Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP)

TEST REPORT #24

Compressor Calorimeter Test of Refrigerant DR-5 in a R-410A Scroll Compressor

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This report has been made available to the public as part of the author company's participation in the AHRI's Low-GWP AREP.

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List of Tested Refrigerants' Compositions (Mass%)

DR-5	R-32/R-1234yf (72.5/27.5)

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Introduction

This Report covers the calorimeter testing results of DR-5 performed by Emerson Climate Technologies, Inc. (Emerson) for the AHRI Low-GWP AREP study. The testing was done in Emerson's A2L Research calorimeter lab test facility located in Sidney, Ohio. The refrigerant was tested with a R-410A Copeland Scroll ZP31K5E-PFV for an air-conditioning or heat pump type application. This report covers a drop-in test. No optimization, oil or hardware changes were made to account for the alternative refrigerant. All compressor tests are performed at a refrigerant's dew point temperature for suction and discharge pressure conditions, per AHRI Standard 540 requirements. This does not have an impact on comparing compressor performance between two or more refrigerants that do not exhibit temperature glide. However, when refrigerants exhibit temperature glide, it is important to note that actual systems operate closer to the mid-point condition. When comparing compressor performance of one refrigerant with glide to another refrigerant without glide, or comparing two refrigerants with significantly different glides, comparison at pressures corresponding to the mid-point of the temperature glide rather than the dew point will yield results that are more representative of actual operation in a system.

Details of Test Setup

Description of Test Refrigerant-Lubricant and Charge

- Refrigerant/Refrigerant Blend tested: DuPont DR-5
  - Initial Refrigerant Charge: 4 lbs (1.8 kg)
- Lubricant:
  - 32-3MAF POE Oil
  - Viscosity grade: 32 cSt
  - Any modifications to base lubricant? No

Description of Compressor

- Hermetic Copeland R-410A Scroll
- No compressor modifications
- Emerson Climate Technologies, Inc. Copeland Brand
- Model No. ZP31K5E-PFV-XXX, Serial No. 10C7308HL
- Motor Nameplate Rating: 208/230V-1Ø-60Hz, 3 hp, 18.6A RLA (MCC/1.4), 3500 RPM (nominal)
- Displacement: 1.8 in^3/rev

- Air Flow Required (Y/N?): Yes
- Quantity: 1,360 ft^3/min (38.5 m^3/min)
- Velocity and Temperature of Air: 95° F Ambient
- Orientation of Air Flow In Relation to the compressor: Perpendicular to the vertical axis of the compressor
- Compressor Test Points (see Test Points in Table 1)

Table 1. Compressor Calorimeter Test Points – Dew Point

Ambient Air Temperature		Suction Pressure		Saturated Suction Temperature		Refrigerant Vapor Temperature Entering Compressor		Discharge Pressure		Saturated Discharge Temperature		Discharge Temperature[1]		Volts-Phase-Frequency	Speed
°F	°C	psia	Bar	°F	°C	°F	°C	psia	Bar	°F	°C	°F	°C	V-Ø-Hz	RPM
95	35.0	47.31	3.22	-10	-23.3	10	-12.2	236.54	16.09	80	26.7	217	102.8	230-1-60	3,551
95	35.0	47.31	3.22	-10	-23.3	10	-12.2	293.72	19.98	95	35.0	262	127.8	230-1-60	3,535
95	35.0	52.68	3.58	-5	-20.6	15	-9.4	314.94	21.42	100	37.8	261	127.2	230-1-60	3,532
95	35.0	58.50	3.98	0	-17.8	20	-6.7	273.61	18.61	90	32.2	217	102.8	230-1-60	3,547
95	35.0	58.50	3.98	0	-17.8	20	-6.7	337.31	22.95	105	40.6	258	125.6	230-1-60	3,527
95	35.0	64.80	4.41	5	-15.0	25	-3.9	360.87	24.55	110	43.3	258	125.6	230-1-60	3,518
95	35.0	71.61	4.87	10	-12.2	30	-1.1	236.54	16.09	80	26.7	177	80.6	230-1-60	3,549
95	35.0	71.61	4.87	10	-12.2	30	-1.1	273.61	18.61	90	32.2	197	91.7	230-1-60	3,544
95	35.0	86.87	5.91	20	-6.7	40	4.4	314.94	21.42	100	37.8	197	91.7	230-1-60	3,537
95	35.0	86.87	5.91	20	-6.7	40	4.4	411.78	28.01	120	48.9	242	116.7	230-1-60	3,508
95	35.0	86.87	5.91	20	-6.7	40	4.4	439.24	29.88	125	51.7	258	125.6	230-1-60	3,499
95	35.0	95.37	6.49	25	-3.9	45	7.2	468.10	31.84	130	54.4	257	125.0	230-1-60	3,489
95	35.0	104.48	7.11	30	-1.1	50	10.0	236.54	16.09	80	26.7	150	65.6	230-1-60	3,554
95	35.0	104.48	7.11	30	-1.1	50	10.0	360.87	24.55	110	43.3	200	93.3	230-1-60	3,523
95	35.0	104.48	7.11	30	-1.1	50	10.0	498.44	33.91	135	57.2	257	125.0	230-1-60	3,481
95	35.0	114.25	7.77	35	1.7	55	12.8	530.32	36.08	140	60.0	260	126.7	230-1-60	3,467
95	35.0	124.70	8.48	40	4.4	60	15.6	273.61	18.61	90	32.2	157	69.4	230-1-60	3,544
95	35.0	124.70	8.48	40	4.4	60	15.6	411.78	28.01	120	48.9	204	95.6	230-1-60	3,515
95	35.0	124.70	8.48	40	4.4	60	15.6	563.84	38.36	145	62.8	261	127.2	230-1-60	3,457
95	35.0	135.86	9.24	45	7.2	65	18.3	314.94	21.42	100	37.8	165	73.9	230-1-60	3,542
95	35.0	135.86	9.24	45	7.2	65	18.3	468.10	31.84	130	54.4	216	102.2	230-1-60	3,496
95	35.0	135.86	9.24	45	7.2	65	18.3	468.10	31.84	130	54.4	218	103.3	230-1-60	3,491

[1] *Measured on Discharge Line 6" from Compressor Discharge Port.*

Description and Size of Test Loop

- Test Loop Components: See Figure 1.
- Instrumentation/Accuracy: See Table 2.

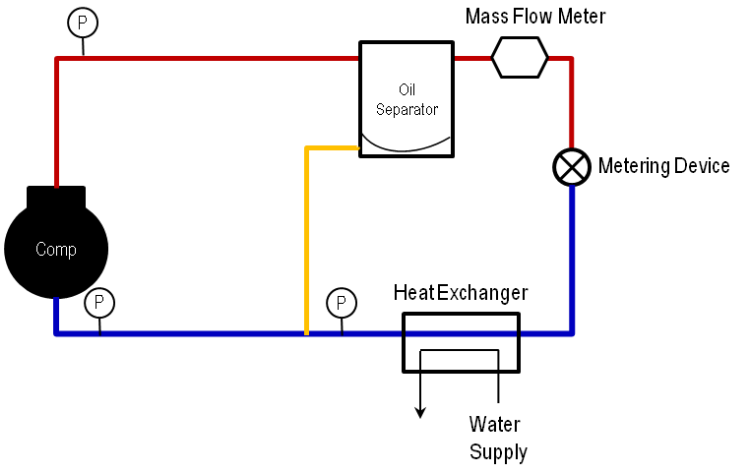

Figure 1. Simplified System Diagram of Test Setup

Table 2. Test Loop Component Accuracy

Device	Instrumentation Accuracy	Full Scale/Span
3051S1TA3A2E11A2AT1		
Suction Pressure Transducer	+/- 0.025 % span	300 psia
Discharge Pressure Transducer	+/- 0.025 % span	800 psia
EVI Pressure Transducer	+/- 0.025 % span	400 psia
G4AD3		
Suction Pressure Signal Conditioning Module	+/_ 0.08% full scale	300 psia
Discharge Pressure Signal Conditioning Module	+/_ 0.08% full scale	800 psia
EVI Pressure Signal Conditioning Module	+/_ 0.08% full scale	400 psia
3144PD1A1NA		
Suction Temperature Transducer	± 0.45°F ±0.02% of span	200 °F
Discharge Temperature Transducer	± 0.45°F ±0.02% of span	400 °F
Compressor Ambient Temperature Transducer	± 0.45°F ±0.02% of span	200 °F
G4AD3		
Suction Temperature Signal Conditioning Module	+/_ 0.08% full scale	200 °F
Discharge Temperature Signal Conditioning Module	+/_ 0.08% full scale	400 °F
Compressor Ambient Temperature Signal Conditioning Module	+/_ 0.08% full scale	200 °F
G4AD18		
EVI Temperature Signal Conditioning Module	± 0.9° C	435 °F
DSP-1Y25A125		
Watts	+/- 0.1% reading +/- 0.01% full scale	155.885kW
Volts	+/- 0.1% full scale	720 V
Amps	+/- 0.1% full scale	125 A
CMF025 W/MVD Transmitter		
Compressor Mass Flow	±0.35% of rate	
CMF010 W/MVD Transmitter		
Oil Circulation Mass Flow	±0.1% of rate	

Results

Table 3 shows the test results from drop-in compressor testing with DR-5. The R-410A baseline data is from published nominal rating data (capacity and EER within ±5% of test data). Capacity calculations for DR-5 are done via measured mass flow multiplied by enthalpy change using the refrigerant properties supplied by the chemical manufacturer. All compressor performance is based on dew temperature/pressure and was tested per AHRI Standard 540-2004.

Table 3. DuPont DR-5 Test Results –Dew Point

Evaporating Temperature, °F (°C)	Evaporator Glide, F (C)	Condensing Temperature, °F (°C)	Condenser Glide, F (C)	Discharge Temperature [1] (°F)	Applicable Superheating, F (C)	Applicable Subcooling, F (C)	Cooling Compressor Capacity, Btu/hr (W)	Refrigerant Mass Flow Rate, lbm/hr (kg/hr)	Amperes, A (A)	Input Power, W (W)	Cooling EER, Btu/W-hr	Cooling COP, W/W	Cooling COP_{alt} / COP_{Base} [2]
-10 (-23)	2 (1.1)	80 (27)	2 (1.1)	217 (103)	20 (11.1)	15 (8.3)	11819 (3464)	113 (51.4)	7	1610	7.34	2.15	0.95
-10 (-23)	2 (1.1)	95 (35)	2 (1.1)	262 (128)	20 (11.1)	15 (8.3)	10202 (2990)	104 (47.2)	9	1971	5.18	1.52	0.87
-5 (-21)	2 (1.1)	100 (38)	2 (1)	261 (127)	20 (11.1)	15 (8.3)	11304 (3313)	117 (53.1)	9	2097	5.39	1.58	0.93
0 (-18)	2 (1.1)	90 (32)	2 (1.1)	217 (103)	20 (11.1)	15 (8.3)	14081 (4127)	139 (63)	8	1821	7.73	2.27	0.88
0 (-18)	2 (1.1)	105 (41)	2 (1)	258 (126)	20 (11.1)	15 (8.3)	12545 (3677)	132 (59.9)	10	2231	5.62	1.65	0.95
5 (-15)	2 (1.1)	110 (43)	2 (1)	258 (126)	20 (11.1)	15 (8.3)	13716 (4020)	147 (66.6)	10	2371	5.78	1.70	0.96
10 (-12)	2 (1.1)	80 (27)	2 (1.1)	177 (81)	20 (11.1)	15 (8.3)	19398 (5685)	181 (82.5)	7	1600	12.12	3.55	0.94
10 (-12)	2 (1.1)	90 (32)	2 (1.1)	197 (92)	20 (11.1)	15 (8.3)	18108 (5307)	176 (80.1)	8	1812	9.99	2.93	1.02
20 (-7)	2 (1.1)	100 (38)	2 (1)	197 (92)	20 (11.1)	15 (8.3)	21755 (6376)	218 (99.3)	9	2037	10.68	3.13	1.02
20 (-7)	2 (1.1)	120 (49)	2 (1)	242 (117)	20 (11.1)	15 (8.3)	18535 (5432)	204 (92.9)	12	2647	7.00	2.05	1.02
20 (-7)	2 (1.1)	125 (52)	2 (0.9)	258 (126)	20 (11.1)	15 (8.3)	17641 (5170)	200 (90.7)	13	2871	6.14	1.80	0.99
25 (-4)	2 (1.1)	130 (54)	2 (0.9)	257 (125)	20 (11.1)	15 (8.3)	19325 (5664)	223 (101.5)	13	3053	6.33	1.86	0.98
30 (-1)	2 (1.1)	80 (27)	2 (1.1)	150 (66)	20 (11.1)	15 (8.3)	30486 (8935)	280 (127.2)	7	1591	19.16	5.62	0.89
30 (-1)	2 (1.1)	110 (43)	2 (1)	200 (93)	20 (11.1)	15 (8.3)	25617 (7508)	266 (121)	10	2303	11.12	3.26	0.95
30 (-1)	2 (1.1)	135 (57)	2 (0.9)	257 (125)	20 (11.1)	15 (8.3)	20896 (6124)	247 (112.2)	14	3226	6.48	1.90	1.02
35 (2)	2 (1.1)	140 (60)	2 (0.8)	260 (127)	20 (11.1)	15 (8.3)	22360 (6553)	270 (122.9)	15	3443	6.49	1.90	0.95
40 (4)	2 (1.1)	90 (32)	2 (1.1)	157 (69)	20 (11.1)	15 (8.3)	35232 (10326)	333 (151.4)	8	1806	19.51	5.72	0.94
40 (4)	2 (1.1)	120 (49)	2 (1)	204 (96)	20 (11.1)	15 (8.3)	29801 (8734)	322 (146.2)	11	2583	11.54	3.38	1.02
40 (4)	2 (1.1)	145 (63)	1 (0.8)	261 (127)	20 (11.1)	15 (8.3)	24022 (7040)	298 (135.4)	16	3681	6.53	1.91	0.87
45 (7)	2 (1.1)	100 (38)	2 (1)	165 (74)	20 (11.1)	15 (8.3)	37299 (10932)	366 (166.3)	9	1965	18.98	5.56	0.94
45 (7)	2 (1.1)	130 (54)	2 (0.9)	216 (102)	20 (11.1)	15 (8.3)	30765 (9017)	348 (158.2)	13	2934	10.49	3.07	0.98
45 (7)	2 (1.1)	130 (54)	2 (0.9)	218 (103)	20 (11.1)	15 (8.3)	30891 (9054)	349 (158.8)	13	3015	10.25	3.00	0.99

1 Measured on Discharge Line 6" from Compressor Discharge Port.

2 Base Refrigerant is R-410A

Performance Curves and Coefficients

The following plots show baseline R-410A and LGWP alternative DR-5 capacity, input power and COP using the 10-Coefficient polynomial equation for each refrigerant (see Figure 2 for DR-5 Coefficients). These coefficients should only be applied within the acceptable compressor operating envelope to avoid excessive extrapolation error in the results. The R-410A operating envelope for the test compressor is shown in Figure 3. The x and y –axes show dew point temperatures. Please note there are no test points beyond 45°F (7.2°C) evaporating temperature and curves are extrapolated to 55°F (12.8°C). The compressor envelope does not show performance below 80°F (26.7°C) condensing.

COOLING CAPACITY (Btu/hr):

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
30142.0983	458.967	-316.2	5.03801	-0.7509	2.296	0.00194	-0.0112	-0.00275	-0.0085

POWER (W):

P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
1006.3657	9.3925	-0.5060	-0.0187	-0.1200	0.0468	-0.0010	0.0008	0.0000	0.0007

Figure 2. DR-5 10-Coefficient Polynomial Equations for Cooling Capacity and Power (20F Superheat, 15F Subcool)

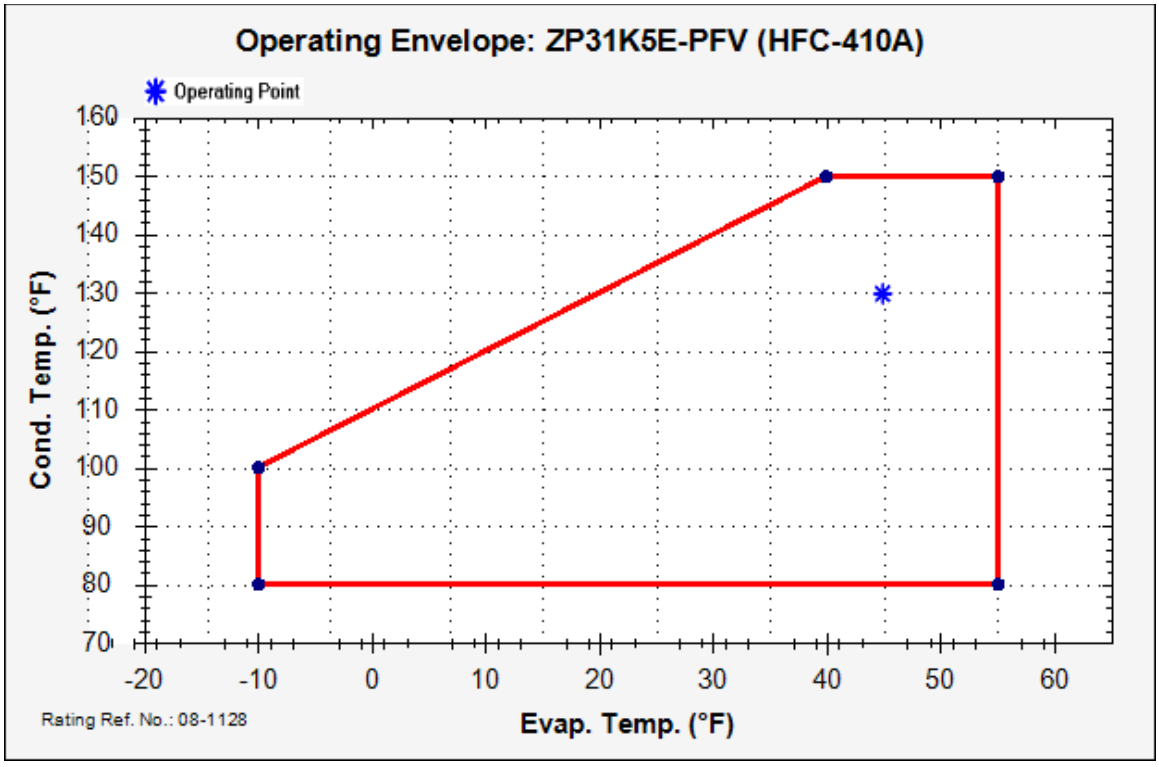

Figure 3. ZP31K5E-PFV R-410A Operating Map (20F Superheat, 15F Subcool)

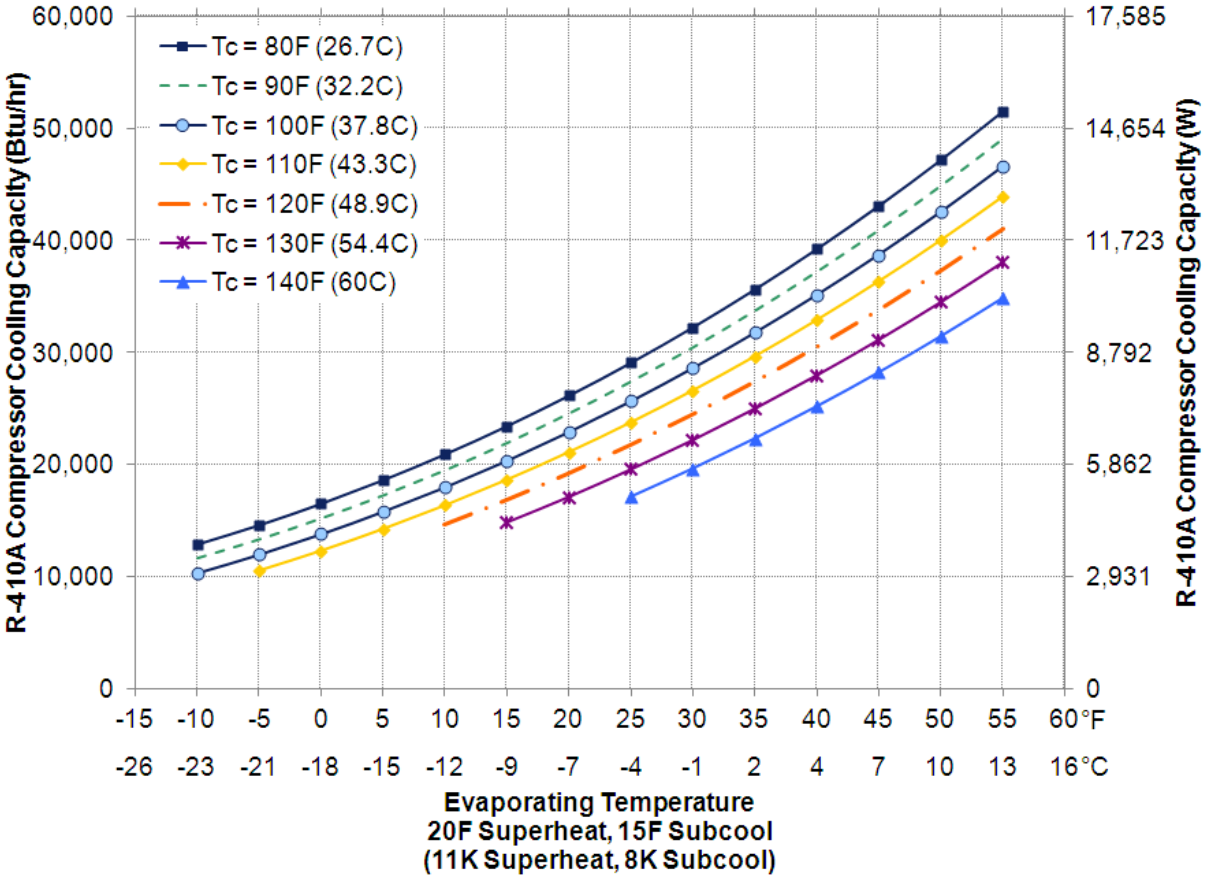

Figure 4. R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

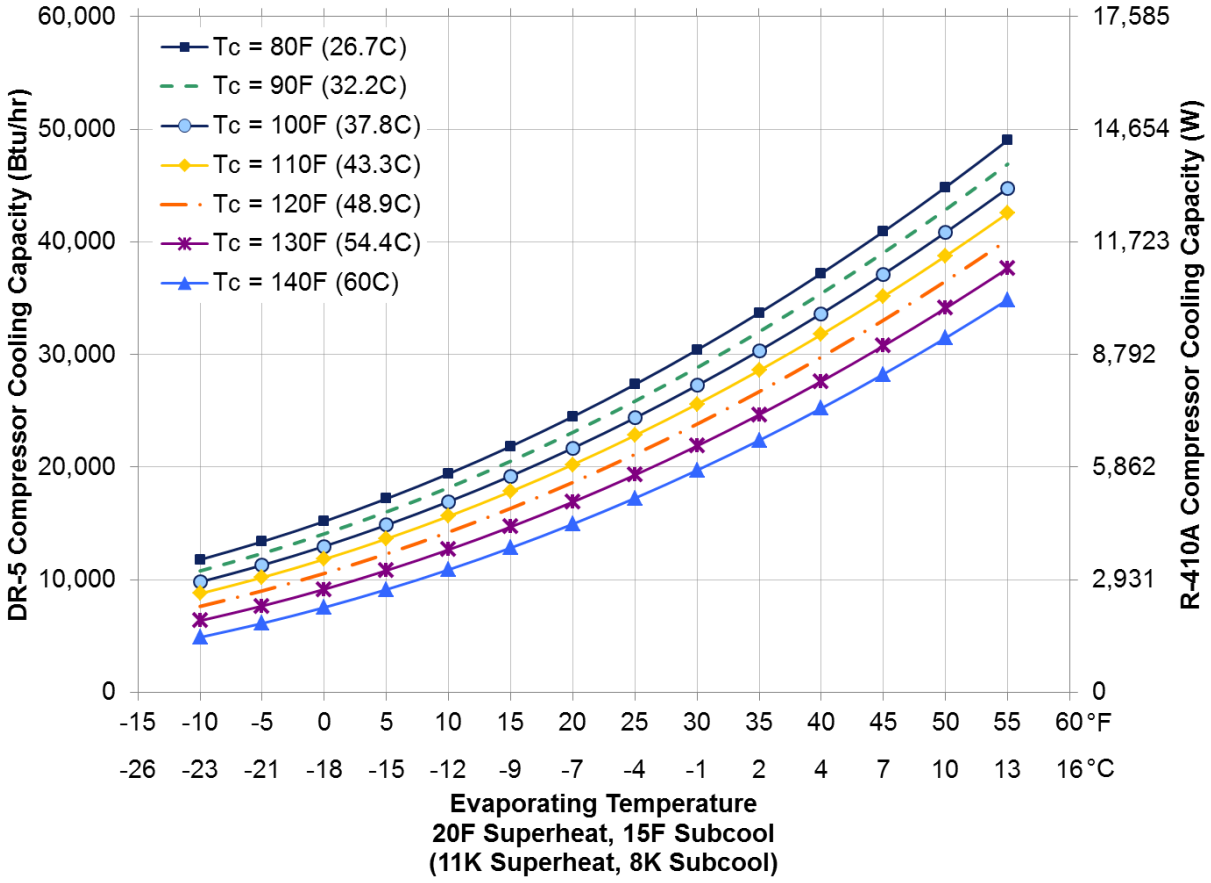

Figure 5. DR-5 Cooling Capacity vs. Evaporating Temperature (Dew Point)

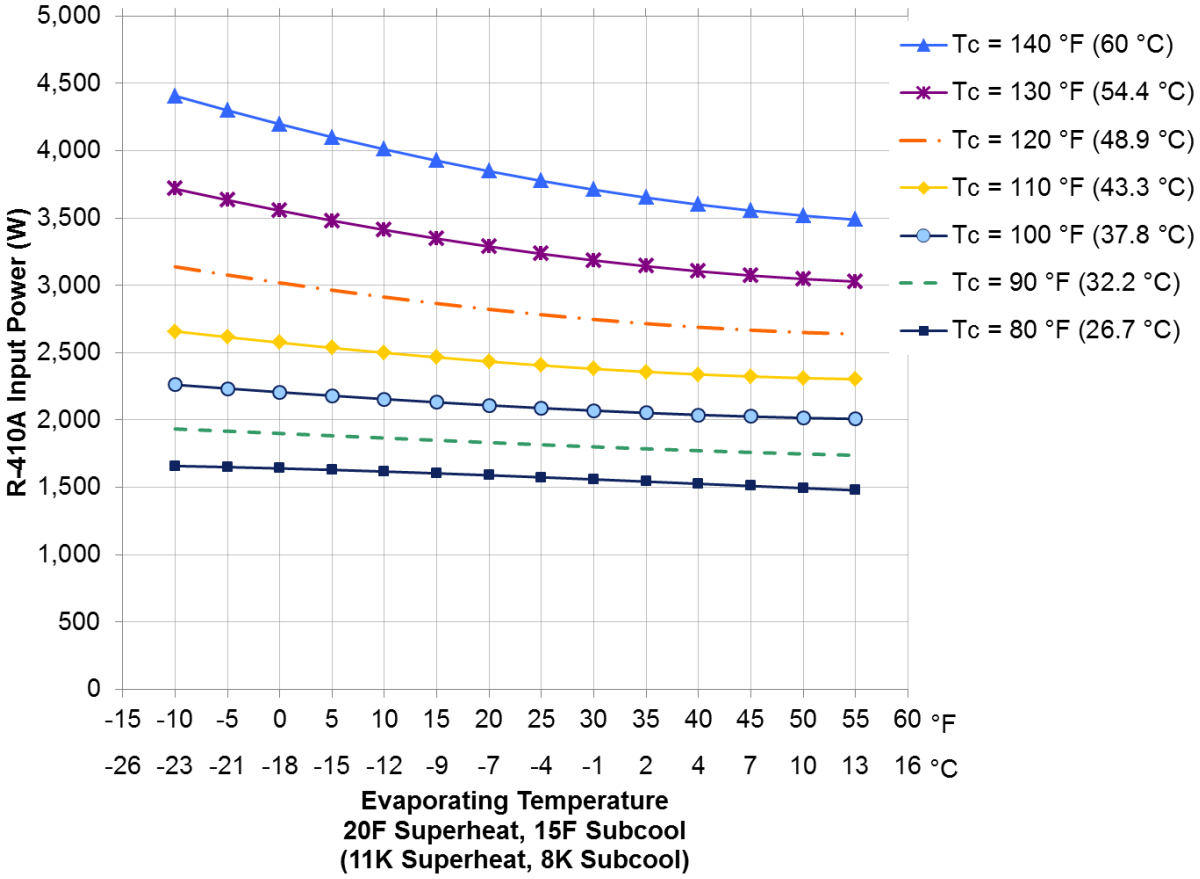

Figure 6. R-410A Input Power vs. Evaporating Temperature (Dew Point)

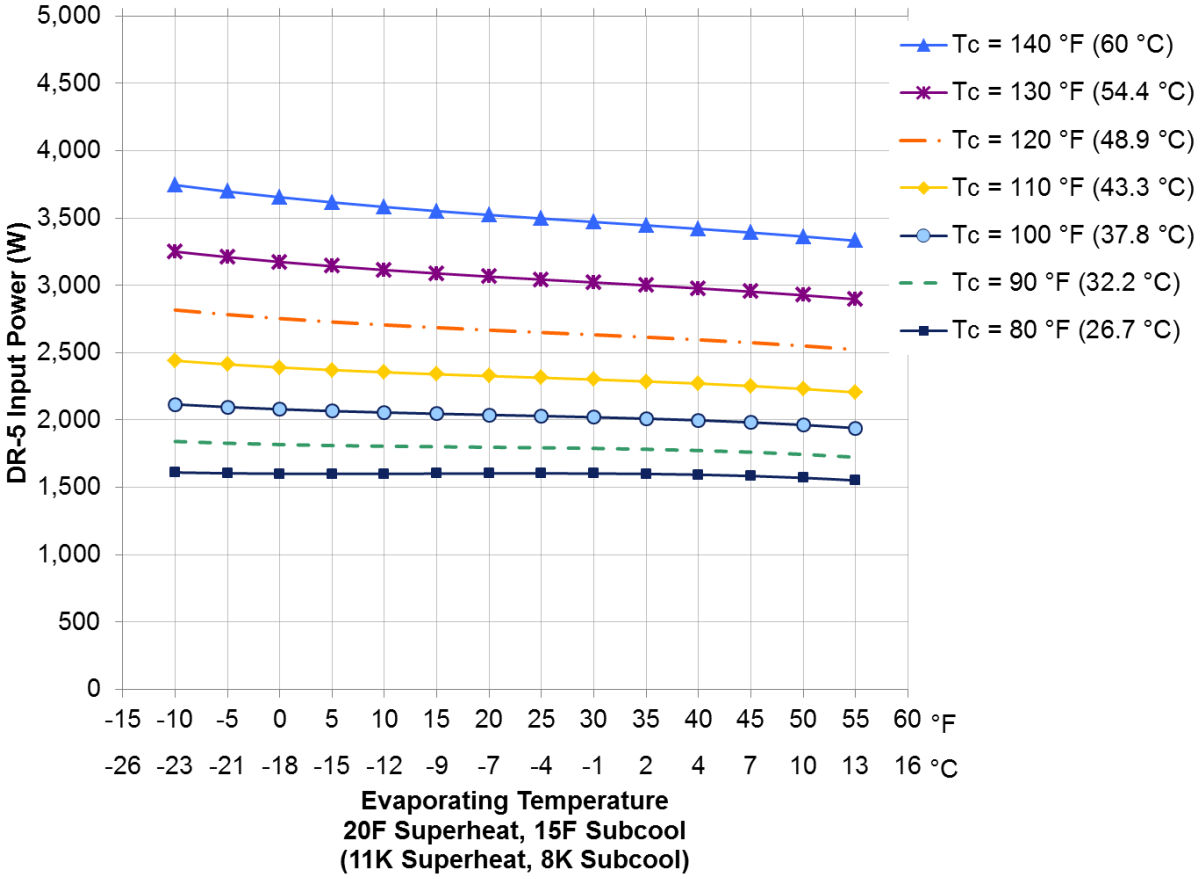

Figure 7. DR-5 Input Power vs. Evaporating Temperature (Dew Point)

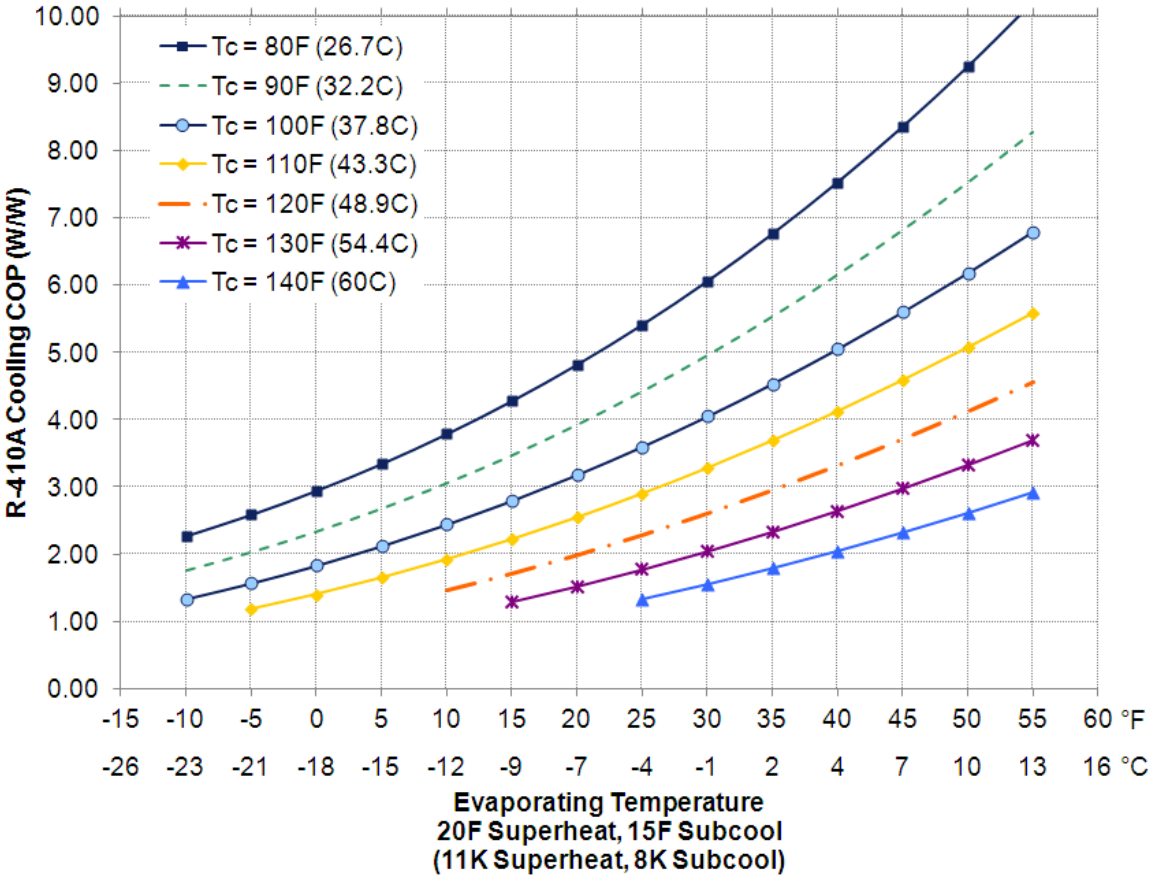

Figure 8. R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

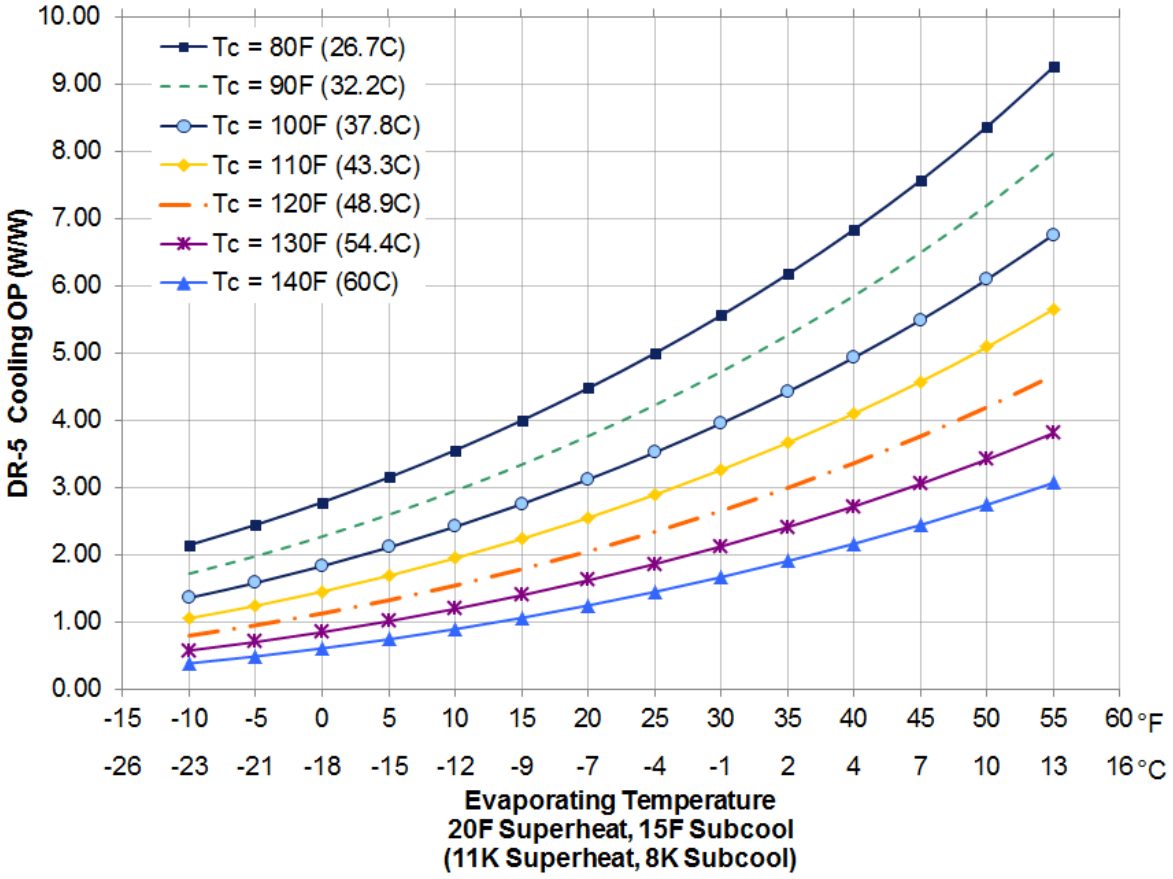

Figure 9. DR-5 Cooling COP vs. Evaporating Temperature (Dew Point)

Comparative Analysis

Figures 10 and 11 show the ratio of DR-5 to R-410A cooling COP and cooling capacity, respectively, versus evaporating temperature. At extreme operating conditions, testing uncertainties could lead to higher than normal variability in reported results.

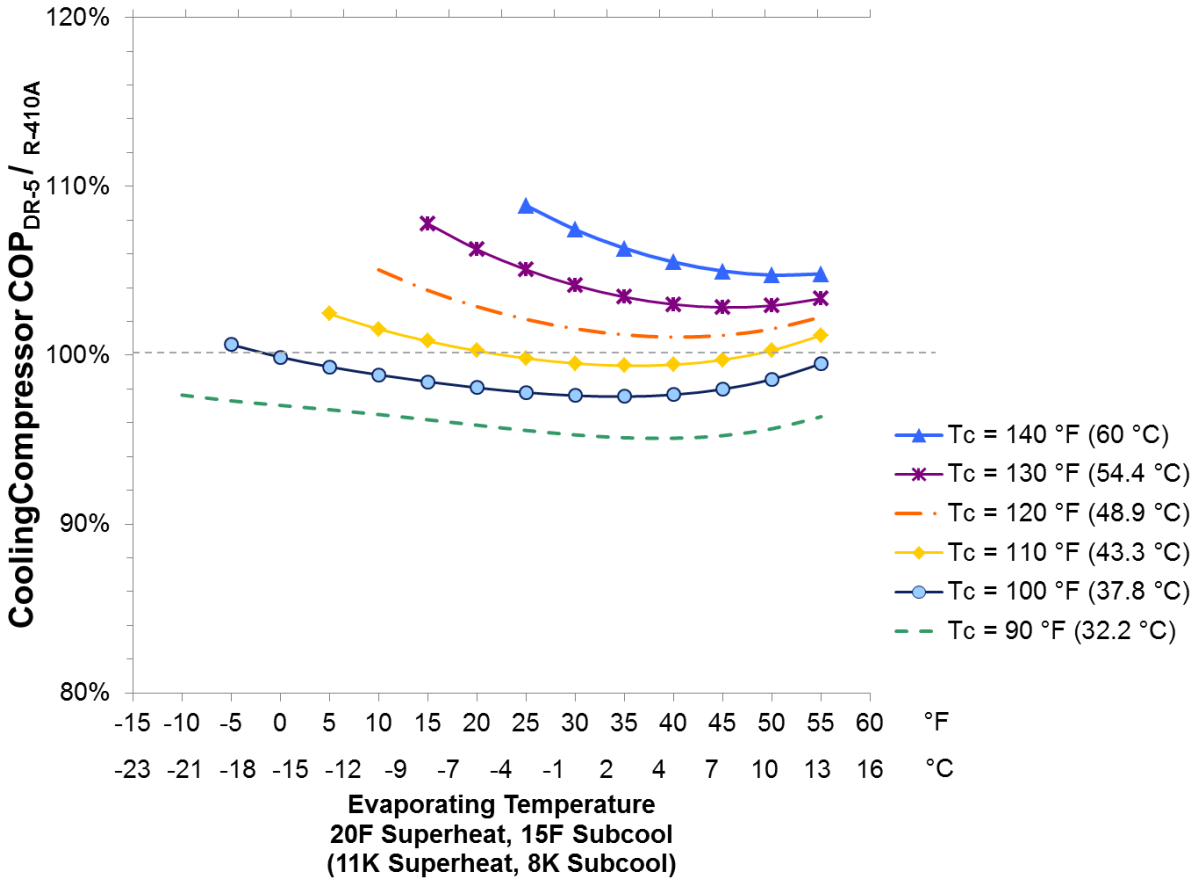

Figure 10. DR-5/R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

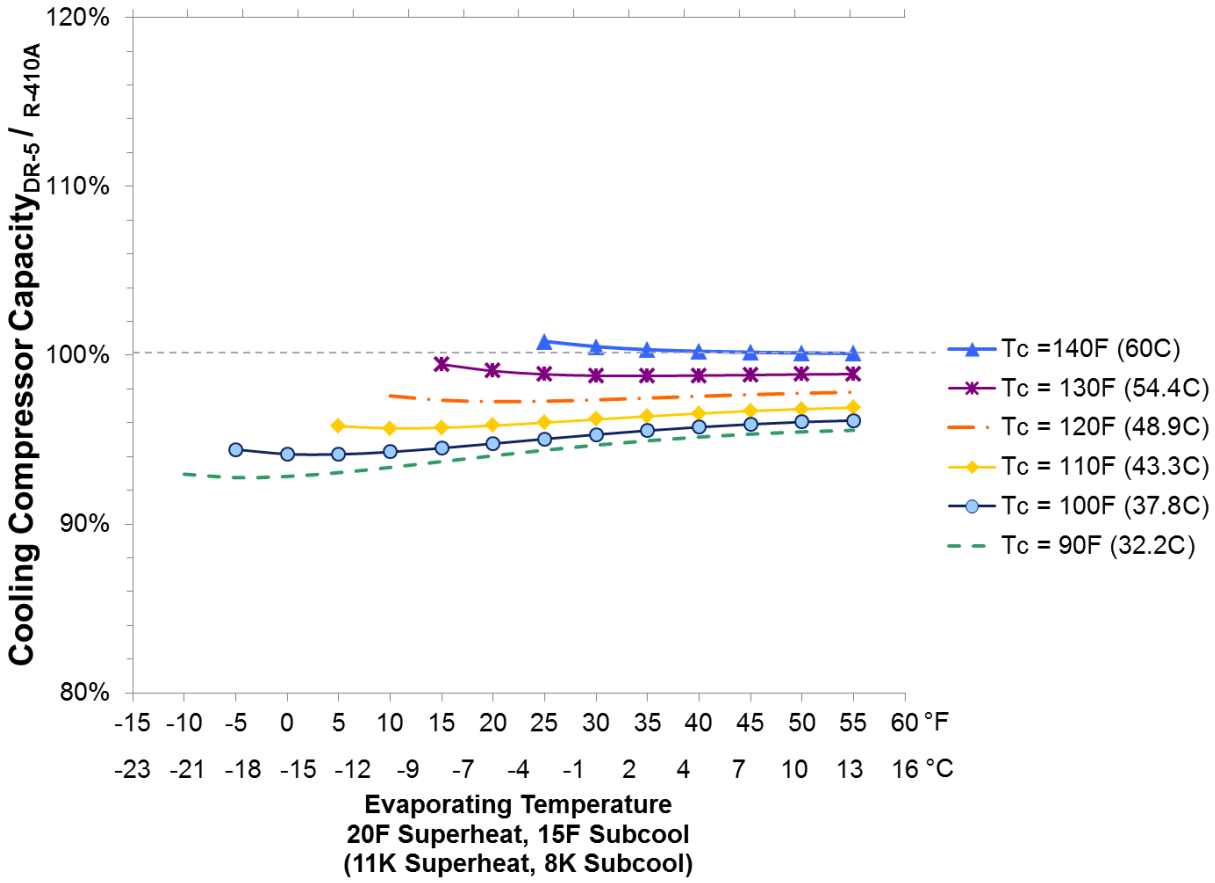

Figure 11. DR-5/R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

Summary

The calorimeter testing of DuPont DR-5 shows comparable performance to R-410A. DR-5 has relatively low refrigerant glide of about 2F (1.1C) across both the evaporator and condenser. The tested compressor capacity versus R-410A is within 90 to 100% of rated performance across the operating map of the tested compressor (refer back to Figure 3). At lower evaporating temperatures, capacity with DR-5 is lower than R-410A. This implies that DR-5 cooling performance is relatively better than its heating performance. The tested compressor COP of DR-5 is between 95 to a 110% of R-410A efficiency within the operating envelope, with efficiency greater at higher condensing temperatures.