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

TEST REPORT #66

Compressor Calorimeter Test of Refrigerant HPR2A in a R-410A Scroll Compressor

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Contents

List of Tested Refrigerant's Composition (Mass%)

HPR2A	R-32/R-1234ze/R-134a (76/18/6)

1. Introduction:

This report covers the calorimeter test results of the refrigerant HPR2A– a low-GWP candidate provided by Mexichem. The tests have been conducted during May to July 2015 in the laboratory of Danfoss Commercial Compressors plant in Tianjin, China.

The refrigerant was drop-in tested with an R-410A compressor SH161A4. Performance data were compared based on dew point reference for evaporating and condensing temperatures. The property library was given by Mexichem as a .mix file for use with Refprop software.

2. Details of Test Setup:

a. Description of Test Refrigerant-Lubricant and Charge

- Refrigerant tested: HPR2A (GWP 573)
  - R-32/R-1234ze/R-134a (76/18/6) (zeotropic blend)
  - total refrigerant charge; 77.2 lbs mass, (35 kg)
- Lubricant
  - 160SZ, POE type
  - viscosity grade: 32 cSt
  - no changes to base oil

b. Description of Compressor

- hermetic fixed speed scroll compressor, low-side design
- no compressor modifications
- Danfoss Commercial Compressors
- model SH161A4; S/N 2756184
- motor nameplate rating: 380-400V / 3ph / 50Hz, LRA 158A, Max oper. current 31A. 2900 RPM
- air flow is not required
- ambient air temperature 24°C ±1°C (75.2°F ±1.8°F)
- compressor operating conditions during test in Table 1.

Table 1. Compressor operating conditions during test

Ambient air temperature		Suction pressure		Saturated suction temperature (Dew)		Suction vapor temperature		Discharge pressure		Saturated discharge temperature (Dew)		Volts / Phase / Frequency	Speed
°F	°C	psi	bar	°F	°C	°F	°C	psi	bar	°F	°C	V / Ø / Hz	RPM
75.2	24	40.8	2.81	-9.9	-23.3	10.1	-12.2	215.4	14.85	80.1	26.7	400 / 3 / 50	2917
75.2	24	40.8	2.81	-9.9	-23.3	10.1	-12.2	249.8	17.23	90.0	32.2	400 / 3 / 50	2892
75.2	24	50.7	3.50	0.0	-17.8	20.0	-6.7	249.8	17.23	90.0	32.2	400 / 3 / 50	2940
75.2	24	56.4	3.89	5.0	-15.0	25.0	-3.9	332.1	22.90	109.9	43.3	400 / 3 / 50	2966
75.2	24	62.6	4.32	10.0	-12.2	30.0	-1.1	215.4	14.85	80.1	26.7	400 / 3 / 50	2986
75.2	24	62.6	4.32	10.0	-12.2	30.0	-1.1	289.1	19.93	100.0	37.8	400 / 3 / 50	2963
75.2	24	69.4	4.78	15.1	-9.4	35.1	1.7	332.1	22.90	109.9	43.3	400 / 3 / 50	2930
75.2	24	76.4	5.27	19.9	-6.7	39.9	4.4	249.8	17.23	90.0	32.2	400 / 3 / 50	2955
75.2	24	76.4	5.27	19.9	-6.7	39.9	4.4	433.8	29.91	129.9	54.4	400 / 3 / 50	2920
75.2	24	84.2	5.80	25.0	-3.9	45.0	7.2	332.1	22.90	109.9	43.3	400 / 3 / 50	2964
75.2	24	92.6	6.39	30.0	-1.1	50.0	10.0	215.4	14.85	80.1	26.7	400 / 3 / 50	2967
75.2	24	92.6	6.39	30.0	-1.1	50.0	10.0	249.8	17.23	90.0	32.2	400 / 3 / 50	2972
75.2	24	92.6	6.39	30.0	-1.1	50.0	10.0	289.1	19.93	100.0	37.8	400 / 3 / 50	2980
75.2	24	101.7	7.01	35.1	1.7	55.1	12.8	433.8	29.91	129.9	54.4	400 / 3 / 50	2961
75.2	24	111.0	7.65	39.9	4.4	59.9	15.5	249.8	17.23	90.0	32.2	400 / 3 / 50	2993
75.2	24	111.0	7.65	39.9	4.4	59.9	15.5	332.1	22.90	109.9	43.3	400 / 3 / 50	2965
75.2	24	111.0	7.65	39.9	4.4	59.9	15.5	493.7	34.04	140.0	60.0	400 / 3 / 50	2966
75.2	24	121.4	8.37	45.0	7.2	65.0	18.3	289.1	19.93	100.0	37.8	400 / 3 / 50	2962
75.2	24	121.4	8.37	45.0	7.2	65.0	18.3	560.1	38.62	150.1	65.6	400 / 3 / 50	2947
75.2	24	121.4	8.37	45.0	7.2	65.0	18.3	433.8	29.91	129.9	54.4	400 / 3 / 50	2955
75.2	24	132.4	9.13	50.0	10.0	70.0	21.1	259.1	17.86	92.4	33.6	400 / 3 / 50	2984
75.2	24	132.4	9.13	50.0	10.0	70.0	21.1	289.1	19.93	100.0	37.8	400 / 3 / 50	2977
75.2	24	132.4	9.13	50.0	10.0	70.0	21.1	380.8	26.25	120.0	48.9	400 / 3 / 50	2967
75.2	24	132.4	9.13	50.0	10.0	70.0	21.1	493.7	34.04	140.0	60.0	400 / 3 / 50	2976
75.2	24	144.3	9.95	55.0	12.8	75.0	23.9	289.1	19.93	100.0	37.8	400 / 3 / 50	2948
75.2	24	144.3	9.95	55.0	12.8	75.0	23.9	332.1	22.90	109.9	43.3	400 / 3 / 50	2952
75.2	24	144.3	9.95	55.0	12.8	75.0	23.9	433.8	29.91	129.9	54.4	400 / 3 / 50	2963
75.2	24	144.3	9.95	55.0	12.8	75.0	23.9	560.1	38.62	150.1	65.6	400 / 3 / 50	2961

c. Description and Size of Test Loop

- description of the test loop components (Figure 1)
- description of instrumentation used, accuracy and measuring points (Table 2)

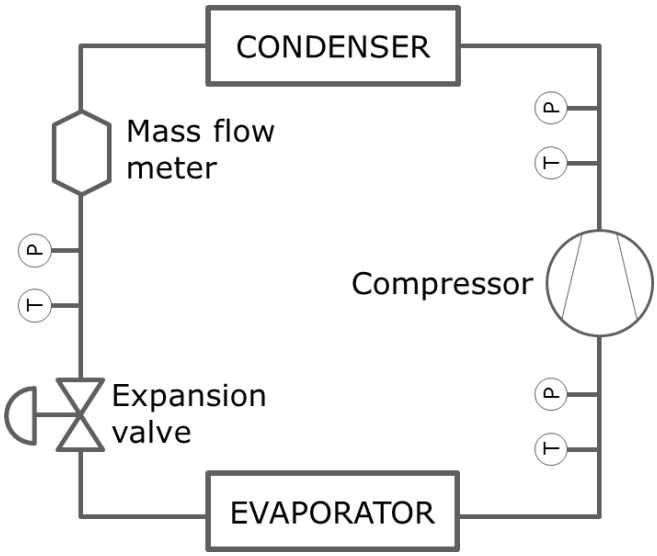

Figure 1. Simplified test loop diagram

Table 2. Test loop instrumentation accuracy

Device	Model	Scale	Accuracy
Liquid pressure Transducer	Rosemount 2088	0-28 bar	±1.0% full scale
Discharge pressure Transducer	Rosemount 2089	0-50 bar	±1.0% full scale
Suction pressure Transducer	Rosemount 2088	0-28 bar	±1.0% full scale
Suction temperature Transducer	PT100	-20-50℃	±0.3 K
Discharge temperature Transducer	PT100	50-180℃	±0.3 K
Suction temperature Transducer	PT100	-20-50℃	±0.3 K
Compressor power	Norma4000	0~150 kW	0.1% Reading +0.1% Range
Mass flow	F050S116CQFNF	544~8160 kg/h	±0.2% of rate

3. Results

All compressor tests are performed at the refrigerant's dew point temperatures 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.

Test measurements are summarized in tables of appendix A. The test process is in accordance with standard EN13771-1. Subcooling is defined based on bubble point of condensing pressure.

Comparison to R410A was done based on published data with experimental validation of several points representing extreme conditions of operating envelope. Based on the results of validating test, adjustment coefficients were introduced to polynomial model (1.013 to cooling capacity and 1.011 to power input). With mentioned adjustments Capacity, Power input and COP deviation of the polynomial model from measured data in extreme conditions is limited to ±0.7%.

10-coefficient polynomial coefficients for capacity, power and amperes can be found in table B1 of appendix B. Polynomial equations are valid within operating envelope in figure B1. Calculated performance curves for R410A and HPR2A and comparative analysis are provided in figures B2 – B10. Also figures B11 – B13 provide comparative analysis with reference to mean temperatures, both for evaporating and condensing.

4. Summary

HPR2A has a moderate temperature glide of 2 – 3 K (3 – 5 F). The capacity of HRP2A is generally lower than R410A except at the highest condensing temperature. It is in range of 87 – 103% compared to capacity of R410A across the operating envelope (Figures B2 – B4). Power consumption is 88 – 93% compared to R410A (Figures B5 – B7). COP is in range of 96 – 112% of R410A, gaining more in higher condensing temperatures (Figures B8 – B10).

Comparing data to mean temperature reference we can see that both cooling capacity and power consumption values of HPR2A improve by 2-4% compared to R410A, while COP does not change much (Figures B11 – B13).

It is also important to notice that with increased subcooling R410A recovers cooling capacity faster than HPR2A, e.g. for 5K subcooling R410A gains around 1 - 4% more capacity than HPR2A, with higher difference at higher condensing temperatures. COP change follows the pattern as power input is not affected.

Appendix A

Table A1. HPR2A Tabular Data (SI)

SST (Dew)	SDT (Dew)	Evap. Temp. (Mean)	Cond. Temp. (Mean)	Evap. glide	Cond. glide	DGT	Applicable SH	Applicable SC	Compressor capacity	Refrigerant mass flow rate	Amperes	Input power	Cooling COP	COPalt/ COPbaseline
°C	°C	°C	°C	K	K	°C	K	K	W	kg/h	A	W	W/W	-
-23.3	26.7	-24.5	25.5	2.3	2.6	114.1	11.1	8.3	14182	200	13.29	5851	2.42	0.96
-23.3	32.2	-24.4	31.0	2.1	2.5	130.4	11.1	8.3	13296	195	14.08	6601	2.01	0.96
-17.8	32.2	-19.0	31.0	2.5	2.5	111.3	11.1	8.3	17315	251	14.20	6703	2.58	0.98
-15	43.3	-16.1	42.2	2.1	2.3	133.2	11.1	8.3	17557	275	16.47	8647	2.03	0.99
-12.2	26.7	-13.4	25.4	2.5	2.6	85.4	11.1	8.3	23213	320	13.47	6020	3.86	0.98
-12.2	37.8	-13.4	36.6	2.4	2.4	110.2	11.1	8.3	20996	313	15.34	7702	2.73	0.98
-9.4	43.3	-10.6	42.2	2.5	2.3	117.3	11.1	8.3	22008	341	16.62	8755	2.51	0.98
-6.7	32.2	-7.9	31.0	2.5	2.5	86.9	11.1	8.3	27430	389	14.42	6893	3.98	0.98
-6.7	54.4	-7.8	53.4	2.3	2.0	140.8	11.1	8.3	21263	362	19.83	11250	1.89	1.00
-3.9	43.3	-5.1	42.2	2.4	2.3	104.5	11.1	8.3	27726	426	16.73	8841	3.14	0.98
-1.1	26.7	-2.3	25.7	2.5	2.6	70.3	11.1	8.3	35789	478	13.70	6223	5.75	1.00
-1.1	32.2	-2.4	30.9	2.5	2.5	79.1	11.1	8.3	34085	479	14.52	6976	4.89	0.98
-1.1	37.8	-2.3	36.6	2.4	2.4	88.7	11.1	8.3	32680	479	15.57	7884	4.15	0.99
1.7	54.4	0.5	53.4	2.3	2.0	118.6	11.1	8.3	29996	503	20.07	11412	2.63	1.00
4.4	32.2	3.2	31.1	2.5	2.5	73.5	11.1	8.3	41831	583	14.66	7101	5.89	0.99
4.4	43.3	3.2	42.2	2.3	2.3	91.5	11.1	8.3	37740	572	16.90	8973	4.21	0.98
4.4	60.0	3.3	59.1	2.1	1.9	126.5	11.1	8.3	30649	541	22.09	12890	2.38	1.03
7.2	37.8	6.0	36.6	2.4	2.4	79.6	11.1	8.3	43718	632	15.74	8023	5.45	0.98
7.2	65.6	6.2	64.8	2.1	1.6	135.3	11.1	8.3	30855	578	24.62	14702	2.10	1.05
7.2	54.4	6.0	53.4	2.3	2.0	109.0	11.1	8.3	36623	608	20.12	11442	3.20	1.00
10	33.6	8.8	32.4	2.4	2.5	70.8	11.1	8.3	50026	699	15.08	7454	6.71	0.98
10	37.8	8.8	36.6	2.4	2.4	76.5	11.1	8.3	48336	696	15.82	8086	5.98	0.98
10	48.9	8.9	47.8	2.3	2.2	94.3	11.1	8.3	43336	682	18.42	10163	4.26	1.00
10	60.0	8.9	59.1	2.1	1.9	116.0	11.1	8.3	37705	660	22.23	12989	2.90	1.03
12.8	37.8	11.5	36.5	2.6	2.4	74.9	11.1	8.3	52529	754	15.93	8176	6.42	0.97
12.8	43.3	11.5	42.1	2.5	2.3	82.6	11.1	8.3	50160	751	17.08	9103	5.51	0.98
12.8	54.4	11.6	53.4	2.4	2.0	101.0	11.1	8.3	44639	736	20.17	11480	3.89	1.01
12.8	65.6	11.8	64.8	2.1	1.6	123.9	11.1	8.3	37982	705	24.69	14745	2.58	1.05

Table A2. HPR2A Tabular Data (IP)

SST (Dew)	SDT (Dew)	Evap. Temp. (Mean)	Cond. Temp. (Mean)	Evap. glide	Cond. glide	DGT	Applicable SH	Applicable SC	Compressor capacity	Refrigerant mass flow rate	Amperes	Input power	Cooling COP	COPalt /COPbaseline
°F	°F	°F	°F	°F	°F	°F	°F	°F	Btu/h	lbs/h	A	W	Btu/h-W	-
-9.9	80.1	-12.0	77.9	4.2	4.6	237.4	20.0	15.0	48390	440	13.29	5851	8.27	0.96
-9.9	90.0	-11.9	87.8	3.8	4.5	266.6	20.0	15.0	45368	429	14.08	6601	6.87	0.96
0.0	90.0	-2.3	87.7	4.4	4.5	232.3	20.0	15.0	59081	553	14.20	6703	8.81	0.98
5.0	109.9	3.1	107.9	3.9	4.1	271.7	20.0	15.0	59908	607	16.47	8647	6.93	0.99
10.0	80.1	7.8	77.7	4.5	4.6	185.7	20.0	15.0	79207	706	13.47	6020	13.16	0.98
10.0	100.0	7.9	97.9	4.3	4.3	230.4	20.0	15.0	71640	691	15.34	7702	9.30	0.98
15.1	109.9	12.8	107.9	4.5	4.1	243.1	20.0	15.0	75094	753	16.62	8755	8.58	0.98
19.9	90.0	17.7	87.7	4.5	4.5	188.4	20.0	15.0	93596	858	14.42	6893	13.58	0.98
19.9	129.9	17.9	128.1	4.1	3.6	285.4	20.0	15.0	72551	799	19.83	11250	6.45	1.00
25.0	109.9	22.8	107.9	4.3	4.1	220.0	20.0	15.0	94605	939	16.73	8841	10.70	0.98
30.0	80.1	27.8	78.3	4.5	4.6	158.5	20.0	15.0	122118	1054	13.70	6223	19.62	1.00
30.0	90.0	27.8	87.6	4.5	4.5	174.4	20.0	15.0	116304	1057	14.52	6976	16.67	0.98
30.0	100.0	27.9	97.9	4.3	4.3	191.6	20.0	15.0	111510	1055	15.57	7884	14.14	0.99
35.1	129.9	33.0	128.1	4.2	3.6	245.5	20.0	15.0	102352	1109	20.07	11412	8.97	1.00
39.9	90.0	37.7	88.0	4.4	4.5	164.3	20.0	15.0	142732	1286	14.66	7101	20.10	0.99
39.9	109.9	37.8	107.9	4.2	4.1	196.6	20.0	15.0	128774	1260	16.90	8973	14.35	0.98
39.9	140.0	38.0	138.3	3.8	3.3	259.7	20.0	15.0	104577	1193	22.09	12890	8.11	1.03
45.0	100.0	42.8	97.9	4.4	4.3	175.3	20.0	15.0	149173	1394	15.74	8023	18.59	0.98
45.0	150.1	43.1	148.6	3.8	3.0	275.6	20.0	15.0	105282	1274	24.62	14702	7.16	1.05
45.0	129.9	42.9	128.1	4.2	3.6	228.2	20.0	15.0	124963	1341	20.12	11442	10.92	1.00
50.0	92.4	47.9	90.2	4.3	4.4	159.4	20.0	15.0	170695	1542	15.08	7454	22.90	0.98
50.0	100.0	47.9	97.8	4.3	4.3	169.7	20.0	15.0	164928	1535	15.82	8086	20.40	0.98
50.0	120.0	47.9	118.1	4.1	3.9	201.8	20.0	15.0	147869	1504	18.42	10163	14.55	1.00
50.0	140.0	48.1	138.3	3.8	3.3	240.8	20.0	15.0	128653	1454	22.23	12989	9.90	1.03
55.0	100.0	52.7	97.8	4.6	4.3	166.8	20.0	15.0	179236	1663	15.93	8176	21.92	0.97
55.0	109.9	52.8	107.7	4.6	4.1	180.8	20.0	15.0	171154	1656	17.08	9103	18.80	0.98
55.0	129.9	52.9	128.1	4.3	3.6	213.8	20.0	15.0	152314	1621	20.17	11480	13.27	1.01
55.0	150.1	53.2	148.6	3.8	3.0	255.0	20.0	15.0	129601	1554	24.69	14745	8.79	1.05

Appendix B

Based on acquired data 10-coefficient polynomial equations were generated for cooling capacity, power input and amperes with reference to dew temperature. The set of coefficients is given in Table B1. The equations are valid within its application envelope given in Figure B1 for conditions with superheat 11 K and subcooling 8.3 K.

Table B1. Coefficients for polynomial equations

For R410A:

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
Capacity	46166	1621.6	-53.31	23.781	-3.035	-5.401	0.1154	-0.1451	-0.1116	0.01567
Power	2697.3	-22.00	199.18	-1.296	2.293	-2.8398	-0.01238	0.03962	-0.0337	0.0432
Amperes	10.238	0.008	0.1815	4.71E-4	7.90E-4	-2.83E-3	1.083E-6	-3.91E-6	-1.79E-5	5.53E-5

For HPR2A:

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9
Capacity	49137	1736	-631.04	24.39	-15.88	9.336	0.1365	-0.1971	0.0762	-0.08898
Power	2945	53.14	125.54	1.799	-1.581	-0.7500	0.02018	-0.04051	0.01535	0.02364
Amperes	11.236	0.08336	0.07039	2.402E-3	-2.877E-3	6.551E-5	2.026E-5	-5.602E-5	3.138E-5	2.947E-5

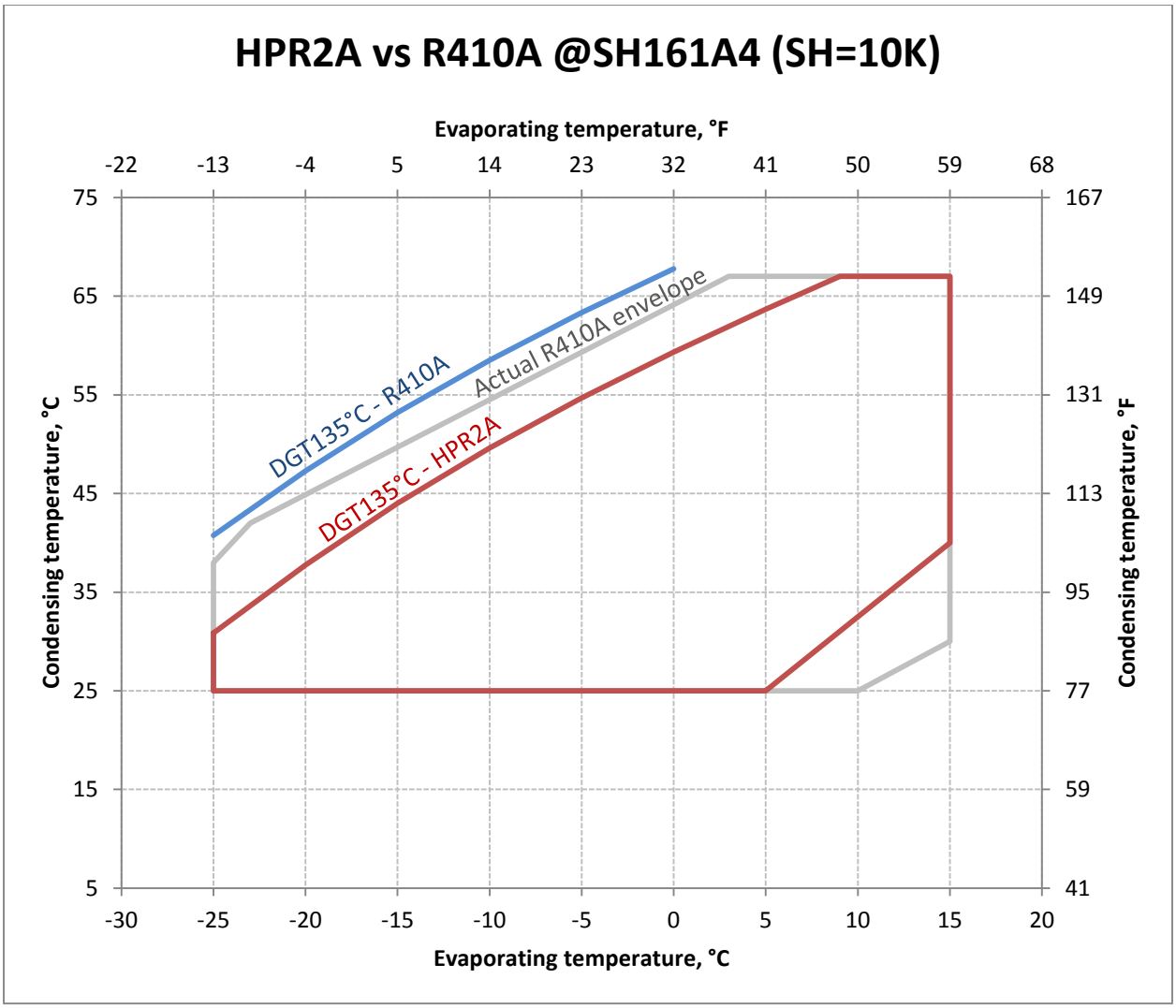

Figure B1. Application envelope of HPR2A in SH161 (DGT – discharge gas temperature)

Data below is calculated for conditions with superheat 10 K and subcooling 0 K. Values are referenced to dew temperatures except for figures B11 – B13, which are referenced to mean temperatures and are to estimate the impact of temperature glide.

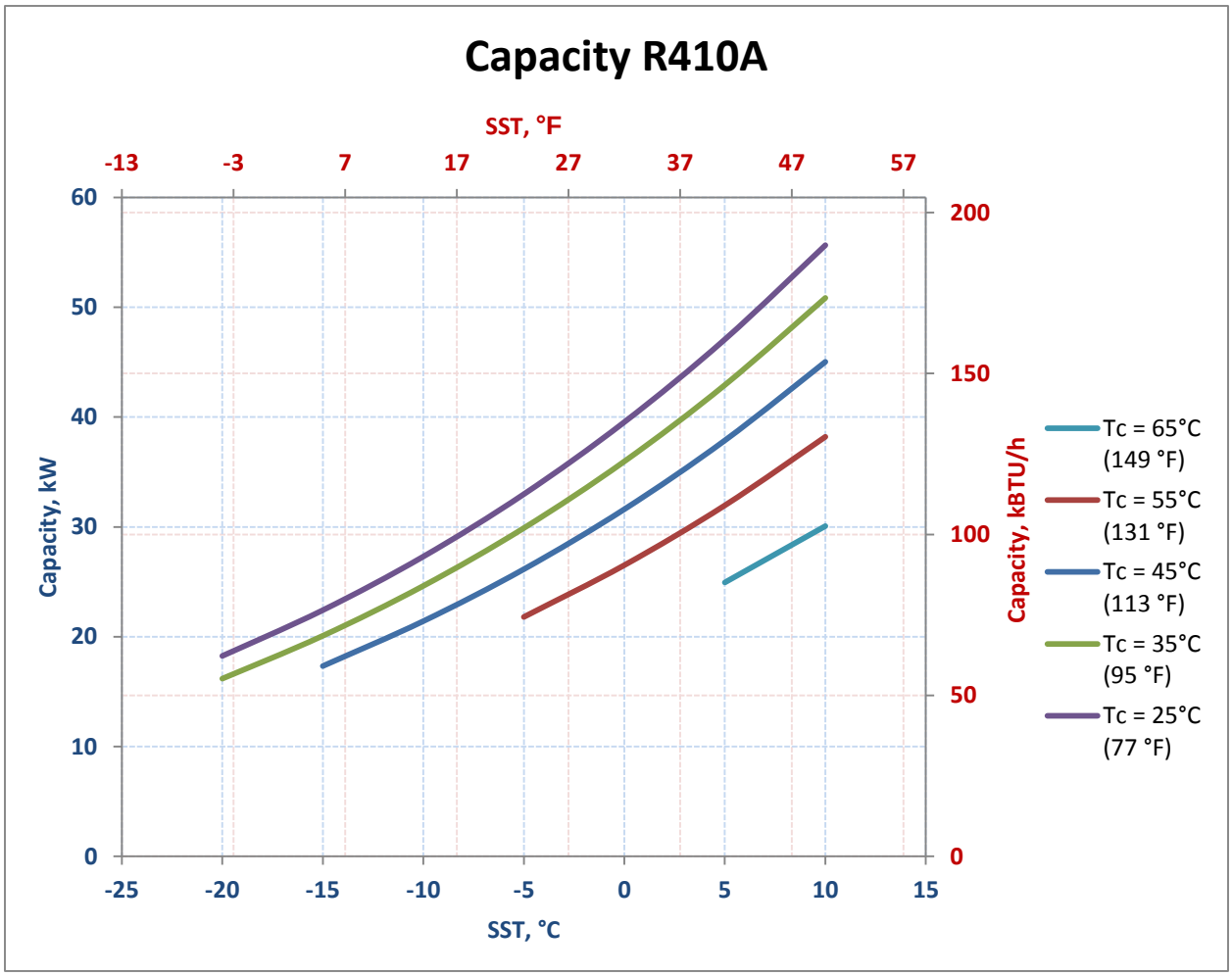

Figure B2. Cooling capacity for R410A (SST – saturated suction temperature)

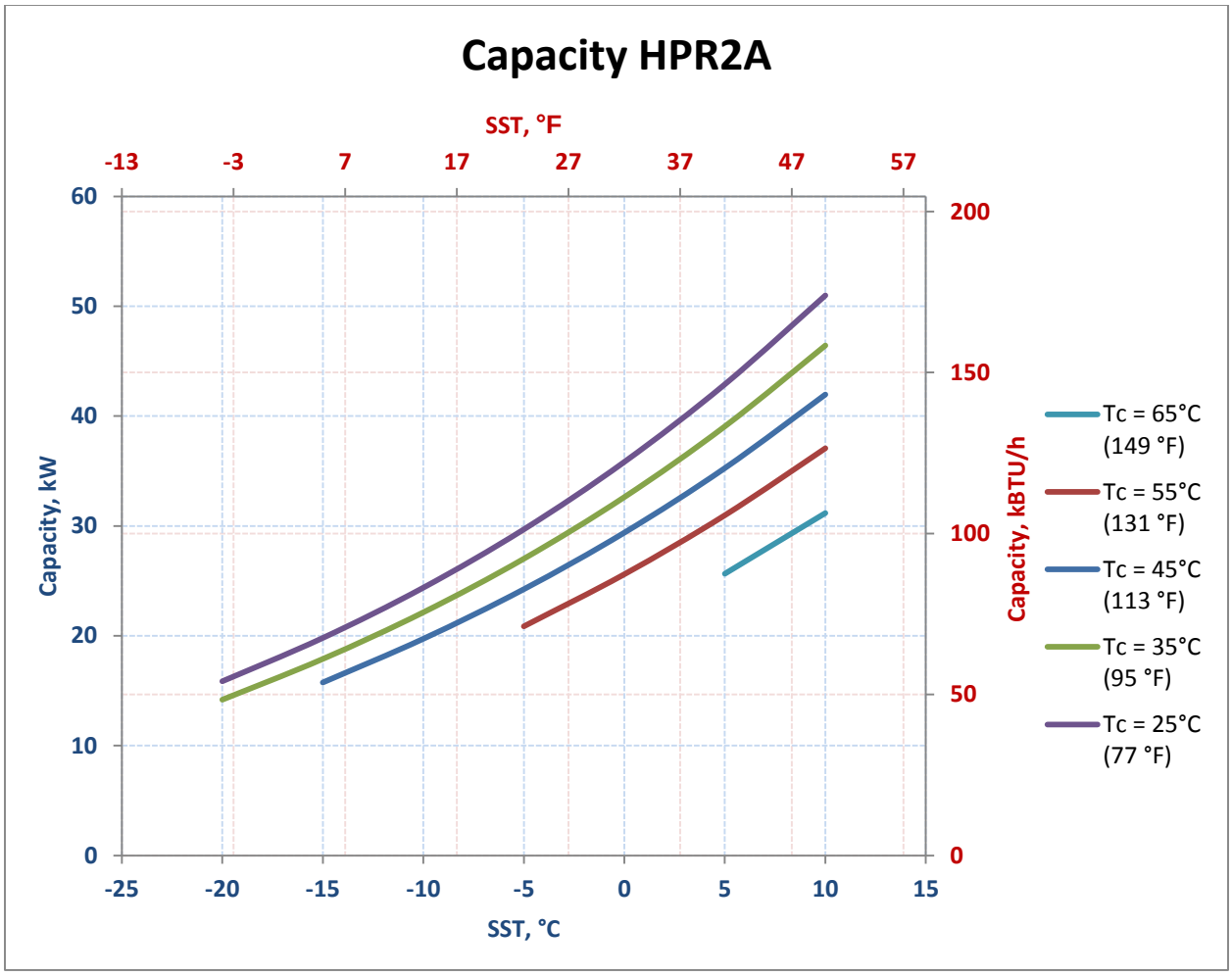

Figure B3. Cooling capacity for HPR2A

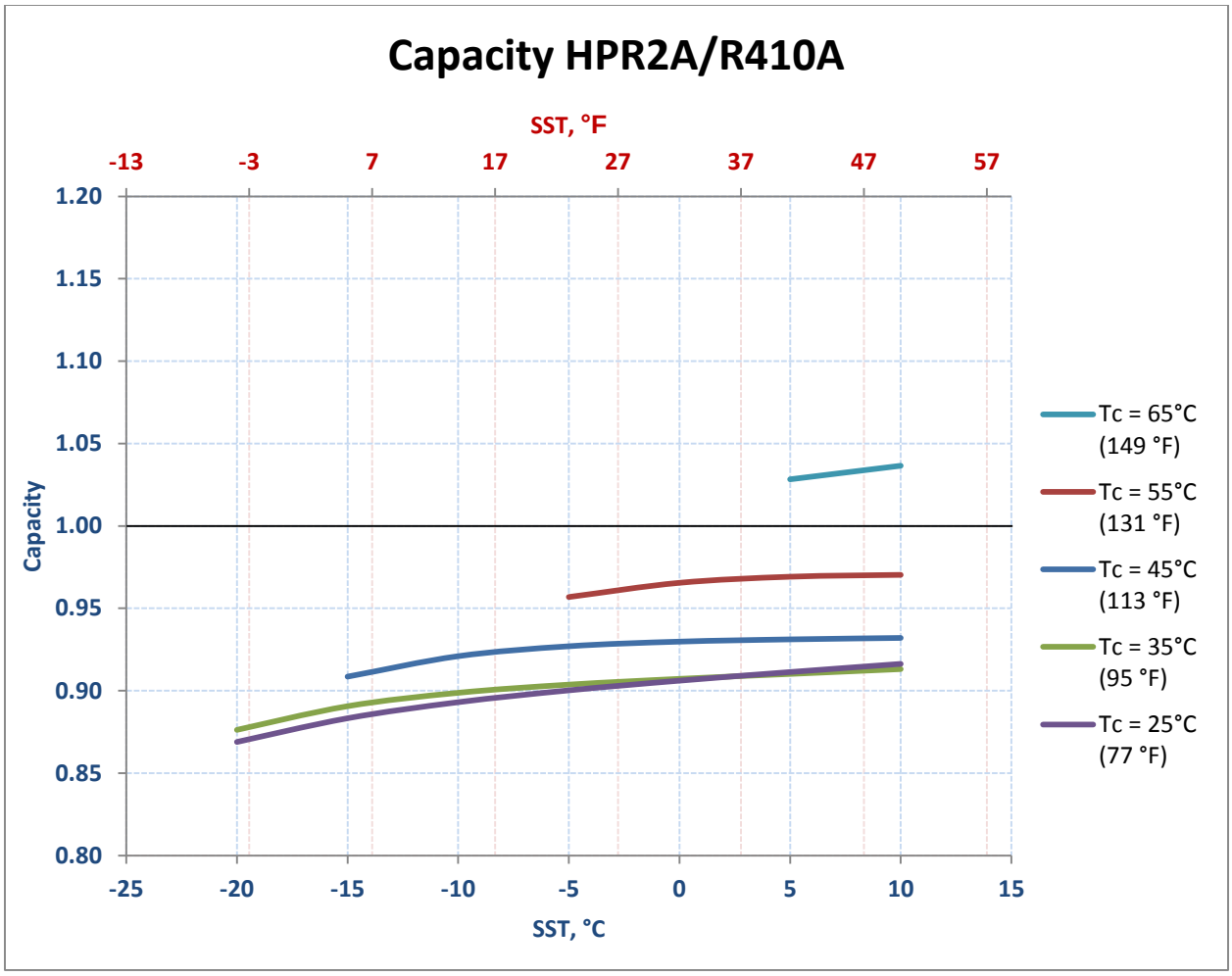

Figure B4. Cooling capacity for HPR2A/R410A

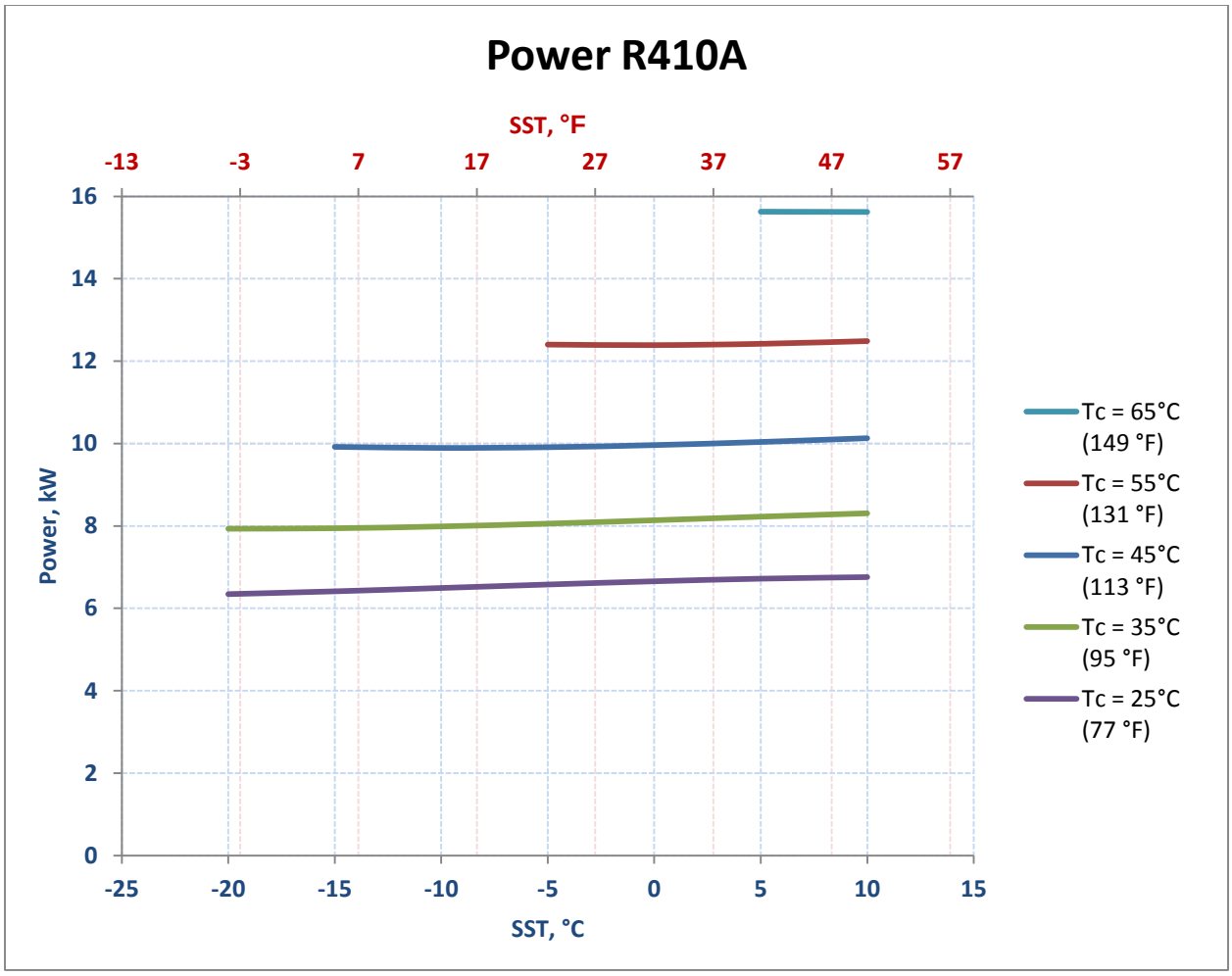

Figure B5. Power input for R410A

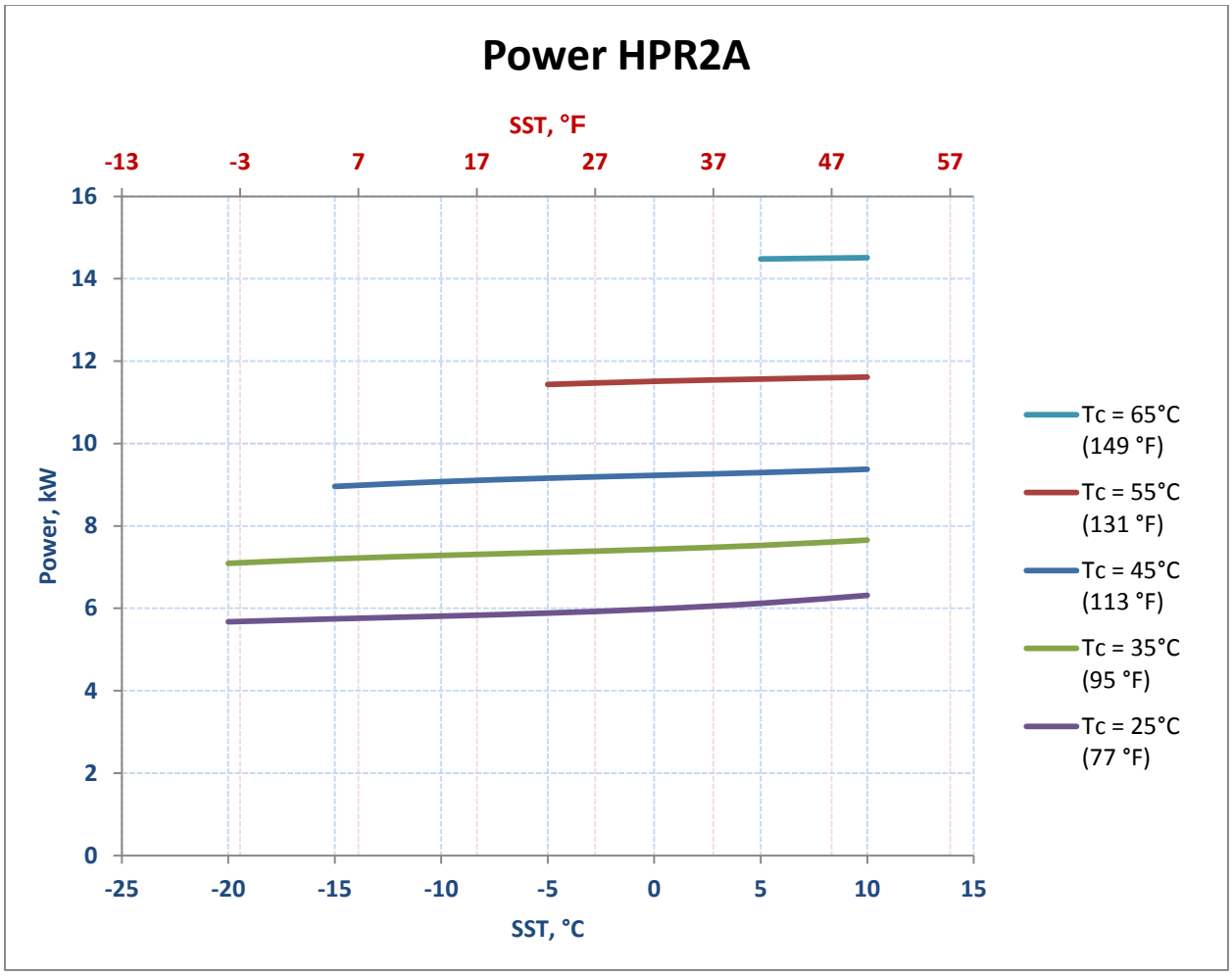

Figure B6. Power input for HPR2A

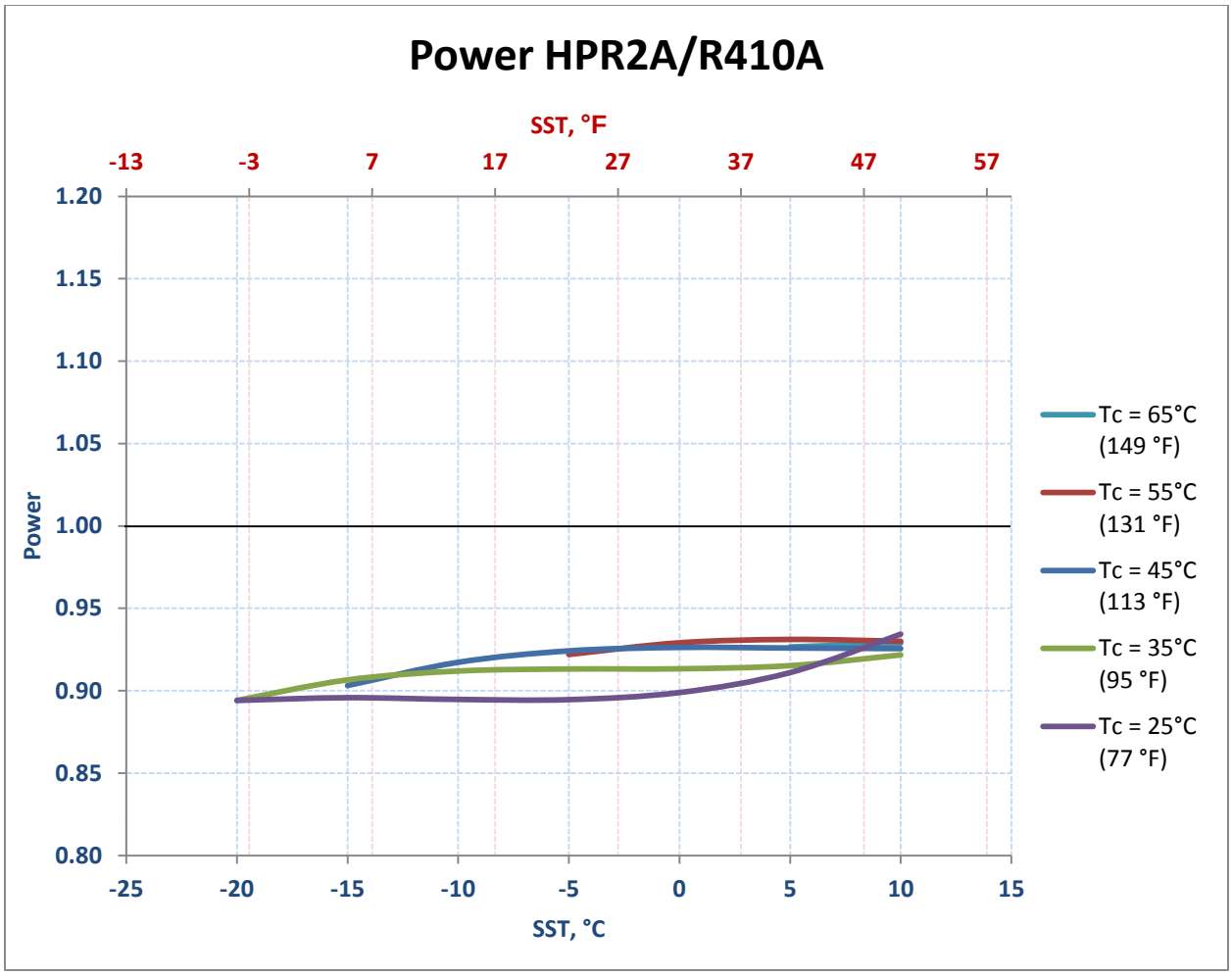

Figure B7. Power input for HPR2A/R410A

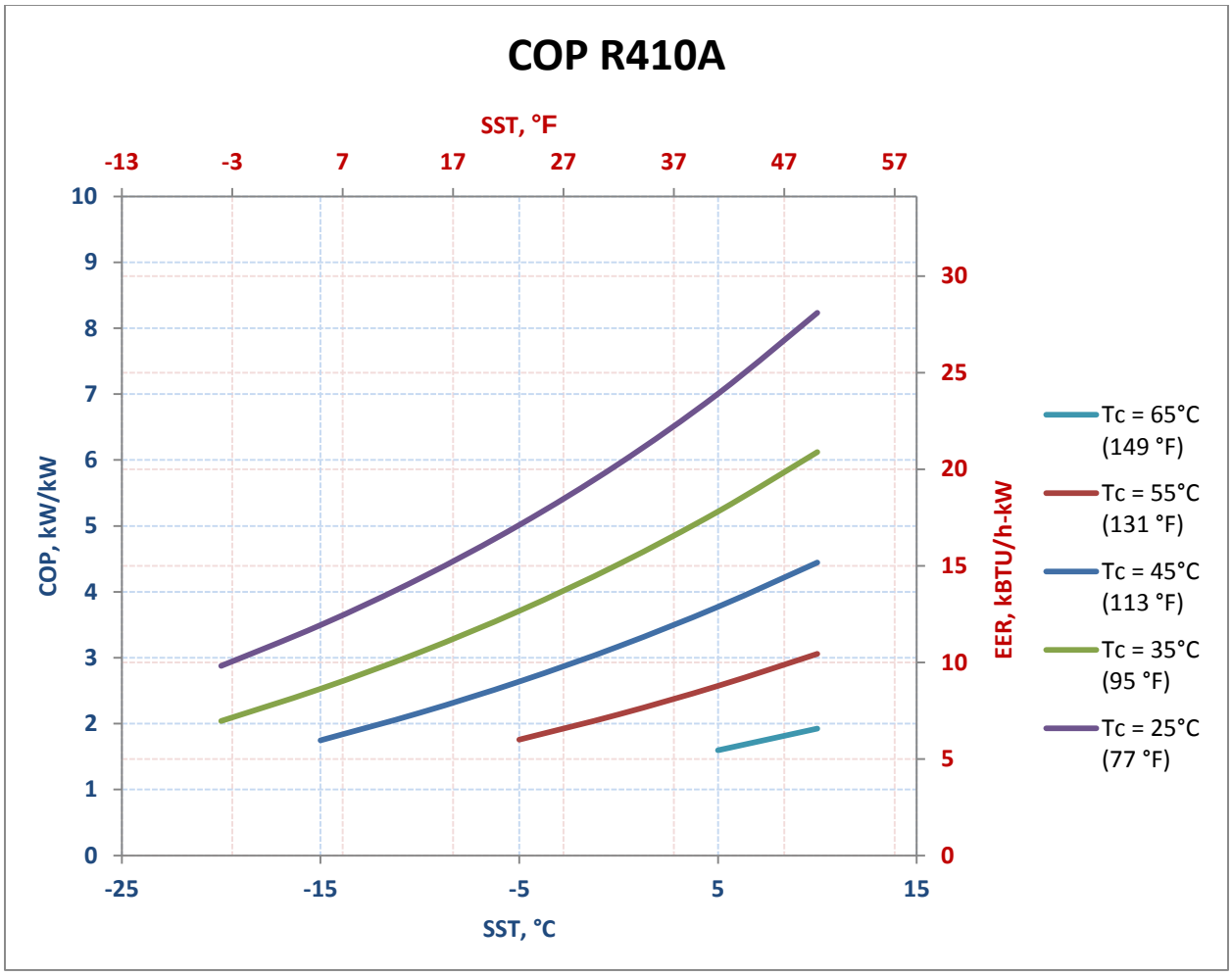

Figure B8. COP for R410A

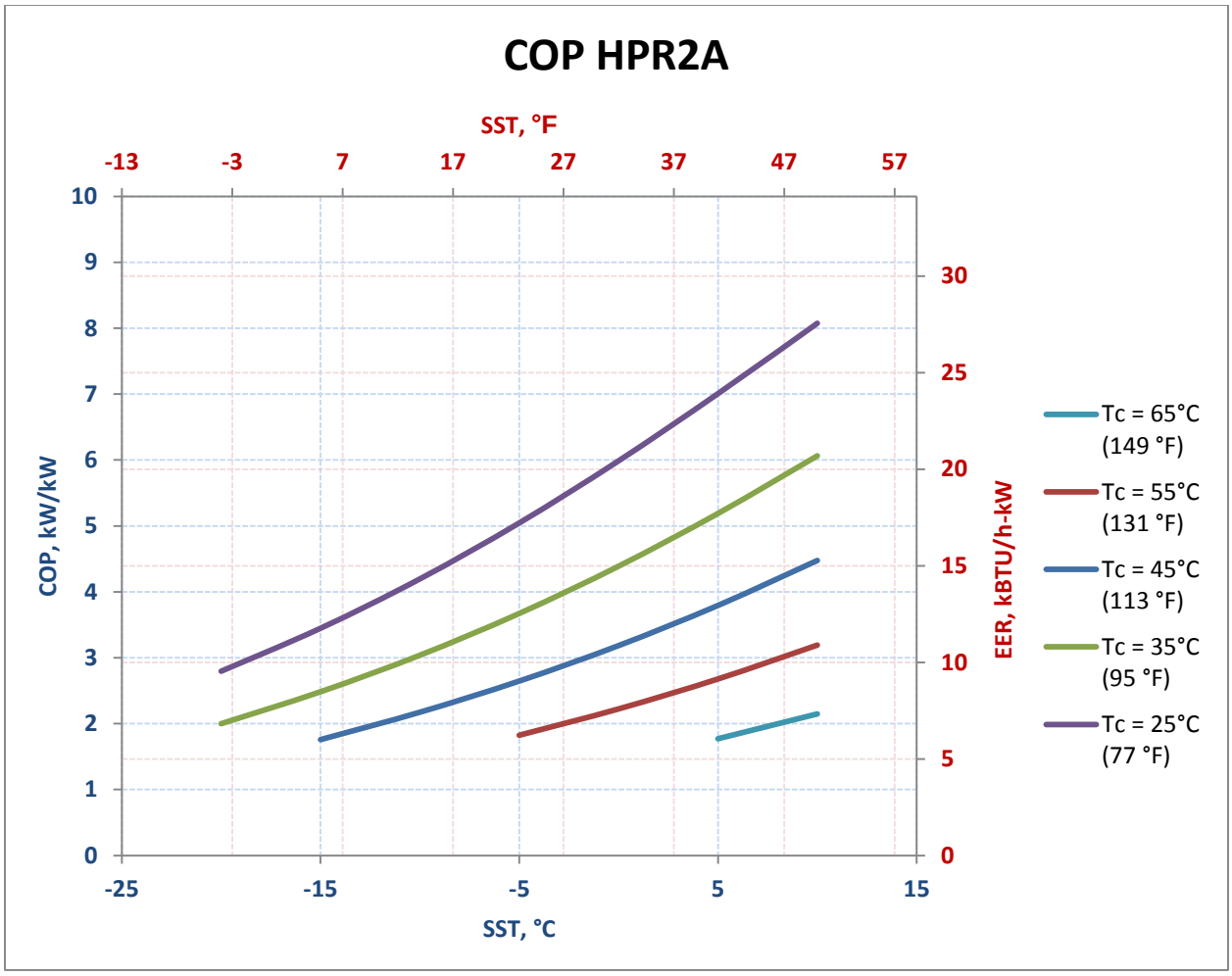

Figure B9. COP for HPR2A

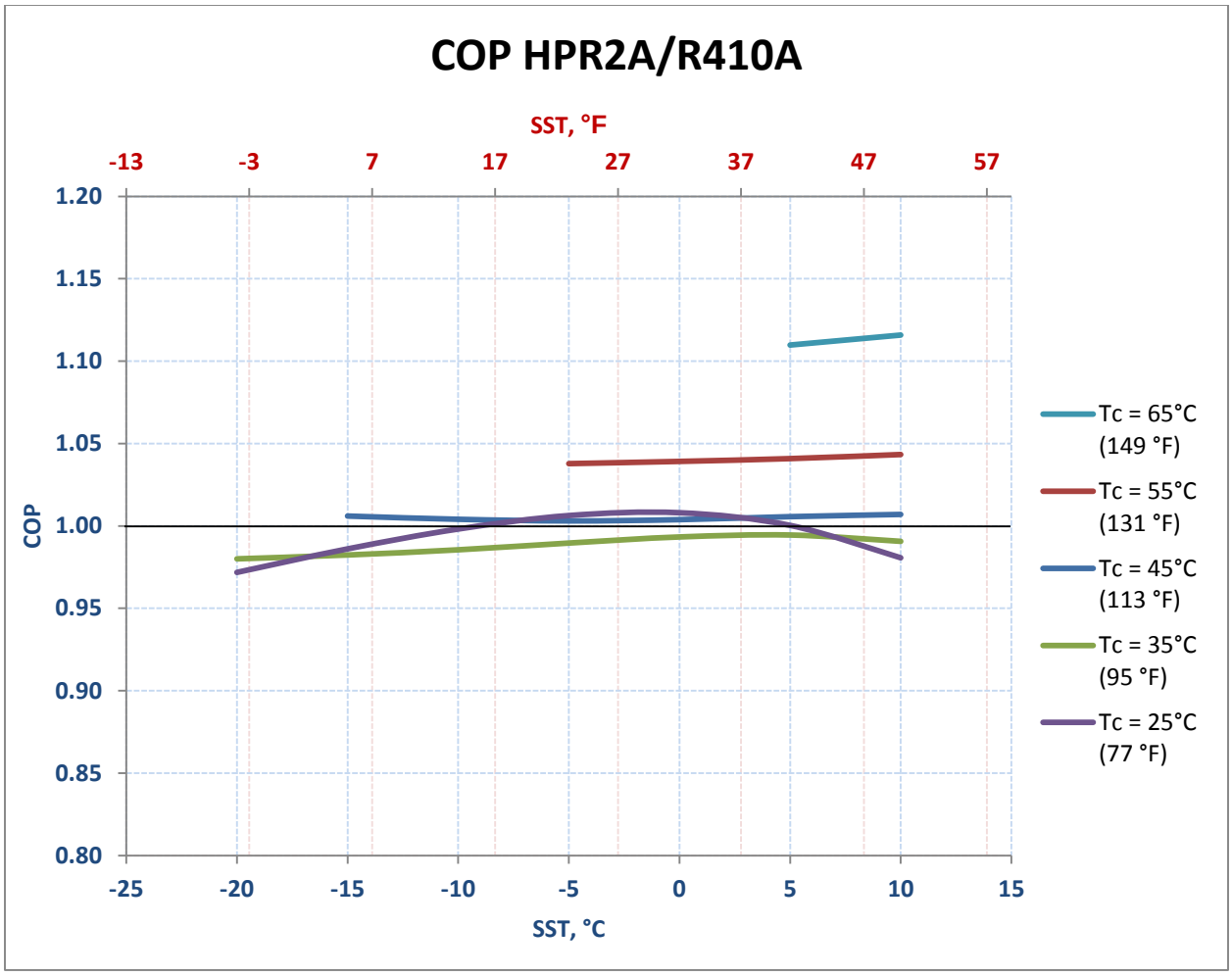

Figure B10. COP for HPR2A/R410A

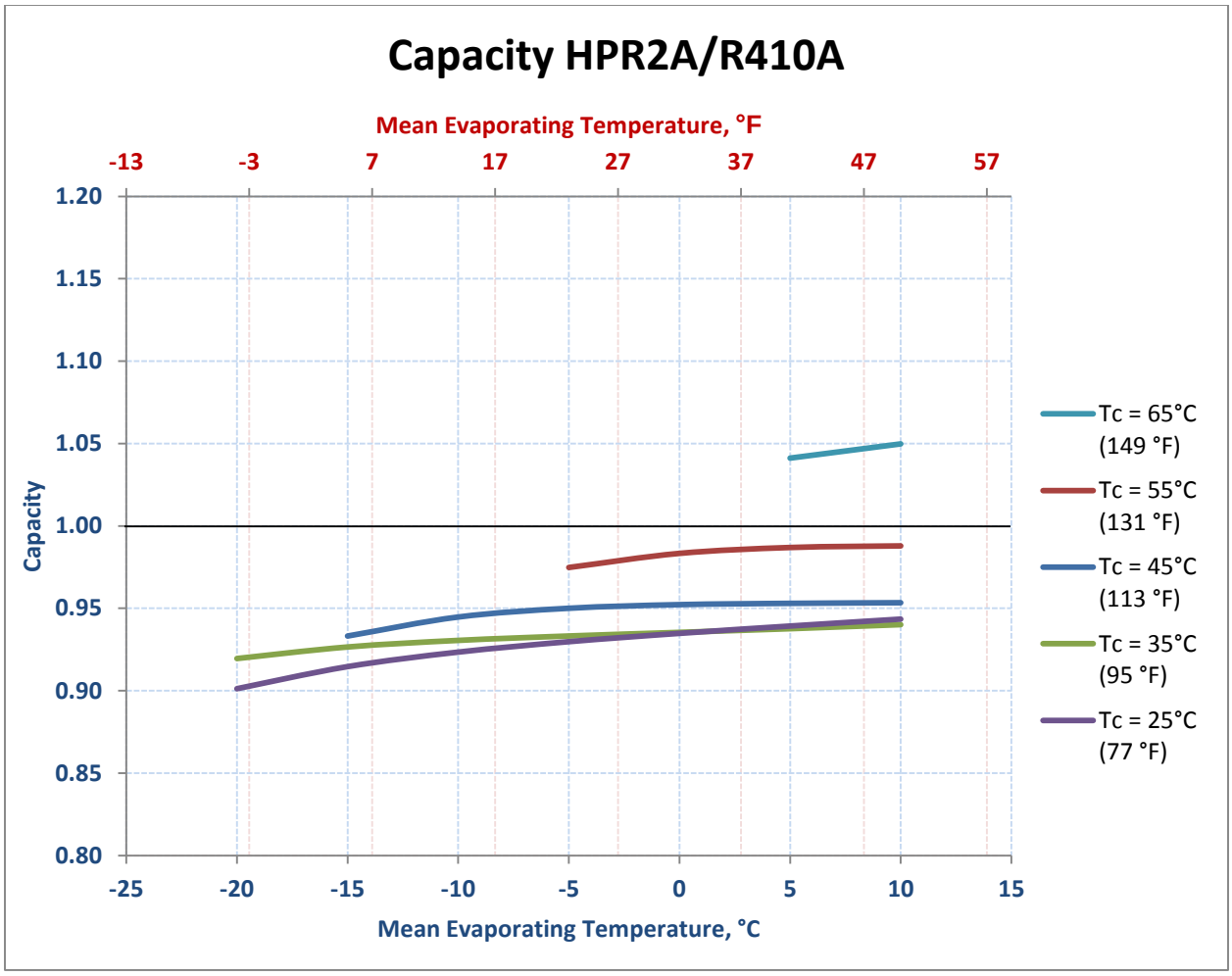

Figure B11. Capacity for HPR2A/R410A referenced to mean temperature

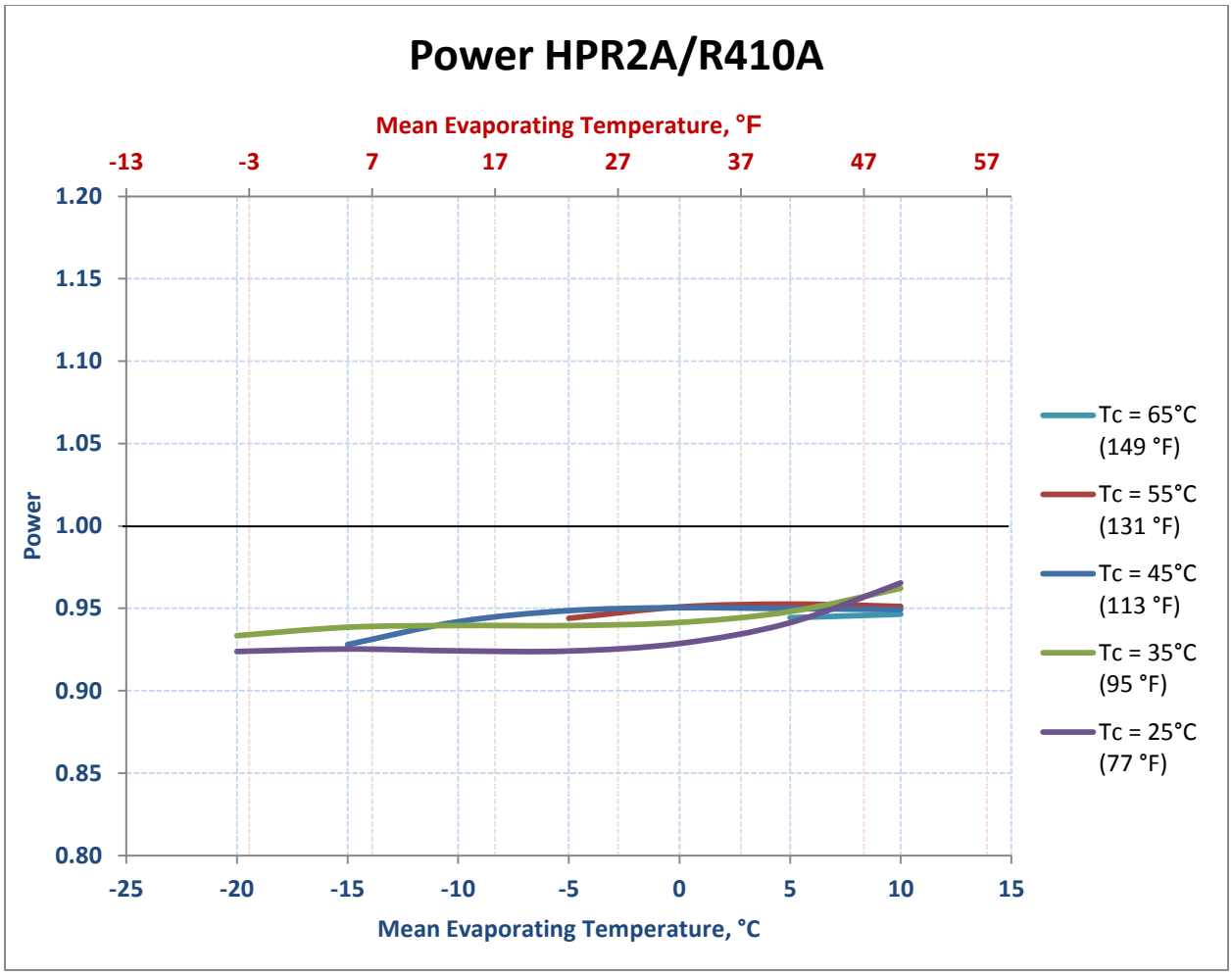

Figure B12. Power input for HPR2A/R410A referenced to mean temperature

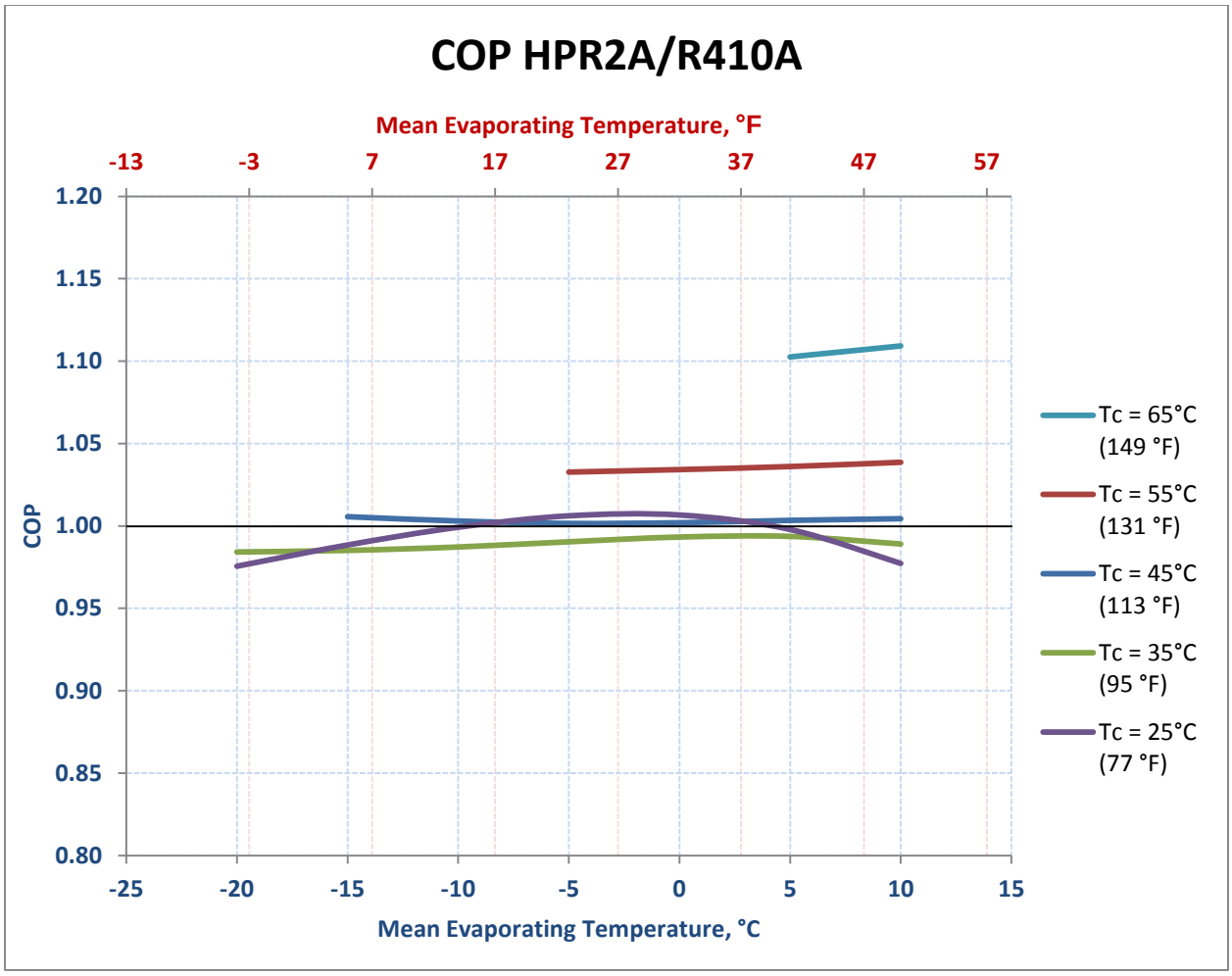

Figure B13. COP for HPR2A/R410A referenced to mean temperature