Process Heat Pump Factory Acceptance Test Results

September 28, 2010

Submitted by

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Executive Summary

Factory acceptance tests were performed on one heat pump unit being manufactured for DFO's new wet lab at the St Andrews Biological Station in St. Andrews, New Brunswick.

A heating and cooling capacity test, an on/off cycling test, and a cold water heat sourcing test were completed on September 20th, 2010.

An average evaporator/condenser coefficient of performance (COP) of 3.6/4.2 was observed during the heating and cooling capacity test. COP is a refrigeration term for efficiency rating that compares heat transferred in the evaporator and/or condenser with electrical energy drawn by the compressor. COP during operation at design conditions at St Andrews wet lab is expected to be greater than observed during testing reaching 4.3/5.0 on average.

It was found that the heat pump unit evaporator with RS-45 refrigerant will perform within less than 5% of the compressor manufacturer's performance table for the compressor using R-22. Therefore the performance table can be used to predict heat pump unit performance at various operating conditions. Losses within the refrigeration system including the condenser and evaporator are as low as 2-3%.

12 motor starts were recorded in a 30 minute period with no adverse effects observed on the heat pump unit. A minimum on-cycle time of 40 seconds is recommended. A minimum off-cycle time of 5 seconds is recommended.

The heat pump unit is capable of efficiently heating water above the design target temperature of 16°C by sourcing heat from cold water. During the test, the heat source water was as cold as 2°C. The average evaporator/condenser COP was 3.4/4.1 during the cold water heat sourcing test.

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Introduction

One of twelve heat pump units being manufactured for the Department of Fisheries and Oceans (DFO) new wet lab project in St. Andrews, New Brunswick, was put through the performance test outlined in **Error! Reference source not found.**Appendix I. Four tests were conducted to determine:

1. Test 1: Heating capacity of heat pump unit
2. Test 2: Cooling capacity of heat pump unit
3. Test 3: Minimum cycling time and maximum allowable start-up frequency of the heat pump unit
4. Test 4: Heating capacity of heat pump unit when sourcing heat from water near 0°C

The testing occurred on September 20, 2010 at Bakers Point Fisheries in East Jeddore, Nova Scotia. All tests were completed although with some minor deviations from the test outline in Appendix I. Despite these deviations, meaningful data was collected to meet all test objectives.

The test was administered by Philip Nickerson, PEng and Jerome Wilson of Wilson Titanium Products Limited. Edgar Nicholson, CET of Scotia Air Balance 1996 Ltd took flow and water measurements that were recorded by Philip Nickerson. All voltage, current, refrigerant pressures, and other measurements and observations presented herein were taken, recorded, and analyzed by Philip Nickerson.

The data collected was used to calculate Coefficient of Performance (COP) of the heat pump unit when heating and cooling near design temperatures and when sourcing heat from water near 0°C.

Heat Pump Factory Acceptance Test Outline

The original test proposal is included in Appendix I. Some of the test proposal details were changed for practical reasons and are listed here along with other pertinent notes to consider when weighing the results.

The refrigerant used was RS-45 (R-434a) manufactured and supplied by Refrigerant Services Inc of Dartmouth, NS. This refrigerant is designed to be a replacement for R-22 in OEM equipment such as the heat pump units. Refrigerant Services Inc claims that the performance of RS-45 will be within 2-3% of the performance of R-22 across the operating range. Due to a temperature glide of 1.5°C, some performance loss may be seen in the evaporator side of the heat pump. However, performance in the condenser may be greater with RS-45 than with R-22.

The order of tests was reversed to allow the use of two water sources rather than three as initially agreed upon. This did not affect the accuracy of the data collected.

The proposed water flow and water temperature instrumentation was not used. Edgar Nicholson CET, an AABC certified water balancer with Scotia Air Balance 1996 Limited was hired to take the water flow and water temperature measurements. An ultrasonic flowmeter was used for flow measurements. A digital temperature meter with a single probe was used for temperature measurements. The probe was moved from one drywell to the next to take all four temperatures sequentially rather than simultaneously.

During the cycling test, there was only time to collect part of the data initially intended to be collected. Current, refrigerant pressures, and event timing were the most pertinent data to indicate system response to cycling and were the only data collected.

The ambient water source that flowed through the condenser during all four tests was not capable of reaching the design flow of 4.6L/s. While this does not affect the data accuracy, low water flow does lower the performance of the heat pumps.

The ambient water (which served as the condenser water) was over 16°C during the tests. The heat pump is designed to meet heat transfer specs when the condensing water is 14.2°C or lower. This factor combined with the lower flow rate than anticipated resulted in the heat pump running a condensing pressure about 20psi higher than under design conditions. The extra head pressure translates into approximately one extra amp of current at 600V and 5% less heat transfer. Both these factors negatively affect the coefficient of performance.

Accuracy of Data Collected

Edgar Nicholson CET claimed that the ultrasonic flow meter provided an accuracy of 2% of full scale and that his temperature meter also had an accuracy of 2-3% of full scale.

During testing, it was discovered that the use of dry wells with one temperature probe was not ideal. A minimum of 15 seconds was required for the probe to settle completely. This was not caught until some of initial measurements in Test 4 had been already recorded. This would affect the temperature measurements by as much as +/- 0.2°C.

The time for probes to settle and to switch from one dry well to another, or one pipe to another for flow, or one wire lead to another for current and voltage, caused each set of measurements to take approximately 4 minutes. This would not affect the accuracy of the measurements but may affect the calculated performance. This is more likely to have an effect on the initial measurements in Test 1 and Test 2 where the unit was switched from Cool mode to Heat mode immediately preceding the test. From the data collected, the heat pump unit has a transient period lasting about 15-20 minutes following the switching of Heat and Cool modes.

Results

A digitized form of the raw data can be reviewed in Appendix II. For a fax, scan, or copy of the original sheets contact Philip Nickerson at 902-746-3855 or panickerson@eastlink.ca

Tests 1, 2, 4 Results

Using the water flow, water temperature differences, heat pump currents, heat pump voltages, and power factor reverse calculated from manufacturer compressor performance tables, the heat pump COPs were calculated. The evaporator and the condenser COP were derived using the above-mentioned factors.

A power factor of 0.75 was assumed for the calculations derived from the manufacturer's performance table for the compressor using HCFC-22 refrigerant.

Parameter	Units	Test 1,2	Test 4
Average Current	Amperes	10.9	10.5
Average Voltage	Volts	599	596
Apparent Power	kVA	6.6	6.3
Real Power (PF=0.75)	kW	8.5	8.2
Evaporator TD	°C	1.6	1.5
Evaporator Heat Transfer	kW	30.4	28.1
Evaporator COP		3.6	3.4
Condensor Heat Transfer	kW	36.0	33.1
Condensor TD	°C	2.4	2.0
Condensor COP		4.2	4.1

Figure 1 Results of Tests 1,2,4

The data collected in tests 1,2,4 was used to calculate at each data point each of the Parameters in Figure 1. The results were then averaged over the duration of the test to arrive at the numbers in Figure 1. To review the calculated parameters at each data point see Appendix III.

Test 3 Results

Test 3 differed in both its objective and in the type and amount of parameters monitored. Its results were analyzed more subjectively by observing heat pump behavior. 12 motor starts were observed in a 30 minute period with cycle on times approximately 40 seconds each. Total cycle time was approximately 2.5 minutes.

By physically touching the compressor the observation was made that it was not overheating. The head of the compressor was warm to the touch but not hot. The discharge pipe leaving the head was the same temperature as the head which indicates the warmth of the head corresponded to the refrigerant temperature at that point of the system rather than heating due to inrush current. The casing near the motor windings was cool to the touch also corresponding to the refrigerant temperature at that point of the system.

The cycle on time was observed to be adequate to allow the electrical current and the refrigerant pressures to stabilize. It would not be enough time for the system to achieve a steady state condition (the thermal expansion valve would not settle that quickly) but any further changes would be minimal.

Heating of the process water was visibly occurring evidenced by the unit being cycled on and off via its temperature probe and controller.

Electrical current was also monitored to observe any changes that might indicate any type of difficulty, fault, or laboring by the compressor. The current measurements did not vary during the recorded cycles.

Refrigerant pressures were recorded near the end of each on cycle. Both the suction and discharge pressures remained consistent across all recorded cycles indicating that the on cycle time is adequate for heat transfer to occur.

Comparison of Results to Compressor Manufacturer Performance Summary

With the use of the refrigerant RS-45, there exists no supporting performance data from the compressor manufacturer. Comparing the results of the heat pump test to the compressor manufacturer's performance tables for the compressor when using R22 supported the claim of Refrigerant Services Inc that performance should emulate R22 closely. Compressor performance table and summary table as supplied by Copeland can be found in Appendix IV. Figure 2 illustrates that the difference between Copeland's (the compressor manufacturer) performance tables using R-22 and the heat pump test results is remarkably close. All recorded data in Tests 1, 2, 4 was used in the preparation of the table in Figure 2, even the transient state data in Tests 1, 2.

Expected Performance from Copeland Performance Tables Based on Refrigerant Pressures			
Parameter	Unit	Test 1, 2	Test 4
Compressor Capacity	btu/hr	108364	100500
	kW	31.8	29.5
Evaporator Loss	%	4.3	4.6
Condensor Loss	%	-13.5	-12.3
Compressor Amps	Amperes	10.9	10.4
Amp Loss (adjusted to 575V)	%	4.0	2.2

Figure 2 Comparison of Copeland R22 performance tables to heat pump test results

From Figure 2 the conclusion is drawn that the manufacturer's performance table for R22 (see Appendix IV) can be used to predict heat pump performance across the design operating range. Notice in the performance table in Appendix IV that as the condensing pressure drops, the amp draw also drops and the efficiency rises.

Discussion of Results

Reaching Steady State Operation

Figure 3 illustrates the transient and steady state split of the heat pump data. Immediately prior to starting Tests 1,2 the heat pump was used to heat the reservoir supplying water to the evaporator during the tests. To begin the test, the heat pump was switched from Cool mode to Heat mode. The transient stage is caused from the basic refrigeration cycle principles that a condenser is filled with liquid. If it instantaneously switches to an evaporator, it takes some time for the then sub-cooled liquid to leave the evaporator allowing the heat pump to return to a steady state condition.

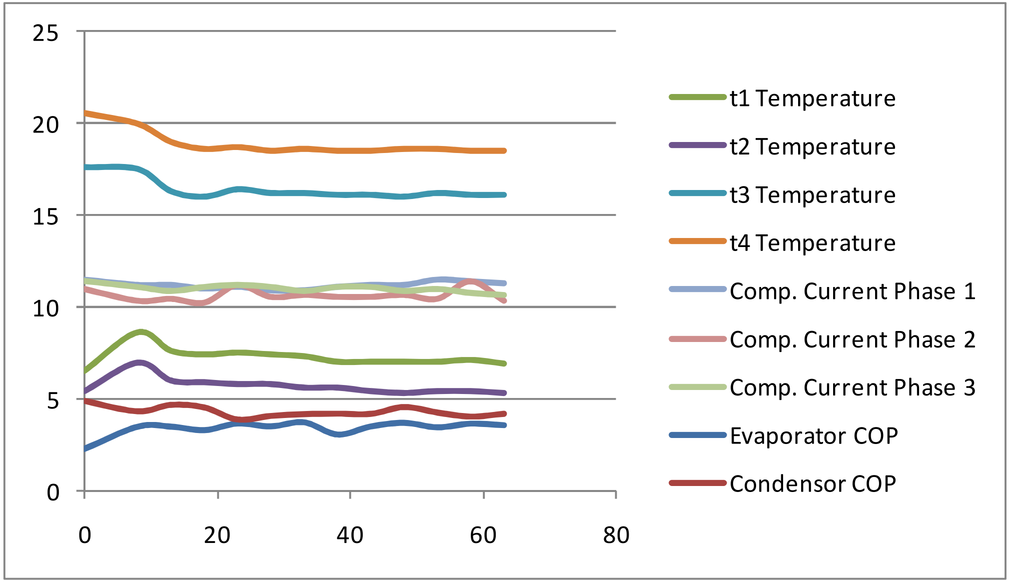


Figure 3 Data from Tests 1,2

Under normal cycling behavior the transient time will be shorter in duration and of less amplitude.

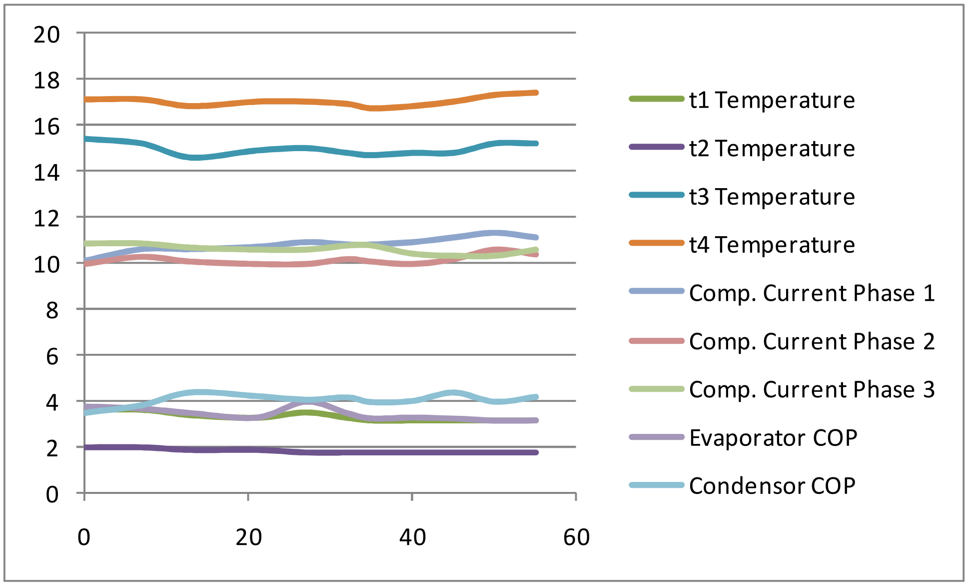


Figure 4 Data from Test 4

Before beginning Test 4 the heat pump unit had been running for approximately 30 minutes and had already reached the steady state condition as evidenced in Figure 4.

System Losses

Refrigerant Services Inc, manufacturer and supplier of the RS-45 refrigerant used in the heat pump test stated prior to the test that there would be a 2-3% loss in performance using RS-45 when compared to R-22. Given that evaporator loss was found to average 4.3-4.6% during the heat pump test when compared to R-22, the actual evaporator loss would be only 2-3%. Evaporator (and condenser) loss is a misnomer as it refers to heat transfer in the evaporator relative to compressor capacity. Therefore evaporator loss in this report would be more aptly described as whole system loss except compressor loss. And, therefore, total system loss would be only 2-3% average.

This 2-3% loss, while nominal, may be attributed to

1. Friction loss of refrigerant in piping
2. Heat transfer to ambient air from exposed refrigerant suction piping

Piping has already been arranged and sized to minimize friction losses. To further increase efficiency the suction piping between evaporator barrels will be insulated prior to delivery.

It can be said that evaporator heat transfer efficiency is greater than 97-98% and is likely approaching 100%. Since the work of the compressor is available to the condenser in addition to the heat removed from the evaporator, the condenser has negative losses in Figure 2.

On Cycle Time

The 40 second on cycle time was very comfortable for the compressor. It is recommended that under normal operation repetitive on-cycles are not less than 40 seconds in duration.

Off-cycle time should be not less than 5 seconds to allow equilibrium of pressures prior to start-up of compressor.

Heat Pump Coefficient of Performance

The Coefficient of Performance (COP) of a refrigeration system is not static. As conditions change, so does performance. In the case of the heat pump tested, as water temperatures change, COP also changes. During the capacity tests of the heat pump an average evaporator/condenser COP of 3.6/4.2 was achieved over the full course of the test. Worthy of high-lighting is that during the cold water heat sourcing test, the COP only marginally decreased to 3.4/4.1 for a test at both extremities of water temperature – lower than normally expected in the evaporator during wet lab operation and higher than needed in the condenser during wet lab operation.

The manufacturer performance table in Appendix IV shows that as the condenser water temperature approaches the design temperature of 14.2°C to 16°C, discharge pressure will drop below 160psi. Given a suction pressure of 45psi as seen during the heat pump test, evaporator/condenser COP should average 4.3/5.0 at full water flow conditions.

Low Flow Rate Conditions

The effect of flow rate on heat transfer was not tested formally but must be commented on. The condenser flow rate was not at the design flow of 4.6L/s which increased the head pressure and amp draw of the compressor, decreasing the COP. However, informal testing was done with flows as low as 0.5L/s to establish a minimum recommended flow. The heat pump units were able to both heat and cool near full capacity at 0.5L/s.

Conclusions

The heat pump unit evaporator with RS-45 refrigerant will perform within less than 5% of the compressor manufacturer's performance table for the compressor using R-22. Therefore the performance table can be used to predict heat pump unit performance at various operating conditions. Losses within the refrigeration system including the condenser and evaporator are as low as 2-3%.

The heat pump unit is capable of heating and cooling at all water temperatures expected to be encountered in the new St Andrews wet lab.

A minimum on-cycle time of 40 seconds is recommended. A minimum off-cycle time of 5 seconds is recommended.

An average evaporator/condenser COP of 3.6/4.2 was observed during the heating and cooling capacity test. COP during operation at design conditions at St Andrews wet lab is expected to be greater than observed during testing reaching 4.3/5.0 on average.

Water flows as low as 0.5L/s will not damage the heat pump. Rather, the heat pump unit can be expected to both heat and cool near full capacity at this low flow.

When changing from Heat mode to Cool mode, the heat pump may take as long as 20 minutes to reach steady state conditions. Performance during the transient period is similar to steady state but may be less than 100% of capacity.

Appendix I - Approved Heat Pump Factory Acceptance Test Outline

Objective

To test a 10hp heat pump unit in an accurate representation of the planned installation. There will be four test scenarios with Test 1 and Test 2 occurring simultaneously:

1. TEST 1: Heating capacity of heat pump unit
2. TEST 2: Cooling capacity of heat pump unit
3. TEST 3: Heat pump tolerance to cycling on/off behavior expected during wet lab operations.
4. TEST 4: Heat pump unit function when heat source water is near the freezing point of the water.

The objective of the heating and cooling capacity tests are not to reach any specific target temperature, but to determine the absolute quantity of heat that the heat pump can add to or remove from the process flow near expected operational conditions (ref. Drawing H 907).

The objective of the cycling on/off test is to determine if frequent cycling will overheat the compressor motor or cause any other equipment performance issues.

The objective of the heat-sourcing-water-near-the-freezing point test is to demonstrate two points:

1. That the heat pumps are capable of sourcing heat from water at that point,
2. And that the evaporator freeze protection systems will be effective.

Materials

1. One of the 10hp heat pump units being built for St. Andrews new Wet Lab project (Two 10hp heat pumps [ie one stacked assembly] will be transported to the site, the non-test heat pump unit may be used for temperature manipulation of reservoirs pre-test period)
2. Three water supplies of 4.6 liters/second that can be maintained:
    a. At 16°C +/- 4°C for three 60 minute periods in one 8 hour day,
    b. At 8°C +/- 2°C for two 60 minute periods in one 8 hour day, and,
    c. At 1°C +/- 2°C for one 60 minute period.
3. Four PT100 temperature probes
4. Four temperature meters with resolution of 0.1°C such as the Eliwell IC 915LX
5. In-line flow meters
6. Clamp-on style amp meter
7. Volt meter rated for greater than 575V
8. A temperature probe such as Supco Temperature Indicator TPM-110 or similar model for calibration of other probes.

All instrumentation must be accurate to 5% or less of full scale.

Location

The test will occur at Bakers Point Fisheries Ltd at 33 Bakers Point Rd in Jeddore Oyster Ponds, Nova Scotia, Canada. Bakers Point Fisheries Ltd has facilities for holding lobsters throughout the year including large tanks and chilling equipment. For the proposed tests, three water sources are available for the duration of the test:

1. a 30,000 US gallon tank which is holding lobsters near 1°C +/- 2°C
2. a 25,000 US gallon tank which is holding lobsters near 8°C +/- 2°C
3. Ambient flow near 16°C +/- 4°C.

Temperatures may be dependent on ambient conditions and time of year. The temperatures listed above are estimates for September 2010.

Test Water Flow Schematics

All temperatures listed in the schematics are approximations. The flow meters are located at f1 and f2. The temperature probes are located at t1, t2, t3, t4.

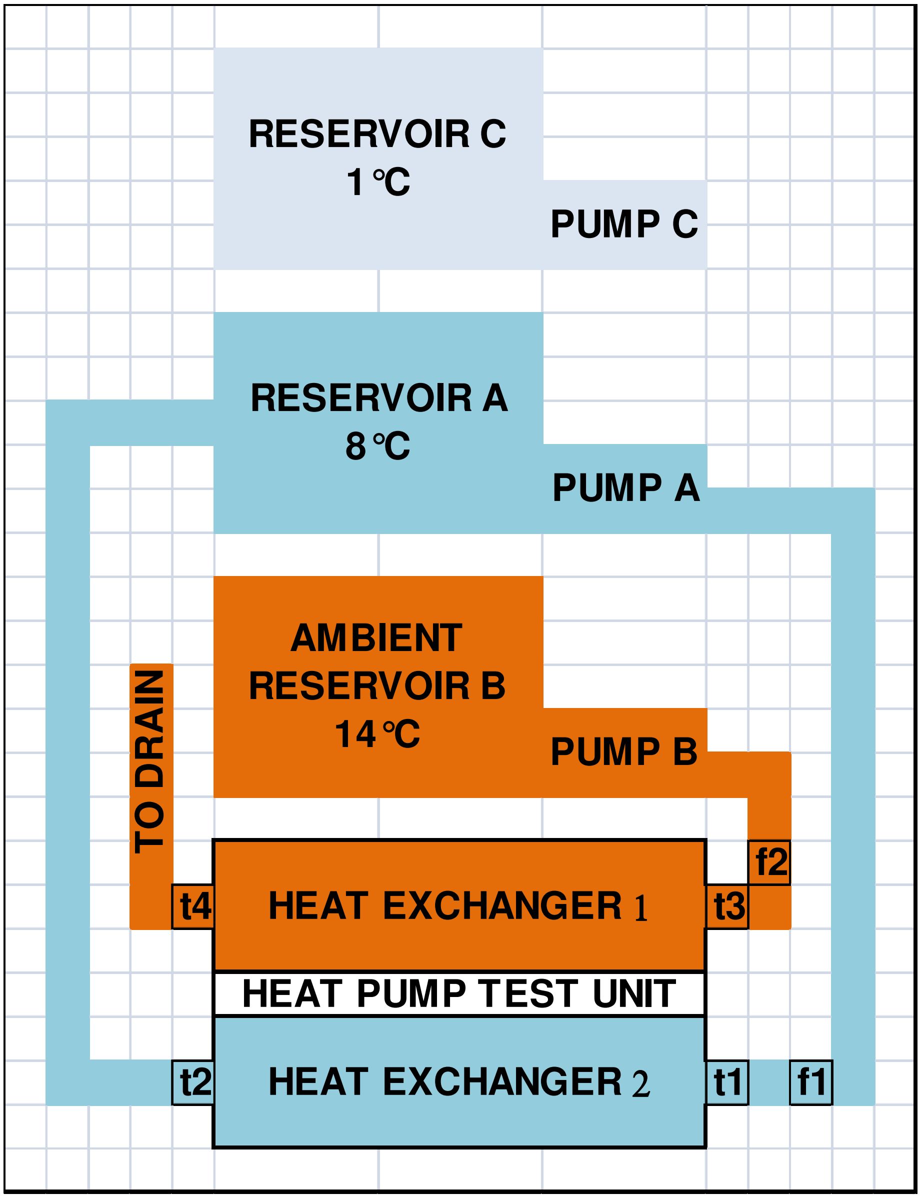


Figure 5 Proposed water flow schematic for TEST 1 and TEST 2 and TEST 3.

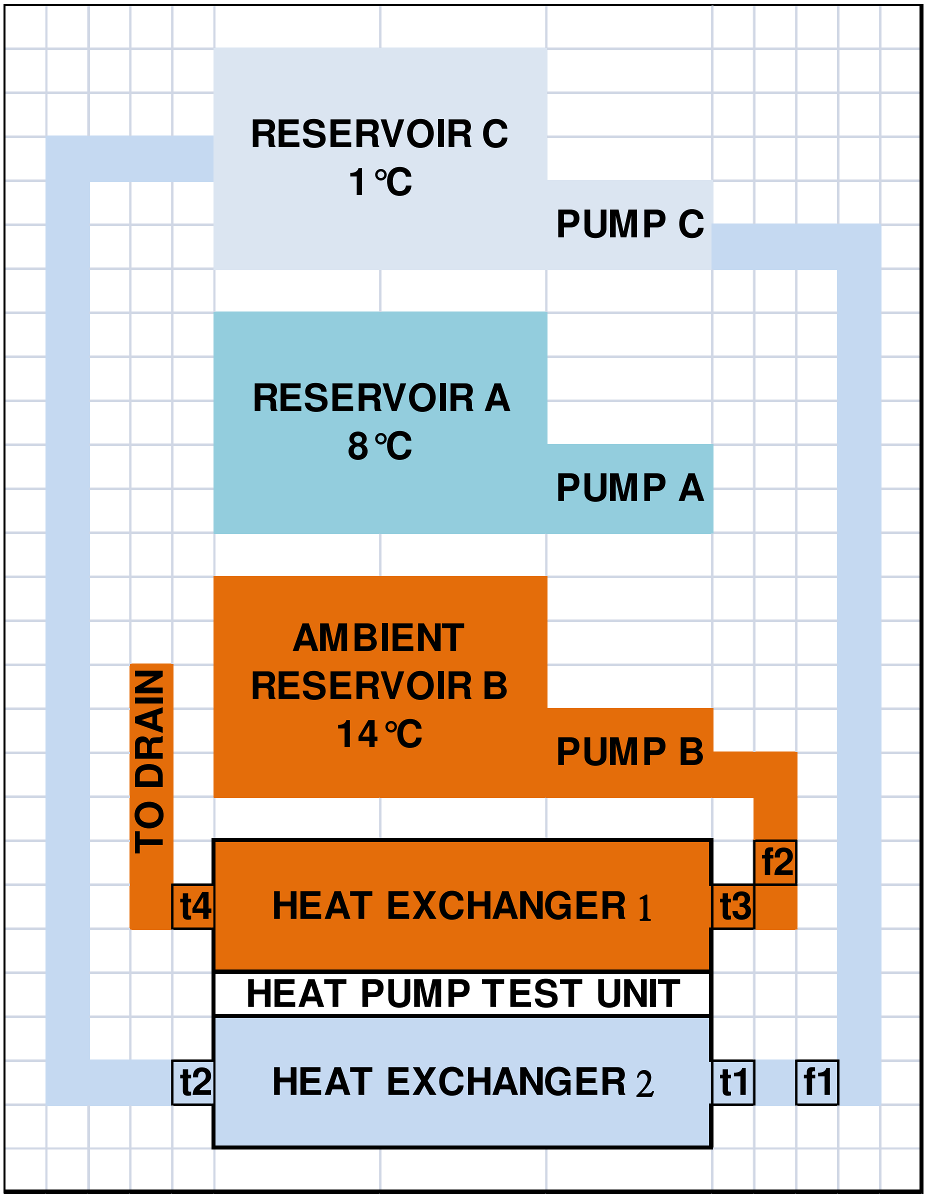


Figure 6 Proposed water flow schematic for TEST 4

Description of Test Water Flow

For all four tests, ambient water will flow through the heat pump condenser (Heat Exchanger 1). A flow meter (f2) and temperature probe (t3) will be placed on the line entering the condenser (Heat Exchanger 1). A second temperature probe (t4) will measure the temperature exiting the condenser (Heat Exchanger 1). Flow exiting the condenser will be directed to a drain or any other reservoir as directed by Bakers Point Fisheries.

Flow and temperature measurements on the evaporator flow will be taken by a temperature probe (t1) and a flow meter (f1) located on the line entering the evaporator. A temperature probe (t2) will measure the temperature of the flow leaving the evaporator.

Evaporator flow for Test 1, Test 2, and Test 3, will be drawn from Reservoir A and returned to either Reservoir A or discharged into a drain at the discretion of Baker's Point Fisheries. Evaporator flow for Test 4 will be drawn from Reservoir B and returned to either Reservoir B or discharged into a drain at the discretion of Baker's Point Fisheries.

Factory Acceptance Test Method

1. Test compressor checked for size and name plate data.
2. Record the type of refrigerant.
3. Chiller barrels checked for length and diameter.
4. Calibrate all temperature probes with the witness of representative(s) of the client.

Heating and Cooling Tests (ref. drawing H 907)

a. Start pumps and/or adjust water valves to begin flow through heat pump according to flow schematic shown in Figure 1. Check water flows in both condenser and evaporator systems. Both systems should be adjusted to have a flow of 4.6 liters per second +/- 0.46 liters per second. (ref. drawing H 907)
    i. Note: 4.6 L/s = 276 Lpm = 72.9 US gpm
b. Set compressor to Heat mode.
c. Set compressor thermostat to a target temperature of "ambient temperature" plus 10°C. This will allow continuous operation of the unit during the test period.
d. Start compressor by switching to Hand mode in heating mode at 100% and record the voltage and currents. Every 5 minutes for a period of 60 minutes record the water flow, the entering and leaving temperatures for each chiller barrel, the high and low refrigerant pressures, the compressor voltage, and the compressor amp draw.
e. Shut the compressor off.
f. (Total time – 2 hours)

Cycling On/Off Test (ref. drawing H 907)

a. Start pumps and/or adjust water valves to begin flow through heat pump according to flow schematic shown in Figure 1. Check water flows in both condenser and evaporator systems. Both systems should be adjusted to have a flow of 4.6 liters per second +/- 0.46 liters per second. (ref. drawing H 907)
b. Set compressor to Heat mode.

c. Set compressor thermostat to “ambient temperature” plus 0.5°C. This will allow the heat pump to reach its target temperature and cycle on/off during the test period.
d. Start compressor by switching to Hand mode. Note the time of each start and stop of the compressor.
e. Record the high and low temperatures observed at t2 and t4 during each cycle or every 5 minutes, whichever occurs less often.
f. Shut the compressor off.
g. (Total time – 2 hours)

Cold Water Heat Sourcing Test

a. Start pumps and/or adjust water valves to begin flow through heat pump according to flow schematic shown in Figure 2. Check water flows in both condenser and evaporator systems. Both systems should be adjusted to have a flow of 4.6 liters per second +/- 0.46 liters per second. (ref. drawing H 907)
b. Set compressor to Heat mode.
c. Set compressor thermostat to a target temperature of “ambient temperature” plus 10°C. This will allow continuous operation of the unit during the test period.
d. Start compressor by switching to Hand mode in heating mode at 100% and record the voltage and currents. Every 5 minutes for a period of 60 minutes record the water flow, the entering and leaving temperatures for each chiller barrel, the high and low refrigerant pressures, the compressor voltage, and the compressor amp draw.
e. Note by manual observation if hot gas bypass is being employed at each measurement.
f. Note compressor behavior should the case of t2 < -1.8°C occur.
g. Shut the compressor off.
h. (Total time – 2 hours)

NOTE: If excessive vibration or noise is noted during this test, shut down the equipment in the interest of safety. Determine the cause. Take corrective action. Restart the test.

Appendix I – Example of Data Recording Sheet for Heat Pump Tests

Heat Pump Compressor Nameplate Data:	
Refrigerant Type	Chiller Barrels Length Chiller Barrels Diameter

Parameter	Units							
Time	minutes	0	5	10	15	20	25	30
f1 Flow	Lpm							
f2 Flow	Lpm							
t1 Temperature	°C							
t2 Temperature	°C							
t3 Temperature	°C							
t4 Temperature	°C							
Comp. Current Phase 1	Amperes							
Comp. Current Phase 2	Amperes							
Comp. Current Phase 3	Amperes							
Comp. Voltage Phase 1	Volts							
Comp. Voltage Phase 2	Volts							
Comp. Voltage Phase 3	Volts							
Refrigerant High Pressure	psi							
Refrigerant Low Pressure	psi							

Comments:

Parameter	Units							
Time	minutes	35	40	45	50	55	60	
f1 Flow	Lpm							
f2 Flow	Lpm							
t1 Temperature	°C							
t2 Temperature	°C							
t3 Temperature	°C							
t4 Temperature	°C							
Comp. Current Phase 1	Amperes							
Comp. Current Phase 2	Amperes							
Comp. Current Phase 3	Amperes							
Comp. Voltage Phase 1	Volts							
Comp. Voltage Phase 2	Volts							
Comp. Voltage Phase 3	Volts							
Refrigerant High Pressure	psi							
Refrigerant Low Pressure	psi							

Appendix II - Raw Data Sheets

Heat Pump Factory Acceptance Test Record Sheet

Refrigerant Type	RS45 (R434A)	Capacity Test Data Tests 1&2

Parameter	Units\Time	1347	1355	1400	1405	1410	1415	1420	1425	1430	1435	1440	1445	1450
Time	minutes	0	8	13	18	23	28	33	38	43	48	53	58	63
f1 Flow	US gpm	72	72	72	72	73	72	72	73	73	72	72	73	73
f2 Flow	US gpm	55	56	56	56	56	57	56	57	57	57	58	56	56
t1 Temperature	°C	6.5	8.6	7.6	7.4	7.5	7.4	7.3	7	7	7	7	7.1	6.9
t2 Temperature	°C	5.4	7	6	5.9	5.8	5.8	5.6	5.6	5.4	5.3	5.4	5.4	5.3
t3 Temperature	°C	17.6	17.5	16.3	16	16.4	16.2	16.2	16.1	16.1	16	16.2	16.1	16.1
t4 Temperature	°C	20.6	20	19	18.6	18.7	18.5	18.6	18.5	18.5	18.6	18.6	18.5	18.5
Comp. Current Phase 1	Amperes	11.5	11.2	11.2	11	11.1	10.9	10.9	11.1	11.2	11.2	11.5	11.4	11.3
Comp. Current Phase 2	Amperes	11	10.4	10.5	10.3	11.2	10.6	10.7	10.6	10.6	10.7	10.5	11.4	10.4
Comp. Current Phase 3	Amperes	11.4	11.1	10.9	11.1	11.2	11.1	10.9	11.1	11.1	10.9	11	10.8	10.7
Comp. Voltage Phase 1-2	Volts	599	596	598	595	598	596	598	601	600	597	599	598	598
Comp. Voltage Phase 2-3	Volts	601	600	600	599	601	597	599	601	603	600	600	601	601
Comp. Voltage Phase 1-3	Volts	599	598	597	598	600	598	599	599	599	597	595	597	595
Refrigerant Low Pressure	psi	59	46	47	49	47	50	45	45	46	48	49	50	49
Refrigerant High Pressur	psi	180	183	180	185	185	175	178	180	176	180	180	180	180

Heat Pump Factory Acceptance Test Record Sheet

Cycling Test Data
Test 3

Parameter	Units											
Time On	actual time	13:00:50	13:02:30	13:05:15	13:08:00	nr	13:16:45	13:18:22	13:21:00	13:23:40	13:26:25	13:29:10
Time Off	actual time	nr	nr	nr	nr	nr	13:17:26	13:19:05	13:21:40	13:24:20	13:27:05	13:29:45
f1 Flow	US gpm	73										
f2 Flow	US gpm	62										
t1 Temperature	°C	15.8										
t2 Temperature	°C	14.0-15.5										
t3 Temperature	°C	Heating Pound										
t4 Temperature	°C	Heating Pound										
Comp. Current Phase 1	Amperes			10.7	10.5	10.4	10.3	10.4	10.6	10.4	10.6	10.4
Comp. Current Phase 2	Amperes			9.9	9.8	10.1	9.9	9.9	9.9	10	10	9.9
Comp. Current Phase 3	Amperes			9.9	10.2	10.4	10.2	10.3	10.3	10.2	10	10.4
Refrigerant Low Pressure	psi	nr	nr	nr	55	nr	54	56	55	56	55	57
Refrigerant High Pressure	psi	nr	nr	nr	160	nr	160	160	160	163	162	165

Comments: (1)Head of compressor remained warm to touch. Suction side (where motor windings are) remained cold to tou

(3)Conferred with Rod Fournier and Peter Dumaresq to end test at 30 minutes as adequate
motor starts had occurred with no signs of compressor labouring.

Heat Pump Factory Acceptance Test Record Sheet

Cold Water Heat Sourcing Test Data

Test 4

Parameter	Units\Time	1120	1127	1133	1141	1147	1152	1155	1200	1205	1210	1215
Time	minutes	0	7	13	21	27	32	35	40	45	50	55
f1 Flow	US gpm	72	72	73	73	73	73	73	73	73	73	73
f2 Flow	US gpm	63	63	62	62	63	62	62	62	62	61	61
t1 Temperature	°C	3.6	3.6	3.4	3.3	3.5	3.3	3.2	3.2	3.2	3.2	3.2
t2 Temperature	°C	2	2	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8
t3 Temperature	°C	15.4	15.2	14.6	14.9	15	14.8	14.7	14.8	14.8	15.2	15.2
t4 Temperature	°C	17.1	17.1	16.8	17	17	16.9	16.7	16.8	17	17.3	17.4
Comp. Current Phase 1	Amperes	10.1	10.6	10.6	10.7	10.9	10.8	10.8	10.9	11.1	11.3	11.1
Comp. Current Phase 2	Amperes	10	10.3	10.1	10	10	10.2	10.1	10	10.2	10.6	10.4
Comp. Current Phase 3	Amperes	10.9	10.9	10.7	10.6	10.6	10.8	10.8	10.4	10.3	10.3	10.6
Comp. Voltage Phase 1-2	Volts	590	588	nr	594	593	592	592	594	596	602	602
Comp. Voltage Phase 2-3	Volts	591	594	nr	598	596	596	596	598	598	605	605
Comp. Voltage Phase 1-3	Volts	591	591	nr	594	591	592	595	593	597	600	601
Refrigerant Low Pressure	psi	40	41	42	44	42	41	43	42	43	43	43
Refrigerant High Pressure	psi	173	173	175	179	170	165	168	165	165	165	168

Comments: Compressor shut down at 1220h via thermostat ending test.

Temperature probe required >15 seconds to stabilize. Initial readings only had approximately 5 seconds to stabilize

Refrigerant high pressure gauge oscillated with compressor pistons +/-10 psi but did not fluctuate. Reading is average

Appendix III - Tables of Calculations

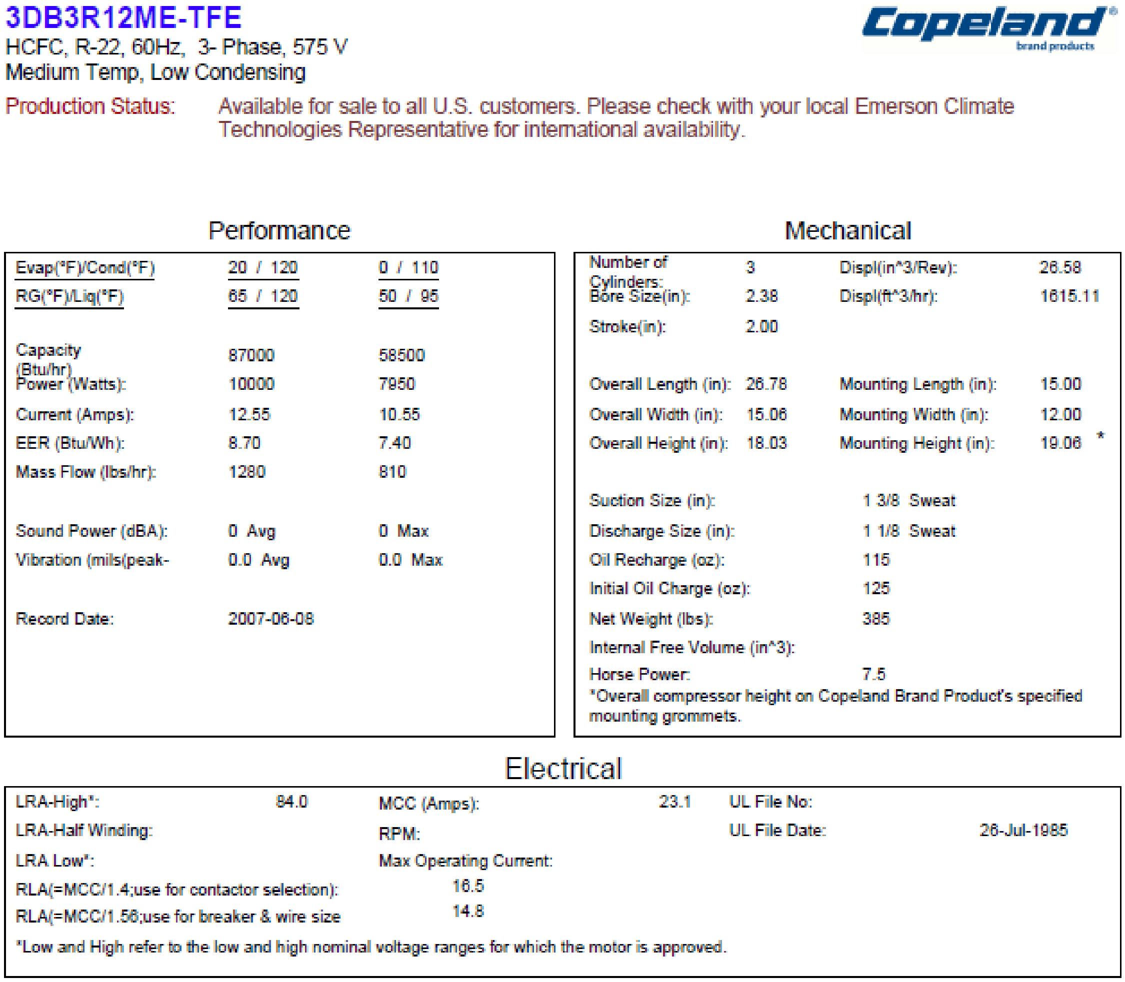
Parameter	Units\Time	0	8	13	18	23	28	33	38	43	48	53	58	63	Averages
Average Current	Amperes	11.3	10.9	10.9	10.8	11.2	10.9	10.8	10.9	11.0	10.9	11.0	11.2	10.8	10.9
Average Voltage	Volts	600	598	598	597	600	597	599	600	601	598	598	599	598	598.6
Apparent Power	kVA	6.8	6.5	6.5	6.5	6.7	6.5	6.5	6.6	6.6	6.5	6.6	6.7	6.5	6.6
Real Power (PF=0.75)	kW	8.8	8.5	8.4	8.4	8.7	8.4	8.4	8.5	8.6	8.5	8.5	8.7	8.4	8.5
Evaporator TD	°C	1.1	1.6	1.6	1.5	1.7	1.6	1.7	1.4	1.6	1.7	1.6	1.7	1.6	1.6
Evaporator Heat Transfer	kW	20.6	30.0	30.0	28.1	32.3	30.0	31.9	26.6	30.4	31.9	30.0	32.3	30.4	30.4
Evaporator COP		2.3	3.5	3.6	3.4	3.7	3.6	3.8	3.1	3.6	3.8	3.5	3.7	3.6	3.6
Condensor Heat Transfer	kW	43.0	36.5	39.4	37.9	33.6	34.2	35.0	35.6	35.6	38.6	36.3	35.0	35.0	36.0
Condensor TD	°C	3.0	2.5	2.7	2.6	2.3	2.3	2.4	2.4	2.4	2.6	2.4	2.4	2.4	2.4
Condensor COP		4.9	4.3	4.7	4.5	3.9	4.1	4.2	4.2	4.2	4.5	4.2	4.0	4.2	4.2
Expected Performance from Copeland Performance Tables Based on Refrigerant Pressures															
Compressor Capacity	btu/hr	140000	106000	106000	114500	109000	114500	109000	106000	109000	106000	106000	106000	106000	108363.6
	kW	41.0	31.1	31.1	33.6	31.9	33.6	31.9	31.1	31.9	31.1	31.1	31.1	31.1	31.8
Evaporator Loss	%	49.7	3.4	3.4	16.2	-1.2	10.6	0.2	14.3	4.8	-2.6	3.4	-4.1	2.1	4.3
Condensor Loss	%	-4.8	-17.4	-26.8	-13.0	-5.0	-1.8	-9.6	-14.7	-11.6	-24.3	-16.7	-12.7	-12.7	-13.5
Compressor Amps	Amperes	11.2	10.9	10.9	11	10.9	11	10.9	10.9	10.9	10.9	11	11	11	10.9
Amp Loss (adjusted to 575V)	%	3.3	3.8	4.2	5.5	1.8	4.9	4.5	3.9	3.7	3.6	3.8	2.2	5.6	4.0

Figure 7 Calculated Parameters for Test 1,2

Parameter	Units\Time	0	7	13	21	27	32	35	40	45	50	55	Averages
Average Current	Amperes	10.3	10.6	10.5	10.4	10.5	10.6	10.6	10.4	10.5	10.7	10.7	10.5
Average Voltage	Volts	591	591	600	595	593	593	594	595	597	602	603	595.9
Apparent Power	kVA	6.1	6.3	6.3	6.2	6.2	6.3	6.3	6.2	6.3	6.5	6.4	6.3
Real Power (PF=0.75)	kW	7.9	8.1	8.2	8.1	8.1	8.2	8.2	8.1	8.2	8.4	8.4	8.2
Evaporator TD	°C	1.6	1.6	1.5	1.4	1.7	1.5	1.4	1.4	1.4	1.4	1.4	1.5
Evaporator Heat Transfer	kW	30.0	30.0	28.5	26.6	32.3	28.5	26.6	26.6	26.6	26.6	26.6	28.1
Evaporator COP		3.8	3.7	3.5	3.3	4.0	3.5	3.3	3.3	3.3	3.2	3.2	3.4
Condensor Heat Transfer	kW	27.9	31.2	35.5	33.9	32.8	33.9	32.3	32.3	35.5	33.4	35.0	33.1
Condensor TD	°C	1.7	1.9	2.2	2.1	2	2.1	2	2	2.2	2.1	2.2	2.0
Condensor COP		3.5	3.8	4.4	4.2	4.1	4.2	4.0	4.0	4.3	4.0	4.2	4.1
Expected Performance from Copeland Performance Tables Based on Refrigerant Pressures													
Compressor Capacity	btu/hr	100500	100500	100500	100500	100500	100500	100500	100500	100500	100500	100500	100500
	kW	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
Evaporator Loss	%	-1.9	-1.9	3.2	9.6	-9.8	3.2	9.6	9.6	9.6	9.6	9.6	4.6
Condensor Loss	%	5.3	-5.9	-20.6	-15.2	-11.4	-15.2	-9.7	-9.7	-20.6	-13.3	-18.7	-12.3
Compressor Amps	Amperes	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Amp Loss (adjusted to 575V)	%	3.3	0.8	3.6	3.1	2.2	1.2	1.7	3.1	2.5	1.5	1.8	2.2

Figure 8 Calculated Parameters for Test 4

Appendix IV - Copeland Compressor Performance Table



3DB3R12ME-TFE

HCFC, R-22, 60Hz, 3- Phase, 575 V
Medium Temp, Low Condensing

Production Status: Available for sale to all U.S. customers. Please check with your local Emerson Climate Technologies Representative for international availability.

Performance

Evap(°F)/Cond(°F)	20 / 120	0 / 110
RG(°F)/Liq(°F)	65 / 120	50 / 95
Capacity (Btu/hr)	87000	58500
Power (Watts):	10000	7950
Current (Amps):	12.55	10.55
EER (Btu/Wh):	8.70	7.40
Mass Flow (lbs/hr):	1280	810
Sound Power (dBA):	0 Avg	0 Max
Vibration (mils(peak-	0.0 Avg	0.0 Max
Record Date:	2007-06-08	

Mechanical

Number of Cylinders:	3	Displ(in^3/Rev):	26.58
Bore Size(in):	2.38	Displ(ft^3/hr):	1615.11
Stroke(in):	2.00		
Overall Length (in):	26.78	Mounting Length (in):	15.00
Overall Width (in):	15.06	Mounting Width (in):	12.00
Overall Height (in):	18.03	Mounting Height (in):	19.06 *

Suction Size (in):	1 3/8 Sweat
Discharge Size (in):	1 1/8 Sweat
Oil Recharge (oz):	115
Initial Oil Charge (oz):	125
Net Weight (lbs):	385
Internal Free Volume (in^3):	
Horse Power:	7.5

*Overall compressor height on Copeland Brand Product's specified mounting grommets.

Electrical

LRA-High*:	84.0	MCC (Amps):	23.1	UL File No:	
LRA-Half Winding:		RPM:		UL File Date:	26-Jul-1985
LRA Low*:		Max Operating Current:			

RLA(=MCC/1.4;use for contactor selection):	16.5
RLA(=MCC/1.56;use for breaker & wire size	14.8

*Low and High refer to the low and high nominal voltage ranges for which the motor is approved.

Evaporating Temperature °F (Sat Dew Pt Pressure, psig)

Condensing Temperature °F (Sat Dew Pt Pressure, psig)		-10(16)	0(24)	5(28)	10(33)	15(38)	20(43)	25(49)	30(55)	35(61)	40(68)	45(76)
140 (337)	C				58500	66000	74000	83000	92500	103000	114000	126000
	P				10100	10700	11200	11700	12200	12700	13100	13500
	A				12.5	13.1	13.7	14.3	14.8	15.3	15.8	16.2
	M				940	1070	1200	1350	1520	1700	1890	2110
	E				5.8	6.2	6.6	7.1	7.6	8.1	8.7	9.3
	%				70.1	70.6	71	71.3	71.4	71.5	71.4	71.2
130 (297)	C			**56500**	64000	72000	80500	90000	100000	111000	123000	136000
	P			**9150**	9650	10200	10600	11100	11500	11900	12200	12500
	A			**11.7**	12.2	12.7	13.2	13.6	14	14.4	14.8	15.1
	M			**860**	975	1100	1240	1390	1560	1740	1940	2150
	E			**6.2**	6.6	7.1	7.6	8.1	8.7	9.4	10.1	10.9
	%			**70.4**	70.9	71.3	71.6	71.7	71.8	71.7	71.6	71.3
120 (260)	C		**54000**	**61500**	69500	78000	87000	97000	108000	120000	133000	146000
	P		**8300**	**8750**	9200	9600	10000	10400	10700	11000	11200	11400
	A		**10.9**	**11.3**	11.8	12.2	12.6	12.9	13.3	13.5	13.8	14
	M		**780**	**890**	1010	1130	1280	1430	1600	1780	1980	2190
	E		**6.5**	**7**	7.5	8.1	8.7	9.4	10.1	10.9	11.8	12.8
	%		**70.2**	**70.8**	71.2	71.6	71.7	71.8	71.8	71.7	71.4	71
110 (226)	C	**45000**	**58500**	**66500**	74500	83500	93500	104000	116000	128000	142000	156000
	P	**7150**	**7950**	**8350**	8700	9050	9350	9650	9900	10100	10200	10300
	A	**9.7**	**10.5**	**10.9**	11.3	11.6	11.9	12.2	12.4	12.6	12.8	12.9
	M	**620**	**810**	**915**	1030	1160	1310	1460	1630	1820	2020	2230
	E	**6.3**	**7.4**	**7.9**	8.6	9.2	10	10.8	11.7	12.7	13.8	15.1
	%	**68.4**	**70.3**	**70.8**	71.2	71.4	71.6	71.6	71.4	71.2	70.8	70.2
100 (196)	C	**48700**	**63000**	**71000**	80000	89500	99500	111000	123000	136000	150000	166000
	P	**6900**	**7550**	**7900**	8150	8450	8650	8850	9000	9100	9150	9150
	A	**9.5**	**10.2**	**10.5**	10.7	11	11.2	11.4	11.5	11.6	11.7	11.7
	M	**640**	**830**	**940**	1060	1190	1330	1490	1660	1850	2050	2270
	E	**7.1**	**8.3**	**9**	9.8	10.6	11.5	12.5	13.7	15	16.4	18.1
	%	**68.3**	**70**	**70.5**	70.8	71	71	70.9	70.7	70.3	69.7	68.9
90 (168)	C	**52500**	**67500**	**75500**	85000	95000	106000	118000	130000	144000	159000	175000
	P	**6600**	**7150**	**7350**	7600	7750	7900	8050	8100	8100	8050	7900
	A	**9.2**	**9.7**	**10**	10.2	10.3	10.5	10.5	10.6	10.6	10.6	10.5
	M	**660**	**855**	**965**	1080	1220	1360	1520	1690	1880	2080	2300
	E	**7.9**	**9.4**	**10.3**	11.2	12.2	13.4	14.7	16.1	17.8	19.8	22.2
	%	**67.9**	**69.4**	**69.9**	70.1	70.2	70.1	69.9	69.5	68.9	68.1	66.9
70 (121)	C	**59500**	**75500**	**85000**	95000	106000	118000	131000	145000	160000	176000	194000
	P	**5850**	**6100**	**6200**	6250	6250	6250	6150	6050	5850	5550	5250
	A	**8.5**	**8.8**	**8.9**	8.9	8.9	8.9	8.8	8.7	8.5	8.3	8
	M	**700**	**895**	**1000**	1130	1260	1410	1570	1740	1930	2140	2360
	E	**10.2**	**12.4**	**13.7**	15.2	16.9	18.9	21.2	24	27.4	31.7	37.1
	%	**66.4**	**67.6**	**67.8**	67.8	67.6	67.2	66.5	65.5	64	62	59
60 (102)	C	**63500**	**80000**	**89500**	100000	111000	124000	137000	152000	168000		
	P	**5350**	**5500**	**5500**	5500	5400	5300	5150	4890	4590		
	A	**8.2**	**8.3**	**8.3**	8.3	8.2	8.1	8	7.8	7.5		
	M	**715**	**910**	**1020**	1150	1280	1430	1590	1760	1950		
	E	**11.8**	**14.5**	**16.2**	18.2	20.5	23.3	26.8	31.1	36.5		
	%	**65.4**	**66.3**	**66.4**	66.2	65.8	65	63.8	62	59.5		
50 (84)	C	**67000**	**84000**	**94000**	105000	117000	130000	144000	159000			
	P	**4850**	**4830**	**4770**	4660	4500	4290	4010	3680			
	A	**7.8**	**7.8**	**7.8**	7.7	7.5	7.4	7.1	6.8			
	M	**735**	**930**	**1040**	1160	1300	1450	1610	1780			
	E	**13.8**	**17.4**	**19.7**	22.5	26	30.3	35.8	43.3			
	%	**64.3**	**64.8**	**64.7**	64.2	63.3	61.8	59.6	56.3			

Nominal Performance Values (±5%) based on 72 hours run-in. Subject to change without notice. Current @ 575 V

C:Capacity(Btu/hr), P:Power(Watts), A:Current(Amps), M:Mass Flow(lbs/hr), E:EER(Btu/Watt-hr), %:Isentropic Efficiency(%)