



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

TEST REPORT #18

Compressor Calorimeter Test of Refrigerants R-134a, N-13a and ARM-42a

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July 8, 2013

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

**The tests in this report were conducted using
different conditions from the program's
requirements. The AHRI Low-GWP AREP Technical
Committee found the results useful and
informative, and approved them for publication as a
non-standard Low-GWP AREP report.**



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List of Tested Refrigerant's Compositions (Mass%)

ARM-42a	R-134a/R-152a/R-1234yf (7/11/82)
N-13a	R-134a/R-1234yf/R-1234ze(E) (42/18/40)

1. Introduction

The purpose of this work is to evaluate promising alternative refrigerants with low GWP (Global Warming Potential).

The compressor used for this study is manufactured by Embraco light commercial refrigeration. For this report, three refrigerants were chosen, R-134a as baseline refrigerant, N-13a and ARM-42a as alternative refrigerants.

Forty-eight tests were performed according to standard ASHRAE 23 during two months. Due to the number of tests and short time, just one level of superheating was applied in this work. Because of restrictions of calorimeter components, tests were executed using different conditions than specified by the Low-GWP AREP participant's handbook. The version 7.0 of NIST REFPROP was used for thermodynamic properties computation.

2. Details of Test Setup:

- Description of Test Refrigerant-Lubricant

- Baseline Refrigerant

 - R-134a

- Alternative Refrigerants

 - N-13a

 - ARM-42a

- Lubricant

 - The mineral lubricant oil is EMKARATE RL 22H, with viscosity ISO 22.

 - No changes were applied for this lubricant.

- b. Description of Compressor

The EG80HLR is a reciprocating compressor, hermetic, low-side design (motor exposed to suction pressure). This compressor is manufactured by Embraco and its compressor label is shown below.



Figure 1 - Compressor Label

Tables 1 presents the test conditions applied for R-134a, N-13a and ARM-42a.

Table 1- Operating conditions with the tested refrigerants

	Suction Pressure [bar]	Suction Saturation Temperature [°C]	Discharge Pressure [bar]	Discharge Saturation Temperature [°C]	Applicable Superheating [°C]	Suction Temperature $T_{sup}-T_{evap}$ [°C]	Ambient Temperature [°C]
R-134a – Baseline Refrigerant	1,113	-24	6,654	25	22,2	-1,8	32
	1,113	-24	8,870	35	22,2	-1,8	32
	1,113	-24	11,599	45	22,2	-1,8	32
	1,113	-24	14,915	55	22,2	-1,8	32
	1,327	-20	6,654	25	22,2	2,2	32
	1,327	-20	8,870	35	22,2	2,2	32
	1,327	-20	11,599	45	22,2	2,2	32
	1,327	-20	14,915	55	22,2	2,2	32
	1,639	-15	7,702	30	22,2	7,2	32
	1,639	-15	8,869	35	22,2	7,2	32
	1,639	-15	11,599	45	22,2	7,2	32
	1,639	-15	14,915	55	22,2	7,2	32
N-13a – Alternative Refrigerant	1,100	-24	6,361	25	22,2	-1,8	32
	1,100	-24	8,441	35	22,2	-1,8	32
	1,100	-24	10,994	45	22,2	-1,8	32
	1,100	-24	14,085	55	22,2	-1,8	32
	1,307	-20	6,361	25	22,2	2,2	32
	1,307	-20	8,441	35	22,2	2,2	32
	1,307	-20	10,994	45	22,2	2,2	32
	1,307	-20	14,085	55	22,2	2,2	32
	1,608	-15	7,346	30	22,2	7,2	32
	1,608	-15	8,441	35	22,2	7,2	32
	1,608	-15	10,994	45	22,2	7,2	32
	1,608	-15	14,085	55	22,2	7,2	32
ARM-42a – Alternative Refrigerant	1,298	-24	6,869	25	22,2	-1,8	32
	1,298	-24	8,982	35	22,2	-1,8	32
	1,298	-24	11,557	45	22,2	-1,8	32
	1,298	-24	14,649	55	22,2	-1,8	32
	1,530	-20	6,869	25	22,2	2,2	32
	1,530	-20	8,982	35	22,2	2,2	32
	1,530	-20	11,557	45	22,2	2,2	32
	1,530	-20	14,649	55	22,2	2,2	32
	1,864	-15	7,867	30	22,2	7,2	32
	1,864	-15	8,982	35	22,2	7,2	32
	1,864	-15	11,557	45	22,2	7,2	32
	1,864	-15	14,649	55	22,2	7,2	32

c. Description and Size of Test Loop

The figure below shows a schematic drawing of the calorimeter and its main components.

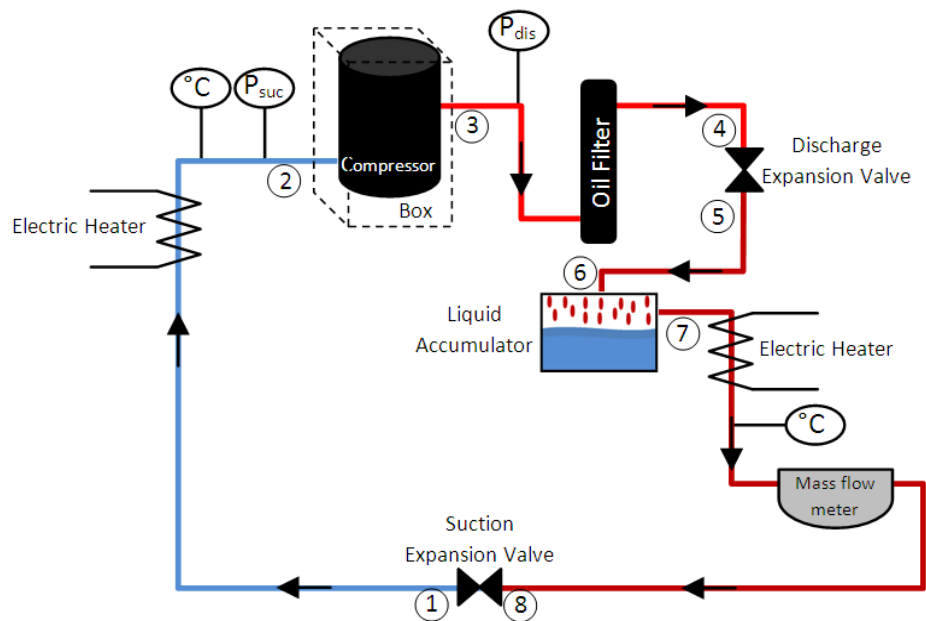


Figure 2 - Calorimeter test apparatus

Pressure and temperature are measured by absolute pressure transducers and resistance temperature detectors (PT100), respectively. Both expansion valves are used to control the compressor inlet and outlet pressure, whereas the electric heaters were used to guarantee that only fluid at the superheated state entered at the mass flow meter and the compressor. A pressure-enthalpy diagram is shown in the Figure 3. It is important to mention that a heat loss along the apparatus tubing is presented from point 5 to 6 on the pressure-enthalpy diagram.

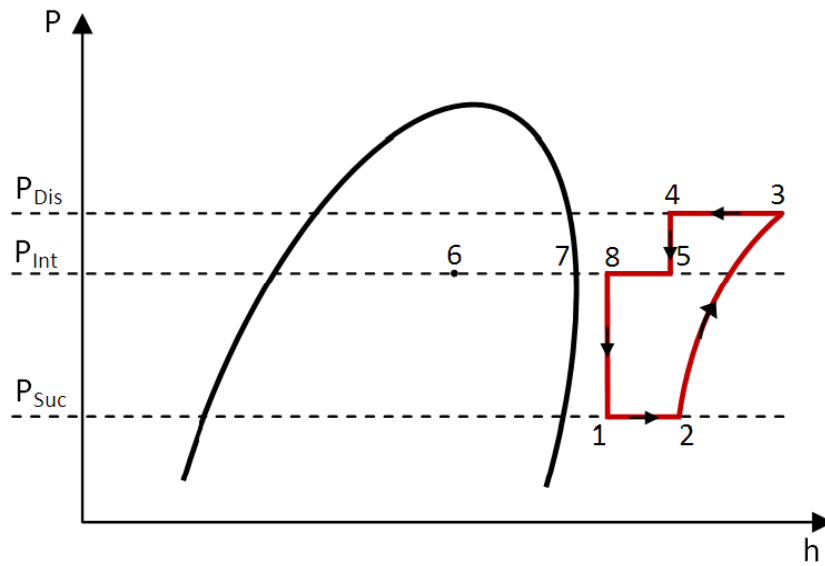


Figure 3 – Pressure x Enthalpy diagram

The air temperature inside the box was controlled by an electric heater and an embedded refrigerating system, as shown in the Figure 4.

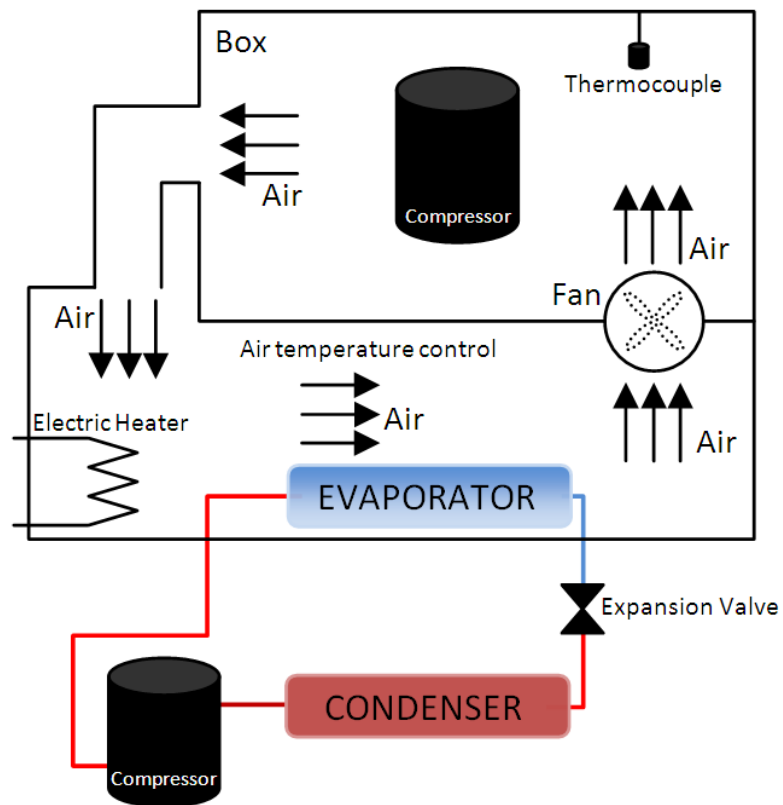


Figure 4 - Compressor Box



Figure 5 – Calorimeter



Figure 6 - Calorimeter

The measurement instruments used in the calorimeter are listed in Table 2, with the associated accuracy.

Table 2 - Instrumentation and catalog accuracy

Type	Model	Accuracy
Mass Flow meter	Metroval – RHM015	$\pm 0,10\%$ of flow rate
Power transducer	Yokogawa – 2285A	$\pm 0,5\%$ of full scale
Suction Pressure Transducer	Wika – P10 1-9 bar	$\pm 0,05\%$ of full scale
Discharge Pressure Transducer	Wika – P10 1-39 bar	$\pm 0,05\%$ of full scale
PT100	-	$\pm(0,15+0,002*T)$ where T is the measured temperature. $E_{\max} = \pm 0,45^{\circ}\text{C}$
Data acquisition	National Instruments SCXI 1000 / SCXI1102 / SCXI 1303	$\pm 0,05\%$

3. Results

The comparison results discussed in this topic are tabulated in Appendix A. All results presented are raw test data, except results Tables 8 to 12.

Appendix A

Tabular Data

The uncertainties calculated for table 3 to 5, were obtained according with the equations presented below:

$$u(E_{max}) = \frac{E_{max}}{\sqrt{3}}$$

$$U = \pm u(E_{max}) \times t$$

Where:

E_{max} : Maximum error

$u(E_{max})$: Standard uncertainty relative for maximum error

U : Expanded uncertainty

t : Student's coefficient for 95,45% of probability and infinite degrees of liberty

Table 3 - Performance data in tabular form within defined accuracies and ranges of operation

R-134a													
Points Evaluated	UNIT	1	2	3	4	5	6	7	8	9	10	11	12
Evaporating Temperature	°F (°C)	-11 (-24)	-11 (-24)	-11 (-24)	-11 (-24)	-4 (-20)	-4 (-20)	-4 (-20)	-4 (-20)	5 (-15)	5 (-15)	5 (-15)	5 (-15)
Condensing Temperature	°F (°C)	77 (25)	95 (35)	113 (45)	131 (55)	77 (25)	95 (35)	113 (45)	131 (55)	86 (30)	95 (35)	113 (45)	131 (55)
Discharge Temperature	°F (°C)	141 (61)	146 (63)	151 (66)	157 (69)	143 (62)	149 (65)	155 (69)	161 (72)	141 (61)	147 (64)	156 (69)	162 (72)
Applicable Superheating	°F (°C)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)
Applicable Subcooling	°F (°C)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)
Compressor Capacity	Btu/h (W)	725 (212)	634 (186)	544 (159)	446 (131)	895 (262)	798 (234)	671 (197)	569 (167)	1116 (327)	1053 (309)	925 (271)	779 (228)
Refrigerant mass flow rate	kg/h (lbm/h)	4,38 (9,7)	4,17 (9,2)	3,94 (8,7)	3,61 (7,9)	5,33 (11,7)	5,17 (11,4)	4,77 (10,5)	4,51 (9,9)	6,78 (15,0)	6,68 (14,7)	6,43 (14,2)	6,02 (13,3)
Mass flow rate uncertainty	kg/h	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04
Current	A	0,56	0,60	0,63	0,64	0,61	0,66	0,69	0,73	0,71	0,73	0,79	0,83
Current uncertainty	A	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03
Power Input	W	118,6	126,6	132,2	135,2	127,3	138,2	145,1	152,5	150,1	154,1	165,2	174,2
Power Input uncertainty	W	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9
EER	Btu/h/ W	6,11	5,01	4,11	3,30	7,03	5,78	4,62	3,73	7,43	6,83	5,60	4,48
COP	W/W	1,79	1,47	1,20	0,97	2,06	1,69	1,36	1,09	2,18	2,00	1,64	1,31
COP _{N-13a} / COP _{R-134a}	-	1,18	1,12	1,10	0,96	0,98	0,98	0,98	0,99	0,98	0,96	0,95	0,97
COP _{ARM-42a} / COP _{R-134a}	-	1,01	1,03	1,01	0,98	1,02	1,02	1,03	1,02	1,03	1,03	1,02	1,00
Suction Pressure	bar	1,113± 0,005	1,113± 0,005	1,113± 0,005	1,113± 0,005	1,327± 0,005	1,327± 0,005	1,327± 0,005	1,327± 0,005	1,639± 0,005	1,639± 0,005	1,639± 0,005	1,639± 0,005
Discharge Pressure	bar	6,654± 0,023	8,870± 0,023	11,599 ±0,023	14,915 ±0,023	6,654± 0,023	8,870± 0,023	11,599± 0,023	14,915± 0,023	7,702± 0,023	8,870± 0,023	11,599± 0,023	14,915 ±0,023

Table 4 - Performance data in tabular form within defined accuracies and ranges of operation

N-13a													
Points Evaluated	UNIT	1	2	3	4	5	6	7	8	9	10	11	12
Evaporating Temperature	°F (°C)	-11 (-24)	-11 (-24)	-11 (-24)	-11 (-24)	-4 (-20)	-4 (-20)	-4 (-20)	-4 (-20)	5 (-15)	5 (-15)	5 (-15)	5 (-15)
Condensing Temperature	°F (°C)	77 (25)	95 (35)	113 (45)	131 (55)	77 (25)	95 (35)	113 (45)	131 (55)	86 (30)	95 (35)	113 (45)	131 (55)
Discharge Temperature	°F (°C)	137 (58)	144 (62)	150 (65)	152 (67)	138 (59)	144 (62)	152 (67)	156 (69)	137 (59)	142 (61)	148 (65)	156 (69)
Applicable Superheating	°F (°C)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)
Applicable Subcooling	°F (°C)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)
Compressor Capacity	Btu/h (W)	839 (246)	754 (221)	647 (190)	459 (134)	865 (254)	764 (224)	647 (190)	534 (157)	1112 (326)	997 (292)	866 (254)	736 (216)
Refrigerant mass flow rate	kg/h (lbm/h)	5,56 (12,2)	5,47 (12,1)	5,21 (11,5)	4,15 (9,2)	5,62 (12,4)	5,44 (12,0)	5,10 (11,3)	4,72 (10,4)	7,07 (15,6)	6,93 (15,3)	6,65 (14,7)	6,31 (13,9)
Mass flow rate uncertainty	kg/h	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04
Current	A	0,55	0,64	0,68	0,69	0,60	0,61	0,68	0,69	0,70	0,72	0,77	0,85
Current uncertainty	A	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03
Power Input	W	116,3	135,1	142,6	144,7	125,2	134,7	143,2	144,8	146,7	151,3	162,4	169,1
Power Input uncertainty	W	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9
EER	Btu/h /W	7,22	5,58	4,53	3,17	6,91	5,67	4,52	3,69	7,26	6,59	5,33	4,35
COP	W/W	2,12	1,64	1,33	0,93	2,02	1,66	1,32	1,08	2,13	1,93	1,56	1,28
COP _{N-13a} / COP _{R-134a}	-	1,18	1,12	1,10	0,96	0,98	0,98	0,98	0,99	0,98	0,96	0,95	0,97
Suction Pressure	bar	1,100± 0,005	1,100± 0,005	1,100± 0,005	1,100± 0,005	1,307± 0,005	1,307± 0,005	1,307± 0,005	1,307± 0,005	1,608± 0,005	1,608± 0,005	1,608± 0,005	1,608± 0,005
Discharge Pressure	bar	6,316± 0,023	8,441± 0,023	10,994± 0,023	14,085± 0,023	6,316± 0,023	8,441± 0,023	10,994± 0,023	14,085± 0,023	7,346± 0,023	8,441± 0,023	10,994± 0,023	14,085± 0,023

Table 5 - Performance data in tabular form within defined accuracies and ranges of operation

ARM-42a													
Points Evaluated	UNIT	1	2	3	4	5	6	7	8	9	10	11	12
Evaporating Temperature	°F (°C)	-11 (-24)	-11 (-24)	-11 (-24)	-11 (-24)	-4 (-20)	-4 (-20)	-4 (-20)	-4 (-20)	5 (-15)	5 (-15)	5 (-15)	5 (-15)
Condensing Temperature	°F (°C)	77 (25)	95 (35)	113 (45)	131 (55)	77 (25)	95 (35)	113 (45)	131 (55)	86 (30)	95 (35)	113 (45)	131 (55)
Discharge Temperature	°F (°C)	134 (57)	141 (61)	146 (63)	153 (67)	135 (57)	141 (60)	146 (63)	155 (69)	137 (58)	142 (61)	149 (65)	158 (70)
Applicable Superheating	°F (°C)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)	40 (22,2)
Applicable Subcooling	°F (°C)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)	10 (5)
Compressor Capacity	Btu/h (W)	811 (238)	715 (210)	601 (176)	477 (140)	1009 (296)	887 (260)	750 (220)	621 (182)	1223 (358)	1154 (338)	1003 (294)	830 (243)
Refrigerant mass flow rate	kg/h (lbm/h)	5,67 (12,5)	5,52 (12,2)	5,19 (11,4)	4,71 (10,4)	6,91 (15,2)	6,70 (14,8)	6,32 (13,9)	5,96 (13,1)	8,56 (18,9)	8,49 (18,7)	8,21 (18,1)	7,69 (17,0)
Mass flow rate uncertainty	kg/h	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04	±0,04
Current	A	0,62	0,66	0,69	0,70	0,67	0,72	0,75	0,78	0,76	0,78	0,84	0,88
Current uncertainty	A	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03	±0,03
Power Input	W	130,9	139,0	145,1	147,1	140,8	151,0	157,2	163,4	159,8	164,0	175,6	184,6
Power Input uncertainty	W	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9	±2,9
EER	Btu/h /W	6,20	5,14	4,14	3,24	7,17	5,87	4,77	3,80	7,65	7,04	5,71	4,49
COP	W/W	1,82	1,51	1,21	0,95	2,10	1,72	1,40	1,11	2,24	2,06	1,67	1,32
COP _{ARM-42a} / COP _{R-134a}	-	1,01	1,03	1,01	0,98	1,02	1,02	1,03	1,02	1,03	1,03	1,02	1,00
Suction Pressure	bar	1,298± 0,005	1,298± 0,005	1,298± 0,005	1,298± 0,005	1,530± 0,005	1,530± 0,005	1,530± 0,005	1,530± 0,005	1,864± 0,005	1,864± 0,005	1,864± 0,005	1,864± 0,005
Discharge Pressure	bar	6,869± 0,023	8,982± 0,023	11,557± 0,023	14,649± 0,023	6,869± 0,023	8,982± 0,023	11,557± 0,023	14,649± 0,023	7,867± 0,023	8,982± 0,023	11,557± 0,023	14,649± 0,023

Table 6 - Percentage gain of N-13a over R-134a

Conditions		Capacity	Power Input	COP
Evaporating Temperature [°C]	Condensing Temperature [°C]			
-24	25	15,8%	-1,9%	18,1%
-24	35	19,0%	6,7%	11,5%
-24	45	19,0%	7,9%	10,3%
-24	55	2,9%	7,0%	-3,8%
-20	25	-3,3%	-1,6%	-1,7%
-20	35	-4,3%	-2,5%	-1,8%
-20	45	-3,5%	-1,3%	-2,3%
-20	55	-6,0%	-5,1%	-1,0%
-15	30	-4,6%	-2,3%	-2,4%
-15	35	-5,4%	-1,8%	-3,6%
-15	45	-6,3%	-1,7%	-4,8%
-15	55	-5,6%	-2,9%	-2,7%

Table 7 - Percentage gain of ARM-42a over R-134a

Conditions		Capacity	Power Input	COP
Evaporating Temperature [°C]	Condensing Temperature [°C]			
-24	25	11,9%	10,4%	1,4%
-24	35	12,8%	9,8%	2,8%
-24	45	10,6%	9,8%	0,7%
-24	55	7,0%	8,8%	-1,6%
-20	25	12,8%	10,7%	1,9%
-20	35	11,1%	9,3%	1,6%
-20	45	11,7%	8,3%	3,1%
-20	55	9,1%	7,1%	1,9%
-15	30	9,6%	6,5%	2,9%
-15	35	9,6%	6,4%	3,0%
-15	45	8,5%	6,3%	2,0%
-15	55	6,4%	6,0%	0,4%

Appendix B

Performance Maps

- Performance map for R-134a
 - o Polynomial equation

Table 8 - Polynomial coefficients

R-134a				
Coefficients	Capacity	Power Input	COP	Mass Flow Rate
A ₀	1007,57	591,99	5,47	-7,01
A ₁	74,18	68,97	0,25	-2,38
A ₂	2,71	3,20	0,01	-0,14
A ₃	0,04	0,05	0,00	0,00
A ₄	2,30	0,14	-0,02	0,19
A ₅	-0,14	-0,01	0,00	0,00
A ₆	0,00	0,00	0,00	0,00
A ₇	0,11	-0,18	0,00	0,01
A ₈	0,00	0,00	0,00	0,00
A ₉	0,00	0,00	0,00	0,00

$$X = A_0 + (A_1 \times S) + (A_2 \times S^2) + (A_3 \times S^3) + (A_4 \times D) + (A_5 \times D^2) + (A_6 \times D^3) \\ + (A_7 \times S \times D) + (A_8 \times S \times D^2) + (A_9 \times D \times S^2)$$

where:

A: Equation coefficient, represents compressor performance

S: Suction dew point temperature, [°C]

D: Discharge dew point temperature, [°C]

X can represent any of the following variables:

- Capacity, [W]
- Power Input, [W]
- COP, [W/W]
- Mass flow rate, [kg/h]

○ Graphics

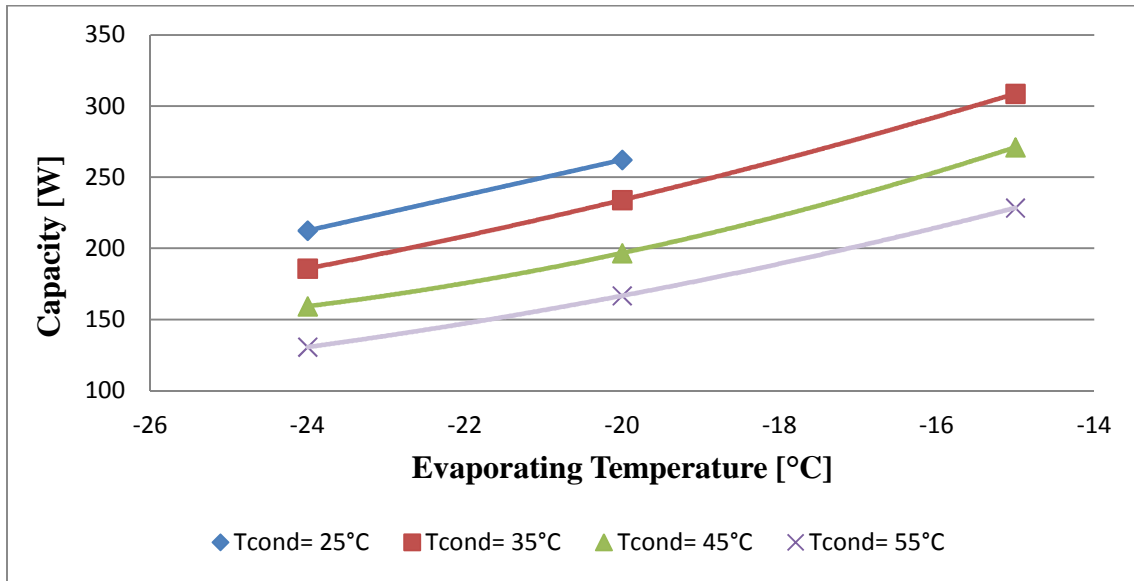


Figure 7 – Cooling capacity for R-134a

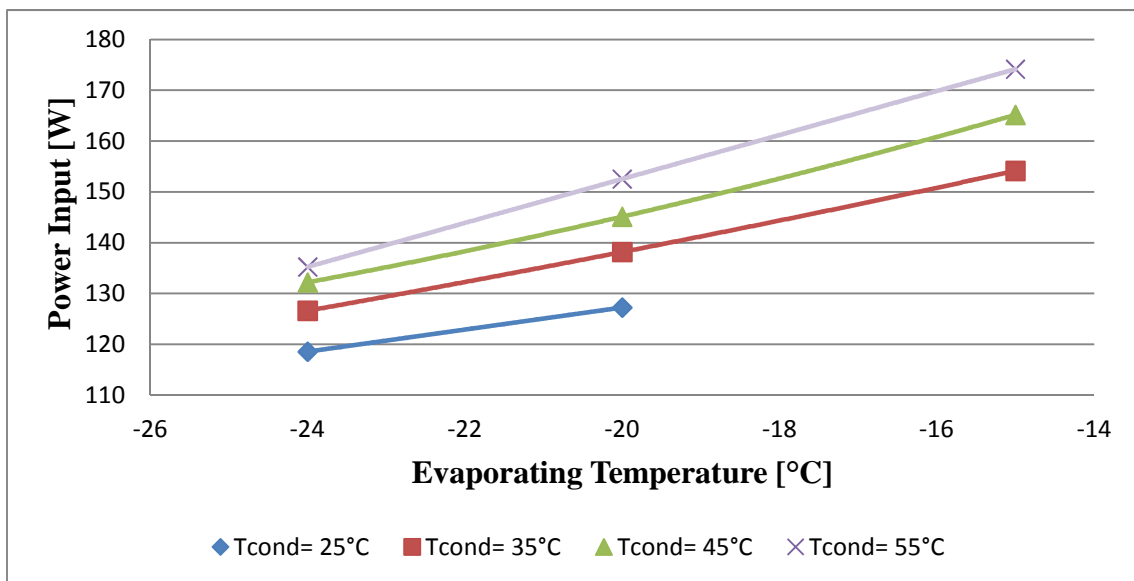


Figure 8 - Power Input for R-134a

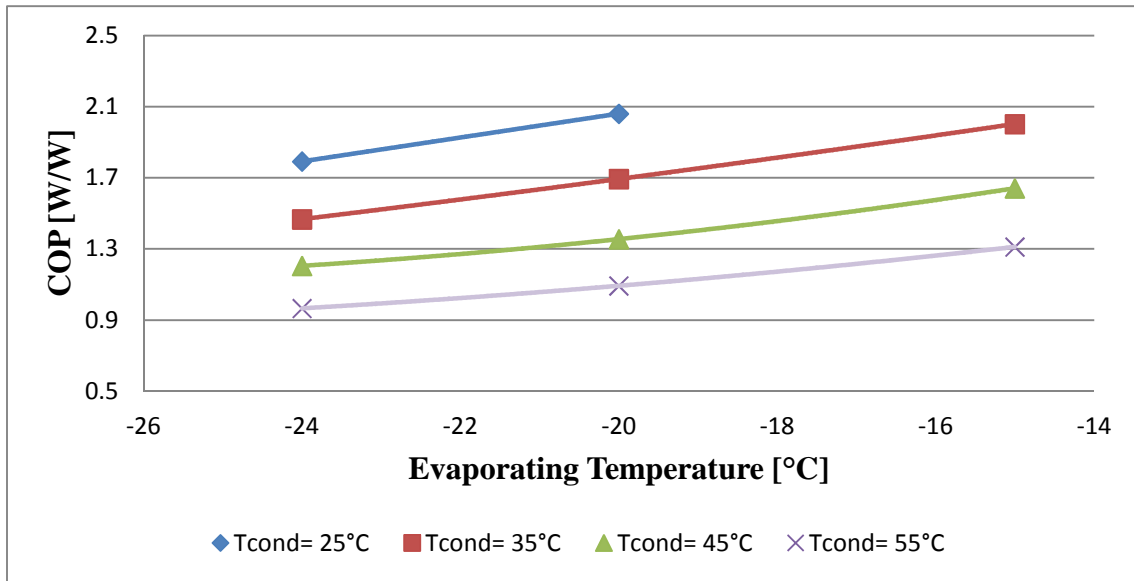


Figure 9 - COP for R-134a

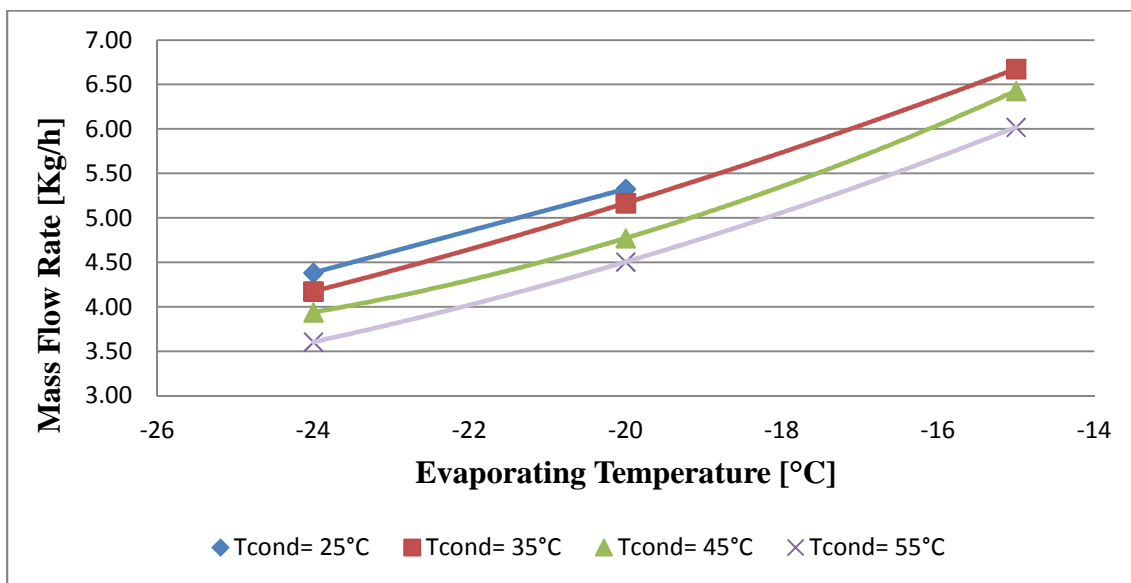


Figure 10 - Mass flow rate for R-134a

- Performance map for N-13a
 - o Polynomial equation

Table 9 - Polynomial coefficients

N-13a				
Coefficients	Capacity	Power Input	COP	Mass Flow Rate
A ₀	2831,50	-80,93	11,91	45,23
A ₁	278,73	-41,87	0,74	3,40
A ₂	10,53	-2,43	0,02	0,09
A ₃	0,14	-0,04	0,00	0,00
A ₄	-37,16	-0,22	-0,27	-0,90
A ₅	0,36	0,09	0,00	0,01
A ₆	0,00	0,00	0,00	0,00
A ₇	-2,06	0,19	-0,01	-0,04
A ₈	0,01	0,00	0,00	0,00
A ₉	-0,03	0,01	0,00	0,00

$$X = A_0 + (A_1 \times S) + (A_2 \times S^2) + (A_3 \times S^3) + (A_4 \times D) + (A_5 \times D^2) + (A_6 \times D^3) + (A_7 \times S \times D) + (A_8 \times S \times D^2) + (A_9 \times D \times S^2)$$

where:

A: Equation coefficient, represents compressor performance

S: Suction dew point temperature, [°C]

D: Discharge dew point temperature, [°C]

X can represent any of the following variables:

- Capacity, [W]
- Power Input, [W]
- COP, [W/W]
- Mass flow rate, [kg/h]

o Graphics

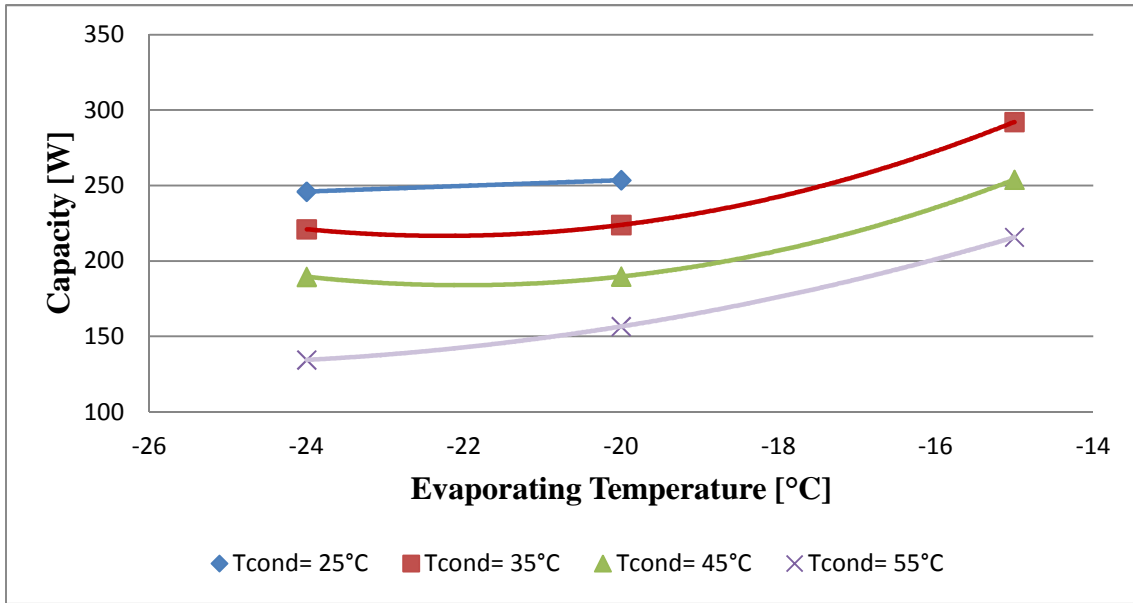


Figure 11 - Cooling capacity for N-13a

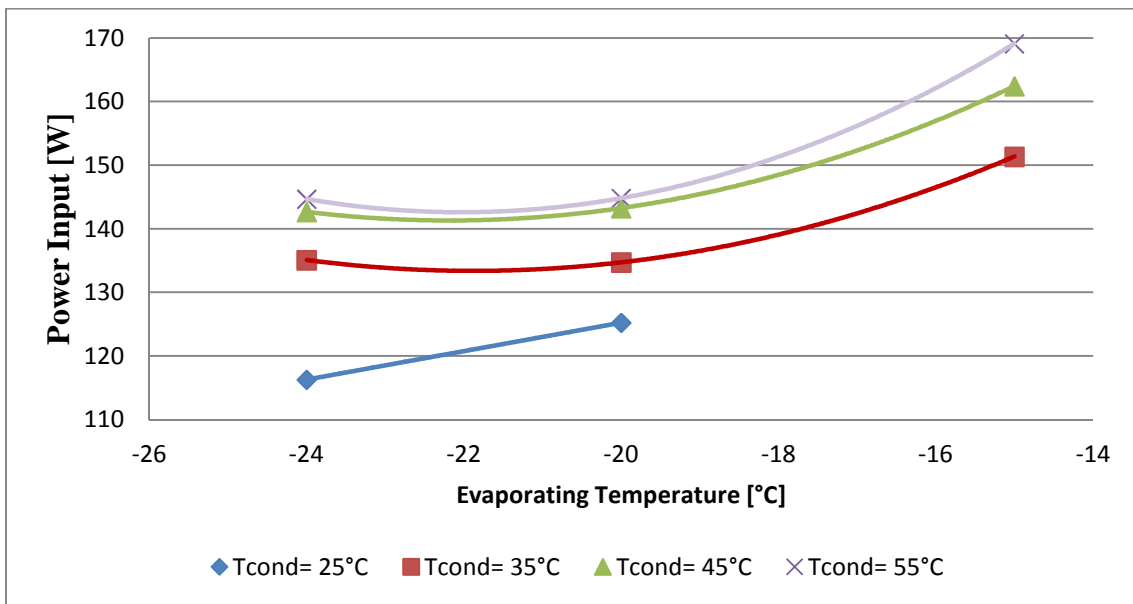


Figure 12 - Power Input for N-13a

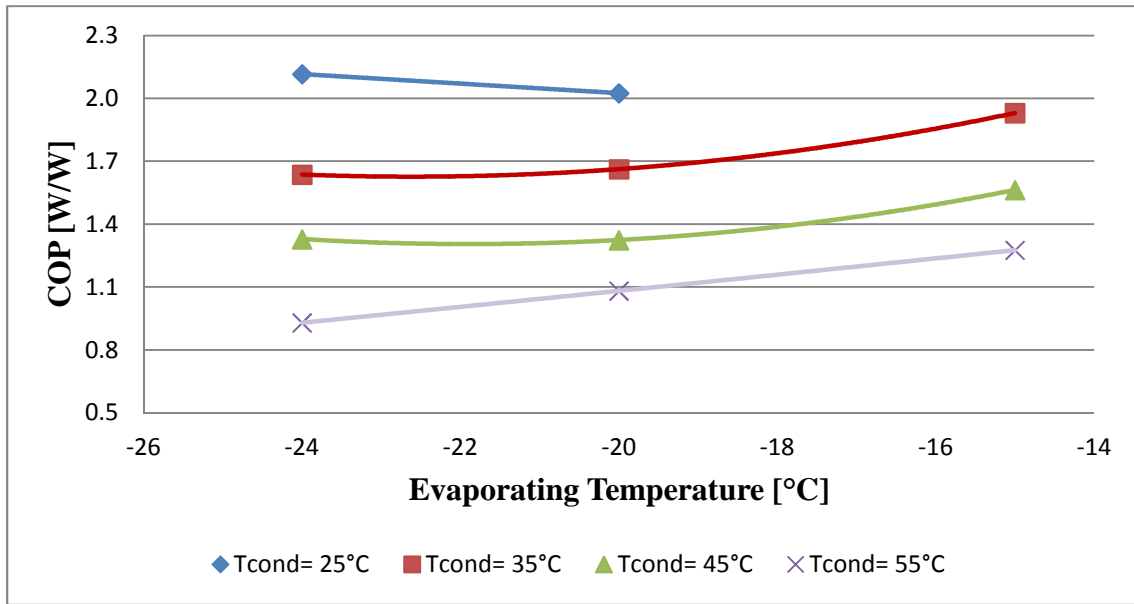


Figure 13 - COP for N-13a

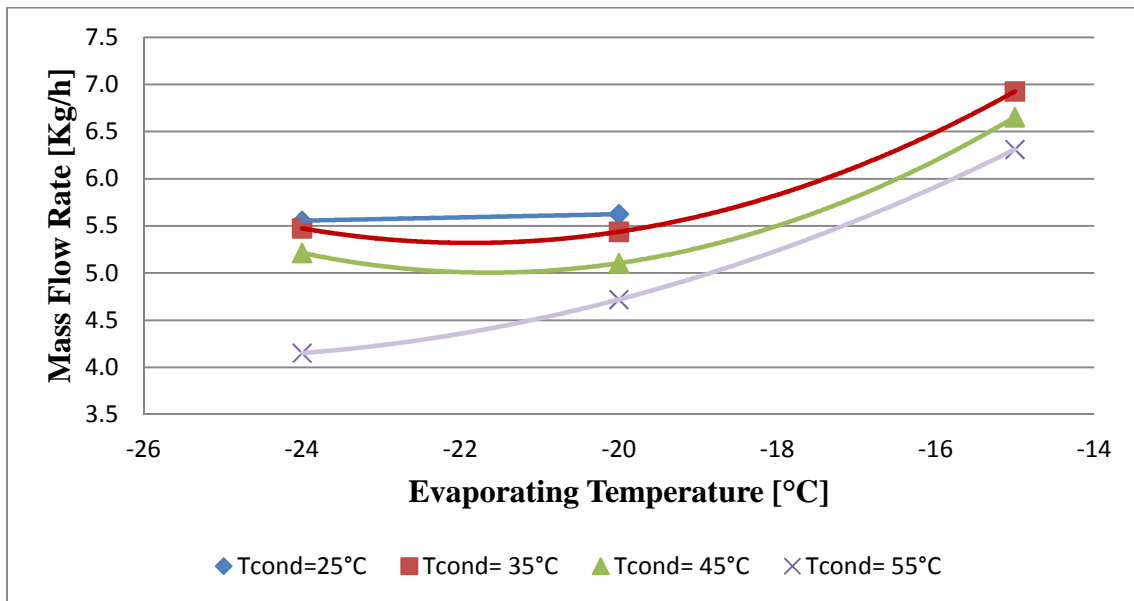


Figure 14 - Mass flow rate for N-13a

- Performance map for ARM-42a
 - o Polynomial equation

Table 10 - Polynomial coefficients

ARM-42a				
Coefficients	Capacity	Power Input	COP	Mass Flow Rate
A ₀	1079,96	-530,53	10,23	-13,03
A ₁	69,49	-107,94	0,90	-3,87
A ₂	2,36	-5,72	0,04	-0,22
A ₃	0,03	-0,10	0,00	0,00
A ₄	-3,05	0,58	-0,07	0,07
A ₅	-0,06	0,02	0,00	0,00
A ₆	0,00	0,00	0,00	0,00
A ₇	-0,08	-0,01	0,00	0,00
A ₈	0,00	0,00	0,00	0,00
A ₉	0,00	0,00	0,00	0,00

$$X = A_0 + (A_1 \times S) + (A_2 \times S^2) + (A_3 \times S^3) + (A_4 \times D) + (A_5 \times D^2) + (A_6 \times D^3) + (A_7 \times S \times D) + (A_8 \times S \times D^2) + (A_9 \times D \times S^2)$$

where:

A: Equation coefficient, represents compressor performance

S: Suction dew point temperature, [°C]

D: Discharge dew point temperature, [°C]

X can represent any of the following variables:

- Capacity, [W]
- Power Input, [W]
- COP, [W/W]
- Mass flow rate, [kg/h]

o Graphics

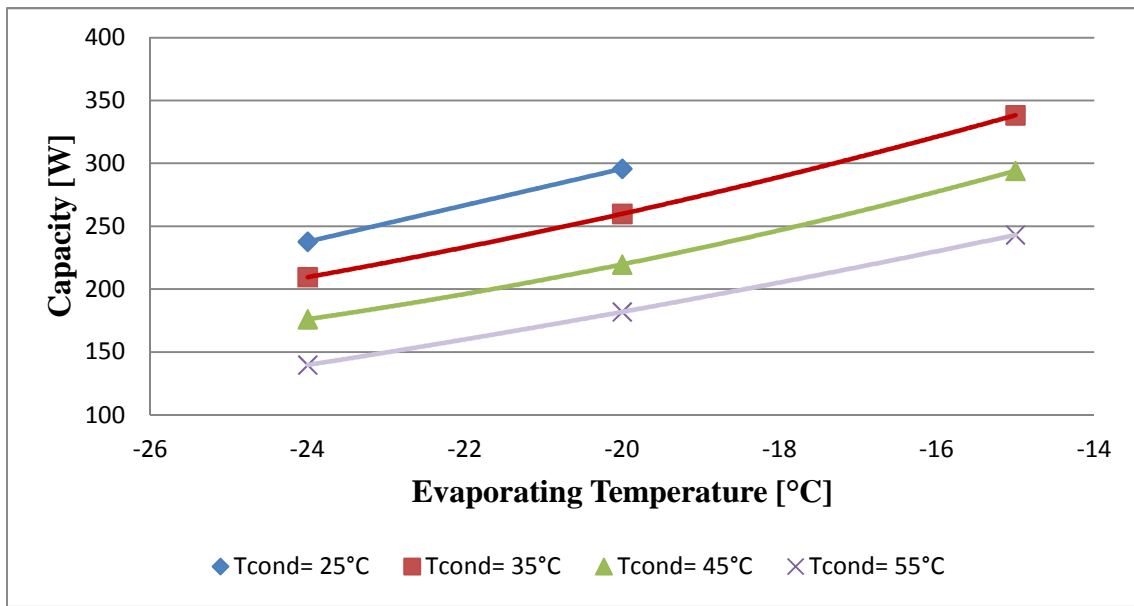


Figure 15 – Cooling capacity for ARM-42a

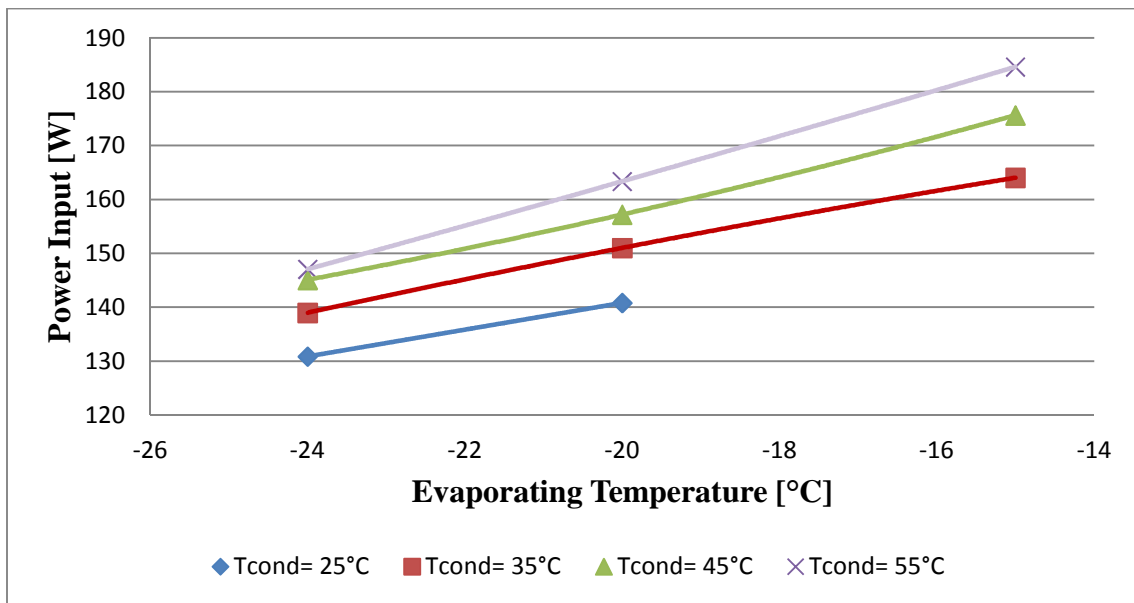


Figure 16 - Power Input for ARM-42a

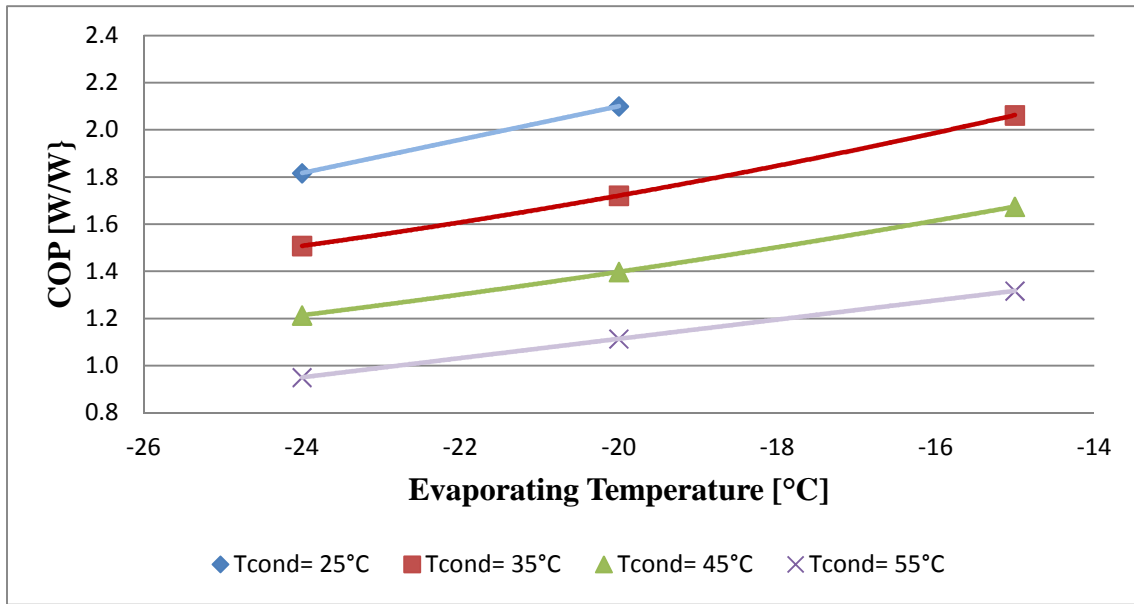


Figure 17 - COP for ARM-42a

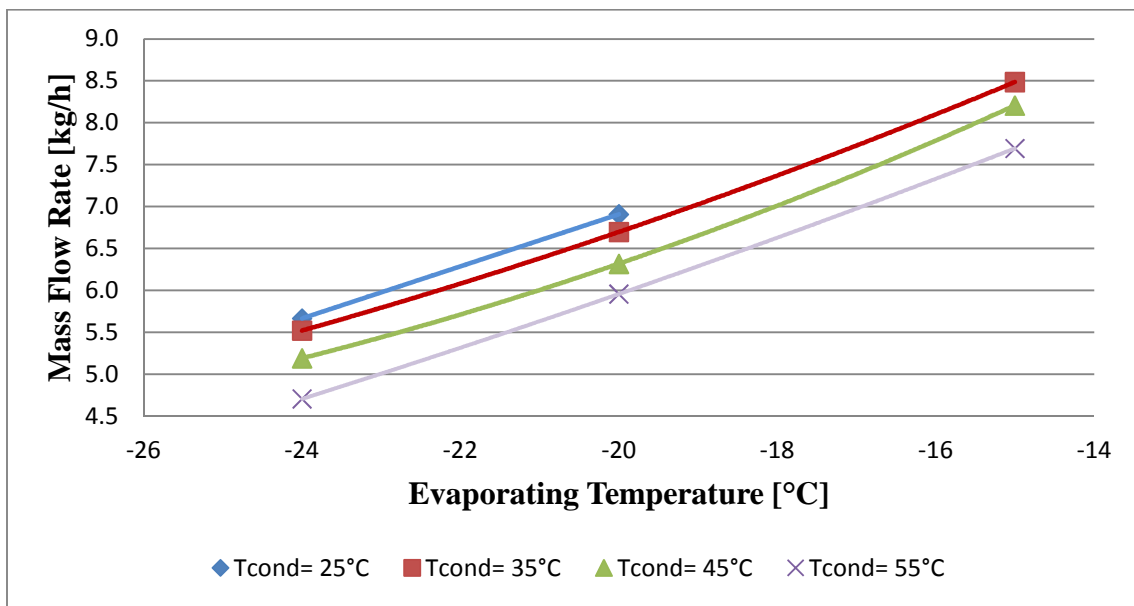


Figure 18 - Mass flow rate for ARM-42a

- Comparative performance map for N-13a and R-134a
 - o Polynomial equation

Table 11 - Polynomial coefficients

N-13a / R-134a	
Coefficients	COP_{N-13a}/COP_{R-134a}
A ₀	14,85
A ₁	1,72
A ₂	0,07
A ₃	0,00
A ₄	-0,22
A ₅	0,00
A ₆	0,00
A ₇	-0,01
A ₈	0,00
A ₉	0,00

$$X = A_0 + (A_1 \times S) + (A_2 \times S^2) + (A_3 \times S^3) + (A_4 \times D) + (A_5 \times D^2) + (A_6 \times D^3) + (A_7 \times S \times D) + (A_8 \times S \times D^2) + (A_9 \times D \times S^2)$$

where:

A: Equation coefficient, represents compressor performance

S: Suction dew point temperature, [°C]

D: Discharge dew point temperature, [°C]

X: COP_{N-13a}/COP_{R-134a}

- o Graphic

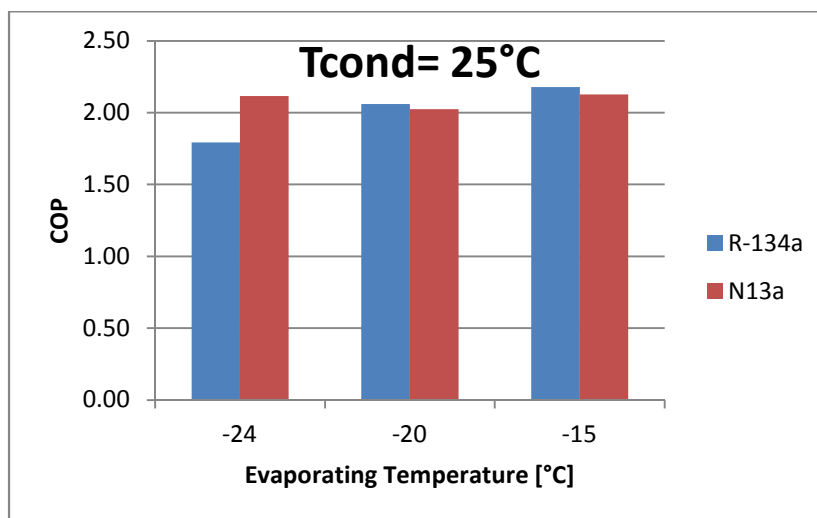


Figure 19 - Comparative COP

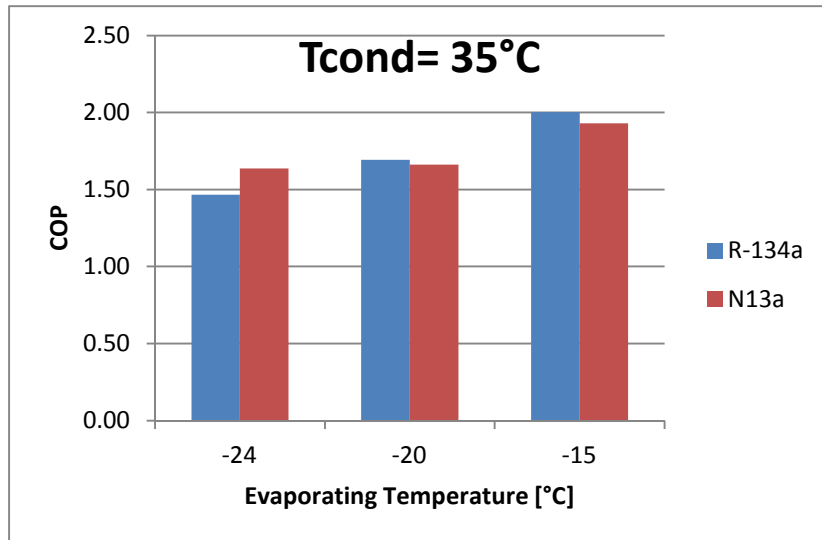


Figure 20 - Comparative COP

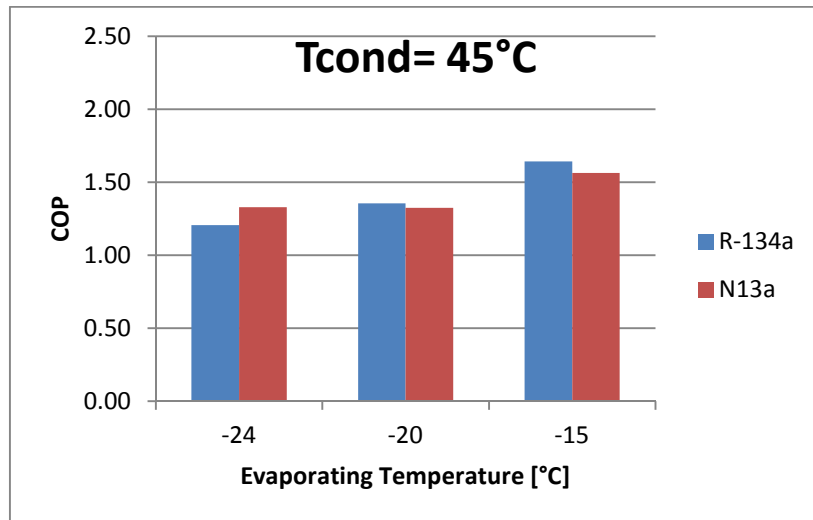


Figure 21 - Comparative COP

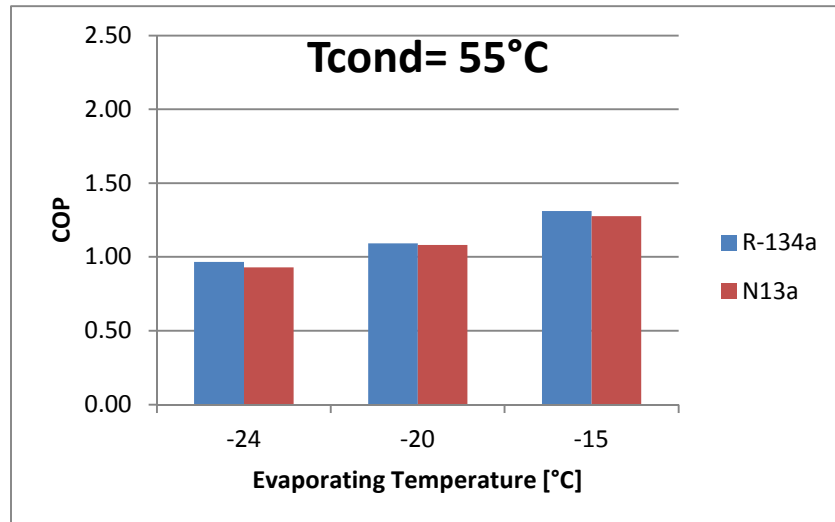


Figure 22 - Comparative COP

- Comparative performance map for ARM-42a and R-134a
 - o Polynomial equation

Table 2 - Polynomial coefficients

ARM-42a / R-134 ^a	
Coefficients	$COP_{ARM-42a}/COP_{R-134a}$
A ₀	8,21
A ₁	1,06
A ₂	0,05
A ₃	0,00
A ₄	-0,04
A ₅	0,00
A ₆	0,00
A ₇	0,00
A ₈	0,00
A ₉	0,00

$$X = A_0 + (A_1 \times S) + (A_2 \times S^2) + (A_3 \times S^3) + (A_4 \times D) + (A_5 \times D^2) + (A_6 \times D^3) + (A_7 \times S \times D) + (A_8 \times S \times D^2) + (A_9 \times D \times S^2)$$

where:

A: Equation coefficient, represents compressor performance

S: Suction dew point temperature, [°C]

D: Discharge dew point temperature, [°C]

X: $COP_{ARM-42a}/COP_{R-134a}$

- o Graphic

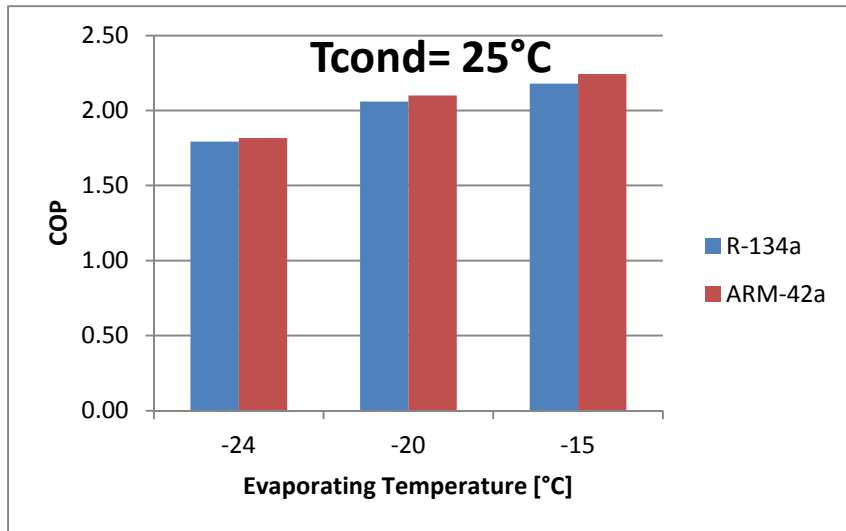


Figure 23 - Comparative COP

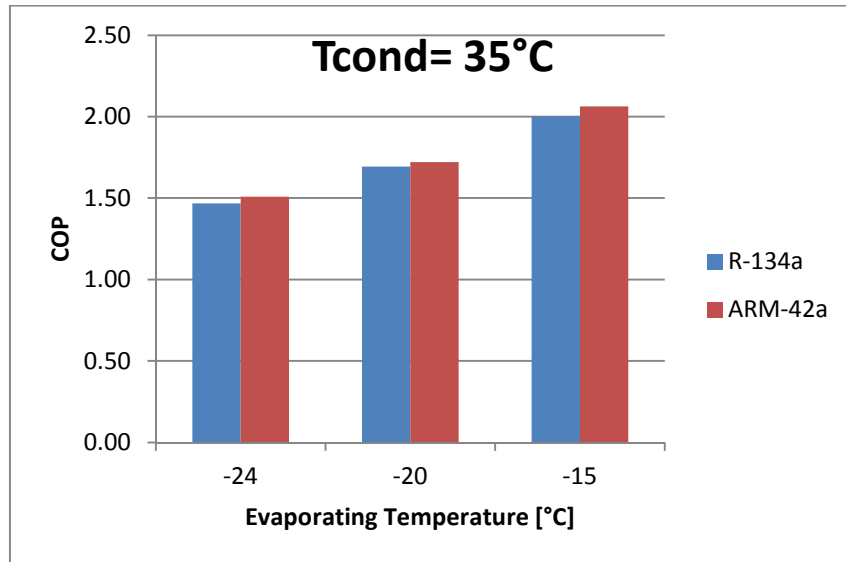


Figure 24 - Comparative COP

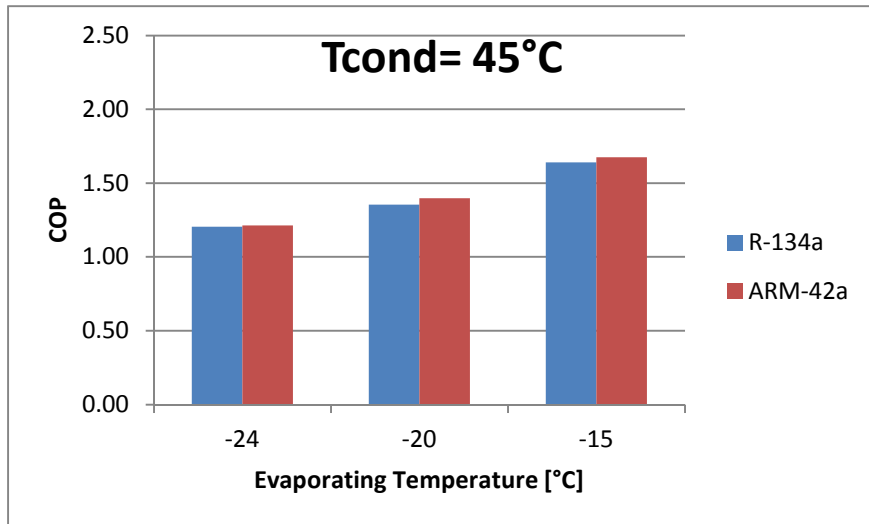


Figure 25 - Comparative COP

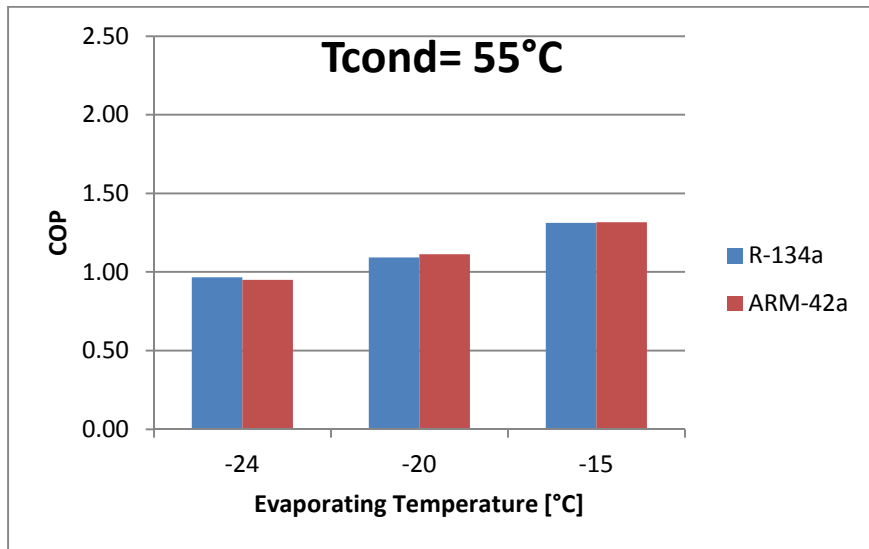


Figure 26 - Comparative COP