. Both models were validated with experimental data taken with R22 and R410A heat exchangers at NIST. Since the current project and ARTI-21CR/605-500100 project partially overlapped in time, the EVAP-COND attached to the ARTI-21CR/605-500100 report included some of upgrades developed under this study, e.g. the option to simulate the evaporator together with a refrigerant distributor. Not included in the release version of EVAP-COND are the upgrades to the evaporator model that account for longitudinal fin

conduction, which were needed to perform simulations with controlled refrigerant superheats at individual refrigerant circuits.

## **4.2 Description of EVAP5**

### 4.2.1 Modeling Approach

Figure 4.2.1.1 presents the refrigerant circuitry and air velocity representation used by EVAP5. The tube-by-tube modeling approach recognizes each tube as a separate entity for which the model performs simulation calculations. These calculations are based on inlet refrigerant and air parameters, their properties, and mass flow rates. The simulation begins with the inlet refrigerant tubes and proceeds to successive tubes along the refrigerant path in the heat exchanger. At the outset of the simulation, the air temperature is only known for the tubes in the first row and has to be estimated for the remaining tubes. A successful simulation run requires several passes (iterations) through the refrigerant circuitry, each time updating inlet air and refrigerant parameters for each tube.

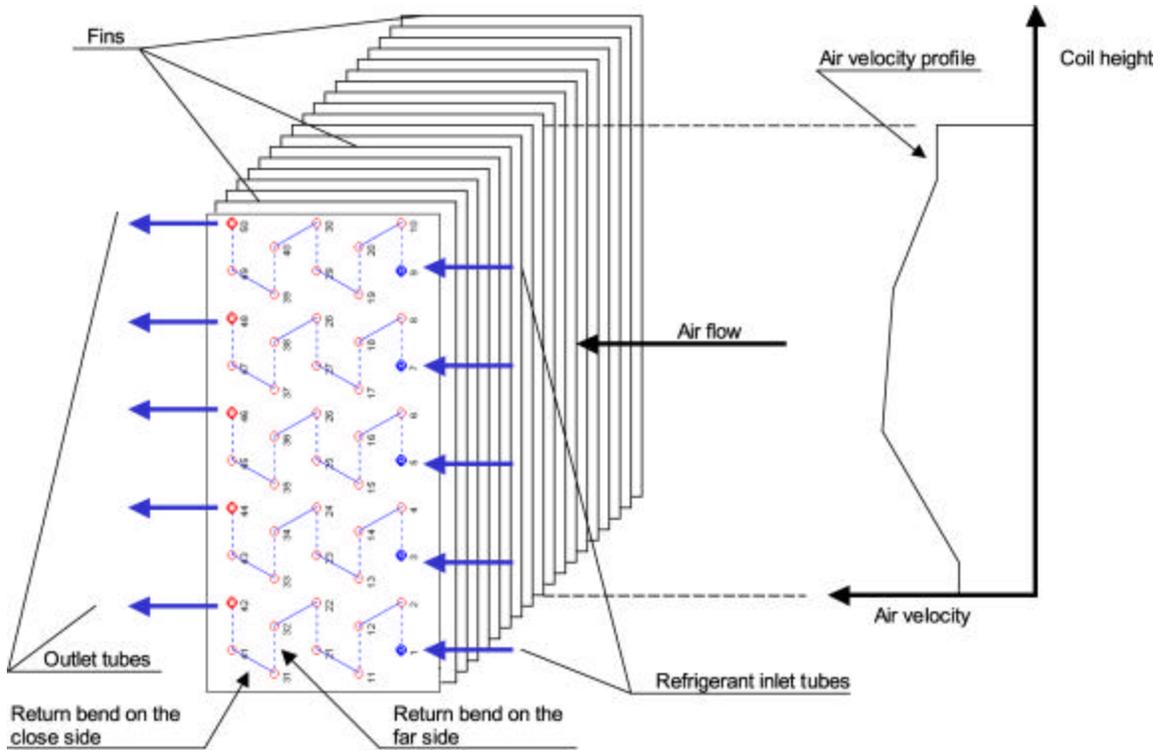


Figure 4.2.1.1: Representation of air distribution and refrigerant circuitry in EVAP5

Heat transfer calculations start by calculating the heat-transfer effectiveness,  $\epsilon$ , by one of the applicable relations (Kays and London, 1984). With the air temperature changing due to heat transfer, the selection of the appropriate relation for  $\epsilon$  depends on whether the refrigerant undergoes a temperature change during heat transfer. Once  $\epsilon$  is determined, heat transfer from air to refrigerant is obtained using equation 4.2.1.1.

$$Q_a = m_a C_{pa} (T_{ai} - T_{ri}) \epsilon \quad (4.2.1.1)$$

The overall heat-transfer coefficient,  $U$ , is calculated by equation 4.2.1.2, which sums up the individual heat-transfer resistances between the refrigerant and the air.

$$U = \left( \frac{A_o}{h_i A_{pi}} + \frac{A_o X_p}{A_{pm} K_p} + \frac{1}{h_l} + \frac{A_o}{A_{po} h_{pf}} + \frac{1}{h_o (1 + \alpha) \left( 1 - \frac{A_f}{A_o} (1 - \ddot{o}) \right)} \right)^{-1} \quad (4.2.1.2)$$

The first term of equation 4.2.1.2 represents the refrigerant-side convective resistance. The second term is the conduction heat-transfer resistance through the tube wall, and the third term accounts for the conduction resistance through the water layer on the fin and tube. The fourth term represents the contact resistance between the outside tube surface and the fin collar. The fifth term is the convective resistance on the air-side where the multiplier  $(1+\alpha)$  in the denominator accounts for the latent heat transfer on the outside surface. For a dry tube  $\alpha = 0.0$  and  $1/h_l = 0.0$ . Once the heat transfer rate from the air to the refrigerant is calculated, the tube wall and fin surface temperatures can be calculated directly using heat-transfer resistances. Then, the humidity ratios for the saturated air at the wall and fin temperatures are calculated, and mass transfer from the moist air to the tube and fin surfaces is determined. For more detailed information on heat transfer calculations refer to Domanski (1991).

#### 4.2.2 Heat Transfer and Pressure Drop Correlations

EVAP5 uses the following correlations for calculating heat transfer and pressure drop.

##### **Air Side**

- heat-transfer coefficient for flat fins: Wang et al. (2000)
- heat-transfer coefficient for wavy fins: Wang et al. (1999a)
- heat-transfer coefficient for slit fins: Wang et al. (2001)

- heat-transfer coefficient for louver fins: Wang et al. (1999b)
- fin efficiency: Schmidt method, described in McQuiston et al. (1982)

A correlation for calculating the tube-collar junction resistance is not listed because all air-side heat transfer correlations authored by Wang include the heat transfer resistance between the tube and collar.

### **Refrigerant Side**

- single-phase heat-transfer coefficient, smooth tube: McAdams, described in ASHRAE (2001)
- evaporation heat-transfer coefficient up to 80% quality, smooth tube: Jung and Didion (1989)
- evaporation heat-transfer coefficient up to 80% quality, rifled tube: Jung and Didion (1989) correlation with a 1.9 enhancement multiplier suggested by Schlager et al. (1989)
- mist flow, smooth and rifled tubes: linear interpolation between heat transfer coefficient values for 80 % and 100 % quality
- single-phase pressure drop, smooth tube: Petukhov (1970)
- two-phase pressure drop, smooth tube, lubricant-free refrigerant: Pierre (1964)
- two-phase pressure drop, rifled tube: Pierre (1964) correlation for smooth tube with a 1.4 multiplier suggested by Schlager et al. (1989)
- single-phase pressure drop, return bend, smooth tube: White, described in Schlichting (1968)
- two-phase pressure drop, return bend, smooth tube: Chisholm, described in Bergles et al. (1981). The length of a return bend depends on the relative locations of the tubes connected by the bend. This length is accounted for in pressure drop calculations.

### 4.2.3 Representation of Refrigerant Properties

Representation of thermodynamic and transport properties is based on REFPROP6 property routines (McLinden et al., 1998). Because EVAP5 simulations are computationally intensive, using a refrigerant property look-up tables is a practical necessity if simulation runs are expected to take less than 60 seconds. This is particularly true in case of REFPROP6 for which property calculations are several times more CPU demanding than for REFPROP5. EVAP-COND employs a pressure-enthalpy-based system of look-up tables, which includes eight different routines that retrieve the desired state or transport property. The look-up scheme is applicable to single component refrigerants and refrigerant mixtures. If a given refrigerant state falls outside the range of the look-up table, then EVAP-COND calls a REFPROP6 refrigerant property routine directly.

Since REFPROP6 property calculations may not converge occasionally, particularly during phase equilibrium calculations for refrigerant mixtures, EVAP-COND employs an error evasive scheme. Under this scheme, EVAP-COND attempts to obtain a given property even if REFPROP flash calculations do not converge, e.g., if a routine PHFLSH crashes, a routine that uses TPRHO is invoked to attempt to iteratively match TPRHO's enthalpy value with the known (target) value. If both REFPROP flash calculations do not converge, then the data point in the refrigerant look-up table is flagged and look-up table routines iterate properties for this point using refrigerant properties in the neighboring nodes of the table.

### **4.3 Modeling Issues**

The following four sections present four major modeling issues that received special consideration during this study.

#### **4.3.1 Refrigerant Distribution**

Simulating refrigerant distribution is an important aspect of heat exchanger simulation because of its impact on the heat exchanger performance. It is also known that in some designs a non-uniform air distribution may affect refrigerant distribution. In a heat exchanger with multiple circuits, refrigerant distributes itself in appropriate proportions so that the refrigerant pressure drop from the inlet to the outlet for all circuits is the same. In the context of simulating refrigerant distribution, a refrigerant circuit starts at the point of the first split of refrigerant stream after leaving the condenser and ends at the final merging point before entering the suction line leading the refrigerant to the compressor. If the refrigerant enters the evaporator by a single tube, the first split, if any, will exist within the coil assembly. If the evaporator has several inlet tubes and a refrigerant distributor is used, the first refrigerant split typically occurs at the inlet to the distributor tubes just after the expansion process in a thermostatic expansion valve (TXV) or a short tube restrictor. Note, that in this design, refrigerant pressures and temperatures at different inlet tubes may be different, as graphically shown in Figure 4.3.1.1. Such different refrigerant pressure and temperature profiles also occurred during the tests with controlled uneven exit superheats (refrigerant distributions), namely tests 3, 4, 7, 8, 11, and 12.

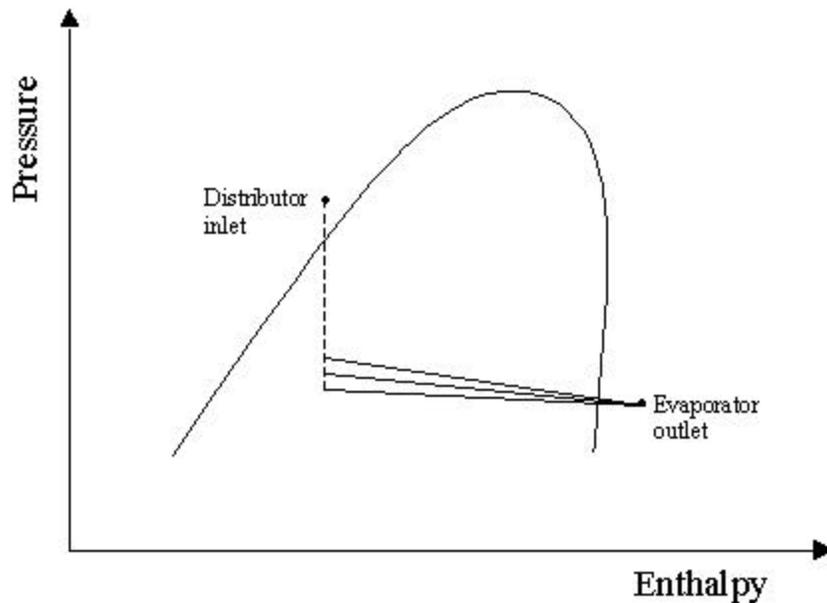


Figure 4.3.1.1: Possible refrigerant pressure profiles in a three-circuit evaporator fed by a refrigerant distributor

Under this project, two simulation methods were developed to simulate evaporator performance with controlled refrigerant superheats at the evaporator outlet tubes. The first scheme involving a general model for a refrigerant distributor was introduced into EVAP-COND as one of the eight evaporator simulation options. When the evaporator is simulated using this option, the refrigerant operating input data are the condenser exit bubble-point temperature, condenser subcooling, evaporator exit dew-point temperature, and evaporator superheat (in the release version of EVAP-COND, condenser subcooling and evaporator superheat are imposed as 5.0 °C (9.0 °F)). For this option, as the first task EVAP-COND runs preliminary simulations to establish dimensions of the refrigerant distributor tubes that would inflict a 70 kPa (10.2 lb/in<sup>2</sup>) refrigerant pressure drop. Once the distributor tubes are sized, EVAP-COND proceeds to main simulations in which it

establishes refrigerant distribution between different circuits based on the total pressure drop. This total pressure drop includes the pressure drop in a given distributor tube and the refrigerant circuit in the coil assembly it feeds. In the test version used in this study, EVAP-COND additionally solicits a “restriction factor” for each distributor tube, which acts as a multiplier to the pressure drop calculated by the program. By inputting values different from 1.0, the user can control refrigerant distribution and refrigerant superheat at different evaporator exit tubes. The program iterates the refrigerant mass flow rate until the overall superheat is reached at the evaporator exit. Figures 4.3.1.2 and 4.3.1.3 present the eight refrigerant input data options and the input data window for EVAP-COND simulations involving a refrigerant distributor, respectively.

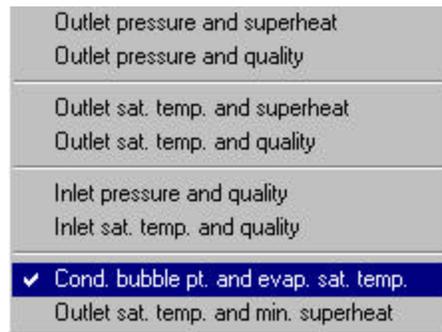


Figure 4.3.1.2: EVAP-COND refrigerant input data options for evaporator simulations

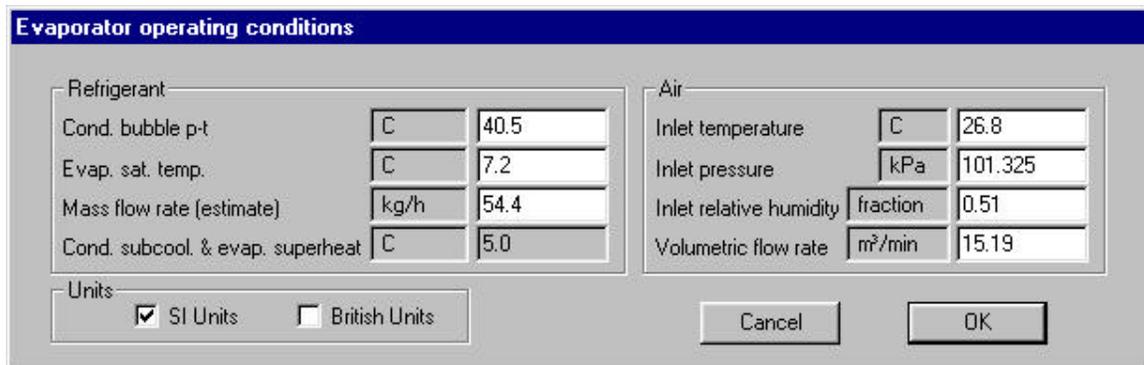


Figure 4.3.1.3: EVAP-COND input data window for simulations involving a refrigerant distributor

While the simulation option involving a refrigerant distributor is useful for a coil designer for typical simulations, this option proved to be somewhat impractical for controlling individual exit superheats when we tried to reproduce our test results. This was due to a non-linear dependence of individual exit superheats on the “restriction factors”. For this reason another simulation scheme was developed in which the user directly assigns refrigerant distribution between different circuits. The operating conditions are as shown in Figure 4.3.1.4 with the refrigerant inlet quality and distribution (in fractions) solicited by the follow-up DOS window. While holding the refrigerant distribution constant, the program iterates the overall refrigerant mass flow rate and inlet pressures at individual inlet tubes to converge on the target exit pressure (the same for each exit tube) and overall target superheat. Different individual superheats can be obtained by specifying different refrigerant distributions. Eventually, all simulation results for this study were obtained using the second scheme.

| Refrigerant               |          | Air  |                         |          |         |
|---------------------------|----------|------|-------------------------|----------|---------|
| Outlet sat. temp.         | C        | 7.2  | Inlet temperature       | C        | 26.9    |
| Superheat                 | C        | 5.5  | Inlet pressure          | kPa      | 101.325 |
| Mass flow rate (estimate) | kg/h     | 54.4 | Inlet relative humidity | fraction | 0.51    |
| Inlet quality             | fraction | 0.20 | Volumetric flow rate    | m³/min   | 15.19   |

Units:  SI Units  British Units

Buttons: Cancel, OK

Figure 4.3.1.4: EVAP-COND input data window for simulations with specified overall evaporator exit saturation temperature and superheat.

#### 4.3.2. Air-side Heat Transfer Correlations

Often the most significant part of heat transfer resistance between the air and refrigerant is on the air-side of the heat exchanger. For this reason, a literature review on the latest air-side heat transfer correlations was performed at the outset of this study. Of our particular interest were correlations for wavy and lanced (slit) fins – the two fin types used in the evaporators tested under this project.

Figure 4.3.2.1 compares the predictions of different correlations available in the literature. These predictions were calculated for typical fin designs for a three-depth-row heat exchanger. The layout of different prediction lines in the figure may serve as an explanation why predicting performance of a finned-tube heat exchanger may be difficult. For wavy fins, the correlation by Wang et al. (1999a) and Kim et al. (1997) are in a close agreement, while the correlation by Webb (1990) calculates heat transfer coefficients up to 50 % lower than the two first methods. In the air velocity range of 1.8 m/s (5.9 ft/s) to 2.1 m/s (6.9 ft/s), the Webb correlation breaks sharply due to switching between two different algorithms with a changing air-side Reynolds number. At some point the Webb correlations provide a value for the wavy fin heat transfer coefficient that is lower than that for a flat fin, which is not a realistic prediction.

For slit (lanced) fins, the correlations by Nakamura and Xu (1983) and Wang et al. (2001) may differ by more than 40 %, depending on air velocity. This spread may be indicative of the general fact that some correlations do not predict well outside the geometries for which they were developed. A measurement uncertainty in one or both

experiments may also be a contributing factor to this large discrepancy. In addition, it should be noted that the Nakayama and Xu (1983) predictions do not approach zero at air velocities below 2 m/s (6.5 ft/s), the trend exhibited by the other correlations. Regarding louver fins, the correlation by Wang et al. (1999b) shows a step change in the 1.5 m/s (4.9 ft/s) to 1.8 m/s (5.9 ft/s) range caused by using two different algorithms, similar to the Webb correlation for the wavy fins.

The analysis of relative predictions of the air-side heat transfer coefficient provided the reason for replacing the existing correlations in EVAP5 with correlations published by Wang and his co-workers for all types of fins, i.e., flat, wavy, louver, and slit fins. It was judged that a better degree of prediction consistency can be obtained with all correlations developed by the same author. Still, the reader should note a reservation regarding the louver fin correlation, which did not provide smooth predictions in Figure 4.3.2.1.

In conclusion, we have to recognize the spread in performance between different enhanced fins, either realistic or perhaps, in some instances, overstated by correlations. To accommodate these differences and facilitate accurate evaporator model predictions, EVAP-COND provides an option that allows the user to “tune” evaporator simulated performance to the laboratory data by specifying a “correcting parameter” for the air-side heat transfer coefficient (such correcting parameters are also allowed for the refrigerant-side heat transfer coefficient, and refrigerant pressure drop).

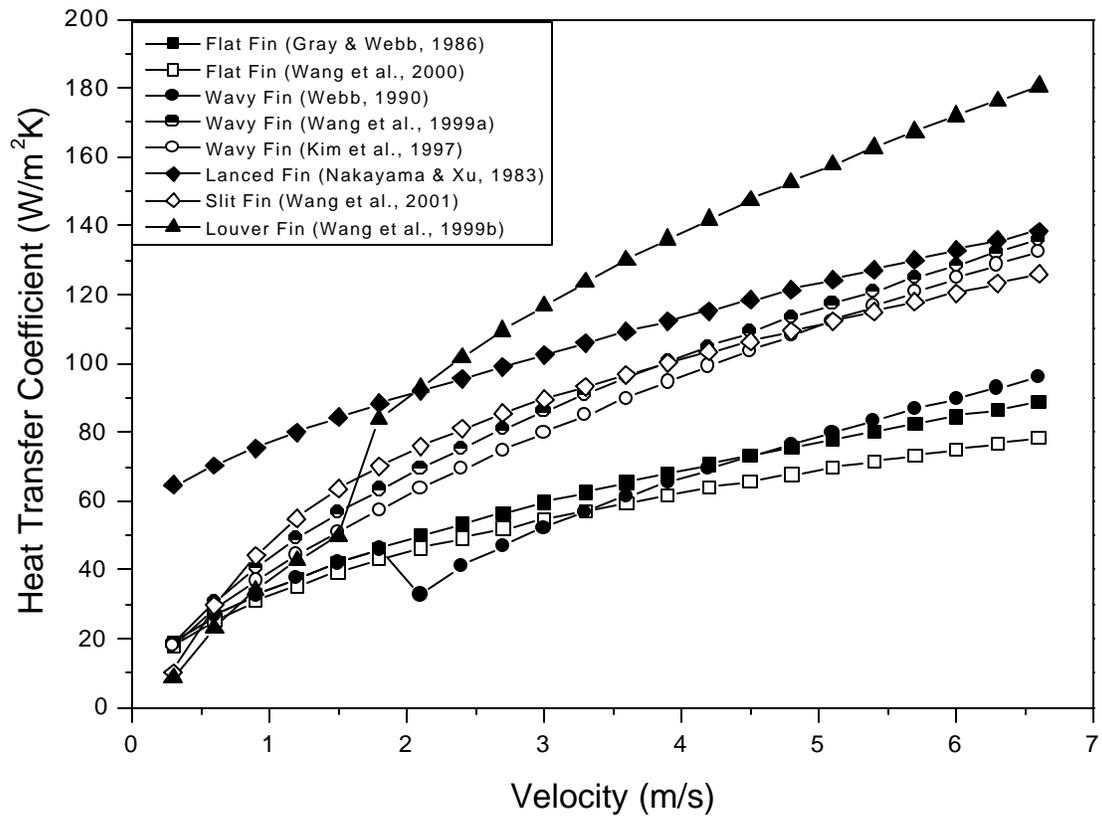


Figure 4.3.2.1: Comparison of air-side heat transfer correlations

### 4.3.3. Internal Heat Transfer in a Finned-Tube Evaporator

The current study stipulated evaporator tests with a superheat as high as 16.7 °C (30.0 °F) to assess capacity degradation at large and uneven superheats. As presented in previous sections, these tests for COIL-E and COIL-EC produced rather interesting data suggesting that internal heat transfer within the evaporator metal body may be the culprit for significant capacity degradation. Figure 4.3.3.1 presents measured capacities at 193 m<sup>3</sup>/kW h (400 cfm/ton) and includes capacities predicted by EVAP5 (internal heat transfer not considered). The figure shows that tested capacities at 5.6 °C (10 °F) overlap for both coils and are reasonably well predicted by EVAP5. However, at 16.7 °C (30 °F) superheat COIL-E capacity was tested to be 346 W (1180 Btu/h) less than COIL-EC capacity and 966 W (3295 Btu/h) less than the simulated value. The lower capacity degradation for COIL-EC can be explained by the fin cuts, which physically separated different tube depth rows and disallowed heat transfer between neighboring rows.

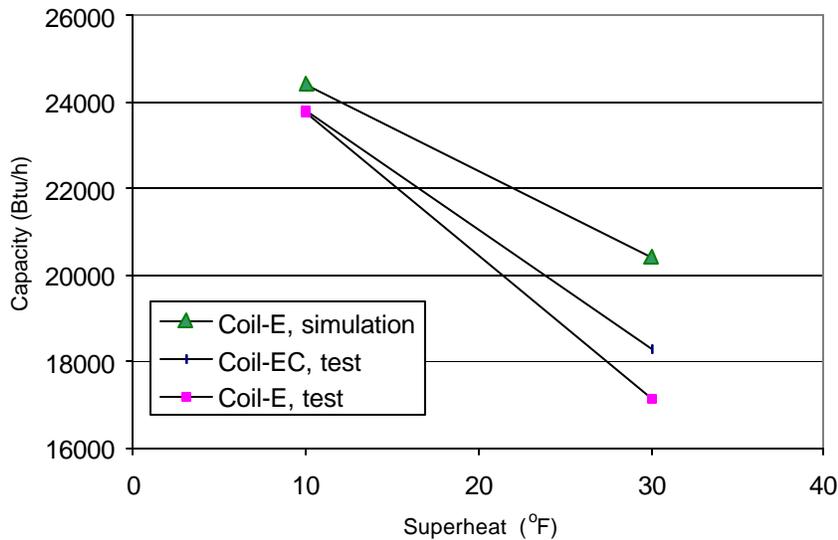


Figure 4.3.3.1: Tested and predicted capacities for COIL-E and COIL-EC at 5.6 °C (10 °F) and 16.7 °C (30 °F) superheats (Test 9 and Test 10 operating conditions. Internal heat transfer within the evaporator metal body not considered.)

The following two sections discuss the two modes of the internal heat transfer, longitudinal tube conduction and longitudinal fin conduction (tube-to-tube heat transfer), and their impact on evaporator performance.

#### 4.3.3.1 Longitudinal Tube Conduction

The general theory states that if a temperature gradient exists in a wall of a heat exchanger, then conduction heat transfer will occur along that wall and may therefore degrade the performance of the heat exchanger. Kays and London (1984) identified the major parameters affecting the magnitude of the performance degradation due to this phenomenon as follows:

$$I = \frac{kA_w}{LC_{\min}}, \quad \frac{C_{\min}}{C_{\max}}, \quad \text{and NTU} \quad (4.3.3.1.1)$$

The magnitude of the performance degradation becomes larger with increasing  $\lambda$ ,  $C_{\min}/C_{\max}$ , and NTU. Kays and London stated that this reduction in performance is seen in heat exchangers designed for high effectiveness ( $\epsilon > 0.9$ ), however, they did not provide much of a quantitative analysis. Ranganayakulu et. al. (1996) carried out a series of finite element simulations to quantify the magnitude of the performance degradation in a heat exchanger due to longitudinal heat conduction.. The results of their simulations are represented by the “conduction effect factor”,  $\tau$ , in terms of the effectiveness with no longitudinal conduction effects,  $e_{NC}$ , and the effectiveness considering longitudinal conduction effects,  $e_{WC}$ .

$$t = \frac{e_{NC} - e_{WC}}{e_{NC}} \quad (4.3.3.1.2)$$

The conduction effect factor can be read from the charts presented in the paper for given  $\epsilon, \lambda, C_{\min}/C_{\max}$ , and NTU. Ranganayakulu et. al. suggested 0.8 as the effectiveness limit below which the impact of longitudinal conduction is negligible.

With the theory and the results from the numerical simulations at hand, the impact of longitudinal tube conduction for a typical finned-tube evaporator was examined. Using EVAP5, a 10.6 kW (3 ton) evaporator was simulated to identify the tubes with two-phase R-22 (in which the longitudinal heat conduction does not occur) and the tubes with a

superheated refrigerant (in which longitudinal heat conduction does take place). Then the capacity penalty for the superheated tubes was calculated as a fraction of capacity of these tubes and as a fraction of the evaporator capacity.

Figure 4.3.3.1.1 displays an evaporator side view with a schematic of the refrigerant circuitry. Figure 4.3.3.1.2 contains a Coil Design Data window from EVAP-COND with the coil design information, and Figure 4.3.3.1.3 presents the operating conditions of the evaporator.

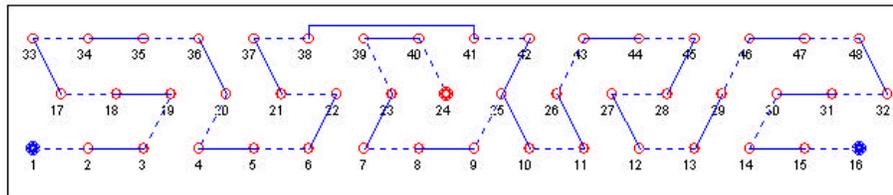


Figure 4.3.3.1.1: Refrigerant circuitry configuration for the analyzed R-22 evaporator (inlet tube: tube # 24, outlet tubes: tube # 1 and tube # 16; )



drop). An example of a tube with superheated vapor, tube number 15, has the following values for the aforementioned parameters.

$$I = \frac{kA_w}{LC_{\min}} = \frac{\left(386 \frac{\text{W}}{\text{mK}}\right) \left(1.1932\text{E}-5\text{m}^2\right)}{(0.454\text{m}) \left(9.476 \frac{\text{W}}{\text{K}}\right)} = 0.0011 \quad (4.3.3.1.3)$$

$$\frac{C_{\min}}{C_{\max}} = 0.441 \quad (4.3.3.1.4)$$

$$\text{NTU} = 0.368 \quad (4.3.3.1.5)$$

These parameters lie below the range of data given by Ranganayakulu. Using extrapolation, it was determined that the conduction effect factor would be approximately 0.0005. This means that this particular tube in the heat exchanger would see a loss in capacity of one twentieth of one percent due to axial heat conduction. When this capacity degradation is summed over all of the tubes in the entire heat exchanger where this effect occurs, the capacity reduction totals 0.13 W (0.45 Btu/h), which is insignificant when compared to the predicted performance of the evaporator being 49 000 W (16 800 Btu/h).

It should be noted that the effectiveness of tube 15 is 0.29. Hence, our result agrees with the general statements by Kays and London and that of Ranganayakulu et. al. that the longitudinal heat transfer has an insignificant effect for heat exchangers with an effectiveness less than 0.8. The negligible impact of the longitudinal tube conduction on evaporator performance permits neglecting this heat transfer in modeling of a finned-tube heat exchanger. It may be further inferred that the same conclusion can be made for the R407C zeotropic mixture. Although a 7 °C (12 °F) glide associated with R407C phase change produces a temperature difference promoting longitudinal heat transfer, in the

analyzed evaporator this glide would be distributed over 10 m (33 ft) of tube passes and would result in a small longitudinal temperature gradient.

#### *4.3.3.2 Tube-to-Tube Heat Transfer via Fins*

If we recognize that longitudinal tube heat conduction has a negligible impact, then the difference in capacity degradation between COIL-E and COIL-EC at 16.7 °C (30 °F) superheat must be due to longitudinal fin conduction. In COIL-EC, the continuous cuts in the fins separating different depth rows prevent heat transfer between different depth rows. However, the fins join the adjacent tubes in the same depth row, and some heat transfer between them occurs. This is why COIL-EC still experiences a decline in capacity, but not as much as COIL-E.

Our literature review located two publications that shed some light on the longitudinal fin conduction phenomenon. Heun and Crawford (1994) performed analytical study of the effects of longitudinal fin conduction on multipass cross-counterflow single-depth-row heat exchanger. They considered the fins to have one-dimensional temperature distributions and solve them using a system of non-dimensional differential equations. Their results showed that longitudinal fin conduction always degrades heat exchanger performance and this effect is stronger for a low normalized fin resistance and large values of the ratio of air-side conductance to air heat capacity rate.

Romero-Mender et al. (1997) also studied tube-to-tube heat transfer in a single-row finned-tube heat exchanger. They assumed the fins to be continuously and uniformly

distributed along the length of each tube. With his continuum assumption, they solved a system of ordinary differential equations for steady-state refrigerant and tube-wall temperatures. They identified four non-dimensional groups that effected the degradation of evaporator capacity. These group are: (1) the ratio of the thermal conductance for convective heat transfer between the refrigerant and the wall to the product of refrigerants heat capacity and mass flow rate, (2) the ratio of the thermal conductance for external heat transfer from the unfinned portion of the tube to the internal thermal conductance, (3) the ratio of the thermal conductance for convection from the fin to the thermal conductance for conduction along it, and (4) the ratio of the thermal conductance for heat conduction along the insulated fin to the thermal conductance between the refrigerant and the wall. Their study also indicated the number of tubes to be an influencing factor. The study by Romero-Mender et al. indicates that tube-to-tube heat transfer always degrades capacity and that the influencing parameters they identified have a non-linear impact on capacity degradation over the wide range of values studied. For some parametric values they found the degradation in a single-row heat exchanger to be as high as 20 %.

Our literature review have not located a publication that would discuss longitudinal fin conduction in a multi-depth-row evaporator, but it may be safely expected that capacity degradation would be higher than that for a single-depth-row coil. The literature review identified a very recent paper which presents three simulation models for finned-tube single-phase dehumidifying heat exchangers, the most advanced of which accounts for tube-to-tube heat transfer (Oliet et al. (2002)). This model, referred to as

“advancedCHESS”, is based on a finite volume approach with discretization of the heat exchanger domain into a set of control volumes as fin-and-tube elements where both local thermophysical properties and empirical coefficients are computed. While “advancedCHESS” appears to be a research model, two other models are more practical for production simulations. The two less advanced models, called “basicCHESS” and “quickCHESS”, do not consider tube-to-tube heat transfer.

While the above publications are very interesting and valuable, they do not offer a methodology for accounting for tube-to-tube heat transfer in a tube-by-tube simulation model. The number of influencing parameters identified for a dry fin by Romero-Mender et al. (1997) suggests that a fully fundamental approach will be difficult to implement into a tube-by-tube evaporator model, which uses the adiabatic fin tip assumption and considers an individual tube as a separate entity for heat transfer calculations. Our attempts to apply a few algorithms derived from their paper, however, were unsuccessful because we were unable to resolve the “clashes” between the fundamental algorithms and the current simulation scheme used in EVAP5. It appears that merging a fundamental scheme into EVAP5 amounts to a separate project that should be dedicated to this task.

To reach the objectives of the project within a stipulated effort and time, a practical scheme was developed, which uses the temperature difference between neighboring tubes as the driving force for heat transfer. This scheme approaches the tube-to-tube heat

transfer problem in a similar way Sheffield (1988) studied fin collar-tube heat transfer resistance as shown in Figure 4.3.3.2.1.

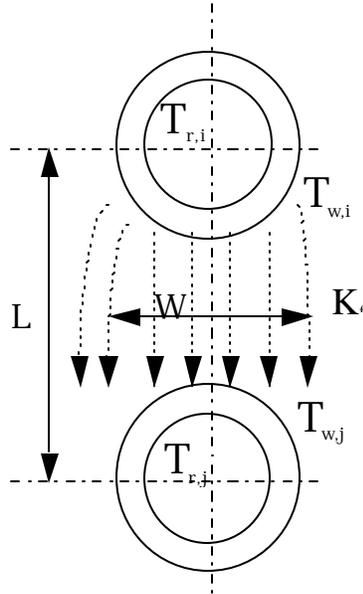


Figure 4.3.3.2.1: Schematic graph for longitudinal fin conduction between two adjacent tubes

To determine the heat transferred, the Fourier Law of Conduction is applied. The effects of the available width and configuration of the conducting material (fin) are represented by a “shape factor”  $S$  used in equation 4.9:

$$(Q_{fin})_{i,j} = \left( \frac{W \cdot t_f}{L} K_f \right) (T_{w,i} - T_{w,j}) = S \frac{t_f}{L} \cdot K_f (T_{w,i} - T_{w,j}) \quad (4.3.3.2.1)$$

To show the impact of fin conduction, Lee and Domanski used this scheme considering up to six immediate neighboring tubes. For example, for the circuitry used in the evaporators tested under this project and shown in Figure 4.3.3.2.2 the intermediate neighbors for tube 25 are tubes 7, 8, 26, 44, 43, and 24.

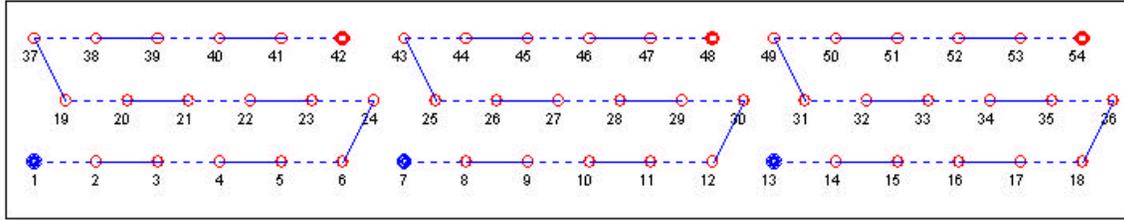


Figure 4.3.3.2.2: Schematic of refrigerant circuitry for COIL-W, COIL-E and COIL-EC in cross-counter flow configuration (inlet tubes: 42, 48, 54; outlet tubes: 1, 7, 13)

Extensive experimenting with this scheme for the coils tested under this project indicated that it was important to add additional neighbors to the group of immediate neighbors considered so far. This need demonstrated itself not only in predicted capacity values but also in simulation runs, which did not yield gradually changing predictions at small changes in imposed refrigerant superheat at the outlet tubes. Based on these observations, depending on location up to six second-order neighbors were added. These are other tubes in the coil assembly that a given tube “can see”. Tube 25 has four second-order neighbors; they are tubes 6, 9, 45, and 42. For tube 9, the immediate neighbors are tube 8, 10, 27, and 26, and the second-order neighbors are tubes 25, 45, and 28. In a three-depth-row coil, the maximum number of second-order neighbors is four. A five-depth-row coil is need for a tube located in the middle depth row to have all six second-order neighbors.

The value of the shape factor depends on a fin design. For flat and wavy fins the fin material is continuous. Lanced fins, however, have numerous cuts, which reduce the fin cross-section area that is available for heat transfer. Hence, the shape factor for flat and wavy fins should be expected to have higher values than for lanced or louver fins. Since

we are not aware of any publication that quantifies the fin shape factor, the values for COIL-W and COIL-E were assigned based on their respective results for test 10. Once these values for shape factors were assigned, they were left unchanged for the remaining simulations. COIL-EC used the same shape factor as COIL-E, however, any tube in COIL-EC could have only two neighbors, the closest two tubes located in the same depth row.

Figure 4.3.3.2.3 shows tested and simulated capacities for COIL-E at conditions of test 1, 2, 9, 10, 13, and 14. For the tests at 5.6 °C (10 °F) superheat (tests 1, 9 and 13), the model predicted measured capacities within 5.1 %. For the tests with 16.7 °C (30 °F) superheat, the differences in between tested and predicted and tested capacities were – 6.7 %, 3.1 %, and - 2.9 %. Without accounting for tube-to-tube heat transfer, EVAP5 would overpredict the capacities at 16.7 °C (30 °F) superheat by approximately 20 %. Section 4.4 presents validation results for all three evaporators.

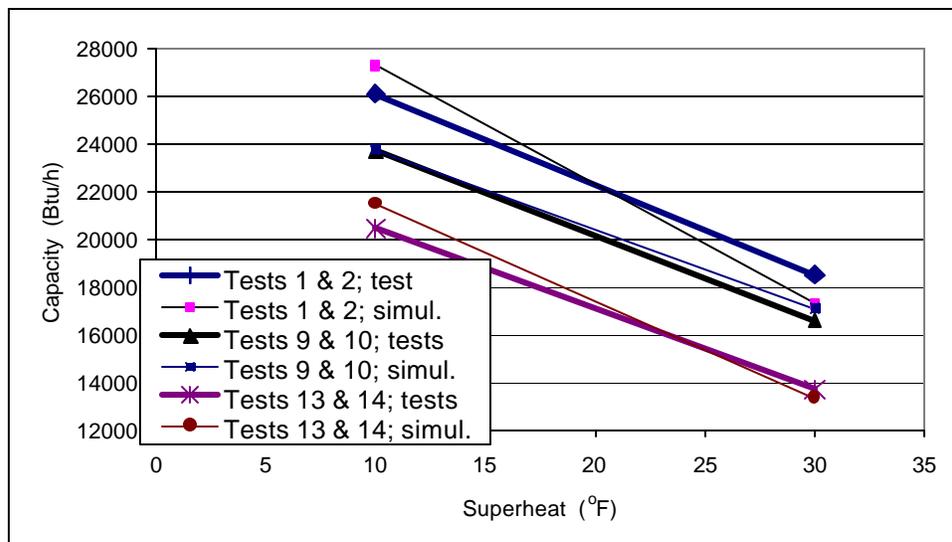


Figure 4.3.3.2.3: COIL-E measured and simulated capacities for tests with 5.6 °C (10 °F) and 16.7 °C (30 °F) superheats (tests 1, 2, 9, 10, 13, 14)

## **4.4 Validation and Simulations with EVAP5**

### 4.4.1 Validation of EVAP5

The majority of laboratory test data measured in this study are for a cross-counter flow configuration with non-disturbed (uniform) air velocity profile at the coil inlet. These measurements for COIL-W, COIL-E, and COIL-EC were used to validate EVAP5 and explore the impact of tube-to-tube heat transfer. The imposed variety of refrigerant superheats at individual exit tubes combined with a wide range of air flow provided a unique set of challenging test data for validating any evaporator model.

The refrigerant circuitry for the tested evaporators has already been presented in Figure 4.3.3.2.2 as it is displayed by the EVAP-COND interface. Also copying from the respective window of EVAP-COND, Figure 4.4.1.1 shows the key design parameters of COIL-W. Except for a different fin design, these parameters were the same for COIL-E and COIL-EC.

At the outset of simulations for each coil, EVAP5 was “tuned” to predict the performance of a given evaporator at the conditions of test 9. This was accomplished by inputting “corrections parameters” for the refrigerant heat transfer coefficient, refrigerant pressure drop, and air-side heat transfer coefficient. (Section 4.3.2 discusses the reasons for using these parameters in the context of prediction discrepancies between different air-side correlations). Figure 4.4.1.2 presents the correction parameters for COIL-W and COIL-E

as they were input into the EVAP-COND window. The input for COIL-EC was different by the value for the air-side heat transfer coefficient, which was 0.62 instead of 0.65. The 1.6 value for the refrigerant pressure drop parameter accounts for the impact of lubricant, which can be responsible for 35 % pressure drop underprediction. Since the parameter for refrigerant heat transfer coefficient was set to 1.0, the 0.65 or 0.62 value for the air-side heat transfer coefficient accommodates the heat transfer adjustment on the air and refrigerant sides. These correction parameters were used in all simulations for the respective coils.

The screenshot shows a software dialog box titled "Coil Design Data". It is divided into several sections for inputting design parameters:

- Data for a section:** A table with five rows for the number of tubes in each depth row.
 

|                               |    |
|-------------------------------|----|
| No. of tubes in depth row #1: | 18 |
| No. of tubes in depth row #2: | 18 |
| No. of tubes in depth row #3: | 18 |
| No. of tubes in depth row #4: | 0  |
| No. of tubes in depth row #5: | 0  |
- Coil Model:** A text box containing "W02027B-3 W-counter (9)".
- Number of repeating sections:** A text box containing "1".
- Units:** Two checkboxes: "SI Units" (unchecked) and "British Units" (checked).
- Tube data:** A list of parameters for the tubes:
 

|                      |              |        |
|----------------------|--------------|--------|
| Tube length          | in           | 18     |
| Inner diameter       | in           | 0.3125 |
| Outer diameter       | in           | 0.375  |
| Tube pitch           | in           | 1      |
| Depth row pitch      | in           | 0.866  |
| Inner surface        |              | Smooth |
| Thermal conductivity | Btu/(ft.h.F) | 223    |
- Fin data:** A list of parameters for the fins:
 

|                      |              |        |
|----------------------|--------------|--------|
| Thickness            | in           | 0.016  |
| Pitch                | in           | 0.0625 |
| Type                 |              | Wavy   |
| Thermal conductivity | Btu/(ft.h.F) | 128    |

At the bottom right of the dialog box are "Cancel" and "OK" buttons.

Figure 4.4.1.1: Design parameters for COIL-W

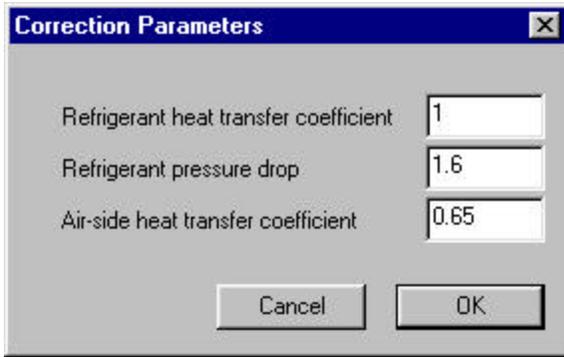


Figure 4.4.1.2: Correction parameters for COIL-W and COIL-E

Tables 4.4.1.1, 4.4.1.2, and 4.4.1.3 show tested and simulated total capacities for COIL-W, COIL-E, and COIL-EC, respectively, in the test matrix format. Tables 4.4.1.4a, 4.4.1.4b, 4.4.1.5a, 4.4.1.5b, 4.4.1.6a, and 4.4.1.6b present total and sensible capacities, sensible heat ratios, and differences between simulated and measured results. It is convenient to screen the accuracy of capacity predictions by reviewing Figures 4.4.1.3 and 4.4.1.4. Figure 4.4.1.3 shows that the maximum error in capacity prediction for wet coil tests was 5.5 % for all air velocities and refrigerant superheat scenarios. For dry coil tests shown in Figure 4.4.1.4, EVAP5 predicted the three capacities at uniform 5.6 °C (10 °F) superheat within 5.0 %. (They are represented by the first bar for each coil). For the remaining six tests at different superheat scenarios, the only capacity predicted within 5.0 % was for COIL-EC (represented by the last bar on the right hand side). Capacities for COIL-W and COIL-E capacities were unpredicted by as much as 20.0 %. The inability of EVAP5 to account accurately for longitudinal fin conduction for dry coil tests can be explained by the fact that the used algorithm considers only temperature differences between neighboring tubes (the first order effect) and neglects variations in air-side heat transfer. This conclusion agrees with the observation by Romero-Mendez et

al. (1997) who indicated thermal conductance for convection from the fin as one of the parameters affecting tube-to-tube heat transfer. This and other effects identified by Romero-Mendez et al. (1997) should receive detailed attention in a future study dedicated to this challenging modeling issue.

Table 4.4.1.1: Measured and Simulated Capacities for COIL-W in Cross-Counter Flow Configuration

| Test Name                      | Test # | Volumetric Flowrate or Air m <sup>3</sup> /min (cfm) |                               |                                | Coil Surface |                               | Overall Superheat                 |                                |                              |                               |                        |                 |                           |                 |
|--------------------------------|--------|--|-------------------------------|--------------------------------|--------------|-------------------------------|-----------------------------------|--------------------------------|------------------------------|-------------------------------|------------------------|-----------------|---------------------------|-----------------|
|                                |        |  |                               |                                |              |                               | Superheats in Individual Circuits |                                |                              |                               |                        |                 |                           |                 |
|                                |        | 145-Q <sup>1</sup><br>(300-Q)                        | 193-Q <sup>1</sup><br>(400-Q) | 242-Q <sup>1</sup><br>(500-Q)  | Dry          | Wet                           | 5.6 °C (10.0 °F)                  |                                | 16.7 °C (30.0 °F)            |                               | 5.6 °C (10.0 °F)       |                 | 5.6 °C (10.0 °F)          |                 |
|                                |        |  |                               |                                |              |                               | 5.6/5.6/5.6<br>(10/10/10)         |                                | 16.7/16.7/16.7<br>(30/30/30) |                               | 16.7*/16.7<br>(30*/30) |                 | */16.7/16.7<br>(* /30/30) |                 |
| Q <sub>test</sub><br>W (Btu/h) |        | Q <sub>sim</sub><br>W (Btu/h)                        |                               | Q <sub>test</sub><br>W (Btu/h) |              | Q <sub>sim</sub><br>W (Btu/h) |                                   | Q <sub>test</sub><br>W (Btu/h) |                              | Q <sub>sim</sub><br>W (Btu/h) |                        |                 |                           |                 |
| W020226A                       | 1      | x  |                               |                                |              | x                             | 5787<br>(19746)                   | 5747<br>(19609)                |                              |                               |                        |                 |                           |                 |
|                                | 2      | x  |                               |                                |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 3      | x  |                               |                                |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 4      | x  |                               |                                |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
| W020225B                       | 5      |  | x                             |                                | x            |                               | 5428<br>(18521)                   | 5417<br>(18485)                |                              |                               |                        |                 |                           |                 |
| W020228A                       | 6      |  | x                             |                                | x            |                               |                                   |                                | 3595<br>(12265)              | 2953<br>(10076)               |                        |                 |                           |                 |
| W020221A                       | 7      |  | x                             |                                | x            |                               |                                   |                                |                              |                               | 3910<br>(13341)        | 3168<br>(10810) |                           |                 |
| W020225A                       | 8      |  | x                             |                                | x            |                               |                                   |                                |                              |                               |                        |                 | 3888<br>(13267)           | 3360<br>(11464) |
| W020207B                       | 9      |  | x                             |                                |              | x                             | 6507<br>(22203)                   | 6485<br>(22127)                |                              |                               |                        |                 |                           |                 |
| W020530A                       | 10     |  | x                             |                                |              | x                             |                                   |                                | 3722<br>(12701)              | 3819<br>(13030)               |                        |                 |                           |                 |
| W020531A                       | 11     |  | x                             |                                |              | x                             |                                   |                                |                              |                               | 3837<br>(13091)        | 3819<br>(13030) |                           |                 |
| W020215B                       | 12     |  | x                             |                                |              | x                             |                                   |                                |                              |                               |                        |                 | 3830<br>(13067)           | 3885<br>(13255) |
| W020301A                       | 13     |  |                               | x                              |              | x                             | 7502<br>(25598)                   | 7727<br>(26367)                |                              |                               |                        |                 |                           |                 |
|                                | 14     |  |                               | x                              |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 15     |  |                               | x                              |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 16     |  |                               | x                              |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |

\* Superheat to be controlled such that the desired overall level of superheat is obtained

1) SI units of m<sup>3</sup>/kW h multiplied by capacity (Q) in kW to determine airflow (IP units of cfm/ton multiplied by capacity (Q) in tons).

Table 4.4.1.2: Measured and Simulated Capacities for COIL-E in Cross-Counter Flow Configuration

| Test Name                      | Test # | Volumetric Flowrate of Air m <sup>3</sup> /h (scfm) |                               |                                | Coil Surface |                               | Overall Superheat                 |                                |                              |                               |                        |                 |                           |                 |
|--------------------------------|--------|---|-------------------------------|--------------------------------|--------------|-------------------------------|-----------------------------------|--------------------------------|------------------------------|-------------------------------|------------------------|-----------------|---------------------------|-----------------|
|                                |        |   |                               |                                |              |                               | Superheats in Individual Circuits |                                |                              |                               |                        |                 |                           |                 |
|                                |        | 145·Q <sup>1</sup><br>(300·Q)                       | 193·Q <sup>1</sup><br>(400·Q) | 242·Q <sup>1</sup><br>(500·Q)  | Dry          | Wet                           | 5.6 °C (10.0 °F)                  |                                | 16.7 °C (30.0 °F)            |                               | 5.6 °C (10.0 °F)       |                 | 5.6 °C (10.0 °F)          |                 |
|                                |        |   |                               |                                |              |                               | 5.6/5.6/5.6<br>(10/10/10)         |                                | 16.7/16.7/16.7<br>(30/30/30) |                               | 16.7*/16.7<br>(30*/30) |                 | */16.7/16.7<br>(*/*30/30) |                 |
| Q <sub>test</sub><br>W (Btu/h) |        | Q <sub>sim</sub><br>W (Btu/h)                       |                               | Q <sub>test</sub><br>W (Btu/h) |              | Q <sub>sim</sub><br>W (Btu/h) |                                   | Q <sub>test</sub><br>W (Btu/h) |                              | Q <sub>sim</sub><br>W (Btu/h) |                        |                 |                           |                 |
| W020320B                       | 1      | x   |                               |                                |              | x                             | 5998<br>(20464)                   | 6239<br>(21289)                |                              |                               |                        |                 |                           |                 |
| W020321A                       | 2      | x   |                               |                                |              | x                             |                                   |                                | 4026<br>(13737)              | 3806<br>(12987)               |                        |                 |                           |                 |
|                                | 3      | x   |                               |                                |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 4      | x   |                               |                                |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
| E020322A                       | 5      |   | x                             |                                | x            |                               | 5603<br>(19115)                   | 5323<br>(18163)                |                              |                               |                        |                 |                           |                 |
| E020321B                       | 6      |   | x                             |                                | x            |                               |                                   |                                | 4302<br>(14677)              | 3466<br>(11828)               |                        |                 |                           |                 |
| E020322C                       | 7      |   | x                             |                                | x            |                               |                                   |                                |                              |                               | 4797<br>(16367)        | 3835<br>(13086) |                           |                 |
| E020328B                       | 8      |   | x                             |                                | x            |                               |                                   |                                |                              |                               |                        |                 | 4700<br>(16037)           | 3794<br>(12945) |
| E020607A                       | 9      |   | x                             |                                |              | x                             | 6956<br>(23733)                   | 6977<br>(23807)                |                              |                               |                        |                 |                           |                 |
| E020318A                       | 10     |   | x                             |                                |              | x                             |                                   |                                | 4865<br>(16599)              | 5055<br>(17249)               |                        |                 |                           |                 |
| E020318B                       | 11     |   | x                             |                                |              | x                             |                                   |                                |                              |                               | 5485<br>(18715)        | 5181<br>(17678) |                           |                 |
| E020319A                       | 12     |   | x                             |                                |              | x                             |                                   |                                |                              |                               |                        |                 | 4736<br>(16157)           | 4774<br>(16289) |
| W020319B                       | 13     |   |                               | x                              |              | x                             | 7653<br>(26109)                   | 8027<br>(27389)                |                              |                               |                        |                 |                           |                 |
| W020320A                       | 14     |   |                               | x                              |              | x                             |                                   |                                | 5429<br>(18524)              | 5693<br>(19427)               |                        |                 |                           |                 |
|                                | 15     |   |                               | x                              |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |
|                                | 16     |   |                               | x                              |              | x                             |                                   |                                |                              |                               |                        |                 |                           |                 |

\* Superheat to be controlled such that the desired overall level of superheat is obtained

1 SI units of m<sup>3</sup>/kW h multiplied by capacity (Q) in kW to determine airflow (IP units of cfm/ton multiplied by capacity (Q) in tons)

Table 4.4.1.3: Measured and Simulated Capacities for COIL-EC in Cross-Counter Flow Configuration

| Test Name                      | Test #                        | Volumetric Flowrate or Air m <sup>3</sup> /h (scfm) |                               |                                | Coil Surface                  |                                | Overall Superheat                 |                                |                               |                 |                          |  |                            |  |
|--------------------------------|-------------------------------|---|-------------------------------|--------------------------------|-------------------------------|--------------------------------|-----------------------------------|--------------------------------|-------------------------------|-----------------|--------------------------|--|----------------------------|--|
|                                |                               |   |                               |                                |                               |                                | Superheats in Individual Circuits |                                |                               |                 |                          |  |                            |  |
|                                |                               | 145·Q <sup>1</sup><br>(300·Q)                       | 193·Q <sup>1</sup><br>(400·Q) | 242·Q <sup>1</sup><br>(500·Q)  | Dry                           | Wet                            | 5.6 °C (10.0 °F)                  |                                | 16.7 °C (30.0 °F)             |                 | 5.6 °C (10.0 °F)         |  | 5.6 °C (10.0 °F)           |  |
|                                |                               |   |                               |                                |                               |                                | 5.6/5.6/5.6<br>(10/10/10)         |                                | 16.7/16.7/16.7<br>(30/30/30)  |                 | 16.7/*/16.7<br>(30/*/30) |  | */16.7/16.7<br>(*/*/30/30) |  |
| Q <sub>test</sub><br>W (Btu/h) | Q <sub>sim</sub><br>W (Btu/h) | Q <sub>test</sub><br>W (Btu/h)                      | Q <sub>sim</sub><br>W (Btu/h) | Q <sub>test</sub><br>W (Btu/h) | Q <sub>sim</sub><br>W (Btu/h) | Q <sub>test</sub><br>W (Btu/h) | Q <sub>sim</sub><br>W (Btu/h)     | Q <sub>test</sub><br>W (Btu/h) | Q <sub>sim</sub><br>W (Btu/h) |                 |                          |  |                            |  |
| E020417A                       | 1                             | x   |                               |                                |                               | x                              | 6085<br>(20760)                   | 6189<br>(21117)                |                               |                 |                          |  |                            |  |
| E020417B                       | 2                             | x   |                               |                                |                               | x                              |                                   |                                | 4647<br>(15855)               | 4890<br>(16684) |                          |  |                            |  |
|                                | 3                             | x   |                               |                                |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |
|                                | 4                             | x   |                               |                                |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |
| E020418A                       | 5                             |   | x                             |                                | x                             |                                | 5578<br>(19032)                   | 5356<br>(18272)                |                               |                 |                          |  |                            |  |
| E020419A                       | 6                             |   | x                             |                                | x                             |                                |                                   |                                | 4170<br>(14226)               | 4291<br>(14640) |                          |  |                            |  |
|                                | 7                             |   | x                             |                                | x                             |                                |                                   |                                |                               |                 |                          |  |                            |  |
|                                | 8                             |   | x                             |                                | x                             |                                |                                   |                                |                               |                 |                          |  |                            |  |
| E020415A                       | 9                             |   | x                             |                                |                               | x                              | 6972<br>(23788)                   | 6989<br>(23845)                |                               |                 |                          |  |                            |  |
| E020509A                       | 10                            |   | x                             |                                |                               | x                              |                                   |                                | 5361<br>(18292)               | 5467<br>(18652) |                          |  |                            |  |
|                                | 11                            |   | x                             |                                |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |
|                                | 12                            |   | x                             |                                |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |
| E020416B                       | 13                            |   |                               | x                              |                               | x                              | 7781<br>(26546)                   | 7927<br>(27047)                |                               |                 |                          |  |                            |  |
| E020416A                       | 14                            |   |                               | x                              |                               | x                              |                                   |                                | 6653<br>(22700)               | 6007<br>(20496) |                          |  |                            |  |
|                                | 15                            |   |                               | x                              |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |
|                                | 16                            |   |                               | x                              |                               | x                              |                                   |                                |                               |                 |                          |  |                            |  |

\* Superheat to be controlled such that the desired overall level of superheat is obtained

1) SI units of m<sup>3</sup>/kW h multiplied by capacity (Q) in kW to determine airflow (IP units of cfm/ton multiplied by capacity (Q) in tons).

Table 4.4.1.4a: EVAP5 Validations for COIL-W (evaporator with wavy fins), SI Units

| Flow configuration | Test name | Test # | Test results          |                          |                                | Simulations with fin conduction included |                          |                                |                         |                         | Simulated capacity w/o fin conduction |                                      |
|--------------------|-----------|--------|-----------------------|--------------------------|--------------------------------|--|--------------------------|--------------------------------|-------------------------|-------------------------|---------------------------------------|--------------------------------------|
|                    |           |        | Total capacity (watt) | Sensible capacity (watt) | Sensible heat ratio (fraction) | Results                                  |                          |                                | Difference <sup>1</sup> |                         | Total capacity (watt)                 | Capacity difference <sup>2</sup> (%) |
|                    |           |        |                       |                          |                                | Total capacity (watt)                    | Sensible capacity (watt) | Sensible heat ratio (fraction) | Total Capacity (%)      | Sensible heat ratio (%) |                                       |                                      |
| cross-counter      | W020226A  | 1      | 5788                  | 3953                     | 0.68                           | 5747                                     | 3706                     | 0.64                           | -0.7                    | -5.9                    | 5837                                  | 1.6                                  |
| cross-counter      | W020225B  | 5      | 5429                  | 5429                     | 1.00                           | 5418                                     | 5418                     | 1.00                           | -0.2                    | 0.0                     | 5425                                  | 0.1                                  |
| cross-counter      | W020228A  | 6      | 3595                  | 3595                     | 1.00                           | 2953                                     | 2954                     | 1.00                           | -17.8                   | 0.0                     | 4816                                  | 63.1                                 |
| cross-counter      | W020221A  | 7      | 3910                  | 3910                     | 1.00                           | 3168                                     | 3168                     | 1.00                           | -19.0                   | 0.0                     |                                       |                                      |
| cross-counter      | W020225A  | 8      | 3889                  | 3889                     | 0.76                           | 3360                                     | 3360                     | 1.00                           | -13.6                   | 0.0                     |                                       |                                      |
| cross-counter      | W020207B  | 9      | 6508                  | 4914                     | 0.76                           | 6485                                     | 4724                     | 0.73                           | -0.3                    | -3.7                    | 6499                                  | 0.2                                  |
| cross-counter      | W020530A  | 10     | 3723                  | 3381                     | 0.91                           | 3819                                     | 3014                     | 0.79                           | 2.6                     | -15.1                   | 5968                                  | 56.3                                 |
| cross-counter      | W020531A  | 11     | 3837                  | 3372                     | 0.88                           | 3819                                     | 2939                     | 0.77                           | -0.5                    | -14.2                   |                                       |                                      |
| cross-counter      | W020215B  | 12     | 3830                  | 3503                     | 0.91                           | 3885                                     | 3013                     | 0.78                           | 1.4                     | -17.9                   | 7810                                  | 1.1                                  |
| cross-counter      | W020301A  | 13     | 7503                  | 5820                     | 0.78                           | 7728                                     | 5678                     | 0.73                           | 3.0                     | -5.6                    |                                       |                                      |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

Table 4.4.1.4b: EVAP5 Validations for COIL-W (evaporator with wavy fins), IP Units

| Flow configuration | Test name | Test # | Test results           |                           |                                | Simulations with fin conduction included |                           |                                |                         |                         | Simulated capacity w/o fin conduction |                                      |
|--------------------|-----------|--------|------------------------|---------------------------|--------------------------------|--|---------------------------|--------------------------------|-------------------------|-------------------------|---------------------------------------|--------------------------------------|
|                    |           |        |                        |                           |                                | Results                                  |                           |                                | Difference <sup>1</sup> |                         |                                       |                                      |
|                    |           |        | Total capacity (Btu/h) | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total capacity (Btu/h)                   | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total Capacity (%)      | Sensible heat ratio (%) | Total capacity (Btu/h)                | Capacity difference <sup>2</sup> (%) |
| cross-counter      | W020226A  | 1      | 19746                  | 13488                     | 0.68                           | 19609                                    | 12643                     | 0.64                           | -0.7                    | -5.9                    | 19916                                 | 1.6                                  |
| cross-counter      | W020225B  | 5      | 18521                  | 18521                     | 1.00                           | 18485                                    | 18485                     | 1.00                           | -0.2                    | 0.0                     | 18509                                 | 0.1                                  |
| cross-counter      | W020228A  | 6      | 12265                  | 12265                     | 1.00                           | 10076                                    | 10077                     | 1.00                           | -17.8                   | 0.0                     | 16431                                 | 63.1                                 |
| cross-counter      | W020221A  | 7      | 13341                  | 13341                     | 1.00                           | 10810                                    | 10810                     | 1.00                           | -19.0                   | 0.0                     |                                       |                                      |
| cross-counter      | W020225A  | 8      | 13267                  | 13267                     | 0.76                           | 11464                                    | 11465                     | 1.00                           | -13.6                   | 0.0                     |                                       |                                      |
| cross-counter      | W020207B  | 9      | 22203                  | 16767                     | 0.76                           | 22127                                    | 16119                     | 0.73                           | -0.3                    | -3.7                    | 22172                                 | 0.2                                  |
| cross-counter      | W020530A  | 10     | 12701                  | 11535                     | 0.91                           | 13030                                    | 10283                     | 0.79                           | 2.6                     | -15.1                   | 20363                                 | 56.3                                 |
| cross-counter      | W020531A  | 11     | 13091                  | 11503                     | 0.88                           | 13030                                    | 10029                     | 0.77                           | -0.5                    | -14.2                   |                                       |                                      |
| cross-counter      | W020215B  | 12     | 13067                  | 11950                     | 0.91                           | 13255                                    | 10281                     | 0.78                           | 1.4                     | -17.9                   |                                       |                                      |
| cross-counter      | W020301A  | 13     | 25598                  | 19857                     | 0.78                           | 26367                                    | 19372                     | 0.73                           | 3.0                     | -5.6                    | 26645                                 | 1.1                                  |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

Table 4.4.1.5a: EVAP5 Validations for COIL-E (evaporator with lanced fins), SI Units

| Flow configuration | Test Name | Test # | Test results          |                          |                                | Simulations with fin conduction included |                          |                                |                         |                         | Simulated capacity w/o conduction |                                      |
|--------------------|-----------|--------|-----------------------|--------------------------|--------------------------------|--|--------------------------|--------------------------------|-------------------------|-------------------------|-----------------------------------|--------------------------------------|
|                    |           |        |                       |                          |                                | Results                                  |                          |                                | Difference <sup>1</sup> |                         |                                   |                                      |
|                    |           |        | Total capacity (watt) | Sensible capacity (watt) | Sensible heat ratio (fraction) | Total capacity (watt)                    | Sensible capacity (watt) | Sensible heat ratio (fraction) | Total Capacity (%)      | Sensible heat ratio (%) | Total capacity (watt)             | Capacity difference <sup>2</sup> (%) |
| cross-counter      | W020320B  | 1      | 5998                  | 3959                     | 0.66                           | 6239                                     | 3876                     | 0.62                           | 4.0                     | -5.9                    | 6238                              | 0.0                                  |
| cross-counter      | W020321A  | 2      | 4026                  | 3171                     | 0.79                           | 3806                                     | 2733                     | 0.72                           | -5.5                    | -8.8                    | 5196                              | 36.5                                 |
| cross-counter      | E020322A  | 5      | 5603                  | 5603                     | 1.0                            | 5323                                     | 5323                     | 1.00                           | -5.0                    | 0.0                     | 5426                              | 1.9                                  |
| cross-counter      | E020321B  | 6      | 4302                  | 4302                     | 1.0                            | 3466                                     | 3466                     | 1.00                           | -19.4                   | 0.0                     | 4572                              | 31.9                                 |
| cross-counter      | E020322C  | 7      | 4797                  | 4797                     | 1.0                            | 3835                                     | 3835                     | 1.00                           | -20.0                   | 0.0                     |                                   |                                      |
| cross-counter      | E020328B  | 8      | 4700                  | 4700                     | 1.0                            | 3794                                     | 3794                     | 1.00                           | -19.3                   | 0.0                     |                                   |                                      |
| cross-counter      | E020607A  | 9      | 6956                  | 5057                     | 0.73                           | 6977                                     | 4677                     | 0.67                           | 0.3                     | -7.8                    | 6952                              | -0.4                                 |
| cross-counter      | E020318A  | 10     | 4865                  | 3981                     | 0.82                           | 5055                                     | 3810                     | 0.75                           | 3.9                     | -7.9                    | 5723                              | 13.2                                 |
| cross-counter      | E020318B  | 11     | 5485                  | 4266                     | 0.78                           | 5181                                     | 3789                     | 0.73                           | -5.5                    | -6.0                    |                                   |                                      |
| cross-counter      | E020319A  | 12     | 4736                  | 3943                     | 0.83                           | 4774                                     | 3541                     | 0.74                           | 0.8                     | -10.9                   |                                   |                                      |
| cross-counter      | W020319B  | 13     | 7653                  | 5720                     | 0.75                           | 8027                                     | 5651                     | 0.70                           | 4.9                     | -5.8                    | 8004                              | -0.3                                 |
| cross-counter      | W020320A  | 14     | 5429                  | 4615                     | 0.85                           | 5693                                     | 4338                     | 0.76                           | 4.9                     | -10.4                   | 6395                              | 12.3                                 |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

Table 4.4.1.5b: EVAP5 Validations for COIL-E (evaporator with lanced fins), IP Units

| Flow configuration | Test Name | Test # | Test results           |                           |                                | Simulations with fin conduction included |                           |                                |                         |                         | Simulated capacity w/o conduction |                                      |
|--------------------|-----------|--------|------------------------|---------------------------|--------------------------------|--|---------------------------|--------------------------------|-------------------------|-------------------------|-----------------------------------|--------------------------------------|
|                    |           |        |                        |                           |                                | Results                                  |                           |                                | Difference <sup>1</sup> |                         |                                   |                                      |
|                    |           |        | Total capacity (Btu/h) | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total capacity (Btu/h)                   | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total Capacity (%)      | Sensible heat ratio (%) | Total capacity (Btu/h)            | Capacity difference <sup>2</sup> (%) |
| cross-counter      | W020320B  | 1      | 20464                  | 13506                     | 0.66                           | 21289                                    | 13224                     | 0.62                           | 4.0                     | -5.9                    | 21284                             | 0.0                                  |
| cross-counter      | W020321A  | 2      | 13737                  | 10819                     | 0.79                           | 12987                                    | 9324                      | 0.72                           | -5.5                    | -8.8                    | 17730                             | 36.5                                 |
| cross-counter      | E020322A  | 5      | 19115                  | 19115                     | 1.0                            | 18163                                    | 18163                     | 1.00                           | -5.0                    | 0.0                     | 18514                             | 1.9                                  |
| cross-counter      | E020321B  | 6      | 14677                  | 14677                     | 1.0                            | 11828                                    | 11828                     | 1.00                           | -19.4                   | 0.0                     | 15602                             | 31.9                                 |
| cross-counter      | E020322C  | 7      | 16367                  | 16367                     | 1.0                            | 13086                                    | 13086                     | 1.00                           | -20.0                   | 0.0                     |                                   |                                      |
| cross-counter      | E020328B  | 8      | 16037                  | 16037                     | 1.0                            | 12945                                    | 12945                     | 1.00                           | -19.3                   | 0.0                     |                                   |                                      |
| cross-counter      | E020607A  | 9      | 23733                  | 17252                     | 0.73                           | 23807                                    | 15957                     | 0.67                           | 0.3                     | -7.8                    | 23720                             | -0.4                                 |
| cross-counter      | E020318A  | 10     | 16599                  | 13581                     | 0.82                           | 17249                                    | 13000                     | 0.75                           | 3.9                     | -7.9                    | 19528                             | 13.2                                 |
| cross-counter      | E020318B  | 11     | 18715                  | 14556                     | 0.78                           | 17678                                    | 12927                     | 0.73                           | -5.5                    | -6.0                    |                                   |                                      |
| cross-counter      | E020319A  | 12     | 16157                  | 13452                     | 0.83                           | 16289                                    | 12081                     | 0.74                           | 0.8                     | -10.9                   |                                   |                                      |
| cross-counter      | W020319B  | 13     | 26109                  | 19517                     | 0.75                           | 27389                                    | 19282                     | 0.70                           | 4.9                     | -5.8                    | 27312                             | -0.3                                 |
| cross-counter      | W020320A  | 14     | 18524                  | 15744                     | 0.85                           | 19427                                    | 14802                     | 0.76                           | 4.9                     | -10.4                   | 21820                             | 12.3                                 |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

Table 4.4.1.6a: EVAP5 Validation for COIL-EC (evaporator with lanced fins, cut between tube depth rows), SI Units

| Flow configuration | Test name | Test # | Test results          |                          |                                | Simulations with fin conduction included |                          |                                |                          |                         | Simulated capacity w/o fin conduction |                              |
|--------------------|-----------|--------|-----------------------|--------------------------|--------------------------------|--|--------------------------|--------------------------------|--------------------------|-------------------------|---------------------------------------|------------------------------|
|                    |           |        |                       |                          |                                | Results                                  |                          |                                | Difference <sup>1)</sup> |                         |                                       |                              |
|                    |           |        | Total capacity (watt) | Sensible capacity (watt) | Sensible heat ratio (fraction) | Total capacity (watt)                    | Sensible capacity (watt) | Sensible heat ratio (fraction) | Total Capacity (%)       | Sensible heat ratio (%) | Total Capacity (watt)                 | Difference <sup>2)</sup> (%) |
| cross-counter      | E020417A  | 1      | 6085                  | 4182                     | 0.69                           | 6189                                     | 3950                     | 0.64                           | 1.7                      | -7.7                    | 6196                                  | 0.1                          |
| cross-counter      | E020417B  | 2      | 4647                  | 3577                     | 0.77                           | 4890                                     | 3329                     | 0.68                           | 5.2                      | -13.1                   | 4962                                  | 1.5                          |
| cross-counter      | E020418A  | 5      | 5578                  | 5578                     | 1.0                            | 5356                                     | 5356                     | 1.0                            | -4.0                     | 0.0                     | 5360                                  | 0.1                          |
| cross-counter      | E020419A  | 6      | 4170                  | 4170                     | 1.0                            | 4291                                     | 4291                     | 1.0                            | 2.9                      | 0.0                     | 4400                                  | 2.5                          |
| cross-counter      | E020415A  | 9      | 6972                  | 5125                     | 0.74                           | 6989                                     | 4816                     | 0.69                           | 0.2                      | -6.7                    | 7005                                  | 0.2                          |
| cross-counter      | E020509A  | 10     | 5361                  | 4361                     | 0.81                           | 5467                                     | 4044                     | 0.74                           | 2.0                      | -10.0                   | 5579                                  | 2.0                          |
| cross-counter      | E020416B  | 13     | 7781                  | 6083                     | 0.78                           | 7927                                     | 5778                     | 0.73                           | 1.9                      | -7.3                    | 7990                                  | 0.8                          |
| cross-counter      | E020416A  | 14     | 6653                  | 5465                     | 0.82                           | 6382                                     | 4893                     | 0.77                           | -4.1                     | -7.1                    | 6694                                  | 4.9                          |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

Table 4.4.1.6b: EVAP5 Validation for COIL-EC (evaporator with lanced fins, cut between tube depth rows), IP Units

| Flow configuration | Test name | Test # | Test results           |                           |                                | Simulations with fin conduction included |                           |                                |                          |                         | Simulated capacity w/o fin conduction |                              |
|--------------------|-----------|--------|------------------------|---------------------------|--------------------------------|--|---------------------------|--------------------------------|--------------------------|-------------------------|---------------------------------------|------------------------------|
|                    |           |        |                        |                           |                                | Results                                  |                           |                                | Difference <sup>1)</sup> |                         |                                       |                              |
|                    |           |        | Total capacity (Btu/h) | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total capacity (Btu/h)                   | Sensible capacity (Btu/h) | Sensible heat ratio (fraction) | Total Capacity (%)       | Sensible heat ratio (%) | Total Capacity (Btu/h)                | Difference <sup>2)</sup> (%) |
| cross-counter      | E020417A  | 1      | 20760                  | 14269                     | 0.69                           | 21117                                    | 13477                     | 0.64                           | 1.7                      | -7.7                    | 21138                                 | 0.1                          |
| cross-counter      | E020417B  | 2      | 15855                  | 12204                     | 0.77                           | 16684                                    | 11359                     | 0.68                           | 5.2                      | -13.1                   | 16928                                 | 1.5                          |
| cross-counter      | E020418A  | 5      | 19032                  | 19032                     | 1.0                            | 18272                                    | 18273                     | 1.0                            | -4.0                     | 0.0                     | 18287                                 | 0.1                          |
| cross-counter      | E020419A  | 6      | 14226                  | 14226                     | 1.0                            | 14640                                    | 14641                     | 1.0                            | 2.9                      | 0.0                     | 15013                                 | 2.5                          |
| cross-counter      | E020415A  | 9      | 23788                  | 17485                     | 0.74                           | 23845                                    | 16432                     | 0.69                           | 0.2                      | -6.7                    | 23898                                 | 0.2                          |
| cross-counter      | E020509A  | 10     | 18292                  | 14880                     | 0.81                           | 18652                                    | 13799                     | 0.74                           | 2.0                      | -10.0                   | 19033                                 | 2.0                          |
| cross-counter      | E020416B  | 13     | 26546                  | 20754                     | 0.78                           | 27047                                    | 19713                     | 0.73                           | 1.9                      | -7.3                    | 27261                                 | 0.8                          |
| cross-counter      | E020416A  | 14     | 22700                  | 18645                     | 0.82                           | 21773                                    | 16693                     | 0.77                           | -4.1                     | -7.1                    | 22840                                 | 4.9                          |

<sup>1</sup> 100 % (simulated value with fin conduction – tested value)/tested value

<sup>2</sup> 100 % (simulated value w/o fin conduction – simulated value with fin conduction)/ simulated value with fin conduction

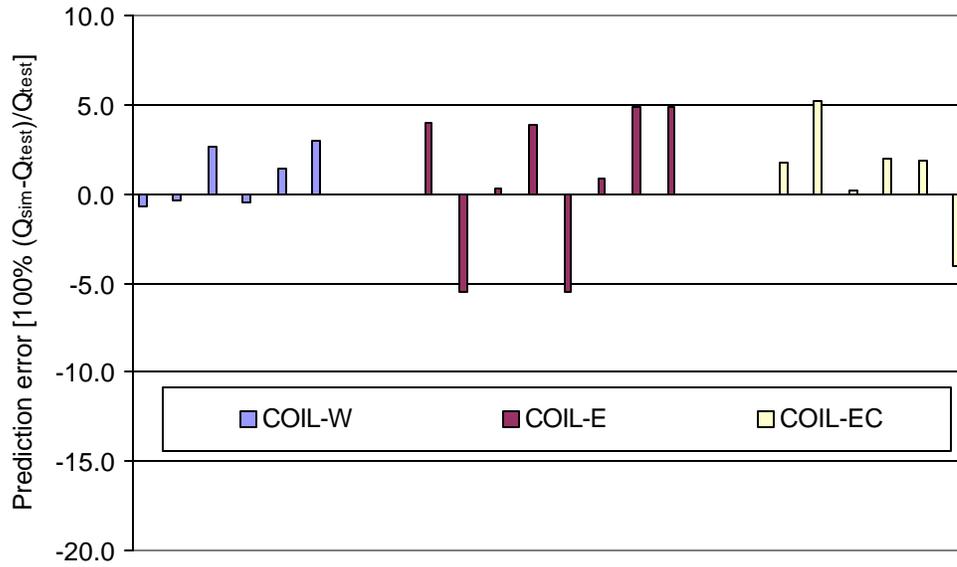


Figure 4.4.1.3: Difference between simulated and measured capacities for all wet coil tests for COIL-W, COIL-E, and COIL-EC

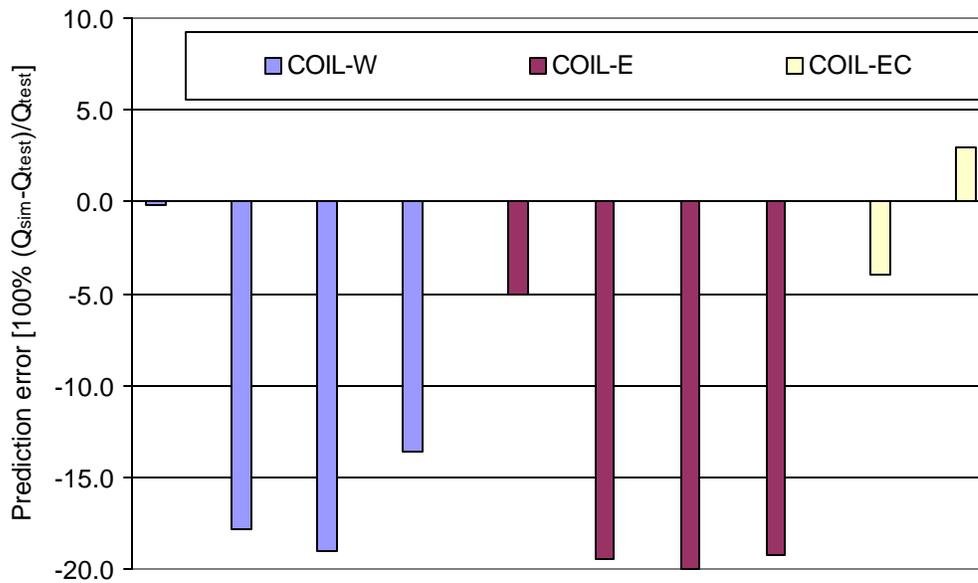
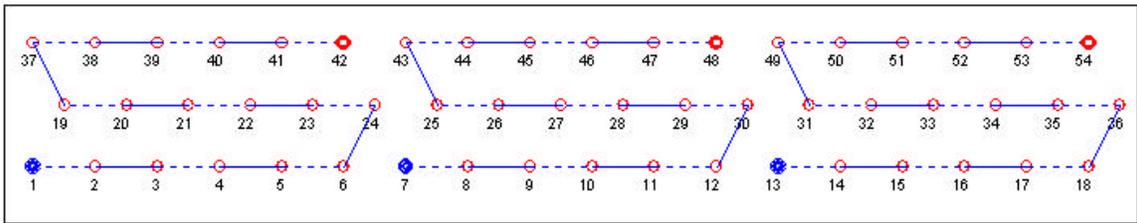
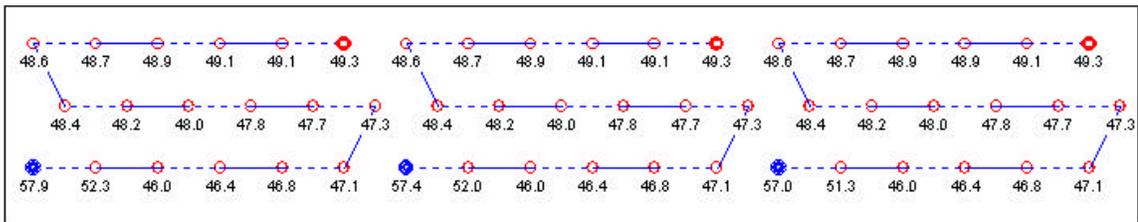
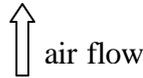


Figure 4.4.1.4 Difference between simulated and measured capacities for all dry coil tests for COIL-W, COIL-E, and COIL-EC

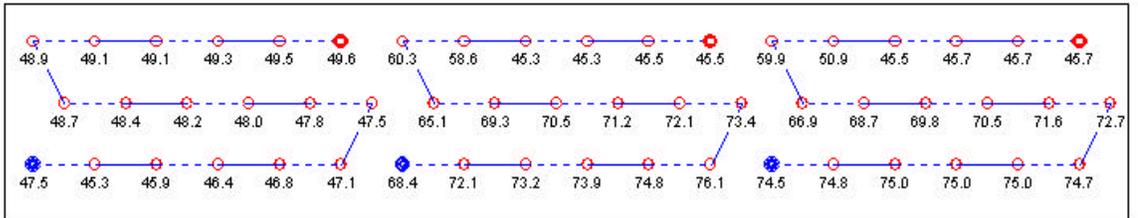
Tube-to-tube heat transfer demonstrates itself in temperatures that can be measured on coils return bends, as it was shown for COIL-W in Figures 3.4.4.1 and 3.4.4.2. Figure 4.4.1.5 shows similar information (refrigerant temperature at tube exits) as it is displayed by EVAP-COND for the same tests. For test 9 with even refrigerant superheat, refrigerant temperatures are similar for each circuit; refrigerant temperatures reflect drop in refrigerant pressure until the last two tubes in each circuit (2 and 1, 8 and 7, and 14 and 13) in which the refrigerant is superheated. For test 12, the first circuit is in two-phase flow until the exit tube 1, while the refrigerant leaving two other exit tubes (7 and 13) is highly superheated. Tubes 7 and 8 experience a drop in temperature compared to tube 9 because of their vicinity to the left-hand side circuit with two-phase, low-temperature refrigerant. Tubes 13 and 14 also experience temperature drop, however, it is small because the adjacent tubes are also superheated. This simulation results agree in principle with the measured return bend temperature of Figures 3.4.4.1 and 3.4.4.2.



Tube numbering



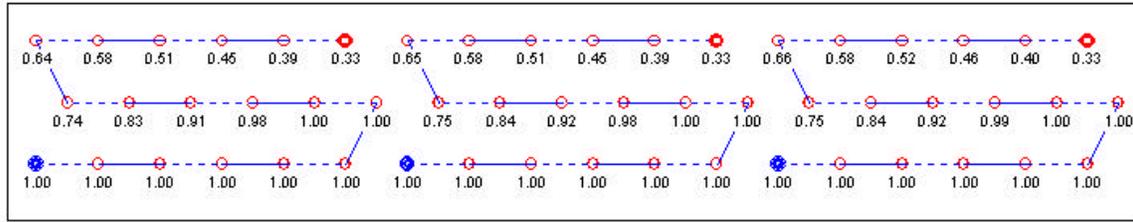
Refrigerant exit temperatures (°F) for COIL-W, test 9



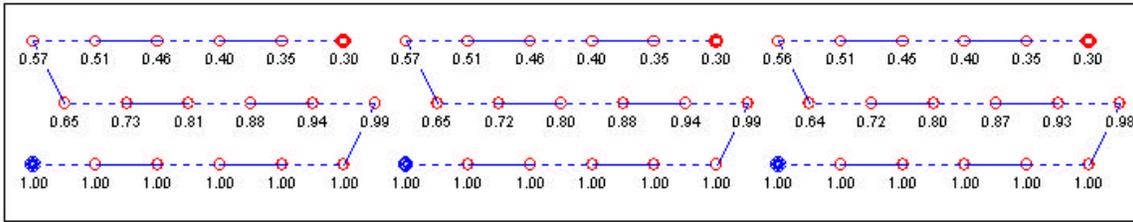
Refrigerant exit temperatures (°F) for COIL-W, test 12

Figure 4.4.1.5: Tube numbering and refrigerant exit temperatures for individual tubes for test 9 and test 12 for COIL-W, (inlet tubes: 42, 48, 54; outlet tubes: 1, 7, 13)

Figure 4.4.1.6 presents refrigerant exit qualities for individual tubes for COIL-E and COIL-EC for test 10 (16.7 °C (30 °F) even superheat). The figure shows that refrigerant reaches superheat (quality 1) two tubes earlier in COIL-E than in COIL-EC in each refrigerant circuit. This is a result of heat transfer between different tube depth rows that was allowed in COIL-E and was inhibited in COIL-EC. Corresponding tube temperatures predicted by EVAP5 agree with those measured during laboratory tests.



Refrigerant exit qualities (fraction) for COIL-E, test 10



Refrigerant exit qualities (fraction) for COIL-EC, test 10

Figure 4.4.1.6: Refrigerant exit qualities for individual tubes for COIL-E and COIL-EC test 10 (16.7 °C (30 °F) even superheat)

The last two columns in Tables 4.4.1.4, 4.4.1.5, and 4.4.1.6 compare simulated capacities that were obtained with and without accounting for tube-to-tube heat transfer. For the tests with a uniform superheat of 5.6 °C (10 °F), the difference in capacities is not greater than 2.7 % for any of the three coils. For the tests with uniform superheat of 16.7 °C (30 °F), the capacities differ by 63.1 % and 56.3 % for COIL-W, 33.6 %, 18.8 %, 19.2 % for COIL-E, and 1.5 %, 2.5 %, 2.5 %, and 4.9 % for COIL-EC. These results demonstrate the impact of fin design on tube-to-tube heat transfer.

The validation of EVAP5 used the full set of COIL-W, COIL-E, and COIL-EC measurements in cross-counter flow configuration, which constituted the majority of the measurements taken in this study. The validation effort was not extended to the eight data points taken in cross-parallel flow configuration because six of these tests that involved 16.7 °C (30 °F) superheat resulted in severe pinching within less than 1 °C (1.8 °F) in at least one of the circuits. Such a close

approach of refrigerant and air causes a profound convergence problem for a tube-by-tube model in which air temperatures upstream of each tube have to be iterated around a target value. Furthermore, for evaluating the potential reduction in heat exchanger volume, only capacity predictions at test 9 with 5.6 °C (10 °F) superheat were needed, and these were attainable with EVAP5.

Test 9 measured capacities for COIL-W and COIL-E were 4729 W (16146 Btu/h) and 4549 W (15522 Btu/h), while EVAP5 predictions were 4796 W (16366 Btu/h) and 5482 W (18705 Btu/h), respectively. This is a very good prediction for COIL-W, within 1.3 %, while the discrepancy for COIL-E is 20.5 %. It should be noted that a higher capacity should be expected for COIL-E than for COIL-W, as it was predicted by EVAP5 and always was obtained from laboratory measurements except this time. It is possible that some condensate holdup might have influenced the measured capacity for COIL-E. With this, it was concluded that EVAP5 properly simulated coils in a cross-parallel flow set up. Consequently, COIL-W was applied in a later section to examine potential savings in evaporator core volume for the cross-parallel configuration.

#### 4.4.2 Possible Savings in Heat Transfer Area Due to Optimized Superheat

##### *4.4.2.1 Cross-Counter Flow Configuration with Uniform Air Flow Distribution*

Considering similar performance degradations for different refrigerant superheat scenarios, possible savings in heat exchanger material are demonstrated using test 12 of COIL-W as an example. In our simulations, it was assumed that smart refrigerant distributors would optimize refrigerant distribution so the evaporator obtains maximum capacity. In these tests with a

uniform air velocity profile, the evaporators reached maximum capacity when the refrigerant split between the three circuits resulted in uniform superheat at the individual outlet tubes.

For these simulations, five alternative coils were coded with a smaller number of tubes than COIL-W. All simulation runs had the same inlet air condition, refrigerant inlet quality, and refrigerant outlet pressure and superheat at the evaporator exit. Also, inlet air velocity was the same for each coil as for COIL-W. A coil with a smaller face area had a lower volumetric flow rate than COIL-W, proportional to the percentage that its face area was reduced.

Figure 4.4.2.1.1 shows coil designs and simulation results. Four out of five alternative coil designs offered both savings in the heat exchanger core volume and an increase in coil capacity. The coils with a lower volumetric flow of air would also provide savings in fan power.

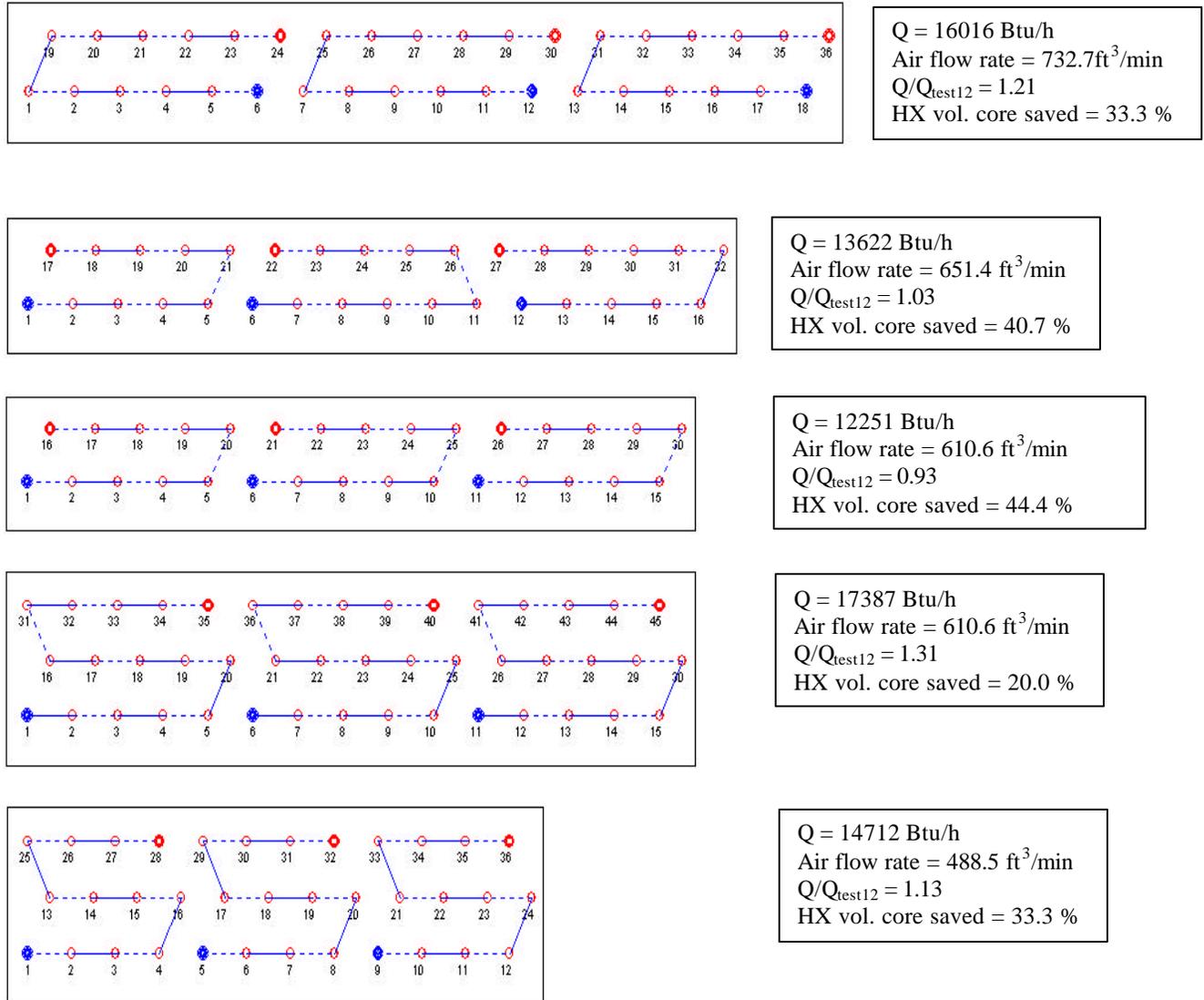


Figure 4.4.2.1.1: Simulation results for alternative coil designs to COIL-W in cross-counter flow configuration. Performance is compared to COIL-W test 12 with simulated capacity of 13225 Btu/h.

#### 4.4.2.2 Cross-Parallel Flow Configuration with Uniform Air Flow Distribution

Simulations were also performed to demonstrate possible savings in coil material (core volume of the heat exchanger) for COIL-W in cross-parallel configuration. Test 9 (W020304a) was used as a reference. Alternative coil designs with two depth rows were only examined because, in the cross-parallel configuration, more depth rows are not beneficial due to pinching.

All simulations were run using test 9 operating conditions, including 6 °C (10.8 °F) superheat, with the difference that the volumetric flow of air was adjusted so that each coil had the same inlet air velocity as COIL-W. This means that a coil with a smaller face area had a lower volumetric flow rate than COIL-W by the same percentage its face area was reduced.

Figure 4.4.2.2.1 shows coil designs and simulation results. Each of the four presented two-depth row designs offered improved capacity and savings in coil core volume. The coils with a lower volumetric flow of air would also provide savings in fan power. The smallest coil with 12x2 tube arrangement matched the capacity of test 12 with a 33.3 % savings in coil material.

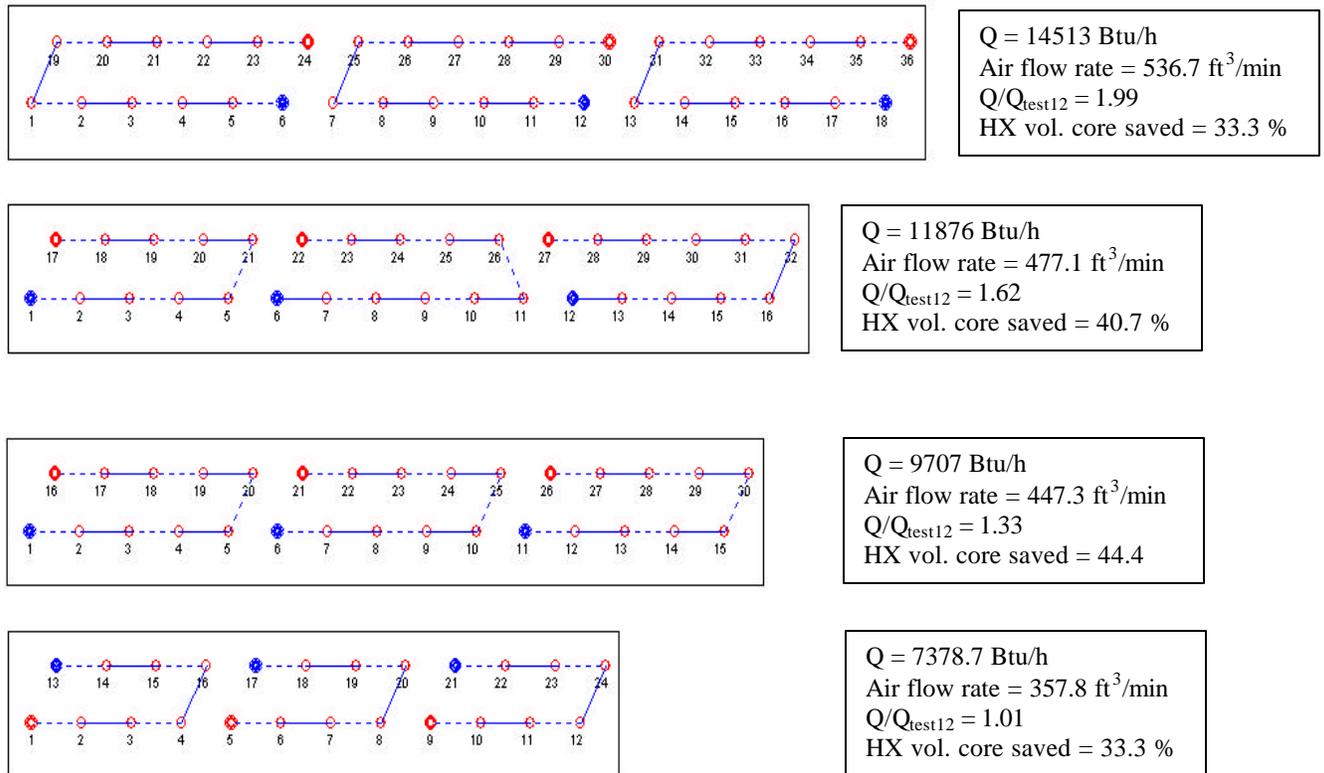


Figure 4.4.2.2.1: Simulation results for alternative coil designs to COIL-W in cross-parallel configuration. Comparisons are to COIL-W, test 12 with tested capacity of 7311 Btu/h.

#### 4.4.2.3 Cross-Counter Flow Arrangement with Non-Uniform Air Flow Distribution

The tests performed in the lab with non-uniform air distributions resulted in complicated velocity profiles that currently cannot be reproduced in EVAP5 simulations. For this reason, the simulations were performed with one-dimensional, non-uniform velocity profiles that were independent of the tests performed in the lab and represented a different application case scenario. For these simulations, COIL-W test 9 with a uniform air distribution was selected as a reference test, and additional simulations were performed for two-step velocity profiles where the top (left) to bottom (right) velocity ratios were 1:1.5, 1:2.0, 1:2.5, 1:3, 1:3.5, and 1:4.

Two runs were performed for each velocity ratio: the first - with a uniform refrigerant distribution, and the second - with a refrigerant distribution optimized to obtain maximum capacity. During all these tests, the external run parameters (refrigerant inlet state, exit pressure and superheat, air flow rate, etc.) were the same. Figure 4.4.2.3.1 presents a velocity profile representation for the 1:3 ratio as it was input into EVAP-COND. Since our velocity profiles have a near step change, they represent a more radical departure from uniformity than the profiles obtained in the laboratory.

Table 4.4.2.3.1 summarizes simulation results, and Figure 4.4.2.3.2 presents simulated capacities as referenced to the capacity of test 9. The table and figure show that the capacity degrades linearly with degradation of the air velocity. For the 1:4 air velocity ratio and uniform refrigerant distribution, the obtained capacity was only 63 % of the reference test 9 value. However, with optimized refrigerant distribution, as is the purpose of smart distributors, the obtained capacity was within 7 % of the reference capacity.

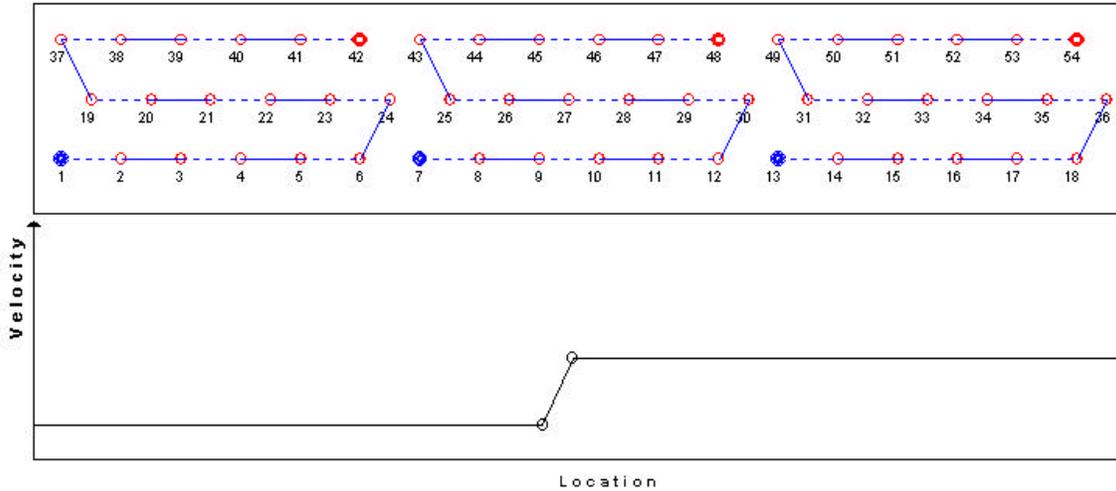


Figure 4.4.2.3.1: Air velocity profile representation for the 1:3 top-to-bottom velocity ratio (during tests the coil was positioned vertically, turned clockwise by 90 °)

Table 4.4.2.3.1: Simulated Capacities and Refrigerant Distributions for Non-Uniform Inlet Air Velocity Profile

| Air velocity ratio (top to bottom)       |                             | 1 : 1 | 1 : 1.5 | 1 : 2 | 1 : 2.5 | 1 : 3 | 1 : 3.5 | 1 : 4 |
|--|-----------------------------|-------|---------|-------|---------|-------|---------|-------|
| Capacity (watt)                          | Uniform ref. distribution   | 7044  | 6748    | 6194  | 5710    | 5199  | 4886    | 4465  |
|  | Optimized ref. distribution | 7044  | 7001    | 6914  | 6849    | 6762  | 6662    | 6582  |
| Capacity (Btu/h)                         | Uniform ref. distribution   | 22127 | 21197   | 19456 | 17935   | 16331 | 15347   | 14024 |
|  | Optimized ref. distribution | 22127 | 21997   | 21718 | 21515   | 21240 | 20928   | 20675 |
| Optimized refig. distribution (fraction) | top (left) circuit          | 0.33  | 0.295   | 0.265 | 0.240   | 0.222 | 0.210   | 0.195 |
|  | middle circuit              | 0.33  | 0.333   | 0.340 | 0.340   | 0.342 | 0.345   | 0.350 |
|  | bottom (right) circuit      | 0.33  | 0.372   | 0.395 | 0.420   | 0.436 | 0.445   | 0.455 |

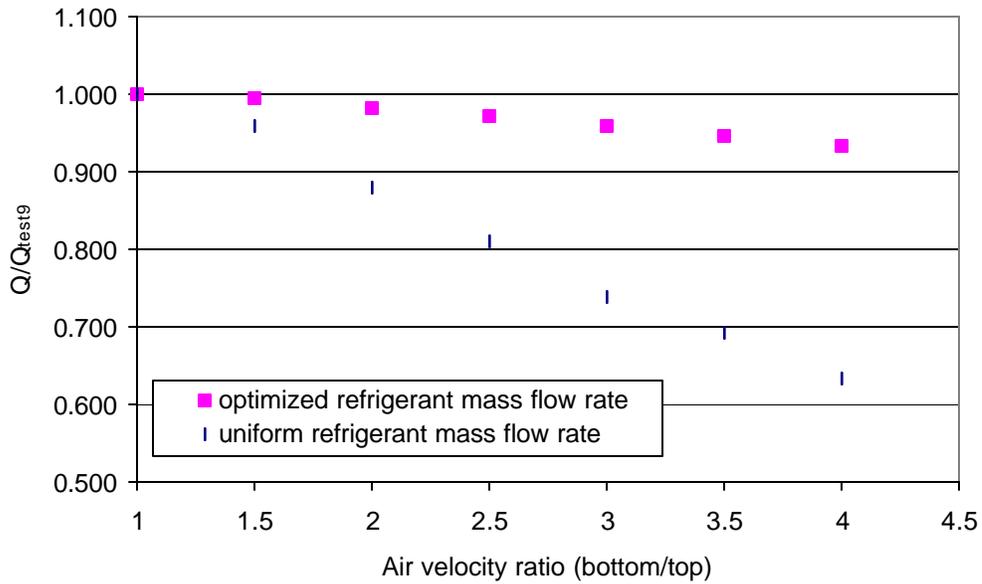
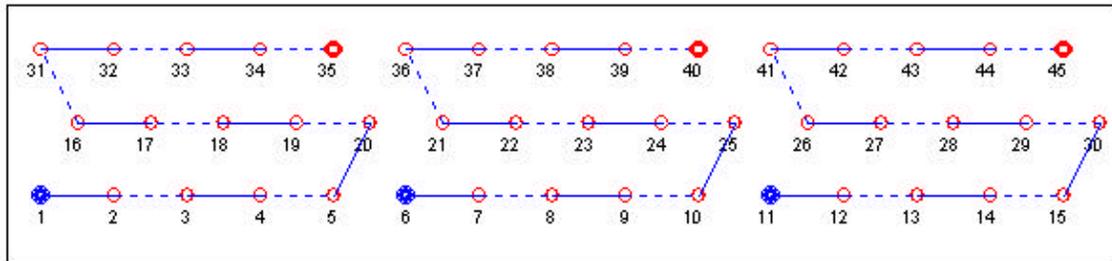
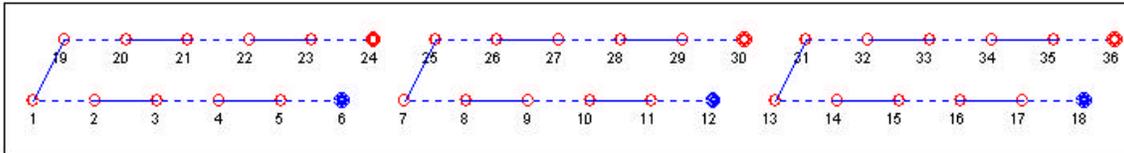


Figure 4.4.2.3.2: COIL-W capacities at different air velocity ratios referenced to capacity at test 9 in cross-counter flow configuration

To assess the savings in the heat exchanger material due to optimized control of refrigerant superheat, two evaporators with reduced number of tubes were coded, shown in Figure 4.4.2.3.3, and simulations were performed for 1:2.5 and 1:4 air velocity profiles. The two-depth row evaporator had the same face area as COIL-W and was simulated with the same volumetric flow rate of air. For the three-depth-row, the volumetric flow rate was reduced by 16.7 %, which corresponds to the reduction of the coil face area in relation to that of COIL-W. The results presented in Table 4.3.3.1.1 show that the benefit of optimizing refrigerant distribution increases with the level of non-uniformity in the air velocity profile. For the 1:4 air velocity ratio, optimizing refrigerant distribution allows a reduction in coil volume of 33.3 %. For the 1:2.5 air velocity ratio, the use of 15x3 coil with a slightly increased volumetric flow rate could produce a 16.7 % reduction in the coil volume.



Coil 15x3



Coil 18x2

Figure 4.4.2.3.3: Two evaporators with a reduced number of tubes

Table 4.4.2.3.2: Savings in Coil Volume Relative to COIL-W due to Optimized Refrigerant for 1:2.5 and 1:4 Air Velocity Ratios

| Coil   | Refrigerant distribution | Air velocity ratio (top to bottom) | Air volumetric flow rate m <sup>3</sup> /min | Capacity watt | Air volumetric flow rate ft <sup>3</sup> /min | Capacity Btu/h | Savings in coil volume % |
|--------|--------------------------|------------------------------------|--|---------------|---|----------------|--------------------------|
| COIL-W | uniform                  | 1 : 1                              | 20.7   | 6485          | 733   | 22127          | 0                        |
| COIL-W | optimized                | 1 : 2.5                            | 20.7   | 6305          | 733   | 21515          | 0                        |
| COIL-W | uniform                  | 1 : 2.5                            | 20.7   | 5256          | 733   | 17935          | 0                        |
| 18x2   | optimized                | 1 : 2.5                            | 20.7   | 4558          | 733   | 15553          | 33.3                     |
| 15x3   | optimized                | 1 : 2.5                            | 17.3   | 4890          | 611   | 16685          | 16.7                     |
| COIL-W | uniform                  | 1 : 1                              | 20.7   | 6485          | 733   | 22127          | 0                        |
| COIL-W | optimized                | 1 : 4                              | 20.7   | 6059          | 733   | 20675          | 0                        |
| COIL-W | uniform                  | 1 : 4                              | 20.7   | 4110          | 733   | 14024          | 0                        |
| 18x2   | optimized                | 1 : 4                              | 20.7   | 4335          | 733   | 14790          | 33.3                     |
| 15x3   | optimized                | 1 : 4                              | 17.3   | 4474          | 611   | 15266          | 16.7                     |

## 5 CONCLUSIONS

This collection of experimental data for the three evaporators has revealed interesting results related to non-uniform refrigerant distribution and conduction between tubes through the fins. With cross-counter refrigerant flow, uniform airflow, and exit manifold superheat fixed at 5.6 °C (10.0 °F), the wavy fin and wavy-lanced fin evaporator's capacity dropped by as much as 41 % and 32 %, respectively, as the superheat was allowed to vary between the circuits. Control of superheat was shown to be even more important during cross-parallel refrigerant flow due to the rapid pinching of the refrigerant and air temperatures. For the wavy and lanced finned evaporators in cross-parallel flow, capacity dropped by 85 % and 78 % as superheat changed from 5.6 °C (10.0 °F) to 16.7 °C (30.0 °F).

As the coil's faces were blocked to produce a non-uniform airflow, control of superheat was shown to restore capacity if the volumetric flow of air was unchanged. The tests showed that when airflow rate was held constant, the losses in capacity due to non-uniform airflow could be recovered to within 2 % of the original uniform airflow capacity by controlling superheat. The more non-uniform the airflow over the coil, the greater was the benefit of controlling superheat. For the lanced fin coil, as the airflow ratio between the top half and lower half of the coil varied from 1:1.26 to 1:2.59, superheat control improved capacity by 1.4 % and 4.6 %, respectively.

In parallel with the experimental effort, the NIST evaporator model EVAP5 was upgraded to control refrigerant distribution and account for tube-to-tube heat transfer. The model was validated with the experimental results and then used to determine the possible savings in

evaporator core volume if refrigerant distribution was controlled by a smart distributor. In extreme cases, the savings in core volume could be as much as 40 %.

A combination of results obtained from laboratory testing and simulations indicated the influence of tube-to-tube heat transfer on capacity degradation. The impact of tube-to-tube heat transfer was negligible in tests with a uniform 5.6 °C (10 °F) superheat, but it was significant in tests involving 16.7 °C (30 °F) superheat. Between two possible conduction mechanisms by which such heat transfer may occur, longitudinal fin conduction was chiefly responsible for degraded performance while longitudinal tube conduction had insignificant effect. The upgraded version of the EVAP5 evaporator model, which accounts for tube-to-tube heat transfer based on tube temperatures, was able to predict key return bend temperatures that indicated the occurrence of tube-to-tube heat transfer. However, the study also confirmed that longitudinal heat conduction is affected by the fin design, air-side heat transfer coefficient, and moisture removal process. Consequently, a more detailed modeling scheme needs to be developed to capture other effects influencing tube-to-tube heat transfer. Such a study would not only improve the modeling of evaporators but also of condensers and of gas coolers, where internal heat transfer may be even more pronounced.

## APPENDIX A. SUMMARY OF TEST RESULTS

### A.1 Wavy fin evaporator in cross-counter flow

Table A.1.1: Wavy Fin Evaporators in Cross-Counter Flow

| Test names | Test type |
|------------|-----------|
| W020225B   | 5         |
| W020228A   | 6         |
| W020221A   | 7         |
| W020225A   | 8         |
| W020207B   | 9         |
| W020530A   | 10        |
| W020531A   | 11        |
| W020215B   | 12        |
| W020301A   | 13        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020225B.DAT SUMMARY FILENAME: W020225B.sum

|   | Range       | Total Air-Side Capacity:    | 18519.09 | 356.27 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.951 0.32 | Sensible Cap (Btu/h):       | 18521.16 | 356.27 |
| Indoor Inlet Dew (F):                         | 32.006 0.00 | Latent Cap (Btu/h):         | -2.07    | 20.64  |
| Indoor Exit Dry-Bulb:                         | 57.653 0.20 | EvapAir Delta T (F):        | 22.85    | 0.43   |
| Indoor Exit Dew (F):                          | 32.009 0.04 | Air/Ref Cap Prcnt Diff:     | -3.32    | 2.05   |
|   |             | Sensible Heat Ratio:        | 1.000    | 0.0011 |
| Indoor Airflow (CFM):                         | 747.89 7.04 | SCFM per Ton:               | 482.95   |        |
| Indoor Airflow (SCFM):                        | 745.32 7.13 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003864    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 62.36    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.937 0.037 |                             |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.108 0.004 |                             |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 270.55 | 0.731 | Ref-side Cap (Btu/h) :                  | 17904.05 155.20 |
| Upstream Temp A (F):       | 104.58 | 0.524 | Ref-side Cap (tons):                    | 1.49 0.01       |
| Upstream Temp B (F):       | 105.01 | 0.524 | Refrigerant Mdot (lbm/h):               | 261.38 1.87     |
| Upstream Temp C (F):       | 104.38 | 0.437 | Coriolis Density (lbm/ft3):             | 69.87 0.16      |
| Upstream Average Temp (F): | 104.66 |       | Upstream R22 Tsat (F):                  | 119.36          |
| Upstream Subcooling A (F): | 14.77  | 0.594 |   |                 |
| Upstream Subcooling B (F): | 14.35  | 0.594 |   |                 |
| Upstream Subcooling C (F): | 14.98  | 0.366 |   |                 |
| Average Subcooling (F):    | 14.70  |       |   |                 |
| Evap Exit Pressure (psia): | 90.75  | 0.365 | Turbine A Frequency (Hz):               | 166.38 1.00     |
| Evap Exit Avg Temp A:      | 53.88  | 1.957 | Turb A Vol Flow (ft3/min):              | 0.0236 0.00     |
| Evap Exit Avg Temp B:      | 53.96  | 1.727 | Turb A Density (lbm/ft3):               | 70.37 0.08      |
| Evap Exit Avg Temp C:      | 53.99  | 1.682 | Turb A Mass Flow (lb/h):                | 99.76 0.62      |
| Circuit A Superheat (F):   | 8.42   | 2.113 | Turbine C Frequency (Hz):               | 146.08 2.00     |
| Circuit B Superheat (F):   | 8.49   | 1.690 | Turb C Vol Flow (ft3/min):              | 0.0217 0.00     |
| Circuit C Superheat (F):   | 8.53   | 1.769 | Turb C Density (lbm/ft3):               | 70.40 0.07      |
| Overall Superheat (F):     | 9.75   | 1.261 | Turb C Mass Flow (lb/h):                | 91.77 1.17      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 69.85 2.24      |
| Evap Circuit Temp 1 (F):   | 49.45  | 1.205 | % Total Mass Flow Thru A:               | 38.17 0.44      |
| Evap Circuit Temp 2 (F):   | 51.08  | 0.511 | % Total Mass Flow Thru B:               | 26.72 0.68      |
| Evap Circuit Temp 3 (F):   | 48.42  | 0.372 | % Total Mass Flow Thru C:               | 35.11 0.35      |
| Evap Circuit Temp 4 (F):   | 49.44  | 1.719 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.47  | 0.651 |   |                 |
| Evap Circuit Temp 6 (F):   | 51.05  | 0.557 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.16  | 1.110 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.39  | 0.651 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.89  | 0.092 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020228A.DAT SUMMARY FILENAME: W020228A.sum

|   | Range        | Total Air-Side Capacity:    | 12176.52 | 563.19 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 79.836 0.16  | Sensible Cap (Btu/h):       | 12264.84 | 510.10 |
| Indoor Inlet Dew (F):                         | 32.006 0.00  | Latent Cap (Btu/h):         | -88.32   | 55.91  |
| Indoor Exit Dry-Bulb:                         | 65.083 0.16  | EvapAir Delta T (F):        | 15.37    | 0.43   |
| Indoor Exit Dew (F):                          | 32.166 0.10  | Air/Ref Cap Prcnt Diff:     | -4.72    | 28.61  |
|   |              | Sensible Heat Ratio:        | 1.007    | 0.0047 |
| Indoor Airflow (CFM):                         | 746.52 15.62 | SCFM per Ton:               | 722.78   |        |
| Indoor Airflow (SCFM):                        | 733.41 15.41 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003889     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 69.75    | 0.54   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.175        | 0.049                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.109        | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                  |
|----------------------------|--------|-------|---|------------------|
| Expansion Valve            |        |       |   |                  |
| Upstream Pressure (psia):  | 270.48 | 0.609 | Ref-side Cap (Btu/h) :                  | 11596.62 3235.79 |
| Upstream Temp A (F):       | 103.19 | 0.702 | Ref-side Cap (tons):                    | 0.97 0.27        |
| Upstream Temp B (F):       | 103.59 | 0.610 | Refrigerant Mdot (lbm/h):               | 164.96 46.19     |
| Upstream Temp C (F):       | 103.06 | 0.787 | Coriolis Density (lbm/ft3):             | 69.84 0.15       |
| Upstream Average Temp (F): | 103.28 |       | Upstream R22 Tsat (F):                  | 119.37           |
| Upstream Subcooling A (F): | 16.18  | 0.597 |   |                  |
| Upstream Subcooling B (F): | 15.78  | 0.610 |   |                  |
| Upstream Subcooling C (F): | 16.31  | 0.682 |   |                  |
| Average Subcooling (F):    | 16.09  |       |   |                  |
| Evap Exit Pressure (psia): | 90.30  | 0.486 | Turbine A Frequency (Hz):               | 98.11 2.00       |
| Evap Exit Avg Temp A:      | 73.95  | 0.469 | Turb A Vol Flow (ft3/min):              | 0.0146 0.00      |
| Evap Exit Avg Temp B:      | 75.11  | 0.560 | Turb A Density (lbm/ft3):               | 70.58 0.11       |
| Evap Exit Avg Temp C:      | 73.61  | 0.470 | Turb A Mass Flow (lb/h):                | 61.62 1.14       |
| Circuit A Superheat (F):   | 28.99  | 0.562 | Turbine C Frequency (Hz):               | 97.20 1.00       |
| Circuit B Superheat (F):   | 30.15  | 0.584 | Turb C Vol Flow (ft3/min):              | 0.0152 0.00      |
| Circuit C Superheat (F):   | 28.65  | 0.605 | Turb C Density (lbm/ft3):               | 70.60 0.12       |
| Overall Superheat (F):     | 29.66  | 0.782 | Turb C Mass Flow (lb/h):                | 64.40 0.64       |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 38.93 46.79      |
| Evap Circuit Temp 1 (F):   | 73.58  | 0.627 | % Total Mass Flow Thru A:               | 37.54 10.49      |
| Evap Circuit Temp 2 (F):   | 74.76  | 0.541 | % Total Mass Flow Thru B:               | 23.23 21.86      |
| Evap Circuit Temp 3 (F):   | 49.44  | 0.603 | % Total Mass Flow Thru C:               | 39.23 11.38      |
| Evap Circuit Temp 4 (F):   | 74.56  | 0.541 |   |                  |
| Evap Circuit Temp 5 (F):   | 73.73  | 0.271 |   |                  |
| Evap Circuit Temp 6 (F):   | 53.21  | 0.555 |   |                  |
| Evap Circuit Temp 7 (F):   | 76.29  | 0.710 |   |                  |
| Evap Circuit Temp 8 (F):   | 72.37  | 0.630 |   |                  |
| Evap Circuit Temp 9 (F):   | 50.68  | 0.557 |   |                  |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020221A.DAT SUMMARY FILENAME: W020221A.sum

|   |        | Range | Total Air-Side Capacity:    | 13341.33 | 317.89 |
|---|--------|-------|-----------------------------|----------|--------|
| Air-Side Conditions                           |        |       |                             |          |        |
| Indoor Dry-Bulb :                             | 80.281 | 0.38  | Sensible Cap (Btu/h):       | 13609.16 | 350.52 |
| Indoor Inlet Dew (F):                         | 41.520 | 0.18  | Latent Cap (Btu/h):         | -267.83  | 87.50  |
| Indoor Exit Dry-Bulb:                         | 63.768 | 0.33  | EvapAir Delta T (F):        | 17.01    | 0.22   |
| Indoor Exit Dew (F):                          | 41.866 | 0.20  | Air/Ref Cap Prcnt Diff:     | -2.31    | 2.12   |
|   |        |       | Sensible Heat Ratio:        | 1.020    | 0.0065 |
| Indoor Airflow (CFM):                         | 745.31 | 9.39  | SCFM per Ton:               | 659.53   |        |
| Indoor Airflow (SCFM):                        | 733.26 | 9.44  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      |        |       | 0.005642                    |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       |        |       | 0.005718                    |          |        |
| Barometric Pressure (in HG):                  | 29.24  |       | Nozzle Temp (F):            | 67.12    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.899  | 0.048 |                             |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.109  | 0.006 |                             |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 270.28 | 0.609 | Ref-side Cap (Btu/h) :                  | 13032.06 | 125.32 |
| Upstream Temp A (F):       | 105.46 | 0.567 | Ref-side Cap (tons):                    | 1.09     | 0.01   |
| Upstream Temp B (F):       | 107.16 | 0.610 | Refrigerant Mdot (lbm/h):               | 190.89   | 1.98   |
| Upstream Temp C (F):       | 104.32 | 0.524 | Coriolis Density (lbm/ft3):             | 69.49    | 0.02   |
| Upstream Average Temp (F): | 105.65 |       | Upstream R22 Tsat (F):                  | 119.31   |        |
| Upstream Subcooling A (F): | 13.84  | 0.663 |   |          |        |
| Upstream Subcooling B (F): | 12.14  | 0.664 |   |          |        |
| Upstream Subcooling C (F): | 14.99  | 0.664 |   |          |        |
| Average Subcooling (F):    | 13.66  |       |   |          |        |
| Evap Exit Pressure (psia): | 89.70  | 0.730 | Turbine A Frequency (Hz):               | 92.68    | 1.00   |
| Evap Exit Avg Temp A:      | 74.78  | 0.538 | Turb A Vol Flow (ft3/min):              | 0.0138   | 0.00   |
| Evap Exit Avg Temp B:      | 47.39  | 0.558 | Turb A Density (lbm/ft3):               | 70.23    | 0.09   |
| Evap Exit Avg Temp C:      | 73.54  | 0.494 | Turb A Mass Flow (lb/h):                | 58.27    | 0.63   |
| Circuit A Superheat (F):   | 30.15  | 0.854 | Turbine C Frequency (Hz):               | 61.94    | 1.00   |
| Circuit B Superheat (F):   | 2.75   | 0.712 | Turb C Vol Flow (ft3/min):              | 0.0105   | 0.00   |
| Circuit C Superheat (F):   | 28.90  | 0.811 | Turb C Density (lbm/ft3):               | 70.41    | 0.08   |
| Overall Superheat (F):     | 11.57  | 3.499 | Turb C Mass Flow (lb/h):                | 44.35    | 0.61   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 88.27    | 1.99   |
| Evap Circuit Temp 1 (F):   | 74.72  | 0.628 | % Total Mass Flow Thru A:               | 30.53    | 0.49   |
| Evap Circuit Temp 2 (F):   | 74.11  | 0.360 | % Total Mass Flow Thru B:               | 46.24    | 0.74   |
| Evap Circuit Temp 3 (F):   | 47.66  | 0.326 | % Total Mass Flow Thru C:               | 23.23    | 0.48   |
| Evap Circuit Temp 4 (F):   | 48.33  | 0.651 |   |          |        |
| Evap Circuit Temp 5 (F):   | 48.79  | 0.279 |   |          |        |
| Evap Circuit Temp 6 (F):   | 53.26  | 0.322 |   |          |        |
| Evap Circuit Temp 7 (F):   | 76.88  | 0.496 |   |          |        |
| Evap Circuit Temp 8 (F):   | 74.72  | 0.541 |   |          |        |
| Evap Circuit Temp 9 (F):   | 50.20  | 0.650 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020225A.DAT SUMMARY FILENAME: W020225A.sum

|   | Range       | Total Air-Side Capacity:    | 13266.99 | 209.99 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.866 0.32 | Sensible Cap (Btu/h):       | 13267.21 | 209.99 |
| Indoor Inlet Dew (F):                         | 32.006 0.00 | Latent Cap (Btu/h):         | -0.22    | 0.00   |
| Indoor Exit Dry-Bulb:                         | 64.004 0.19 | EvapAir Delta T (F):        | 16.53    | 0.22   |
| Indoor Exit Dew (F):                          | 32.006 0.00 | Air/Ref Cap Prcnt Diff:     | -4.70    | 1.54   |
|   |             | Sensible Heat Ratio:        | 1.000    | 0.0000 |
| Indoor Airflow (CFM):                         | 749.54 7.42 | SCFM per Ton:               | 667.44   |        |
| Indoor Airflow (SCFM):                        | 737.91 7.29 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003864    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 67.29    | 0.22   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.922       | 0.038                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.108       | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 268.55 | 0.974 | Ref-side Cap (Btu/h) :                  | 12643.95 225.83 |
| Upstream Temp A (F):       | 104.91 | 0.438 | Ref-side Cap (tons):                    | 1.05 0.02       |
| Upstream Temp B (F):       | 103.59 | 0.963 | Refrigerant Mdot (lbm/h):               | 184.34 3.63     |
| Upstream Temp C (F):       | 103.95 | 0.611 | Coriolis Density (lbm/ft3):             | 69.78 0.03      |
| Upstream Average Temp (F): | 104.15 |       | Upstream R22 Tsat (F):                  | 118.82          |
| Upstream Subcooling A (F): | 13.91  | 0.480 |   |                 |
| Upstream Subcooling B (F): | 15.23  | 0.718 |   |                 |
| Upstream Subcooling C (F): | 14.87  | 0.751 |   |                 |
| Average Subcooling (F):    | 14.67  |       |   |                 |
| Evap Exit Pressure (psia): | 89.70  | 0.486 | Turbine A Frequency (Hz):               | 166.47 1.00     |
| Evap Exit Avg Temp A:      | 46.78  | 0.697 | Turb A Vol Flow (ft3/min):              | 0.0236 0.00     |
| Evap Exit Avg Temp B:      | 73.15  | 0.628 | Turb A Density (lbm/ft3):               | 70.32 0.07      |
| Evap Exit Avg Temp C:      | 74.87  | 0.516 | Turb A Mass Flow (lb/h):                | 99.74 0.63      |
| Circuit A Superheat (F):   | 2.15   | 0.756 | Turbine C Frequency (Hz):               | 97.83 1.00      |
| Circuit B Superheat (F):   | 28.52  | 0.563 | Turb C Vol Flow (ft3/min):              | 0.0153 0.00     |
| Circuit C Superheat (F):   | 30.24  | 0.586 | Turb C Density (lbm/ft3):               | 70.46 0.09      |
| Overall Superheat (F):     | 9.55   | 3.225 | Turb C Mass Flow (lb/h):                | 64.64 0.65      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 19.96 3.63      |
| Evap Circuit Temp 1 (F):   | 74.75  | 0.541 | % Total Mass Flow Thru A:               | 54.11 1.06      |
| Evap Circuit Temp 2 (F):   | 50.67  | 0.648 | % Total Mass Flow Thru B:               | 10.83 1.76      |
| Evap Circuit Temp 3 (F):   | 48.88  | 0.650 | % Total Mass Flow Thru C:               | 35.06 0.87      |
| Evap Circuit Temp 4 (F):   | 73.84  | 0.542 |   |                 |
| Evap Circuit Temp 5 (F):   | 74.78  | 0.585 |   |                 |
| Evap Circuit Temp 6 (F):   | 52.67  | 0.178 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.49  | 0.601 |   |                 |
| Evap Circuit Temp 8 (F):   | 73.03  | 0.720 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.18  | 0.462 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020207B.DAT SUMMARY FILENAME: W020207B.sum

|   | Range       | Total Air-Side Capacity:    | 22203.15                                | 606.34   | Range  |
|---|-------------|-----------------------------|---|----------|--------|
| Air-Side Conditions                           |             |                             |   |          |        |
| Indoor Dry-Bulb :                             | 79.787 0.39 | Sensible Cap (Btu/h):       | 16766.90                                | 535.59   |        |
| Indoor Inlet Dew (F):                         | 59.265 0.20 | Latent Cap (Btu/h):         | 5436.25                                 | 242.97   |        |
| Indoor Exit Dry-Bulb:                         | 59.520 0.24 | EvapAir Delta T (F):        | 20.80                                   | 0.44     |        |
| Indoor Exit Dew (F):                          | 55.107 0.15 | Air/Ref Cap Prcnt Diff:     | -1.92                                   | 2.93     |        |
|   |             | Sensible Heat Ratio:        | 0.755                                   | 0.0129   |        |
| Indoor Airflow (CFM):                         | 740.40 8.24 | SCFM per Ton:               | 395.99                                  |          |        |
| Indoor Airflow (SCFM):                        | 732.68 8.26 | (0.075 lb/ft3 standard air) |   |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011004    |                             |   |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009449    |                             |   |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 64.00                                   | 0.73     |        |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.885       | 0.042                       |   |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.148       | 0.008                       |   |          |        |
| -----   |             |                             |   |          |        |
| Refrigerant Side Conditions                   |             |                             |   |          |        |
| Expansion Valve                               |             |                             |   |          |        |
| Upstream Pressure (psia):                     | 274.00      | 0.731                       | Ref-side Cap (Btu/h) :                  | 21775.54 | 176.49 |
| Upstream Temp A (F):                          | 105.16      | 0.866                       | Ref-side Cap (tons):                    | 1.81     | 0.01   |
| Upstream Temp B (F):                          | 105.48      | 0.737                       | Refrigerant Mdot (lbm/h):               | 317.95   | 2.64   |
| Upstream Temp C (F):                          | 104.86      | 0.910                       | Coriolis Density (lbm/ft3):             | 69.81    | 0.18   |
| Upstream Average Temp (F):                    | 105.16      |                             | Upstream R22 Tsat (F):                  | 120.32   |        |
| Upstream Subcooling A (F):                    | 15.16       | 0.796                       |   |          |        |
| Upstream Subcooling B (F):                    | 14.84       | 0.681                       |   |          |        |
| Upstream Subcooling C (F):                    | 15.46       | 0.841                       |   |          |        |
| Average Subcooling (F):                       | 15.16       |                             |   |          |        |
| Evap Exit Pressure (psia):                    | 91.35       | 0.851                       | Turbine A Frequency (Hz):               | 206.85   | 3.00   |
| Evap Exit Avg Temp A:                         | 56.12       | 2.488                       | Turb A Vol Flow (ft3/min):              | 0.0290   | 0.00   |
| Evap Exit Avg Temp B:                         | 56.16       | 2.094                       | Turb A Density (lbm/ft3):               | 70.28    | 0.13   |
| Evap Exit Avg Temp C:                         | 55.82       | 1.778                       | Turb A Mass Flow (lb/h):                | 122.32   | 1.73   |
| Circuit A Superheat (F):                      | 10.09       | 2.644                       | Turbine C Frequency (Hz):               | 177.75   | 2.00   |
| Circuit B Superheat (F):                      | 10.14       | 2.250                       | Turb C Vol Flow (ft3/min):              | 0.0260   | 0.00   |
| Circuit C Superheat (F):                      | 9.80        | 1.778                       | Turb C Density (lbm/ft3):               | 70.32    | 0.14   |
| Overall Superheat (F):                        | 11.37       | 1.246                       | Turb C Mass Flow (lb/h):                | 109.50   | 1.18   |
|   |             |                             | Circuit B Calculated Mass Flow (lbm/h): | 86.12    | 3.08   |
| Evap Circuit Temp 1 (F):                      | 50.39       | 2.217                       | % Total Mass Flow Thru A:               | 38.47    | 0.68   |
| Evap Circuit Temp 2 (F):                      | 49.07       | 0.650                       | % Total Mass Flow Thru B:               | 27.09    | 0.85   |
| Evap Circuit Temp 3 (F):                      | 49.85       | 0.648                       | % Total Mass Flow Thru C:               | 34.44    | 0.51   |
| Evap Circuit Temp 4 (F):                      | 50.84       | 2.413                       |   |          |        |
| Evap Circuit Temp 5 (F):                      | 48.03       | 0.707                       |   |          |        |
| Evap Circuit Temp 6 (F):                      | 51.13       | 0.675                       |   |          |        |
| Evap Circuit Temp 7 (F):                      | 53.55       | 2.470                       |   |          |        |
| Evap Circuit Temp 8 (F):                      | 48.13       | 0.656                       |   |          |        |
| Evap Circuit Temp 9 (F):                      | 50.11       | 0.739                       |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020530A.dat SUMMARY FILENAME: W020530A.sum

|   | Range       | Total Air-Side Capacity:    | 12700.90 | 282.03 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.025 0.40 | Sensible Cap (Btu/h):       | 11535.04 | 253.92 |
| Indoor Inlet Dew (F):                         | 60.331 0.16 | Latent Cap (Btu/h):         | 1165.85  | 160.77 |
| Indoor Exit Dry-Bulb:                         | 66.020 0.33 | EvapAir Delta T (F):        | 14.37    | 0.22   |
| Indoor Exit Dew (F):                          | 59.510 0.15 | Air/Ref Cap Prcnt Diff:     | -2.54    | 3.42   |
|   |             | Sensible Heat Ratio:        | 0.908    | 0.0115 |
| Indoor Airflow (CFM):                         | 745.80 8.24 | SCFM per Ton:               | 688.01   |        |
| Indoor Airflow (SCFM):                        | 728.20 8.17 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011439    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.011103    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 66.69    | 0.09   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.720       | 0.016                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.132       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 276.09 | 0.487 | Ref-side Cap (Btu/h) :                  | 12378.19 446.76 |
| Upstream Temp A (F):       | 104.83 | 0.262 | Ref-side Cap (tons):                    | 1.03 0.04       |
| Upstream Temp B (F):       | 105.65 | 0.087 | Refrigerant Mdot (lbm/h):               | 177.51 6.41     |
| Upstream Temp C (F):       | 104.91 | 0.611 | Coriolis Density (lbm/ft3):             | 82.69 0.12      |
| Upstream Average Temp (F): | 105.13 |       | Upstream R22 Tsat (F):                  | 120.41          |
| Upstream Subcooling A (F): | 15.58  | 0.262 |   |                 |
| Upstream Subcooling B (F): | 14.76  | 0.087 |   |                 |
| Upstream Subcooling C (F): | 15.50  | 0.593 |   |                 |
| Average Subcooling (F):    | 15.28  |       |   |                 |
| Evap Exit Pressure (psia): | 90.22  | 0.486 | Turbine A Frequency (Hz):               | 109.56 1.00     |
| Evap Exit Avg Temp A:      | 73.82  | 0.628 | Turb A Vol Flow (ft3/min):              | 0.0161 0.00     |
| Evap Exit Avg Temp B:      | 73.93  | 0.629 | Turb A Density (lbm/ft3):               | 70.33 0.04      |
| Evap Exit Avg Temp C:      | 73.69  | 0.584 | Turb A Mass Flow (lb/h):                | 67.82 0.60      |
| Circuit A Superheat (F):   | 28.89  | 0.651 | Turbine C Frequency (Hz):               | 101.78 1.00     |
| Circuit B Superheat (F):   | 29.00  | 0.629 | Turb C Vol Flow (ft3/min):              | 0.0158 0.00     |
| Circuit C Superheat (F):   | 28.76  | 0.584 | Turb C Density (lbm/ft3):               | 70.32 0.09      |
| Overall Superheat (F):     | 29.29  | 0.740 | Turb C Mass Flow (lb/h):                | 66.72 0.65      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 42.96 6.97      |
| Evap Circuit Temp 1 (F):   | 73.22  | 0.630 | % Total Mass Flow Thru A:               | 38.21 1.70      |
| Evap Circuit Temp 2 (F):   | 48.03  | 0.326 | % Total Mass Flow Thru B:               | 24.20 3.07      |
| Evap Circuit Temp 3 (F):   | 47.38  | 0.373 | % Total Mass Flow Thru C:               | 37.59 1.42      |
| Evap Circuit Temp 4 (F):   | 67.86  | 0.910 |   |                 |
| Evap Circuit Temp 5 (F):   | 67.36  | 0.091 |   |                 |
| Evap Circuit Temp 6 (F):   | 74.19  | 0.812 |   |                 |
| Evap Circuit Temp 7 (F):   | 49.90  | 0.369 |   |                 |
| Evap Circuit Temp 8 (F):   | 72.37  | 0.633 |   |                 |
| Evap Circuit Temp 9 (F):   | 74.22  | 0.902 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020531A.dat SUMMARY FILENAME: W020531A.sum

|   | Range        | Total Air-Side Capacity:    | 13090.69 | 728.87 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 80.047 0.23  | Sensible Cap (Btu/h):       | 11502.99 | 467.38 |
| Indoor Inlet Dew (F):                         | 60.394 0.39  | Latent Cap (Btu/h):         | 1587.70  | 384.87 |
| Indoor Exit Dry-Bulb:                         | 66.142 0.72  | EvapAir Delta T (F):        | 14.33    | 0.44   |
| Indoor Exit Dew (F):                          | 59.273 0.49  | Air/Ref Cap Prcnt Diff:     | -0.54    | 6.79   |
|   |              | Sensible Heat Ratio:        | 0.879    | 0.0228 |
| Indoor Airflow (CFM):                         | 745.76 10.22 | SCFM per Ton:               | 667.36   |        |
| Indoor Airflow (SCFM):                        | 728.02 10.57 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011465     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.011008     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 66.79    | 0.91   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.720        | 0.020                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.140        | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 277.55 | 2.557 | Ref-side Cap (Btu/h) :                  | 13018.97 765.62 |
| Upstream Temp A (F):       | 104.35 | 1.048 | Ref-side Cap (tons):                    | 1.08 0.06       |
| Upstream Temp B (F):       | 105.59 | 1.048 | Refrigerant Mdot (lbm/h):               | 189.68 11.35    |
| Upstream Temp C (F):       | 103.77 | 1.049 | Coriolis Density (lbm/ft3):             | 82.54 0.44      |
| Upstream Average Temp (F): | 104.57 |       | Upstream R22 Tsat (F):                  | 120.83          |
| Upstream Subcooling A (F): | 16.48  | 0.663 |   |                 |
| Upstream Subcooling B (F): | 15.23  | 0.579 |   |                 |
| Upstream Subcooling C (F): | 17.06  | 0.649 |   |                 |
| Average Subcooling (F):    | 16.26  |       |   |                 |
| Evap Exit Pressure (psia): | 90.36  | 0.730 | Turbine A Frequency (Hz):               | 95.85 2.00      |
| Evap Exit Avg Temp A:      | 75.21  | 0.448 | Turb A Vol Flow (ft3/min):              | 0.0143 0.00     |
| Evap Exit Avg Temp B:      | 47.61  | 1.115 | Turb A Density (lbm/ft3):               | 70.40 0.16      |
| Evap Exit Avg Temp C:      | 72.59  | 0.540 | Turb A Mass Flow (lb/h):                | 60.20 1.13      |
| Circuit A Superheat (F):   | 30.07  | 0.505 | Turbine C Frequency (Hz):               | 32.75 7.00      |
| Circuit B Superheat (F):   | 2.46   | 0.880 | Turb C Vol Flow (ft3/min):              | 0.0066 0.00     |
| Circuit C Superheat (F):   | 27.44  | 0.776 | Turb C Density (lbm/ft3):               | 70.49 0.16      |
| Overall Superheat (F):     | 11.12  | 3.861 | Turb C Mass Flow (lb/h):                | 27.93 3.93      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 101.55 9.23     |
| Evap Circuit Temp 1 (F):   | 70.50  | 0.588 | % Total Mass Flow Thru A:               | 31.74 1.92      |
| Evap Circuit Temp 2 (F):   | 47.59  | 0.653 | % Total Mass Flow Thru B:               | 53.54 3.10      |
| Evap Circuit Temp 3 (F):   | 47.19  | 0.606 | % Total Mass Flow Thru C:               | 14.72 2.30      |
| Evap Circuit Temp 4 (F):   | 67.21  | 0.637 |   |                 |
| Evap Circuit Temp 5 (F):   | 66.65  | 0.638 |   |                 |
| Evap Circuit Temp 6 (F):   | 74.16  | 0.718 |   |                 |
| Evap Circuit Temp 7 (F):   | 49.54  | 1.115 |   |                 |
| Evap Circuit Temp 8 (F):   | 69.63  | 0.318 |   |                 |
| Evap Circuit Temp 9 (F):   | 75.05  | 0.811 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020215B.DAT SUMMARY FILENAME: W020215B.sum

|   | Range       | Total Air-Side Capacity:    | 13066.57 | 353.33 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.901 0.18 | Sensible Cap (Btu/h):       | 11950.49 | 217.05 |
| Indoor Inlet Dew (F):                         | 58.505 0.05 | Latent Cap (Btu/h):         | 1116.08  | 136.28 |
| Indoor Exit Dry-Bulb:                         | 65.673 0.18 | EvapAir Delta T (F):        | 14.83    | 0.22   |
| Indoor Exit Dew (F):                          | 57.675 0.10 | Air/Ref Cap Prcnt Diff:     | 0.46     | 3.04   |
|   |             | Sensible Heat Ratio:        | 0.915    | 0.0081 |
| Indoor Airflow (CFM):                         | 748.84 4.67 | SCFM per Ton:               | 672.23   |        |
| Indoor Airflow (SCFM):                        | 731.98 4.61 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.010704    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010384    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 68.79    | 0.41   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.905       | 0.024                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.132       | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                |
|----------------------------|--------|-------|---|----------------|
| Expansion Valve            |        |       |   |                |
| Upstream Pressure (psia):  | 277.28 | 0.487 | Ref-side Cap (Btu/h) :                  | 13125.68 92.23 |
| Upstream Temp A (F):       | 108.74 | 0.522 | Ref-side Cap (tons):                    | 1.09 0.01      |
| Upstream Temp B (F):       | 103.63 | 1.050 | Refrigerant Mdot (lbm/h):               | 193.41 1.32    |
| Upstream Temp C (F):       | 107.75 | 0.433 | Coriolis Density (lbm/ft3):             | 69.17 0.04     |
| Upstream Average Temp (F): | 106.71 |       | Upstream R22 Tsat (F):                  | 121.29         |
| Upstream Subcooling A (F): | 12.55  | 0.480 |   |                |
| Upstream Subcooling B (F): | 17.66  | 1.050 |   |                |
| Upstream Subcooling C (F): | 13.54  | 0.459 |   |                |
| Average Subcooling (F):    | 14.59  |       |   |                |
| Evap Exit Pressure (psia): | 90.57  | 0.486 | Turbine A Frequency (Hz):               | 199.61 1.00    |
| Evap Exit Avg Temp A:      | 47.78  | 0.788 | Turb A Vol Flow (ft3/min):              | 0.0280 0.00    |
| Evap Exit Avg Temp B:      | 72.17  | 0.223 | Turb A Density (lbm/ft3):               | 69.72 0.08     |
| Evap Exit Avg Temp C:      | 73.81  | 0.539 | Turb A Mass Flow (lb/h):                | 117.33 0.65    |
| Circuit A Superheat (F):   | 2.55   | 0.945 | Turbine C Frequency (Hz):               | 118.78 1.00    |
| Circuit B Superheat (F):   | 26.94  | 0.393 | Turb C Vol Flow (ft3/min):              | 0.0181 0.00    |
| Circuit C Superheat (F):   | 28.58  | 0.649 | Turb C Density (lbm/ft3):               | 69.88 0.07     |
| Overall Superheat (F):     | 10.11  | 1.904 | Turb C Mass Flow (lb/h):                | 75.82 0.63     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 0.27 1.84      |
| Evap Circuit Temp 1 (F):   | 73.26  | 0.357 | % Total Mass Flow Thru A:               | 60.66 0.63     |
| Evap Circuit Temp 2 (F):   | 49.12  | 0.324 | % Total Mass Flow Thru B:               | 0.14 0.95      |
| Evap Circuit Temp 3 (F):   | 51.36  | 0.602 | % Total Mass Flow Thru C:               | 39.20 0.49     |
| Evap Circuit Temp 4 (F):   | 72.64  | 1.085 |   |                |
| Evap Circuit Temp 5 (F):   | 75.34  | 0.541 |   |                |
| Evap Circuit Temp 6 (F):   | 52.93  | 0.745 |   |                |
| Evap Circuit Temp 7 (F):   | 51.65  | 0.411 |   |                |
| Evap Circuit Temp 8 (F):   | 72.31  | 0.360 |   |                |
| Evap Circuit Temp 9 (F):   | 49.82  | 0.649 |   |                |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020301A.DAT SUMMARY FILENAME: W020301A.sum

|   | Range        | Total Air-Side Capacity:    | 25598.17 | Range | 856.04 |
|---|--------------|-----------------------------|----------|-------|--------|
| Air-Side Conditions                           |              | Sensible Cap (Btu/h):       | 19857.00 |       | 726.72 |
| Indoor Dry-Bulb :                             | 80.471 0.65  | Latent Cap (Btu/h):         | 5741.17  |       | 451.86 |
| Indoor Inlet Dew (F):                         | 60.264 0.16  | EvapAir Delta T (F):        | 19.46    |       | 0.43   |
| Indoor Exit Dry-Bulb:                         | 61.646 0.32  | Air/Ref Cap Prcnt Diff:     | -0.25    |       | 3.44   |
| Indoor Exit Dew (F):                          | 56.949 0.30  | Sensible Heat Ratio:        | 0.776    |       | 0.0176 |
| Indoor Airflow (CFM):                         | 940.48 14.48 | SCFM per Ton:               | 434.25   |       |        |
| Indoor Airflow (SCFM):                        | 926.34 14.62 | (0.075 lb/ft3 standard air) |          |       |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011411     |                             |          |       |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010112     |                             |          |       |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 67.54    | 0.82  |        |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.867        | 0.058                       |          |       |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.224        | 0.010                       |          |       |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 317.57 | 0.609 | Ref-side Cap (Btu/h) :                  | 25532.14 | 335.91 |
| Upstream Temp A (F):       | 105.66 | 0.524 | Ref-side Cap (tons):                    | 2.13     | 0.03   |
| Upstream Temp B (F):       | 105.98 | 0.262 | Refrigerant Mdot (lbm/h):               | 373.69   | 4.95   |
| Upstream Temp C (F):       | 105.44 | 0.262 | Coriolis Density (lbm/ft3):             | 69.91    | 0.07   |
| Upstream Average Temp (F): | 105.69 |       | Upstream R22 Tsat (F):                  | 132.01   |        |
| Upstream Subcooling A (F): | 26.35  | 0.617 |   |          |        |
| Upstream Subcooling B (F): | 26.02  | 0.293 |   |          |        |
| Upstream Subcooling C (F): | 26.57  | 0.386 |   |          |        |
| Average Subcooling (F):    | 26.31  |       |   |          |        |
| Evap Exit Pressure (psia): | 91.29  | 0.486 | Turbine A Frequency (Hz):               | 244.24   | 2.00   |
| Evap Exit Avg Temp A:      | 56.21  | 1.951 | Turb A Vol Flow (ft3/min):              | 0.0340   | 0.00   |
| Evap Exit Avg Temp B:      | 57.07  | 2.250 | Turb A Density (lbm/ft3):               | 70.20    | 0.08   |
| Evap Exit Avg Temp C:      | 56.51  | 1.973 | Turb A Mass Flow (lb/h):                | 143.13   | 1.26   |
| Circuit A Superheat (F):   | 10.00  | 1.884 | Turbine C Frequency (Hz):               | 210.33   | 1.00   |
| Circuit B Superheat (F):   | 10.86  | 2.173 | Turb C Vol Flow (ft3/min):              | 0.0303   | 0.00   |
| Circuit C Superheat (F):   | 10.30  | 1.818 | Turb C Density (lbm/ft3):               | 70.24    | 0.04   |
| Overall Superheat (F):     | 11.46  | 1.807 | Turb C Mass Flow (lb/h):                | 127.69   | 0.60   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 102.87   | 5.48   |
| Evap Circuit Temp 1 (F):   | 51.28  | 1.480 | % Total Mass Flow Thru A:               | 38.30    | 0.66   |
| Evap Circuit Temp 2 (F):   | 51.53  | 0.602 | % Total Mass Flow Thru B:               | 27.53    | 1.10   |
| Evap Circuit Temp 3 (F):   | 51.21  | 0.647 | % Total Mass Flow Thru C:               | 34.17    | 0.58   |
| Evap Circuit Temp 4 (F):   | 51.80  | 1.112 |   |          |        |
| Evap Circuit Temp 5 (F):   | 49.78  | 0.648 |   |          |        |
| Evap Circuit Temp 6 (F):   | 52.38  | 0.467 |   |          |        |
| Evap Circuit Temp 7 (F):   | 53.55  | 1.242 |   |          |        |
| Evap Circuit Temp 8 (F):   | 49.47  | 1.024 |   |          |        |
| Evap Circuit Temp 9 (F):   | 51.32  | 0.693 |   |          |        |

A.2 Wavy fin evaporator in cross-parallel flow

Table A.2.1: Wavy Fin Evaporator in Cross-Parallel Flow

| Test names | Test type |
|------------|-----------|
| W020304A   | 9         |
| W020311B   | 10        |
| W020306A   | 11        |
| W020307A   | 12        |

SMART DISTRIBUTOR SUMMARY SHEET  
 DATA FILENAME: W020304A.DAT SUMMARY FILENAME: W020304A.sum

| Air-Side Conditions                           | Range  | Total Air-Side Capacity: | 16146.00                    | Range    | 333.86 |
|---|--------|--------------------------|-----------------------------|----------|--------|
| Indoor Dry-Bulb :                             | 80.044 | 0.31                     | Sensible Cap (Btu/h):       | 12113.40 | 173.85 |
| Indoor Inlet Dew (F):                         | 60.110 | 0.20                     | Latent Cap (Btu/h):         | 4032.60  | 165.48 |
| Indoor Exit Dry-Bulb:                         | 60.190 | 0.17                     | EvapAir Delta T (F):        | 20.50    | 0.00   |
| Indoor Exit Dew (F):                          | 56.020 | 0.20                     | Air/Ref Cap Prcnt Diff:     | 3.44     | 2.06   |
|   |        |                          | Sensible Heat Ratio:        | 0.750    | 0.0054 |
| Indoor Airflow (CFM):                         | 543.06 | 7.69                     | SCFM per Ton:               | 398.87   |        |
| Indoor Airflow (SCFM):                        | 536.68 | 7.65                     | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      |        | 0.011348                 |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       |        | 0.009773                 |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24  |                          | Nozzle Temp (F):            | 68.01    | 0.86   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.628  | 0.018                    |                             |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.088  | 0.004                    |                             |          |        |

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 Refrigerant Side Conditions

|                            |        |       |   |          |       |
|----------------------------|--------|-------|---|----------|-------|
| Expansion Valve            |        |       |   |          |       |
| Upstream Pressure (psia):  | 274.31 | 0.609 | Ref-side Cap (Btu/h) :                  | 16700.38 | 88.35 |
| Upstream Temp A (F):       | 105.86 | 0.523 | Ref-side Cap (tons):                    | 1.39     | 0.01  |
| Upstream Temp B (F):       | 106.23 | 0.524 | Refrigerant Mdot (lbm/h):               | 244.87   | 1.10  |
| Upstream Temp C (F):       | 105.40 | 0.608 | Coriolis Density (lbm/ft3):             | 69.65    | 0.03  |
| Upstream Average Temp (F): | 105.83 |       | Upstream R22 Tsat (F):                  | 120.39   |       |
| Upstream Subcooling A (F): | 14.54  | 0.593 |   |          |       |
| Upstream Subcooling B (F): | 14.16  | 0.662 |   |          |       |
| Upstream Subcooling C (F): | 14.99  | 0.620 |   |          |       |
| Average Subcooling (F):    | 14.56  |       |   |          |       |
| Evap Exit Pressure (psia): | 90.59  | 0.486 | Turbine A Frequency (Hz):               | 166.94   | 1.00  |
| Evap Exit Avg Temp A:      | 54.68  | 0.365 | Turb A Vol Flow (ft3/min):              | 0.0237   | 0.00  |
| Evap Exit Avg Temp B:      | 56.50  | 0.275 | Turb A Density (lbm/ft3):               | 70.17    | 0.08  |
| Evap Exit Avg Temp C:      | 55.35  | 0.436 | Turb A Mass Flow (lb/h):                | 99.79    | 0.66  |
| Circuit A Superheat (F):   | 9.39   | 0.377 | Turbine C Frequency (Hz):               | 133.10   | 2.00  |
| Circuit B Superheat (F):   | 11.22  | 0.432 | Turb C Vol Flow (ft3/min):              | 0.0200   | 0.00  |
| Circuit C Superheat (F):   | 10.07  | 0.571 | Turb C Density (lbm/ft3):               | 70.24    | 0.09  |
| Overall Superheat (F):     | 10.84  | 0.786 | Turb C Mass Flow (lb/h):                | 84.26    | 1.12  |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 60.82    | 1.15  |
| Evap Circuit Temp 1 (F):   | 49.39  | 0.645 | % Total Mass Flow Thru A:               | 40.75    | 0.34  |
| Evap Circuit Temp 2 (F):   | 48.82  | 0.089 | % Total Mass Flow Thru B:               | 24.84    | 0.40  |
| Evap Circuit Temp 3 (F):   | 54.41  | 0.599 | % Total Mass Flow Thru C:               | 34.41    | 0.49  |
| Evap Circuit Temp 4 (F):   | 48.25  | 0.089 |   |          |       |
| Evap Circuit Temp 5 (F):   | 48.30  | 0.369 |   |          |       |
| Evap Circuit Temp 6 (F):   | 57.70  | 0.173 |   |          |       |
| Evap Circuit Temp 7 (F):   | 55.01  | 0.407 |   |          |       |
| Evap Circuit Temp 8 (F):   | 48.80  | 0.368 |   |          |       |
| Evap Circuit Temp 9 (F):   | 56.44  | 0.365 |   |          |       |

SMART DISTRIBUTOR SUMMARY SHEET  
 DATA FILENAME: W020311B.DAT SUMMARY FILENAME: W020311B.sum

| Air-Side Conditions                           | Range  | Total Air-Side Capacity: | 2461.30                     | Range   |        |
|---|--------|--------------------------|-----------------------------|---------|--------|
| Indoor Dry-Bulb :                             | 79.792 | 0.27                     | Sensible Cap (Btu/h):       | 3078.41 | 135.79 |
| Indoor Inlet Dew (F):                         | 60.549 | 0.07                     | Latent Cap (Btu/h):         | -617.11 | 149.23 |
| Indoor Exit Dry-Bulb:                         | 75.282 | 0.27                     | EvapAir Delta T (F):        | 5.20    | 0.22   |
| Indoor Exit Dew (F):                          | 61.121 | 0.16                     | Air/Ref Cap Prcnt Diff:     | 11.08   | 9.87   |
|   |        |                          | Sensible Heat Ratio:        | 1.251   | 0.0755 |
| Indoor Airflow (CFM):                         | 559.56 | 6.70                     | SCFM per Ton:               | 2617.04 |        |
| Indoor Airflow (SCFM):                        | 536.78 | 6.58                     | (0.075 lb/ft3 standard air) |         |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      |        |                          | 0.011529                    |         |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       |        |                          | 0.011771                    |         |        |
| Barometric Pressure (in HG):                  | 29.24  |                          | Nozzle Temp (F):            | 75.49   | 0.58   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.077  | 0.026                    |                             |         |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.070  | 0.003                    |                             |         |        |

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 Refrigerant Side Conditions

|                            |        |       |   |         |        |
|----------------------------|--------|-------|---|---------|--------|
| Expansion Valve            |        |       |   |         |        |
| Upstream Pressure (psia):  | 307.47 | 1.948 | Ref-side Cap (Btu/h) :                  | 2732.66 | 102.12 |
| Upstream Temp A (F):       | 105.67 | 0.878 | Ref-side Cap (tons):                    | 0.23    | 0.01   |
| Upstream Temp B (F):       | 106.10 | 0.879 | Refrigerant Mdot (lbm/h):               | 39.31   | 1.54   |
| Upstream Temp C (F):       | 105.60 | 0.878 | Coriolis Density (lbm/ft3):             | 68.20   | 0.04   |
| Upstream Average Temp (F): | 105.79 |       | Upstream R22 Tsat (F):                  | 129.48  |        |
| Upstream Subcooling A (F): | 23.81  | 0.524 |   |         |        |
| Upstream Subcooling B (F): | 23.38  | 0.498 |   |         |        |
| Upstream Subcooling C (F): | 23.88  | 0.624 |   |         |        |
| Average Subcooling (F):    | 23.69  |       |   |         |        |
| Evap Exit Pressure (psia): | 89.60  | 1.946 | Turbine A Frequency (Hz):               | 18.57   | 1.00   |
| Evap Exit Avg Temp A:      | 74.28  | 0.313 | Turb A Vol Flow (ft3/min):              | 0.0040  | 0.00   |
| Evap Exit Avg Temp B:      | 74.05  | 0.691 | Turb A Density (lbm/ft3):               | 70.20   | 0.14   |
| Evap Exit Avg Temp C:      | 76.15  | 0.577 | Turb A Mass Flow (lb/h):                | 16.74   | 0.59   |
| Circuit A Superheat (F):   | 29.88  | 0.906 | Turbine C Frequency (Hz):               | 21.90   | 2.00   |
| Circuit B Superheat (F):   | 29.65  | 1.270 | Turb C Vol Flow (ft3/min):              | 0.0052  | 0.00   |
| Circuit C Superheat (F):   | 31.74  | 0.888 | Turb C Density (lbm/ft3):               | 70.21   | 0.14   |
| Overall Superheat (F):     | 30.26  | 1.194 | Turb C Mass Flow (lb/h):                | 21.72   | 1.11   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 0.84    | 1.85   |
| Evap Circuit Temp 1 (F):   | 48.64  | 1.586 | % Total Mass Flow Thru A:               | 42.60   | 2.65   |
| Evap Circuit Temp 2 (F):   | 71.56  | 0.902 | % Total Mass Flow Thru B:               | 2.14    | 4.69   |
| Evap Circuit Temp 3 (F):   | 73.85  | 0.629 | % Total Mass Flow Thru C:               | 55.26   | 3.07   |
| Evap Circuit Temp 4 (F):   | 50.06  | 6.634 |   |         |        |
| Evap Circuit Temp 5 (F):   | 70.52  | 1.360 |   |         |        |
| Evap Circuit Temp 6 (F):   | 74.23  | 0.627 |   |         |        |
| Evap Circuit Temp 7 (F):   | 55.80  | 5.294 |   |         |        |
| Evap Circuit Temp 8 (F):   | 68.68  | 4.634 |   |         |        |
| Evap Circuit Temp 9 (F):   | 76.45  | 0.401 |   |         |        |

SMART DISTRIBUTOR SUMMARY SHEET  
 DATA FILENAME: W020306A.DAT SUMMARY FILENAME: W020306A.sum

|   |             |                             |         |        |
|---|-------------|-----------------------------|---------|--------|
| Air-Side Conditions                           | Range       | Total Air-Side Capacity:    | 8887.11 | 111.33 |
| Indoor Dry-Bulb :                             | 80.396 0.30 | Sensible Cap (Btu/h):       | 7708.24 | 109.55 |
| Indoor Inlet Dew (F):                         | 60.252 0.10 | Latent Cap (Btu/h):         | 1178.87 | 109.95 |
| Indoor Exit Dry-Bulb:                         | 68.001 0.20 | EvapAir Delta T (F):        | 13.03   | 0.00   |
| Indoor Exit Dew (F):                          | 59.117 0.05 | Air/Ref Cap Prcnt Diff:     | 4.83    | 28.08  |
|   |             | Sensible Heat Ratio:        | 0.867   | 0.0112 |
| Indoor Airflow (CFM):                         | 551.47 7.81 | SCFM per Ton:               | 724.51  |        |
| Indoor Airflow (SCFM):                        | 536.57 7.63 | (0.075 lb/ft3 standard air) |         |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011406    |                             |         |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010945    |                             |         |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 70.38   | 4.40   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.061       | 0.030                       |         |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.081       | 0.003                       |         |        |

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 Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 273.97 | 0.974 | Ref-side Cap (Btu/h) :                  | 9316.15 2432.86 |
| Upstream Temp A (F):       | 103.36 | 0.524 | Ref-side Cap (tons):                    | 0.78 0.20       |
| Upstream Temp B (F):       | 111.52 | 0.784 | Refrigerant Mdot (lbm/h):               | 136.90 35.63    |
| Upstream Temp C (F):       | 104.76 | 0.743 | Coriolis Density (lbm/ft3):             | 64.97 1.17      |
| Upstream Average Temp (F): | 106.55 |       | Upstream R22 Tsat (F):                  | 120.39          |
| Upstream Subcooling A (F): | 17.03  | 0.490 |   |                 |
| Upstream Subcooling B (F): | 8.87   | 0.715 |   |                 |
| Upstream Subcooling C (F): | 15.63  | 0.743 |   |                 |
| Average Subcooling (F):    | 13.84  |       |   |                 |
| Evap Exit Pressure (psia): | 90.80  | 1.095 | Turbine A Frequency (Hz):               | 29.07 1.00      |
| Evap Exit Avg Temp A:      | 70.24  | 0.406 | Turb A Vol Flow (ft3/min):              | 0.0054 0.00     |
| Evap Exit Avg Temp B:      | 51.46  | 1.848 | Turb A Density (lbm/ft3):               | 70.55 0.08      |
| Evap Exit Avg Temp C:      | 72.44  | 0.518 | Turb A Mass Flow (lb/h):                | 22.74 0.59      |
| Circuit A Superheat (F):   | 25.03  | 1.022 | Turbine C Frequency (Hz):               | 32.19 2.00      |
| Circuit B Superheat (F):   | 6.25   | 2.199 | Turb C Vol Flow (ft3/min):              | 0.0065 0.00     |
| Circuit C Superheat (F):   | 27.23  | 1.055 | Turb C Density (lbm/ft3):               | 70.34 0.11      |
| Overall Superheat (F):     | 11.74  | 1.251 | Turb C Mass Flow (lb/h):                | 27.55 1.13      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 86.61 36.19     |
| Evap Circuit Temp 1 (F):   | 48.56  | 0.647 | % Total Mass Flow Thru A:               | 16.68 4.59      |
| Evap Circuit Temp 2 (F):   | 69.49  | 2.179 | % Total Mass Flow Thru B:               | 63.12 10.51     |
| Evap Circuit Temp 3 (F):   | 69.92  | 0.816 | % Total Mass Flow Thru C:               | 20.21 5.92      |
| Evap Circuit Temp 4 (F):   | 50.51  | 0.648 |   |                 |
| Evap Circuit Temp 5 (F):   | 49.61  | 0.648 |   |                 |
| Evap Circuit Temp 6 (F):   | 51.42  | 0.835 |   |                 |
| Evap Circuit Temp 7 (F):   | 54.68  | 1.661 |   |                 |
| Evap Circuit Temp 8 (F):   | 62.05  | 7.423 |   |                 |
| Evap Circuit Temp 9 (F):   | 72.71  | 0.587 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET  
 DATA FILENAME: W020307A.DAT SUMMARY FILENAME: W020307A.sum

| Air-Side Conditions                           | Range       | Total Air-Side Capacity:    | 7310.90 | Range | 200.11 |
|---|-------------|-----------------------------|---------|-------|--------|
| Indoor Dry-Bulb :                             | 79.931 0.27 | Sensible Cap (Btu/h):       | 6963.53 |       | 164.86 |
| Indoor Inlet Dew (F):                         | 60.090 0.21 | Latent Cap (Btu/h):         | 347.37  |       | 153.90 |
| Indoor Exit Dry-Bulb:                         | 68.811 0.23 | EvapAir Delta T (F):        | 11.74   |       | 0.22   |
| Indoor Exit Dew (F):                          | 59.759 0.25 | Air/Ref Cap Prcnt Diff:     | 10.56   |       | 3.69   |
|   |             | Sensible Heat Ratio:        | 0.953   |       | 0.0201 |
| Indoor Airflow (CFM):                         | 554.06 8.18 | SCFM per Ton:               | 883.36  |       |        |
| Indoor Airflow (SCFM):                        | 538.18 7.84 | (0.075 lb/ft3 standard air) |         |       |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011339    |                             |         |       |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.011204    |                             |         |       |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 69.62   | 0.63  |        |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.069 0.031 |                             |         |       |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.080 0.005 |                             |         |       |        |

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 Refrigerant Side Conditions

|                            |        |       |   |         |        |
|----------------------------|--------|-------|---|---------|--------|
| Expansion Valve            |        |       |   |         |        |
| Upstream Pressure (psia):  | 265.64 | 1.461 | Ref-side Cap (Btu/h) :                  | 8082.88 | 144.34 |
| Upstream Temp A (F):       | 104.59 | 0.877 | Ref-side Cap (tons):                    | 0.67    | 0.01   |
| Upstream Temp B (F):       | 100.08 | 4.034 | Refrigerant Mdot (lbm/h):               | 116.63  | 2.20   |
| Upstream Temp C (F):       | 101.52 | 2.015 | Coriolis Density (lbm/ft3):             | 69.77   | 0.11   |
| Upstream Average Temp (F): | 102.06 |       | Upstream R22 Tsat (F):                  | 117.98  |        |
| Upstream Subcooling A (F): | 13.40  | 0.680 |   |         |        |
| Upstream Subcooling B (F): | 17.91  | 4.176 |   |         |        |
| Upstream Subcooling C (F): | 16.46  | 1.874 |   |         |        |
| Average Subcooling (F):    | 15.92  |       |   |         |        |
| Evap Exit Pressure (psia): | 90.38  | 0.730 | Turbine A Frequency (Hz):               | 165.03  | 2.00   |
| Evap Exit Avg Temp A:      | 49.25  | 1.320 | Turb A Vol Flow (ft3/min):              | 0.0234  | 0.00   |
| Evap Exit Avg Temp B:      | 72.79  | 0.449 | Turb A Density (lbm/ft3):               | 70.37   | 0.13   |
| Evap Exit Avg Temp C:      | 74.44  | 0.426 | Turb A Mass Flow (lb/h):                | 99.00   | 1.22   |
| Circuit A Superheat (F):   | 4.24   | 1.554 | Turbine C Frequency (Hz):               | 27.73   | 2.00   |
| Circuit B Superheat (F):   | 27.78  | 0.764 | Turb C Vol Flow (ft3/min):              | 0.0059  | 0.00   |
| Circuit C Superheat (F):   | 29.44  | 1.030 | Turb C Density (lbm/ft3):               | 70.83   | 0.30   |
| Overall Superheat (F):     | 9.75   | 1.418 | Turb C Mass Flow (lb/h):                | 25.22   | 1.13   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | -7.58   | 2.41   |
| Evap Circuit Temp 1 (F):   | 50.37  | 1.848 | % Total Mass Flow Thru A:               | 84.88   | 2.14   |
| Evap Circuit Temp 2 (F):   | 49.31  | 0.934 | % Total Mass Flow Thru B:               | -6.50   | 2.17   |
| Evap Circuit Temp 3 (F):   | 48.20  | 0.650 | % Total Mass Flow Thru C:               | 21.62   | 0.82   |
| Evap Circuit Temp 4 (F):   | 67.81  | 0.812 |   |         |        |
| Evap Circuit Temp 5 (F):   | 72.33  | 0.997 |   |         |        |
| Evap Circuit Temp 6 (F):   | 69.41  | 0.644 |   |         |        |
| Evap Circuit Temp 7 (F):   | 54.67  | 0.932 |   |         |        |
| Evap Circuit Temp 8 (F):   | 71.66  | 1.896 |   |         |        |
| Evap Circuit Temp 9 (F):   | 74.97  | 0.629 |   |         |        |

A.3 Enhanced fin (wavy-lanced) evaporator in cross-counter flow

Table A.3.1: Enhanced Fin (Wavy Lanced) Evaporators in Cross-Counter Flow

| Test names | Test type |
|------------|-----------|
| W020320B   | 1         |
| W020321A   | 2         |
| W020322A   | 5         |
| W020321B   | 6         |
| W020322C   | 7         |
| W020322B   | 8         |
| E020607A   | 9         |
| W020318A   | 10        |
| W020318B   | 11        |
| W020319A   | 12        |
| W020319B   | 13        |
| W020320A   | 14        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020320B.DAT SUMMARY FILENAME: W020320B.sum

|   | Range       | Total Air-Side Capacity:    | 20463.67 | 511.47 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.050 0.15 | Sensible Cap (Btu/h):       | 13506.42 | 433.45 |
| Indoor Inlet Dew (F):                         | 60.805 0.30 | Latent Cap (Btu/h):         | 6957.25  | 195.51 |
| Indoor Exit Dry-Bulb:                         | 59.937 0.20 | EvapAir Delta T (F):        | 20.62    | 0.43   |
| Indoor Exit Dew (F):                          | 54.342 0.25 | Air/Ref Cap Prcnt Diff:     | -1.54    | 2.19   |
|   |             | Sensible Heat Ratio:        | 0.660    | 0.0094 |
| Indoor Airflow (CFM):                         | 601.63 8.03 | SCFM per Ton:               | 348.88   |        |
| Indoor Airflow (SCFM):                        | 594.94 8.02 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011637    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009185    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 63.00    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.282       | 0.034                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.166       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.78 | 0.487 | Ref-side Cap (Btu/h) :                  | 20146.95 214.63 |
| Upstream Temp A (F):       | 105.01 | 0.262 | Ref-side Cap (tons):                    | 1.68 0.02       |
| Upstream Temp B (F):       | 105.14 | 0.567 | Refrigerant Mdot (lbm/h):               | 293.36 3.30     |
| Upstream Temp C (F):       | 104.76 | 0.085 | Coriolis Density (lbm/ft3):             | 70.21 0.02      |
| Upstream Average Temp (F): | 104.97 |       | Upstream R22 Tsat (F):                  | 119.69          |
| Upstream Subcooling A (F): | 14.68  | 0.332 |   |                 |
| Upstream Subcooling B (F): | 14.55  | 0.567 |   |                 |
| Upstream Subcooling C (F): | 14.93  | 0.225 |   |                 |
| Average Subcooling (F):    | 14.72  |       |   |                 |
| Evap Exit Pressure (psia): | 90.57  | 0.608 | Turbine A Frequency (Hz):               | 185.79 2.00     |
| Evap Exit Avg Temp A:      | 55.72  | 2.870 | Turb A Vol Flow (ft3/min):              | 0.0262 0.00     |
| Evap Exit Avg Temp B:      | 56.18  | 1.563 | Turb A Density (lbm/ft3):               | 70.30 0.04      |
| Evap Exit Avg Temp C:      | 56.55  | 2.066 | Turb A Mass Flow (lb/h):                | 110.56 1.14     |
| Circuit A Superheat (F):   | 10.27  | 2.635 | Turbine C Frequency (Hz):               | 172.72 1.00     |
| Circuit B Superheat (F):   | 10.74  | 1.563 | Turb C Vol Flow (ft3/min):              | 0.0253 0.00     |
| Circuit C Superheat (F):   | 11.11  | 2.222 | Turb C Density (lbm/ft3):               | 70.34 0.01      |
| Overall Superheat (F):     | 13.18  | 0.874 | Turb C Mass Flow (lb/h):                | 106.70 0.58     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 76.11 3.01      |
| Evap Circuit Temp 1 (F):   | 53.82  | 2.307 | % Total Mass Flow Thru A:               | 37.69 0.49      |
| Evap Circuit Temp 2 (F):   | 49.80  | 0.324 | % Total Mass Flow Thru B:               | 25.94 0.79      |
| Evap Circuit Temp 3 (F):   | 53.05  | 0.555 | % Total Mass Flow Thru C:               | 36.37 0.49      |
| Evap Circuit Temp 4 (F):   | 51.74  | 1.946 |   |                 |
| Evap Circuit Temp 5 (F):   | 51.98  | 0.647 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.36  | 0.597 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.80  | 2.217 |   |                 |
| Evap Circuit Temp 8 (F):   | 53.31  | 0.600 |   |                 |
| Evap Circuit Temp 9 (F):   | 54.18  | 0.277 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020321A.DAT SUMMARY FILENAME: W020321A.sum

|   | Range        | Total Air-Side Capacity:    | 13737.21 | 461.23 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 80.071 0.27  | Sensible Cap (Btu/h):       | 10818.72 | 382.69 |
| Indoor Inlet Dew (F):                         | 60.627 0.10  | Latent Cap (Btu/h):         | 2918.49  | 219.40 |
| Indoor Exit Dry-Bulb:                         | 64.222 0.16  | EvapAir Delta T (F):        | 16.45    | 0.43   |
| Indoor Exit Dew (F):                          | 58.072 0.10  | Air/Ref Cap Prcnt Diff:     | -3.58    | 4.38   |
|   |              | Sensible Heat Ratio:        | 0.788    | 0.0118 |
| Indoor Airflow (CFM):                         | 608.69 11.13 | SCFM per Ton:               | 521.14   |        |
| Indoor Airflow (SCFM):                        | 596.58 10.93 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011562     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010536     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 66.56    | 0.45   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.301        | 0.047                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.129        | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 270.29 | 0.365 | Ref-side Cap (Btu/h) :                  | 13243.77 227.41 |
| Upstream Temp A (F):       | 105.71 | 0.481 | Ref-side Cap (tons):                    | 1.10 0.02       |
| Upstream Temp B (F):       | 105.90 | 0.610 | Refrigerant Mdot (lbm/h):               | 190.17 3.30     |
| Upstream Temp C (F):       | 105.54 | 0.619 | Coriolis Density (lbm/ft3):             | 69.91 0.02      |
| Upstream Average Temp (F): | 105.72 |       | Upstream R22 Tsat (F):                  | 119.31          |
| Upstream Subcooling A (F): | 13.60  | 0.481 |   |                 |
| Upstream Subcooling B (F): | 13.41  | 0.610 |   |                 |
| Upstream Subcooling C (F): | 13.76  | 0.619 |   |                 |
| Average Subcooling (F):    | 13.59  |       |   |                 |
| Evap Exit Pressure (psia): | 90.41  | 0.486 | Turbine A Frequency (Hz):               | 120.18 2.00     |
| Evap Exit Avg Temp A:      | 74.48  | 0.470 | Turb A Vol Flow (ft3/min):              | 0.0175 0.00     |
| Evap Exit Avg Temp B:      | 76.45  | 0.534 | Turb A Density (lbm/ft3):               | 70.19 0.07      |
| Evap Exit Avg Temp C:      | 75.17  | 0.398 | Turb A Mass Flow (lb/h):                | 73.64 1.13      |
| Circuit A Superheat (F):   | 29.43  | 0.623 | Turbine C Frequency (Hz):               | 117.36 1.00     |
| Circuit B Superheat (F):   | 31.40  | 0.710 | Turb C Vol Flow (ft3/min):              | 0.0179 0.00     |
| Circuit C Superheat (F):   | 30.12  | 0.569 | Turb C Density (lbm/ft3):               | 70.22 0.10      |
| Overall Superheat (F):     | 30.67  | 0.768 | Turb C Mass Flow (lb/h):                | 75.39 0.66      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 41.13 3.73      |
| Evap Circuit Temp 1 (F):   | 76.63  | 0.755 | % Total Mass Flow Thru A:               | 38.73 0.98      |
| Evap Circuit Temp 2 (F):   | 75.42  | 0.728 | % Total Mass Flow Thru B:               | 21.63 1.66      |
| Evap Circuit Temp 3 (F):   | 52.54  | 0.555 | % Total Mass Flow Thru C:               | 39.65 0.92      |
| Evap Circuit Temp 4 (F):   | 77.08  | 0.815 |   |                 |
| Evap Circuit Temp 5 (F):   | 76.80  | 0.804 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.76  | 0.641 |   |                 |
| Evap Circuit Temp 7 (F):   | 77.43  | 0.883 |   |                 |
| Evap Circuit Temp 8 (F):   | 75.87  | 0.806 |   |                 |
| Evap Circuit Temp 9 (F):   | 53.66  | 0.464 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020322A.DAT SUMMARY FILENAME: W020322A.sum

|   | Range       | Total Air-Side Capacity:    | 19115.01 | 412.49 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.098 0.37 | Sensible Cap (Btu/h):       | 19115.23 | 412.49 |
| Indoor Inlet Dew (F):                         | 32.006 0.00 | Latent Cap (Btu/h):         | -0.22    | 0.00   |
| Indoor Exit Dry-Bulb:                         | 57.457 0.22 | EvapAir Delta T (F):        | 23.19    | 0.22   |
| Indoor Exit Dew (F):                          | 32.006 0.00 | Air/Ref Cap Prcnt Diff:     | -4.37    | 2.42   |
|   |             | Sensible Heat Ratio:        | 1.000    | 0.0000 |
| Indoor Airflow (CFM):                         | 760.02 9.45 | SCFM per Ton:               | 475.64   |        |
| Indoor Airflow (SCFM):                        | 757.65 9.55 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003864    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 60.88    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.276       | 0.032                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.131       | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 272.97 | 0.487 | Ref-side Cap (Btu/h) :                  | 18279.72 241.19 |
| Upstream Temp A (F):       | 105.01 | 0.524 | Ref-side Cap (tons):                    | 1.52 0.02       |
| Upstream Temp B (F):       | 105.18 | 0.693 | Refrigerant Mdot (lbm/h):               | 266.22 3.19     |
| Upstream Temp C (F):       | 104.77 | 0.524 | Coriolis Density (lbm/ft3):             | 70.21 0.02      |
| Upstream Average Temp (F): | 104.99 |       | Upstream R22 Tsat (F):                  | 120.02          |
| Upstream Subcooling A (F): | 15.01  | 0.593 |   |                 |
| Upstream Subcooling B (F): | 14.84  | 0.762 |   |                 |
| Upstream Subcooling C (F): | 15.25  | 0.482 |   |                 |
| Average Subcooling (F):    | 15.03  |       |   |                 |
| Evap Exit Pressure (psia): | 90.14  | 0.486 | Turbine A Frequency (Hz):               | 170.89 2.00     |
| Evap Exit Avg Temp A:      | 55.43  | 2.086 | Turb A Vol Flow (ft3/min):              | 0.0242 0.00     |
| Evap Exit Avg Temp B:      | 55.13  | 1.732 | Turb A Density (lbm/ft3):               | 70.30 0.08      |
| Evap Exit Avg Temp C:      | 56.00  | 2.454 | Turb A Mass Flow (lb/h):                | 102.20 1.12     |
| Circuit A Superheat (F):   | 10.35  | 2.244 | Turbine C Frequency (Hz):               | 151.21 2.00     |
| Circuit B Superheat (F):   | 10.04  | 1.830 | Turb C Vol Flow (ft3/min):              | 0.0224 0.00     |
| Circuit C Superheat (F):   | 10.91  | 2.454 | Turb C Density (lbm/ft3):               | 70.34 0.08      |
| Overall Superheat (F):     | 13.38  | 1.086 | Turb C Mass Flow (lb/h):                | 94.58 1.21      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 69.44 3.35      |
| Evap Circuit Temp 1 (F):   | 54.25  | 6.450 | % Total Mass Flow Thru A:               | 38.39 0.58      |
| Evap Circuit Temp 2 (F):   | 49.21  | 0.647 | % Total Mass Flow Thru B:               | 26.08 1.04      |
| Evap Circuit Temp 3 (F):   | 53.40  | 0.403 | % Total Mass Flow Thru C:               | 35.53 0.61      |
| Evap Circuit Temp 4 (F):   | 51.86  | 1.191 |   |                 |
| Evap Circuit Temp 5 (F):   | 54.36  | 0.643 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.74  | 0.596 |   |                 |
| Evap Circuit Temp 7 (F):   | 54.66  | 1.662 |   |                 |
| Evap Circuit Temp 8 (F):   | 53.21  | 0.699 |   |                 |
| Evap Circuit Temp 9 (F):   | 55.06  | 0.564 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020321B.DAT SUMMARY FILENAME: W020321B.sum

|   | Range        | Total Air-Side Capacity:    | 14676.52 | 192.51 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 79.773 0.20  | Sensible Cap (Btu/h):       | 15018.79 | 198.01 |
| Indoor Inlet Dew (F):                         | 44.526 0.06  | Latent Cap (Btu/h):         | -342.27  | 86.94  |
| Indoor Exit Dry-Bulb:                         | 62.101 0.19  | EvapAir Delta T (F):        | 18.30    | 0.00   |
| Indoor Exit Dew (F):                          | 44.915 0.06  | Air/Ref Cap Prcnt Diff:     | -7.09    | 1.73   |
|   |              | Sensible Heat Ratio:        | 1.023    | 0.0061 |
| Indoor Airflow (CFM):                         | 761.16 10.07 | SCFM per Ton:               | 613.93   |        |
| Indoor Airflow (SCFM):                        | 750.87 9.91  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.006339     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.006435     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 64.72    | 0.36   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.267        | 0.033                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.134        | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 269.73 | 0.487 | Ref-side Cap (Btu/h) :                  | 13636.52 | 222.68 |
| Upstream Temp A (F):       | 104.74 | 0.524 | Ref-side Cap (tons):                    | 1.14     | 0.02   |
| Upstream Temp B (F):       | 104.93 | 0.087 | Refrigerant Mdot (lbm/h):               | 195.05   | 2.97   |
| Upstream Temp C (F):       | 104.60 | 0.567 | Coriolis Density (lbm/ft3):             | 70.16    | 0.05   |
| Upstream Average Temp (F): | 104.76 |       | Upstream R22 Tsat (F):                  | 119.14   |        |
| Upstream Subcooling A (F): | 14.41  | 0.559 |   |          |        |
| Upstream Subcooling B (F): | 14.21  | 0.262 |   |          |        |
| Upstream Subcooling C (F): | 14.55  | 0.567 |   |          |        |
| Average Subcooling (F):    | 14.39  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.47  | 0.608 | Turbine A Frequency (Hz):               | 124.95   | 2.00   |
| Evap Exit Avg Temp A:      | 73.99  | 0.359 | Turb A Vol Flow (ft3/min):              | 0.0181   | 0.00   |
| Evap Exit Avg Temp B:      | 75.87  | 0.627 | Turb A Density (lbm/ft3):               | 70.34    | 0.08   |
| Evap Exit Avg Temp C:      | 74.77  | 0.358 | Turb A Mass Flow (lb/h):                | 76.48    | 1.14   |
| Circuit A Superheat (F):   | 28.91  | 0.516 | Turbine C Frequency (Hz):               | 120.20   | 1.00   |
| Circuit B Superheat (F):   | 30.79  | 0.784 | Turb C Vol Flow (ft3/min):              | 0.0183   | 0.00   |
| Circuit C Superheat (F):   | 29.70  | 0.516 | Turb C Density (lbm/ft3):               | 70.36    | 0.09   |
| Overall Superheat (F):     | 30.09  | 0.593 | Turb C Mass Flow (lb/h):                | 77.15    | 0.66   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 41.43    | 2.88   |
| Evap Circuit Temp 1 (F):   | 76.17  | 0.357 | % Total Mass Flow Thru A:               | 39.21    | 0.82   |
| Evap Circuit Temp 2 (F):   | 73.24  | 0.632 | % Total Mass Flow Thru B:               | 21.24    | 1.20   |
| Evap Circuit Temp 3 (F):   | 52.92  | 0.647 | % Total Mass Flow Thru C:               | 39.55    | 0.58   |
| Evap Circuit Temp 4 (F):   | 76.36  | 0.855 |   |          |        |
| Evap Circuit Temp 5 (F):   | 76.62  | 0.629 |   |          |        |
| Evap Circuit Temp 6 (F):   | 56.40  | 0.642 |   |          |        |
| Evap Circuit Temp 7 (F):   | 76.98  | 0.540 |   |          |        |
| Evap Circuit Temp 8 (F):   | 74.18  | 0.316 |   |          |        |
| Evap Circuit Temp 9 (F):   | 54.92  | 1.755 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020322C.DAT SUMMARY FILENAME: W020322C.sum

|   | Range        | Total Air-Side Capacity:    | 16367.24 | 1962.29 |
|---|--------------|-----------------------------|----------|---------|
| Air-Side Conditions                           |              |                             |          |         |
| Indoor Dry-Bulb :                             | 80.050 0.28  | Sensible Cap (Btu/h):       | 16367.46 | 1962.29 |
| Indoor Inlet Dew (F):                         | 32.006 0.00  | Latent Cap (Btu/h):         | -0.22    | 0.00    |
| Indoor Exit Dry-Bulb:                         | 60.669 0.20  | EvapAir Delta T (F):        | 19.96    | 2.15    |
| Indoor Exit Dew (F):                          | 32.006 0.00  | Air/Ref Cap Prcnt Diff:     | -5.37    | 13.42   |
|   |              | Sensible Heat Ratio:        | 1.000    | 0.0000  |
| Indoor Airflow (CFM):                         | 760.98 12.30 | SCFM per Ton:               | 552.76   |         |
| Indoor Airflow (SCFM):                        | 753.93 12.21 | (0.075 lb/ft3 standard air) |          |         |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864     |                             |          |         |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003864     |                             |          |         |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 63.59    | 0.55    |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.271        | 0.041                       |          |         |
| Evaporator Coil Air Pressure Drop (in Water): | 0.132        | 0.006                       |          |         |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 278.74 | 2.923 | Ref-side Cap (Btu/h) :                  | 15478.92 | 222.72 |
| Upstream Temp A (F):       | 106.91 | 0.127 | Ref-side Cap (tons):                    | 1.29     | 0.02   |
| Upstream Temp B (F):       | 107.25 | 0.347 | Refrigerant Mdot (lbm/h):               | 227.86   | 2.64   |
| Upstream Temp C (F):       | 106.65 | 0.170 | Coriolis Density (lbm/ft3):             | 69.87    | 0.06   |
| Upstream Average Temp (F): | 106.94 |       | Upstream R22 Tsat (F):                  | 121.70   |        |
| Upstream Subcooling A (F): | 14.79  | 0.754 |   |          |        |
| Upstream Subcooling B (F): | 14.46  | 0.754 |   |          |        |
| Upstream Subcooling C (F): | 15.05  | 0.754 |   |          |        |
| Average Subcooling (F):    | 14.77  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.79  | 2.311 | Turbine A Frequency (Hz):               | 127.38   | 2.00   |
| Evap Exit Avg Temp A:      | 74.01  | 0.495 | Turb A Vol Flow (ft3/min):              | 0.0184   | 0.00   |
| Evap Exit Avg Temp B:      | 47.36  | 0.558 | Turb A Density (lbm/ft3):               | 70.01    | 0.02   |
| Evap Exit Avg Temp C:      | 74.32  | 0.539 | Turb A Mass Flow (lb/h):                | 77.47    | 1.11   |
| Circuit A Superheat (F):   | 28.59  | 1.481 | Turbine C Frequency (Hz):               | 103.21   | 2.00   |
| Circuit B Superheat (F):   | 1.94   | 1.531 | Turb C Vol Flow (ft3/min):              | 0.0160   | 0.00   |
| Circuit C Superheat (F):   | 28.90  | 1.872 | Turb C Density (lbm/ft3):               | 70.05    | 0.03   |
| Overall Superheat (F):     | 11.45  | 3.853 | Turb C Mass Flow (lb/h):                | 67.27    | 1.11   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 83.13    | 4.07   |
| Evap Circuit Temp 1 (F):   | 76.62  | 6.583 | % Total Mass Flow Thru A:               | 34.00    | 0.85   |
| Evap Circuit Temp 2 (F):   | 72.82  | 1.716 | % Total Mass Flow Thru B:               | 36.48    | 1.40   |
| Evap Circuit Temp 3 (F):   | 53.43  | 0.135 | % Total Mass Flow Thru C:               | 29.52    | 0.66   |
| Evap Circuit Temp 4 (F):   | 51.27  | 0.556 |   |          |        |
| Evap Circuit Temp 5 (F):   | 55.05  | 0.277 |   |          |        |
| Evap Circuit Temp 6 (F):   | 57.46  | 2.941 |   |          |        |
| Evap Circuit Temp 7 (F):   | 76.80  | 5.038 |   |          |        |
| Evap Circuit Temp 8 (F):   | 77.12  | 1.167 |   |          |        |
| Evap Circuit Temp 9 (F):   | 55.42  | 0.599 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020322B.DAT SUMMARY FILENAME: W020322B.sum

|   | Range       | Total Air-Side Capacity:    | 16037.21 | 244.39 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.955 0.20 | Sensible Cap (Btu/h):       | 16037.43 | 244.39 |
| Indoor Inlet Dew (F):                         | 32.006 0.00 | Latent Cap (Btu/h):         | -0.22    | 0.00   |
| Indoor Exit Dry-Bulb:                         | 61.106 0.18 | EvapAir Delta T (F):        | 19.60    | 0.22   |
| Indoor Exit Dew (F):                          | 32.006 0.00 | Air/Ref Cap Prcnt Diff:     | -6.22    | 1.61   |
|   |             | Sensible Heat Ratio:        | 1.000    | 0.0000 |
| Indoor Airflow (CFM):                         | 760.08 6.71 | SCFM per Ton:               | 562.99   |        |
| Indoor Airflow (SCFM):                        | 752.40 6.84 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.003864    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.003864    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 63.97    | 0.59   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.267       | 0.023                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.132       | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 276.86 | 0.244 | Ref-side Cap (Btu/h) :                  | 15039.85 234.64 |
| Upstream Temp A (F):       | 105.34 | 0.347 | Ref-side Cap (tons):                    | 1.25 0.02       |
| Upstream Temp B (F):       | 105.23 | 0.524 | Refrigerant Mdot (lbm/h):               | 219.73 3.08     |
| Upstream Temp C (F):       | 105.11 | 0.085 | Coriolis Density (lbm/ft3):             | 70.13 0.07      |
| Upstream Average Temp (F): | 105.23 |       | Upstream R22 Tsat (F):                  | 121.16          |
| Upstream Subcooling A (F): | 15.82  | 0.347 |   |                 |
| Upstream Subcooling B (F): | 15.93  | 0.593 |   |                 |
| Upstream Subcooling C (F): | 16.05  | 0.154 |   |                 |
| Average Subcooling (F):    | 15.93  |       |   |                 |
| Evap Exit Pressure (psia): | 91.03  | 0.365 | Turbine A Frequency (Hz):               | 167.48 1.00     |
| Evap Exit Avg Temp A:      | 47.22  | 0.486 | Turb A Vol Flow (ft3/min):              | 0.0238 0.00     |
| Evap Exit Avg Temp B:      | 74.24  | 0.357 | Turb A Density (lbm/ft3):               | 70.25 0.05      |
| Evap Exit Avg Temp C:      | 75.32  | 0.269 | Turb A Mass Flow (lb/h):                | 100.21 0.63     |
| Circuit A Superheat (F):   | 1.69   | 0.565 | Turbine C Frequency (Hz):               | 122.48 1.00     |
| Circuit B Superheat (F):   | 28.71  | 0.448 | Turb C Vol Flow (ft3/min):              | 0.0186 0.00     |
| Circuit C Superheat (F):   | 29.80  | 0.347 | Turb C Density (lbm/ft3):               | 70.29 0.01      |
| Overall Superheat (F):     | 10.93  | 3.666 | Turb C Mass Flow (lb/h):                | 78.34 0.58      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 41.18 3.77      |
| Evap Circuit Temp 1 (F):   | 76.78  | 0.625 | % Total Mass Flow Thru A:               | 45.61 0.80      |
| Evap Circuit Temp 2 (F):   | 49.73  | 0.603 | % Total Mass Flow Thru B:               | 18.74 1.49      |
| Evap Circuit Temp 3 (F):   | 53.96  | 0.322 | % Total Mass Flow Thru C:               | 35.65 0.69      |
| Evap Circuit Temp 4 (F):   | 75.62  | 0.584 |   |                 |
| Evap Circuit Temp 5 (F):   | 76.51  | 0.357 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.66  | 0.553 |   |                 |
| Evap Circuit Temp 7 (F):   | 54.14  | 0.598 |   |                 |
| Evap Circuit Temp 8 (F):   | 74.96  | 0.358 |   |                 |
| Evap Circuit Temp 9 (F):   | 55.71  | 0.643 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020607A.dat SUMMARY FILENAME: E020607A.sum

|   | Range       | Total Air-Side Capacity:    | 23732.88 | Range  |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.851 0.39 | Sensible Cap (Btu/h):       | 17252.27 | 350.17 |
| Indoor Inlet Dew (F):                         | 60.360 0.11 | Latent Cap (Btu/h):         | 6480.61  | 153.02 |
| Indoor Exit Dry-Bulb:                         | 59.725 0.19 | EvapAir Delta T (F):        | 20.59    | 0.22   |
| Indoor Exit Dew (F):                          | 55.721 0.15 | Air/Ref Cap Prcnt Diff:     | -0.48    | 3.41   |
|   |             | Sensible Heat Ratio:        | 0.727    | 0.0062 |
| Indoor Airflow (CFM):                         | 769.76 7.65 | SCFM per Ton:               | 384.76   |        |
| Indoor Airflow (SCFM):                        | 760.95 7.53 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011451    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009666    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 60.70    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.776       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.340       | 0.008                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 273.97 | 0.609 | Ref-side Cap (Btu/h) :                  | 23619.08 522.68 |
| Upstream Temp A (F):       | 105.06 | 0.610 | Ref-side Cap (tons):                    | 1.97 0.04       |
| Upstream Temp B (F):       | 105.52 | 0.262 | Refrigerant Mdot (lbm/h):               | 344.39 7.78     |
| Upstream Temp C (F):       | 105.08 | 0.524 | Coriolis Density (lbm/ft3):             | 82.28 0.08      |
| Upstream Average Temp (F): | 105.22 |       | Upstream R22 Tsat (F):                  | 119.69          |
| Upstream Subcooling A (F): | 14.63  | 0.644 |   |                 |
| Upstream Subcooling B (F): | 14.17  | 0.297 |   |                 |
| Upstream Subcooling C (F): | 14.62  | 0.524 |   |                 |
| Average Subcooling (F):    | 14.47  |       |   |                 |
| Evap Exit Pressure (psia): | 90.83  | 0.486 | Turbine A Frequency (Hz):               | 221.44 1.00     |
| Evap Exit Avg Temp A:      | 55.78  | 1.263 | Turb A Vol Flow (ft3/min):              | 0.0309 0.00     |
| Evap Exit Avg Temp B:      | 55.97  | 1.747 | Turb A Density (lbm/ft3):               | 70.29 0.09      |
| Evap Exit Avg Temp C:      | 55.76  | 2.343 | Turb A Mass Flow (lb/h):                | 130.53 0.71     |
| Circuit A Superheat (F):   | 10.04  | 1.419 | Turbine C Frequency (Hz):               | 198.44 1.00     |
| Circuit B Superheat (F):   | 10.23  | 1.668 | Turb C Vol Flow (ft3/min):              | 0.0287 0.00     |
| Circuit C Superheat (F):   | 10.02  | 2.656 | Turb C Density (lbm/ft3):               | 70.29 0.08      |
| Overall Superheat (F):     | 12.83  | 1.228 | Turb C Mass Flow (lb/h):                | 121.09 0.59     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 92.76 8.08      |
| Evap Circuit Temp 1 (F):   | 49.92  | 0.279 | % Total Mass Flow Thru A:               | 37.90 0.93      |
| Evap Circuit Temp 2 (F):   | 51.11  | 0.557 | % Total Mass Flow Thru B:               | 26.93 1.81      |
| Evap Circuit Temp 3 (F):   | 50.37  | 0.649 | % Total Mass Flow Thru C:               | 35.16 0.93      |
| Evap Circuit Temp 4 (F):   | 49.15  | 0.558 |   |                 |
| Evap Circuit Temp 5 (F):   | 49.04  | 0.325 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.12  | 0.368 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.23  | 0.644 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.02  | 0.558 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.96  | 0.279 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020318A.DAT SUMMARY FILENAME: W020318A.sum

|   | Range       | Total Air-Side Capacity:    | 16598.91 | 513.92 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.345 0.17 | Sensible Cap (Btu/h):       | 13581.22 | 484.67 |
| Indoor Inlet Dew (F):                         | 60.173 0.15 | Latent Cap (Btu/h):         | 3017.69  | 116.88 |
| Indoor Exit Dry-Bulb:                         | 64.613 0.26 | EvapAir Delta T (F):        | 16.23    | 0.43   |
| Indoor Exit Dew (F):                          | 58.083 0.15 | Air/Ref Cap Prcnt Diff:     | -3.92    | 2.95   |
|   |             | Sensible Heat Ratio:        | 0.818    | 0.0084 |
| Indoor Airflow (CFM):                         | 775.54 7.57 | SCFM per Ton:               | 548.99   |        |
| Indoor Airflow (SCFM):                        | 759.38 7.39 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011373    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010540    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 66.26    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 2.106       | 0.041                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.212       | 0.008                       |          |        |

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Refrigerant Side Conditions

Expansion Valve

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Upstream Pressure (psia):  | 273.41 | 0.487 | Ref-side Cap (Btu/h) :                  | 15947.44 | 296.80 |
| Upstream Temp A (F):       | 105.24 | 0.262 | Ref-side Cap (tons):                    | 1.33     | 0.02   |
| Upstream Temp B (F):       | 105.29 | 0.524 | Refrigerant Mdot (lbm/h):               | 228.49   | 4.18   |
| Upstream Temp C (F):       | 105.06 | 0.524 | Coriolis Density (lbm/ft3):             | 70.16    | 0.06   |
| Upstream Average Temp (F): | 105.20 |       | Upstream R22 Tsat (F):                  | 120.18   |        |
| Upstream Subcooling A (F): | 14.94  | 0.366 |   |          |        |
| Upstream Subcooling B (F): | 14.90  | 0.663 |   |          |        |
| Upstream Subcooling C (F): | 15.13  | 0.455 |   |          |        |
| Average Subcooling (F):    | 14.99  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.51  | 0.486 | Turbine A Frequency (Hz):               | 137.33   | 2.00   |
| Evap Exit Avg Temp A:      | 75.20  | 0.425 | Turb A Vol Flow (ft3/min):              | 0.0198   | 0.00   |
| Evap Exit Avg Temp B:      | 75.81  | 0.134 | Turb A Density (lbm/ft3):               | 70.27    | 0.04   |
| Evap Exit Avg Temp C:      | 74.79  | 0.404 | Turb A Mass Flow (lb/h):                | 83.33    | 1.12   |
| Circuit A Superheat (F):   | 29.99  | 0.582 | Turbine C Frequency (Hz):               | 144.83   | 1.00   |
| Circuit B Superheat (F):   | 30.61  | 0.427 | Turb C Vol Flow (ft3/min):              | 0.0216   | 0.00   |
| Circuit C Superheat (F):   | 29.59  | 0.449 | Turb C Density (lbm/ft3):               | 70.29    | 0.08   |
| Overall Superheat (F):     | 30.39  | 0.851 | Turb C Mass Flow (lb/h):                | 90.93    | 0.61   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 54.23    | 4.64   |
| Evap Circuit Temp 1 (F):   | 76.35  | 0.583 | % Total Mass Flow Thru A:               | 36.47    | 0.89   |
| Evap Circuit Temp 2 (F):   | 75.92  | 0.359 | % Total Mass Flow Thru B:               | 23.73    | 1.60   |
| Evap Circuit Temp 3 (F):   | 52.34  | 0.092 | % Total Mass Flow Thru C:               | 39.80    | 0.79   |
| Evap Circuit Temp 4 (F):   | 76.32  | 0.629 |   |          |        |
| Evap Circuit Temp 5 (F):   | 76.23  | 0.540 |   |          |        |
| Evap Circuit Temp 6 (F):   | 55.96  | 0.642 |   |          |        |
| Evap Circuit Temp 7 (F):   | 78.23  | 0.356 |   |          |        |
| Evap Circuit Temp 8 (F):   | 74.36  | 0.541 |   |          |        |
| Evap Circuit Temp 9 (F):   | 53.94  | 0.323 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020318B.DAT SUMMARY FILENAME: W020318B.sum

|   | Range       | Total Air-Side Capacity:    | 18714.97 | 298.10 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.289 0.34 | Sensible Cap (Btu/h):       | 14556.00 | 277.25 |
| Indoor Inlet Dew (F):                         | 60.077 0.10 | Latent Cap (Btu/h):         | 4158.97  | 169.33 |
| Indoor Exit Dry-Bulb:                         | 63.435 0.14 | EvapAir Delta T (F):        | 17.40    | 0.22   |
| Indoor Exit Dew (F):                          | 57.148 0.10 | Air/Ref Cap Prcnt Diff:     | -1.67    | 2.30   |
|   |             | Sensible Heat Ratio:        | 0.778    | 0.0068 |
| Indoor Airflow (CFM):                         | 773.75 9.07 | SCFM per Ton:               | 486.97   |        |
| Indoor Airflow (SCFM):                        | 759.46 8.91 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011334    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010186    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 65.20    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 2.101       | 0.049                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.228       | 0.010                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 269.16 | 0.731 | Ref-side Cap (Btu/h) :                  | 18401.73 293.95 |
| Upstream Temp A (F):       | 102.85 | 0.262 | Ref-side Cap (tons):                    | 1.53 0.02       |
| Upstream Temp B (F):       | 103.15 | 0.349 | Refrigerant Mdot (lbm/h):               | 266.99 3.96     |
| Upstream Temp C (F):       | 102.69 | 0.611 | Coriolis Density (lbm/ft3):             | 70.50 0.04      |
| Upstream Average Temp (F): | 102.90 |       | Upstream R22 Tsat (F):                  | 118.95          |
| Upstream Subcooling A (F): | 16.10  | 0.316 |   |                 |
| Upstream Subcooling B (F): | 15.80  | 0.411 |   |                 |
| Upstream Subcooling C (F): | 16.27  | 0.603 |   |                 |
| Average Subcooling (F):    | 16.06  |       |   |                 |
| Evap Exit Pressure (psia): | 90.08  | 0.486 | Turbine A Frequency (Hz):               | 138.54 1.00     |
| Evap Exit Avg Temp A:      | 75.05  | 0.538 | Turb A Vol Flow (ft3/min):              | 0.0199 0.00     |
| Evap Exit Avg Temp B:      | 46.96  | 0.350 | Turb A Density (lbm/ft3):               | 70.63 0.04      |
| Evap Exit Avg Temp C:      | 73.57  | 0.404 | Turb A Mass Flow (lb/h):                | 84.44 0.61      |
| Circuit A Superheat (F):   | 29.94  | 0.695 | Turbine C Frequency (Hz):               | 134.36 1.00     |
| Circuit B Superheat (F):   | 1.85   | 0.446 | Turb C Vol Flow (ft3/min):              | 0.0202 0.00     |
| Circuit C Superheat (F):   | 28.47  | 0.562 | Turb C Density (lbm/ft3):               | 70.66 0.09      |
| Overall Superheat (F):     | 8.08   | 3.255 | Turb C Mass Flow (lb/h):                | 85.47 0.62      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 97.07 4.53      |
| Evap Circuit Temp 1 (F):   | 76.37  | 0.540 | % Total Mass Flow Thru A:               | 31.63 0.68      |
| Evap Circuit Temp 2 (F):   | 75.49  | 0.315 | % Total Mass Flow Thru B:               | 36.36 1.16      |
| Evap Circuit Temp 3 (F):   | 51.99  | 0.370 | % Total Mass Flow Thru C:               | 32.01 0.54      |
| Evap Circuit Temp 4 (F):   | 51.30  | 0.370 |   |                 |
| Evap Circuit Temp 5 (F):   | 52.50  | 0.556 |   |                 |
| Evap Circuit Temp 6 (F):   | 57.06  | 0.365 |   |                 |
| Evap Circuit Temp 7 (F):   | 78.01  | 0.539 |   |                 |
| Evap Circuit Temp 8 (F):   | 76.11  | 0.270 |   |                 |
| Evap Circuit Temp 9 (F):   | 53.54  | 0.091 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020319A.DAT SUMMARY FILENAME: W020319A.sum

|   | Range       | Total Air-Side Capacity:    | 16157.00 | 574.90 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.951 0.39 | Sensible Cap (Btu/h):       | 13451.72 | 416.34 |
| Indoor Inlet Dew (F):                         | 60.169 0.10 | Latent Cap (Btu/h):         | 2705.28  | 226.59 |
| Indoor Exit Dry-Bulb:                         | 64.635 0.14 | EvapAir Delta T (F):        | 16.00    | 0.43   |
| Indoor Exit Dew (F):                          | 58.311 0.15 | Air/Ref Cap Prcnt Diff:     | 0.54     | 3.90   |
|   |             | Sensible Heat Ratio:        | 0.833    | 0.0112 |
| Indoor Airflow (CFM):                         | 779.33 6.30 | SCFM per Ton:               | 566.71   |        |
| Indoor Airflow (SCFM):                        | 763.02 6.13 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011372    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010629    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 66.13    | 0.72   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 2.126       | 0.034                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.212       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 275.15 | 0.487 | Ref-side Cap (Btu/h) :                  | 16242.29 243.60 |
| Upstream Temp A (F):       | 105.64 | 0.609 | Ref-side Cap (tons):                    | 1.35 0.02       |
| Upstream Temp B (F):       | 105.62 | 0.524 | Refrigerant Mdot (lbm/h):               | 237.98 3.30     |
| Upstream Temp C (F):       | 105.38 | 0.524 | Coriolis Density (lbm/ft3):             | 70.06 0.13      |
| Upstream Average Temp (F): | 105.55 |       | Upstream R22 Tsat (F):                  | 120.68          |
| Upstream Subcooling A (F): | 15.04  | 0.643 |   |                 |
| Upstream Subcooling B (F): | 15.06  | 0.559 |   |                 |
| Upstream Subcooling C (F): | 15.30  | 0.524 |   |                 |
| Average Subcooling (F):    | 15.13  |       |   |                 |
| Evap Exit Pressure (psia): | 90.56  | 0.486 | Turbine A Frequency (Hz):               | 197.48 2.00     |
| Evap Exit Avg Temp A:      | 47.14  | 0.630 | Turb A Vol Flow (ft3/min):              | 0.0278 0.00     |
| Evap Exit Avg Temp B:      | 74.83  | 0.269 | Turb A Density (lbm/ft3):               | 70.20 0.09      |
| Evap Exit Avg Temp C:      | 75.28  | 0.425 | Turb A Mass Flow (lb/h):                | 116.95 1.22     |
| Circuit A Superheat (F):   | 1.87   | 0.558 | Turbine C Frequency (Hz):               | 143.52 1.00     |
| Circuit B Superheat (F):   | 29.56  | 0.379 | Turb C Vol Flow (ft3/min):              | 0.0214 0.00     |
| Circuit C Superheat (F):   | 30.01  | 0.513 | Turb C Density (lbm/ft3):               | 70.24 0.08      |
| Overall Superheat (F):     | 9.96   | 3.499 | Turb C Mass Flow (lb/h):                | 90.13 0.65      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 30.91 3.74      |
| Evap Circuit Temp 1 (F):   | 76.87  | 0.270 | % Total Mass Flow Thru A:               | 49.14 0.90      |
| Evap Circuit Temp 2 (F):   | 50.12  | 0.467 | % Total Mass Flow Thru B:               | 12.99 1.40      |
| Evap Circuit Temp 3 (F):   | 53.65  | 0.554 | % Total Mass Flow Thru C:               | 37.87 0.74      |
| Evap Circuit Temp 4 (F):   | 76.40  | 0.540 |   |                 |
| Evap Circuit Temp 5 (F):   | 77.30  | 0.627 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.01  | 0.597 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.01  | 0.643 |   |                 |
| Evap Circuit Temp 8 (F):   | 75.59  | 0.672 |   |                 |
| Evap Circuit Temp 9 (F):   | 53.97  | 0.555 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020319B.dat SUMMARY FILENAME: W020319B.sum

|   | Range        | Total Air-Side Capacity:    | 26108.83 | 370.27 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 79.699 0.49  | Sensible Cap (Btu/h):       | 19517.33 | 433.61 |
| Indoor Inlet Dew (F):                         | 60.531 0.11  | Latent Cap (Btu/h):         | 6591.50  | 280.97 |
| Indoor Exit Dry-Bulb:                         | 62.441 0.24  | EvapAir Delta T (F):        | 17.87    | 0.43   |
| Indoor Exit Dew (F):                          | 56.993 0.20  | Air/Ref Cap Prcnt Diff:     | -1.19    | 1.71   |
|   |              | Sensible Heat Ratio:        | 0.748    | 0.0094 |
| Indoor Airflow (CFM):                         | 1008.70 8.47 | SCFM per Ton:               | 455.76   |        |
| Indoor Airflow (SCFM):                        | 991.62 8.25  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011522     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010128     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 64.54    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.321        | 0.022                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.381        | 0.012                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 273.73 | 0.731 | Ref-side Cap (Btu/h) :                  | 25796.98 257.49 |
| Upstream Temp A (F):       | 104.55 | 0.262 | Ref-side Cap (tons):                    | 2.15 0.02       |
| Upstream Temp B (F):       | 104.78 | 0.525 | Refrigerant Mdot (lbm/h):               | 375.15 3.74     |
| Upstream Temp C (F):       | 104.42 | 0.567 | Coriolis Density (lbm/ft3):             | 70.28 0.13      |
| Upstream Average Temp (F): | 104.58 |       | Upstream R22 Tsat (F):                  | 120.19          |
| Upstream Subcooling A (F): | 15.63  | 0.401 |   |                 |
| Upstream Subcooling B (F): | 15.41  | 0.594 |   |                 |
| Upstream Subcooling C (F): | 15.77  | 0.636 |   |                 |
| Average Subcooling (F):    | 15.60  |       |   |                 |
| Evap Exit Pressure (psia): | 90.74  | 0.730 | Turbine A Frequency (Hz):               | 240.70 2.00     |
| Evap Exit Avg Temp A:      | 55.77  | 1.240 | Turb A Vol Flow (ft3/min):              | 0.0335 0.00     |
| Evap Exit Avg Temp B:      | 56.10  | 1.378 | Turb A Density (lbm/ft3):               | 70.37 0.04      |
| Evap Exit Avg Temp C:      | 55.63  | 1.793 | Turb A Mass Flow (lb/h):                | 141.49 1.20     |
| Circuit A Superheat (F):   | 9.87   | 1.396 | Turbine C Frequency (Hz):               | 221.52 1.00     |
| Circuit B Superheat (F):   | 10.20  | 1.534 | Turb C Vol Flow (ft3/min):              | 0.0318 0.00     |
| Circuit C Superheat (F):   | 9.73   | 1.811 | Turb C Density (lbm/ft3):               | 70.39 0.09      |
| Overall Superheat (F):     | 12.60  | 0.982 | Turb C Mass Flow (lb/h):                | 134.28 0.72     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 99.38 4.38      |
| Evap Circuit Temp 1 (F):   | 53.56  | 0.877 | % Total Mass Flow Thru A:               | 37.71 0.48      |
| Evap Circuit Temp 2 (F):   | 50.68  | 0.557 | % Total Mass Flow Thru B:               | 26.49 0.90      |
| Evap Circuit Temp 3 (F):   | 55.23  | 0.599 | % Total Mass Flow Thru C:               | 35.79 0.53      |
| Evap Circuit Temp 4 (F):   | 53.06  | 0.601 |   |                 |
| Evap Circuit Temp 5 (F):   | 53.49  | 0.555 |   |                 |
| Evap Circuit Temp 6 (F):   | 58.94  | 0.088 |   |                 |
| Evap Circuit Temp 7 (F):   | 54.53  | 0.598 |   |                 |
| Evap Circuit Temp 8 (F):   | 53.77  | 0.277 |   |                 |
| Evap Circuit Temp 9 (F):   | 56.19  | 0.553 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020320A.DAT SUMMARY FILENAME: W020320A.sum

|   | Range         | Total Air-Side Capacity:    | 18523.84 | 650.32 |
|---|---------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |               |                             |          |        |
| Indoor Dry-Bulb :                             | 79.855 0.61   | Sensible Cap (Btu/h):       | 15744.03 | 886.72 |
| Indoor Inlet Dew (F):                         | 60.782 0.74   | Latent Cap (Btu/h):         | 2779.82  | 656.32 |
| Indoor Exit Dry-Bulb:                         | 66.088 0.21   | EvapAir Delta T (F):        | 14.38    | 0.65   |
| Indoor Exit Dew (F):                          | 59.354 0.49   | Air/Ref Cap Prcnt Diff:     | -4.23    | 4.10   |
|   |               | Sensible Heat Ratio:        | 0.850    | 0.0342 |
| Indoor Airflow (CFM):                         | 1017.56 14.36 | SCFM per Ton:               | 643.26   |        |
| Indoor Airflow (SCFM):                        | 992.98 14.03  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011628      |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.011041      |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24         | Nozzle Temp (F):            | 67.54    | 0.27   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.334         | 0.038                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.329         | 0.009                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.74 | 0.487 | Ref-side Cap (Btu/h) :                  | 17738.75 356.37 |
| Upstream Temp A (F):       | 103.20 | 0.567 | Ref-side Cap (tons):                    | 1.48 0.03       |
| Upstream Temp B (F):       | 103.43 | 0.262 | Refrigerant Mdot (lbm/h):               | 251.93 5.28     |
| Upstream Temp C (F):       | 103.17 | 0.567 | Coriolis Density (lbm/ft3):             | 70.48 0.07      |
| Upstream Average Temp (F): | 103.27 |       | Upstream R22 Tsat (F):                  | 119.70          |
| Upstream Subcooling A (F): | 16.50  | 0.567 |   |                 |
| Upstream Subcooling B (F): | 16.27  | 0.332 |   |                 |
| Upstream Subcooling C (F): | 16.52  | 0.706 |   |                 |
| Average Subcooling (F):    | 16.43  |       |   |                 |
| Evap Exit Pressure (psia): | 90.54  | 0.486 | Turbine A Frequency (Hz):               | 147.04 1.00     |
| Evap Exit Avg Temp A:      | 75.88  | 0.559 | Turb A Vol Flow (ft3/min):              | 0.0211 0.00     |
| Evap Exit Avg Temp B:      | 75.08  | 0.607 | Turb A Density (lbm/ft3):               | 70.58 0.09      |
| Evap Exit Avg Temp C:      | 75.31  | 0.673 | Turb A Mass Flow (lb/h):                | 89.17 0.62      |
| Circuit A Superheat (F):   | 30.55  | 0.537 | Turbine C Frequency (Hz):               | 153.19 2.00     |
| Circuit B Superheat (F):   | 29.75  | 0.607 | Turb C Vol Flow (ft3/min):              | 0.0227 0.00     |
| Circuit C Superheat (F):   | 29.98  | 0.538 | Turb C Density (lbm/ft3):               | 70.58 0.09      |
| Overall Superheat (F):     | 30.44  | 0.616 | Turb C Mass Flow (lb/h):                | 96.03 1.22      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 66.73 5.38      |
| Evap Circuit Temp 1 (F):   | 77.00  | 0.625 | % Total Mass Flow Thru A:               | 35.39 0.76      |
| Evap Circuit Temp 2 (F):   | 76.63  | 0.540 | % Total Mass Flow Thru B:               | 26.49 1.58      |
| Evap Circuit Temp 3 (F):   | 53.30  | 0.645 | % Total Mass Flow Thru C:               | 38.12 0.84      |
| Evap Circuit Temp 4 (F):   | 75.65  | 0.584 |   |                 |
| Evap Circuit Temp 5 (F):   | 74.86  | 0.541 |   |                 |
| Evap Circuit Temp 6 (F):   | 56.91  | 0.087 |   |                 |
| Evap Circuit Temp 7 (F):   | 78.70  | 1.077 |   |                 |
| Evap Circuit Temp 8 (F):   | 75.74  | 0.628 |   |                 |
| Evap Circuit Temp 9 (F):   | 54.81  | 0.644 |   |                 |

A.4 Enhanced fin (wavy-lanced) evaporator in cross-parallel flow

Table A.4.1: Enhanced Fin (Wavy-Lanced) Evaporators in Cross-Parallel Flow

| Test names | Test type |
|------------|-----------|
| E020403A   | 9         |
| E020404A   | 10        |
| E020408A   | 11        |
| E020409A   | 12        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020403A.dat SUMMARY FILENAME: E020403A.sum

|   | Range       | Total Air-Side Capacity:    | 15522.67 | 330.44 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.192 0.40 | Sensible Cap (Btu/h):       | 10855.53 | 193.09 |
| Indoor Inlet Dew (F):                         | 60.751 0.27 | Latent Cap (Btu/h):         | 4667.14  | 184.87 |
| Indoor Exit Dry-Bulb:                         | 61.800 0.33 | EvapAir Delta T (F):        | 18.77    | 0.22   |
| Indoor Exit Dew (F):                          | 55.959 0.30 | Air/Ref Cap Prcnt Diff:     | 0.98     | 3.60   |
|   |             | Sensible Heat Ratio:        | 0.699    | 0.0107 |
| Indoor Airflow (CFM):                         | 533.03 6.06 | SCFM per Ton:               | 405.92   |        |
| Indoor Airflow (SCFM):                        | 525.08 5.97 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011614    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009751    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 65.08    | 0.59   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.623       | 0.014                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.135       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.30 | 0.852 | Ref-side Cap (Btu/h) :                  | 15674.41 478.40 |
| Upstream Temp A (F):       | 104.13 | 0.617 | Ref-side Cap (tons):                    | 1.31 0.04       |
| Upstream Temp B (F):       | 104.30 | 0.698 | Refrigerant Mdot (lbm/h):               | 227.91 6.96     |
| Upstream Temp C (F):       | 104.03 | 0.740 | Coriolis Density (lbm/ft3):             | 82.14 0.11      |
| Upstream Average Temp (F): | 104.16 |       | Upstream R22 Tsat (F):                  | 119.00          |
| Upstream Subcooling A (F): | 14.87  | 0.741 |   |                 |
| Upstream Subcooling B (F): | 14.70  | 0.698 |   |                 |
| Upstream Subcooling C (F): | 14.96  | 0.635 |   |                 |
| Average Subcooling (F):    | 14.84  |       |   |                 |
| Evap Exit Pressure (psia): | 90.75  | 0.243 | Turbine A Frequency (Hz):               | 134.83 1.00     |
| Evap Exit Avg Temp A:      | 55.71  | 0.508 | Turb A Vol Flow (ft3/min):              | 0.0194 0.00     |
| Evap Exit Avg Temp B:      | 55.76  | 0.461 | Turb A Density (lbm/ft3):               | 70.44 0.09      |
| Evap Exit Avg Temp C:      | 55.18  | 0.596 | Turb A Mass Flow (lb/h):                | 82.13 0.67      |
| Circuit A Superheat (F):   | 10.36  | 0.621 | Turbine C Frequency (Hz):               | 141.57 1.00     |
| Circuit B Superheat (F):   | 10.40  | 0.526 | Turb C Vol Flow (ft3/min):              | 0.0211 0.00     |
| Circuit C Superheat (F):   | 9.82   | 0.573 | Turb C Density (lbm/ft3):               | 70.45 0.11      |
| Overall Superheat (F):     | 10.92  | 0.675 | Turb C Mass Flow (lb/h):                | 89.29 0.71      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 56.49 7.50      |
| Evap Circuit Temp 1 (F):   | 52.38  | 0.621 | % Total Mass Flow Thru A:               | 36.04 1.16      |
| Evap Circuit Temp 2 (F):   | 49.79  | 0.558 | % Total Mass Flow Thru B:               | 24.78 2.54      |
| Evap Circuit Temp 3 (F):   | 61.63  | 0.780 | % Total Mass Flow Thru C:               | 39.18 1.43      |
| Evap Circuit Temp 4 (F):   | 51.69  | 0.655 |   |                 |
| Evap Circuit Temp 5 (F):   | 51.98  | 0.556 |   |                 |
| Evap Circuit Temp 6 (F):   | 63.51  | 0.636 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.75  | 0.733 |   |                 |
| Evap Circuit Temp 8 (F):   | 52.56  | 0.739 |   |                 |
| Evap Circuit Temp 9 (F):   | 60.70  | 0.508 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020404A.DAT SUMMARY FILENAME: E020404A.sum

|   | Range       | Total Air-Side Capacity:    | 3469.93 | 343.64 |
|---|-------------|-----------------------------|---------|--------|
| Air-Side Conditions                           |             |                             |         |        |
| Indoor Dry-Bulb :                             | 80.155 0.25 | Sensible Cap (Btu/h):       | 3877.22 | 283.77 |
| Indoor Inlet Dew (F):                         | 60.865 0.11 | Latent Cap (Btu/h):         | -407.28 | 118.68 |
| Indoor Exit Dry-Bulb:                         | 73.938 0.15 | EvapAir Delta T (F):        | 6.63    | 0.43   |
| Indoor Exit Dew (F):                          | 61.245 0.15 | Air/Ref Cap Prcnt Diff:     | -5.87   | 11.71  |
|   |             | Sensible Heat Ratio:        | 1.117   | 0.0399 |
| Indoor Airflow (CFM):                         | 551.04 6.93 | SCFM per Ton:               | 1832.54 |        |
| Indoor Airflow (SCFM):                        | 529.90 6.63 | (0.075 lb/ft3 standard air) |         |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011662    |                             |         |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.011824    |                             |         |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 74.94   | 0.59   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.650       | 0.016                       |         |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.084       | 0.004                       |         |        |

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Refrigerant Side Conditions

|                            |        |       |   |                |
|----------------------------|--------|-------|---|----------------|
| Expansion Valve            |        |       |   |                |
| Upstream Pressure (psia):  | 287.28 | 1.096 | Ref-side Cap (Btu/h) :                  | 3264.20 286.12 |
| Upstream Temp A (F):       | 105.41 | 0.785 | Ref-side Cap (tons):                    | 0.27 0.02      |
| Upstream Temp B (F):       | 105.99 | 0.699 | Refrigerant Mdot (lbm/h):               | 46.98 4.12     |
| Upstream Temp C (F):       | 106.05 | 0.786 | Coriolis Density (lbm/ft3):             | 84.78 0.11     |
| Upstream Average Temp (F): | 105.82 |       | Upstream R22 Tsat (F):                  | 123.58         |
| Upstream Subcooling A (F): | 18.17  | 0.517 |   |                |
| Upstream Subcooling B (F): | 17.59  | 0.491 |   |                |
| Upstream Subcooling C (F): | 17.53  | 0.651 |   |                |
| Average Subcooling (F):    | 17.76  |       |   |                |
| Evap Exit Pressure (psia): | 90.21  | 1.946 | Turbine A Frequency (Hz):               | 24.09 1.00     |
| Evap Exit Avg Temp A:      | 73.88  | 0.292 | Turb A Vol Flow (ft3/min):              | 0.0047 0.00    |
| Evap Exit Avg Temp B:      | 73.46  | 0.606 | Turb A Density (lbm/ft3):               | 70.24 0.12     |
| Evap Exit Avg Temp C:      | 73.55  | 0.539 | Turb A Mass Flow (lb/h):                | 19.84 0.58     |
| Circuit A Superheat (F):   | 29.09  | 1.150 | Turbine C Frequency (Hz):               | 36.17 1.00     |
| Circuit B Superheat (F):   | 28.67  | 1.263 | Turb C Vol Flow (ft3/min):              | 0.0071 0.00    |
| Circuit C Superheat (F):   | 28.76  | 1.308 | Turb C Density (lbm/ft3):               | 70.14 0.12     |
| Overall Superheat (F):     | 28.88  | 1.123 | Turb C Mass Flow (lb/h):                | 29.71 0.60     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | -2.58 4.12     |
| Evap Circuit Temp 1 (F):   | 52.30  | 2.824 | % Total Mass Flow Thru A:               | 42.27 3.70     |
| Evap Circuit Temp 2 (F):   | 72.64  | 2.171 | % Total Mass Flow Thru B:               | -5.56 9.30     |
| Evap Circuit Temp 3 (F):   | 75.80  | 0.540 | % Total Mass Flow Thru C:               | 63.29 5.61     |
| Evap Circuit Temp 4 (F):   | 52.47  | 3.334 |   |                |
| Evap Circuit Temp 5 (F):   | 70.86  | 3.262 |   |                |
| Evap Circuit Temp 6 (F):   | 76.17  | 0.540 |   |                |
| Evap Circuit Temp 7 (F):   | 56.97  | 3.270 |   |                |
| Evap Circuit Temp 8 (F):   | 60.35  | 6.607 |   |                |
| Evap Circuit Temp 9 (F):   | 75.32  | 0.541 |   |                |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020408A.DAT SUMMARY FILENAME: E020408A.sum

|   | Range       | Total Air-Side Capacity:    | 11507.75 | 318.74 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             | Sensible Cap (Btu/h):       | 9384.29  | 283.84 |
| Indoor Dry-Bulb :                             | 80.129 0.15 | Latent Cap (Btu/h):         | 2123.46  | 131.06 |
| Indoor Inlet Dew (F):                         | 60.343 0.09 | EvapAir Delta T (F):        | 16.19    | 0.43   |
| Indoor Exit Dry-Bulb:                         | 64.462 0.22 | Air/Ref Cap Prcnt Diff:     | 0.19     | 3.93   |
| Indoor Exit Dew (F):                          | 58.231 0.05 | Sensible Heat Ratio:        | 0.815    | 0.0099 |
| Indoor Airflow (CFM):                         | 536.99 6.49 | SCFM per Ton:               | 548.56   |        |
| Indoor Airflow (SCFM):                        | 526.06 6.26 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011444    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010598    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 67.37    | 0.63   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.629       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.121       | 0.004                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 273.06 | 0.852 | Ref-side Cap (Btu/h) :                  | 11529.24 314.29 |
| Upstream Temp A (F):       | 104.61 | 0.524 | Ref-side Cap (tons):                    | 0.96 0.03       |
| Upstream Temp B (F):       | 105.25 | 0.567 | Refrigerant Mdot (lbm/h):               | 168.32 4.58     |
| Upstream Temp C (F):       | 104.59 | 0.567 | Coriolis Density (lbm/ft3):             | 82.46 0.15      |
| Upstream Average Temp (F): | 104.82 |       | Upstream R22 Tsat (F):                  | 119.58          |
| Upstream Subcooling A (F): | 14.97  | 0.594 |   |                 |
| Upstream Subcooling B (F): | 14.32  | 0.602 |   |                 |
| Upstream Subcooling C (F): | 14.98  | 0.636 |   |                 |
| Average Subcooling (F):    | 14.76  |       |   |                 |
| Evap Exit Pressure (psia): | 90.58  | 0.486 | Turbine A Frequency (Hz):               | 69.08 1.00      |
| Evap Exit Avg Temp A:      | 63.32  | 0.701 | Turb A Vol Flow (ft3/min):              | 0.0107 0.00     |
| Evap Exit Avg Temp B:      | 47.25  | 0.558 | Turb A Density (lbm/ft3):               | 70.36 0.08      |
| Evap Exit Avg Temp C:      | 63.07  | 0.270 | Turb A Mass Flow (lb/h):                | 45.13 0.61      |
| Circuit A Superheat (F):   | 18.14  | 0.949 | Turbine C Frequency (Hz):               | 79.15 2.00      |
| Circuit B Superheat (F):   | 2.07   | 0.715 | Turb C Vol Flow (ft3/min):              | 0.0128 0.00     |
| Circuit C Superheat (F):   | 17.89  | 0.505 | Turb C Density (lbm/ft3):               | 70.37 0.09      |
| Overall Superheat (F):     | 10.10  | 0.906 | Turb C Mass Flow (lb/h):                | 54.02 1.14      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 69.17 5.16      |
| Evap Circuit Temp 1 (F):   | 51.32  | 0.644 | % Total Mass Flow Thru A:               | 26.82 0.91      |
| Evap Circuit Temp 2 (F):   | 49.04  | 0.649 | % Total Mass Flow Thru B:               | 41.09 1.95      |
| Evap Circuit Temp 3 (F):   | 68.89  | 1.267 | % Total Mass Flow Thru C:               | 32.10 1.22      |
| Evap Circuit Temp 4 (F):   | 52.24  | 0.601 |   |                 |
| Evap Circuit Temp 5 (F):   | 52.41  | 0.646 |   |                 |
| Evap Circuit Temp 6 (F):   | 55.49  | 0.743 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.71  | 1.388 |   |                 |
| Evap Circuit Temp 8 (F):   | 52.08  | 0.323 |   |                 |
| Evap Circuit Temp 9 (F):   | 67.92  | 0.177 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020409A.DAT SUMMARY FILENAME: E020409A.sum

|   | Range       | Total Air-Side Capacity:    | 9542.99 | 418.18 |
|---|-------------|-----------------------------|---------|--------|
| Air-Side Conditions                           |             |                             |         |        |
| Indoor Dry-Bulb :                             | 80.006 0.52 | Sensible Cap (Btu/h):       | 7901.04 | 292.10 |
| Indoor Inlet Dew (F):                         | 60.361 0.31 | Latent Cap (Btu/h):         | 1641.95 | 182.36 |
| Indoor Exit Dry-Bulb:                         | 66.911 0.42 | EvapAir Delta T (F):        | 13.57   | 0.43   |
| Indoor Exit Dew (F):                          | 58.748 0.39 | Air/Ref Cap Prcnt Diff:     | -0.27   | 6.54   |
|   |             | Sensible Heat Ratio:        | 0.828   | 0.0155 |
| Indoor Airflow (CFM):                         | 541.60 8.59 | SCFM per Ton:               | 664.02  |        |
| Indoor Airflow (SCFM):                        | 528.06 8.74 | (0.075 lb/ft3 standard air) |         |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011451    |                             |         |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010800    |                             |         |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 69.37   | 0.63   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.637       | 0.020                       |         |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.106       | 0.003                       |         |        |

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Refrigerant Side Conditions

|                            |        |       |   |                |
|----------------------------|--------|-------|---|----------------|
| Expansion Valve            |        |       |   |                |
| Upstream Pressure (psia):  | 274.70 | 0.244 | Ref-side Cap (Btu/h) :                  | 9515.76 411.79 |
| Upstream Temp A (F):       | 104.15 | 0.654 | Ref-side Cap (tons):                    | 0.79 0.03      |
| Upstream Temp B (F):       | 103.60 | 0.698 | Refrigerant Mdot (lbm/h):               | 138.13 5.86    |
| Upstream Temp C (F):       | 103.47 | 0.173 | Coriolis Density (lbm/ft3):             | 82.30 0.10     |
| Upstream Average Temp (F): | 103.74 |       | Upstream R22 Tsat (F):                  | 120.05         |
| Upstream Subcooling A (F): | 15.90  | 0.654 |   |                |
| Upstream Subcooling B (F): | 16.45  | 0.681 |   |                |
| Upstream Subcooling C (F): | 16.58  | 0.173 |   |                |
| Average Subcooling (F):    | 16.31  |       |   |                |
| Evap Exit Pressure (psia): | 90.61  | 0.730 | Turbine A Frequency (Hz):               | 139.20 2.00    |
| Evap Exit Avg Temp A:      | 46.71  | 0.650 | Turb A Vol Flow (ft3/min):              | 0.0200 0.00    |
| Evap Exit Avg Temp B:      | 69.85  | 0.360 | Turb A Density (lbm/ft3):               | 70.43 0.10     |
| Evap Exit Avg Temp C:      | 68.68  | 0.721 | Turb A Mass Flow (lb/h):                | 84.58 1.17     |
| Circuit A Superheat (F):   | 1.63   | 0.581 | Turbine C Frequency (Hz):               | 64.16 1.00     |
| Circuit B Superheat (F):   | 24.77  | 0.606 | Turb C Vol Flow (ft3/min):              | 0.0108 0.00    |
| Circuit C Superheat (F):   | 23.60  | 0.755 | Turb C Density (lbm/ft3):               | 70.54 0.03     |
| Overall Superheat (F):     | 10.76  | 2.618 | Turb C Mass Flow (lb/h):                | 45.69 0.58     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 7.87 6.38      |
| Evap Circuit Temp 1 (F):   | 51.00  | 1.113 | % Total Mass Flow Thru A:               | 61.24 2.96     |
| Evap Circuit Temp 2 (F):   | 49.84  | 0.557 | % Total Mass Flow Thru B:               | 5.68 4.34      |
| Evap Circuit Temp 3 (F):   | 50.73  | 1.067 | % Total Mass Flow Thru C:               | 33.08 1.71     |
| Evap Circuit Temp 4 (F):   | 51.94  | 2.825 |   |                |
| Evap Circuit Temp 5 (F):   | 56.65  | 7.969 |   |                |
| Evap Circuit Temp 6 (F):   | 73.43  | 0.716 |   |                |
| Evap Circuit Temp 7 (F):   | 53.62  | 0.599 |   |                |
| Evap Circuit Temp 8 (F):   | 51.44  | 0.648 |   |                |
| Evap Circuit Temp 9 (F):   | 72.13  | 0.904 |   |                |

A.5 Enhanced-Cut fin (wavy-lanced) evaporator in cross-counter flow

Table A.5.1: Enhanced-Cut Fin (Wavy-Lanced) Evaporator in Cross-Counter Flow

| Test names | Test type |
|------------|-----------|
| E020417A   | 1         |
| E020417B   | 2         |
| E020418A   | 5         |
| E020419A   | 6         |
| E020415A   | 9         |
| E020509A   | 10        |
| E020416B   | 13        |
| E020416A   | 14        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020417A.DAT SUMMARY FILENAME: E020417A.sum

|   | Range       | Total Air-Side Capacity:    | 20760.16 | 428.20 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.979 0.35 | Sensible Cap (Btu/h):       | 14269.36 | 468.38 |
| Indoor Inlet Dew (F):                         | 60.397 0.27 | Latent Cap (Btu/h):         | 6490.80  | 180.28 |
| Indoor Exit Dry-Bulb:                         | 58.508 0.21 | EvapAir Delta T (F):        | 21.86    | 0.65   |
| Indoor Exit Dew (F):                          | 54.303 0.25 | Air/Ref Cap Prcnt Diff:     | 1.19     | 3.53   |
|   |             | Sensible Heat Ratio:        | 0.687    | 0.0092 |
| Indoor Airflow (CFM):                         | 598.10 5.65 | SCFM per Ton:               | 342.83   |        |
| Indoor Airflow (SCFM):                        | 593.10 5.58 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011467    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009172    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 59.68    | 0.60   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.270       | 0.024                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.157       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 275.47 | 0.852 | Ref-side Cap (Btu/h) :                  | 21005.77 577.37 |
| Upstream Temp A (F):       | 104.55 | 0.524 | Ref-side Cap (tons):                    | 1.75 0.05       |
| Upstream Temp B (F):       | 104.69 | 0.262 | Refrigerant Mdot (lbm/h):               | 305.27 7.96     |
| Upstream Temp C (F):       | 104.39 | 0.524 | Coriolis Density (lbm/ft3):             | 82.16 0.16      |
| Upstream Average Temp (F): | 104.54 |       | Upstream R22 Tsat (F):                  | 120.18          |
| Upstream Subcooling A (F): | 15.63  | 0.593 |   |                 |
| Upstream Subcooling B (F): | 15.49  | 0.366 |   |                 |
| Upstream Subcooling C (F): | 15.79  | 0.515 |   |                 |
| Average Subcooling (F):    | 15.64  |       |   |                 |
| Evap Exit Pressure (psia): | 90.50  | 0.608 | Turbine A Frequency (Hz):               | 199.27 2.00     |
| Evap Exit Avg Temp A:      | 55.36  | 1.931 | Turb A Vol Flow (ft3/min):              | 0.0280 0.00     |
| Evap Exit Avg Temp B:      | 54.85  | 1.310 | Turb A Density (lbm/ft3):               | 70.37 0.08      |
| Evap Exit Avg Temp C:      | 56.24  | 2.159 | Turb A Mass Flow (lb/h):                | 118.23 1.12     |
| Circuit A Superheat (F):   | 9.90   | 2.037 | Turbine C Frequency (Hz):               | 171.80 2.00     |
| Circuit B Superheat (F):   | 9.40   | 1.310 | Turb C Vol Flow (ft3/min):              | 0.0252 0.00     |
| Circuit C Superheat (F):   | 10.79  | 2.271 | Turb C Density (lbm/ft3):               | 70.40 0.08      |
| Overall Superheat (F):     | 13.18  | 0.956 | Turb C Mass Flow (lb/h):                | 106.26 1.19     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 80.78 7.83      |
| Evap Circuit Temp 1 (F):   | 50.12  | 1.484 | % Total Mass Flow Thru A:               | 38.73 1.02      |
| Evap Circuit Temp 2 (F):   | 48.55  | 0.558 | % Total Mass Flow Thru B:               | 26.46 1.87      |
| Evap Circuit Temp 3 (F):   | 49.69  | 0.605 | % Total Mass Flow Thru C:               | 34.81 0.91      |
| Evap Circuit Temp 4 (F):   | 49.16  | 0.743 |   |                 |
| Evap Circuit Temp 5 (F):   | 47.56  | 0.280 |   |                 |
| Evap Circuit Temp 6 (F):   | 50.81  | 0.649 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.45  | 1.203 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.11  | 0.743 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.80  | 0.605 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020417B.DAT SUMMARY FILENAME: E020417B.sum

|   | Range       | Total Air-Side Capacity:    | 15855.26 | 298.26 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.014 0.12 | Sensible Cap (Btu/h):       | 12203.85 | 260.58 |
| Indoor Inlet Dew (F):                         | 60.375 0.02 | Latent Cap (Btu/h):         | 3651.40  | 102.26 |
| Indoor Exit Dry-Bulb:                         | 61.822 0.18 | EvapAir Delta T (F):        | 18.70    | 0.22   |
| Indoor Exit Dew (F):                          | 57.092 0.06 | Air/Ref Cap Prcnt Diff:     | -3.21    | 3.50   |
|   |             | Sensible Heat Ratio:        | 0.770    | 0.0060 |
| Indoor Airflow (CFM):                         | 601.66 8.27 | SCFM per Ton:               | 448.44   |        |
| Indoor Airflow (SCFM):                        | 592.51 8.10 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011458    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010165    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 62.65    | 0.41   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.277       | 0.035                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.142       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 297.86 | 0.731 | Ref-side Cap (Btu/h) :                  | 15346.55 464.96 |
| Upstream Temp A (F):       | 102.90 | 0.569 | Ref-side Cap (tons):                    | 1.28 0.04       |
| Upstream Temp B (F):       | 103.07 | 0.525 | Refrigerant Mdot (lbm/h):               | 217.44 6.59     |
| Upstream Temp C (F):       | 102.75 | 0.351 | Coriolis Density (lbm/ft3):             | 81.87 0.19      |
| Upstream Average Temp (F): | 102.91 |       | Upstream R22 Tsat (F):                  | 126.40          |
| Upstream Subcooling A (F): | 23.49  | 0.623 |   |                 |
| Upstream Subcooling B (F): | 23.33  | 0.611 |   |                 |
| Upstream Subcooling C (F): | 23.65  | 0.548 |   |                 |
| Average Subcooling (F):    | 23.49  |       |   |                 |
| Evap Exit Pressure (psia): | 90.84  | 0.486 | Turbine A Frequency (Hz):               | 139.28 1.00     |
| Evap Exit Avg Temp A:      | 76.02  | 0.360 | Turb A Vol Flow (ft3/min):              | 0.0200 0.00     |
| Evap Exit Avg Temp B:      | 76.73  | 0.268 | Turb A Density (lbm/ft3):               | 70.62 0.09      |
| Evap Exit Avg Temp C:      | 75.23  | 0.538 | Turb A Mass Flow (lb/h):                | 84.85 0.67      |
| Circuit A Superheat (F):   | 30.62  | 0.517 | Turbine C Frequency (Hz):               | 129.36 1.00     |
| Circuit B Superheat (F):   | 31.33  | 0.425 | Turb C Vol Flow (ft3/min):              | 0.0195 0.00     |
| Circuit C Superheat (F):   | 29.82  | 0.616 | Turb C Density (lbm/ft3):               | 70.65 0.05      |
| Overall Superheat (F):     | 31.06  | 0.673 | Turb C Mass Flow (lb/h):                | 82.64 0.63      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 49.95 6.37      |
| Evap Circuit Temp 1 (F):   | 75.45  | 0.223 | % Total Mass Flow Thru A:               | 39.03 1.32      |
| Evap Circuit Temp 2 (F):   | 72.93  | 0.726 | % Total Mass Flow Thru B:               | 22.97 2.33      |
| Evap Circuit Temp 3 (F):   | 48.37  | 0.653 | % Total Mass Flow Thru C:               | 38.01 1.04      |
| Evap Circuit Temp 4 (F):   | 76.19  | 0.723 |   |                 |
| Evap Circuit Temp 5 (F):   | 73.76  | 0.679 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.53  | 0.462 |   |                 |
| Evap Circuit Temp 7 (F):   | 77.76  | 0.672 |   |                 |
| Evap Circuit Temp 8 (F):   | 71.55  | 0.635 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.21  | 0.605 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020418A.DAT SUMMARY FILENAME: E020418A.sum

|   |          | Range |                             |          | Range  |
|---|----------|-------|-----------------------------|----------|--------|
| Air-Side Conditions                           |          |       | Total Air-Side Capacity:    | 19031.65 | 517.13 |
| Indoor Dry-Bulb :                             | 79.855   | 0.49  | Sensible Cap (Btu/h):       | 19485.39 | 562.65 |
| Indoor Inlet Dew (F):                         | 48.872   | 0.21  | Latent Cap (Btu/h):         | -453.74  | 66.94  |
| Indoor Exit Dry-Bulb:                         | 57.438   | 0.39  | EvapAir Delta T (F):        | 22.80    | 0.43   |
| Indoor Exit Dew (F):                          | 49.299   | 0.21  | Air/Ref Cap Prcnt Diff:     | -1.20    | 4.20   |
|   |          |       | Sensible Heat Ratio:        | 1.024    | 0.0035 |
| Indoor Airflow (CFM):                         | 784.81   | 13.11 | SCFM per Ton:               | 492.16   |        |
| Indoor Airflow (SCFM):                        | 780.56   | 13.05 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.007484 |       |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.007606 |       |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24    |       | Nozzle Temp (F):            | 58.49    | 0.65   |
| Air Chamber Nozzle Pressure Drop (in Water):  |          | 0.811 | 0.027                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): |          | 0.168 | 0.007                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 276.43 | 0.731 | Ref-side Cap (Btu/h) :                  | 18802.24 | 432.99 |
| Upstream Temp A (F):       | 105.93 | 0.612 | Ref-side Cap (tons):                    | 1.57     | 0.04   |
| Upstream Temp B (F):       | 106.00 | 0.569 | Refrigerant Mdot (lbm/h):               | 274.77   | 6.41   |
| Upstream Temp C (F):       | 105.73 | 0.262 | Coriolis Density (lbm/ft3):             | 82.52    | 0.16   |
| Upstream Average Temp (F): | 105.89 |       | Upstream R22 Tsat (F):                  | 120.46   |        |
| Upstream Subcooling A (F): | 14.53  | 0.716 |   |          |        |
| Upstream Subcooling B (F): | 14.46  | 0.638 |   |          |        |
| Upstream Subcooling C (F): | 14.73  | 0.469 |   |          |        |
| Average Subcooling (F):    | 14.57  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.97  | 0.730 | Turbine A Frequency (Hz):               | 177.61   | 1.00   |
| Evap Exit Avg Temp A:      | 55.72  | 2.571 | Turb A Vol Flow (ft3/min):              | 0.0251   | 0.00   |
| Evap Exit Avg Temp B:      | 55.69  | 2.391 | Turb A Density (lbm/ft3):               | 70.16    | 0.09   |
| Evap Exit Avg Temp C:      | 55.54  | 4.962 | Turb A Mass Flow (lb/h):                | 105.75   | 0.70   |
| Circuit A Superheat (F):   | 10.10  | 2.259 | Turbine C Frequency (Hz):               | 157.36   | 2.00   |
| Circuit B Superheat (F):   | 10.08  | 2.313 | Turb C Vol Flow (ft3/min):              | 0.0232   | 0.00   |
| Circuit C Superheat (F):   | 9.92   | 4.806 | Turb C Density (lbm/ft3):               | 70.19    | 0.04   |
| Overall Superheat (F):     | 13.54  | 1.654 | Turb C Mass Flow (lb/h):                | 97.84    | 1.18   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 71.18    | 6.84   |
| Evap Circuit Temp 1 (F):   | 50.04  | 2.784 | % Total Mass Flow Thru A:               | 38.49    | 1.02   |
| Evap Circuit Temp 2 (F):   | 48.21  | 0.464 | % Total Mass Flow Thru B:               | 25.90    | 2.01   |
| Evap Circuit Temp 3 (F):   | 49.38  | 0.557 | % Total Mass Flow Thru C:               | 35.61    | 1.08   |
| Evap Circuit Temp 4 (F):   | 49.12  | 1.673 |   |          |        |
| Evap Circuit Temp 5 (F):   | 47.46  | 0.654 |   |          |        |
| Evap Circuit Temp 6 (F):   | 50.40  | 0.603 |   |          |        |
| Evap Circuit Temp 7 (F):   | 51.37  | 1.158 |   |          |        |
| Evap Circuit Temp 8 (F):   | 48.17  | 0.327 |   |          |        |
| Evap Circuit Temp 9 (F):   | 49.81  | 0.652 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020419A.DAT SUMMARY FILENAME: E020419A.sum

|   |             | Range |                             |                 |
|---|-------------|-------|-----------------------------|-----------------|
| Air-Side Conditions                           |             |       | Total Air-Side Capacity:    | 14125.73 490.90 |
| Indoor Dry-Bulb :                             | 79.724 0.32 |       | Sensible Cap (Btu/h):       | 14523.20 504.52 |
| Indoor Inlet Dew (F):                         | 48.502 0.16 |       | Latent Cap (Btu/h):         | -397.47 76.25   |
| Indoor Exit Dry-Bulb:                         | 63.019 0.37 |       | EvapAir Delta T (F):        | 17.08 0.44      |
| Indoor Exit Dew (F):                          | 48.883 0.15 |       | Air/Ref Cap Prcnt Diff:     | -5.67 6.95      |
|   |             |       | Sensible Heat Ratio:        | 1.028 0.0059    |
| Indoor Airflow (CFM):                         | 789.23 8.25 |       | SCFM per Ton:               | 659.76          |
| Indoor Airflow (SCFM):                        | 776.63 7.86 |       | (0.075 lb/ft3 standard air) |                 |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.007380    |       |                             |                 |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.007487    |       |                             |                 |
| Barometric Pressure (in HG):                  | 29.24       |       | Nozzle Temp (F):            | 63.78 0.55      |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.812       | 0.016 |                             |                 |
| Evaporator Coil Air Pressure Drop (in Water): | 0.170       | 0.008 |                             |                 |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 277.85 | 2.192 | Ref-side Cap (Btu/h) :                  | 13323.55 | 673.13 |
| Upstream Temp A (F):       | 107.88 | 1.179 | Ref-side Cap (tons):                    | 1.11     | 0.06   |
| Upstream Temp B (F):       | 108.09 | 1.136 | Refrigerant Mdot (lbm/h):               | 192.94   | 10.25  |
| Upstream Temp C (F):       | 107.62 | 1.135 | Coriolis Density (lbm/ft3):             | 83.35    | 0.22   |
| Upstream Average Temp (F): | 107.87 |       | Upstream R22 Tsat (F):                  | 120.91   |        |
| Upstream Subcooling A (F): | 13.03  | 0.652 |   |          |        |
| Upstream Subcooling B (F): | 12.82  | 0.747 |   |          |        |
| Upstream Subcooling C (F): | 13.29  | 0.687 |   |          |        |
| Average Subcooling (F):    | 13.05  |       |   |          |        |
| Evap Exit Pressure (psia): | 91.02  | 0.486 | Turbine A Frequency (Hz):               | 127.60   | 2.00   |
| Evap Exit Avg Temp A:      | 76.68  | 0.717 | Turb A Vol Flow (ft3/min):              | 0.0185   | 0.00   |
| Evap Exit Avg Temp B:      | 77.23  | 0.605 | Turb A Density (lbm/ft3):               | 69.86    | 0.18   |
| Evap Exit Avg Temp C:      | 77.04  | 0.628 | Turb A Mass Flow (lb/h):                | 77.42    | 1.02   |
| Circuit A Superheat (F):   | 31.18  | 0.628 | Turbine C Frequency (Hz):               | 110.12   | 2.00   |
| Circuit B Superheat (F):   | 31.73  | 0.481 | Turb C Vol Flow (ft3/min):              | 0.0169   | 0.00   |
| Circuit C Superheat (F):   | 31.54  | 0.605 | Turb C Density (lbm/ft3):               | 69.90    | 0.18   |
| Overall Superheat (F):     | 31.90  | 0.770 | Turb C Mass Flow (lb/h):                | 70.99    | 1.08   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 44.52    | 9.15   |
| Evap Circuit Temp 1 (F):   | 77.70  | 0.539 | % Total Mass Flow Thru A:               | 40.13    | 1.88   |
| Evap Circuit Temp 2 (F):   | 74.36  | 1.175 | % Total Mass Flow Thru B:               | 23.07    | 3.61   |
| Evap Circuit Temp 3 (F):   | 48.34  | 0.606 | % Total Mass Flow Thru C:               | 36.80    | 1.73   |
| Evap Circuit Temp 4 (F):   | 76.94  | 0.810 |   |          |        |
| Evap Circuit Temp 5 (F):   | 75.66  | 0.586 |   |          |        |
| Evap Circuit Temp 6 (F):   | 49.54  | 0.604 |   |          |        |
| Evap Circuit Temp 7 (F):   | 78.43  | 1.077 |   |          |        |
| Evap Circuit Temp 8 (F):   | 76.15  | 0.632 |   |          |        |
| Evap Circuit Temp 9 (F):   | 48.94  | 0.653 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020415A.DAT SUMMARY FILENAME: E020415A.sum

|   | Range       | Total Air-Side Capacity:    | 23788.22 | 627.38 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.121 0.42 | Sensible Cap (Btu/h):       | 17485.19 | 457.67 |
| Indoor Inlet Dew (F):                         | 60.369 0.47 | Latent Cap (Btu/h):         | 6303.03  | 279.03 |
| Indoor Exit Dry-Bulb:                         | 60.258 0.37 | EvapAir Delta T (F):        | 20.32    | 0.44   |
| Indoor Exit Dew (F):                          | 55.995 0.39 | Air/Ref Cap Prcnt Diff:     | -0.68    | 2.68   |
|   |             | Sensible Heat Ratio:        | 0.735    | 0.0113 |
| Indoor Airflow (CFM):                         | 791.02 9.05 | SCFM per Ton:               | 394.12   |        |
| Indoor Airflow (SCFM):                        | 781.29 9.07 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011455    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009764    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 63.09    | 0.82   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.369       | 0.031                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.254       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 295.10 | 0.731 | Ref-side Cap (Btu/h) :                  | 23625.71 519.24 |
| Upstream Temp A (F):       | 106.36 | 0.611 | Ref-side Cap (tons):                    | 1.97 0.04       |
| Upstream Temp B (F):       | 106.39 | 0.786 | Refrigerant Mdot (lbm/h):               | 346.04 7.32     |
| Upstream Temp C (F):       | 106.19 | 0.524 | Coriolis Density (lbm/ft3):             | 82.62 0.27      |
| Upstream Average Temp (F): | 106.31 |       | Upstream R22 Tsat (F):                  | 125.57          |
| Upstream Subcooling A (F): | 19.22  | 0.578 |   |                 |
| Upstream Subcooling B (F): | 19.18  | 0.731 |   |                 |
| Upstream Subcooling C (F): | 19.38  | 0.557 |   |                 |
| Average Subcooling (F):    | 19.26  |       |   |                 |
| Evap Exit Pressure (psia): | 90.94  | 0.486 | Turbine A Frequency (Hz):               | 226.62 2.00     |
| Evap Exit Avg Temp A:      | 55.82  | 3.720 | Turb A Vol Flow (ft3/min):              | 0.0316 0.00     |
| Evap Exit Avg Temp B:      | 56.22  | 3.719 | Turb A Density (lbm/ft3):               | 70.09 0.09      |
| Evap Exit Avg Temp C:      | 56.55  | 3.557 | Turb A Mass Flow (lb/h):                | 133.06 1.20     |
| Circuit A Superheat (F):   | 9.88   | 3.720 | Turbine C Frequency (Hz):               | 195.31 1.00     |
| Circuit B Superheat (F):   | 10.28  | 3.774 | Turb C Vol Flow (ft3/min):              | 0.0283 0.00     |
| Circuit C Superheat (F):   | 10.61  | 3.479 | Turb C Density (lbm/ft3):               | 70.12 0.08      |
| Overall Superheat (F):     | 13.26  | 2.197 | Turb C Mass Flow (lb/h):                | 119.04 0.70     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 93.95 6.96      |
| Evap Circuit Temp 1 (F):   | 50.62  | 1.159 | % Total Mass Flow Thru A:               | 38.45 0.86      |
| Evap Circuit Temp 2 (F):   | 49.01  | 0.746 | % Total Mass Flow Thru B:               | 27.15 1.46      |
| Evap Circuit Temp 3 (F):   | 50.49  | 0.651 | % Total Mass Flow Thru C:               | 34.40 0.70      |
| Evap Circuit Temp 4 (F):   | 49.71  | 0.745 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.28  | 0.511 |   |                 |
| Evap Circuit Temp 6 (F):   | 52.07  | 0.738 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.75  | 0.738 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.88  | 0.652 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.67  | 0.604 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020509A.dat SUMMARY FILENAME: E020509A.sum

|   | Range        | Total Air-Side Capacity:    | 18291.86 | 685.26 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 79.875 0.24  | Sensible Cap (Btu/h):       | 14879.62 | 619.90 |
| Indoor Inlet Dew (F):                         | 60.358 0.10  | Latent Cap (Btu/h):         | 3412.24  | 107.75 |
| Indoor Exit Dry-Bulb:                         | 63.170 0.13  | EvapAir Delta T (F):        | 17.26    | 0.43   |
| Indoor Exit Dew (F):                          | 58.071 0.07  | Air/Ref Cap Prcnt Diff:     | -4.19    | 4.45   |
|   |              | Sensible Heat Ratio:        | 0.813    | 0.0081 |
| Indoor Airflow (CFM):                         | 796.91 13.83 | SCFM per Ton:               | 513.29   |        |
| Indoor Airflow (SCFM):                        | 782.42 13.62 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011451     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010536     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 64.04    | 0.59   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.825        | 0.028                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.226        | 0.008                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.33 | 0.731 | Ref-side Cap (Btu/h) :                  | 17523.19 551.53 |
| Upstream Temp A (F):       | 103.34 | 0.347 | Ref-side Cap (tons):                    | 1.46 0.05       |
| Upstream Temp B (F):       | 103.54 | 0.305 | Refrigerant Mdot (lbm/h):               | 248.82 7.78     |
| Upstream Temp C (F):       | 103.15 | 0.610 | Coriolis Density (lbm/ft3):             | 81.81 0.14      |
| Upstream Average Temp (F): | 103.34 |       | Upstream R22 Tsat (F):                  | 119.04          |
| Upstream Subcooling A (F): | 15.70  | 0.382 |   |                 |
| Upstream Subcooling B (F): | 15.50  | 0.340 |   |                 |
| Upstream Subcooling C (F): | 15.89  | 0.610 |   |                 |
| Average Subcooling (F):    | 15.70  |       |   |                 |
| Evap Exit Pressure (psia): | 91.31  | 0.486 | Turbine A Frequency (Hz):               | 157.80 1.00     |
| Evap Exit Avg Temp A:      | 76.06  | 0.537 | Turb A Vol Flow (ft3/min):              | 0.0225 0.00     |
| Evap Exit Avg Temp B:      | 75.89  | 0.403 | Turb A Density (lbm/ft3):               | 70.56 0.05      |
| Evap Exit Avg Temp C:      | 75.56  | 0.425 | Turb A Mass Flow (lb/h):                | 95.20 0.63      |
| Circuit A Superheat (F):   | 30.26  | 0.650 | Turbine C Frequency (Hz):               | 142.88 1.00     |
| Circuit B Superheat (F):   | 30.09  | 0.537 | Turb C Vol Flow (ft3/min):              | 0.0213 0.00     |
| Circuit C Superheat (F):   | 29.75  | 0.649 | Turb C Density (lbm/ft3):               | 70.59 0.09      |
| Overall Superheat (F):     | 30.54  | 0.892 | Turb C Mass Flow (lb/h):                | 90.20 0.62      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 63.42 7.75      |
| Evap Circuit Temp 1 (F):   | 75.77  | 0.626 | % Total Mass Flow Thru A:               | 38.26 1.20      |
| Evap Circuit Temp 2 (F):   | 73.07  | 0.630 | % Total Mass Flow Thru B:               | 25.48 2.32      |
| Evap Circuit Temp 3 (F):   | 49.31  | 0.649 | % Total Mass Flow Thru C:               | 36.26 1.23      |
| Evap Circuit Temp 4 (F):   | 75.44  | 0.541 |   |                 |
| Evap Circuit Temp 5 (F):   | 72.22  | 0.631 |   |                 |
| Evap Circuit Temp 6 (F):   | 50.75  | 0.601 |   |                 |
| Evap Circuit Temp 7 (F):   | 77.72  | 0.355 |   |                 |
| Evap Circuit Temp 8 (F):   | 72.43  | 0.631 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.87  | 0.648 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020416B.DAT SUMMARY FILENAME: E020416B.sum

|   | Range         | Total Air-Side Capacity:    | 26546.29 | 745.84 |
|---|---------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |               |                             |          |        |
| Indoor Dry-Bulb :                             | 80.142 0.28   | Sensible Cap (Btu/h):       | 20754.50 | 771.24 |
| Indoor Inlet Dew (F):                         | 60.258 0.52   | Latent Cap (Btu/h):         | 5791.80  | 509.00 |
| Indoor Exit Dry-Bulb:                         | 61.442 0.32   | EvapAir Delta T (F):        | 19.08    | 0.44   |
| Indoor Exit Dew (F):                          | 57.130 0.34   | Air/Ref Cap Prcnt Diff:     | -0.79    | 4.28   |
|   |               | Sensible Heat Ratio:        | 0.782    | 0.0169 |
| Indoor Airflow (CFM):                         | 1002.55 17.60 | SCFM per Ton:               | 446.36   |        |
| Indoor Airflow (SCFM):                        | 987.44 17.77  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011409      |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010179      |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24         | Nozzle Temp (F):            | 63.44    | 0.60   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.323 0.047   |                             |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.374 0.012   |                             |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 274.04 | 0.731 | Ref-side Cap (Btu/h) :                  | 26335.16 619.99 |
| Upstream Temp A (F):       | 105.19 | 0.524 | Ref-side Cap (tons):                    | 2.19 0.05       |
| Upstream Temp B (F):       | 105.32 | 0.524 | Refrigerant Mdot (lbm/h):               | 383.61 8.97     |
| Upstream Temp C (F):       | 104.94 | 0.568 | Coriolis Density (lbm/ft3):             | 82.25 0.14      |
| Upstream Average Temp (F): | 105.15 |       | Upstream R22 Tsat (F):                  | 119.72          |
| Upstream Subcooling A (F): | 14.53  | 0.539 |   |                 |
| Upstream Subcooling B (F): | 14.39  | 0.664 |   |                 |
| Upstream Subcooling C (F): | 14.78  | 0.619 |   |                 |
| Average Subcooling (F):    | 14.57  |       |   |                 |
| Evap Exit Pressure (psia): | 90.76  | 0.486 | Turbine A Frequency (Hz):               | 250.13 2.00     |
| Evap Exit Avg Temp A:      | 56.18  | 1.951 | Turb A Vol Flow (ft3/min):              | 0.0348 0.00     |
| Evap Exit Avg Temp B:      | 56.73  | 2.799 | Turb A Density (lbm/ft3):               | 70.27 0.08      |
| Evap Exit Avg Temp C:      | 56.51  | 2.848 | Turb A Mass Flow (lb/h):                | 146.58 1.14     |
| Circuit A Superheat (F):   | 10.26  | 2.084 | Turbine C Frequency (Hz):               | 218.50 1.00     |
| Circuit B Superheat (F):   | 10.82  | 2.644 | Turb C Vol Flow (ft3/min):              | 0.0314 0.00     |
| Circuit C Superheat (F):   | 10.60  | 2.848 | Turb C Density (lbm/ft3):               | 70.31 0.09      |
| Overall Superheat (F):     | 13.48  | 1.740 | Turb C Mass Flow (lb/h):                | 132.43 0.73     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 104.61 8.93     |
| Evap Circuit Temp 1 (F):   | 50.69  | 1.205 | % Total Mass Flow Thru A:               | 38.21 0.88      |
| Evap Circuit Temp 2 (F):   | 49.54  | 0.326 | % Total Mass Flow Thru B:               | 27.27 1.70      |
| Evap Circuit Temp 3 (F):   | 51.16  | 0.603 | % Total Mass Flow Thru C:               | 34.52 0.85      |
| Evap Circuit Temp 4 (F):   | 49.88  | 0.652 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.62  | 0.653 |   |                 |
| Evap Circuit Temp 6 (F):   | 52.93  | 0.692 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.31  | 1.111 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.65  | 0.652 |   |                 |
| Evap Circuit Temp 9 (F):   | 51.21  | 0.651 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020416A.DAT SUMMARY FILENAME: E020416A.sum

|   | Range         | Total Air-Side Capacity:    | 22768.45 | 680.51 |
|---|---------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |               |                             |          |        |
| Indoor Dry-Bulb :                             | 80.037 0.29   | Sensible Cap (Btu/h):       | 18645.28 | 510.26 |
| Indoor Inlet Dew (F):                         | 60.534 0.37   | Latent Cap (Btu/h):         | 4123.17  | 349.67 |
| Indoor Exit Dry-Bulb:                         | 63.363 0.35   | EvapAir Delta T (F):        | 17.05    | 0.22   |
| Indoor Exit Dew (F):                          | 58.372 0.37   | Air/Ref Cap Prcnt Diff:     | -3.52    | 4.43   |
|   |               | Sensible Heat Ratio:        | 0.819    | 0.0110 |
| Indoor Airflow (CFM):                         | 1011.50 19.34 | SCFM per Ton:               | 523.03   |        |
| Indoor Airflow (SCFM):                        | 992.38 19.44  | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011524      |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.010652      |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24         | Nozzle Temp (F):            | 65.00    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 1.341         | 0.052                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.347         | 0.010                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 270.94 | 0.974 | Ref-side Cap (Btu/h) :                  | 21966.14 576.47 |
| Upstream Temp A (F):       | 103.42 | 0.613 | Ref-side Cap (tons):                    | 1.83 0.05       |
| Upstream Temp B (F):       | 103.44 | 0.089 | Refrigerant Mdot (lbm/h):               | 312.41 8.42     |
| Upstream Temp C (F):       | 103.22 | 0.613 | Coriolis Density (lbm/ft3):             | 81.76 0.11      |
| Upstream Average Temp (F): | 103.36 |       | Upstream R22 Tsat (F):                  | 118.87          |
| Upstream Subcooling A (F): | 15.45  | 0.823 |   |                 |
| Upstream Subcooling B (F): | 15.43  | 0.440 |   |                 |
| Upstream Subcooling C (F): | 15.65  | 0.709 |   |                 |
| Average Subcooling (F):    | 15.51  |       |   |                 |
| Evap Exit Pressure (psia): | 90.50  | 0.243 | Turbine A Frequency (Hz):               | 203.68 1.00     |
| Evap Exit Avg Temp A:      | 74.20  | 0.561 | Turb A Vol Flow (ft3/min):              | 0.0286 0.00     |
| Evap Exit Avg Temp B:      | 74.23  | 0.853 | Turb A Density (lbm/ft3):               | 70.54 0.09      |
| Evap Exit Avg Temp C:      | 74.45  | 0.584 | Turb A Mass Flow (lb/h):                | 121.00 0.72     |
| Circuit A Superheat (F):   | 28.69  | 0.783 | Turbine C Frequency (Hz):               | 175.48 1.00     |
| Circuit B Superheat (F):   | 28.72  | 0.853 | Turb C Vol Flow (ft3/min):              | 0.0256 0.00     |
| Circuit C Superheat (F):   | 28.94  | 0.806 | Turb C Density (lbm/ft3):               | 70.57 0.09      |
| Overall Superheat (F):     | 29.39  | 0.604 | Turb C Mass Flow (lb/h):                | 108.61 0.70     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 82.79 8.69      |
| Evap Circuit Temp 1 (F):   | 74.73  | 0.541 | % Total Mass Flow Thru A:               | 38.73 1.19      |
| Evap Circuit Temp 2 (F):   | 68.13  | 1.636 | % Total Mass Flow Thru B:               | 26.50 2.13      |
| Evap Circuit Temp 3 (F):   | 50.12  | 0.326 | % Total Mass Flow Thru C:               | 34.77 1.08      |
| Evap Circuit Temp 4 (F):   | 73.35  | 1.084 |   |                 |
| Evap Circuit Temp 5 (F):   | 68.01  | 1.590 |   |                 |
| Evap Circuit Temp 6 (F):   | 51.52  | 0.556 |   |                 |
| Evap Circuit Temp 7 (F):   | 75.74  | 0.585 |   |                 |
| Evap Circuit Temp 8 (F):   | 70.28  | 1.088 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.01  | 0.279 |   |                 |

## A.6 Wavy fin evaporator with non-uniform airflow

Table A.6.1: Wavy Fin Evaporator with Non-Uniform Airflow

| Test names | Test type <sup>1</sup> | Velocity ratio |
|------------|------------------------|----------------|
| W020522A   | 9                      | 1:1            |
| W020523A   | 9A                     | 1:1.5          |
| W020524A   | 9B                     | 1:1.5          |
| W020528B   | 9                      | 1:1            |
| W020528C   | 9A                     | 1:2            |
| W020529A   | 9B                     | 1:2            |

- 1) Test 9: uniform airflow with superheat on all circuits of 5.6 °C (10.0 °F), 9A: same expansion valve setting as test 9 but with non-uniform airflow and no superheat adjustment, 9B: expansion valves adjusted to yield 5.6 °C (10.0 °F) superheat on all circuits with non-uniform airflow.

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020522A.dat SUMMARY FILENAME: W020522A.sum

|   | Range       | Total Air-Side Capacity:    | 22514.69 | 769.28 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.990 0.36 | Sensible Cap (Btu/h):       | 16410.41 | 555.80 |
| Indoor Inlet Dew (F):                         | 60.385 0.44 | Latent Cap (Btu/h):         | 6104.28  | 358.61 |
| Indoor Exit Dry-Bulb:                         | 60.154 0.34 | EvapAir Delta T (F):        | 20.35    | 0.44   |
| Indoor Exit Dew (F):                          | 55.855 0.34 | Air/Ref Cap Prcnt Diff:     | 1.56     | 4.23   |
|   |             | Sensible Heat Ratio:        | 0.729    | 0.0150 |
| Indoor Airflow (CFM):                         | 740.98 9.54 | SCFM per Ton:               | 390.26   |        |
| Indoor Airflow (SCFM):                        | 732.22 9.38 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011461    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009714    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.66    | 0.59   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.719       | 0.018                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.152       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                  |
|----------------------------|--------|-------|---|------------------|
| Expansion Valve            |        |       |   |                  |
| Upstream Pressure (psia):  | 306.67 | 1.461 | Ref-side Cap (Btu/h) :                  | 22864.18 1037.16 |
| Upstream Temp A (F):       | 105.20 | 0.086 | Ref-side Cap (tons):                    | 1.91 0.09        |
| Upstream Temp B (F):       | 105.56 | 0.567 | Refrigerant Mdot (lbm/h):               | 334.30 15.10     |
| Upstream Temp C (F):       | 105.25 | 0.567 | Coriolis Density (lbm/ft3):             | 82.44 0.21       |
| Upstream Average Temp (F): | 105.34 |       | Upstream R22 Tsat (F):                  | 128.66           |
| Upstream Subcooling A (F): | 23.46  | 0.352 |   |                  |
| Upstream Subcooling B (F): | 23.10  | 0.663 |   |                  |
| Upstream Subcooling C (F): | 23.41  | 0.502 |   |                  |
| Average Subcooling (F):    | 23.33  |       |   |                  |
| Evap Exit Pressure (psia): | 90.98  | 0.730 | Turbine A Frequency (Hz):               | 215.95 2.00      |
| Evap Exit Avg Temp A:      | 54.60  | 2.254 | Turb A Vol Flow (ft3/min):              | 0.0302 0.00      |
| Evap Exit Avg Temp B:      | 55.08  | 2.390 | Turb A Density (lbm/ft3):               | 70.27 0.01       |
| Evap Exit Avg Temp C:      | 54.97  | 2.163 | Turb A Mass Flow (lb/h):                | 127.42 1.12      |
| Circuit A Superheat (F):   | 8.74   | 1.942 | Turbine C Frequency (Hz):               | 187.18 2.00      |
| Circuit B Superheat (F):   | 9.22   | 2.096 | Turb C Vol Flow (ft3/min):              | 0.0272 0.00      |
| Circuit C Superheat (F):   | 9.11   | 2.163 | Turb C Density (lbm/ft3):               | 70.26 0.09       |
| Overall Superheat (F):     | 10.71  | 1.731 | Turb C Mass Flow (lb/h):                | 114.72 1.26      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 92.17 14.97      |
| Evap Circuit Temp 1 (F):   | 49.77  | 0.558 | % Total Mass Flow Thru A:               | 38.12 1.74       |
| Evap Circuit Temp 2 (F):   | 51.18  | 0.557 | % Total Mass Flow Thru B:               | 27.56 3.27       |
| Evap Circuit Temp 3 (F):   | 50.46  | 0.278 | % Total Mass Flow Thru C:               | 34.32 1.53       |
| Evap Circuit Temp 4 (F):   | 49.54  | 0.371 |   |                  |
| Evap Circuit Temp 5 (F):   | 48.64  | 0.650 |   |                  |
| Evap Circuit Temp 6 (F):   | 49.05  | 0.603 |   |                  |
| Evap Circuit Temp 7 (F):   | 52.98  | 0.366 |   |                  |
| Evap Circuit Temp 8 (F):   | 49.05  | 0.604 |   |                  |
| Evap Circuit Temp 9 (F):   | 49.63  | 1.115 |   |                  |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020523A.dat SUMMARY FILENAME: W020523A.sum

|   | Range       | Total Air-Side Capacity:    | 21669.58 | 550.13 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.900 0.30 | Sensible Cap (Btu/h):       | 16030.95 | 471.81 |
| Indoor Inlet Dew (F):                         | 60.247 0.10 | Latent Cap (Btu/h):         | 5638.63  | 178.27 |
| Indoor Exit Dry-Bulb:                         | 60.624 0.12 | EvapAir Delta T (F):        | 19.75    | 0.43   |
| Indoor Exit Dew (F):                          | 56.098 0.05 | Air/Ref Cap Prcnt Diff:     | 2.88     | 3.55   |
|   |             | Sensible Heat Ratio:        | 0.740    | 0.0073 |
| Indoor Airflow (CFM):                         | 746.69 7.28 | SCFM per Ton:               | 408.17   |        |
| Indoor Airflow (SCFM):                        | 737.07 7.12 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011405    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009801    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.88    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.729       | 0.014                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.199       | 0.008                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.86 | 0.852 | Ref-side Cap (Btu/h) :                  | 22292.27 552.09 |
| Upstream Temp A (F):       | 105.78 | 0.524 | Ref-side Cap (tons):                    | 1.86 0.05       |
| Upstream Temp B (F):       | 106.14 | 0.524 | Refrigerant Mdot (lbm/h):               | 330.43 7.96     |
| Upstream Temp C (F):       | 105.72 | 0.567 | Coriolis Density (lbm/ft3):             | 82.44 0.14      |
| Upstream Average Temp (F): | 105.88 |       | Upstream R22 Tsat (F):                  | 119.13          |
| Upstream Subcooling A (F): | 13.35  | 0.524 |   |                 |
| Upstream Subcooling B (F): | 12.98  | 0.594 |   |                 |
| Upstream Subcooling C (F): | 13.41  | 0.664 |   |                 |
| Average Subcooling (F):    | 13.25  |       |   |                 |
| Evap Exit Pressure (psia): | 90.87  | 0.365 | Turbine A Frequency (Hz):               | 214.67 2.00     |
| Evap Exit Avg Temp A:      | 46.16  | 0.441 | Turb A Vol Flow (ft3/min):              | 0.0300 0.00     |
| Evap Exit Avg Temp B:      | 59.17  | 1.051 | Turb A Density (lbm/ft3):               | 70.18 0.08      |
| Evap Exit Avg Temp C:      | 62.86  | 1.024 | Turb A Mass Flow (lb/h):                | 126.54 1.17     |
| Circuit A Superheat (F):   | 0.36   | 0.441 | Turbine C Frequency (Hz):               | 186.76 1.00     |
| Circuit B Superheat (F):   | 13.37  | 1.160 | Turb C Vol Flow (ft3/min):              | 0.0272 0.00     |
| Circuit C Superheat (F):   | 17.06  | 1.024 | Turb C Density (lbm/ft3):               | 70.19 0.09      |
| Overall Superheat (F):     | 1.14   | 0.729 | Turb C Mass Flow (lb/h):                | 114.36 0.69     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 89.53 7.47      |
| Evap Circuit Temp 1 (F):   | 49.89  | 0.558 | % Total Mass Flow Thru A:               | 38.30 0.96      |
| Evap Circuit Temp 2 (F):   | 50.53  | 0.741 | % Total Mass Flow Thru B:               | 27.09 1.68      |
| Evap Circuit Temp 3 (F):   | 49.87  | 0.557 | % Total Mass Flow Thru C:               | 34.61 0.76      |
| Evap Circuit Temp 4 (F):   | 49.13  | 0.696 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.43  | 0.279 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.07  | 0.558 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.45  | 0.645 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.36  | 0.558 |   |                 |
| Evap Circuit Temp 9 (F):   | 48.36  | 0.512 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020524A.dat SUMMARY FILENAME: W020524A.sum

|   | Range       | Total Air-Side Capacity:    | 22297.78 | Range | 425.38 |
|---|-------------|-----------------------------|----------|-------|--------|
| Air-Side Conditions                           |             |                             |          |       |        |
| Indoor Dry-Bulb :                             | 79.959 0.65 | Sensible Cap (Btu/h):       | 16261.99 |       | 405.47 |
| Indoor Inlet Dew (F):                         | 60.365 0.26 | Latent Cap (Btu/h):         | 6035.79  |       | 279.77 |
| Indoor Exit Dry-Bulb:                         | 60.328 0.41 | EvapAir Delta T (F):        | 20.10    |       | 0.44   |
| Indoor Exit Dew (F):                          | 55.904 0.30 | Air/Ref Cap Prcnt Diff:     | 0.28     |       | 3.09   |
|   |             | Sensible Heat Ratio:        | 0.729    |       | 0.0114 |
| Indoor Airflow (CFM):                         | 743.96 5.75 | SCFM per Ton:               | 395.46   |       |        |
| Indoor Airflow (SCFM):                        | 734.82 5.95 | (0.075 lb/ft3 standard air) |          |       |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011453    |                             |          |       |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009731    |                             |          |       |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.63    | 0.60  |        |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.724       | 0.011                       |          |       |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.200       | 0.008                       |          |       |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 279.51 | 0.731 | Ref-side Cap (Btu/h) :                  | 22358.83 | 522.64 |
| Upstream Temp A (F):       | 105.36 | 0.086 | Ref-side Cap (tons):                    | 1.86     | 0.04   |
| Upstream Temp B (F):       | 105.77 | 0.611 | Refrigerant Mdot (lbm/h):               | 326.72   | 7.41   |
| Upstream Temp C (F):       | 105.44 | 0.524 | Coriolis Density (lbm/ft3):             | 82.37    | 0.14   |
| Upstream Average Temp (F): | 105.53 |       | Upstream R22 Tsat (F):                  | 121.32   |        |
| Upstream Subcooling A (F): | 15.95  | 0.224 |   |          |        |
| Upstream Subcooling B (F): | 15.54  | 0.611 |   |          |        |
| Upstream Subcooling C (F): | 15.88  | 0.558 |   |          |        |
| Average Subcooling (F):    | 15.79  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.79  | 0.486 | Turbine A Frequency (Hz):               | 192.30   | 1.00   |
| Evap Exit Avg Temp A:      | 56.12  | 1.630 | Turb A Vol Flow (ft3/min):              | 0.0271   | 0.00   |
| Evap Exit Avg Temp B:      | 57.04  | 1.812 | Turb A Density (lbm/ft3):               | 70.25    | 0.01   |
| Evap Exit Avg Temp C:      | 57.12  | 2.202 | Turb A Mass Flow (lb/h):                | 114.12   | 0.58   |
| Circuit A Superheat (F):   | 10.42  | 1.475 | Turbine C Frequency (Hz):               | 198.00   | 2.00   |
| Circuit B Superheat (F):   | 11.33  | 1.812 | Turb C Vol Flow (ft3/min):              | 0.0287   | 0.00   |
| Circuit C Superheat (F):   | 11.41  | 2.201 | Turb C Density (lbm/ft3):               | 70.24    | 0.08   |
| Overall Superheat (F):     | 12.16  | 1.257 | Turb C Mass Flow (lb/h):                | 120.75   | 1.08   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 91.85    | 7.89   |
| Evap Circuit Temp 1 (F):   | 49.34  | 0.324 | % Total Mass Flow Thru A:               | 34.93    | 0.90   |
| Evap Circuit Temp 2 (F):   | 50.10  | 0.604 | % Total Mass Flow Thru B:               | 28.11    | 1.84   |
| Evap Circuit Temp 3 (F):   | 49.20  | 0.743 | % Total Mass Flow Thru C:               | 36.96    | 1.00   |
| Evap Circuit Temp 4 (F):   | 48.60  | 0.139 |   |          |        |
| Evap Circuit Temp 5 (F):   | 47.86  | 0.559 |   |          |        |
| Evap Circuit Temp 6 (F):   | 48.70  | 0.414 |   |          |        |
| Evap Circuit Temp 7 (F):   | 51.89  | 0.601 |   |          |        |
| Evap Circuit Temp 8 (F):   | 48.80  | 0.650 |   |          |        |
| Evap Circuit Temp 9 (F):   | 52.45  | 3.981 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020528B.dat SUMMARY FILENAME: W020528B.sum

|   | Range       | Total Air-Side Capacity:    | 22643.61 | 572.83 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.028 0.45 | Sensible Cap (Btu/h):       | 16466.36 | 489.00 |
| Indoor Inlet Dew (F):                         | 60.360 0.17 | Latent Cap (Btu/h):         | 6177.26  | 251.94 |
| Indoor Exit Dry-Bulb:                         | 60.090 0.23 | EvapAir Delta T (F):        | 20.41    | 0.43   |
| Indoor Exit Dew (F):                          | 55.773 0.20 | Air/Ref Cap Prcnt Diff:     | 0.69     | 4.12   |
|   |             | Sensible Heat Ratio:        | 0.727    | 0.0109 |
| Indoor Airflow (CFM):                         | 741.52 8.14 | SCFM per Ton:               | 388.38   |        |
| Indoor Airflow (SCFM):                        | 732.86 8.24 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011451    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009684    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.33    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.720       | 0.016                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.153       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 277.49 | 0.852 | Ref-side Cap (Btu/h) :                  | 22798.19 490.12 |
| Upstream Temp A (F):       | 105.26 | 0.524 | Ref-side Cap (tons):                    | 1.90 0.04       |
| Upstream Temp B (F):       | 105.75 | 0.524 | Refrigerant Mdot (lbm/h):               | 333.16 6.96     |
| Upstream Temp C (F):       | 105.23 | 0.611 | Coriolis Density (lbm/ft3):             | 82.40 0.15      |
| Upstream Average Temp (F): | 105.41 |       | Upstream R22 Tsat (F):                  | 120.72          |
| Upstream Subcooling A (F): | 15.46  | 0.524 |   |                 |
| Upstream Subcooling B (F): | 14.98  | 0.643 |   |                 |
| Upstream Subcooling C (F): | 15.49  | 0.611 |   |                 |
| Average Subcooling (F):    | 15.31  |       |   |                 |
| Evap Exit Pressure (psia): | 90.80  | 0.608 | Turbine A Frequency (Hz):               | 215.22 1.00     |
| Evap Exit Avg Temp A:      | 56.32  | 1.102 | Turb A Vol Flow (ft3/min):              | 0.0301 0.00     |
| Evap Exit Avg Temp B:      | 55.29  | 0.896 | Turb A Density (lbm/ft3):               | 70.26 0.08      |
| Evap Exit Avg Temp C:      | 55.85  | 1.379 | Turb A Mass Flow (lb/h):                | 126.99 0.69     |
| Circuit A Superheat (F):   | 10.62  | 1.102 | Turbine C Frequency (Hz):               | 187.44 1.00     |
| Circuit B Superheat (F):   | 9.60   | 1.029 | Turb C Vol Flow (ft3/min):              | 0.0272 0.00     |
| Circuit C Superheat (F):   | 10.16  | 1.535 | Turb C Density (lbm/ft3):               | 70.27 0.09      |
| Overall Superheat (F):     | 11.61  | 1.139 | Turb C Mass Flow (lb/h):                | 114.87 0.67     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 91.30 7.59      |
| Evap Circuit Temp 1 (F):   | 49.89  | 0.746 | % Total Mass Flow Thru A:               | 38.12 0.95      |
| Evap Circuit Temp 2 (F):   | 50.99  | 0.557 | % Total Mass Flow Thru B:               | 27.40 1.76      |
| Evap Circuit Temp 3 (F):   | 50.48  | 0.650 | % Total Mass Flow Thru C:               | 34.48 0.83      |
| Evap Circuit Temp 4 (F):   | 49.77  | 0.697 |   |                 |
| Evap Circuit Temp 5 (F):   | 49.17  | 0.976 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.88  | 0.603 |   |                 |
| Evap Circuit Temp 7 (F):   | 53.19  | 1.020 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.55  | 1.023 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.69  | 1.625 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020528C.dat SUMMARY FILENAME: W020528C.sum

|   | Range       | Total Air-Side Capacity:    | 21085.08 | Range  |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.941 0.34 | Sensible Cap (Btu/h):       | 15581.68 | 449.88 |
| Indoor Inlet Dew (F):                         | 60.424 0.10 | Latent Cap (Btu/h):         | 5503.40  | 399.80 |
| Indoor Exit Dry-Bulb:                         | 60.960 0.17 | EvapAir Delta T (F):        | 19.40    | 160.10 |
| Indoor Exit Dew (F):                          | 56.361 0.15 | Air/Ref Cap Prcnt Diff:     | 5.17     | 0.43   |
|   |             | Sensible Heat Ratio:        | 0.739    | 4.14   |
|   |             |                             |          | 0.0092 |
| Indoor Airflow (CFM):                         | 739.51 7.97 | SCFM per Ton:               | 415.14   |        |
| Indoor Airflow (SCFM):                        | 729.45 7.82 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011478    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009896    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 62.18    | 0.64   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.715       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.214       | 0.010                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 269.87 | 1.218 | Ref-side Cap (Btu/h) :                  | 22173.27 535.33 |
| Upstream Temp A (F):       | 103.87 | 0.524 | Ref-side Cap (tons):                    | 1.85 0.04       |
| Upstream Temp B (F):       | 104.35 | 0.525 | Refrigerant Mdot (lbm/h):               | 325.78 7.87     |
| Upstream Temp C (F):       | 103.86 | 0.481 | Coriolis Density (lbm/ft3):             | 81.91 0.18      |
| Upstream Average Temp (F): | 104.03 |       | Upstream R22 Tsat (F):                  | 118.55          |
| Upstream Subcooling A (F): | 14.68  | 0.665 |   |                 |
| Upstream Subcooling B (F): | 14.20  | 0.420 |   |                 |
| Upstream Subcooling C (F): | 14.70  | 0.517 |   |                 |
| Average Subcooling (F):    | 14.52  |       |   |                 |
| Evap Exit Pressure (psia): | 91.43  | 0.486 | Turbine A Frequency (Hz):               | 209.64 3.00     |
| Evap Exit Avg Temp A:      | 46.33  | 0.372 | Turb A Vol Flow (ft3/min):              | 0.0294 0.00     |
| Evap Exit Avg Temp B:      | 58.24  | 0.824 | Turb A Density (lbm/ft3):               | 70.48 0.08      |
| Evap Exit Avg Temp C:      | 64.31  | 0.363 | Turb A Mass Flow (lb/h):                | 124.23 1.55     |
| Circuit A Superheat (F):   | 0.26   | 0.527 | Turbine C Frequency (Hz):               | 182.45 1.00     |
| Circuit B Superheat (F):   | 12.16  | 0.980 | Turb C Vol Flow (ft3/min):              | 0.0266 0.00     |
| Circuit C Superheat (F):   | 18.24  | 0.441 | Turb C Density (lbm/ft3):               | 70.48 0.07      |
| Overall Superheat (F):     | 0.90   | 0.436 | Turb C Mass Flow (lb/h):                | 112.40 0.68     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 89.14 7.53      |
| Evap Circuit Temp 1 (F):   | 50.19  | 0.557 | % Total Mass Flow Thru A:               | 38.14 0.86      |
| Evap Circuit Temp 2 (F):   | 50.65  | 0.650 | % Total Mass Flow Thru B:               | 27.36 1.68      |
| Evap Circuit Temp 3 (F):   | 49.90  | 0.650 | % Total Mass Flow Thru C:               | 34.50 0.98      |
| Evap Circuit Temp 4 (F):   | 49.61  | 0.558 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.98  | 0.651 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.47  | 0.558 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.53  | 0.600 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.91  | 0.325 |   |                 |
| Evap Circuit Temp 9 (F):   | 48.85  | 0.651 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: W020529A.dat SUMMARY FILENAME: W020529A.sum

|   | Range       | Total Air-Side Capacity:    | 21520.92 | 640.29 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.988 0.50 | Sensible Cap (Btu/h):       | 15838.75 | 469.14 |
| Indoor Inlet Dew (F):                         | 60.290 0.21 | Latent Cap (Btu/h):         | 5682.17  | 361.99 |
| Indoor Exit Dry-Bulb:                         | 60.608 0.24 | EvapAir Delta T (F):        | 19.75    | 0.43   |
| Indoor Exit Dew (F):                          | 56.059 0.25 | Air/Ref Cap Prcnt Diff:     | 0.26     | 3.87   |
|   |             | Sensible Heat Ratio:        | 0.736    | 0.0159 |
| Indoor Airflow (CFM):                         | 737.94 9.18 | SCFM per Ton:               | 406.15   |        |
| Indoor Airflow (SCFM):                        | 728.40 9.17 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011422    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009787    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.76    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.712       | 0.018                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.236       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 321.32 | 1.218 | Ref-side Cap (Btu/h) :                  | 21575.13 | 653.24 |
| Upstream Temp A (F):       | 104.25 | 0.262 | Ref-side Cap (tons):                    | 1.80     | 0.05   |
| Upstream Temp B (F):       | 104.91 | 0.524 | Refrigerant Mdot (lbm/h):               | 314.00   | 9.43   |
| Upstream Temp C (F):       | 104.48 | 0.306 | Coriolis Density (lbm/ft3):             | 82.37    | 0.12   |
| Upstream Average Temp (F): | 104.55 |       | Upstream R22 Tsat (F):                  | 132.44   |        |
| Upstream Subcooling A (F): | 28.18  | 0.385 |   |          |        |
| Upstream Subcooling B (F): | 27.52  | 0.648 |   |          |        |
| Upstream Subcooling C (F): | 27.96  | 0.399 |   |          |        |
| Average Subcooling (F):    | 27.89  |       |   |          |        |
| Evap Exit Pressure (psia): | 91.11  | 0.486 | Turbine A Frequency (Hz):               | 173.30   | 2.00   |
| Evap Exit Avg Temp A:      | 55.99  | 1.378 | Turb A Vol Flow (ft3/min):              | 0.0245   | 0.00   |
| Evap Exit Avg Temp B:      | 55.99  | 1.493 | Turb A Density (lbm/ft3):               | 70.42    | 0.04   |
| Evap Exit Avg Temp C:      | 55.87  | 2.022 | Turb A Mass Flow (lb/h):                | 103.72   | 1.13   |
| Circuit A Superheat (F):   | 10.17  | 1.378 | Turbine C Frequency (Hz):               | 199.25   | 1.00   |
| Circuit B Superheat (F):   | 10.17  | 1.493 | Turb C Vol Flow (ft3/min):              | 0.0288   | 0.00   |
| Circuit C Superheat (F):   | 10.05  | 2.022 | Turb C Density (lbm/ft3):               | 70.38    | 0.05   |
| Overall Superheat (F):     | 11.47  | 1.166 | Turb C Mass Flow (lb/h):                | 121.71   | 0.63   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 88.57    | 9.20   |
| Evap Circuit Temp 1 (F):   | 49.26  | 0.369 | % Total Mass Flow Thru A:               | 33.03    | 0.94   |
| Evap Circuit Temp 2 (F):   | 50.18  | 0.557 | % Total Mass Flow Thru B:               | 28.20    | 2.10   |
| Evap Circuit Temp 3 (F):   | 49.06  | 0.651 | % Total Mass Flow Thru C:               | 38.76    | 1.30   |
| Evap Circuit Temp 4 (F):   | 48.60  | 0.279 |   |          |        |
| Evap Circuit Temp 5 (F):   | 47.81  | 0.559 |   |          |        |
| Evap Circuit Temp 6 (F):   | 48.80  | 0.649 |   |          |        |
| Evap Circuit Temp 7 (F):   | 51.84  | 0.601 |   |          |        |
| Evap Circuit Temp 8 (F):   | 49.01  | 0.279 |   |          |        |
| Evap Circuit Temp 9 (F):   | 53.97  | 3.328 |   |          |        |

A.7 Enhanced fin (wavy-lanced) evaporator with non-uniform airflow

Table A.7.1: Enhanced-Cut Fin (Wavy-Lanced) Evaporator with Non-Uniform Airflow

| Test names | Test type <sup>1</sup> | Velocity ratio |
|------------|------------------------|----------------|
| E020604A   | 9                      | 1:1            |
| E020604B   | 9A                     | 1:1.26         |
| E020605A   | 9B                     | 1:1.26         |
| E020607A   | 9                      | 1:1            |
| E020607B   | 9A                     | 1:1.36         |
| E020610A   | 9B                     | 1:1.36         |
| E020611A   | 9A                     | 1:1.62         |
| E020612A   | 9B                     | 1:1.62         |
| E020613A   | 9A                     | 1:1.75         |
| E020620A   | 9B                     | 1:1.75         |
| E020621A   | 9A                     | 1:2.59         |
| E020624A   | 9B                     | 1:2.59         |

- 1) Test 9: uniform airflow with superheat on all circuits of 5.6 °C (10.0 °F), 9A: same expansion valve setting as test 9 but with non-uniform airflow and no superheat adjustment, 9B: expansion valves adjusted to yield 5.6 °C (10.0 °F) superheat on all circuits with non-uniform airflow.

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020604A.dat SUMMARY FILENAME: E020604A.sum

|   | Range        | Total Air-Side Capacity:    | 23833.08 | 462.49 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 80.206 0.47  | Sensible Cap (Btu/h):       | 17220.20 | 445.56 |
| Indoor Inlet Dew (F):                         | 60.500 0.26  | Latent Cap (Btu/h):         | 6612.88  | 271.81 |
| Indoor Exit Dry-Bulb:                         | 59.854 0.33  | EvapAir Delta T (F):        | 20.83    | 0.43   |
| Indoor Exit Dew (F):                          | 55.712 0.25  | Air/Ref Cap Prcnt Diff:     | -1.50    | 3.11   |
|   |              | Sensible Heat Ratio:        | 0.723    | 0.0114 |
| Indoor Airflow (CFM):                         | 759.74 10.21 | SCFM per Ton:               | 378.03   |        |
| Indoor Airflow (SCFM):                        | 750.80 10.05 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011509     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009663     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 61.33    | 0.37   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.756        | 0.020                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.372        | 0.016                       |          |        |

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Refrigerant Side Conditions

Expansion Valve

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Upstream Pressure (psia):  | 275.71 | 0.731 | Ref-side Cap (Btu/h) :                  | 23476.20 | 675.67 |
| Upstream Temp A (F):       | 103.90 | 0.043 | Ref-side Cap (tons):                    | 1.96     | 0.06   |
| Upstream Temp B (F):       | 104.21 | 0.306 | Refrigerant Mdot (lbm/h):               | 340.40   | 9.61   |
| Upstream Temp C (F):       | 104.02 | 0.524 | Coriolis Density (lbm/ft3):             | 81.94    | 0.14   |
| Upstream Average Temp (F): | 104.04 |       | Upstream R22 Tsat (F):                  | 120.22   |        |
| Upstream Subcooling A (F): | 16.32  | 0.208 |   |          |        |
| Upstream Subcooling B (F): | 16.01  | 0.401 |   |          |        |
| Upstream Subcooling C (F): | 16.20  | 0.732 |   |          |        |
| Average Subcooling (F):    | 16.18  |       |   |          |        |
| Evap Exit Pressure (psia): | 91.05  | 0.973 | Turbine A Frequency (Hz):               | 215.39   | 1.00   |
| Evap Exit Avg Temp A:      | 56.46  | 2.755 | Turb A Vol Flow (ft3/min):              | 0.0301   | 0.00   |
| Evap Exit Avg Temp B:      | 56.19  | 3.166 | Turb A Density (lbm/ft3):               | 70.47    | 0.01   |
| Evap Exit Avg Temp C:      | 55.97  | 4.415 | Turb A Mass Flow (lb/h):                | 127.46   | 0.57   |
| Circuit A Superheat (F):   | 10.53  | 2.773 | Turbine C Frequency (Hz):               | 197.67   | 1.00   |
| Circuit B Superheat (F):   | 10.26  | 3.166 | Turb C Vol Flow (ft3/min):              | 0.0286   | 0.00   |
| Circuit C Superheat (F):   | 10.04  | 4.393 | Turb C Density (lbm/ft3):               | 70.45    | 0.08   |
| Overall Superheat (F):     | 12.80  | 1.178 | Turb C Mass Flow (lb/h):                | 120.94   | 0.70   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 92.00    | 9.02   |
| Evap Circuit Temp 1 (F):   | 50.01  | 0.557 | % Total Mass Flow Thru A:               | 37.45    | 1.05   |
| Evap Circuit Temp 2 (F):   | 50.00  | 0.372 | % Total Mass Flow Thru B:               | 27.02    | 1.91   |
| Evap Circuit Temp 3 (F):   | 49.88  | 0.557 | % Total Mass Flow Thru C:               | 35.53    | 0.90   |
| Evap Circuit Temp 4 (F):   | 48.93  | 0.558 |   |          |        |
| Evap Circuit Temp 5 (F):   | 48.77  | 0.279 |   |          |        |
| Evap Circuit Temp 6 (F):   | 49.34  | 0.558 |   |          |        |
| Evap Circuit Temp 7 (F):   | 51.88  | 0.646 |   |          |        |
| Evap Circuit Temp 8 (F):   | 49.06  | 0.558 |   |          |        |
| Evap Circuit Temp 9 (F):   | 50.57  | 0.557 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020604B.dat SUMMARY FILENAME: E020604B.sum

|   | Range       | Total Air-Side Capacity:    | 23654.81 | 336.15 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.937 0.37 | Sensible Cap (Btu/h):       | 17008.27 | 317.97 |
| Indoor Inlet Dew (F):                         | 60.484 0.37 | Latent Cap (Btu/h):         | 6646.54  | 294.02 |
| Indoor Exit Dry-Bulb:                         | 59.911 0.37 | EvapAir Delta T (F):        | 20.49    | 0.22   |
| Indoor Exit Dew (F):                          | 55.688 0.34 | Air/Ref Cap Prcnt Diff:     | -1.24    | 1.89   |
|   |             | Sensible Heat Ratio:        | 0.719    | 0.0113 |
| Indoor Airflow (CFM):                         | 762.89 9.67 | SCFM per Ton:               | 382.36   |        |
| Indoor Airflow (SCFM):                        | 753.71 9.93 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011503    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009654    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.41    | 0.82   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.762       | 0.020                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.435       | 0.019                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 274.33 | 1.218 | Ref-side Cap (Btu/h) :                  | 23360.84 436.80 |
| Upstream Temp A (F):       | 103.65 | 0.524 | Ref-side Cap (tons):                    | 1.95 0.04       |
| Upstream Temp B (F):       | 104.04 | 0.525 | Refrigerant Mdot (lbm/h):               | 340.61 7.14     |
| Upstream Temp C (F):       | 103.68 | 0.262 | Coriolis Density (lbm/ft3):             | 81.84 0.19      |
| Upstream Average Temp (F): | 103.79 |       | Upstream R22 Tsat (F):                  | 119.84          |
| Upstream Subcooling A (F): | 16.19  | 0.594 |   |                 |
| Upstream Subcooling B (F): | 15.80  | 0.420 |   |                 |
| Upstream Subcooling C (F): | 16.16  | 0.383 |   |                 |
| Average Subcooling (F):    | 16.05  |       |   |                 |
| Evap Exit Pressure (psia): | 90.33  | 0.608 | Turbine A Frequency (Hz):               | 214.28 2.00     |
| Evap Exit Avg Temp A:      | 46.75  | 0.419 | Turb A Vol Flow (ft3/min):              | 0.0300 0.00     |
| Evap Exit Avg Temp B:      | 60.86  | 1.506 | Turb A Density (lbm/ft3):               | 70.51 0.08      |
| Evap Exit Avg Temp C:      | 64.18  | 1.227 | Turb A Mass Flow (lb/h):                | 126.91 1.13     |
| Circuit A Superheat (F):   | 1.31   | 0.419 | Turbine C Frequency (Hz):               | 196.56 1.00     |
| Circuit B Superheat (F):   | 15.41  | 1.369 | Turb C Vol Flow (ft3/min):              | 0.0285 0.00     |
| Circuit C Superheat (F):   | 18.74  | 1.227 | Turb C Density (lbm/ft3):               | 70.51 0.04      |
| Overall Superheat (F):     | 7.22   | 4.196 | Turb C Mass Flow (lb/h):                | 120.40 0.63     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 93.30 6.47      |
| Evap Circuit Temp 1 (F):   | 49.74  | 0.648 | % Total Mass Flow Thru A:               | 37.26 0.78      |
| Evap Circuit Temp 2 (F):   | 49.45  | 0.558 | % Total Mass Flow Thru B:               | 27.39 1.46      |
| Evap Circuit Temp 3 (F):   | 49.28  | 0.557 | % Total Mass Flow Thru C:               | 35.35 0.74      |
| Evap Circuit Temp 4 (F):   | 48.54  | 0.558 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.45  | 0.558 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.80  | 0.090 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.16  | 0.368 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.77  | 0.558 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.05  | 0.512 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020605A.dat SUMMARY FILENAME: E020605A.sum

|   | Range       | Total Air-Side Capacity:    | 23983.95 | 393.40 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.988 0.42 | Sensible Cap (Btu/h):       | 17310.40 | 380.89 |
| Indoor Inlet Dew (F):                         | 60.310 0.20 | Latent Cap (Btu/h):         | 6673.55  | 209.49 |
| Indoor Exit Dry-Bulb:                         | 59.630 0.28 | EvapAir Delta T (F):        | 20.85    | 0.43   |
| Indoor Exit Dew (F):                          | 55.465 0.20 | Air/Ref Cap Prcnt Diff:     | -1.22    | 2.90   |
|   |             | Sensible Heat Ratio:        | 0.722    | 0.0076 |
| Indoor Airflow (CFM):                         | 762.67 7.99 | SCFM per Ton:               | 377.23   |        |
| Indoor Airflow (SCFM):                        | 753.95 7.96 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011431    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009575    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 60.85    | 0.37   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.762       | 0.016                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.428       | 0.012                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 271.09 | 0.365 | Ref-side Cap (Btu/h) :                  | 23689.75 531.76 |
| Upstream Temp A (F):       | 104.46 | 0.262 | Ref-side Cap (tons):                    | 1.97 0.04       |
| Upstream Temp B (F):       | 105.00 | 0.612 | Refrigerant Mdot (lbm/h):               | 344.83 8.33     |
| Upstream Temp C (F):       | 104.66 | 0.350 | Coriolis Density (lbm/ft3):             | 82.15 0.16      |
| Upstream Average Temp (F): | 104.71 |       | Upstream R22 Tsat (F):                  | 118.89          |
| Upstream Subcooling A (F): | 14.43  | 0.297 |   |                 |
| Upstream Subcooling B (F): | 13.89  | 0.603 |   |                 |
| Upstream Subcooling C (F): | 14.24  | 0.350 |   |                 |
| Average Subcooling (F):    | 14.19  |       |   |                 |
| Evap Exit Pressure (psia): | 90.36  | 0.486 | Turbine A Frequency (Hz):               | 209.06 2.00     |
| Evap Exit Avg Temp A:      | 55.17  | 3.217 | Turb A Vol Flow (ft3/min):              | 0.0293 0.00     |
| Evap Exit Avg Temp B:      | 55.33  | 2.528 | Turb A Density (lbm/ft3):               | 70.39 0.04      |
| Evap Exit Avg Temp C:      | 54.76  | 2.600 | Turb A Mass Flow (lb/h):                | 123.75 1.18     |
| Circuit A Superheat (F):   | 9.70   | 3.061 | Turbine C Frequency (Hz):               | 206.71 1.00     |
| Circuit B Superheat (F):   | 9.87   | 2.685 | Turb C Vol Flow (ft3/min):              | 0.0298 0.00     |
| Circuit C Superheat (F):   | 9.29   | 2.600 | Turb C Density (lbm/ft3):               | 70.36 0.05      |
| Overall Superheat (F):     | 12.49  | 1.533 | Turb C Mass Flow (lb/h):                | 125.86 0.59     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 95.22 8.33      |
| Evap Circuit Temp 1 (F):   | 49.38  | 0.091 | % Total Mass Flow Thru A:               | 35.89 0.87      |
| Evap Circuit Temp 2 (F):   | 49.90  | 0.373 | % Total Mass Flow Thru B:               | 27.61 1.75      |
| Evap Circuit Temp 3 (F):   | 49.48  | 0.557 | % Total Mass Flow Thru C:               | 36.50 0.92      |
| Evap Circuit Temp 4 (F):   | 48.28  | 0.279 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.19  | 0.467 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.64  | 0.279 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.45  | 0.278 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.50  | 0.558 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.50  | 1.069 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020607A.dat SUMMARY FILENAME: E020607A.sum

|   | Range       | Total Air-Side Capacity:    | 23732.88 | Range | 459.67 |
|---|-------------|-----------------------------|----------|-------|--------|
| Air-Side Conditions                           |             |                             |          |       |        |
| Indoor Dry-Bulb :                             | 79.851 0.39 | Sensible Cap (Btu/h):       | 17252.27 |       | 350.17 |
| Indoor Inlet Dew (F):                         | 60.360 0.11 | Latent Cap (Btu/h):         | 6480.61  |       | 153.02 |
| Indoor Exit Dry-Bulb:                         | 59.725 0.19 | EvapAir Delta T (F):        | 20.59    |       | 0.22   |
| Indoor Exit Dew (F):                          | 55.721 0.15 | Air/Ref Cap Prcnt Diff:     | -0.48    |       | 3.41   |
|   |             | Sensible Heat Ratio:        | 0.727    |       | 0.0062 |
| Indoor Airflow (CFM):                         | 769.76 7.65 | SCFM per Ton:               | 384.76   |       |        |
| Indoor Airflow (SCFM):                        | 760.95 7.53 | (0.075 lb/ft3 standard air) |          |       |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011451    |                             |          |       |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009666    |                             |          |       |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 60.70    | 0.64  |        |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.776       | 0.015                       |          |       |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.340       | 0.008                       |          |       |        |

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Refrigerant Side Conditions

|                            |        |       |   |          |        |
|----------------------------|--------|-------|---|----------|--------|
| Expansion Valve            |        |       |   |          |        |
| Upstream Pressure (psia):  | 273.97 | 0.609 | Ref-side Cap (Btu/h) :                  | 23619.08 | 522.68 |
| Upstream Temp A (F):       | 105.06 | 0.610 | Ref-side Cap (tons):                    | 1.97     | 0.04   |
| Upstream Temp B (F):       | 105.52 | 0.262 | Refrigerant Mdot (lbm/h):               | 344.39   | 7.78   |
| Upstream Temp C (F):       | 105.08 | 0.524 | Coriolis Density (lbm/ft3):             | 82.28    | 0.08   |
| Upstream Average Temp (F): | 105.22 |       | Upstream R22 Tsat (F):                  | 119.69   |        |
| Upstream Subcooling A (F): | 14.63  | 0.644 |   |          |        |
| Upstream Subcooling B (F): | 14.17  | 0.297 |   |          |        |
| Upstream Subcooling C (F): | 14.62  | 0.524 |   |          |        |
| Average Subcooling (F):    | 14.47  |       |   |          |        |
| Evap Exit Pressure (psia): | 90.83  | 0.486 | Turbine A Frequency (Hz):               | 221.44   | 1.00   |
| Evap Exit Avg Temp A:      | 55.78  | 1.263 | Turb A Vol Flow (ft3/min):              | 0.0309   | 0.00   |
| Evap Exit Avg Temp B:      | 55.97  | 1.747 | Turb A Density (lbm/ft3):               | 70.29    | 0.09   |
| Evap Exit Avg Temp C:      | 55.76  | 2.343 | Turb A Mass Flow (lb/h):                | 130.53   | 0.71   |
| Circuit A Superheat (F):   | 10.04  | 1.419 | Turbine C Frequency (Hz):               | 198.44   | 1.00   |
| Circuit B Superheat (F):   | 10.23  | 1.668 | Turb C Vol Flow (ft3/min):              | 0.0287   | 0.00   |
| Circuit C Superheat (F):   | 10.02  | 2.656 | Turb C Density (lbm/ft3):               | 70.29    | 0.08   |
| Overall Superheat (F):     | 12.83  | 1.228 | Turb C Mass Flow (lb/h):                | 121.09   | 0.59   |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 92.76    | 8.08   |
| Evap Circuit Temp 1 (F):   | 49.92  | 0.279 | % Total Mass Flow Thru A:               | 37.90    | 0.93   |
| Evap Circuit Temp 2 (F):   | 51.11  | 0.557 | % Total Mass Flow Thru B:               | 26.93    | 1.81   |
| Evap Circuit Temp 3 (F):   | 50.37  | 0.649 | % Total Mass Flow Thru C:               | 35.16    | 0.93   |
| Evap Circuit Temp 4 (F):   | 49.15  | 0.558 |   |          |        |
| Evap Circuit Temp 5 (F):   | 49.04  | 0.325 |   |          |        |
| Evap Circuit Temp 6 (F):   | 49.12  | 0.368 |   |          |        |
| Evap Circuit Temp 7 (F):   | 53.23  | 0.644 |   |          |        |
| Evap Circuit Temp 8 (F):   | 49.02  | 0.558 |   |          |        |
| Evap Circuit Temp 9 (F):   | 49.96  | 0.279 |   |          |        |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020607B.dat SUMMARY FILENAME: E020607B.sum

|   | Range       | Total Air-Side Capacity:    | 23191.63 | 450.61 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.967 0.30 | Sensible Cap (Btu/h):       | 17080.76 | 474.14 |
| Indoor Inlet Dew (F):                         | 60.310 0.12 | Latent Cap (Btu/h):         | 6110.87  | 116.49 |
| Indoor Exit Dry-Bulb:                         | 60.086 0.16 | EvapAir Delta T (F):        | 20.41    | 0.43   |
| Indoor Exit Dew (F):                          | 55.942 0.10 | Air/Ref Cap Prcnt Diff:     | -0.36    | 3.03   |
|   |             | Sensible Heat Ratio:        | 0.736    | 0.0062 |
| Indoor Airflow (CFM):                         | 769.56 8.57 | SCFM per Ton:               | 393.27   |        |
| Indoor Airflow (SCFM):                        | 760.05 8.42 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011430    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009745    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.10    | 0.73   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.775       | 0.017                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.413       | 0.014                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 269.24 | 0.365 | Ref-side Cap (Btu/h) :                  | 23106.51 418.87 |
| Upstream Temp A (F):       | 104.31 | 0.697 | Ref-side Cap (tons):                    | 1.93 0.03       |
| Upstream Temp B (F):       | 104.74 | 0.700 | Refrigerant Mdot (lbm/h):               | 340.01 6.77     |
| Upstream Temp C (F):       | 104.37 | 0.654 | Coriolis Density (lbm/ft3):             | 82.09 0.10      |
| Upstream Average Temp (F): | 104.48 |       | Upstream R22 Tsat (F):                  | 118.36          |
| Upstream Subcooling A (F): | 14.05  | 0.732 |   |                 |
| Upstream Subcooling B (F): | 13.62  | 0.736 |   |                 |
| Upstream Subcooling C (F): | 13.99  | 0.646 |   |                 |
| Average Subcooling (F):    | 13.88  |       |   |                 |
| Evap Exit Pressure (psia): | 90.73  | 0.365 | Turbine A Frequency (Hz):               | 217.50 1.00     |
| Evap Exit Avg Temp A:      | 46.35  | 0.304 | Turb A Vol Flow (ft3/min):              | 0.0304 0.00     |
| Evap Exit Avg Temp B:      | 60.82  | 0.728 | Turb A Density (lbm/ft3):               | 70.41 0.11      |
| Evap Exit Avg Temp C:      | 65.84  | 0.860 | Turb A Mass Flow (lb/h):                | 128.53 0.73     |
| Circuit A Superheat (F):   | 0.70   | 0.520 | Turbine C Frequency (Hz):               | 194.29 1.00     |
| Circuit B Superheat (F):   | 15.17  | 0.963 | Turb C Vol Flow (ft3/min):              | 0.0282 0.00     |
| Circuit C Superheat (F):   | 20.19  | 1.126 | Turb C Density (lbm/ft3):               | 70.40 0.10      |
| Overall Superheat (F):     | 1.81   | 1.038 | Turb C Mass Flow (lb/h):                | 118.94 0.73     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 92.54 6.90      |
| Evap Circuit Temp 1 (F):   | 49.66  | 0.513 | % Total Mass Flow Thru A:               | 37.80 0.86      |
| Evap Circuit Temp 2 (F):   | 50.55  | 0.276 | % Total Mass Flow Thru B:               | 27.21 1.52      |
| Evap Circuit Temp 3 (F):   | 49.87  | 0.464 | % Total Mass Flow Thru C:               | 34.98 0.71      |
| Evap Circuit Temp 4 (F):   | 48.90  | 0.512 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.60  | 0.651 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.94  | 0.648 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.71  | 0.555 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.88  | 0.604 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.12  | 0.512 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020610A.dat SUMMARY FILENAME: E020610A.sum

|   | Range       | Total Air-Side Capacity:    | 23226.10 | 446.20 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.897 0.21 | Sensible Cap (Btu/h):       | 16802.07 | 476.20 |
| Indoor Inlet Dew (F):                         | 60.349 0.32 | Latent Cap (Btu/h):         | 6424.03  | 235.43 |
| Indoor Exit Dry-Bulb:                         | 60.164 0.29 | EvapAir Delta T (F):        | 20.15    | 0.44   |
| Indoor Exit Dew (F):                          | 55.729 0.20 | Air/Ref Cap Prcnt Diff:     | -0.85    | 3.18   |
|   |             | Sensible Heat Ratio:        | 0.723    | 0.0112 |
| Indoor Airflow (CFM):                         | 766.90 5.72 | SCFM per Ton:               | 391.30   |        |
| Indoor Airflow (SCFM):                        | 757.36 5.86 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011447    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009668    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.39    | 0.60   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.769       | 0.012                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.409       | 0.012                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 274.91 | 0.487 | Ref-side Cap (Btu/h) :                  | 23028.12 410.82 |
| Upstream Temp A (F):       | 105.46 | 0.524 | Ref-side Cap (tons):                    | 1.92 0.03       |
| Upstream Temp B (F):       | 106.05 | 0.524 | Refrigerant Mdot (lbm/h):               | 336.43 5.86     |
| Upstream Temp C (F):       | 105.62 | 0.262 | Coriolis Density (lbm/ft3):             | 82.44 0.16      |
| Upstream Average Temp (F): | 105.71 |       | Upstream R22 Tsat (F):                  | 119.98          |
| Upstream Subcooling A (F): | 14.52  | 0.593 |   |                 |
| Upstream Subcooling B (F): | 13.93  | 0.663 |   |                 |
| Upstream Subcooling C (F): | 14.36  | 0.331 |   |                 |
| Average Subcooling (F):    | 14.27  |       |   |                 |
| Evap Exit Pressure (psia): | 91.15  | 0.486 | Turbine A Frequency (Hz):               | 201.47 1.00     |
| Evap Exit Avg Temp A:      | 56.72  | 1.720 | Turb A Vol Flow (ft3/min):              | 0.0283 0.00     |
| Evap Exit Avg Temp B:      | 56.18  | 1.652 | Turb A Density (lbm/ft3):               | 70.23 0.08      |
| Evap Exit Avg Temp C:      | 56.63  | 2.112 | Turb A Mass Flow (lb/h):                | 119.23 0.70     |
| Circuit A Superheat (F):   | 10.73  | 1.824 | Turbine C Frequency (Hz):               | 203.89 2.00     |
| Circuit B Superheat (F):   | 10.19  | 1.808 | Turb C Vol Flow (ft3/min):              | 0.0294 0.00     |
| Circuit C Superheat (F):   | 10.64  | 1.957 | Turb C Density (lbm/ft3):               | 70.21 0.04      |
| Overall Superheat (F):     | 12.89  | 1.268 | Turb C Mass Flow (lb/h):                | 124.02 1.20     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 93.18 5.88      |
| Evap Circuit Temp 1 (F):   | 49.72  | 0.558 | % Total Mass Flow Thru A:               | 35.44 0.69      |
| Evap Circuit Temp 2 (F):   | 50.01  | 0.557 | % Total Mass Flow Thru B:               | 27.70 1.36      |
| Evap Circuit Temp 3 (F):   | 49.93  | 0.510 | % Total Mass Flow Thru C:               | 36.86 0.72      |
| Evap Circuit Temp 4 (F):   | 48.76  | 0.605 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.53  | 0.512 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.85  | 0.558 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.29  | 0.556 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.82  | 0.558 |   |                 |
| Evap Circuit Temp 9 (F):   | 51.12  | 1.392 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020611A.dat SUMMARY FILENAME: E020611A.sum

|   | Range       | Total Air-Side Capacity:    | 23033.79 | Range  |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.924 0.22 | Sensible Cap (Btu/h):       | 16747.09 | 210.65 |
| Indoor Inlet Dew (F):                         | 60.397 0.11 | Latent Cap (Btu/h):         | 6286.70  | 141.28 |
| Indoor Exit Dry-Bulb:                         | 60.364 0.24 | EvapAir Delta T (F):        | 20.05    | 0.22   |
| Indoor Exit Dew (F):                          | 55.898 0.15 | Air/Ref Cap Prcnt Diff:     | 1.14     | 2.25   |
|   |             | Sensible Heat Ratio:        | 0.727    | 0.0059 |
| Indoor Airflow (CFM):                         | 768.41 7.65 | SCFM per Ton:               | 395.17   |        |
| Indoor Airflow (SCFM):                        | 758.53 7.57 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011467    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009729    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.63    | 0.37   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.772       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.406       | 0.006                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                     |
|----------------------------|--------|-------|---|---------------------|
| Expansion Valve            |        |       |   |                     |
| Upstream Pressure (psia):  | 289.57 | 1.827 | Ref-side Cap (Btu/h) :                  | 23295.57 494.28     |
| Upstream Temp A (F):       | 104.07 | 0.699 | Ref-side Cap (tons):                    | 1.94 0.04           |
| Upstream Temp B (F):       | 104.49 | 0.525 | Refrigerant Mdot (lbm/h):               | 342.69 7.23         |
| Upstream Temp C (F):       | 104.19 | 0.262 | Coriolis Density (lbm/ft3):             | 82.15 0.30          |
| Upstream Average Temp (F): | 104.25 |       | Upstream R22 Tsat (F):                  | 124.07              |
| Upstream Subcooling A (F): | 20.00  | 0.825 |   |                     |
| Upstream Subcooling B (F): | 19.58  | 0.725 |   |                     |
| Upstream Subcooling C (F): | 19.89  | 0.555 |   |                     |
| Average Subcooling (F):    | 19.82  |       |   |                     |
| Evap Exit Pressure (psia): | 90.45  | 0.486 | Turbine A Frequency (Hz):               | %4574.87 %65315.00  |
| Evap Exit Avg Temp A:      | 46.14  | 0.372 | Turb A Vol Flow (ft3/min):              | 0.6098 8.68         |
| Evap Exit Avg Temp B:      | 59.66  | 1.532 | Turb A Density (lbm/ft3):               | 70.45 0.11          |
| Evap Exit Avg Temp C:      | 67.10  | 1.200 | Turb A Mass Flow (lb/h):                | %2578.31 %36720.25  |
| Circuit A Superheat (F):   | 0.62   | 0.326 | Turbine C Frequency (Hz):               | 180.33 %195.00      |
| Circuit B Superheat (F):   | 14.15  | 1.532 | Turb C Vol Flow (ft3/min):              | 0.0263 0.03         |
| Circuit C Superheat (F):   | 21.58  | 1.357 | Turb C Density (lbm/ft3):               | 70.43 0.04          |
| Overall Superheat (F):     | 1.37   | 0.437 | Turb C Mass Flow (lb/h):                | 111.12 %109.96      |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | %-2346.75 %36617.35 |
| Evap Circuit Temp 1 (F):   | 49.67  | 0.324 | % Total Mass Flow Thru A:               | 757.96 %10799.68    |
| Evap Circuit Temp 2 (F):   | 50.15  | 0.651 | % Total Mass Flow Thru B:               | %-690.37 %10768.28  |
| Evap Circuit Temp 3 (F):   | 49.75  | 0.325 | % Total Mass Flow Thru C:               | 32.41 32.15         |
| Evap Circuit Temp 4 (F):   | 48.66  | 0.093 |   |                     |
| Evap Circuit Temp 5 (F):   | 48.38  | 0.605 |   |                     |
| Evap Circuit Temp 6 (F):   | 48.65  | 0.649 |   |                     |
| Evap Circuit Temp 7 (F):   | 52.21  | 0.278 |   |                     |
| Evap Circuit Temp 8 (F):   | 49.02  | 0.465 |   |                     |
| Evap Circuit Temp 9 (F):   | 49.24  | 0.558 |   |                     |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020612A.dat SUMMARY FILENAME: E020612A.sum

|   | Range       | Total Air-Side Capacity:    | 23591.22                                | 284.07          |
|---|-------------|-----------------------------|---|-----------------|
| Air-Side Conditions                           |             |                             |   |                 |
| Indoor Dry-Bulb :                             | 79.802 0.40 | Sensible Cap (Btu/h):       | 16924.82                                | 234.35          |
| Indoor Inlet Dew (F):                         | 60.323 0.21 | Latent Cap (Btu/h):         | 6666.40                                 | 213.13          |
| Indoor Exit Dry-Bulb:                         | 59.765 0.28 | EvapAir Delta T (F):        | 20.49                                   | 0.22            |
| Indoor Exit Dew (F):                          | 55.458 0.25 | Air/Ref Cap Prcnt Diff:     | -1.34                                   | 2.63            |
|   |             | Sensible Heat Ratio:        | 0.717                                   | 0.0078          |
| Indoor Airflow (CFM):                         | 758.94 7.46 | SCFM per Ton:               | 381.56                                  |                 |
| Indoor Airflow (SCFM):                        | 750.11 7.31 | (0.075 lb/ft3 standard air) |   |                 |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011436    |                             |   |                 |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009573    |                             |   |                 |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 60.70                                   | 0.37            |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.754       | 0.015                       |   |                 |
| Evaporator Coil Air Pressure Drop (in Water): | 0.407       | 0.009                       |   |                 |
| -----   |             |                             |   |                 |
| Refrigerant Side Conditions                   |             |                             |   |                 |
| Expansion Valve                               |             |                             |   |                 |
| Upstream Pressure (psia):                     | 310.59      | 0.244                       | Ref-side Cap (Btu/h) :                  | 23275.77 462.97 |
| Upstream Temp A (F):                          | 103.56      | 0.612                       | Ref-side Cap (tons):                    | 1.94 0.04       |
| Upstream Temp B (F):                          | 104.04      | 0.175                       | Refrigerant Mdot (lbm/h):               | 337.47 6.41     |
| Upstream Temp C (F):                          | 103.73      | 0.568                       | Coriolis Density (lbm/ft3):             | 81.98 0.14      |
| Upstream Average Temp (F):                    | 103.78      |                             | Upstream R22 Tsat (F):                  | 129.68          |
| Upstream Subcooling A (F):                    | 26.13       | 0.675                       |   |                 |
| Upstream Subcooling B (F):                    | 25.64       | 0.238                       |   |                 |
| Upstream Subcooling C (F):                    | 25.95       | 0.631                       |   |                 |
| Average Subcooling (F):                       | 25.91       |                             |   |                 |
| Evap Exit Pressure (psia):                    | 90.71       | 0.365                       | Turbine A Frequency (Hz):               | 196.14 1.00     |
| Evap Exit Avg Temp A:                         | 55.49       | 2.574                       | Turb A Vol Flow (ft3/min):              | 0.0276 0.00     |
| Evap Exit Avg Temp B:                         | 54.96       | 2.852                       | Turb A Density (lbm/ft3):               | 70.52 0.09      |
| Evap Exit Avg Temp C:                         | 53.96       | 1.681                       | Turb A Mass Flow (lb/h):                | 116.73 0.65     |
| Circuit A Superheat (F):                      | 9.79        | 2.574                       | Turbine C Frequency (Hz):               | 207.21 2.00     |
| Circuit B Superheat (F):                      | 9.27        | 2.696                       | Turb C Vol Flow (ft3/min):              | 0.0299 0.00     |
| Circuit C Superheat (F):                      | 8.26        | 1.681                       | Turb C Density (lbm/ft3):               | 70.50 0.09      |
| Overall Superheat (F):                        | 11.96       | 1.978                       | Turb C Mass Flow (lb/h):                | 126.40 1.26     |
|   |             |                             | Circuit B Calculated Mass Flow (lbm/h): | 94.34 6.24      |
| Evap Circuit Temp 1 (F):                      | 49.35       | 0.226                       | % Total Mass Flow Thru A:               | 34.59 0.47      |
| Evap Circuit Temp 2 (F):                      | 49.98       | 0.651                       | % Total Mass Flow Thru B:               | 27.95 1.31      |
| Evap Circuit Temp 3 (F):                      | 49.52       | 0.326                       | % Total Mass Flow Thru C:               | 37.46 0.84      |
| Evap Circuit Temp 4 (F):                      | 48.52       | 0.373                       |   |                 |
| Evap Circuit Temp 5 (F):                      | 48.33       | 0.652                       |   |                 |
| Evap Circuit Temp 6 (F):                      | 48.72       | 0.370                       |   |                 |
| Evap Circuit Temp 7 (F):                      | 52.06       | 0.413                       |   |                 |
| Evap Circuit Temp 8 (F):                      | 48.51       | 0.186                       |   |                 |
| Evap Circuit Temp 9 (F):                      | 50.51       | 2.041                       |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020613A.dat SUMMARY FILENAME: E020613A.sum

|   | Range       | Total Air-Side Capacity:    | 22705.13 | 318.70 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 80.129 0.43 | Sensible Cap (Btu/h):       | 16720.22 | 567.51 |
| Indoor Inlet Dew (F):                         | 60.324 0.25 | Latent Cap (Btu/h):         | 5984.91  | 300.83 |
| Indoor Exit Dry-Bulb:                         | 60.575 0.17 | EvapAir Delta T (F):        | 20.03    | 0.65   |
| Indoor Exit Dew (F):                          | 56.043 0.15 | Air/Ref Cap Prcnt Diff:     | 2.77     | 3.22   |
|   |             | Sensible Heat Ratio:        | 0.736    | 0.0156 |
| Indoor Airflow (CFM):                         | 768.35 7.35 | SCFM per Ton:               | 400.67   |        |
| Indoor Airflow (SCFM):                        | 758.10 7.27 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011436    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009781    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.82    | 0.27   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.771       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.423       | 0.005                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 283.27 | 0.852 | Ref-side Cap (Btu/h) :                  | 23333.33 419.27 |
| Upstream Temp A (F):       | 104.99 | 0.567 | Ref-side Cap (tons):                    | 1.94 0.03       |
| Upstream Temp B (F):       | 105.27 | 0.524 | Refrigerant Mdot (lbm/h):               | 344.67 6.13     |
| Upstream Temp C (F):       | 105.14 | 0.524 | Coriolis Density (lbm/ft3):             | 82.34 0.11      |
| Upstream Average Temp (F): | 105.13 |       | Upstream R22 Tsat (F):                  | 122.31          |
| Upstream Subcooling A (F): | 17.32  | 0.431 |   |                 |
| Upstream Subcooling B (F): | 17.04  | 0.451 |   |                 |
| Upstream Subcooling C (F): | 17.17  | 0.592 |   |                 |
| Average Subcooling (F):    | 17.18  |       |   |                 |
| Evap Exit Pressure (psia): | 90.90  | 0.243 | Turbine A Frequency (Hz):               | 222.71 2.00     |
| Evap Exit Avg Temp A:      | 46.23  | 0.233 | Turb A Vol Flow (ft3/min):              | 0.0311 0.00     |
| Evap Exit Avg Temp B:      | 58.64  | 1.144 | Turb A Density (lbm/ft3):               | 70.30 0.09      |
| Evap Exit Avg Temp C:      | 66.51  | 0.770 | Turb A Mass Flow (lb/h):                | 131.27 0.98     |
| Circuit A Superheat (F):   | 0.44   | 0.389 | Turbine C Frequency (Hz):               | 196.14 1.00     |
| Circuit B Superheat (F):   | 12.85  | 1.300 | Turb C Vol Flow (ft3/min):              | 0.0284 0.00     |
| Circuit C Superheat (F):   | 20.73  | 0.926 | Turb C Density (lbm/ft3):               | 70.28 0.08      |
| Overall Superheat (F):     | 1.08   | 0.482 | Turb C Mass Flow (lb/h):                | 119.79 0.56     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 93.61 6.36      |
| Evap Circuit Temp 1 (F):   | 50.10  | 0.557 | % Total Mass Flow Thru A:               | 38.09 0.74      |
| Evap Circuit Temp 2 (F):   | 50.11  | 0.557 | % Total Mass Flow Thru B:               | 27.16 1.42      |
| Evap Circuit Temp 3 (F):   | 50.10  | 0.604 | % Total Mass Flow Thru C:               | 34.76 0.72      |
| Evap Circuit Temp 4 (F):   | 49.31  | 0.558 |   |                 |
| Evap Circuit Temp 5 (F):   | 49.22  | 0.558 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.10  | 0.648 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.38  | 0.645 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.28  | 0.371 |   |                 |
| Evap Circuit Temp 9 (F):   | 49.08  | 0.093 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020620A.dat SUMMARY FILENAME: E020620A.sum

|   | Range        | Total Air-Side Capacity:    | 23465.24 | 560.85 |
|---|--------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |              |                             |          |        |
| Indoor Dry-Bulb :                             | 79.961 0.31  | Sensible Cap (Btu/h):       | 17050.87 | 438.61 |
| Indoor Inlet Dew (F):                         | 60.128 0.30  | Latent Cap (Btu/h):         | 6414.37  | 488.23 |
| Indoor Exit Dry-Bulb:                         | 60.004 0.18  | EvapAir Delta T (F):        | 20.42    | 0.43   |
| Indoor Exit Dew (F):                          | 55.487 0.15  | Air/Ref Cap Prcnt Diff:     | -1.13    | 3.58   |
|   |              | Sensible Heat Ratio:        | 0.727    | 0.0151 |
| Indoor Airflow (CFM):                         | 767.80 11.63 | SCFM per Ton:               | 387.89   |        |
| Indoor Airflow (SCFM):                        | 758.49 11.56 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011356     |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009583     |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24        | Nozzle Temp (F):            | 60.93    | 0.09   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.771        | 0.023                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.415        | 0.015                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 318.93 | 0.974 | Ref-side Cap (Btu/h) :                  | 23199.58 478.64 |
| Upstream Temp A (F):       | 103.95 | 0.350 | Ref-side Cap (tons):                    | 1.93 0.04       |
| Upstream Temp B (F):       | 104.32 | 0.088 | Refrigerant Mdot (lbm/h):               | 336.95 6.96     |
| Upstream Temp C (F):       | 104.05 | 0.568 | Coriolis Density (lbm/ft3):             | 82.07 0.19      |
| Upstream Average Temp (F): | 104.11 |       | Upstream R22 Tsat (F):                  | 131.81          |
| Upstream Subcooling A (F): | 27.85  | 0.423 |   |                 |
| Upstream Subcooling B (F): | 27.48  | 0.205 |   |                 |
| Upstream Subcooling C (F): | 27.75  | 0.680 |   |                 |
| Average Subcooling (F):    | 27.70  |       |   |                 |
| Evap Exit Pressure (psia): | 90.53  | 0.486 | Turbine A Frequency (Hz):               | 191.06 2.00     |
| Evap Exit Avg Temp A:      | 53.89  | 5.563 | Turb A Vol Flow (ft3/min):              | 0.0269 0.00     |
| Evap Exit Avg Temp B:      | 54.92  | 2.849 | Turb A Density (lbm/ft3):               | 70.46 0.05      |
| Evap Exit Avg Temp C:      | 56.77  | 2.821 | Turb A Mass Flow (lb/h):                | 113.77 1.17     |
| Circuit A Superheat (F):   | 8.38   | 5.877 | Turbine C Frequency (Hz):               | 209.06 2.00     |
| Circuit B Superheat (F):   | 9.41   | 3.139 | Turb C Vol Flow (ft3/min):              | 0.0301 0.00     |
| Circuit C Superheat (F):   | 11.26  | 3.056 | Turb C Density (lbm/ft3):               | 70.45 0.09      |
| Overall Superheat (F):     | 11.90  | 2.422 | Turb C Mass Flow (lb/h):                | 127.35 1.18     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 95.82 6.94      |
| Evap Circuit Temp 1 (F):   | 49.60  | 0.279 | % Total Mass Flow Thru A:               | 33.77 0.79      |
| Evap Circuit Temp 2 (F):   | 49.56  | 0.372 | % Total Mass Flow Thru B:               | 28.44 1.53      |
| Evap Circuit Temp 3 (F):   | 49.29  | 0.094 | % Total Mass Flow Thru C:               | 37.80 0.80      |
| Evap Circuit Temp 4 (F):   | 48.31  | 0.094 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.22  | 0.559 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.82  | 0.558 |   |                 |
| Evap Circuit Temp 7 (F):   | 51.56  | 0.646 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.77  | 0.652 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.13  | 3.803 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020621A.dat SUMMARY FILENAME: E020621A.sum

|   | Range       | Total Air-Side Capacity:    | 22434.90 | 441.26 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.970 0.46 | Sensible Cap (Btu/h):       | 16483.48 | 284.76 |
| Indoor Inlet Dew (F):                         | 60.420 0.21 | Latent Cap (Btu/h):         | 5951.42  | 389.14 |
| Indoor Exit Dry-Bulb:                         | 60.854 0.16 | EvapAir Delta T (F):        | 19.60    | 0.22   |
| Indoor Exit Dew (F):                          | 56.212 0.15 | Air/Ref Cap Prcnt Diff:     | 2.90     | 3.38   |
|   |             | Sensible Heat Ratio:        | 0.735    | 0.0146 |
| Indoor Airflow (CFM):                         | 774.23 7.31 | SCFM per Ton:               | 408.39   |        |
| Indoor Airflow (SCFM):                        | 763.52 7.18 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011476    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009842    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.72    | 0.55   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.783       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.397       | 0.013                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 302.15 | 1.218 | Ref-side Cap (Btu/h) :                  | 23083.84 624.28 |
| Upstream Temp A (F):       | 103.97 | 0.568 | Ref-side Cap (tons):                    | 1.92 0.05       |
| Upstream Temp B (F):       | 104.39 | 0.262 | Refrigerant Mdot (lbm/h):               | 339.33 9.43     |
| Upstream Temp C (F):       | 103.86 | 0.568 | Coriolis Density (lbm/ft3):             | 82.02 0.19      |
| Upstream Average Temp (F): | 104.07 |       | Upstream R22 Tsat (F):                  | 127.44          |
| Upstream Subcooling A (F): | 23.48  | 0.697 |   |                 |
| Upstream Subcooling B (F): | 23.06  | 0.367 |   |                 |
| Upstream Subcooling C (F): | 23.59  | 0.633 |   |                 |
| Average Subcooling (F):    | 23.38  |       |   |                 |
| Evap Exit Pressure (psia): | 91.18  | 0.608 | Turbine A Frequency (Hz):               | 217.86 2.00     |
| Evap Exit Avg Temp A:      | 46.39  | 0.558 | Turb A Vol Flow (ft3/min):              | 0.0305 0.00     |
| Evap Exit Avg Temp B:      | 60.66  | 1.233 | Turb A Density (lbm/ft3):               | 70.46 0.09      |
| Evap Exit Avg Temp C:      | 68.09  | 0.972 | Turb A Mass Flow (lb/h):                | 128.83 1.14     |
| Circuit A Superheat (F):   | 0.44   | 0.636 | Turbine C Frequency (Hz):               | 191.09 2.00     |
| Circuit B Superheat (F):   | 14.71  | 1.274 | Turb C Vol Flow (ft3/min):              | 0.0277 0.00     |
| Circuit C Superheat (F):   | 22.15  | 1.148 | Turb C Density (lbm/ft3):               | 70.48 0.09      |
| Overall Superheat (F):     | 0.80   | 0.715 | Turb C Mass Flow (lb/h):                | 117.27 1.21     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 93.22 9.55      |
| Evap Circuit Temp 1 (F):   | 50.41  | 1.114 | % Total Mass Flow Thru A:               | 37.97 1.11      |
| Evap Circuit Temp 2 (F):   | 50.86  | 0.603 | % Total Mass Flow Thru B:               | 27.47 2.14      |
| Evap Circuit Temp 3 (F):   | 50.21  | 0.557 | % Total Mass Flow Thru C:               | 34.56 1.03      |
| Evap Circuit Temp 4 (F):   | 49.20  | 0.651 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.95  | 0.279 |   |                 |
| Evap Circuit Temp 6 (F):   | 49.26  | 0.603 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.93  | 1.200 |   |                 |
| Evap Circuit Temp 8 (F):   | 49.69  | 0.837 |   |                 |
| Evap Circuit Temp 9 (F):   | 48.89  | 0.604 |   |                 |

SMART DISTRIBUTOR SUMMARY SHEET

DATA FILENAME: E020624A.dat SUMMARY FILENAME: E020624A.sum

|   | Range       | Total Air-Side Capacity:    | 23455.84 | 506.67 |
|---|-------------|-----------------------------|----------|--------|
| Air-Side Conditions                           |             |                             |          |        |
| Indoor Dry-Bulb :                             | 79.945 0.23 | Sensible Cap (Btu/h):       | 16834.92 | 440.93 |
| Indoor Inlet Dew (F):                         | 60.379 0.31 | Latent Cap (Btu/h):         | 6620.92  | 194.35 |
| Indoor Exit Dry-Bulb:                         | 60.216 0.23 | EvapAir Delta T (F):        | 20.14    | 0.43   |
| Indoor Exit Dew (F):                          | 55.624 0.25 | Air/Ref Cap Prcnt Diff:     | -1.51    | 5.46   |
|   |             | Sensible Heat Ratio:        | 0.718    | 0.0080 |
| Indoor Airflow (CFM):                         | 768.99 7.34 | SCFM per Ton:               | 388.48   |        |
| Indoor Airflow (SCFM):                        | 759.35 7.23 | (0.075 lb/ft3 standard air) |          |        |
| Evap Inlet Humidity Ratio (lbH2O/lbAir):      | 0.011459    |                             |          |        |
| Evap Exit Humidity Ratio (lbH2O/lbAir):       | 0.009631    |                             |          |        |
| Barometric Pressure (in HG):                  | 29.24       | Nozzle Temp (F):            | 61.07    | 0.60   |
| Air Chamber Nozzle Pressure Drop (in Water):  | 0.773       | 0.015                       |          |        |
| Evaporator Coil Air Pressure Drop (in Water): | 0.409       | 0.010                       |          |        |

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Refrigerant Side Conditions

|                            |        |       |   |                 |
|----------------------------|--------|-------|---|-----------------|
| Expansion Valve            |        |       |   |                 |
| Upstream Pressure (psia):  | 315.48 | 0.487 | Ref-side Cap (Btu/h) :                  | 23100.69 853.85 |
| Upstream Temp A (F):       | 105.60 | 0.523 | Ref-side Cap (tons):                    | 1.93 0.07       |
| Upstream Temp B (F):       | 106.33 | 0.262 | Refrigerant Mdot (lbm/h):               | 338.35 12.54    |
| Upstream Temp C (F):       | 105.90 | 0.524 | Coriolis Density (lbm/ft3):             | 82.65 0.16      |
| Upstream Average Temp (F): | 105.94 |       | Upstream R22 Tsat (F):                  | 130.91          |
| Upstream Subcooling A (F): | 25.31  | 0.618 |   |                 |
| Upstream Subcooling B (F): | 24.58  | 0.419 |   |                 |
| Upstream Subcooling C (F): | 25.02  | 0.461 |   |                 |
| Average Subcooling (F):    | 24.97  |       |   |                 |
| Evap Exit Pressure (psia): | 90.66  | 0.486 | Turbine A Frequency (Hz):               | 187.88 1.00     |
| Evap Exit Avg Temp A:      | 55.73  | 2.848 | Turb A Vol Flow (ft3/min):              | 0.0265 0.00     |
| Evap Exit Avg Temp B:      | 55.12  | 2.851 | Turb A Density (lbm/ft3):               | 70.21 0.08      |
| Evap Exit Avg Temp C:      | 54.49  | 2.901 | Turb A Mass Flow (lb/h):                | 111.58 0.62     |
| Circuit A Superheat (F):   | 10.19  | 3.004 | Turbine C Frequency (Hz):               | 215.88 2.00     |
| Circuit B Superheat (F):   | 9.57   | 3.008 | Turb C Vol Flow (ft3/min):              | 0.0310 0.00     |
| Circuit C Superheat (F):   | 8.95   | 3.058 | Turb C Density (lbm/ft3):               | 70.16 0.08      |
| Overall Superheat (F):     | 11.89  | 2.136 | Turb C Mass Flow (lb/h):                | 130.67 1.27     |
|                            |        |       | Circuit B Calculated Mass Flow (lbm/h): | 96.10 12.24     |
| Evap Circuit Temp 1 (F):   | 49.53  | 0.603 | % Total Mass Flow Thru A:               | 32.98 1.23      |
| Evap Circuit Temp 2 (F):   | 50.03  | 0.325 | % Total Mass Flow Thru B:               | 28.40 2.62      |
| Evap Circuit Temp 3 (F):   | 49.50  | 0.604 | % Total Mass Flow Thru C:               | 38.62 1.41      |
| Evap Circuit Temp 4 (F):   | 48.36  | 0.093 |   |                 |
| Evap Circuit Temp 5 (F):   | 48.28  | 0.652 |   |                 |
| Evap Circuit Temp 6 (F):   | 48.65  | 0.558 |   |                 |
| Evap Circuit Temp 7 (F):   | 52.31  | 0.645 |   |                 |
| Evap Circuit Temp 8 (F):   | 48.69  | 0.372 |   |                 |
| Evap Circuit Temp 9 (F):   | 50.68  | 2.876 |   |                 |

## APPENDIX B. CAPACITY UNCERTAINTY

Table B.1 lists the relative uncertainty in the air-side capacity for two representative tests at low and high evaporator capacity. Two tests are shown below, with the first test being a typical test at a capacity comparable to a majority of the other tests for all coils. The second test listed in Table B.1 shows a worst case test for COIL-W in parallel flow with an extremely low capacity. For the majority of tests, the uncertainty in the evaporator capacity was at the 4 % to 5 % level. A complete description of the propagation of error technique used to calculate uncertainty is given in Payne and Domanski (2001).

Table B.1: Relative Uncertainties of Two Evaporator Tests

| Test Name | Coil Designation | Capacity, kW (Btu/h) | Uncertainty Description     | Capacity, kW (Btu/h) | Percent Uncertainty at a 95 % Confidence Limit on the Mean |
|-----------|------------------|----------------------|-----------------------------|----------------------|--|
| E020416B  | Enhanced-Cut     | 7.8 (26546)          | <i>Typical of all tests</i> | 7.8 (26546)          | 4.2  |
| W020311B  | Wavy             | 0.90 (3078)          | <i>Worst case</i>           | 0.90 (3078)          | 8.9  |

## **APPENDIX C. USER'S INSTRUCTION FOR THE EVAP-COND VERSION USED IN THIS STUDY**

A CD attached to this report contains a version of EVAP-COND that was specifically developed for this study. The following pages describe how to install and use the model. As needed for this study, this version of EVAP-COND simulates only evaporators with multiple inlets using the option that solicits refrigerant outlet saturation temperatures and global superheat. This option is identified in the figure below with the EVAPORATOR OPERATING CONDITIONS. The condenser, which normally is included in the EVAP-COND package is not provided here.

The attached CD package contains the following two files:

EV-CD.exe           - self-extracting file with all files needed for  
                          executing EVAP-COND.

EVAP-COND instructions.pdf       - file with visual instructions on how to use EVAP-  
  COND. (You need Version 5 of Adobe Reader to  
  read this file.). The instructions are also included  
  in this appendix.

### **Installation of EVAP-COND on your PC**

Execute file EV-CD.exe to expand it on your hard drive. You will be prompted to select a directory where you want the program to reside. When the installation is completed, you should see EVAP-COND directory and two subdirectories called FLUIDS and MIXTURES.

In the main directory (EVAP-COND), EVAP-COND.exe is the interface. EVAP5.exe is the evaporator. Files with the affix.dat are example cases of input data used in this study. Files with the affix.opc extension contain corresponding operating conditions.

### **Next step**

Refer to the following pages or EVAP-COND instructions.pdf for further information about EVAP-COND capabilities and limitations. They will also assist you in your first evaporator simulation run. It is recommended for the user to follow the steps described there to familiarize yourself with the model. Because of constant upgrading of the model, the simulation results you are going to obtain may not be the same as those presented in EVAP-COND instructions.pdf.

### ***Control of the option to simulate with or without longitudinal fin conduction***

The user can control the option of using longitudinal fin conduction in a simulation by accessing file TUNE.TXT selecting 0 or 1 for the flag, as it is explained in the file, and saving the file. TUNE.TXT is located in the EVAP-COND directory.

The following pages contain general visual instructions for using EVAP-COND as they are presented in the file EVAP-COND instructions.pdf located on the attached CD. The option developed for this project is marked and available in this package is marked.

# EVAP- COND INSTRUCTIONS

**EVAP-COND** is a software package that contains NIST's simulation models for a finned-tube evaporator (**EVAP5**) and condenser (**COND5**). The following pages provide basic instructions on how to use this package. The instructions include preparation of input data, execution of the program, and examination of simulation results.

**Capabilities include:**

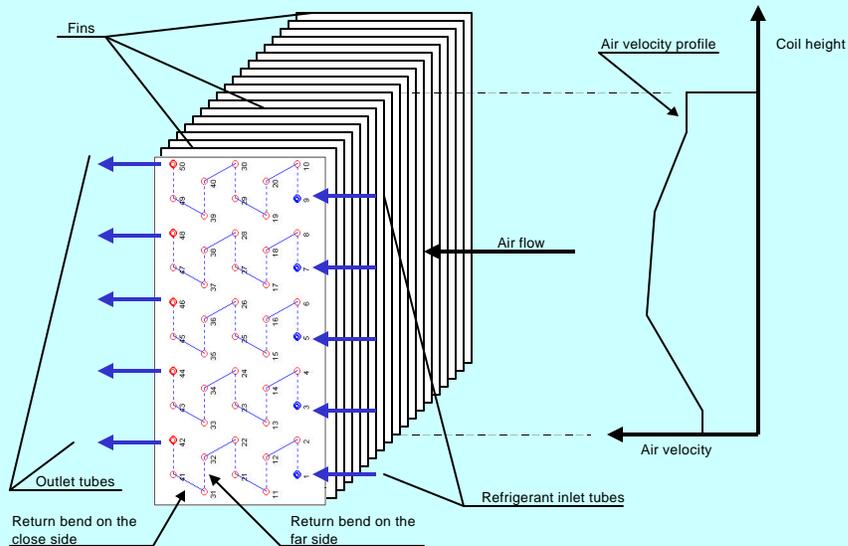
- tube-by-tube simulation
- non-uniform air distribution
- simulation of refrigerant distribution
- condenser model capable of simulations above the critical point
- 10 refrigerants and refrigerant mixtures
- REFPROP6 refrigerant properties



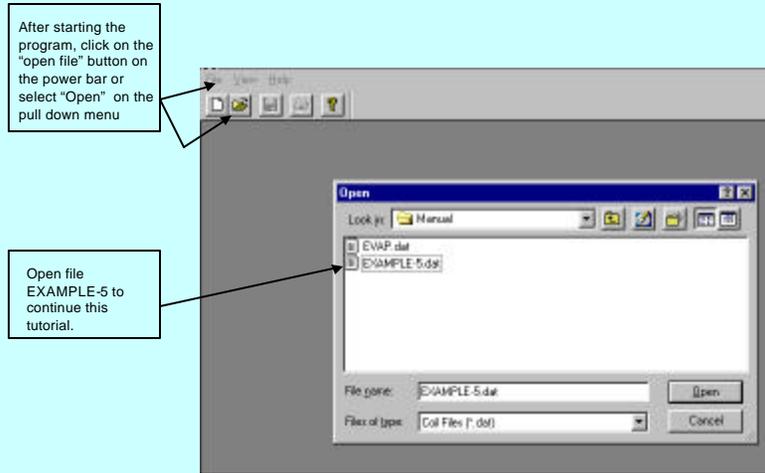
Piotr A. Domanski  
National Institute of Standards and Technology  
Building and Fire Research Laboratory  
Gaithersburg, MD, USA

Smart Distributor Version, Aug. 5, 2002

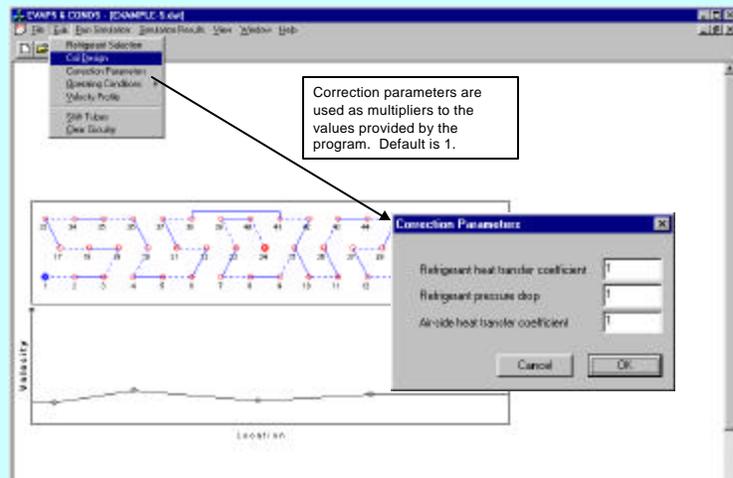
# EVAPORATOR REPRESENTATION



## LOADING A FILE



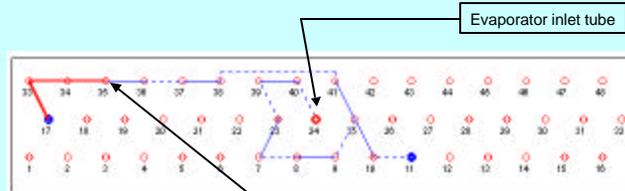
## PREPARING A SIMULATION RUN



# REFRIGERANT CIRCUIT DESIGN

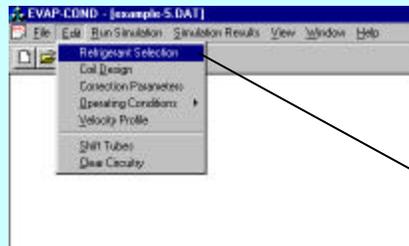
Follow the steps below to design a circuitry:

1. place the pointer on the tube
2. press the left mouse button
3. drag the pointer to the next tube
4. release the left button.



**Option:**  
You may remove a part of the circuit by positioning the pointer on a given tube and clicking twice with the left button.

# REFRIGERANT SELECTION



EXAMPLE-5 was set up to use refrigerant inlet pressure and quality as input data (see Operating Conditions). Since the specified inlet pressure is for R22, use the pull-down menu to select R22.



## COIL DESIGN DATA

**Coil Design Data**

Data for a section

No. of tubes in depth row #1: 16  
 No. of tubes in depth row #2: 16  
 No. of tubes in depth row #3: 16  
 No. of tubes in depth row #4: 0  
 No. of tubes in depth row #5: 0

Tube data

Tube length: 454.005 mm  
 Inner diameter: 3.2202 mm  
 Outer diameter: 10.0076 mm  
 Tube pitch: 25.4 mm  
 Depth row pitch: 32.225 mm  
 Inner surface: Smooth  
 Thermal conductivity: 0.386013 kW/m.K

Fin data

Thickness: 0.2032 mm  
 Pitch: 2.00406 mm  
 Type: Wavy  
 Thermal conductivity: 0.221568 kW/m.K

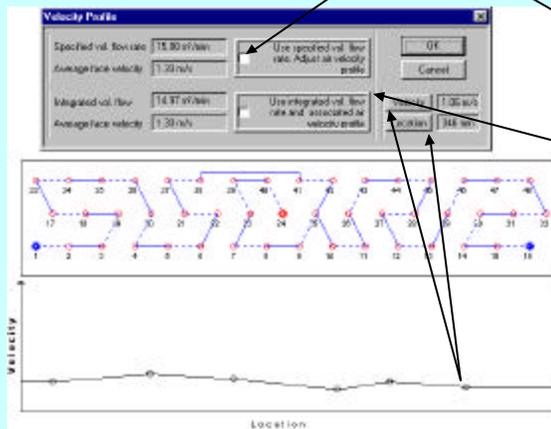
Number of repeating sections: 1

Units:  SI Units  British Units

Cancel OK

Value 1 must be used for this version of EVAP-COND.

## AIR VELOCITY PROFILE



Recall that the operating conditions input data included the volumetric flow rate of air. Before you leave this window you must decide between the two options:

- to use the previously specified vol. flow rate and have the velocity profile scaled to match that value (recommended)

or

- to disregard the previously specified vol. flow rate and calculate a new volumetric flow rate from the velocity profile

To specify velocity at a given point, place the pointer at that point and click with the left button. The window above shows the coordinates. Up to sixteen velocity points may be specified.

Click on a given point to remove it.

The Velocity Profile window must be open to make air velocity profile changes.

# EVAPORATOR OPERATING CONDITIONS

(Eight options)

This option was used for simulation runs for this project

The mark indicates the currently selected option.

All input options include air inlet temperature, pressure, relative humidity, and volumetric flow rate.

Input includes estimated refrigerant mass flow rate, which is later iterated by EVAP5. Inlet quality is imposed at 0.20.

Input includes refrigerant mass flow rate.

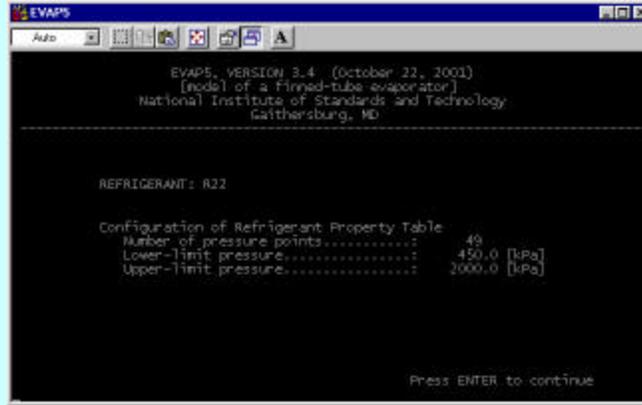
This option includes a refrigerant distributor. Condenser subcooling and evaporator superheat are imposed to be 5 °C (9 ° F).

Input includes estimated refrigerant mass flow rate, which is later iterated so the least superheated tube has the specified minimum superheat. Inlet quality is imposed at 0.20.

# EXECUTION OF EVAP5

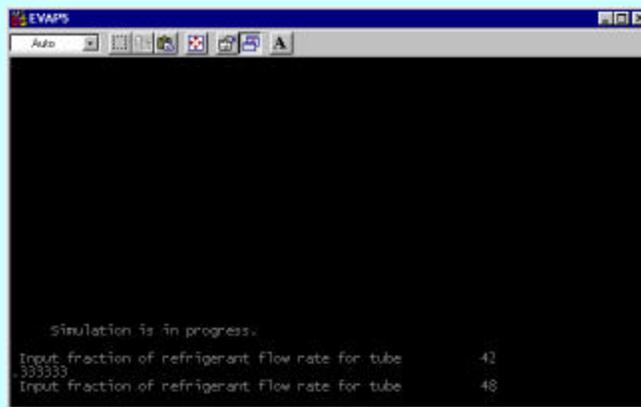
Use the pull-down menu to execute EVAP5.

## EVAP5 OPENING WINDOW

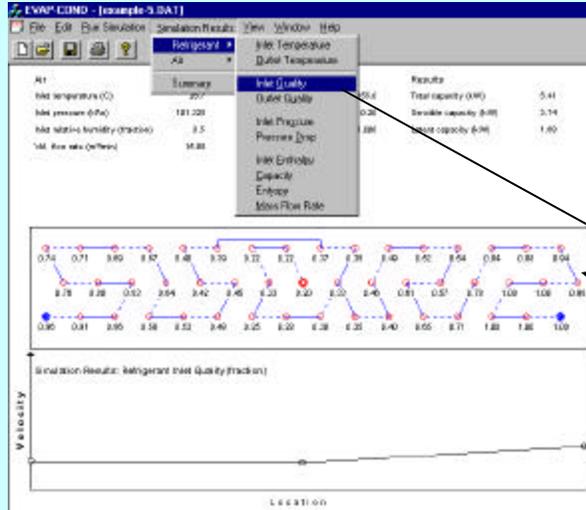


## EVAP5 SOLICITS REFRIGERANT DISTRIBUTION

This window appears only in this version of EVAP- COND for the simulation option used for this study



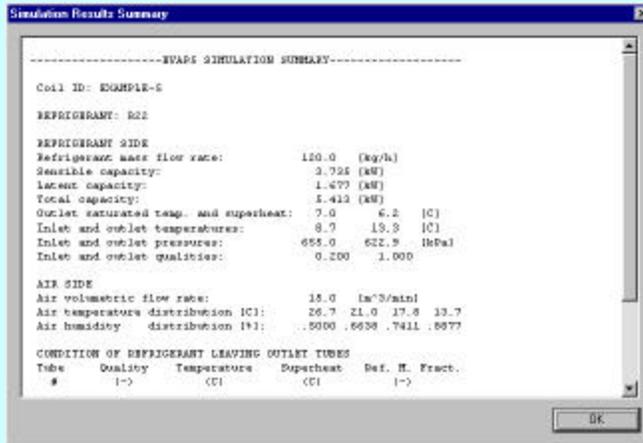
# SIMULATION RESULTS



Global simulation results are summarized in the background, under the pull-down menu **Summary**, and in files si.res and bt.res located in the EVAP-COND directory.

Detailed refrigerant and air parameters can be displayed on the screen for individual tubes.

# SIMULATION SUMMARY



The Simulation Results Summary window displays results in the units selected for the input data. Files si.res and bt.res have the same information in the SI and Inch-Pound units, respectively.

## SIMULATION SUMMARY (cont.)

(Complete printout of file si.res)

```
-----EVAP5 SIMULATION SUMMARY-----
Coil ID: EXAMPLE-6
REFRIGERANT: R22
REFRIGERANT SIDE
Refrigerant mass flow rate:      120.0 [kg/h]
Sensible capacity:              3.735 [kW]
Latent capacity:                1.677 [kW]
Total capacity:                 5.413 [kW]
Outlet saturated temp. and superheat: 7.0 8.2 [C]
Inlet and outlet temperatures:  8.7 13.3 [C]
Inlet and outlet pressures:     655.0 622.9 [kPa]
Inlet and outlet qualities:     0.200 1.000

AIR SIDE
Air volumetric flow rate:       15.0 [m³/min]
Air temperature distribution [C]: 26.7 21.0 17.8 13.7
Air humidity distribution [%]:  .5000 .6638 .7411 .8877

CONDITION OF REFRIGERANT LEAVING OUTLET TUBES
Tube #    Quality (-)    Temperature (C)    Superheat (C)    Ref. M. Fract. (-)
-----
1         0.989             7.6               0.0              0.522
16        1.000            23.0              16.0              0.478

Multiplier for refrig. heat transfer coeff.: 1.00
Multiplier for refrigerant pressure drop.: 1.00
Multiplier for air-side heat trans. coeff.: 1.00
```

## HOW TO SIMULATE EVAPORATOR ?

(An example using the existing file EXAMPLE-5.dat)

Run Windows Explorer and go to the directory containing EVAP-COND.exe.  
Double-click on EVAP-COND.exe to start the program.

Open file EXAMPLE-5.dat to simulate the evaporator. After the file is loaded, you will see a schematic representing a side view of the evaporator. The red circle(s) indicates the inlet tube to the evaporator. The blue circles indicate the outlet tubes. The horizontal line at the bottom of the screen indicates the air velocity profile at the evaporator inlet.

Review Input Data. Click on the **Edit/Coil Design** menu item to review the evaporator design information. You may select either the SI or British system of units for your input data and simulation results.

Click on the **Edit/Operating Conditions/Evaporator/inlet pressure and quality** menu item to review operation conditions. Note, that the loaded option has a mark on the left-hand side. Since EVAP5 simulates performance tube-by-tube from the inlet to outlet, the options that specify any outlet refrigerant parameter involve iterative calls to the option that specifies refrigerant inlet pressure and quality until the target outlet parameters are obtained (e.g., saturation temperature and superheat).

Click on the **Edit/Velocity Profile** menu item to review the air velocity profile. You may use the air mass flow rate specified earlier in the **Operating Conditions** window or integrate the air velocity profile. In general, the first option is recommended unless very detailed and accurate local measurements of the velocity profile were taken. You may change the air velocity profile using a mouse by clicking the left button.

Run a simulation. Click on the **Run Simulation** menu item and select EVAP5. An MS-DOS window will appear and will give you a message when a simulation run is successfully completed.

Examine local and global simulation results. EVAP5 writes global simulation results to file SI.res (SI system of units) and BT.res (British system of units). The same information is provided in the pull-down menu in the units selected for data input.

## HOW TO PREPARE YOUR DATA FILE ?

Start with **Edit/Coil Design** menu item. Input all information.

Select **Edit/Operating Conditions** menu item to input operating conditions data.

Select **Edit/Velocity Profile** to change the velocity profile using a mouse (left button).

Specify refrigerant circuitry.

If you are coding evaporator circuitry, start with one of the inlet tubes and proceed downstream. If you are coding condenser circuitry, start with one of the outlet tubes and proceed upstream, i.e., in either case you have to start from the side that is closer to the saturated liquid line.

To draw a return bend, point the mouse on a tube, press the left button, drag the mouse to the next tube, and release.

If you want to modify a circuitry, you may delete a part of it starting from a given tube end ending by the exit tube by pointing the mouse on the given tube and double-clicking the left button.

Once a circuit is coded, it can be used for both evaporator and condenser simulations based on specified operating conditions.

**COMMENTS**

**SUGGESTIONS**

**QUESTIONS**

**?**

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