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

TEST REPORT #65

Compressor Calorimeter Test of Refrigerant L-41-2 (R-447A) in a R-410A Scroll Compressor

Rajan Rajendran
Hung Pham
Bachir Bella
Tim Skillen

Emerson Climate Technologies, Inc.
1675 West Campbell Rd.
Sidney, OH 45373-0669

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List of Tested Refrigerants' Compositions (Mass%)

R-447A	R-32(68%) R-125(3.5%) R-1234ze(E)(28.5%)

GWP of Tested Refrigerants

R-410A	GWP 2080
R-447A	GWP 570

Contents

Introduction

This Report covers the calorimeter testing results of R-447A performed by Emerson Climate Technologies, Inc. (Emerson) for the AHRI Low-GWP AREP 2 Study. The testing was done in Emerson's A2L Research calorimeter lab test facility located in Mikulov, Czech Republic. The refrigerant was tested with a R-410A Copeland Scroll Compressor ZP122KCE-TFD for Air Conditioning applications. This report is based on 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 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 and Test Setup

Description of Test Refrigerant-Lubricant and Charge

- Refrigerant / Refrigerant Blend Tested:
    - Initial Refrigerant Charge: 3.5 lbs (1.6 kg)
- Lubricant:
    - Oil: 32-3MAF POE Oil
    - Viscosity Grade: 32 Cst.
    - Any modifications to base lubricant? No

Description of Compressor

- Copeland R-410A Scroll Compressor
- No Compressor Modifications
- Emerson Climate Technologies, Inc. Copeland Brand
- Model No. ZP122KCE-TFD, Serial No.14AAD980L
- Motor Nameplate Rating: 380/420V
- Displacement: 6.853 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		Absolute Suction Pressure		Saturated Suction Temperature (Dew Point)[1]		Refrigerant Gas Temperature Entering Compressor		Absolute Discharge Pressure		Saturated Discharge Temperature (Dew Point)[1]		Discharge Temperature		Volts – Phase - Frequency	Speed (nominal)
°F	°C	psia	bar	°F	°C	°F	°C	psia	bar	°F	°C	°F	°C		rpm
78	26	35.4	2.44	-12.9	-24.9	5.2	-14.9	192.1	13.2	76.8	24.9	237	113.9	380-3-50	2900
77	25	43.4	2.99	-3.9	-19.9	14.5	-9.7	192.1	13.2	76.8	24.9	209	98.1	380-3-50	2900
80	26	63.3	4.36	14.0	-10.0	31.4	-0.4	192.2	13.3	76.8	24.9	171	77.3	380-3-50	2900
80	26	89.6	6.18	32.0	0.0	49.2	9.5	192.2	13.3	76.8	24.9	148	64.2	380-3-50	2900
78	26	123.7	8.53	49.9	10.0	68.0	20.0	220.5	15.2	85.8	29.9	147	63.8	380-3-50	2900
81	27	52.6	3.62	5.0	-15.0	21.9	-5.6	252.0	17.4	94.8	34.9	228	109.0	380-3-50	2900
81	27	71.2	4.91	19.9	-6.7	38.2	3.5	251.9	17.4	94.8	34.9	193	89.6	380-3-50	2900
80	27	104.7	7.22	40.5	4.7	58.9	14.9	252.1	17.4	94.8	34.9	167	75.0	380-3-50	2900
73	23	166.8	11.5	67.8	19.9	86.0	30.0	252.1	17.4	94.9	34.9	150	65.6	380-3-50	2900
82	28	63.2	4.36	14.0	-10.0	32.1	0.0	325.7	22.5	112.9	45.0	249	120.4	380-3-50	2900
77	25	71.2	4.91	19.9	-6.7	37.4	3.0	368.3	25.4	122.0	50.0	253	122.5	380-3-50	2900
78	26	105.6	7.28	40.9	4.9	59.0	15.0	368.5	25.4	122.0	50.0	209	98.6	380-3-50	2900
70	21	144.0	9.93	58.9	14.9	77.0	25.0	368.4	25.4	122.0	50.0	190	88.0	380-3-50	2900
80	27	166.8	11.5	67.8	19.9	86.0	30.0	368.4	25.4	122.0	50.0	186	85.4	380-3-50	2900
71	22	123.7	8.53	49.9	10.0	68.0	20.0	467.5	32.2	140.2	60.1	232	111.3	380-3-50	2900
74	23	166.8	11.5	67.8	19.9	86.0	30.0	467.5	32.2	140.2	60.1	212	100.1	380-3-50	2900
68	20	105.6	7.28	40.9	4.9	59.0	15.0	467.5	32.2	140.2	60.1	247	119.4	380-3-50	2900
73	23	123.7	8.53	49.9	10.0	68.0	20.0	524.5	36.2	149.3	65.2	251	121.8	380-3-50	2900
69	20	105.6	7.28	40.9	5.0	58.7	14.8	524.3	36.2	149.3	65.2	271	132.7	380-3-50	2900
69	20	99.0	6.82	37.3	3.0	55.4	13.0	524.4	36.2	149.3	65.2	280	137.8	380-3-50	2900
66	19	35.3	2.43	-13.0	-25.0	5.3	-14.9	220.4	15.2	85.8	29.9	266	130.0	380-3-50	2900
66	19	35.5	2.45	-12.7	-24.8	4.4	-15.3	232.9	16.1	89.5	31.9	278	136.9	380-3-50	2900
68	20	166.8	11.5	67.8	19.9	86.0	30.0	524.4	36.2	149.3	65.2	228	109.0	380-3-50	2900

[1] *Discharge temperature measured 6 in. (152.4 mm) downstream of compressor discharge port*

[2] *Applied Superheat of 20 °F*

Description and Size of Test Loop

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

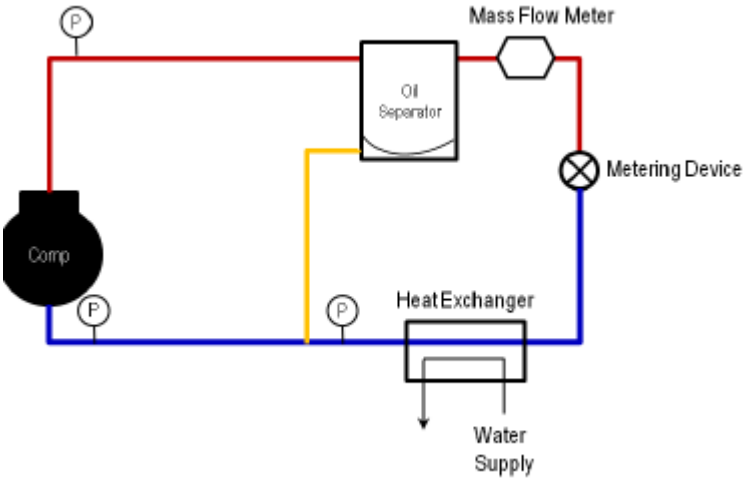

Figure 1: Simplified System Diagram of Test Setup

Table 2 Test Loop Component Accuracy

Device	Instrumentation Accuracy	Full Scale/Span
Rosemount 3051 4-20 mA		
Suction Pressure Transducer	± .065 % of span	290 psia
Discharge Pressure Transducer	± .065 % of span	725 psia
EVI Pressure Transducer	± .065 % of span	725 psia
Pt100		
Suction Temperature Transducer	± 0.15 °C ± 0.02 % of rate	-200 to + 600 °C
Discharge Temperature Transducer	± 0.15 °C ± 0.02 % of rate	-200 to + 600 °C
EVI Temperature Transducer	± 0.15 °C ± 0.02 % of rate	-200 to + 600 °C
PM850MG		
Watts	± 0.5 % of full scale	15 kW
Volts	± 0.1 % of full scale	600 V
Amps	± 0.1 % of full scale	100 A
Frequency	± 0.01 Hz	45-67 Hz
CMF 050		
Compressor Mass Flow	Gas flow rate: ± 0.35 % rate	

Results

Table 3 shows the test results from drop-in compressor testing with R-447A. The R-410A baseline data is from published nominal rating data (Capacity and EER within ±5% of test data). Capacity calculations for R-447A 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 R-447A Test Results

Evaporating Temperature (Dew Point)		Evaporator Glide[1]		Condensing Temperature (Dew Point)		Condenser Glide[1]		Applicable Superheating		Applicable Subcooling		Cooling Capacity		Refrigerant Mass Flow rate		Current	Input Power	Cooling EER	Cooling COP	Cooling COP Ratio R-447A/R-410A
°F	°C	°R	K	°F	°C	°R	K	°R	K	°R	K	BTU/h	W	lb/h	kg/s	A	W	Btu/Wh		
-12.9	-24.9	7.0	3.9	76.8	24.9	7.9	4.4	20.0	11.1	15.0	8.3	28,985	8,495	55.9	0.0342	12.0	3902	7.43	2.18	0.86
-3.9	-19.9	7.1	4.0	76.8	24.9	7.9	4.4	20.0	11.1	15.0	8.3	37,018	10,849	70.6	0.0432	11.9	3953	9.36	2.74	0.86
14.0	-10.0	7.4	4.1	76.8	24.9	7.9	4.4	20.0	11.1	15.0	8.3	56,767	16,637	106.2	0.0650	12.0	4065	13.96	4.09	0.87
32.0	0.0	7.7	4.3	76.8	24.9	7.9	4.4	20.0	11.1	15.0	8.3	84,212	24,680	154.8	0.0948	12.2	4158	20.26	5.94	0.89
49.9	10.0	7.7	4.3	85.8	29.9	7.7	4.3	20.0	11.1	15.0	8.3	117,302	34,378	219.4	0.1344	12.3	4708	24.92	7.30	0.93
5.0	-15.0	6.8	3.8	94.8	34.9	7.4	4.1	20.0	11.1	15.0	8.3	41,539	12,174	84.2	0.0516	12.9	4987	8.33	2.44	0.86
19.9	-6.7	7.0	3.9	94.8	34.9	7.4	4.1	20.0	11.1	15.0	8.3	60,213	17,647	120.0	0.0735	12.8	5047	11.93	3.50	0.89
40.5	4.7	7.3	4.0	94.8	34.9	7.4	4.1	20.0	11.1	15.0	8.3	93,274	27,336	182.2	0.1116	12.8	5158	18.08	5.30	0.92
67.8	19.9	7.6	4.2	94.9	34.9	7.4	4.1	20.0	11.1	15.0	8.3	152,920	44,817	292.3	0.1790	12.9	5371	28.47	8.34	0.92
14.0	-10.0	6.3	3.5	112.9	45.0	6.9	3.8	20.0	11.1	15.0	8.3	46,215	13,544	100.5	0.0615	13.8	6211	7.44	2.18	0.89
19.9	-6.7	6.1	3.4	122.0	50.0	6.6	3.7	20.0	11.1	15.0	8.3	50,479	14,794	113.9	0.0698	14.5	6945	7.27	2.13	0.92
40.9	4.9	6.4	3.6	122.0	50.0	6.6	3.7	20.0	11.1	15.0	8.3	82,691	24,235	182.3	0.1116	14.8	7107	11.64	3.41	0.96
58.9	14.9	6.6	3.7	122.0	50.0	6.6	3.7	20.0	11.1	15.0	8.3	116,354	34,100	252.1	0.1544	14.6	7142	16.29	4.77	0.97
67.8	19.9	6.7	3.7	122.0	50.0	6.6	3.7	20.0	11.1	15.0	8.3	134,369	39,380	289.1	0.1770	14.9	7244	18.55	5.44	0.95
49.9	10.0	5.9	3.3	140.2	60.1	5.8	3.2	20.0	11.1	15.0	8.3	86,763	25,428	209.1	0.1280	16.5	8864	9.79	2.87	0.99
67.8	19.9	6.1	3.4	140.2	60.1	5.8	3.2	20.0	11.1	15.0	8.3	121,252	35,536	287.3	0.1760	16.4	8848	13.70	4.02	1.00
40.9	4.9	5.8	3.2	140.2	60.1	5.8	3.2	20.0	11.1	15.0	8.3	71,893	21,070	175.0	0.1072	16.6	8793	8.18	2.40	0.99
49.9	10.0	5.5	3.1	149.3	65.2	5.2	2.9	20.0	11.1	15.0	8.3	80,391	23,561	205.1	0.1256	17.7	9846	8.16	2.39	1.01
40.9	5.0	5.4	3.0	149.3	65.2	5.2	2.9	20.0	11.1	15.0	8.3	64,875	19,013	167.2	0.1024	17.7	9788	6.63	1.94	1.00
37.3	3.0	5.4	3.0	149.3	65.2	5.2	2.9	20.0	11.1	15.0	8.3	59,630	17,476	154.4	0.0946	17.6	9778	6.10	1.79	0.99
-13.0	-25.0	6.8	3.8	85.8	29.9	7.7	4.3	20.0	11.1	15.0	8.3	26,735	7,835	53.4	0.0327	12.0	4325	6.18	1.81	0.85
-12.7	-24.8	6.6	3.7	89.5	31.9	7.6	4.2	20.0	11.1	15.0	8.3	25,877	7,584	52.5	0.0321	12.1	4517	5.73	1.68	0.84
67.8	19.9	5.7	3.2	149.3	65.2	5.2	2.9	20.0	11.1	15.0	8.3	112,545	32,984	282.1	0.1727	17.7	9868	11.41	3.34	1.00

[1]Theoretical temperature change during isobaric phase transition

Performance Curves and Coefficients

The following plots show baseline R-410A and LGWP alternative R-447A capacity, input power and COP using the 10-Coefficient polynomial equation for each refrigerant (See Figure 2 for R-447A Coefficients). These coefficients should only be applied within the acceptable compressor operating envelope to avoid excessive extrapolation error in the results.

R-410A Coefficients

CAPACITY:									
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
7.9314E+04	1.8261E+03	-4.5695E+02	2.0681E+01	-1.1288E+01	3.8901E+00	8.9573E-02	-1.4581E-01	5.3367E-02	-2.3697E-02

POWER:									
P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
1.2811E+03	7.4958E+00	4.7003E+01	3.7443E-01	-2.3526E-01	-2.0653E-01	7.0345E-04	-3.4911E-03	1.5767E-03	2.3633E-03

R-447A Coefficients

CAPACITY:									
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
2.9704E+04	1.1601E+03	-2.6794E+02	1.7928E+01	-1.1960E+01	4.0152E+00	7.5062E-02	-2.0896E-01	9.8460E-02	-5.1657E-02

POWER:									
P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
2.0645E+03	-2.9584E+00	8.8501E+01	-3.5787E-02	7.4437E-01	-5.6932E-01	0.0000E+00	0.0000E+00	-9.5451E-03	1.5753E-02

Figure 2 R-410A & R-447A 10-Coefficient Polynomial Equations for Cooling Capacity and Power (20F Superheat, 15F Subcool)

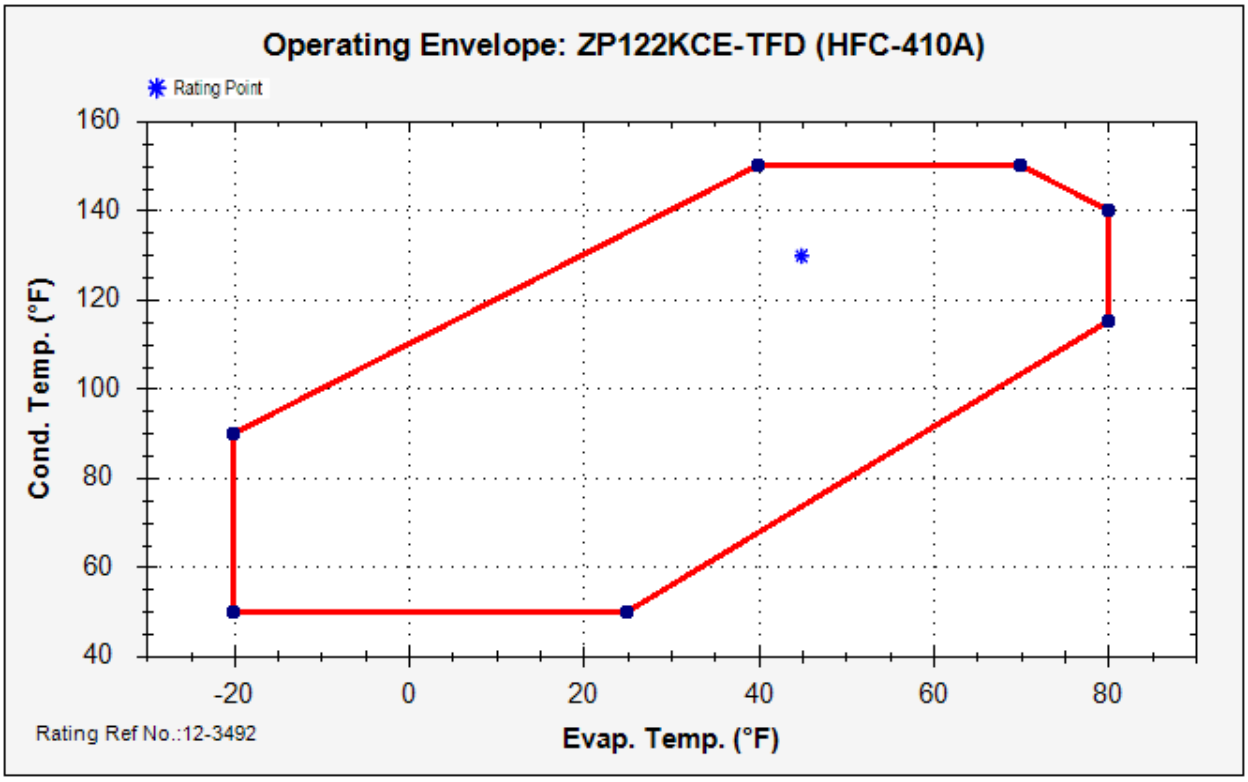

Figure 3 ZP122KCE-TFD R-10A Operating Map (20F Superheat, 15F Subcool)

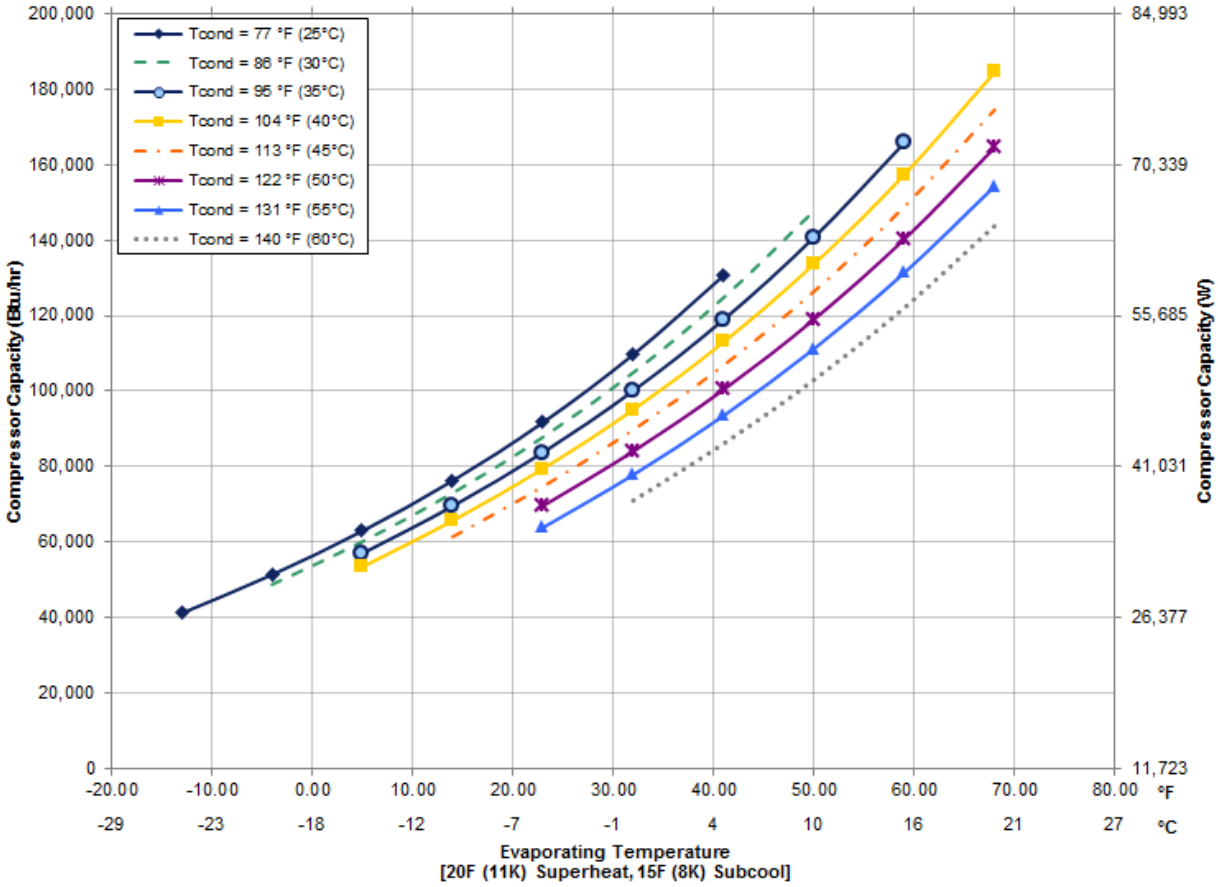

Figure 4 R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

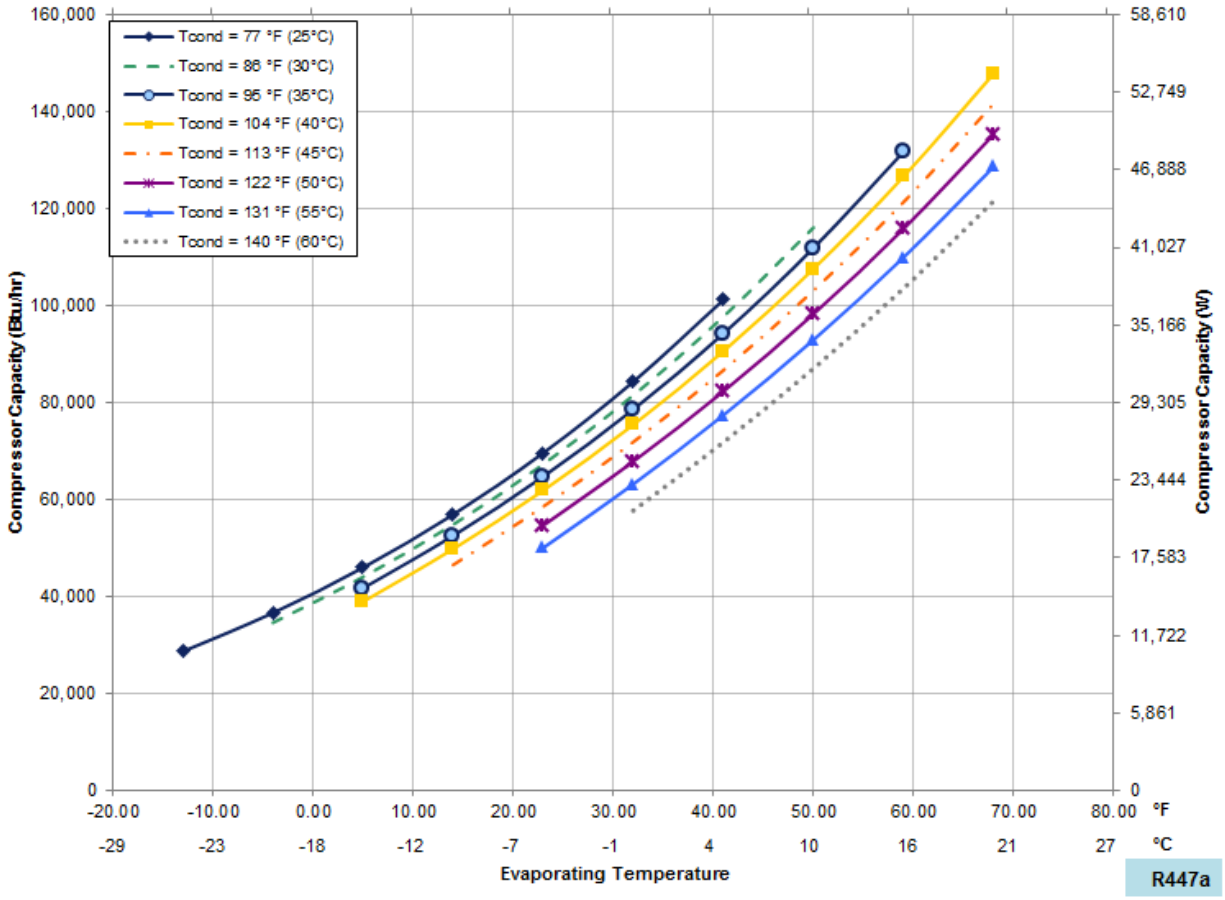

Figure 5 R-447A Cooling Capacity vs. Evaporating Temperature (Dew Point)

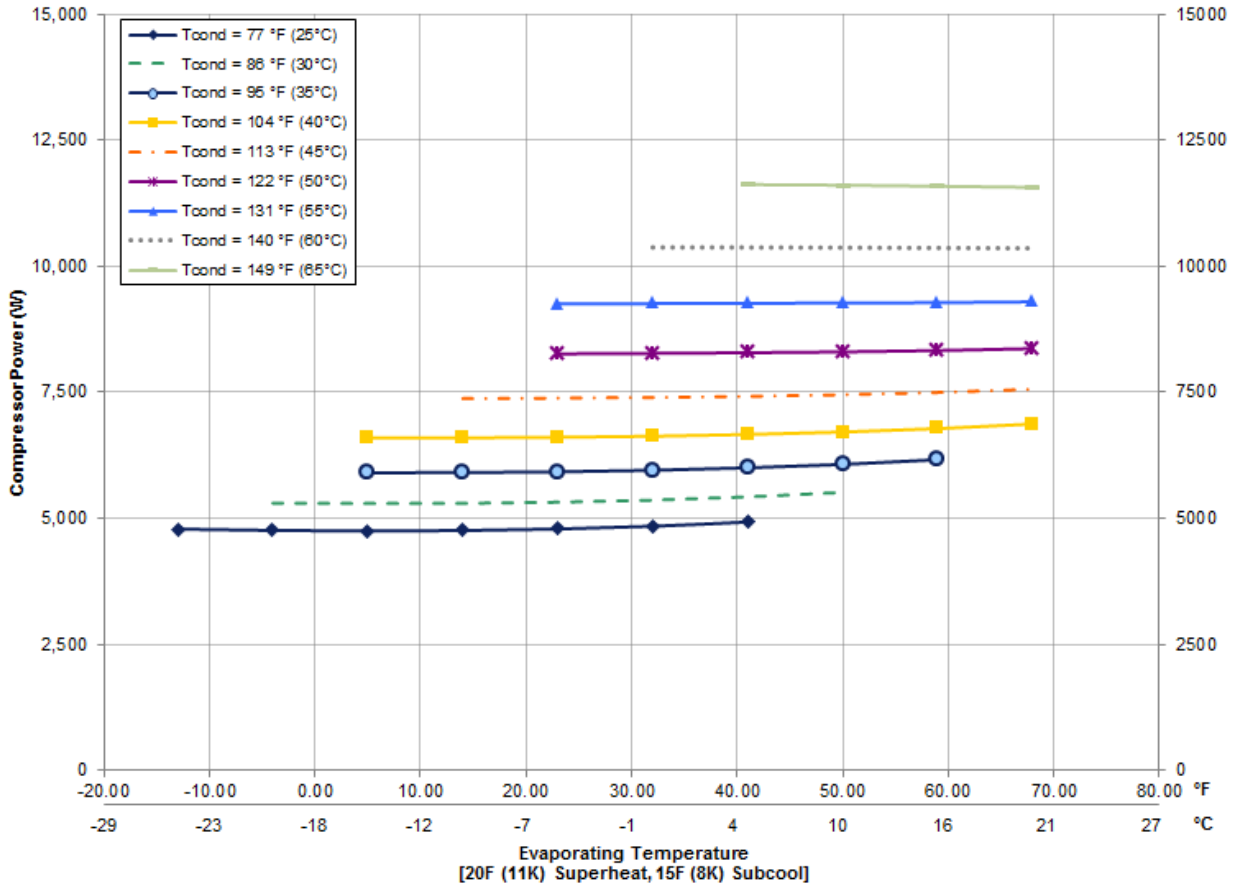

Figure 6 R410A Input Power vs. Evaporating Temperature (Dew Point)

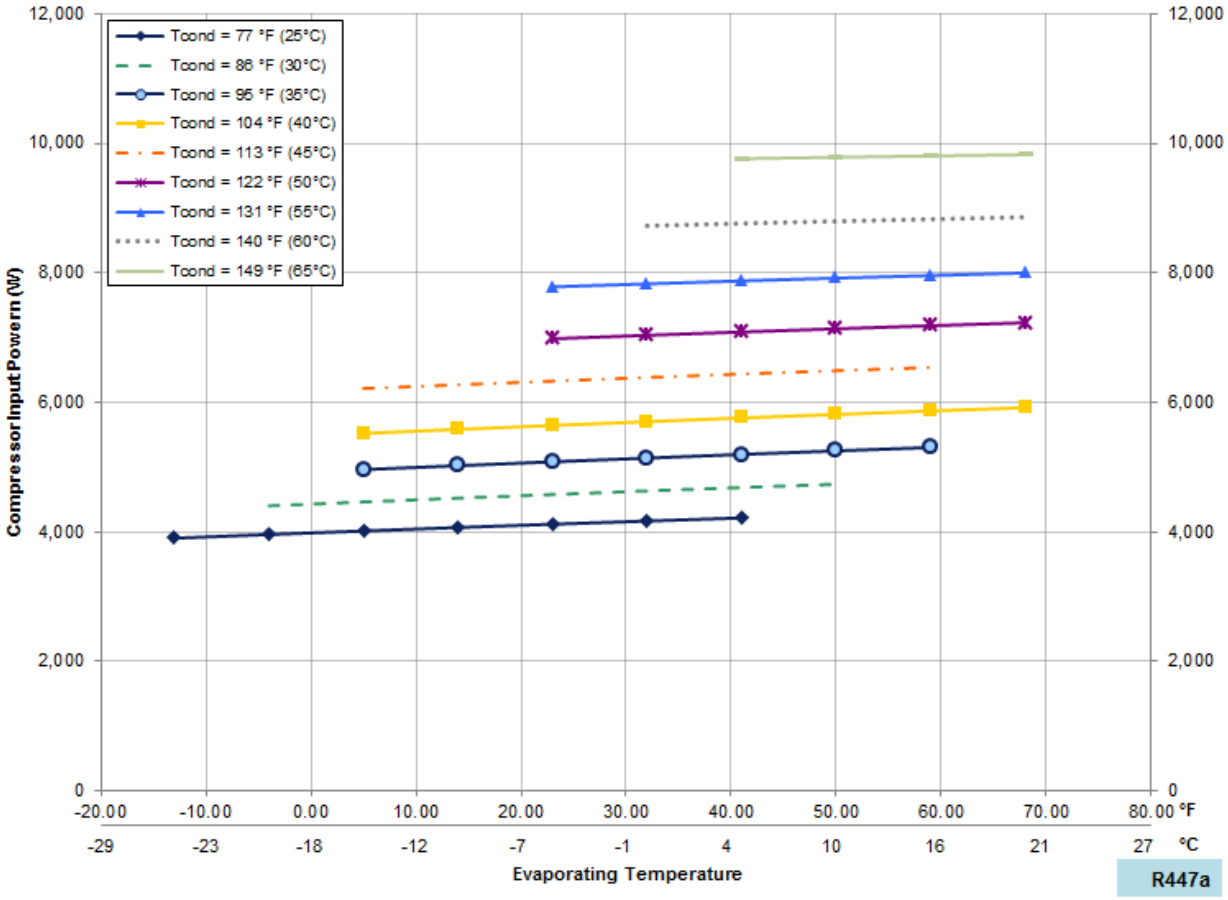

Figure 7 R-447A Input Power vs. Evaporating Temperature (Dew Point)

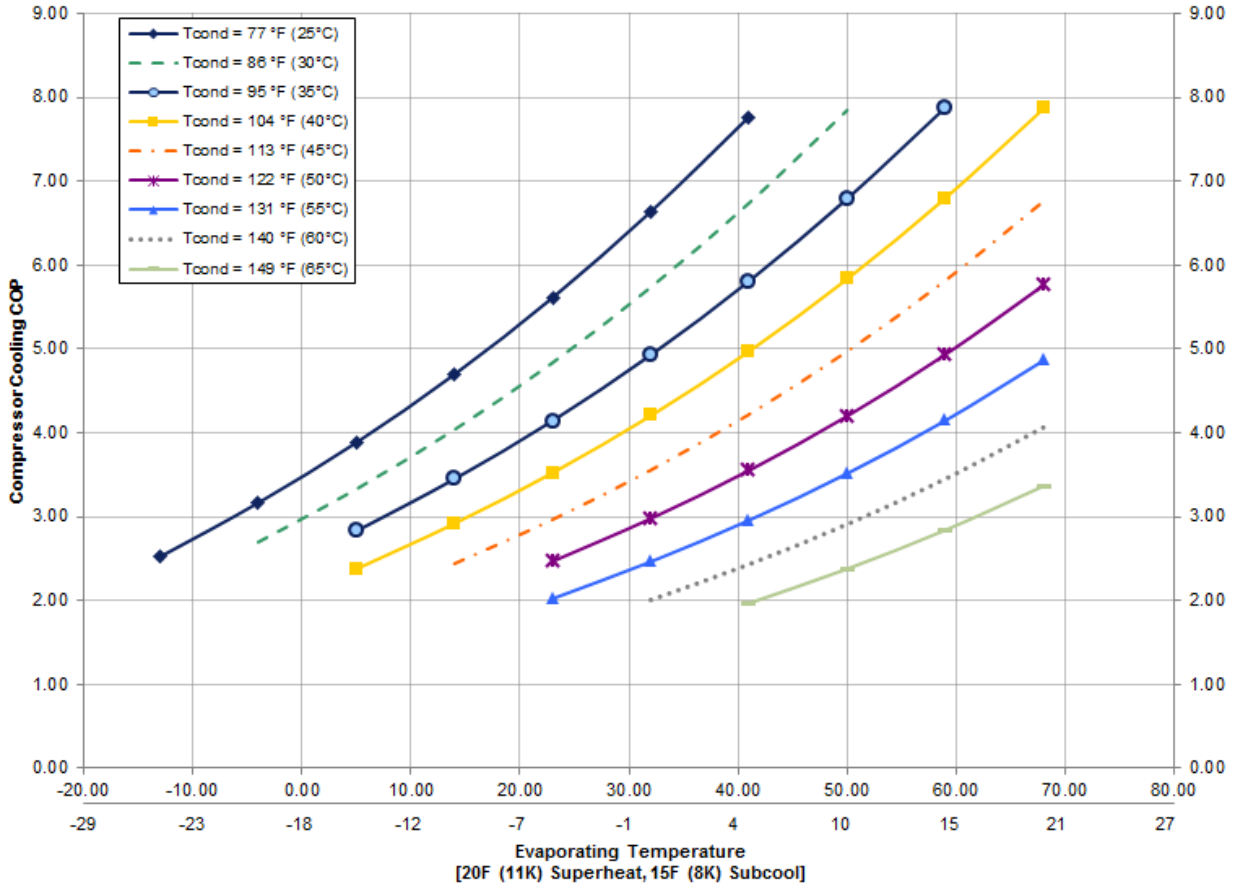

Figure 8 R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

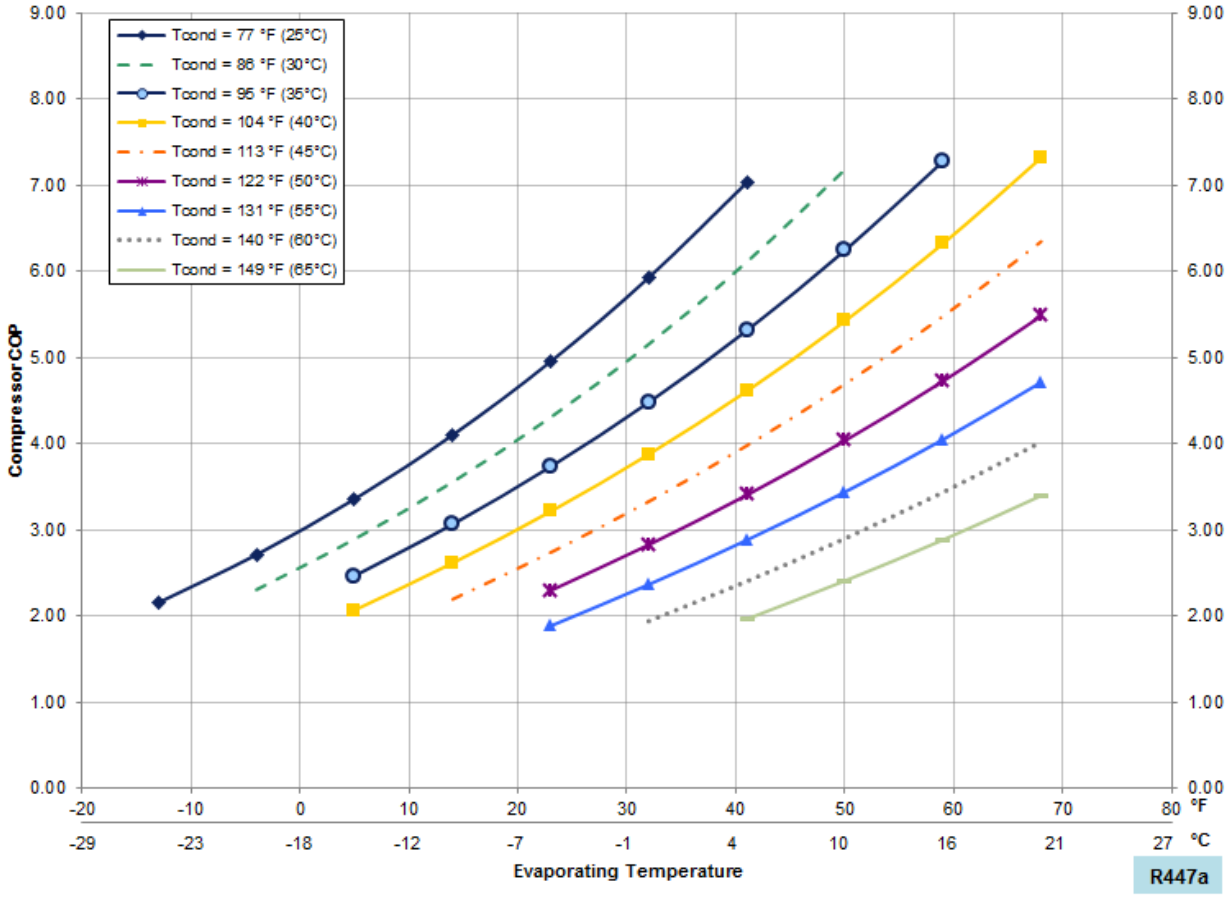

Figure 9 R-447A Cooling COP Vs. Evaporating Temperature (Dew Point)

Comparative Analysis

Figures 10 and 11 show the ratio of R-447A 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.

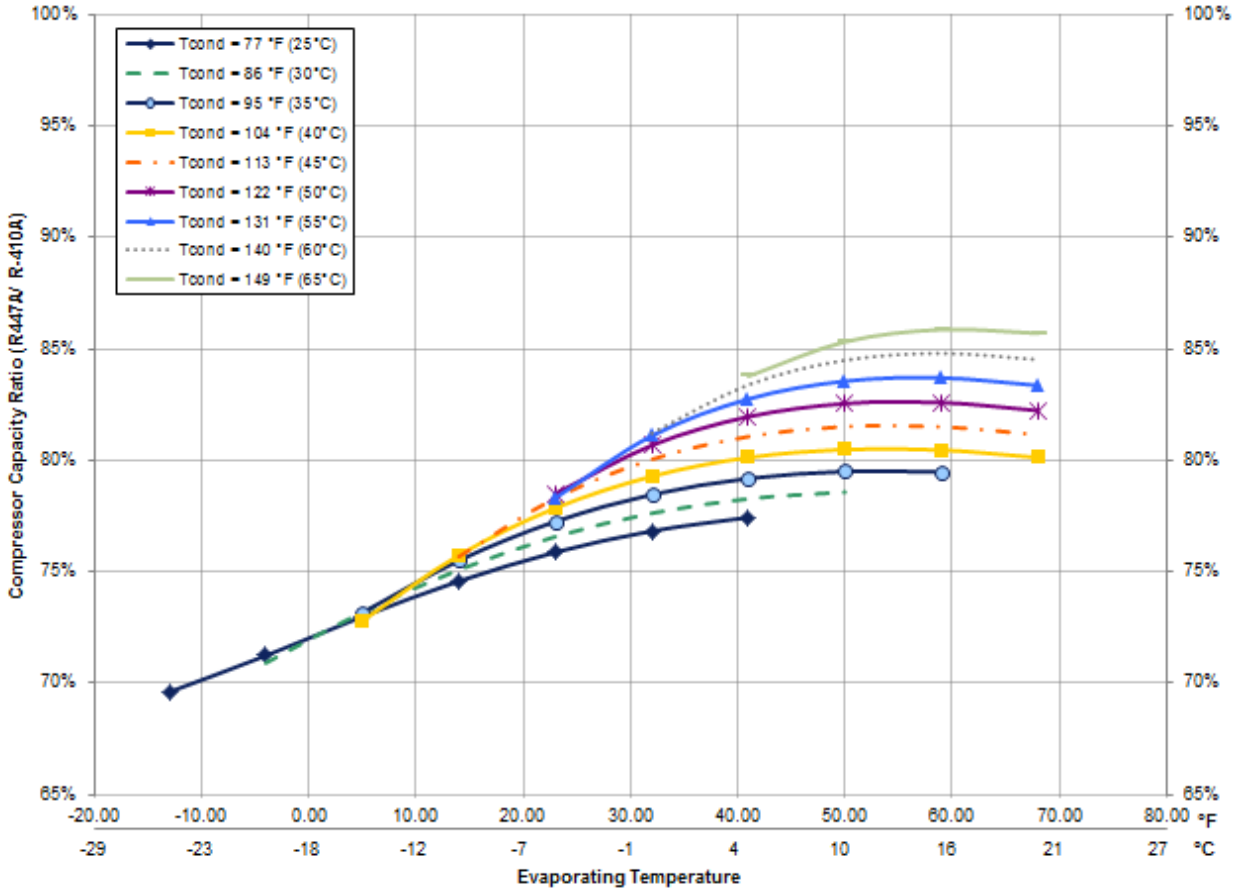

Figure 10 R-447A / R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

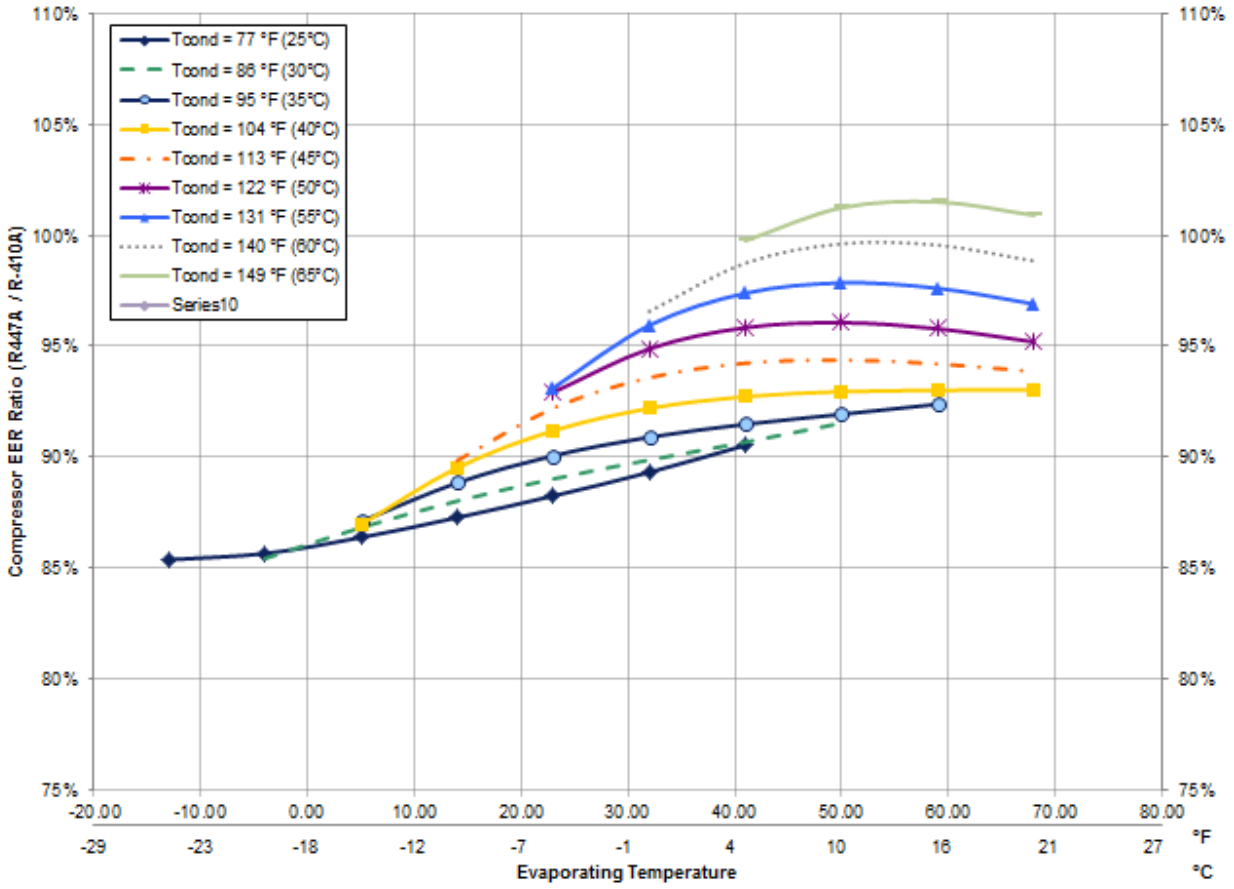

Figure 11 R-447A / R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

Summary

The calorimeter testing of R-447A was carried out at dew point conditions and compared to R-410A. The compressor cooling capacity vs R-410A is between 70-85% of the rated performance across the operating map of the tested compressor. (See Figures 3A and 3B for Operating Maps). The Compressor COP of R-447A is between 85-105% across the compressor operating envelope.