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

TEST REPORT #38

Compressor Calorimeter Test of Refrigerant L-41b 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%)

L-41b	R-32/R-1234ze(E) (73/27)

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Contents

Introduction 3

Details of Test Setup 3

Description of Test Refrigerant-Lubricant and Charge 3

Description of Compressor 3

Table 1. Compressor Calorimeter Test Points 4

Description and Size of Test Loop 5

Figure 1. Simplified System Diagram of Test Setup 5

Table 2. Test Loop Component Accuracy 6

Results 7

Table 3. Honeywell L-41b Test Results 8

Performance Curves and Coefficients 9

Figure 2. L-41b 10-Coefficient Polynomial Equations for Cooling Capacity and Power (20F Superheat, 15F Subcool) 9

Figure 3. ZP31K5E-PFV R-410A Operating Map (20F Superheat, 15F Subcool) 9

Figure 4. R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point) 10

Figure 5. L-41b Cooling Capacity vs. Evaporating Temperature (Dew Point) 11

Figure 6. R-410A Input Power vs. Evaporating Temperature (Dew Point) 12

Figure 7. L-41b Input Power vs. Evaporating Temperature (Dew Point) 13

Figure 8. R-410A Cooling COP vs. Evaporating Temperature (Dew Point) 14

Figure 9. L-41b Cooling COP vs. Evaporating Temperature (Dew Point) 15

Comparative Analysis 16

Figure 10. L-41b/R-410A Cooling COP vs. Evaporating Temperature (Dew Point) 17

Figure 11. L-41b/R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point) 18

Summary 19

Introduction

This Report covers the calorimeter testing results of L-41b 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: Honeywell L-41b
  - 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. 10C28D08L

- 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

Ambient Air Temperature		Suction Pressure		Saturated Suction Temperature (Dew Point)		Refrigerant Vapor Temperature Entering Compressor		Discharge Pressure		Saturated Discharge Temperature (Dew Point)		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	38.9	2.6	-10	-23.3	10	-12.2	206.2	14.0	80	26.7	232	111.1	230-1-60	3,556
95	35.0	38.9	2.6	-10	-23.3	10	-12.2	239.6	16.3	90	32.2	262	127.8	230-1-60	3,547
95	35.0	43.5	3.0	-5	-20.6	15	-9.4	257.9	17.5	95	35.0	259	126.1	230-1-60	3,542
95	35.0	48.5	3.3	0	-17.8	20	-6.7	239.6	16.3	90	32.2	228	108.9	230-1-60	3,551
95	35.0	48.5	3.3	0	-17.8	20	-6.7	297.4	20.2	105	40.6	275	135.0	230-1-60	3,535
95	35.0	53.9	3.7	5	-15.0	25	-3.9	318.9	21.7	110	43.3	276	135.6	230-1-60	3,530
95	35.0	59.8	4.1	10	-12.2	30	-1.1	206.2	14.0	80	26.7	186	85.6	230-1-60	3,559
95	35.0	59.8	4.1	10	-12.2	30	-1.1	239.6	16.3	90	32.2	206	96.7	230-1-60	3,551
95	35.0	73.1	5.0	20	-6.7	40	4.4	277.1	18.9	100	37.8	208	97.8	230-1-60	3,544
95	35.0	73.1	5.0	20	-6.7	40	4.4	365.4	24.9	120	48.9	258	125.6	230-1-60	3,474
95	35.0	73.1	5.0	20	-6.7	40	4.4	390.6	26.6	125	51.7	269	131.7	230-1-60	3,508
95	35.0	80.6	5.5	25	-3.9	45	7.2	417.2	28.4	130	54.4	267	130.6	230-1-60	3,501
95	35.0	88.6	6.0	30	-1.1	50	10.0	206.2	14.0	80	26.7	156	68.9	230-1-60	3,556
95	35.0	88.6	6.0	30	-1.1	50	10.0	318.9	21.7	110	43.3	211	99.4	230-1-60	3,535
95	35.0	88.6	6.0	30	-1.1	50	10.0	445.1	30.3	135	57.2	273	133.9	230-1-60	3,494
95	35.0	97.2	6.6	35	1.7	55	12.8	474.6	32.3	140	60.0	272	133.3	230-1-60	3,486
95	35.0	106.4	7.2	40	4.4	60	15.6	239.6	16.3	90	32.2	160	71.1	230-1-60	3,554
95	35.0	106.4	7.2	40	4.4	60	15.6	365.4	24.9	120	48.9	212	100.0	230-1-60	3,523
95	35.0	106.4	7.2	40	4.4	60	15.6	505.6	34.4	145	62.8	273	133.9	230-1-60	3,474
95	35.0	116.2	7.9	45	7.2	65	18.3	277.1	18.9	100	37.8	171	77.2	230-1-60	3,544
95	35.0	116.2	7.9	45	7.2	65	18.3	417.2	28.4	130	54.4	225	107.2	230-1-60	3,508
95	35.0	116.2	7.9	45	7.2	65	18.3	417.2	28.4	130	54.4	224	106.7	230-1-60	3,561
95	35.0	116.2	7.9	45	7.2	65	18.3	474.6	32.3	140	60.0	247	119.4	230-1-61	3,488
95	35.0	124.6	8.5	49	9.4	69	20.6	433.8	29.5	133	56.1	225	107.2	230-1-62	3,501
95	35.0	126.8	8.6	50	10.0	70	21.1	277.1	18.9	100	37.8	167	75.0	230-1-63	3,544
95	35.0	126.8	8.6	50	10.0	70	21.1	341.6	23.2	115	46.1	190	87.8	230-1-64	3,530
95	35.0	138.0	9.4	55	12.8	75	23.9	206.2	14.0	80	26.7	135	57.2	230-1-65	3,561
95	35.0	138.0	9.4	55	12.8	75	23.9	365.4	24.9	120	48.9	193	89.4	230-1-66	3,525
95	35.0	138.0	9.4	55	12.8	75	23.9	474.6	32.3	140	60.0	230	110.0	230-1-67	3,489
95	35.0	138.0	9.4	55	12.8	75	23.9	538.3	36.6	150	65.6	252	122.2	230-1-68	3,469

[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.

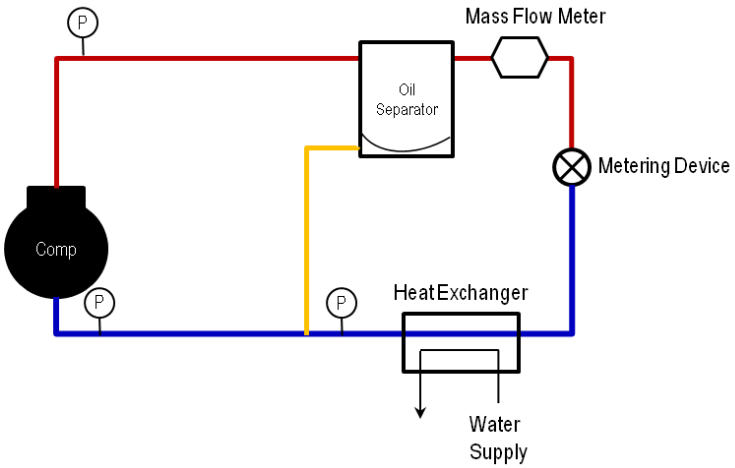

Figure 1. Simplified System Diagram of Test Setup

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	± 1.62° F	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 L-41b. The R-410A baseline data is from published nominal rating data (capacity and EER within ±5% of test data). Capacity calculations for L-41b 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. Honeywell L-41b Test Results

Evaporating Temperature, °F (°C) *Dew Point*	Evaporator Glide, F (C)	Condensing Temperature, °F (°C) *Dew Point*	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)	8 (4.5)	80 (27)	7 (4)	232 (111)	20 (11.1)	15 (8.3)	9382 (2750)	86 (39)	6	1435	6.54	1.92	0.84
-10 (-23)	8 (4.5)	90 (32)	7 (3.8)	262 (128)	20 (11.1)	15 (8.3)	8658 (2538)	83 (37.9)	7	1644	5.27	1.54	0.88
-5 (-21)	8 (4.5)	95 (35)	7 (3.8)	259 (126)	20 (11.1)	15 (8.3)	9631 (2823)	93 (42.2)	8	1749	5.51	1.61	0.90
0 (-18)	8 (4.5)	90 (32)	7 (3.8)	228 (109)	20 (11.1)	15 (8.3)	11659 (3417)	110 (49.8)	7	1618	7.21	2.11	0.90
0 (-18)	8 (4.5)	105 (41)	7 (3.6)	275 (135)	20 (11.1)	15 (8.3)	10177 (2983)	102 (46.3)	9	1989	5.12	1.50	0.93
5 (-15)	8 (4.4)	110 (43)	6 (3.6)	276 (136)	20 (11.1)	15 (8.3)	11211 (3286)	114 (51.8)	9	2132	5.26	1.54	0.94
10 (-12)	8 (4.4)	80 (27)	7 (4)	186 (86)	20 (11.1)	15 (8.3)	15953 (4676)	143 (64.9)	6	1425	11.20	3.28	0.87
10 (-12)	8 (4.4)	90 (32)	7 (3.8)	206 (97)	20 (11.1)	15 (8.3)	15114 (4430)	141 (63.9)	7	1614	9.36	2.74	0.90
20 (-7)	8 (4.4)	100 (38)	7 (3.7)	208 (98)	20 (11.1)	15 (8.3)	17826 (5225)	171 (77.6)	8	1826	9.76	2.86	0.90
20 (-7)	8 (4.4)	120 (49)	6 (3.4)	258 (126)	20 (11.1)	15 (8.3)	15331 (4493)	161 (73)	11	2381	6.44	1.89	0.95
20 (-7)	8 (4.4)	125 (52)	6 (3.3)	269 (132)	20 (11.1)	15 (8.3)	14995 (4395)	161 (73.2)	11	2559	5.86	1.72	0.98
25 (-4)	8 (4.4)	130 (54)	6 (3.2)	267 (131)	20 (11.1)	15 (8.3)	16660 (4883)	182 (82.9)	12	2725	6.11	1.79	1.01
30 (-1)	8 (4.3)	80 (27)	7 (4)	156 (69)	20 (11.1)	15 (8.3)	25541 (7486)	224 (101.9)	6	1399	18.26	5.35	0.88
30 (-1)	8 (4.3)	110 (43)	6 (3.6)	211 (99)	20 (11.1)	15 (8.3)	21063 (6173)	208 (94.8)	9	2071	10.17	2.98	0.91
30 (-1)	8 (4.3)	135 (57)	6 (3.1)	273 (134)	20 (11.1)	15 (8.3)	17290 (5067)	193 (87.9)	13	2910	5.94	1.74	0.98
35 (2)	8 (4.3)	140 (60)	5 (2.9)	272 (133)	20 (11.1)	15 (8.3)	18795 (5508)	215 (97.7)	14	3105	6.05	1.77	0.99
40 (4)	8 (4.3)	90 (32)	7 (3.8)	160 (71)	20 (11.1)	15 (8.3)	30155 (8838)	272 (123.9)	7	1579	19.10	5.60	0.91
40 (4)	8 (4.3)	120 (49)	6 (3.4)	212 (100)	20 (11.1)	15 (8.3)	25230 (7394)	259 (117.6)	10	2340	10.78	3.16	0.95
40 (4)	8 (4.3)	145 (63)	5 (2.8)	273 (134)	20 (11.1)	15 (8.3)	20381 (5973)	239 (108.5)	15	3301	6.17	1.81	1.01
45 (7)	8 (4.2)	100 (38)	7 (3.7)	171 (77)	20 (11.1)	15 (8.3)	31085 (9110)	291 (132.2)	8	1784	17.42	5.11	0.91
45 (7)	8 (4.2)	130 (54)	6 (3.2)	225 (107)	20 (11.1)	15 (8.3)	26013 (7624)	279 (126.8)	12	2679	9.71	2.85	0.96
45 (7)	8 (4.2)	130 (54)	6 (3.2)	224 (107)	20 (11.1)	15 (8.3)	26372 (7729)	283 (128.5)	12	2682	9.83	2.88	0.97
45 (7)	8 (4.2)	140 (60)	5 (2.9)	247 (119)	20 (11.1)	15 (8.3)	24174 (7085)	274 (124.3)	14	3064	7.89	2.31	0.99
49 (9)	8 (4.2)	133 (56)	6 (3.1)	225 (107)	20 (11.1)	15 (8.3)	27744 (8131)	301 (136.8)	12	2782	9.97	2.92	0.97
50 (10)	8 (4.2)	100 (38)	7 (3.7)	167 (75)	20 (11.1)	15 (8.3)	34129 (10003)	318 (144.6)	8	1795	19.01	5.57	0.90
50 (10)	8 (4.2)	115 (46)	6 (3.5)	190 (88)	20 (11.1)	15 (8.3)	31819 (9326)	316 (143.7)	10	2167	14.68	4.30	0.94
55 (13)	8 (4.2)	80 (27)	7 (4)	135 (57)	20 (11.1)	15 (8.3)	41637 (12203)	358 (162.9)	6	1335	31.19	9.14	0.90
55 (13)	8 (4.2)	120 (49)	6 (3.4)	193 (89)	20 (11.1)	15 (8.3)	34102 (9995)	345 (156.9)	10	2302	14.81	4.34	0.95
55 (13)	8 (4.2)	140 (60)	5 (2.9)	230 (110)	20 (11.1)	15 (8.3)	29939 (8775)	336 (152.5)	13	3023	9.90	2.90	0.99
55 (13)	8 (4.2)	150 (66)	5 (2.6)	252 (122)	20 (11.1)	15 (8.3)	27537 (8071)	327 (148.8)	15	3481	7.91	2.32	1.02

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 L-41b capacity, input power and COP using the 10-Coefficient polynomial equation for each refrigerant (see Figure 2 for L-41b Coefficients). These coefficients should only be applied within the acceptable compressor operating envelope to avoid excessive extrapolation error in the results.

COOLING CAPACITY (Btu/hr):

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
35820.0970	550.0112	-591.7621	3.7595	-3.2850	5.0716	-0.0021	-0.0001	0.0070	-0.0167

POWER (W):

P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
94.4002	-4.1835	23.0330	-0.0749	0.1358	-0.1853	-0.0008	0.0013	-0.0012	0.0013

Figure 2. L-41b 10-Coefficient Polynomial Equations for Cooling Capacity and Power (20F Superheat, 15F Subcool)

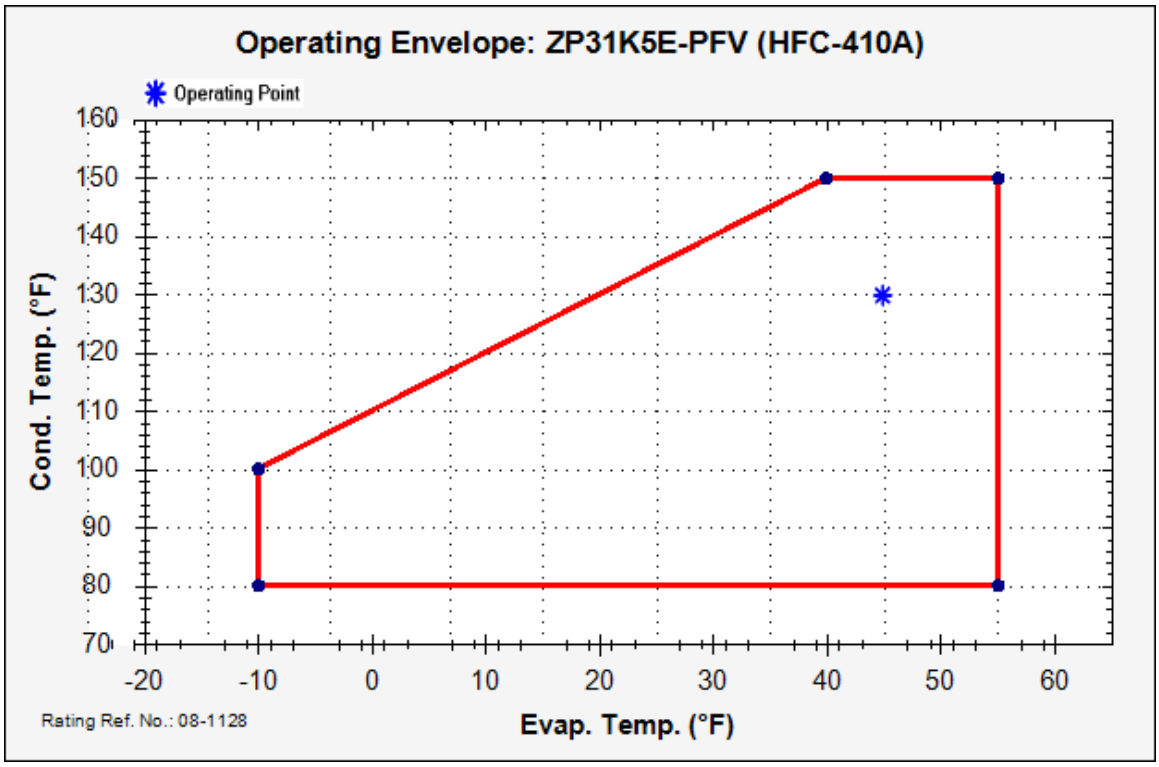

Figure 3. ZP31K5E-PFV R-410A Operating Map (20F Superheat, 15F Subcool)

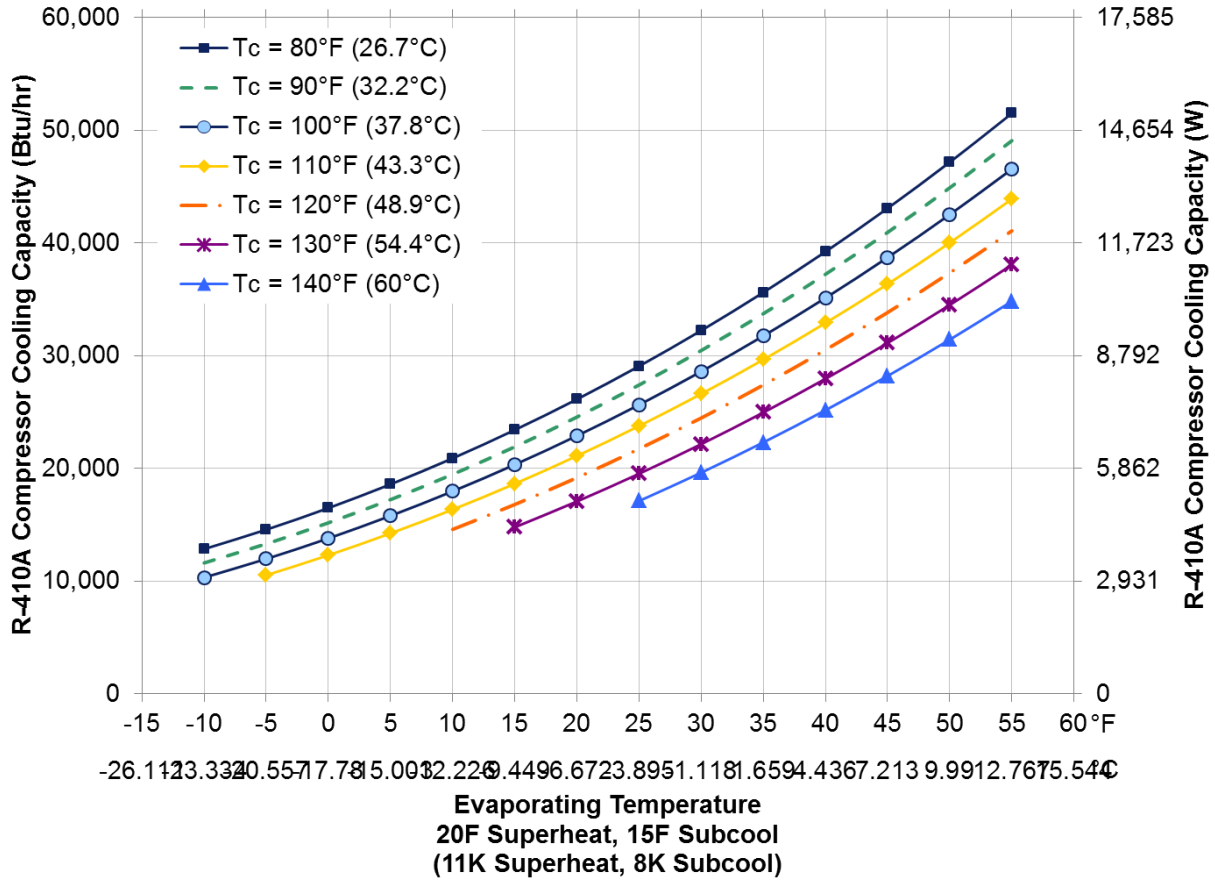

Figure 4. R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

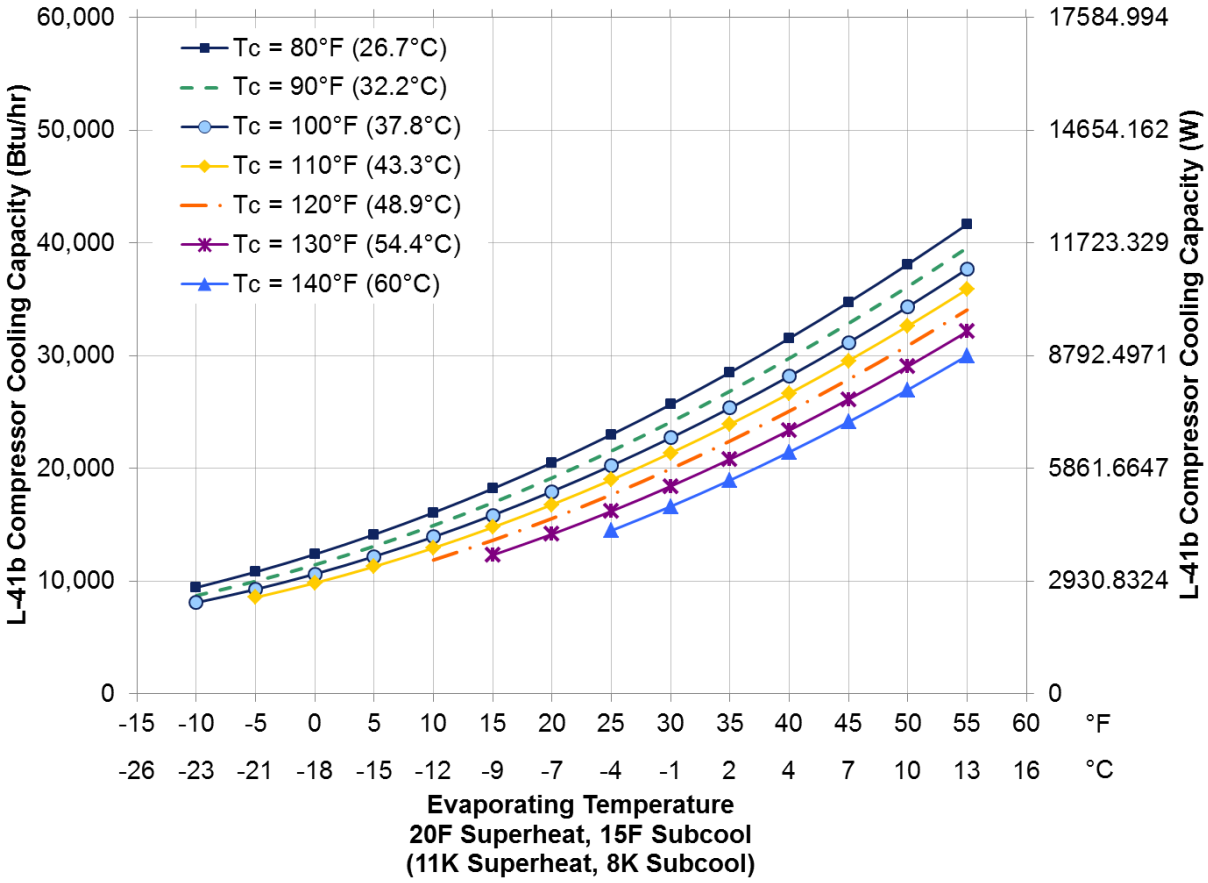

Figure 5. L-41b Cooling Capacity vs. Evaporating Temperature (Dew Point)

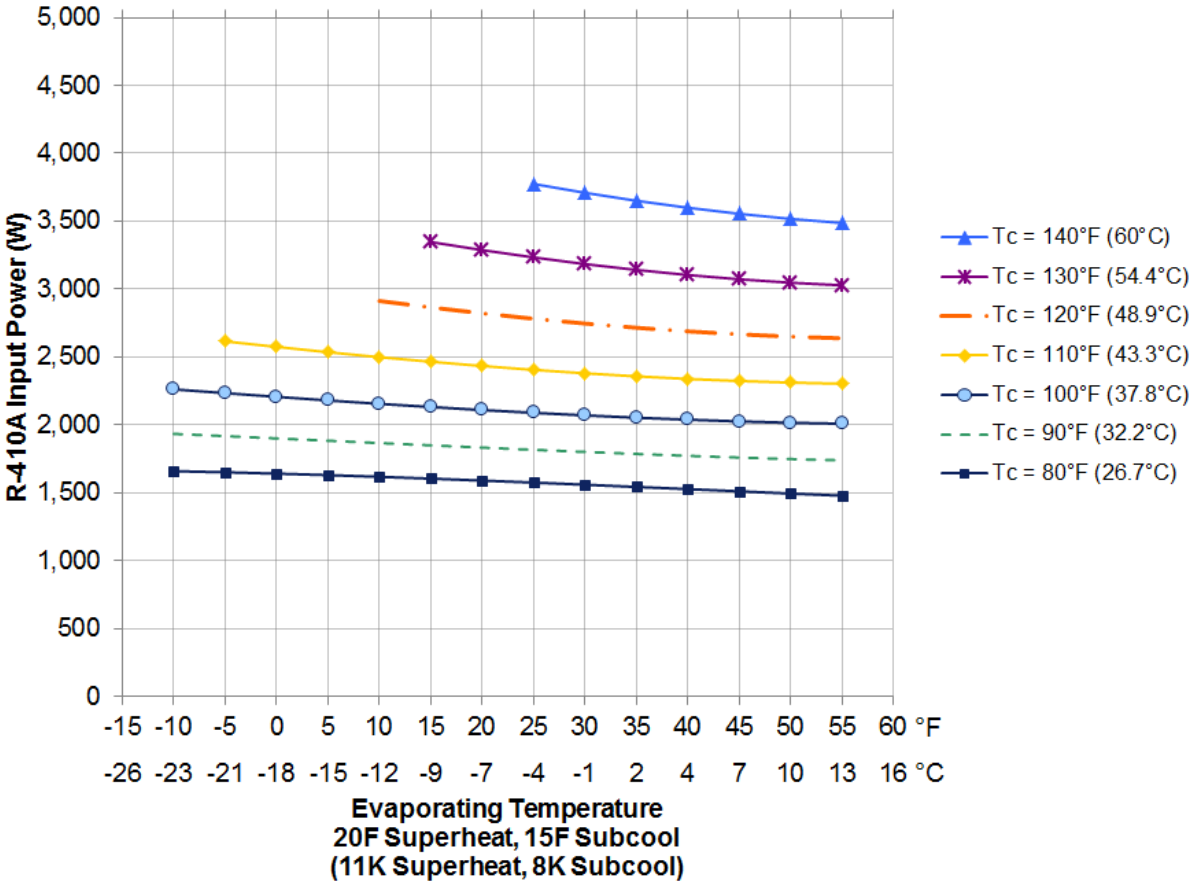

Figure 6. R-410A Input Power vs. Evaporating Temperature (Dew Point)

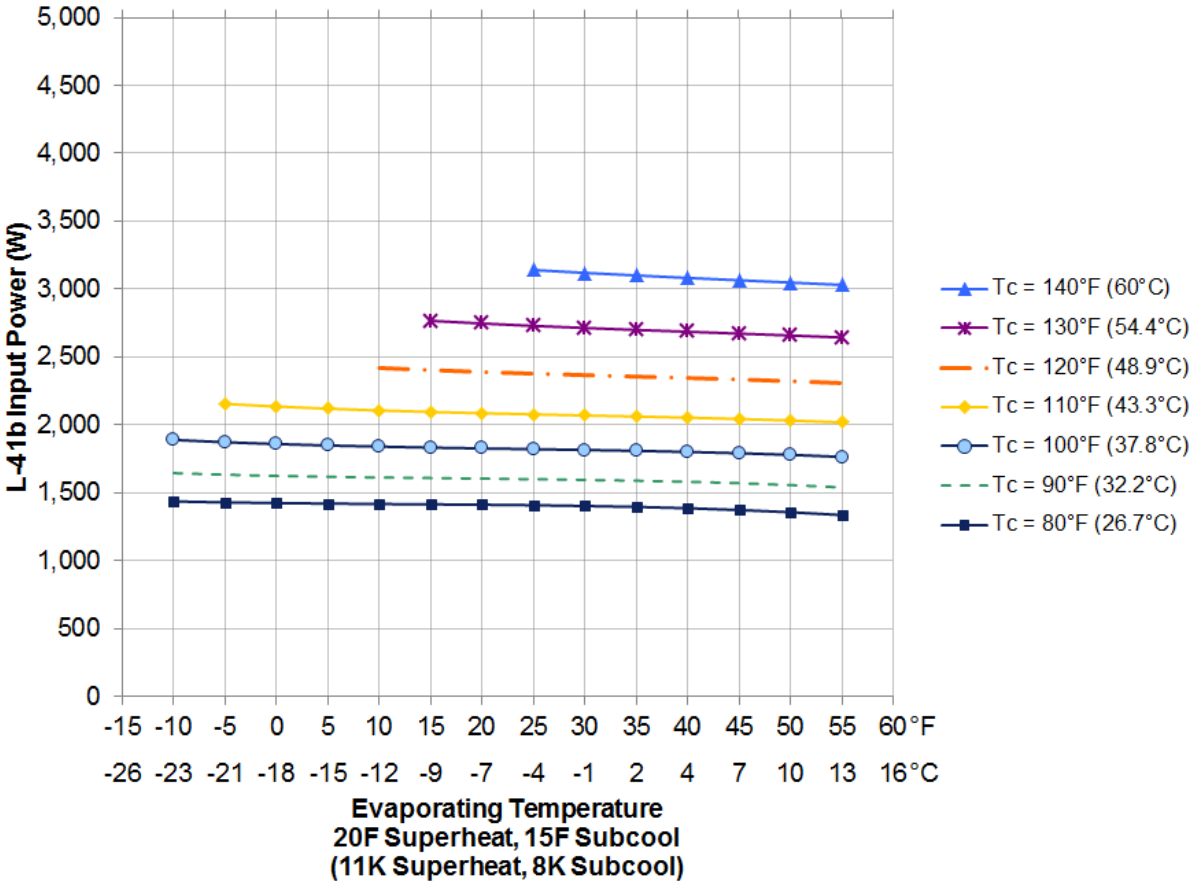

Figure 7. L-41b Input Power vs. Evaporating Temperature (Dew Point)

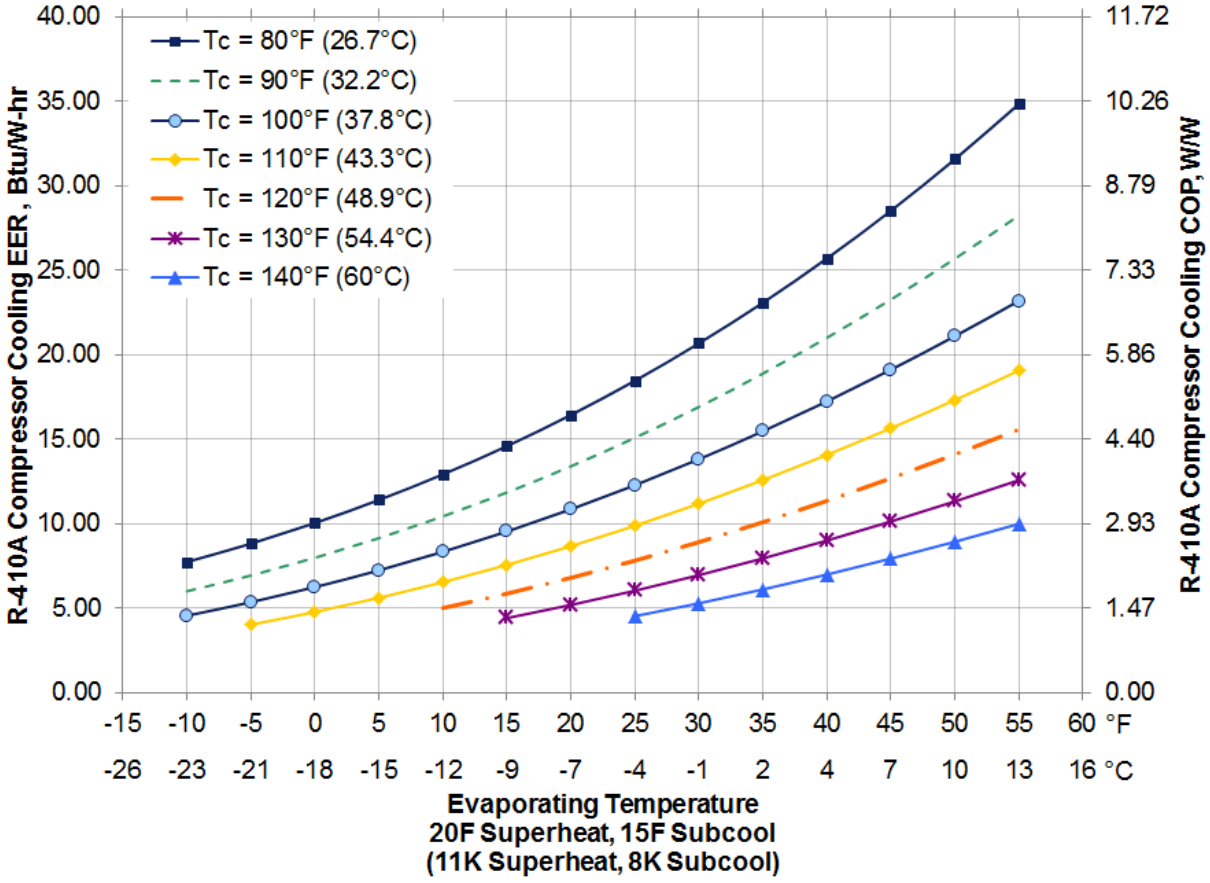

Figure 8. R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

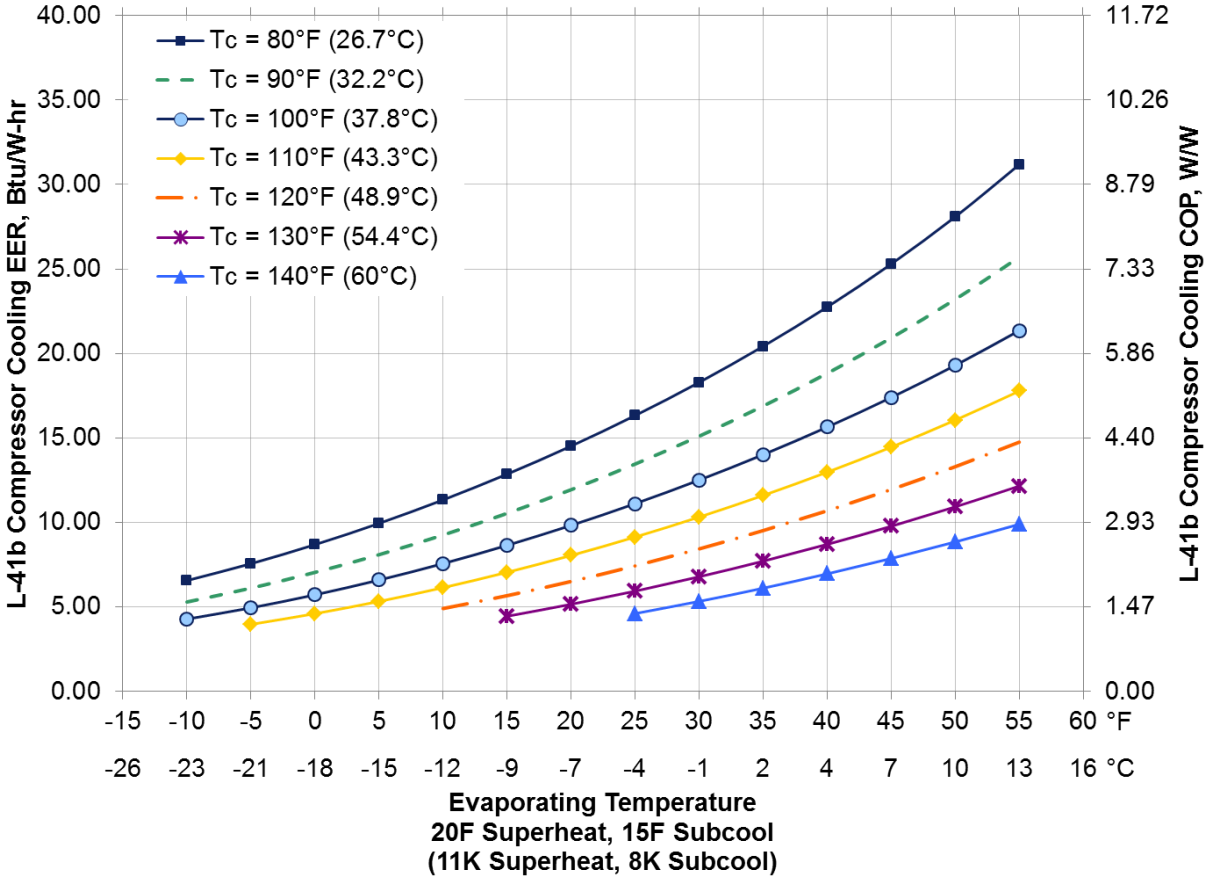

Figure 9. L-41b Cooling COP vs. Evaporating Temperature (Dew Point)

Comparative Analysis

Figures 10 and 11 show the ratio of L-41b 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.

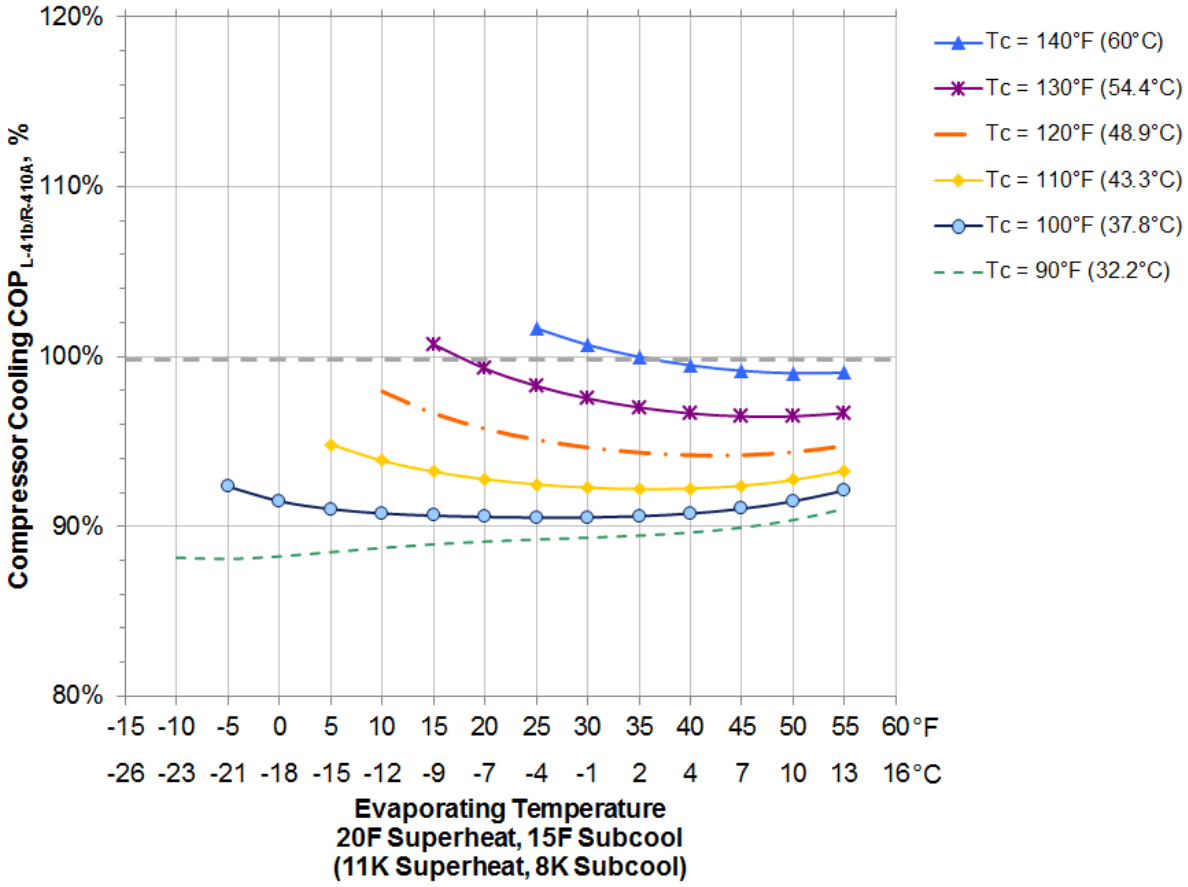

Figure 10. L-41b/R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

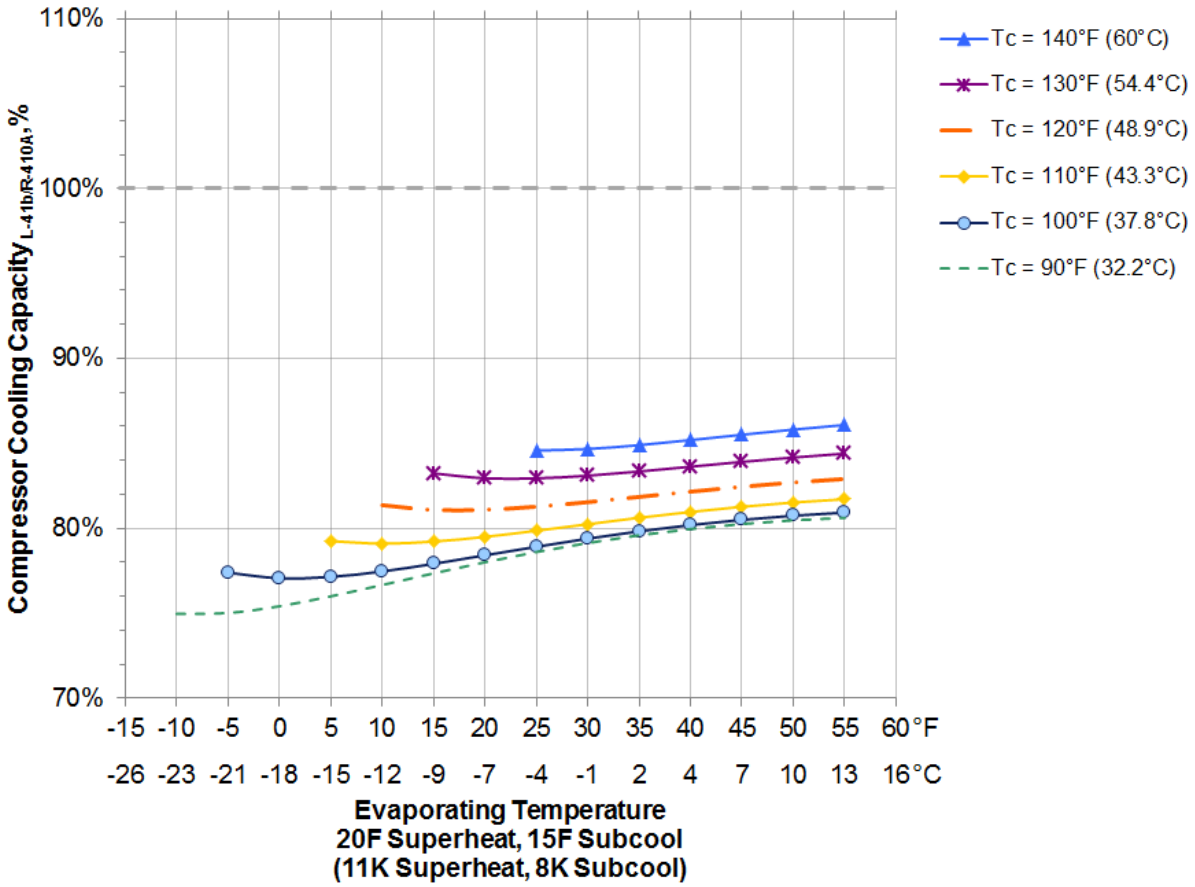

Figure 11. L-41b/R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

Summary

The calorimeter testing of Honeywell L-41b was carried out at dew point conditions and compared to R-410A. L-41b has moderate refrigerant glide of about 8F (4.5C). The tested compressor capacity versus R-410A is within 75 to 85% of rated performance across the operating map of the tested compressor (refer back to Figure 3). At lower evaporating temperatures, capacity with L-41b is lower than R-410A. This implies that L-41b compressor performance in cooling is relatively better than its performance in heating. The tested compressor COP of L-41b is between 85 and 100% of R-410A within the operating envelope.