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

TEST REPORT #39

Compressor Calorimeter Test of Refrigerant R-32 in a R-410A Scroll Compressor

Rajan Rajendran
Autumn Nicholson

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

April 14, 2014

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

Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Boulevard, Suite 500
Arlington VA 22201
(703) 524-8800
www.ahrinet.org

List of Tested Refrigerants’ Compositions (Mass%)

R-32	R-32 (100)

Contents

Introduction

This Report covers the calorimeter testing results of R-32 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: R-32 (Pure)
  - Initial Refrigerant Charge: 4 lbs (1.8kg)
- 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, 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	51.8	3.5	-10	-23.3	10.0	-12.2	256.2	17.4	80	26.7	250	121.1	230-1-60	3,539
95	35.0	63.9	4.4	0	-17.8	20.0	-6.7	296.0	20.1	90	32.2	247	119.4	230-1-60	3,538
95	35.0	63.9	4.4	0	-17.8	20.0	-6.7	340.4	23.2	100	37.8	278	136.7	230-1-60	3,520
95	35.0	78.2	5.3	10	-12.2	30.0	-1.1	296.0	20.1	90	32.2	220	104.4	230-1-60	3,539
95	35.0	78.2	5.3	10	-12.2	30.0	-1.1	389.6	26.5	110	43.3	277	136.1	230-1-60	3,506
95	35.0	94.7	6.4	20	-6.7	40.0	4.4	256.2	17.4	80	26.7	178	81.1	230-1-60	3,536
95	35.0	94.7	6.4	20	-6.7	40.0	4.4	444.0	30.2	120	48.9	278	136.7	230-1-60	3,491
95	35.0	103.9	7.1	25	-3.9	45.0	7.2	317.6	21.6	95	35.0	199	92.8	230-1-60	3,536
95	35.0	113.8	7.7	30	-1.1	50.0	10.0	389.6	26.5	110	43.3	224	106.7	230-1-60	3,513
95	35.0	113.8	7.7	30	-1.1	50.0	10.0	504.2	34.3	130	54.4	278	136.7	230-1-60	3,472
95	35.0	135.7	9.2	40	4.4	60.0	15.6	296.0	20.1	90	32.2	168	75.6	230-1-60	3,532
95	35.0	135.7	9.2	40	4.4	60.0	15.6	444.0	30.2	120	48.9	227	108.3	230-1-60	3,496
95	35.0	135.7	9.2	40	4.4	60.0	15.6	536.5	36.5	135	57.2	266	130.0	230-1-60	3,460
95	35.0	147.7	10.0	45	7.2	65.0	18.3	340.4	23.2	100	37.8	181	82.8	230-1-60	3,530
95	35.0	147.7	10.0	45	7.2	65.0	18.3	389.6	26.5	110	43.3	199	92.8	230-1-60	3,515
95	35.0	147.7	10.0	45	7.2	65.0	18.3	504.2	34.3	130	54.4	243	117.2	230-1-60	3,479
95	35.0	147.7	10.0	45	7.2	65.0	18.3	504.2	34.3	130	54.4	243	117.2	230-1-60	3,479
95	35.0	147.7	10.0	45	7.2	65.0	18.3	504.2	34.3	130	54.4	242	116.7	230-1-60	3,479
95	35.0	147.7	10.0	45	7.2	65.0	18.3	504.2	34.3	130	54.4	243	117.2	230-1-60	3,479
95	35.0	160.5	10.9	50	10.0	70.0	21.1	340.4	23.2	100	37.8	175	79.4	230-1-60	3,531
95	35.0	160.5	10.9	50	10.0	70.0	21.1	416.1	28.3	115	46.1	202	94.4	230-1-60	3,516
95	35.0	174.2	11.9	55	12.8	75.0	23.9	340.4	23.2	100	37.8	170	76.7	230-1-60	3,532
95	35.0	174.2	11.9	55	12.8	75.0	23.9	606.1	41.2	145	62.8	261	127.2	230-1-60	3,437

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

Description and Size of Test Loop

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

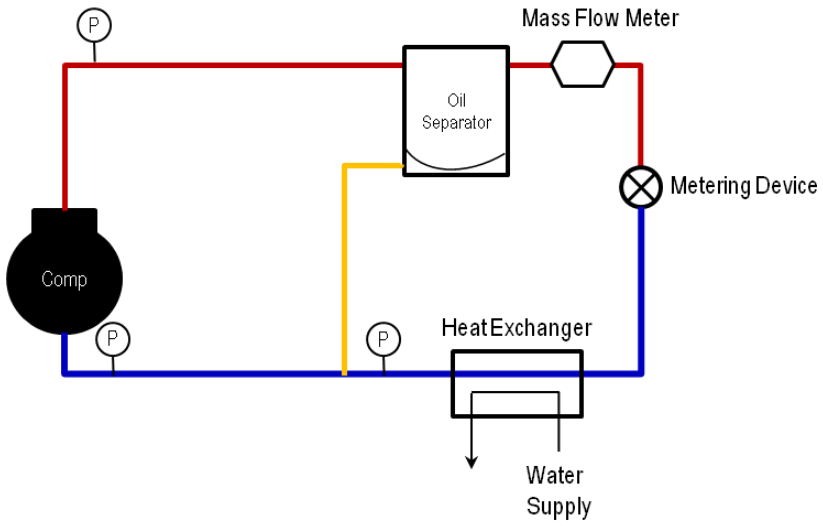

Figure 1. Simplified System Diagram of Test Setup

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 R-32. The R-410A baseline data is from published nominal rating data (capacity and EER within ±5% of test data). Capacity calculations for R-32 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-32 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 (°C)	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	Cooling EER, Btu/W-hr	Cooling COP, W/W	Cooling COP_{R-32} / COP_{R-410A}
-10 (-23)	0 (0)	80 (26.7)	0 (0)	250 (121.1)	20 (11)	15 (8.3)	12068 (3537)	98 (44)	7.8	1,744	6.92	2.03	0.89
0 (-18)	0 (0)	90 (32.2)	0 (0)	247 (119.4)	20 (11)	15 (8.3)	15133 (4435)	126 (57)	8.8	1,980	7.64	2.24	0.96
0 (-18)	0 (0)	100 (37.8)	0 (0)	278 (136.7)	20 (11)	15 (8.3)	13693 (4013)	119 (54)	10.1	2,289	5.98	1.75	0.96
10 (-12)	0 (0)	90 (32.2)	0 (0)	220 (104.4)	20 (11)	15 (8.3)	19364 (5675)	160 (73)	8.7	1,963	9.87	2.89	0.95
10 (-12)	0 (0)	110 (43.3)	0 (0)	277 (136.1)	20 (11)	15 (8.3)	16736 (4905)	150 (68)	11.5	2,594	6.45	1.89	0.99
20 (-7)	0 (0)	80 (26.7)	0 (0)	178 (81.1)	20 (11)	15 (8.3)	26363 (7727)	209 (95)	7.7	1,714	15.38	4.51	0.94
20 (-7)	0 (0)	120 (48.9)	0 (0)	278 (136.7)	20 (11)	15 (8.3)	20134 (5901)	187 (85)	13.0	2,945	6.68	1.96	0.98
25 (-4)	0 (0)	95 (35)	0 (0)	199 (92.8)	20 (11)	15 (8.3)	27261 (7990)	227 (103)	9.2	2,081	13.10	3.84	0.96
30 (-1)	0 (0)	110 (43.3)	0 (0)	224 (106.7)	20 (11)	15 (8.3)	27102 (7943)	239 (109)	11.2	2,544	10.65	3.12	0.95
30 (-1)	0 (0)	130 (54.4)	0 (0)	278 (136.7)	20 (11)	15 (8.3)	23477 (6881)	227 (103)	14.9	3,369	6.97	2.04	1.00
40 (4)	0 (0)	90 (32.2)	0 (0)	168 (75.6)	20 (11)	15 (8.3)	38016 (11142)	309 (140)	8.5	1,910	19.91	5.84	0.95
40 (4)	0 (0)	120 (48.9)	0 (0)	227 (108.3)	20 (11)	15 (8.3)	32111 (9411)	295 (134)	12.7	2,883	11.14	3.26	0.98
40 (4)	0 (0)	135 (57.2)	0 (0)	266 (130)	20 (11)	15 (8.3)	28474 (8345)	281 (128)	15.8	3,570	7.98	2.34	1.00
45 (7)	0 (0)	100 (37.8)	0 (0)	181 (82.8)	20 (11)	15 (8.3)	39144 (11472)	329 (150)	9.7	2,188	17.89	5.24	0.94
45 (7)	0 (0)	110 (43.3)	0 (0)	199 (92.8)	20 (11)	15 (8.3)	37636 (11030)	330 (150)	11.1	2,510	15.00	4.40	0.96
45 (7)	0 (0)	130 (54.4)	0 (0)	243 (117.2)	20 (11)	15 (8.3)	32780 (9607)	314 (143)	14.7	3,331	9.84	2.88	0.97
45 (7)	0 (0)	130 (54.4)	0 (0)	243 (117.2)	20 (11)	15 (8.3)	32811 (9616)	315 (143)	14.7	3,324	9.87	2.89	0.97
45 (7)	0 (0)	130 (54.4)	0 (0)	242 (116.7)	20 (11)	15 (8.3)	32681 (9578)	313 (142)	14.6	3,309	9.88	2.90	0.98
45 (7)	0 (0)	130 (54.4)	0 (0)	243 (117.2)	20 (11)	15 (8.3)	32169 (9428)	309 (140)	14.6	3,309	9.72	2.85	0.96
50 (10)	0 (0)	100 (37.8)	0 (0)	175 (79.4)	20 (11)	15 (8.3)	43281 (12685)	363 (165)	9.6	2,175	19.90	5.83	0.94
50 (10)	0 (0)	115 (46.1)	0 (0)	202 (94.4)	20 (11)	15 (8.3)	40060 (11741)	358 (163)	11.8	2,680	14.95	4.38	0.96
55 (13)	0 (0)	100 (37.8)	0 (0)	170 (76.7)	20 (11)	15 (8.3)	47837 (14020)	401 (182)	9.5	2,153	22.21	6.51	0.96
55 (13)	0 (0)	145 (62.8)	0 (0)	261 (127.2)	20 (11)	15 (8.3)	35002 (10258)	361 (164)	18.0	4,064	8.61	2.52	0.97

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

Performance Curves and Coefficients

The following plots show baseline R-410A and LGWP alternative R-32 capacity, input power and COP using the 10-Coefficient polynomial equation for each refrigerant (see Figure 2 for R-32 Coefficients). These coefficients should only be applied within the acceptable compressor operating envelope to avoid excessive extrapolation error in the results.

CAPACITY:									
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
38769.346	540.7301	-531.132	5.83762	-1.88442	4.376893	0.018319	-0.03371	0.007508	-0.01576

POWER:									
P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
135.0886	-12.4809	29.49107	-0.25732	0.385788	-0.2769	-0.00123	0.00358	-0.00303	0.001969

Figure 2. R-32 10-Coefficient Polynomial Equations for Cooling Capacity and Power (20F Superheat, 15F Subcool)

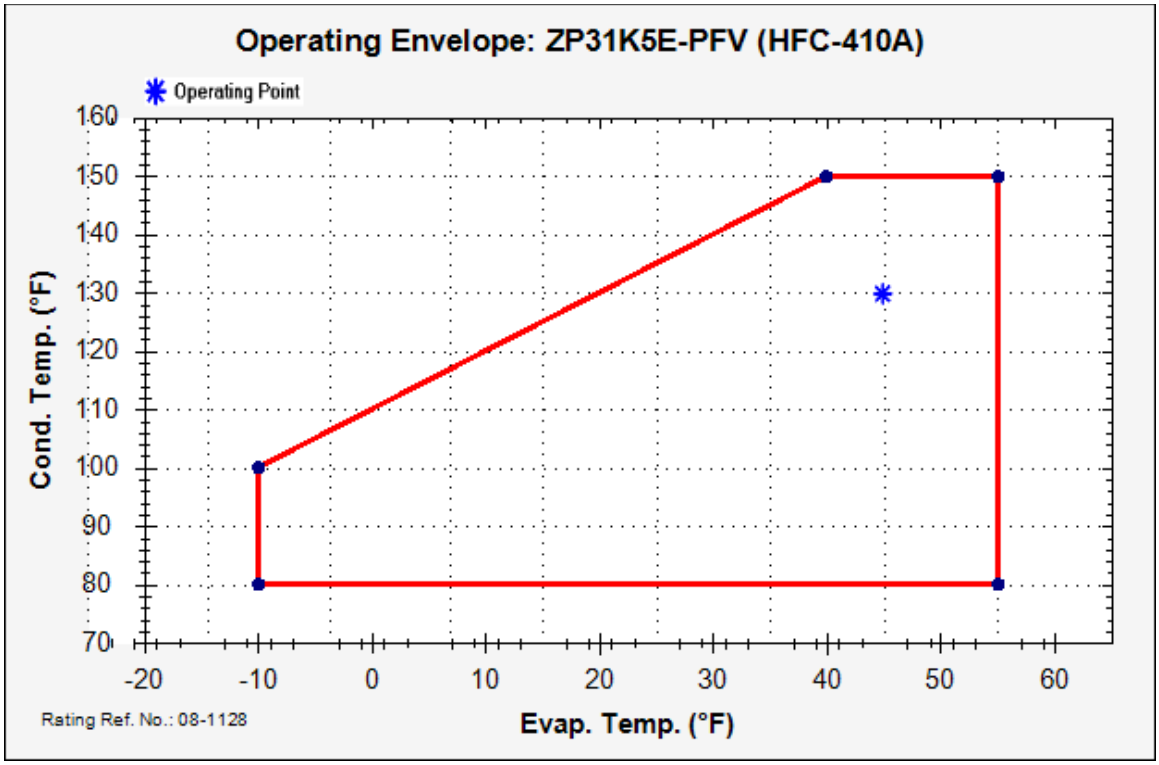

Figure 3. ZP31K5E-PFV R-410A Operating Map (20F Superheat, 15F Subcool)

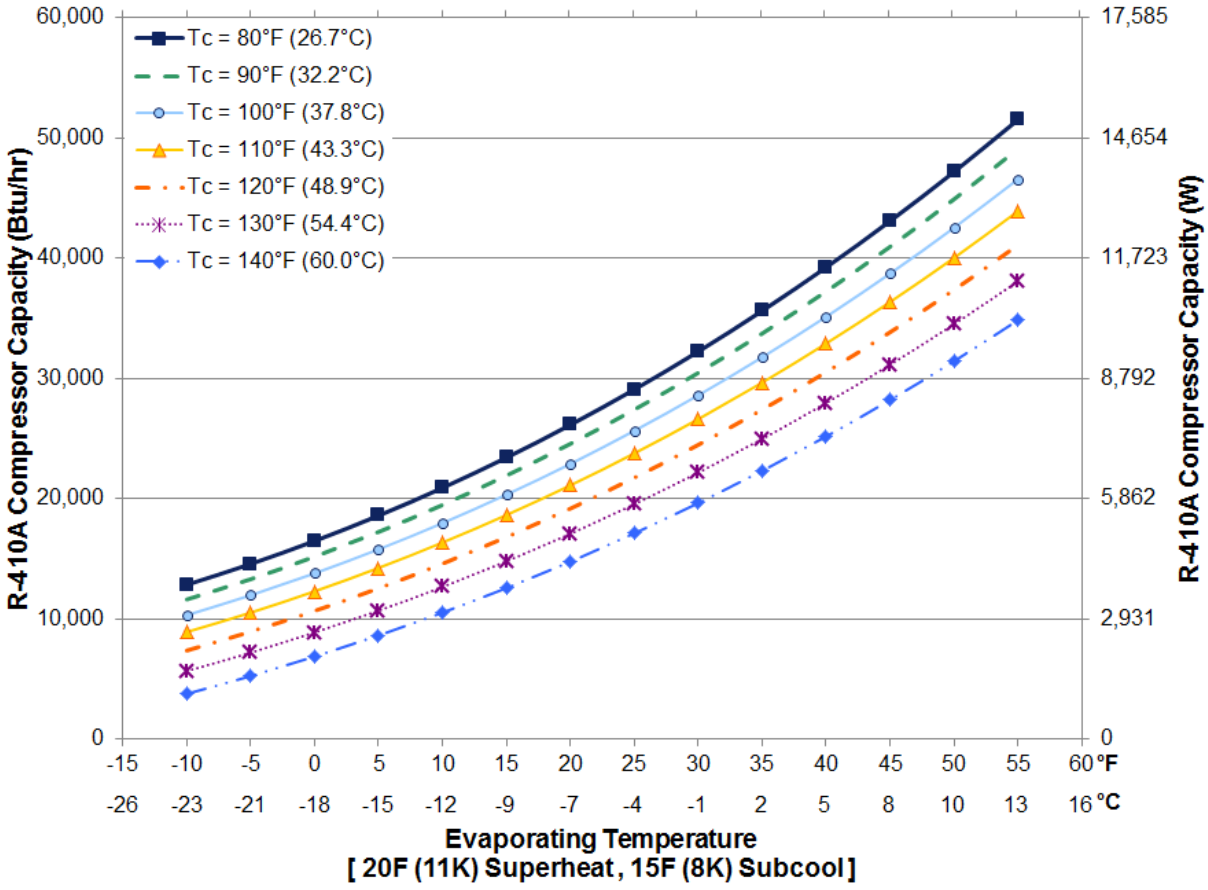

Figure 4. R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

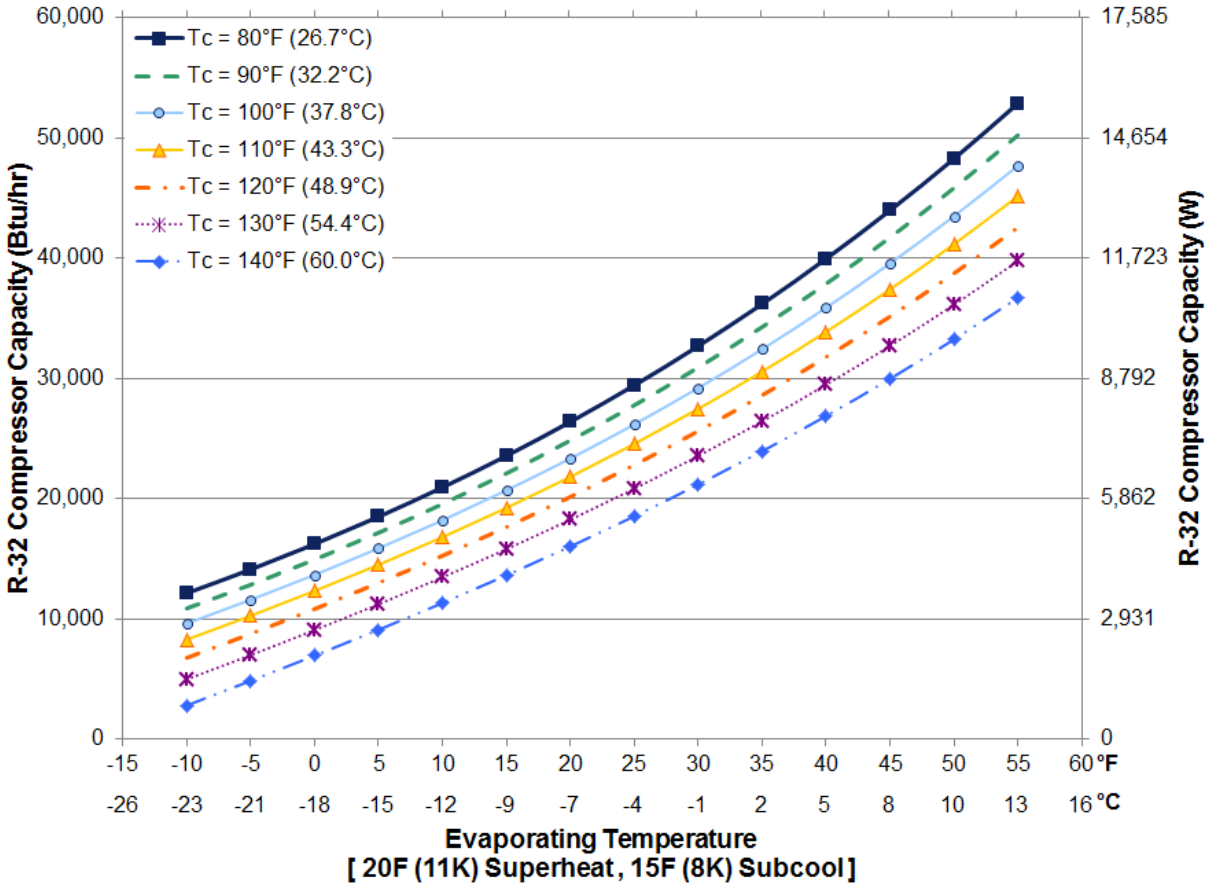

Figure 5. R-32 Cooling Capacity vs. Evaporating Temperature (Dew Point)

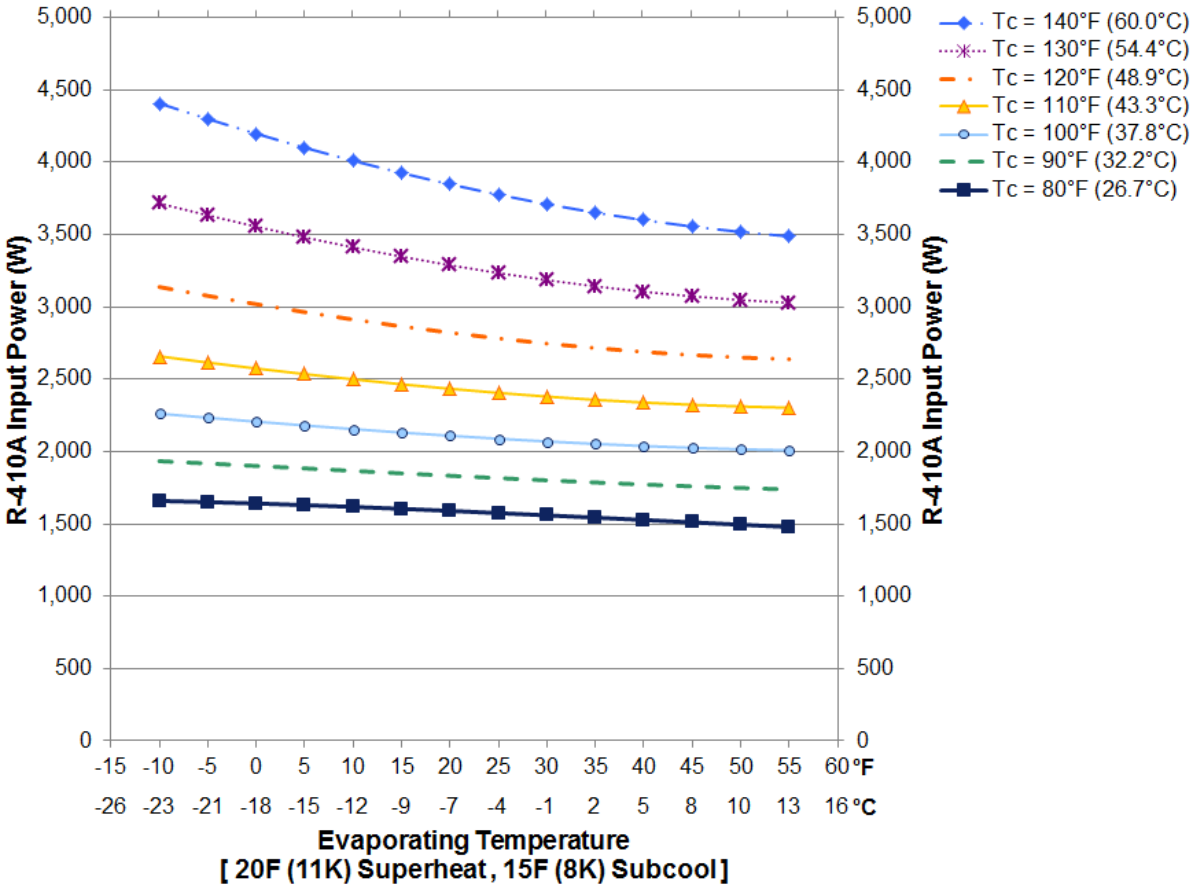

Figure 6. R-410A Input Power vs. Evaporating Temperature (Dew Point)

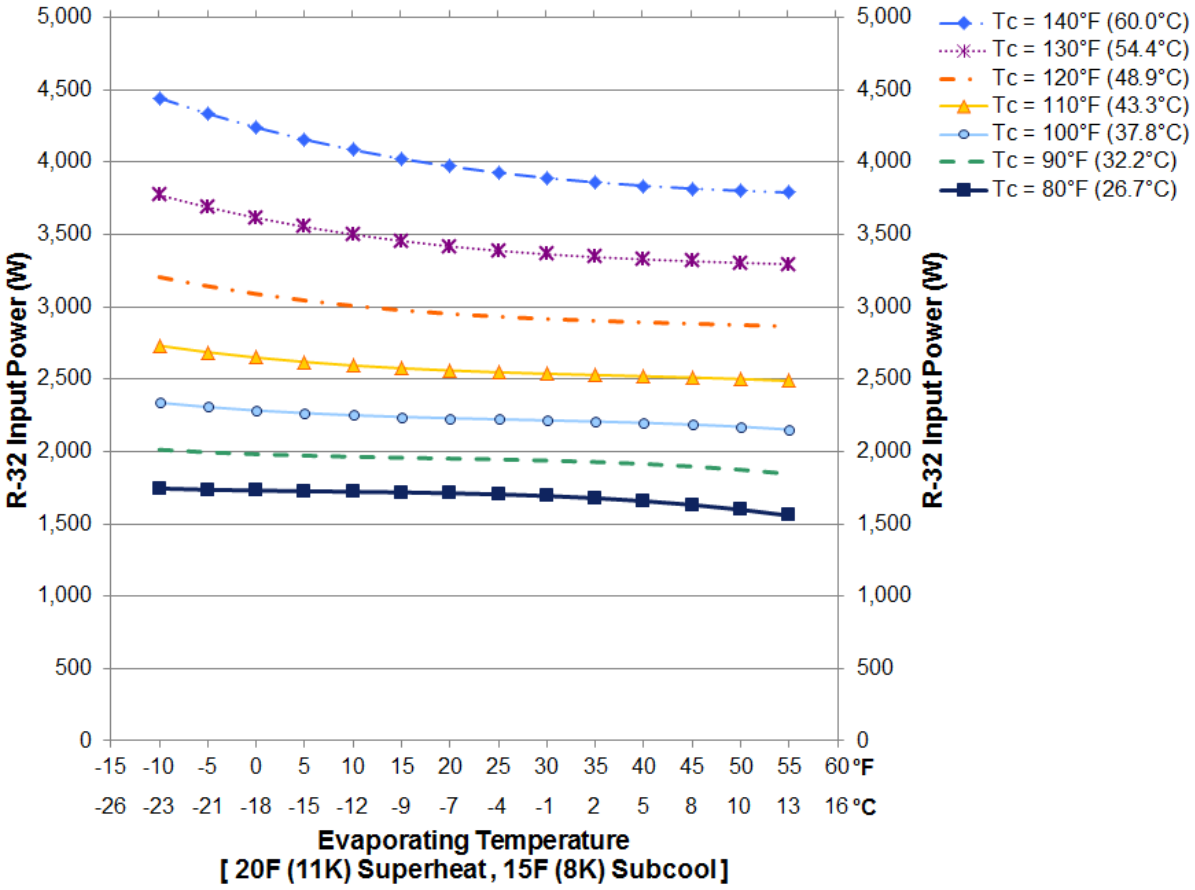

Figure 7. R-32 Input Power vs. Evaporating Temperature (Dew Point)

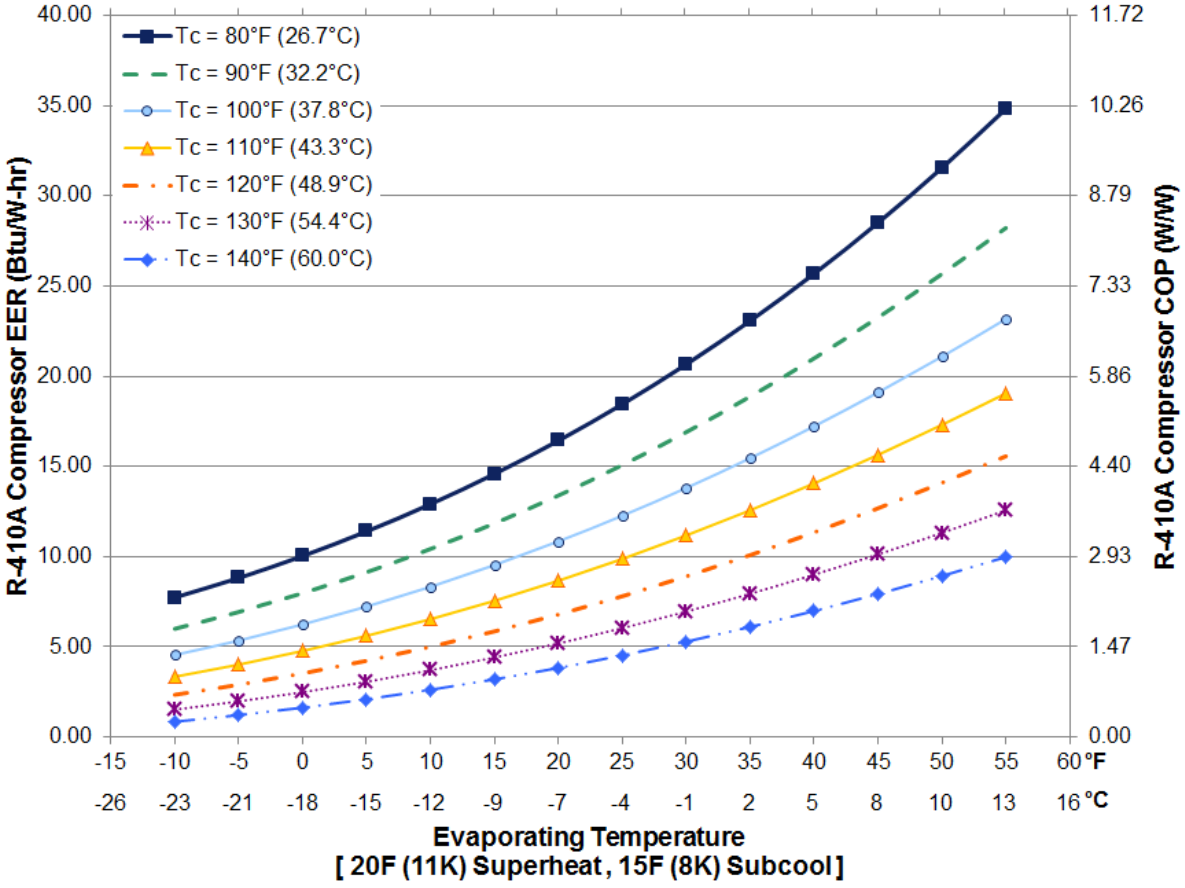

Figure 8. R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

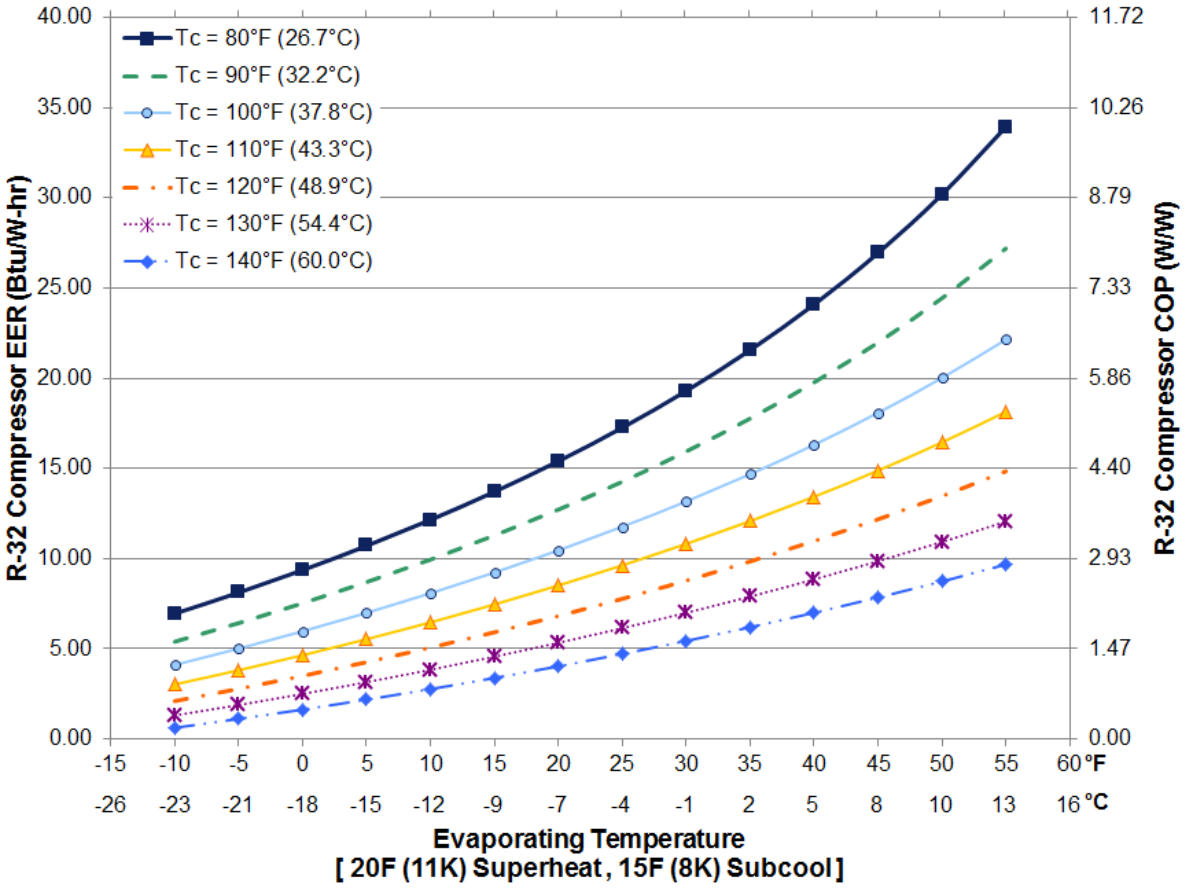

Figure 9. R-32 Cooling COP vs. Evaporating Temperature (Dew Point)

Comparative Analysis

Figures 10 and 11 show the ratio of R-32 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.

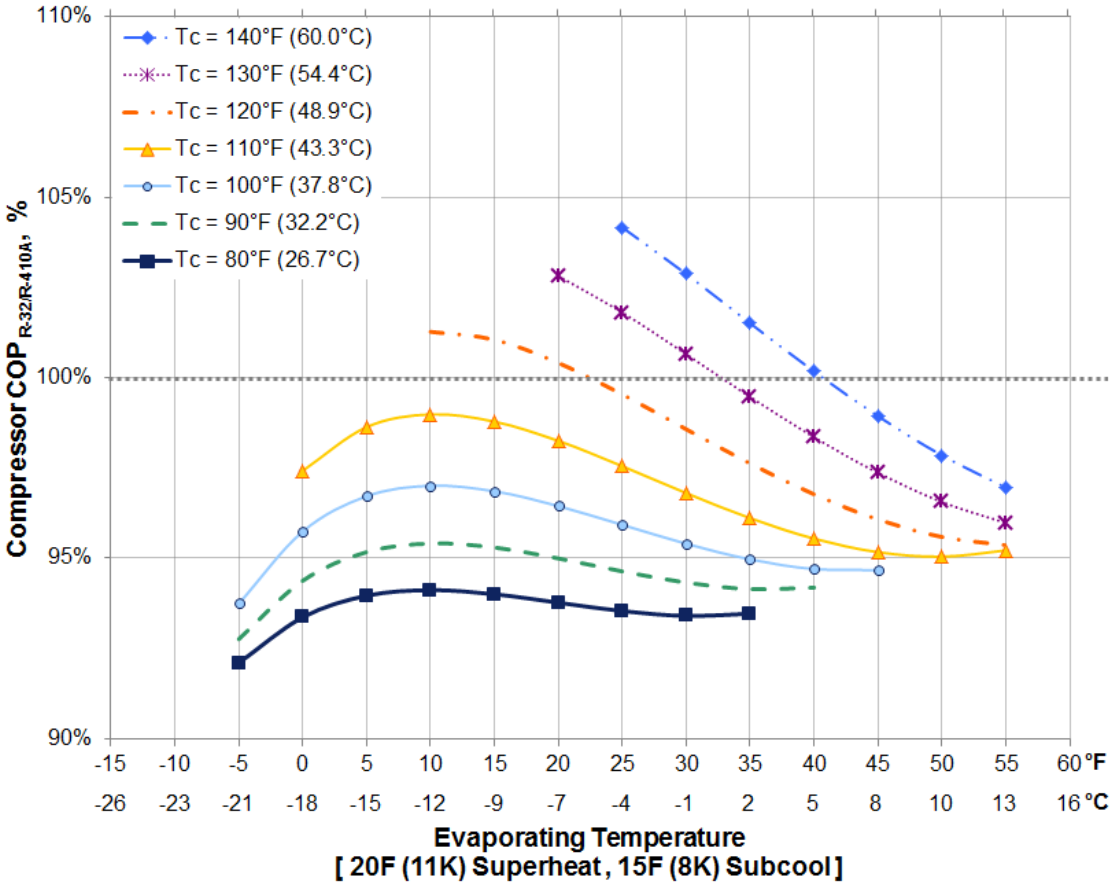

Figure 10. R-32/R-410A Cooling COP vs. Evaporating Temperature (Dew Point)

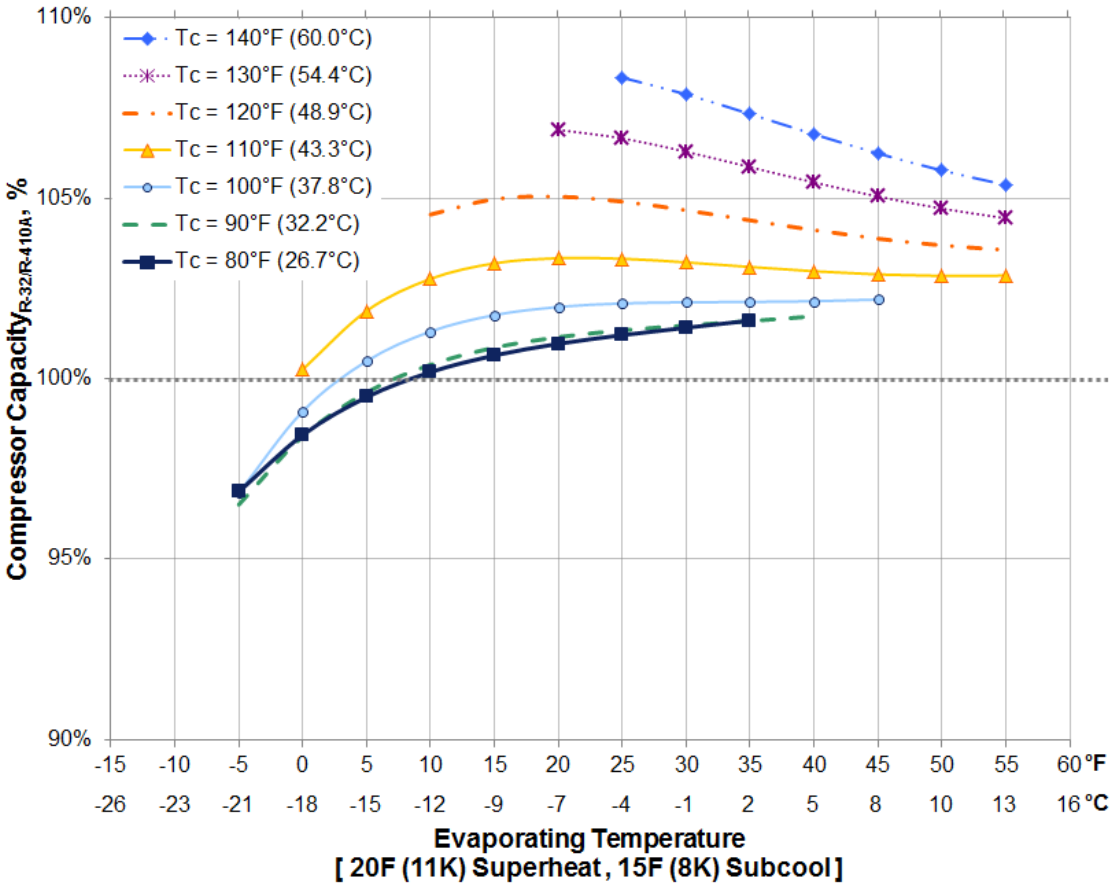

Figure 11. R-32/R-410A Cooling Capacity vs. Evaporating Temperature (Dew Point)

Summary

The calorimeter testing of R-32 was carried out a dew point conditions and compared to R-410A. R-32 is a pure fluid and therefore has no refrigerant glide. R-32 runs about 3-5% higher capacity than R-410A, but about 3-5% lower EER. The higher capacity is due to R-32's much higher specific heat overcoming its lower mass flow.