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

TEST REPORT #27

System Drop-In Test of Refrigerant Blend ARM-70a and DR-5 in An Air to Water Heat Pump

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November 21, 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.

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List of Tested Refrigerants' Compositions (Mass%)

ARM-70a	R-32/R-134a/R-1234yf (50/10/40)
DR-5	R-32/R-1234yf (72.5/27.5)

1. Introduction:

The present report describes the low GWP blends, ARM-70a and DR5, drop in tests realized in an air to water heat pump. The tested heat pump is sold charged with R-410A blend.
Tests are first realized with the heat pump as bought following the AHRI551/591-2011 standard conditions. These tests are considered as reference for the comparison with the drop in tests.

2. Details of Test Setup:

a. Description of System

The tested equipment is an air to water heat pump that has the following characteristics:

- Brand: AERMEC
- Model: ANL020H
- Nominal heating capacity 6.26 kW (@7°C DB air temp. and 75% RH and inlet water temperature of 35°C)
- Baseline refrigerant R-410A
- Refrigerant charge 1500 g

b. Description of Modifications to System

The drop in tests were conducted without any change to the equipment. For each tested low GWP blend, tests are repeated for three different refrigerant charges.

c. Description of Tests Conducted

Tests are conducted following the AHRI 551/591-2011 standard. Heat pump is tested at full capacity for the following conditions:

- TC1: Air DB temperature -8°C, -9°C WB and water inlet/outlet temperature to the heat pump of 35°C/40°C;
- TC2: Air DB temperature 8°C, 6°C WB and water inlet/outlet temperature to the heat pump of 35°C/40°C;
- TC3: Air DB temperature 8°C, 6°C WB and water inlet/outlet temperature to the heat pump of 45°C/50°C;

The experimental set up is presented in the figure 1 below.

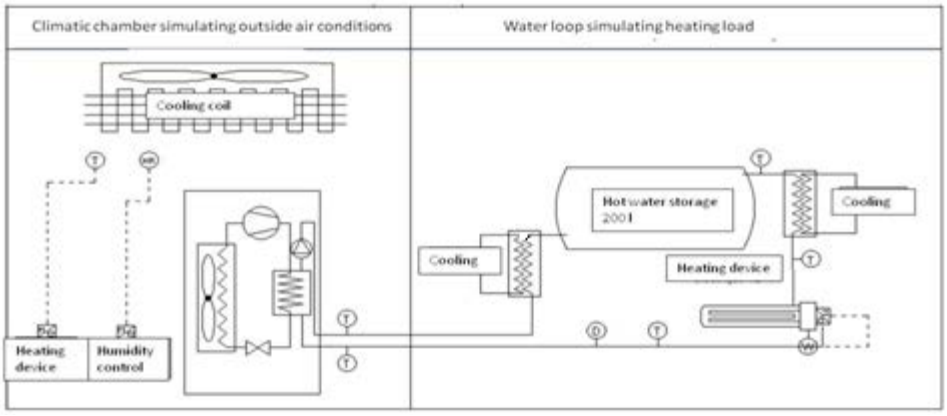

Figure 1 – Experimental set up for the air to water heat pump characterization

It is composed of a climatic chamber simulating the outside ambient conditions and a water loop simulating the heating load.

The climatic chamber has an ultra sound humidifier permitting to control air humidity and a cooling and heating device for controlling temperature. Air temperature is measured at 2 positions in the climatic chamber using PT100 temperature sensors with an accuracy of ±0.05°C and relative humidity is measured with an accuracy of ±1%.

The water loop is equipped with:
- A first cooling section;
- A water capacity of 200 l simulating the thermal inertia of hydronic systems in case of partial load tests;
- A second cooling section needed for high capacity heat pumps;
- And a heating device permitting a fine control of water return temperature to the heat pump.

Inlet and outlet temperatures of water at the condenser of the heat pump are measured using intrusive PT100 sensors with an accuracy of ±0.05°C. Water mass flow rate through the condenser is measured using an electromagnetic mass flow meter with an accuracy of ±1%.

Heating capacity of the heat pump is then derived at full load operation and after reaching the steady state condition. In case of defrost cycles, heat capacity is evaluated only out of the defrost periods as shown in the equation below.

$$(q_{cd})_{avg} = \frac{1}{\tau_2 - \tau_1} \int_{\tau_1}^{\tau_2} q_{cd} \cdot \delta_\tau = \frac{1}{\tau_2 - \tau_1} \sum_{i=1}^{n} (q_{cd})_i \cdot \Delta\tau_i$$

Where:

q : heat produced out of the defrost period

τ_1 : cycle starting time

τ_2 : cycle final time

δ_τ: Integration variable

Δ_{τ_i} : data acquisition time span

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Here we have the results of the three test conditions {TC1, TC2, TC3} with the baseline refrigerant
Alternative Refrigerant	**R-410A**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R410a - // n/a
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**TC1**	**TC2**	**TC3**	**SI Units**	**TC1**	**TC2**	**TC3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.50			kg	3.31			lb
Composition										
Ambient Temps.	Outdoor	db	-8.6	7.5	7.5	C	18.3	45.3	45.5	F
		wb	-9.9	5.5	5.5	C	16.2	41.9	41.9	F
Ambient Temps.	Outdoor	db	-7.6	7.4	7.5	C	16.5	45.5	45.5	F
		wb	-8.8	5.5	5.5	C	14.2	41.9	41.9	F
Heated Water	Indoor		35.2	34.9	45.0	C	95.4	94.8	113	F
	Outdoor		37.4	39.9	49.7	C	99.3	104	121	F
Total Capacity			4,041	6,397	5,909	W	**13,788**	**21,827**	**20,162**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			1,943	2,063	2,484	W	1,943	2,063	2,484	W
Compressor Power Input			1,631	1,753	2,165	W	1,631	1,753	2,165	W
COP or EER (total)[1]			2.08	3.10	2.38	W/W	**7.10**	**10.6**	**8.12**	Btu/W.hr
COP or EER (Compressor only)			2.48	3.65	2.73	W/W	**8.46**	**12.4**	**9.32**	Btu/W.hr

Air/Water Side Data	**TC1**	**TC2**	**TC3**	**SI Units**	**TC1**	**TC2**	**TC3**	**IP Units**
Evaporator								
Heat Exchange Fluid	Air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature 1	-8.60	7.50	7.50	C	16.5	45.5	45.5	F
Inlet Temperature 2	-7.60	7.40	7.50	C	18.3	45.3	45.5	F
Condenser								
Heat Exchange Fluid	Water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	35.2	34.9	45.0	C	95.4	94.8	113	F
Outlet Temperature	37.4	39.9	49.7	C	99.3	104	121	F

[1] Total system COP includes the compressor, the fan and pump electrical power input

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 1 : Heated water Temps : 35.0°C/95.0°F Ambient Temps : -8.00°C/17.6°F (db) -8.90°C/16°F (wb)
Alternative Refrigerant	**ARM-70a**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.35	1.50	1.65	Kg	2.97	3.31	3.63	lb
Composition										
Ambient Temps.	Outdoor	db	-8.40	-8.60	n/a	C	16.9	16.5	n/a	F
		wb	-9.50	-9.30	n/a	C	14.9	15.3	n/a	F
Ambient Temps.	Outdoor	db	-7.10	-8.00	-8.3	C	19.2	17.6	17	F
		wb	-8.75	-9.00	-9.1	C	16.2	15.8	15.6	F
Heated Water	Inlet		35	35.4	35.1	C	95	95.7	95.2	F
	Outlet		38.3	38.7	38.4	C	101	102	101.1	F
Total Capacity			4065	4204	4176	W	**13870**	**14345**	**14249**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			1907	1946	2112	W	**1907**	**1946**	**2112**	W
Compressor Power Input			1585	1625	1771	W	**1585**	**1625**	**1771**	W
COP or EER (total)			2.13	2.16	1.98	W/W	**7.27**	**7.37**	**6.74**	Btu/W.hr
COP or EER (Compressor only)			2.56	2.59	2.36	W/W	**8.74**	**8.84**	**8.04**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	Air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature 1	-8.40	-8.60	n/a	C	16.9	16.5	n/a	F
Inlet Temperature 2	-7.10	-8.00	-8.3	C	19.2	17.6	17	F
Condenser								
Heat Exchange Fluid	Water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	35	35.4	35.1	C	95	95.7	95.2	F
Outlet Temperature	38.3	38.7	38.4	C	101	102	101.1	F

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 2 : Heated water Temps : 35.0°C/95.0°F Ambient Temps : 8.00°C/46.4°F (db) 6.00°C/42.8°F (wb)
Alternative Refrigerant	**ARM-70a**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.35	1.50	1.65	kg	2.97	3.31	3.63	lb
Composition										
Ambient Temps.	Outdoor	db	8.30	7.80	7.8	C	46.9	46.0	46	F
		wb	6.20	5.80	5.6	C	43.2	42.4	42.2	F
Ambient Temps.	Outdoor	db	8.40	7.80	8	C	47.1	46.0	46.4	F
		wb	6.20	5.80	5.8	C	43.2	42.4	42.4	F
Heated Water	Inlet		34.6	34.7	34.2	C	94.3	94.5	93.6	F
	Outlet		39.7	39.9	39.5	C	103	104	103.1	F
Total Capacity			6395	6521	6690	W	**21821**	**22251**	**22827**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			1974	2023	2400	W	**1974**	**2023**	**2400**	W
Compressor Power Input			1657	1688	2055	W	**1657**	**1688**	**2055**	W
COP or EER (total)			3.24	3.22	2.79	W/W	**11.06**	**10.99**	**9.51**	Btu/W.hr
COP or EER (Compressor only)			3.86	3.86	3.25	W/W	**13.17**	**13.17**	**11.1**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	Air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature 1	8.30	7.80	7.8	C	46.9	46.0	46	F
Inlet Temperature 2	8.40	7.80	8	C	47.1	46.0	46.4	F
Condenser								
Heat Exchange Fluid	water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	34.6	34.7	34.2	C	94.3	94.5	93.6	F
Outlet Temperature	39.7	39.9	39.5	C	103	104	103.1	F

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 3: Heated water Temps. : 45.0°C/113°F Ambient Temps. : 8.00°C/46.4°F (db) 6.00°C/42.8°F (wb)
Alternative Refrigerant	**ARM-70a**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Make and Model of System	//
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.35	1.50	1.65	Kg	2.97	3.31	3.63	lb
Composition										
Ambient Temps.	Outdoor	db	8.20	7.30	8.2	C	46.8	45.1	46.8	F
		wb	5.70	5.60	6.1	C	42.3	42.1	43	F
Ambient Temps.	Outdoor	db	7.90	7.70	8.2	C	46.2	45.9	46.8	F
		wb	5.60	5.80	6.1	C	42.1	42.4	43	F
Heated Water	Inlet		44.9	44.7	44.8	C	112.8	112.5	112.6	F
	Outlet		49.8	49.8	49.1	C	122	122	120.4	F
Total Capacity			6206	6489	5336	W	**21176**	**22141**	**18207**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			2413	2560	2540	W	**2413**	**2560**	**2540**	W
Compressor Power Input			2088	2215	2212	W	**2088**	**2215**	**2212**	W
COP or EER (total)			2.57	2.53	2.1	W/W	**8.77**	**8.63**	**7.16**	Btu/W.hr
COP or EER (Compressor only)			2.97	2.93	2.4	W/W	**10.13**	**10**	**8.23**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature 1	8.20	7.30	8.2	C	46.8	45.1	46.8	F
Inlet Temperature 2	7.90	7.70	8.2	C	46.2	45.9	46.8	F
Condenser								
Heat Exchange Fluid	water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	44.9	44.7	44.8	C	112.8	112.5	112.6	F
Outlet Temperature	49.8	49.8	49.1	C	122	122	120.4	F

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 1 : Heated water Temps : 35.0°C/95.0°F Ambient Temps : -8.00°C/17.6°F (db) -8.90°C/16°F (wb)
Alternative Refrigerant	**DR-5**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.40	1.50	1.6	Kg	3.09	3.31	3.52	lb
Composition										
Ambient Temps.	Outdoor	db	-8.40	-8.80	-8.2	C	16.9	16.2	17.2	F
		wb	-9.20	-9.20	-9.4	C	15.4	15.4	15	F
Ambient Temps.	Outdoor	db	-7.80	-7.10	n/a	C	18.0	19.2	n/a	F
		wb	-8.50	-8.30	n/a	C	16.7	17.1	n/a	F
Heated Water	Inlet		35.3	35.3	35.3	C	95.5	95.5	95.5	F
	Outlet		38.9	38.9	38.6	C	102	102	101.5	F
Total Capacity			4590	4611	4169	W	**15662**	**15733**	**14225**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			1950	2073	2230	W	**1950**	**2073**	**2230**	W
Compressor Power Input			1628	1752	1888	W	**1628**	**1752**	**1888**	W
COP or EER (total)			2.35	2.22	1.87	W/W	**8.02**	**7.57**	**6.37**	Btu/W.hr
COP or EER (Compressor only)			2.82	2.63	2.21	W/W	**9.62**	**8.97**	**7.53**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature1	-8.40	-8.80	-8.2	C	16.9	16.2	17.24	F
Inlet Temperature2	-7.80	-7.10	n/a	C	18.0	19.2	n/a	F
Condenser								
Heat Exchange Fluid	water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	35.3	35.3	35.3	C	95.5	95.5	95.5	F
Outlet Temperature	38.9	38.9	38.6	C	102	102	101.5	F

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 2 : Heated water Temps : 35.0°C/95.0°F Ambient Temps : 8.00°C/46.4°F (db) 6.00°C/42.8°F (wb)
Alternative Refrigerant	**DR-5**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			Heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.40	1.50	1.6	Kg	3.09	3.31	3.52	lb
Composition										
Ambient Temps.	Outdoor	db	7.20	7.40	8.7	C	45.0	45.3	47.6	F
		wb	5.50	5.60	6.1	C	41.9	42.1	43	F
Ambient Temps.	Outdoor	db	7.40	7.70	7.6	C	45.3	45.9	45.7	F
		wb	5.60	5.80	5.2	C	42.1	42.4	41.4	F
Heated Water	Inlet		34.5	34.5	34.6	C	94.1	94.1	94.3	F
	Outlet		39.9	40.1	40	C	104	104	104	F
Total Capacity			6758	7007	6823	W	**23059**	**23909**	**23281**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			2188	2272	2523	W	**2188**	**2272**	**2523**	W
Compressor Power Input			1871	1936	2178	W	**1871**	**1936**	**2178**	W
COP or EER (total)			3.09	3.08	2.7	W/W	**10.54**	**10.51**	**9.22**	Btu/W.hr
COP or EER (Compressor only)			3.61	3.62	3.13	W/W	**12.32**	**12.35**	**10.7**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	Air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature 1	7.20	7.40	8.7	C	45.0	45.3	47.6	F
Inlet Temperature 2	7.40	7.70	7.6	C	45.3	45.9	45.7	F
Condenser								
Heat Exchange Fluid	water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	34.5	34.5	34.6	C	94.1	94.1	94.3	F
Outlet Temperature	39.9	40.1	40	C	104	104	104	F

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Basic Information	Test Condition 3: Heated water Temps. : 45.0°C/113°F Ambient Temps. : 8.00°C/46.4°F (db) 6.00°C/42.8°F (wb)
Alternative Refrigerant	**DR-5**
Alternative Lubricant Type and ISO Viscosity	POE synthetic oil Emkarate RL 32 3MAF
Baseline Refrigerant and Lubricant	R-410A - POE synthetic oil Emkarate RL 32 3MAF
Nominal Capacity and Type of System	5.67 kW cooling / 6.26 kW heating (1.61tons/1.78tons)

Comparison Data			**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Mode (Heating/Cooling)			heating							
Compressor Type			scroll compressor							
Refrigerant Charge			1.40	1.50	1.6	kg	3.09	3.31	3.52	lb
Composition										
Ambient Temps.	Outdoor	db	7.10	7.60	7.7	C	44.8	45.7	45.9	F
		wb	5.30	5.40	5.5	C	41.5	41.7	41.9	F
Ambient Temps.	Outdoor	db	7.70	7.60	7.8	C	45.9	45.7	46	F
		wb	5.50	5.40	5.6	C	41.9	41.7	42	F
Heated Water	Inlet		44.8	45.9	44.8	C	112.6	114.6	112.6	F
	Outlet		50.2	50.6	50	C	122	123	122	F
Total Capacity			6762	6020	6493	W	**23073**	**20541**	**22155**	Btu/hr
Sensible Capacity			n/a	n/a	n/a	W	n/a	n/a	n/a	Btu/hr
Total System Power Input			2577	2730	2717	W	**2577**	**2730**	**2717**	W
Compressor Power Input			2253	2385	2389	W	**2253**	**2385**	**2389**	W
COP or EER (total)			2.62	2.21	2.39	W/W	**8.95**	**7.52**	**8.15**	Btu/W.hr
COP or EER (Compressor only)			3	2.52	2.72	W/W	**10.24**	**8.61**	**9.27**	Btu/W.hr

Air/Water Side Data	**Charge 1**	**Charge 2**	**Charge 3**	**SI Units**	**Charge 1**	**Charge 2**	**Charge 3**	**IP Units**
Evaporator								
Heat Exchange Fluid	Air							
Flow Rate (gas)	41.7			m^3/min	1472			ft^3/min
Inlet Temperature1	7.1	7.6	7.7	C	44.8	45.7	45.9	F
Inlet Temperature2	7.7	7.6	7.8	C	45.9	45.7	46	F
Condenser								
Heat Exchange Fluid	Water							
Flow Rate (liquid)	980			L/min	259			gal/min
Inlet Temperature	44.8	45.9	44.8	C	112.6	114.6	112.6	F
Outlet Temperature	50.2	50.6	50	C	122	123	122	F

Discussion

Both low GWP blends ARM-70a and DR-5 have shown a higher heating capacity and system COP.
Figure 2 compares the heating capacity obtained with R-410A, ARM-70a (3 refrigerant charges) and DR-5 (3 refrigerant charges).
DR5 presents the highest heating capacities between the three refrigerants and its optimal charge with regard to the heating capacity is 1.50 kg.

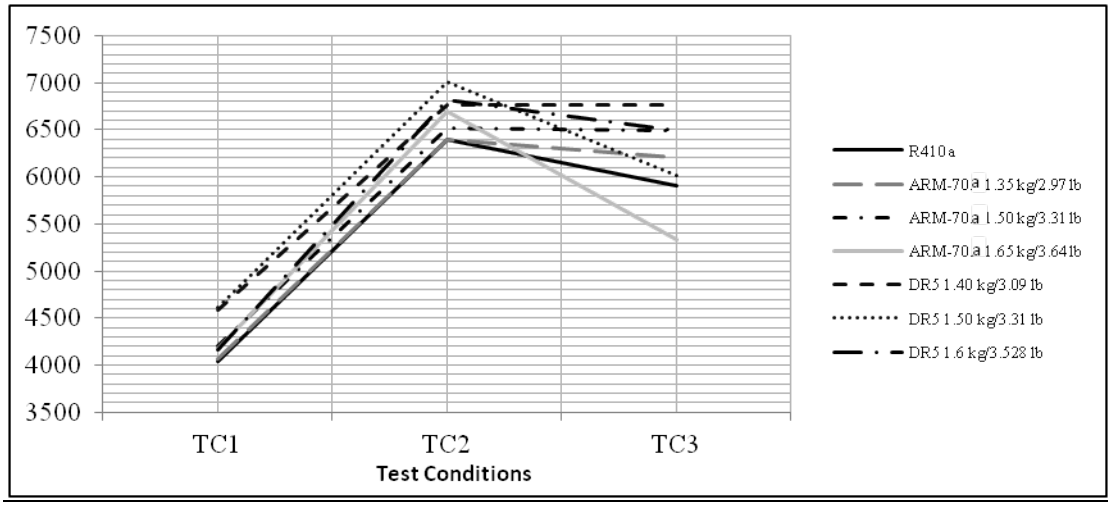

Figure 2 – Heating capacity comparison

Figure 3 compares the system COP obtained in the all the tests performed. Both ARM-70a and DR5 permit to obtain comparable results (10% higher for DR-5 at TC 1, 5% higher for ARM-70a at TC2 2 and equivalent performances for the TC 3).

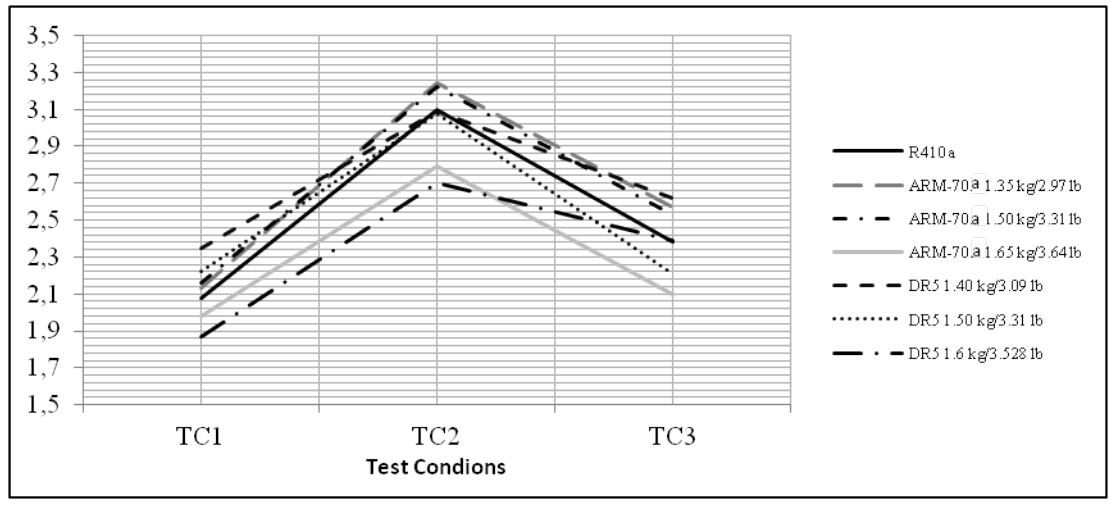

Figure 3 – System COP comparison