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

TEST REPORT #51

Compressor Calorimeter Test of Refrigerant Blend DR-33 (R449A) in a R-404A Reciprocating 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 Refrigerant's Compositions (Mass %)

R449A	R32/R125/R134a/R1234yf (24/25/26/25)

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Introduction

This report provides the performance results for R449A as an alternative to R404A. These tests were conducted in January of 2014 at BITZER's lab facility in Schkeuditz, Germany in accordance with the testing standard DIN 13771-1: 2003. The refrigerant data source is ASEREP v3.5.0.

Details of Test Setup

- Description of Test Refrigerant-Lubricant and Charge
  - Refrigerant or Refrigerant Blend tested / Charge
    - R449A (GWP 1397) / 55.1lb (25 kg) – Not optimized
    - R404A (GWP 3992) / 55.1lb (25 kg) – Not optimized
  - Lubricant:
    - BSE 32 (Solest 31-HE)
    - Viscosity 32.7 cST @ 40 °C
    - No modifications

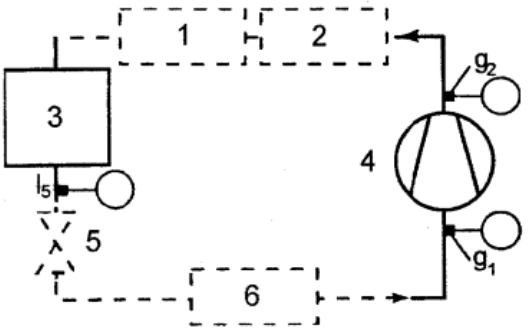
- Description of Compressor
  - Semi-hermetic reciprocating compressor
  - Standard compressor - No modification
  - BITZER m/n: 4GE-23-40P, s/n: 1678812036 (ID TE-10: B5-6.XXII)
  - Nameplate rating: 380-420v, 50Hz, 97/158 LRA, 2984 CFH, 1450RPM
  - Airflow required (Y/N): No
  - Compressor operating conditions during test (Table 1):

Table 1: Compressor Operating Condition (R449A Dew Point)

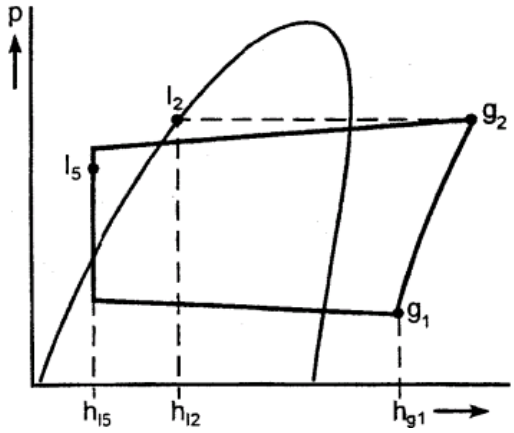
Ambient Temperature DIN 12900: 2005		Saturated Suction Temperature		Suction Pressure		Return Gas Temperature		Saturated Condensing Temperature		Discharge Pressure	
°F	°C	°F	°C	psia	Bar	°F	°C	°F	°C	psia	Bar
89.6	32	41	5	81.17	5.60	68	20	104	40	224.06	15.45
89.6	32	32	0	68.66	4.73	68	20	68	20	129.32	8.92
89.6	32	32	0	68.66	4.73	68	20	104	40	224.06	15.45
89.6	32	23	-5	57.67	3.98	68	20	68	20	129.32	8.92
89.6	32	23	-5	57.67	3.98	68	20	104	40	224.06	15.45
89.6	32	23	-5	57.67	3.98	68	20	140	60	364.97	25.16
89.6	32	14	-10	48.09	3.32	68	20	113	45	254.40	17.54
89.6	32	14	-10	48.09	3.32	68	20	140	60	364.97	25.16
89.6	32	-4	-20	32.63	2.25	68	20	68	20	129.32	8.92
89.6	32	-4	-20	32.63	2.25	68	20	104	40	224.06	15.45
89.6	32	-4	-20	32.63	2.25	68	20	140	60	364.97	25.16
89.6	32	-31	-35	16.99	1.17	68	20	68	20	129.32	8.92
89.6	32	-31	-35	16.99	1.17	68	20	104	40	224.06	15.45
89.6	32	-40	-40	13.37	0.92	32	0	104	40	224.06	15.45
89.6	32	-49	-45	10.39	0.72	-13	-25	104	40	224.06	15.45
89.6	32	-49	-45	10.39	0.72	68	20	68	20	129.32	8.92

- Description and Size of Test Loop
  - Test Loop Diagram (Figure 1)
    i. Measurement System E according to DIN 13771-1 - 2003
  - Instrumentation Information (Table 2)

Figure 1: Test Loop Diagram



Test Loop Diagram



Ph Diagram

Legend

1	Subcooler
2	Condenser
3	Flow meter
4	Compressor
5	Expansion valve
6	Evaporator

Table 2: Instrumentation Information and Accuracy

Reference description	**Standard**	**TEK-10 ID No.** (Test Equipment no)	**Type of measuring device**	**accuracy class** (**DIN 13771-1 – 2003**)	**full scale**
pg1	DIN 13771-1 - 2003	ND6-1/032	Pressure transducer	± 1%	10 bara
pg2	DIN 13771-1 - 2003	ND6-1/034	Pressure transducer	± 1%	32 bara
qm	DIN 13771-1 - 2003	MZ6-1-005	Massflowmeter	± 1%	90 kg/min
ta	DIN 13771-1 - 2003	PT6-1/036	PT100	± 0,3 K	50 °C
tga	DIN 13771-1 - 2003	PT6-1/038	PT100	± 0,3 K	70 °C
pl5 - Eingang Expansionseinrichtung	DIN 13771-1 - 2003	ND6-1/035	Pressure transducer	± 1%	32 bara
Tl5 - Eingang Expansionseinrichtung	DIN 13771-1 - 2003	PT6-1/037	PT100	± 0,3 K	90 °C
Pa	DIN 13771-1 - 2003	LM6-1/009	Wattmeter	± 0,5 %	50 kW
U	DIN 13771-1 - 2003 BITZER	LM6-1/009	Wattmeter	± 0,5 %	400 V
Fa	DIN 13771-1 - 2003 BITZER	LM6-1/009	Wattmeter	± 0,5 %	50 Hz

Results

"All compressor tests are performed at a refrigerant's dew point temperature for suction and discharge pressure conditions. 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."

Table 3 shows the deviation in capacity, power, COP and discharge temperature of R449A compared to R404A. The tests were conducted at a saturated suction temperature between 0°C and -45°C and a saturated condensing temperature between 20°C and 60°C with a 20°C return gas temperature and 0°K subcooling.

Table 3: Performance of R449A compared to R404A

Refrigerant		Capacity	Power	COP	Discharge Temperature
R449A	Over Entire Test Range	-19% to +5%	-16% to -10	-4% to +17%	+9% to +17%
	Average	-7.4%	-13.4%	+6.8%	+13%

Appendix A provides the result of the tests in tabular form. Appendix B provides the coefficients for the 10-coefficient polynomial equation. Also included in Appendix B are performance and comparative plots for capacity, power and COP.

The typical temperature glide for R449A is 5°K (9°R); R404A is 0.7°K (1.2°R).

Summary

As the saturated suction temperature drops, the compressor capacity of R449A decreases when compared to R404A. The decrease in the required input power for R449A is greater than the corresponding decrease in capacity resulting in generally higher COPs for R449A. The discharge temperature for R449A is consistently higher than that of R404A.

Appendix A – Tabular Data

Table A1: R449A Test Results (Dew Point – SI Units)

Amb	SST	RGT	SCT	DGT	SH	SC	Cooling Capacity	Amps	Mass flow	Power	COP	COP Ratio	Freq
°C	°C	°C	°C	°C	°C	°K	W	A	kg/hr	W	W/W		Hz
32	0	20	20.0	56.1	20	0	87444	23.2	1623	12937	6.76	1.08	50
32	0	20	40.0	81.1	20	0	68297	32.5	1511	19289	3.54	1.10	50
32	-5	20	20.0	64.5	25	0	71844	23.1	1321	12857	5.59	1.05	50
32	-5	20	40.0	89.3	25	0	55901	30.6	1224	18075	3.09	1.08	50
32	-5	20	60.0	118.0	25	0	39000	37.6	1091	22595	1.73	1.17	50
32	-10	20	45.0	105.1	30	0	41869	29.9	959	17649	2.37	1.08	50
32	-10	20	60.0	126.5	30	0	31569	33.8	872	20188	1.56	1.16	50
32	-20	20	20.0	88.7	40	0	37710	20.3	681	10823	3.48	1.03	50
32	-20	20	40.0	115.2	40	0	29103	24.0	624	13680	2.13	1.05	50
32	-20	20	60.0	143.0	40	0	19387	26.2	527	15145	1.28	1.14	50
32	-35	20	20.0	118.9	55	0	17384	16.5	312	7872	2.21	0.97	50
32	-35	20	40.0	144.7	55	0	12237	17.1	259	8508	1.44	1.00	50
32	-40	0	40.0	149.9	40	0	8207	15.6	191	7245	1.13	0.98	50
32	-45	-25	40.0	149.8	20	0	4941	14.0	133	5745	0.86	0.99	50
32	-45	20	20.0	140.0	65	0	9271	14.0	165	5733	1.62	0.96	50

Table A2: R449A Test Results (Dew Point – IP Units)

Amb	SST	RGT	SCT	DGT	SH	SC	Cooling Capacity	Amps	Mass flow	Power	EER	EER Ratio	Freq
°F	°F	°F	°F	°F	°F	°F	Btu/hr	A	lbm/hr	W	btu/hr-W		Hz
89.6	32	68	68.0	133.0	36	0	298566	23.2	3578	12937	23.08	1.08	50
89.6	32	68	104.0	178.0	36	0	233191	32.5	3331	19289	12.09	1.10	50
89.6	23	68	68.0	148.1	45	0	245302	23.1	2912	12857	19.08	1.05	50
89.6	23	68	104.0	192.7	45	0	190867	30.6	2698	18075	10.56	1.08	50
89.6	23	68	140.0	244.4	45	0	133160	37.6	2405	22595	5.89	1.17	50
89.6	14	68	113.0	221.2	54	0	142956	29.9	2114	17649	8.10	1.08	50
89.6	14	68	140.0	259.7	54	0	107788	33.8	1922	20188	5.34	1.16	50
89.6	-4	68	68.0	191.7	72	0	128756	20.3	1501	10823	11.90	1.03	50
89.6	-4	68	104.0	239.4	72	0	99368	24.0	1376	13680	7.26	1.05	50
89.6	-4	68	140.0	289.4	72	0	66194	26.2	1162	15145	4.37	1.14	50
89.6	-31	68	68.0	246.0	99	0	59355	16.5	688	7872	7.54	0.97	50
89.6	-31	68	104.0	292.5	99	0	41782	17.1	571	8508	4.91	1.00	50
89.6	-40	32	104.0	301.8	72	0	28022	15.6	421	7245	3.87	0.98	50
89.6	-49	-13	104.0	301.6	36	0	16870	14.0	293	5745	2.94	0.99	50
89.6	-49	68	68.0	284.0	117	0	31655	14.0	364	5733	5.52	0.96	50

Table A3: R404A Test Results (Dew Point – SI Units)

Amb	SST	RGT	SCT	DGT	SH	SC	Cooling Capacity	Amps	Mass flow	Power	COP	COP Ratio	Freq
°C	°C	°C	°C	°C	°C	°K	W	A	kg/hr	W	W/W		Hz
32	0	20	20.0	51.7	20	0	94538	26.4	2172	15112	6.26	1.08	50
32	0	20	40.0	73.6	20	0	69906	36.2	2009	21677	3.22	1.10	50
32	-5	20	20.0	58.0	25	0	78275	25.5	1779	14764	5.30	1.05	50
32	-5	20	40.0	80.0	25	0	58100	34.3	1648	20382	2.85	1.08	50
32	-5	20	60.0	103.4	25	0	37107	41.5	1485	25152	1.48	1.17	50
32	-10	20	45.0	92.3	30	0	43650	33.6	1311	19943	2.19	1.08	50
32	-10	20	60.0	109.4	30	0	30668	37.7	1208	22712	1.35	1.16	50
32	-20	20	20.0	78.5	40	0	42717	22.8	949	12611	3.39	1.03	50
32	-20	20	40.0	100.7	40	0	31737	27.1	874	15713	2.02	1.05	50
32	-20	20	60.0	124.7	40	0	19840	30	763	17689	1.12	1.14	50
32	-35	20	20.0	102.5	55	0	21195	18.5	464	9353	2.27	0.97	50
32	-35	20	40.0	124.0	55	0	15091	19.9	409	10516	1.44	1.00	50
32	-40	0	40.0	116.4	40	0	10197	17.8	316	8801	1.16	0.98	50
32	-45	-25	40.0	114.4	20	0	6233	15.9	233	7185	0.87	0.99	50
32	-45	20	20.0	126.3	65	0	11461	15.4	250	6796	1.69	0.96	50

Table A4: R404A Test Results (Dew Point – IP Units)

Amb	SST	RGT	SCT	DGT	SH	SC	Cooling Capacity	Amps	Mass flow	Power	EER	EER Ratio	Freq
°F	°F	°F	°F	°F	°F	°F	Btu/hr	A	lbm/hr	W	btu/hr-W		Hz
89.6	32	68	68.0	125.1	36	0	322787	26.4	4789	15112	21.36	1.08	50
89.6	32	68	104.0	164.5	36	0	238685	36.2	4429	21677	11.01	1.10	50
89.6	23	68	68.0	136.4	45	0	267260	25.5	3923	14764	18.10	1.05	50
89.6	23	68	104.0	176.0	45	0	198375	34.3	3632	20382	9.73	1.08	50
89.6	23	68	140.0	218.1	45	0	126697	41.5	3275	25152	5.04	1.17	50
89.6	14	68	113.0	198.1	54	0	149037	33.6	2890	19943	7.47	1.08	50
89.6	14	68	140.0	228.9	54	0	104712	37.7	2664	22712	4.61	1.16	50
89.6	-4	68	68.0	173.3	72	0	145852	22.8	2092	12611	11.57	1.03	50
89.6	-4	68	104.0	213.3	72	0	108362	27.1	1928	15713	6.90	1.05	50
89.6	-4	68	140.0	256.5	72	0	67741.1	30	1682	17689	3.83	1.14	50
89.6	-31	68	68.0	216.5	99	0	72367.5	18.5	1024	9353	7.74	0.97	50
89.6	-31	68	104.0	255.2	99	0	51526.2	19.9	901	10516	4.90	1.00	50
89.6	-40	32	104.0	241.5	72	0	34816.3	17.8	696	8801	3.96	0.98	50
89.6	-49	-13	104.0	237.9	36	0	21281.8	15.9	514	7185	2.96	0.99	50
89.6	-49	68	68.0	259.3	117	0	39132.1	15.4	550	6796	5.76	0.96	50

Appendix A – Performance Maps

- 10-Coefficient polynomial equation for each test refrigerant

The coefficient data in Table B1and B2 was derived from BITZER Software v6.4.3 rev1302. The coefficients are based on dew point temperatures, 20°C return gas temperature and 0°K subcooling. These coefficients are only applicable within the standard operating envelope of the compressor.

Table B1: 10-Coefficient for R449A

Coefficient	Q (W)	P (W)	m (kg/h)	I (A)
c1	104753	4293.901	1678.006	10.34852
c2	3800.987	-282.185	64.12175	-0.45966
c3	-760.273	460.8356	-1.18059	0.618148
c4	48.97549	-8.4725	0.948744	-0.01412
c5	-26.6325	14.25441	-0.03495	0.022061
c6	-3.71045	-2.14235	-0.07079	-0.00139
c7	0.226687	-0.06672	0.005856	-0.00013
c8	-0.28111	0.090409	-0.00065	0.000173
c9	-0.04968	-0.0437	-0.00115	-4.35E-05
c10	0.017777	0.001964	0.00016	-5.96E-06

Table B2: 10-Coefficient for R404A

Coefficient	Q (W)	P (W)	m (kg/h)	I (A)
c1	115994	5725.46	2248.541	11.70526
c2	3958.224	-269.327	82.29016	-0.46386
c3	-985.271	499.0444	-1.58842	0.722848
c4	46.94308	-8.14816	1.165699	-0.0141
c5	-32.5123	14.81175	-0.05244	0.024414
c6	-3.43912	-2.15205	-0.08729	-0.00194
c7	0.188973	-0.05198	0.006806	-0.00011
c8	-0.32208	0.1093	-0.00086	0.000201
c9	-0.05602	-0.03392	-0.00135	-4.76E-05
c10	0.010997	-0.0015	0.000176	-1.05E-05

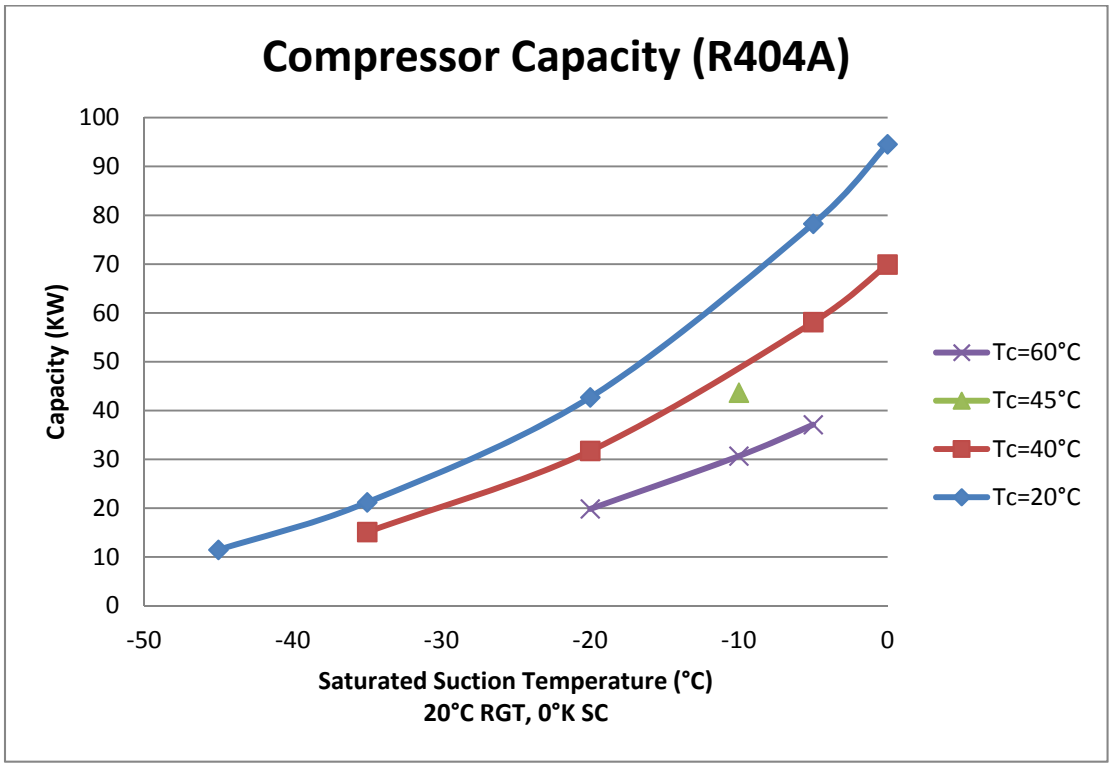


Figure 2: Capacity for R404A

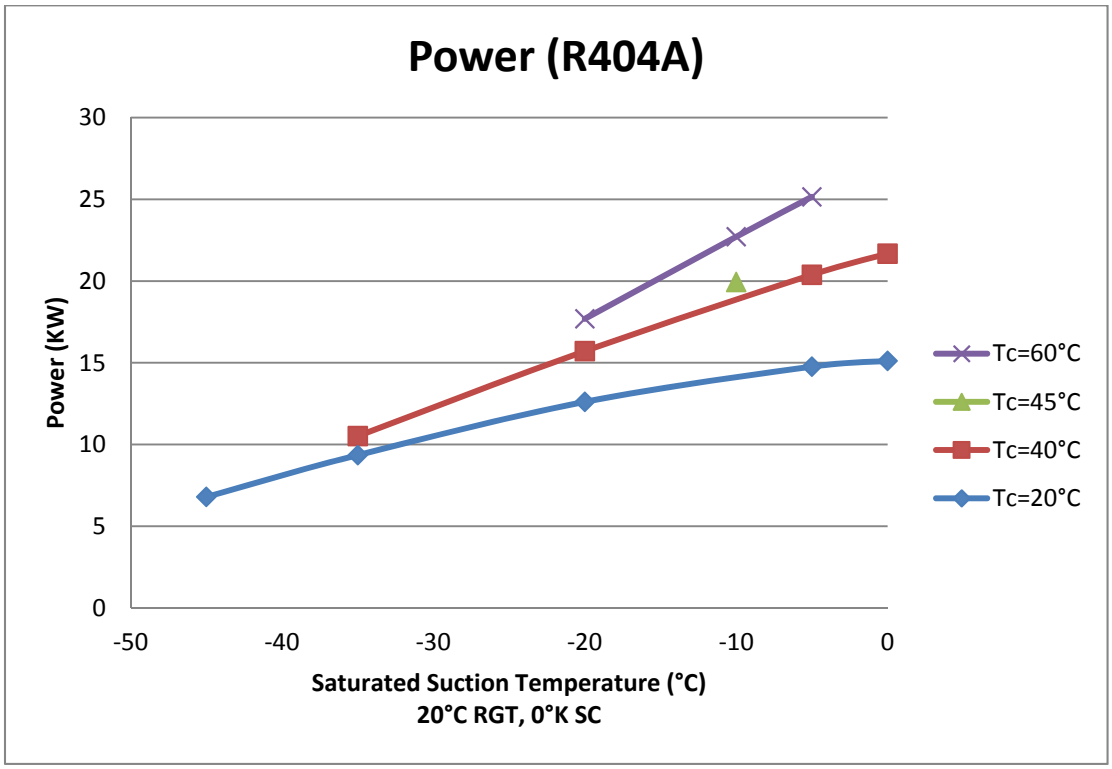


Figure 3: Power for R404A

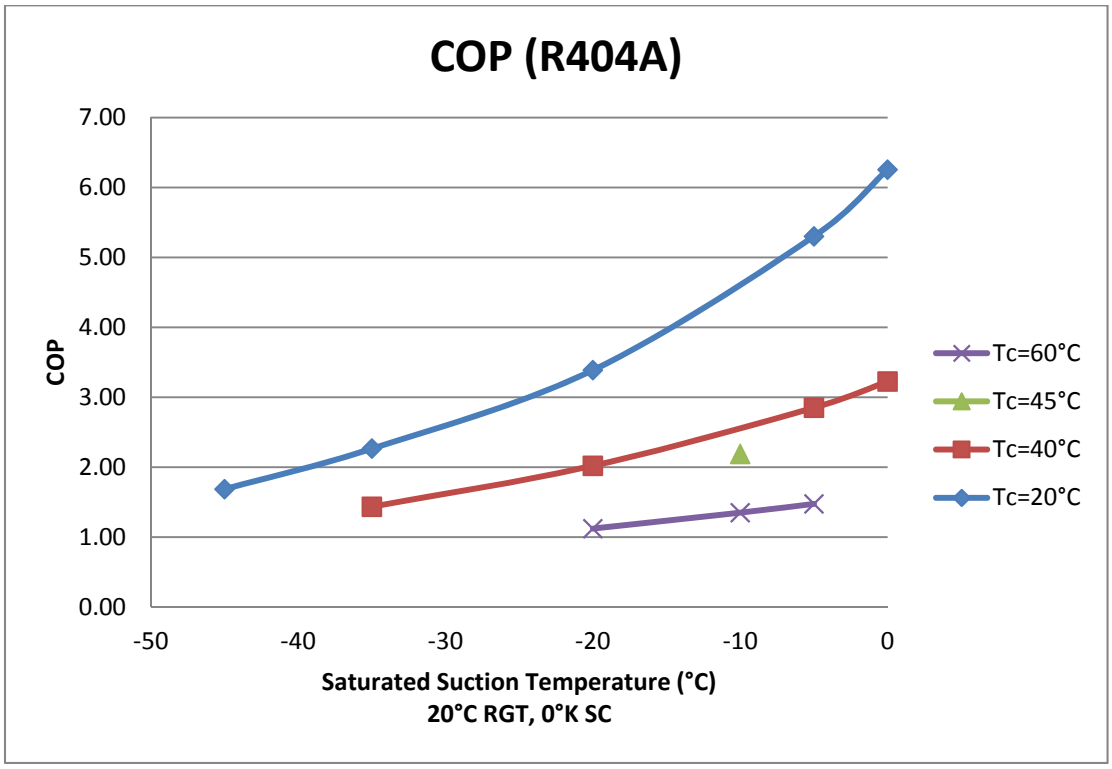


Figure 4: COP for R404A

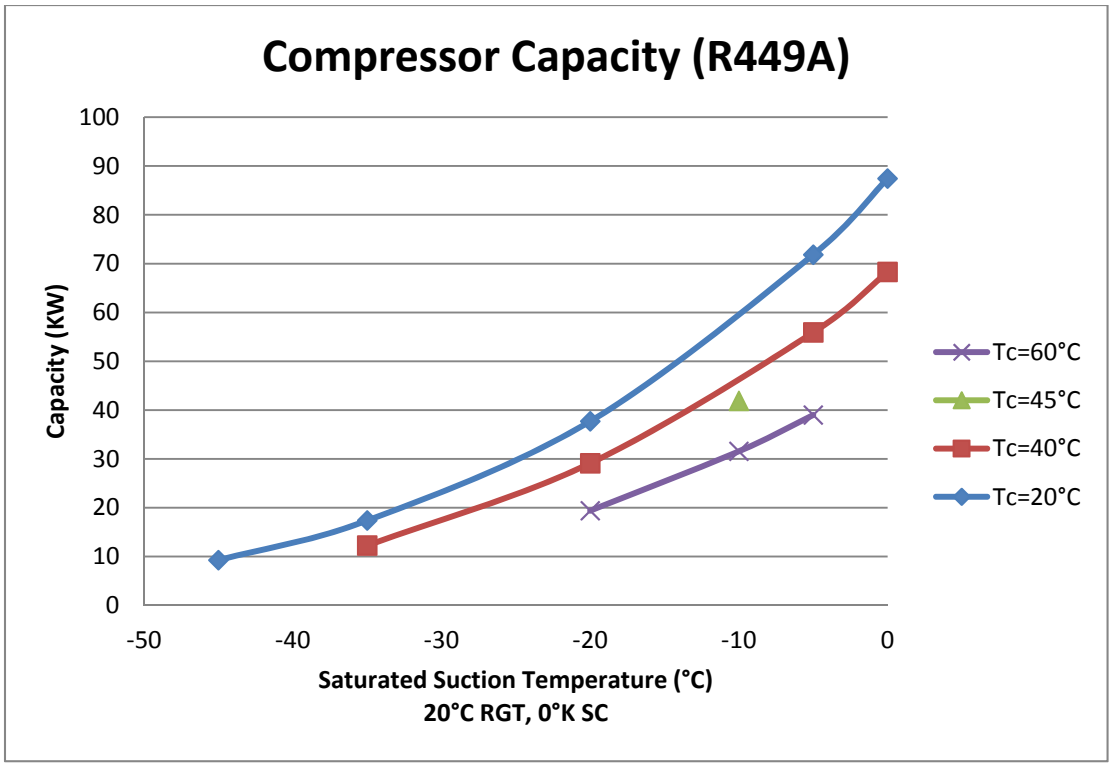


Figure 5: Capacity for R449A

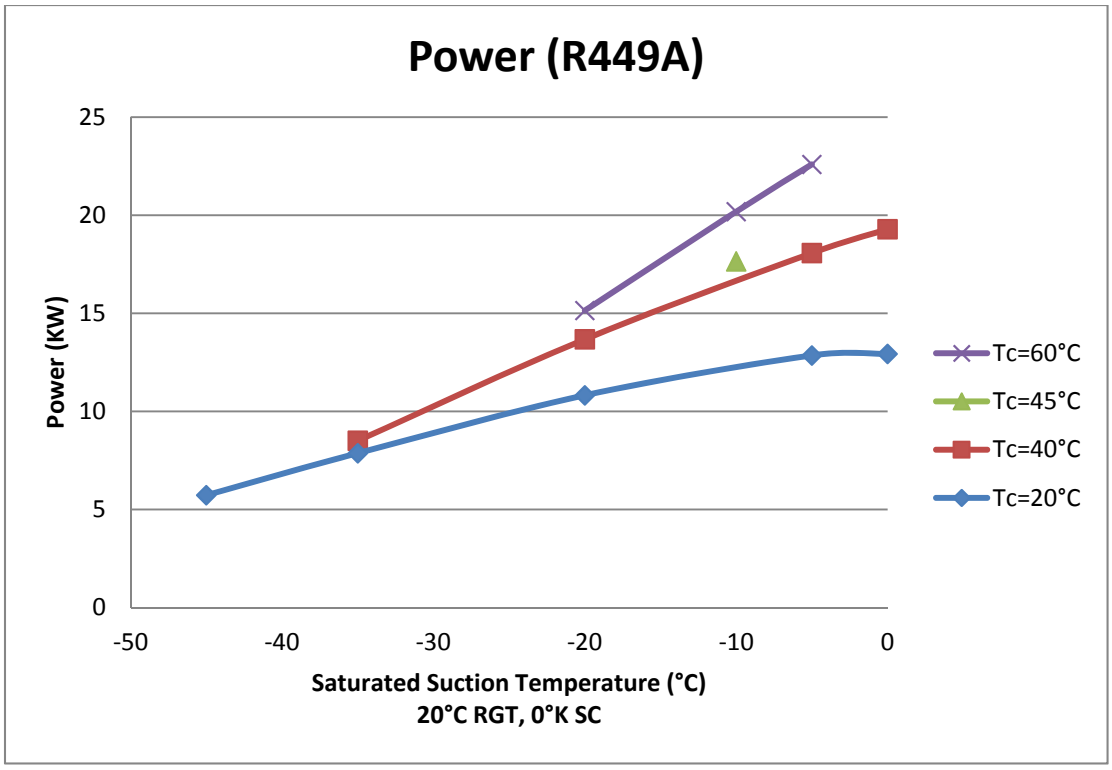


Figure 6: Power for R449A

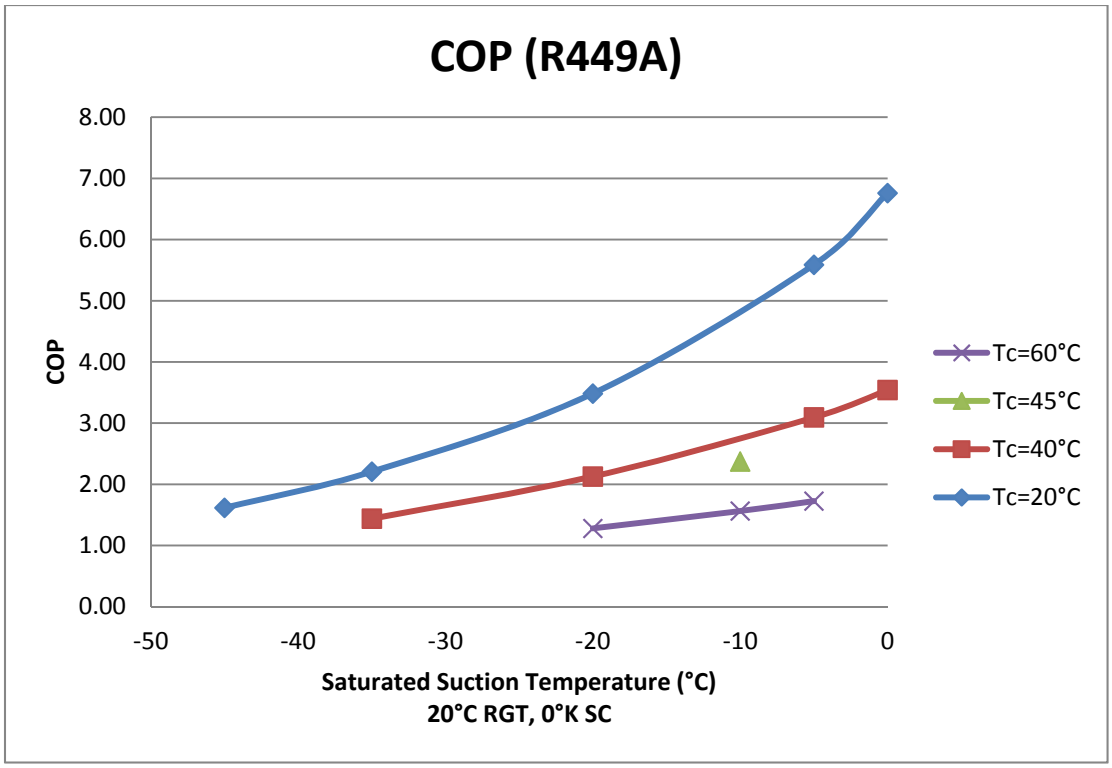


Figure 7: COP for R449A

- Comparative Analysis

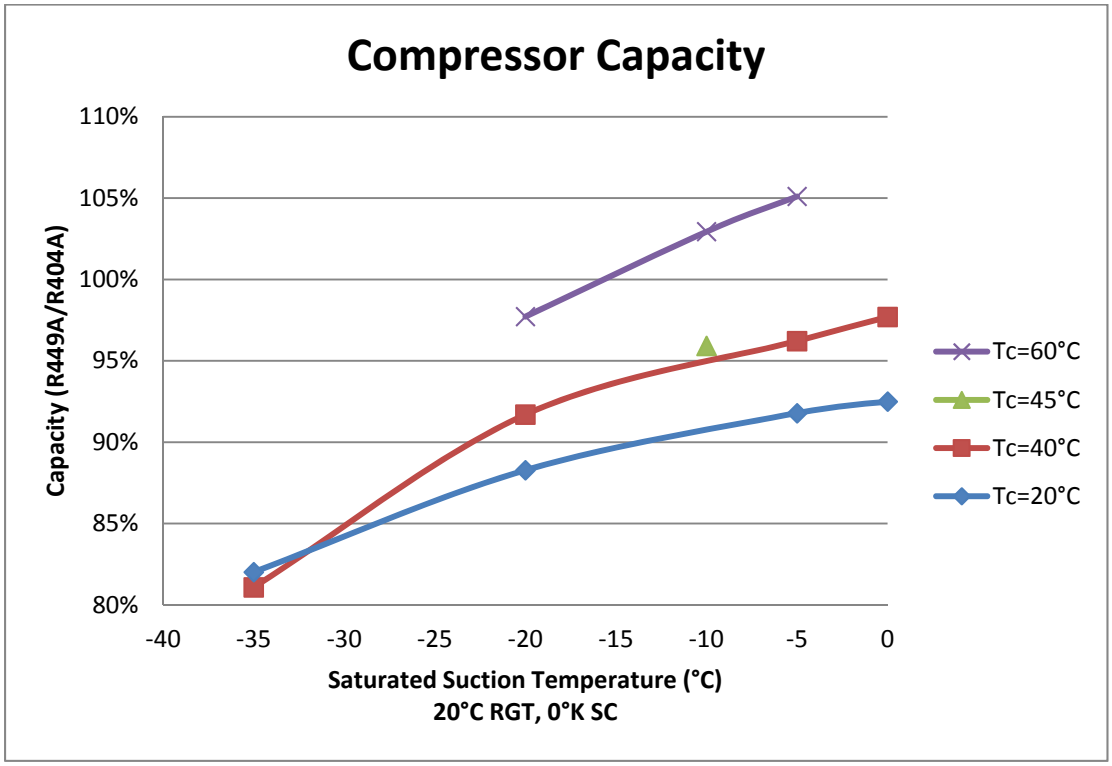


Figure 8: Capacity R449A/R404A

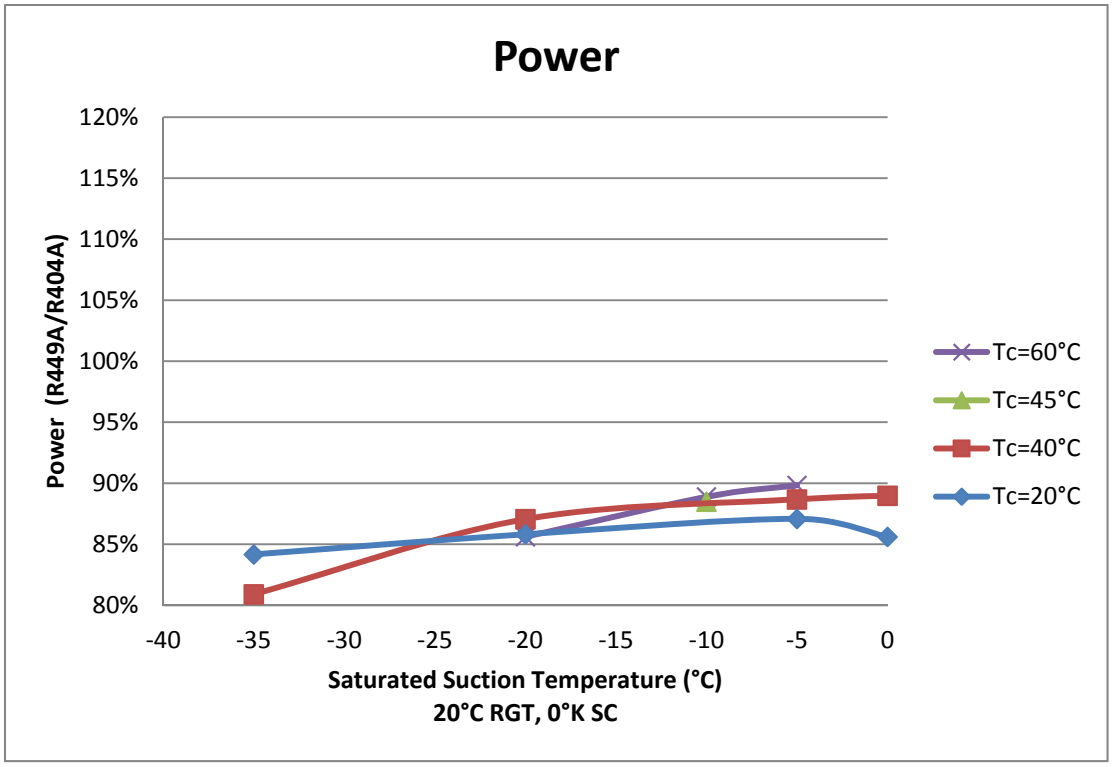


Figure 9: Power R449A/R404A

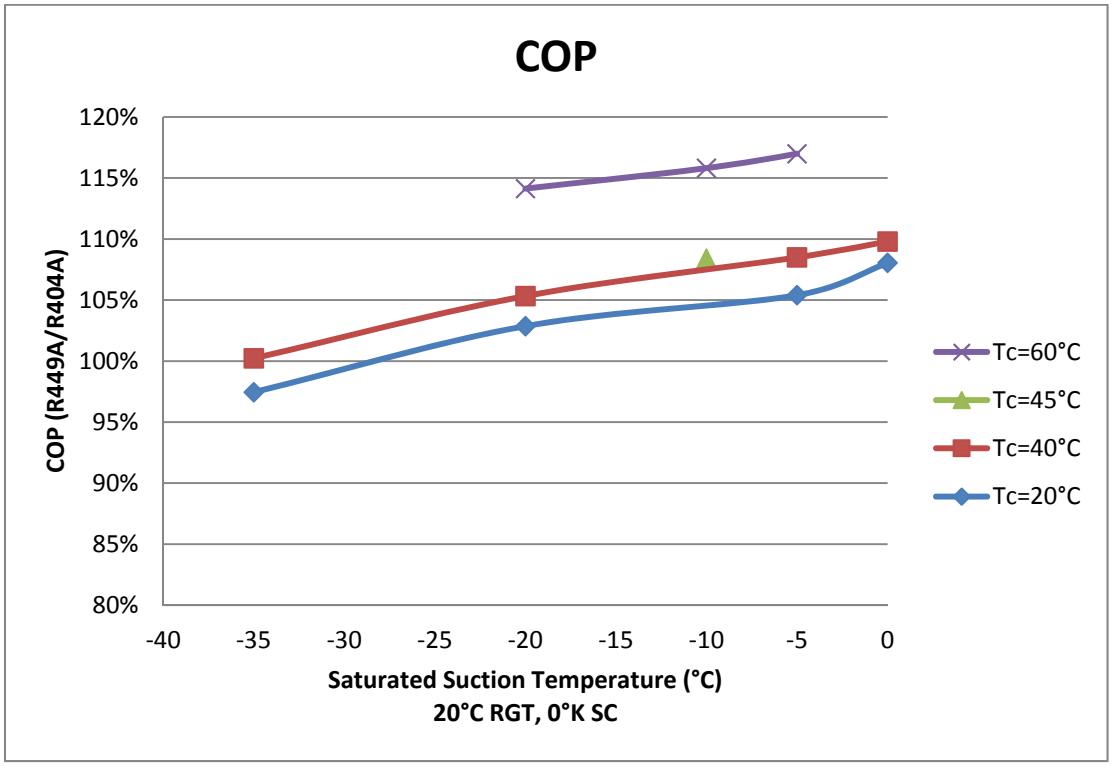


Figure 10: COP R449A/R404A

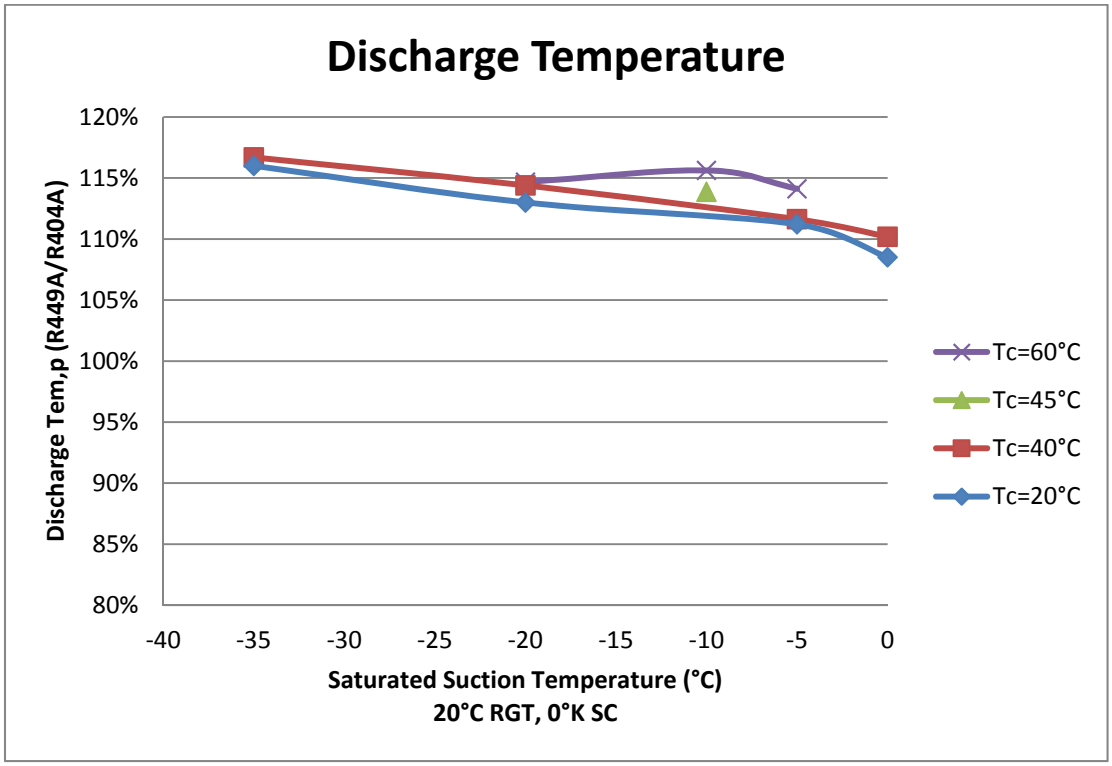


Figure 11: Discharge Temperature R449/R404A