



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

TEST REPORT #46

System Drop-in Test of Refrigerants R32, DR-5A, L-41-1 and L-41-2 in a Water Chiller

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1. Introduction:

Air conditioning and refrigeration industry has been subjected to several changes in order to reduce the environmental impact and to improve the performances. Finding new refrigerants with low GWP able to replace existing ones taking into account the system performance and other properties, represents an important issue in this subject.

In the intent to substitute the R-410A which is characterized by a high volumetric cooling capacity and good transport and thermal properties, refrigerant blends including R-32 (GWP = 675, ODP = 0), HFO (R-1234yf (GWP = 4, ODP = 0), R-1234ze (GWP = 6, ODP = 0)), R-600a (GWP = 20, ODP = 0) and R-125 (GWP = 3420, ODP = 0) represent potential alternatives.

Many fluids have been tested in an attempt to replace the R-410A in heat pumps or air conditioning equipments. Among these works we can find in literature:

- A test of retrofit of R-410A in an air to water heat pump where DR-5 and ARM-70A refrigerants showed higher heating capacity and system COP than R-410A (Besbes, 2013).
- A system drop-in test of R-32 in a VRF multi-split heat pump in which the R-32 improved cooling capacity and COP but showed higher compressor discharge temperature than R-410A (Tsujii, 2013).
- Drop-in performance of low GWP refrigerants in an heat pump system for residential applications where the R-32 presented comparable cooling and heating capacities and COPs similar to those of the R-410A, but it presented high discharge temperature and pressure, the R-1234yf was tested too and it provided similar COPs but lower capacities even with charge optimization (Barve, 2012).
- An air conditioning system model which simulates the replacing of R-410A by the R-32 and many other refrigerant blends. These refrigerants showed a COP equal or higher than that of the R-410A but only R-32 permitted higher capacity than that of the R-410A. However R-32 causes high operating stress on compressor and lubricant because of its high discharge temperatures and pressures (Leck, 2010).

The present report presents, within the AREP2 initiative, results and discussions of drop in tests of four low GWP refrigerants in a water chiller (that can operate with and without a liquid receiver) which is originally charged by R-410A. The alternative refrigerants that are tested are the R-32, the DR-5A (manufactured by DuPont), the L-41-1 and the L-41-2 (manufactured by Honeywell).

First tests are realized on the chiller with the R-410A. These tests determine a reference to draw conclusions concerning R-410A replacement candidates.

2. Details of Test Setup:

a. Description of System

The tested equipment is a water chiller. It is tested in two different configurations, with and without liquid receiver since the liquid receiver could be bypassed (as shown in the figure 1).

The equipment is originally sold without liquid receiver. As bought, the chiller has the following characteristics:

- Name of the tested system: AERMEC.
- Model: ANL040M.
- Nominal cooling capacity 8.48 kW (at 35 °C DB air temperature, 7°C outlet water temperature).
- Baseline refrigerant R-410A.
- Refrigerant charge 2.7 kg.
- Lubricant type Emkarate RL32-3 MAF.

When tested with a liquid receiver the chiller has the following characteristics:

- Nominal cooling capacity 7.87 kW (at 35 °C DB air temperature, 7 °C outlet water temperature).
- Baseline refrigerant R-410A.
- Refrigerant charge 3.2 kg.
- Lubricant type Emkarate RL 32-3 MAF.

b. Description of Modifications to System

A liquid receiver is added to the chiller in order to be able to realize tests to the system with liquid receiver. This liquid receiver could be bypassed to retrieve the original design of the chiller (as shown in figure 1).

For the measurements of temperatures and pressures on the chiller refrigerant circuit, immersion thermocouples with an accuracy of ± 0.5 °C and pressure sensors with an accuracy of ± 15 kPa are installed at inlets and outlets of the chiller components for both configurations. A flow meter is integrated to the circuit in order to measure the refrigerant flow.

The literature demonstrates that the expansion device was adjusted in many retrofit tests in order to achieve a COP optimization (Barve, 2012) and superheat and subcooling control (Park, 2007). In the presented tests, expansion device was adjusted for each alternative refrigerant which could be considered as a minor change to the system that didn't involve any additional material or extra design and cost (Barve, 2012). During the tests presented in this report, the expansion valve was adjusted by the use of the setting spindle on the valve in order to reduce high refrigerant mass flow fluctuations (and superheat fluctuations) or hunting phenomenon observed during some of the tests. So the expansion valve was adjusted to stabilize the refrigerant mass flow and to prevent liquid refrigerant aspiration by the compressor which could damage it. The effect of this adjustment is shown later in figure 2 (section d). The expansion valve adjustment is done at 35 °C ambient temperature test condition and kept without any modification for all the other ambient temperatures.

For R-410A and for each of tested alternative refrigerants, the tests are conducted for 2.7 kg refrigerant charge without liquid receiver and for 3.2 kg and 3.9 kg refrigerant charges with a liquid receiver. These refrigerant charges were chosen by considering the R-410A original charge and the two other charges were arbitrary chosen; therefore charge optimization tests were not conducted for any refrigerant.

c. Description of Tests Conducted

The experimental setup is formed of a temperature controlled room (climatic room) representing outside conditions and a water loop representing the cooling load. This experimental setup is shown in Figure 1.

The water chiller is installed in the climatic room which is equipped with a cooling coil permitting to cool and control the room temperature by compensating the heat rejected by the chiller (on the condenser side). Air temperature is measured at three different vertical positions at the condenser air inlet using two PT100 temperature sensors with an accuracy of ± 0.3 °C and a thermocouple with an accuracy of ± 0.5 °C.

The water loop is equipped with: a water storage tank of 200 L, two cooling sections installed before and after the water storage tank relatively to the water flow direction, a heating device and a circulating pump to control the water flow rate. Water temperature is measured at the inlet and outlet of the chiller evaporator using PT100 immersion sensors with an accuracy of ± 0.15 °C. An electromagnetic flow meter with an accuracy of ± 1 % is used to measure the water volumetric flow rate.

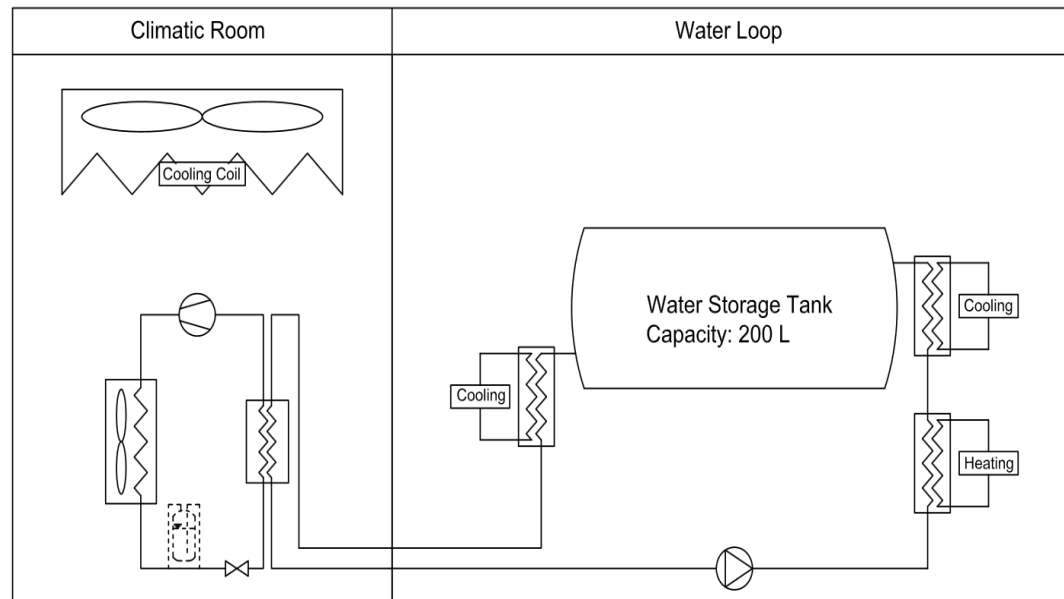


Figure 1: Experimental setup for the climatic room, the water loop and water chiller.

For safety reasons, tests were limited to 126 °C discharge temperature. All tests are conducted with 0.4586 l/s water volume flow rate. The chiller is tested at full load under the following conditions:

- Air DB temperature of 30 °C and water outlet temperature from the chiller evaporator of 7 °C (temperature condition 1: TC1)
- Air DB temperature of 35 °C and water outlet temperature from the chiller evaporator of 7 °C (temperature condition 2: TC2)
- Air DB temperature of 40 °C and water outlet temperature from the chiller evaporator of 7 °C (temperature condition 3: TC3)
- Air DB temperature of 45 °C and water outlet temperature from the chiller evaporator of 7 °C (temperature condition 4: TC4)

During all tests, evaporator inlet water temperature is controlled in order to maintain a water temperature of 7 °C at the outlet of the evaporator.

3. Results

For all realized tests, the cooling capacity is calculated relatively to water mass flow rate and water temperature at the inlet and outlet of the evaporator according to eq. (1).

$$Total\ Capacity = \dot{m}_w c_{p,w} (T_i - T_o) \quad (1)$$

Energy efficiency ratio (EER) is calculated according to eq. (2). EER is the ratio of the cooling capacity to the system power consumption which includes the condenser fan power consumption.

$$EER = \frac{Q_{cold}}{W_{comp} + W_{fan}} \quad (2)$$

The fan power consumption is constant (about 210W to 220W) in all tests.

Another energy efficiency ratio $EER_{compressor}$ is also calculated according to eq. (3). $EER_{compressor}$ is the ratio of the cooling capacity to the compressor power consumption.

$$EER_{compressor} = \frac{Q_{cold}}{W_{comp}} \quad (3)$$

In the following results, in addition to the system performance and cooling capacity, relative pressure and temperature at the compressor outlet are shown.

Hereafter are shown the different tested refrigerants and the tests results (In these results, the compressor suction temperature is not mentioned because the temperature was only measured at the evaporator outlet, and it should be almost equal to the compressor suction temperature since the tube length is short between the compressor suction and the evaporator outlet). The superheat values for alternative refrigerants DR-5A, L-41-1 and L-41-2 are not calculated since the mixture composition of the mentioned refrigerants is unknown and hence their properties are not available. However, the superheat and subcooling of R-410A and R-32 are calculated according to temperature and pressure measurements and using the properties of R-410A and R-32 according to REFPROP[®] version 9.0.

Basic Information				
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	R-32	DR-5A	L-41-1	L-41-2
Alternative Lubricant Type and ISO Viscosity	Emkarate RL 32-3 MAF			
Baseline Refrigerant and Lubricant	R-410A / Emkarate RL32-3 MAF			
Make and Model of System	AERMEC / Model: ANL040M			
Nominal Capacity and Type of System	8.48 kW (without liquid receiver) / 7.87 kW (With liquid receiver)			

a. Tests without liquid receiver for a refrigerant charge of 2.7 kg.

Case of R-410A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min				
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb				
Refrigerant Charge	2.70				kg	5.52				lb				
Refrigerant Mass Flow Rate	3.15	3.13	3.11	3.10	kg/min	6.45	6.40	6.36	6.34	lb/min				
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	30.01	34.87	40.15	44.99	C	86.02	94.77	104.27	112.98	F				
Total Capacity	9091.2	8499.1	7830.7	7207.6	W	31020.5	29000.1	26719.5	24593.4	Btu/hr				
Sensible Capacity					W					Btu/hr				
Total System Power Input	3066.0	3370.0	3726.0	4089.0	W	3066.0	3370.0	3726.0	4089.0	W				
Compressor Power Input	2846.0	3150.0	3506.0	3869.0	W	2846.0	3150.0	3506.0	3869.0	W				
Energy Efficiency Ratio (EER)	2.97	2.52	2.10	1.76	W/W	10.13	8.60	7.17	6.01	Btu/Whr				
Energy Efficiency Ratio (EER,compressor)	3.19	2.70	2.23	1.86	W/W	10.90	9.21	7.62	6.36	Btu/Whr				

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio				
											TC1	TC2	TC3	TC4	
Evaporator															
Heat Exchange Fluid	Water														
Flow Rate (liquid)	0.4580	0.4581	0.4577	0.4572	L/min	0.1210	0.1210	0.1209	0.1208	gal/min					
Inlet Temperature	11.74	11.46	11.10	10.80	C	53.1	52.6	52.0	51.4	F					
Outlet Temperature	6.98	7.01	7.00	7.02	C	44.6	44.6	44.6	44.6	F					
Condenser															
Heat Exchange Fluid	Air														
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min					
Inlet Temperature	30.01	34.87	40.15	44.99	C	86.0	94.8	104.3	113.0	F					
Outlet Temperature	42.63	47.64	52.80	57.80	C	108.7	117.8	127.0	136.0	F					

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	80.9	2881.08	88.0	3159.38	177.6	417.77	190.4	459.32
Condenser Inlet	79.8	2869.55	86.9	3148.37	175.6	416.19	188.4	456.63
Condenser Outlet	33.5	2811.57	38.3	3098.34	92.3	407.78	100.9	449.38
Expansion Device Inlet	33.5	2796.15	38.3	3079.98	92.3	405.55	100.9	446.71
Subcooling, at expan. device	12.5		11.8		2.5		21.2	
Evaporator Inlet	4.9	927.16	5.6	943.46	40.8	134.47	42.1	136.84
Evaporator Outlet	5.0	857.39	4.4	866.17	41.0	124.35	39.9	125.63
Evaporator Superheat	2.7		1.8		4.9		3.2	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	96.7	3486.87	104.6	3800.80	206.1	503.62	220.3	549.60
Condenser Inlet	95.6	3475.62	103.4	3790.67	204.1	522.32	218.1	549.79
Condenser Outlet	43.6	3434.39	48.7	3755.38	110.5	498.12	119.7	544.67
Expansion Device Inlet	43.6	3412.45	48.7	3730.71	110.5	494.93	119.7	541.09
Subcooling, at expan. device	11.1		10.0		20.0		18.0	
Evaporator Inlet	6.5	961.98	7.5	985.54	43.7	139.52	45.5	142.94
Evaporator Outlet	4.4	873.58	4.4	886.56	39.9	126.70	39.9	128.58
Evaporator Superheat	1.5		1.1		2.7		2.0	

Case of DR-5A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	2.70				kg	5.52				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.67	2.77	2.84	2.98	kg/min	5.46	5.67	5.81	6.10	lb/min	0.85	0.88	0.91	0.96
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.62	35.07	40.16	45.63	C	85.32	95.13	104.29	114.13	F				
Total Capacity	8788.1	8229.7	7484.5	6681.8	W	29986.2	28080.9	25538.2	22799.2	Btu/hr	0.97	0.97	0.96	0.93
Sensible Capacity					W					Btu/hr				
Total System Power Input	3019.0	3318.0	3644.0	3926.0	W	3019.0	3318.0	3644.0	3926.0	W	0.98	0.98	0.98	0.96
Compressor Power Input	2799.0	3098.0	3424.0	3706.0	W	2799.0	3098.0	3424.0	3706.0	W	0.98	0.98	0.98	0.96
Energy Efficiency Ratio (EER)	2.91	2.48	2.05	1.70	W/W	9.93	8.46	6.99	5.80	Btu/Whr	0.98	0.98	0.98	0.97
Energy Efficiency Ratio (EER,compressor)	3.14	2.66	2.19	1.80	W/W	10.71	9.06	7.46	6.15	Btu/Whr	0.98	0.99	0.98	0.97

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4586	0.4584	0.4583	0.4581	L/min	0.1211	0.1211	0.1211	0.1210	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.66	11.32	10.96	10.44	C	52.99	52.38	51.73	50.79	F				
Outlet Temperature	7.07	7.02	7.04	6.94	C	44.73	44.64	44.67	44.49	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.62	35.07	40.16	45.63	C	85.32	95.13	104.29	114.13	F				
Outlet Temperature	41.51	47.06	52.46	57.37	C	106.72	116.71	126.43	135.27	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	77.0	2756.56	80.2	3052.95	170.6	399.81	176.4	442.79
Condenser Inlet	75.3	2747.10	78.8	3043.74	167.5	398.43	173.8	441.46
Condenser Outlet	32.3	2698.94	39.3	2998.62	90.1	391.45	102.7	434.91
Expansion Device Inlet	32.5	2686.08	39.3	2981.51	90.5	389.58	102.7	432.43
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	4.3	864.69	5.7	896.56	39.7	125.41	42.3	130.04
Evaporator Outlet	3.1	811.47	3.9	831.98	37.6	117.69	39.0	120.67
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	84.1	3345.77	85.0	3606.06	183.4	485.26	185.0	523.01
Condenser Inlet	82.8	3335.50	84.0	3597.27	181.0	483.77	183.2	521.74
Condenser Outlet	46.5	3294.40	53.7	3554.23	115.7	477.81	128.7	515.50
Expansion Device Inlet	46.5	3272.44	53.7	3527.00	115.7	474.62	128.7	511.55
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	7.0	937.01	8.7	984.69	44.6	135.90	47.7	142.82
Evaporator Outlet	4.4	856.57	5.3	878.08	39.9	124.23	41.5	127.35
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-1

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	2.70				kg	5.52				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.36	2.38	2.44	n/a	kg/min	4.83	4.87	4.99	n/a	lb/min	1.53	1.56	1.60	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.91	35.05	39.91	45.35	C	85.84	95.09	103.84	113.63	F				
Total Capacity	8714.4	8337.8	7799.9	7100.0	W	29734.8	28449.8	26614.4	24226.2	Btu/hr	0.96	0.98	1.00	0.99
Sensible Capacity					W					Btu/hr				
Total System Power Input	3163.0	3498.0	3846.0	4327.0	W	3163.0	3498.0	3846.0	4327.0	W	1.03	1.04	1.03	1.06
Compressor Power Input	2943.0	3278.0	3626.0	4107.0	W	2943.0	3278.0	3626.0	4107.0	W	1.03	1.04	1.03	1.06
Energy Efficiency Ratio (EER)	2.76	2.38	2.03	1.64	W/W	9.42	8.12	6.93	5.60	Btu/Whr	0.93	0.94	0.97	0.93
Energy Efficiency Ratio (EER_compressor)	2.96	2.54	2.15	1.73	W/W	10.10	8.68	7.34	5.90	Btu/Whr	0.93	0.94	0.96	0.93

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4580	0.4578	0.4580	0.4582	L/min	0.1210	0.1209	0.1210	0.1210	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.56	11.38	11.07	10.71	C	52.81	52.48	51.93	51.28	F				
Outlet Temperature	7.00	7.02	6.99	6.99	C	44.60	44.64	44.58	44.58	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.91	35.05	39.91	45.35	C	85.84	95.09	103.84	113.63	F				
Outlet Temperature	42.40	48.02	53.02	58.98	C	108.32	118.44	127.44	138.16	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	88.9	2871.36	91.6	3201.46	192.0	417.31	196.9	463.95
Condenser Inlet	86.4	2866.17	89.4	3195.50	187.5	415.70	192.9	463.47
Condenser Outlet	32.1	2827.91	38.0	3161.98	89.8	410.15	100.4	458.61
Expansion Device Inlet	32.3	2818.69	38.2	3147.21	90.1	408.82	100.8	456.46
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	3.3	845.58	4.4	881.12	37.9	122.64	39.9	127.80
Evaporator Outlet	3.2	806.28	3.7	831.14	37.8	116.94	38.7	120.55
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	95.8	3505.59	100.6	3872.87	204.4	509.30	213.1	558.20
Condenser Inlet	93.8	3499.43	98.8	3863.16	200.8	507.55	209.8	557.69
Condenser Outlet	43.7	3469.08	51.3	3834.14	110.7	503.15	124.3	556.09
Expansion Device Inlet	43.8	3450.83	51.4	3812.21	110.8	500.50	124.5	552.91
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	5.4	907.41	7.0	956.38	41.7	131.61	44.6	138.71
Evaporator Outlet	4.1	849.11	4.7	881.37	39.4	123.15	40.5	127.83
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-2

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	2.70				kg	5.52				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.32	n/a	n/a	n/a	kg/min	4.75	n/a	n/a	n/a	lb/min	0.74	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.86	34.96	39.99	44.99	C	85.75	94.93	103.98	112.98	F				
Total Capacity	8744.7	8362.9	7835.7	7193.5	W	29838.2	28535.4	26736.5	24545.2	Btu/hr	0.96	0.98	1.00	1.00
Sensible Capacity					W					Btu/hr				
Total System Power Input	3173.0	3490.0	3807.0	4235.0	W	3173.0	3490.0	3807.0	4235.0	W	1.03	1.04	1.02	1.04
Compressor Power Input	2953.0	3270.0	3587.0	4015.0	W	2953.0	3270.0	3587.0	4015.0	W	1.04	1.04	1.02	1.04
Energy Efficiency Ratio (EER)	2.76	2.40	2.06	1.70	W/W	9.42	8.19	7.03	5.80	Btu/Whr	0.93	0.95	0.98	0.97
Energy Efficiency Ratio (EER,compressor)	2.96	2.56	2.18	1.79	W/W	10.10	8.73	7.45	6.11	Btu/Whr	0.93	0.95	0.98	0.96

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4591	0.4590	0.4588	0.4590	L/min	0.1213	0.1213	0.1212	0.1213	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.56	11.38	11.09	10.74	C	52.81	52.48	51.96	51.33	F				
Outlet Temperature	7.00	7.01	6.99	6.98	C	44.60	44.62	44.58	44.56	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.86	34.96	39.99	44.99	C	85.75	94.93	103.98	112.98	F				
Outlet Temperature	42.26	47.53	52.74	58.10	C	108.07	117.55	126.93	136.58	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	89.0	2849.72	93.3	3166.58	192.2	413.32	199.9	459.27
Condenser Inlet	87.1	2842.30	91.5	3159.19	188.8	412.24	196.7	458.20
Condenser Outlet	31.9	2803.80	37.4	3123.89	89.4	406.66	99.3	453.08
Expansion Device Inlet	32.1	2794.05	37.5	3111.21	89.8	405.24	99.5	451.24
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	3.2	839.80	4.3	870.03	37.8	121.80	39.7	126.24
Evaporator Outlet	3.0	799.53	3.6	822.51	37.4	115.96	38.5	119.29
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	95.3	3481.30	99.8	3806.99	203.5	504.92	211.6	552.16
Condenser Inlet	93.8	3472.41	98.5	3796.34	200.8	503.63	209.3	550.61
Condenser Outlet	43.5	3438.67	50.6	3766.45	110.3	498.74	123.1	546.28
Expansion Device Inlet	43.5	3422.67	50.7	3745.38	110.3	496.42	123.3	543.22
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	5.6	904.83	6.9	947.96	42.1	131.23	44.4	137.49
Evaporator Outlet	4.1	846.40	4.7	799.53	39.4	122.76	40.5	115.96
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of R-32

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	2.70				kg	5.52				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	3.14	n/a	n/a	n/a	kg/min	6.43	n/a	n/a	n/a	lb/min	1.00	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.36	35.05	39.15	n/a	C	84.85	95.09	102.47	n/a	F				
Total Capacity	9301.9	8679.4	8184.1	n/a	W	31739.4	29615.3	27925.3	n/a	Btu/hr	1.02	1.02	1.05	n/a
Sensible Capacity					W					Btu/hr				
Total System Power Input	3364.0	3803.0	4121.0	n/a	W	3364.0	3803.0	4121.0	n/a	W	1.10	1.13	1.11	n/a
Compressor Power Input	3144.0	3583.0	3901.0	n/a	W	3144.0	3583.0	3901.0	n/a	W	1.10	1.14	1.11	n/a
Energy Efficiency Ratio (EER)	2.77	2.28	1.99	n/a	W/W	9.45	7.78	6.79	n/a	Btu/Whr	0.93	0.90	0.95	n/a
Energy Efficiency Ratio (EER,compressor)	2.96	2.42	2.10	n/a	W/W	10.10	8.27	7.16	n/a	Btu/Whr	0.93	0.90	0.94	n/a

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4582	0.4580	0.4583	n/a	L/min	0.1210	0.1210	0.1211	n/a	gal/min	1.00	1.00	1.00	n/a
Inlet Temperature	11.47	11.53	11.28	n/a	C	52.65	52.75	52.30	n/a	F				
Outlet Temperature	7.00	6.99	7.00	n/a	C	44.60	44.58	44.60	n/a	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	n/a	m ³ /min	2059.90	2059.90	2059.90	n/a	ft ³ /min	1.00	1.00	1.00	n/a
Inlet Temperature	29.36	35.05	39.15	n/a	C	84.85	95.09	102.47	n/a	F				
Outlet Temperature	42.55	48.62	52.68	n/a	C	108.59	119.52	126.82	n/a	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	105.1	3020.61	118.6	3385.68	221.2	438.10	245.5	491.05
Condenser Inlet	102.7	3010.78	116.0	3377.17	216.9	436.68	240.8	489.82
Condenser Outlet	28.9	2976.16	34.8	3350.81	84.0	431.66	94.6	485.99
Expansion Device Inlet	28.8	2971.41	34.7	3341.89	83.8	430.97	94.5	484.70
Subcooling, at expan. device	18.8		18.0		33.8		32.4	
Evaporator Inlet	2.4	865.76	3.2	880.09	2502	125.57	37.8	127.65
Evaporator Outlet	2.8	837.83	2.5	847.47	37.0	121.52	36.5	122.92
Evaporator Superheat	1.9		1.2		3.4		2.2	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	124.9	3625.61	n/a	n/a	256.8	525.85	n/a	n/a
Condenser Inlet	123.3	3665.56	n/a	n/a	253.9	531.64	n/a	n/a
Condenser Outlet	40.2	3592.62	n/a	n/a	104.4	521.07	n/a	n/a
Expansion Device Inlet	40.1	3583.48	n/a	n/a	104.2	519.74	n/a	n/a
Subcooling, at expan. device	15.7		n/a		28.3		n/a	
Evaporator Inlet	3.5	884.62	n/a	n/a	38.3	128.30	n/a	n/a
Evaporator Outlet	2.0	846.73	n/a	n/a	35.6	122.81	n/a	n/a
Evaporator Superheat	0.7		n/a		1.3		n/a	

b. Tests with liquid receiver for a refrigerant charge of 3.2 kg.

Case of R-410A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min				
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb				
Refrigerant Charge	3.20				kg	6.55				lb				
Refrigerant Mass Flow Rate	3.14	n/a	n/a	n/a	kg/min	6.43	n/a	n/a	n/a	lb/min				
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	30.02	35.10	39.85	44.83	C	86.04	95.18	103.73	112.69	F				
Total Capacity	8549.6	7855.1	7228.4	6581.4	W	29172.4	26802.7	24664.3	22456.7	Btu/hr				
Sensible Capacity					W					Btu/hr				
Total System Power Input	2969.0	3245.0	3535.0	3890.0	W	2969.0	3245.0	3535.0	3890.0	W				
Compressor Power Input	2749.0	3025.0	3315.0	3670.0	W	2749.0	3025.0	3315.0	3670.0	W				
Energy Efficiency Ratio (EER)	2.88	2.42	2.04	1.69	W/W	9.83	8.26	6.96	5.77	Btu/Whr				
Energy Efficiency Ratio (EER _{compressor})	3.11	2.60	2.18	1.79	W/W	10.61	8.86	7.44	6.12	Btu/Whr				

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4591	0.4590	0.4587	0.4586	L/min	0.1213	0.1213	0.1212	0.1211	gal/min				
Inlet Temperature	11.47	11.12	10.78	10.45	C	52.65	52.02	51.40	50.81	F				
Outlet Temperature	7.00	7.02	7.00	7.01	C	44.60	44.64	44.60	44.62	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min				
Inlet Temperature	30.02	35.10	39.85	44.83	C	86.04	95.18	103.73	112.69	F				
Outlet Temperature	42.55	47.40	52.17	57.38	C	108.59	117.32	125.91	135.28	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	77.2	2702.97	83.8	2978.32	171.0	392.03	182.8	431.97
Condenser Inlet	76.3	2688.60	82.9	2963.91	169.3	389.95	181.2	429.88
Condenser Outlet	41.9	2610.46	46.3	2896.90	107.4	378.62	115.3	420.16
Expansion Device Inlet	42.2	2582.92	46.5	2867.51	108.0	374.62	115.7	415.90
Subcooling, at expan. device	1.2		1.3		2.2		2.3	
Evaporator Inlet	6.9	978.59	7.2	989.72	44.4	141.93	45.0	143.55
Evaporator Outlet	8.2	881.88	6.7	882.67	46.8	127.91	44.1	128.02
Evaporator Superheat	5.1		3.5		9.2		6.3	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	91.9	3250.11	99.1	3575.09	197.4	471.39	210.4	518.52
Condenser Inlet	90.9	3237.75	98.0	3562.19	195.6	469.60	208.4	516.65
Condenser Outlet	50.6	3182.57	54.8	3514.08	123.1	561.59	130.6	509.67
Expansion Device Inlet	50.8	3148.32	55.1	3477.98	123.4	456.63	131.2	504.44
Subcooling, at expan. device	1.0		1.2		1.8		2.2	
Evaporator Inlet	8.0	1005.04	8.8	1028.21	46.4	145.77	47.8	149.13
Evaporator Outlet	6.4	891.27	6.2	900.88	43.5	129.27	43.2	130.66
Evaporator Superheat	2.9		2.3		5.2		4.1	

Case of DR-5A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.20				kg	6.55				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.58	2.80	2.84	3.03	kg/min	5.28	5.73	5.81	6.20	lb/min	0.82	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.59	34.75	39.48	45.11	C	85.26	94.55	103.06	113.20	F				
Total Capacity	8017.4	7605.9	7087.8	6240.0	W	27356.5	25952.4	24184.6	21291.8	Btu/hr	0.94	0.97	0.98	0.95
Sensible Capacity					W					Btu/hr				
Total System Power Input	2801.0	3121.0	3433.0	3812.0	W	2801.0	3121.0	3433.0	3812.0	W	0.94	0.96	0.97	0.98
Compressor Power Input	2581.0	2901.0	3213.0	3592.0	W	2581.0	2901.0	3213.0	3592.0	W	0.94	0.96	0.97	0.98
Energy Efficiency Ratio (EER)	2.86	2.44	2.06	1.64	W/W	9.76	8.33	7.03	5.60	Btu/Whr	0.99	1.01	1.01	0.97
Energy Efficiency Ratio (EER,compressor)	3.11	2.62	2.21	1.74	W/W	10.61	8.94	7.54	5.94	Btu/Whr	1.00	1.01	1.01	0.97

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4585	0.4586	0.4586	0.4583	L/min	0.1211	0.1211	0.1211	0.1211	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.19	10.96	10.66	10.24	C	52.14	51.73	51.19	50.43	F				
Outlet Temperature	7.00	6.98	6.96	6.98	C	44.60	44.56	44.53	44.56	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.59	34.75	39.48	45.11	C	85.26	94.55	103.06	113.20	F				
Outlet Temperature	41.56	46.83	51.53	57.18	C	106.81	116.29	124.75	134.92	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	73.2	2519.95	73.8	2858.70	163.8	369.49	164.8	414.62
Condenser Inlet	71.5	2511.85	72.5	2848.67	160.7	364.31	162.5	413.16
Condenser Outlet	41.0	2446.39	46.8	2787.48	105.8	354.82	116.2	404.29
Expansion Device Inlet	41.5	2426.20	47.1	2760.79	106.7	351.89	116.8	400.42
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	5.0	880.83	7.2	934.67	41.0	127.75	45.0	135.56
Evaporator Outlet	3.4	812.87	4.6	848.51	38.1	117.90	40.3	123.07
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	79.3	3152.40	81.4	3542.03	174.7	457.22	178.5	513.73
Condenser Inlet	78.0	3140.64	80.6	3526.80	172.4	455.51	177.1	511.52
Condenser Outlet	51.2	3088.26	56.7	3474.94	124.2	447.91	134.1	504.00
Expansion Device Inlet	51.6	3057.67	56.9	3438.34	124.9	443.48	134.4	498.69
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	7.9	954.72	9.7	1005.09	46.2	138.47	49.5	145.69
Evaporator Outlet	4.9	857.53	5.9	882.78	40.8	124.37	42.6	128.04
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-1

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.20				kg	6.55				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.11	2.18	n/a	n/a	kg/min	4.32	4.46	n/a	n/a	lb/min	0.67	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.93	34.83	39.83	45.19	C	85.87	94.69	103.69	113.34	F				
Total Capacity	8010.5	7628.9	7181.2	6609.5	W	27333.0	26030.9	24503.3	22552.6	Btu/hr	0.94	0.97	0.99	1.00
Sensible Capacity					W					Btu/hr				
Total System Power Input	2850.0	3133.0	3474.0	3907.0	W	2850.0	3133.0	3474.0	3907.0	W	0.96	0.97	0.98	1.00
Compressor Power Input	2630.0	2913.0	3254.0	3687.0	W	2630.0	2913.0	3254.0	3687.0	W	0.96	0.96	0.98	1.00
Energy Efficiency Ratio (EER)	2.81	2.44	2.07	1.69	W/W	9.59	8.33	7.06	5.77	Btu/Whr	0.98	1.01	1.01	1.00
Energy Efficiency Ratio (EER,compressor)	3.05	2.62	2.21	1.79	W/W	10.41	8.94	7.54	6.11	Btu/Whr	0.98	1.01	1.01	1.00

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4578	0.4575	0.4580	0.4578	L/min	0.1209	0.1209	0.1210	0.1209	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.20	11.03	10.76	10.46	C	52.16	51.85	51.37	50.83	F				
Outlet Temperature	7.01	7.04	7.00	7.00	C	44.62	44.67	44.60	44.60	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.93	34.83	39.83	45.19	C	85.87	94.69	103.69	113.34	F				
Outlet Temperature	42.21	47.22	52.37	57.99	C	107.98	117.00	126.27	136.38	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	86.5	2551.85	91.9	2833.32	187.7	370.11	197.4	411.70
Condenser Inlet	83.8	2546.75	89.3	2833.32	182.8	369.37	192.7	410.94
Condenser Outlet	41.2	2496.44	46.0	2789.08	106.2	362.08	114.8	404.52
Expansion Device Inlet	41.6	2480.48	46.4	2769.87	106.9	359.76	115.5	401.74
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	3.4	845.84	4.4	869.60	38.1	122.68	39.9	126.12
Evaporator Outlet	3.3	793.75	3.8	810.86	37.9	115.12	38.8	117.61
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	95.9	3161.78	99.0	3573.63	204.6	458.58	210.2	518.31
Condenser Inlet	93.7	3157.30	97.1	3565.42	200.7	457.93	206.8	517.12
Condenser Outlet	50.9	3116.92	56.4	3529.79	123.6	452.07	133.5	511.95
Expansion Device Inlet	51.3	3094.34	56.7	3502.21	124.3	448.80	134.1	507.95
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	5.7	902.65	7.3	946.94	42.3	130.92	45.1	137.34
Evaporator Outlet	4.5	833.57	5.2	863.81	40.1	120.90	41.4	125.29
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-2

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.20				kg	6.55				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.21	n/a	n/a	n/a	kg/min	4.52	n/a	n/a	n/a	lb/min	0.70	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.83	34.79	39.81	44.96	C	85.69	94.62	103.66	112.93	F				
Total Capacity	8145.1	7767.8	7319.8	6628.9	W	27792.2	26504.8	24976.2	22618.7	Btu/hr	0.95	0.99	1.01	1.01
Sensible Capacity					W					Btu/hr				
Total System Power Input	2810.0	3113.0	3470.0	3961.0	W	2810.0	3113.0	3470.0	3961.0	W	0.95	0.96	0.98	1.02
Compressor Power Input	2590.0	2893.0	3250.0	3741.0	W	2590.0	2893.0	3250.0	3741.0	W	0.94	0.96	0.98	1.02
Energy Efficiency Ratio (EER)	2.90	2.50	2.11	1.67	W/W	9.90	8.53	7.20	5.70	Btu/Whr	1.01	1.03	1.03	0.99
Energy Efficiency Ratio (EER,compressor)	3.14	2.69	2.25	1.77	W/W	10.71	9.18	7.68	6.04	Btu/Whr	1.01	1.03	1.03	0.99

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4581	0.4579	0.4579	0.4579	L/min	0.1210	0.1210	0.1210	0.1210	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.28	11.08	10.83	10.45	C	52.30	51.94	51.49	50.81	F				
Outlet Temperature	7.02	7.01	7.00	6.98	C	44.64	44.62	44.60	44.56	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.83	34.79	39.81	44.96	C	85.69	94.62	103.66	112.93	F				
Outlet Temperature	42.20	47.32	52.57	57.94	C	107.96	117.18	126.63	136.29	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	83.3	2565.77	86.6	2880.33	181.9	372.13	187.9	417.76
Condenser Inlet	81.6	2559.87	85.1	2873.39	178.9	371.28	185.2	416.75
Condenser Outlet	41.4	2505.82	46.5	2823.85	106.5	363.44	115.7	409.56
Expansion Device Inlet	41.8	2489.78	46.8	2804.10	107.2	361.11	116.2	406.70
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	3.8	851.49	5.1	886.60	38.8	123.50	41.2	128.59
Evaporator Outlet	3.3	799.52	4.0	822.91	37.9	115.96	39.2	119.35
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	89.5	3239.81	93.6	3646.79	193.1	469.89	200.5	528.92
Condenser Inlet	88.2	3230.02	92.6	3632.13	190.8	468.47	198.7	526.80
Condenser Outlet	51.6	3185.23	56.9	3592.22	124.9	461.98	134.4	521.01
Expansion Device Inlet	52.0	3160.83	57.2	3563.18	125.6	458.44	135.0	516.80
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	6.5	925.58	8.0	971.00	43.7	134.24	46.4	140.83
Evaporator Outlet	4.6	850.28	5.3	879.07	40.3	123.32	41.5	127.50
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of R-32

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.20				kg	6.55				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	1.96	1.98	1.97	1.99	kg/min	4.01	4.05	4.03	4.07	lb/min	0.62	n/a	n/a	n/a
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	30.00	34.72	39.30	45.08	C	86.00	94.50	102.74	113.14	F				
Total Capacity	8378.5	7912.1	7434.1	6968.8	W	28588.6	26997.2	25366.2	23778.5	Btu/hr	0.98	1.01	1.03	1.06
Sensible Capacity					W					Btu/hr				
Total System Power Input	3021.0	3316.0	3639.0	4141.0	W	3021.0	3316.0	3639.0	4141.0	W	1.02	1.02	1.03	1.06
Compressor Power Input	2801.0	3096.0	3419.0	3921.0	W	2801.0	3096.0	3419.0	3921.0	W	1.02	1.02	1.03	1.07
Energy Efficiency Ratio (EER)	2.77	2.39	2.04	1.68	W/W	9.45	8.16	6.96	5.73	Btu/Whr	0.96	0.99	1.00	0.99
Energy Efficiency Ratio (EER,compressor)	2.99	2.56	2.17	1.78	W/W	10.20	8.74	7.40	6.07	Btu/Whr	0.96	0.98	1.00	0.99

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4588	0.4587	0.4585	0.4587	L/min	0.1212	0.1212	0.1211	0.1212	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.40	11.16	10.88	10.65	C	52.52	52.09	51.58	51.17	F				
Outlet Temperature	7.02	7.02	7.00	7.01	C	44.64	44.64	44.60	44.62	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	30.00	34.72	39.30	45.08	C	86.00	94.50	102.74	113.14	30.00				
Outlet Temperature	42.39	47.29	52.05	57.96	C	108.30	117.12	125.69	136.33	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	95.4	2685.41	105.0	2965.31	203.7	389.49	221.0	430.08
Condenser Inlet	93.5	2679.95	102.9	2955.70	200.3	388.69	217.2	428.69
Condenser Outlet	41.2	2631.84	45.6	2915.78	106.2	381.72	114.1	422.90
Expansion Device Inlet	41.7	2617.85	46.1	2898.82	107.1	379.69	115.0	420.44
Subcooling, at expan. device	0.6		0.4		1.1		0.7	
Evaporator Inlet	2.9	877.21	3.5	892.42	37.2	127.23	38.3	129.43
Evaporator Outlet	1.1	833.82	1.5	844.17	34.0	120.94	34.7	122.44
Evaporator Superheat	0.3		0.3		0.5		0.5	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	114.4	3251.71	124.5	3646.32	237.9	471.62	256.1	528.85
Condenser Inlet	112.3	3238.89	122.2	3637.15	234.1	469.76	252.0	527.52
Condenser Outlet	49.8	3205.73	55.2	3607.69	121.6	464.95	131.4	523.25
Expansion Device Inlet	50.2	3186.30	55.5	3588.12	122.4	462.13	131.9	520.41
Subcooling, at expan. device	0.4		0.4		0.7		0.7	
Evaporator Inlet	4.1	906.13	5.3	933.69	39.4	131.42	41.5	135.42
Evaporator Outlet	1.9	852.96	2.8	873.38	35.4	123.71	37.0	126.67
Evaporator Superheat	0.4		0.5		0.7		0.9	

c. Tests with liquid receiver for a refrigerant charge of 3.9 kg.

Case of R-410A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min				
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb				
Refrigerant Charge	3.90				kg	7.98				lb				
Refrigerant Mass Flow Rate	3.14	3.15	3.16	3.16	kg/min	6.43	6.45	6.47	6.47	lb/min				
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.65	35.07	40.13	45.28	C	85.37	95.13	104.23	113.50	F				
Total Capacity	8584.3	7854.6	7224.5	6539.3	W	29290.9	26801.0	24651.0	22313.0	Btu/hr				
Sensible Capacity					W					Btu/hr				
Total System Power Input	2909.0	3217.0	3531.0	3895.0	W	2909	3217	3531	3895	W				
Compressor Power Input	2689.0	2993.0	3311.0	3675.0	W	2689.0	2993.0	3311.0	3675.0	W				
Energy Efficiency Ratio (EER)	2.95	2.44	2.05	1.68	W/W	10.07	8.33	6.99	5.73	Btu/Whr				
Energy Efficiency Ratio (EER,compressor)	3.19	2.62	2.18	1.78	W/W	10.89	8.95	7.45	6.07	Btu/Whr				

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio						
											TC1	TC2	TC3	TC4			
Evaporator																	
Heat Exchange Fluid	Water																
Flow Rate (liquid)	0.4587	0.4585	0.4587	0.4586	L/min	0.1212	0.1211	0.1212	0.1211	gal/min							
Inlet Temperature	11.50	11.14	10.78	10.43	C	52.70	52.05	51.40	50.77	F							
Outlet Temperature	7.01	7.03	7.00	7.01	C	44.62	44.65	44.60	44.62	F							
Condenser																	
Heat Exchange Fluid	Air																
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min							
Inlet Temperature	29.65	35.07	40.13	45.28	C	85.37	95.13	104.23	113.50	F							
Outlet Temperature	42.21	47.49	52.49	57.75	C	107.98	117.48	126.48	135.95	F							

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	76.7	2684.64	84.1	2976.55	170.1	389.37	183.4	431.71
Condenser Inlet	75.8	2670.46	83.2	2963.74	168.4	387.32	181.8	429.85
Condenser Outlet	41.4	2592.12	46.4	2898.30	106.5	375.96	115.5	420.36
Expansion Device Inlet	41.7	2565.33	46.6	2868.98	107.1	372.07	115.9	416.11
Subcooling, at expan. device	0.6		0.5		1.1		0.9	
Evaporator Inlet	6.7	975.04	7.3	987.78	44.1	141.42	45.1	143.27
Evaporator Outlet	8.1	879.53	6.9	883.17	46.6	127.57	44.4	128.09
Evaporator Superheat	5.0		3.7		9.0		6.7	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	91.8	3275.32	100.0	3607.68	197.2	475.05	212.0	523.25
Condenser Inlet	90.9	3262.95	99.0	3595.11	195.6	473.25	210.2	521.43
Condenser Outlet	51.0	3207.67	35.5	3548.91	123.8	465.23	95.9	514.73
Expansion Device Inlet	51.1	3174.29	55.7	3512.64	124.0	460.39	132.3	509.47
Subcooling, at expan. device	0.0		0.2		0.0		0.36	
Evaporator Inlet	8.2	1008.13	8.9	1027.63	46.8	146.22	48.0	149.05
Evaporator Outlet	6.5	891.58	6.7	899.60	43.7	129.31	44.1	130.48
Evaporator Superheat	3.0		2.9		5.4		5.2	

Case of DR-5A

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.90				kg	7.98				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.78	3.18	3.37	3.81	kg/min	5.69	6.51	6.90	7.80	lb/min	0.89	1.01	1.07	1.21
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.95	34.85	40.05	44.86	C	85.91	94.73	104.09	112.75	F				
Total Capacity	8250.0	7755.0	6819.0	5588.0	W	28150.2	26461.2	23267.4	19067.0	Btu/hr	0.96	0.99	0.94	0.85
Sensible Capacity					W					Btu/hr				
Total System Power Input	2869.0	3144.0	3482.0	3722.0	W	2869.0	3144.0	3482.0	3722.0	W	0.99	0.98	0.99	0.96
Compressor Power Input	2649.0	2924.0	3262.0	3502.0	W	2649.0	2924.0	3262.0	3502.0	W	0.99	0.98	0.99	0.95
Energy Efficiency Ratio (EER)	2.88	2.47	1.96	1.50	W/W	9.83	8.43	6.69	5.12	Btu/Whr	0.98	1.01	0.96	0.89
Energy Efficiency Ratio (EER,compressor)	3.11	2.65	2.09	1.60	W/W	10.63	9.05	7.13	5.44	Btu/Whr	0.98	1.01	0.96	0.90

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4582	0.4580	0.4581	0.4580	L/min	0.1210	0.1210	0.1210	0.1210	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.32	11.08	10.56	9.94	C	52.38	51.94	51.01	49.89	F				
Outlet Temperature	7.00	7.02	6.99	7.01	C	44.60	44.64	44.58	44.62	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.95	34.85	40.05	44.86	C	85.91	94.73	104.09	112.75	F				
Outlet Temperature	42.03	46.64	51.81	55.62	C	107.65	115.95	125.26	132.12	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	66.6	2619.21	62.5	2920.50	151.9	379.88	144.5	423.58
Condenser Inlet	65.5	2609.92	61.9	2903.38	149.9	378.54	143.4	421.10
Condenser Outlet	42.5	2538.83	47.4	2820.80	108.5	368.23	117.3	409.12
Expansion Device Inlet	42.8	2515.43	47.5	2788.18	109.0	364.83	117.5	404.39
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	6.7	928.74	9.2	998.63	44.1	134.70	48.6	144.84
Evaporator Outlet	4.4	853.58	6.1	896.78	39.9	123.80	43.0	130.07
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	65.0	3257.15	63.9	3536.91	149.0	472.41	147.0	512.99
Condenser Inlet	64.6	3240.65	63.6	3519.14	148.3	470.02	146.5	510.41
Condenser Outlet	52.4	3161.77	56.2	3442.03	126.3	458.58	133.2	499.22
Expansion Device Inlet	52.5	3123.63	56.6	3391.69	126.5	453.04	133.9	491.92
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	10.4	1029.67	12.2	1074.34	50.7	149.34	54.0	155.82
Evaporator Outlet	6.4	902.41	6.5	902.85	43.5	130.88	43.7	130.95
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-1

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.90				kg	7.98				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	2.15	2.23	2.33	2.48	kg/min	4.40	4.56	4.77	5.07	lb/min	0.68	0.71	0.74	0.78
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.86	35.23	39.87	45.15	C	85.75	95.41	103.77	113.27	F				
Total Capacity	8027.5	7620.1	7251.5	6577.2	W	27391.0	26000.9	24743.1	22442.3	Btu/hr	0.94	0.97	1.00	1.01
Sensible Capacity					W					Btu/hr				
Total System Power Input	2849.0	3150.0	3464.0	3900.0	W	2849.0	3150.0	3464.0	3900.0	W	0.98	0.98	0.98	1.00
Compressor Power Input	2629.0	2930.0	3244.0	3680.0	W	2629.0	2930.0	3244.0	3680.0	W	0.98	0.98	0.98	1.00
Energy Efficiency Ratio (EER)	2.82	2.42	2.09	1.69	W/W	9.62	8.26	7.13	5.77	Btu/Whr	0.96	0.99	1.02	1.01
Energy Efficiency Ratio (EER,compressor)	3.05	2.60	2.24	1.79	W/W	10.42	8.87	7.63	6.10	Btu/Whr	0.96	0.99	1.02	1.00

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4590	0.4588	0.4589	0.4591	L/min	0.1213	0.1212	0.1212	0.1213	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.20	10.97	10.80	10.44	C	52.16	51.75	51.44	50.79	F				
Outlet Temperature	7.01	6.99	7.01	7.00	C	44.62	44.58	44.62	44.60	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.86	35.23	39.87	45.15	C	85.75	95.41	103.77	113.27	F				
Outlet Temperature	42.00	47.50	52.30	57.86	C	107.60	117.50	126.14	136.15	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	86.0	2535.83	90.4	2858.52	186.8	367.79	194.7	414.59
Condenser Inlet	84.0	2529.73	88.7	2851.69	183.2	366.91	191.7	413.60
Condenser Outlet	41.0	2477.86	46.4	2804.95	105.8	359.38	115.5	406.82
Expansion Device Inlet	41.5	2463.52	46.7	2787.44	106.7	357.30	116.1	404.28
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	3.4	843.69	4.7	874.54	38.1	122.37	40.5	126.84
Evaporator Outlet	3.4	792.42	4.0	816.08	38.1	114.93	39.2	118.36
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	92.6	3182.87	96.3	3587.12	198.7	461.64	205.3	520.27
Condenser Inlet	91.2	3171.26	95.1	3571.99	196.2	459.95	203.2	518.07
Condenser Outlet	51.1	3129.50	56.4	3533.54	124.0	453.90	133.5	512.50
Expansion Device Inlet	51.4	3106.72	56.7	3507.36	124.5	450.59	134.1	508.70
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	5.9	909.35	7.5	953.76	42.6	131.89	45.5	138.33
Evaporator Outlet	4.6	837.78	5.2	867.00	40.3	121.51	41.4	125.75
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of L-41-2

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.90				kg	7.98				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	n/a	2.41	2.49	2.77	kg/min	n/a	4.93	5.10	5.67	lb/min	n/a	0.77	0.79	0.88
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	29.88	34.91	40.05	44.82	C	85.78	94.84	104.09	112.68	F				
Total Capacity	8084.5	7691.5	7153.6	6613.3	W	27585.5	26244.5	24409.1	22565.5	Btu/hr	0.94	0.98	0.99	1.01
Sensible Capacity					W					Btu/hr				
Total System Power Input	2746.0	3066.0	3432.0	3818.0	W	2746.0	3066.0	3432.0	3818.0	W	0.94	0.95	0.97	0.98
Compressor Power Input	2526.0	2846.0	3212.0	3598.0	W	2526.0	2846.0	3212.0	3598.0	W	0.94	0.95	0.97	0.98
Energy Efficiency Ratio (EER)	2.94	2.51	2.08	1.73	W/W	10.03	8.56	7.10	5.90	Btu/Whr	1.00	1.03	1.01	1.03
Energy Efficiency Ratio (EER,compressor)	3.20	2.70	2.23	1.84	W/W	10.92	9.22	7.60	6.27	Btu/Whr	1.00	1.03	1.02	1.03

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4575	0.4578	0.4574	0.4574	L/min	0.1209	0.1209	0.1208	0.1208	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.24	11.01	10.74	10.55	C	52.23	51.82	51.33	50.99	F				
Outlet Temperature	7.01	6.99	6.99	7.08	C	44.62	44.58	44.58	44.74	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	29.88	34.91	40.05	44.82	C	85.78	94.84	104.09	112.68	F				
Outlet Temperature	42.06	47.05	52.41	57.31	C	107.71	116.69	126.34	135.16	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	78.9	2539.42	81.9	2853.82	174.0	368.31	179.4	413.91
Condenser Inlet	77.3	2533.11	80.6	2845.24	171.1	367.40	177.1	412.67
Condenser Outlet	41.4	2477.58	46.4	2794.56	106.5	359.34	115.5	405.32
Expansion Device Inlet	41.8	2461.95	46.7	2774.64	107.2	357.08	116.1	402.43
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	4.0	844.94	5.3	880.10	39.2	122.55	41.5	127.65
Evaporator Outlet	3.7	790.16	4.2	814.68	38.7	114.60	39.6	118.16
Evaporator Superheat	n/a		n/a		n/a		n/a	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	86.5	3221.88	90.0	3592.36	187.7	467.29	194.0	521.03
Condenser Inlet	85.3	3206.00	88.9	3579.56	185.5	464.99	192.0	519.17
Condenser Outlet	51.6	3160.34	56.8	3530.53	124.9	458.37	134.2	512.06
Expansion Device Inlet	51.9	3136.41	57.0	3499.43	125.4	454.90	134.6	507.55
Subcooling, at expan. device	n/a		n/a		n/a		n/a	
Evaporator Inlet	6.6	920.03	8.9	980.79	43.9	133.44	48.0	142.25
Evaporator Outlet	4.8	842.63	6.2	878.51	40.6	122.21	43.2	127.42
Evaporator Superheat	n/a		n/a		n/a		n/a	

Case of R-32

Comparison Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Mode (Heating/Cooling)	Cooling													
Compressor Type	Scroll													
Compressor Displacement	6.74				M ³ /min	238.02				Ft ³ /min	1.00	1.00	1.00	1.00
Nominal Motor Size					hp									
Motor Speed	2900				rpm									
Expansion Device Type	TX Valve													
Lubricant Charge	1.22				kg	2.50				lb	1.00	1.00	1.00	1.00
Refrigerant Charge	3.90				kg	7.98				lb	1.00	1.00	1.00	1.00
Refrigerant Mass Flow Rate	1.95	1.96	1.97	2.00	kg/min	3.99	4.01	4.03	4.09	lb/min	0.62	0.62	0.62	0.63
Composition, at compr. Inlet if applicable					% wt									
Evaporator Face Area					m ²					ft ²				
Condenser Face Area					m ²					ft ²				
Ambient Temps. Outdoor	30.80	34.81	39.49	45.16	C	87.44	94.66	103.08	113.29	F				
Total Capacity	8252.5	7858.8	7381.3	6963.3	W	28158.7	26815.3	25186.0	23759.8	Btu/hr	0.96	1.00	1.02	1.06
Sensible Capacity					W					Btu/hr				
Total System Power Input	3092.0	3325.0	3653.0	4108.0	W	3092.0	3325.0	3653.0	4108.0	W	1.06	1.03	1.03	1.05
Compressor Power Input	2872.0	3105.0	3433.0	3898.0	W	2872.0	3105.0	3433.0	3898.0	W	1.07	1.04	1.04	1.06
Energy Efficiency Ratio (EER)	2.67	2.36	2.02	1.70	W/W	9.11	8.05	6.89	5.80	Btu/Whr	0.91	0.97	0.99	1.01
Energy Efficiency Ratio (EER,compressor)	2.87	2.53	2.15	1.79	W/W	9.80	8.64	7.34	6.10	Btu/Whr	0.90	0.96	0.99	1.00

Air/Water Side Data	TC1	TC2	TC3	TC4	SI Units	TC1	TC2	TC3	TC4	IP Units	Ratio			
											TC1	TC2	TC3	TC4
Evaporator														
Heat Exchange Fluid	Water													
Flow Rate (liquid)	0.4590	0.4587	0.4588	0.4588	L/min	0.1213	0.1212	0.1212	0.1212	gal/min	1.00	1.00	1.00	1.00
Inlet Temperature	11.31	11.13	10.85	10.63	C	52.36	52.03	51.53	51.13	F				
Outlet Temperature	7.00	7.02	6.99	6.99	C	44.60	44.64	44.58	44.58	F				
Condenser														
Heat Exchange Fluid	Air													
Flow Rate (gas)	58.33	58.33	58.33	58.33	m ³ /min	2059.90	2059.90	2059.90	2059.90	ft ³ /min	1.00	1.00	1.00	1.00
Inlet Temperature	30.80	34.81	39.49	45.16	C	87.44	94.66	103.08	113.29	F				
Outlet Temperature	43.16	47.30	52.26	58.03	C	109.69	117.14	126.07	136.45	F				

Refrigerant Side Data Temperatures & Pressures	TC1		TC2		TC1		TC2	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	97.4	2725.46	105.8	2962.99	207.3	395.29	222.4	429.75
Condenser Inlet	95.4	2720.50	103.7	2953.96	203.7	394.58	218.7	428.44
Condenser Outlet	41.8	2673.82	45.6	2914.31	107.2	387.80	114.1	422.68
Expansion Device Inlet	42.3	2660.09	46.0	2898.75	108.1	385.81	114.8	420.43
Subcooling, at expan. device	0.6		0.5		1.1		0.9	
Evaporator Inlet	2.8	874.84	3.4	886.58	37.0	126.88	38.1	128.89
Evaporator Outlet	1.2	830.87	1.5	838.84	34.2	120.51	34.7	121.66
Evaporator Superheat	0.5		0.5		0.9		0.9	

Refrigerant Side Data Temperatures & Pressures	TC3		TC4		TC3		TC4	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Discharge	115.9	3258.22	125.1	3649.75	240.6	472.56	257.2	529.35
Condenser Inlet	113.7	3248.41	122.7	3639.91	236.7	471.14	252.9	527.92
Condenser Outlet	50.0	3216.02	55.2	3610.90	122.0	466.44	131.4	523.72
Expansion Device Inlet	50.4	3197.61	55.4	3592.26	122.7	463.77	131.7	521.01
Subcooling, at expan. device	0.4		0.5		0.7		0.9	
Evaporator Inlet	4.0	901.26	5.1	927.56	39.2	130.72	41.2	134.5
Evaporator Outlet	1.9	848.79	2.6	868.02	35.4	123.11	36.7	125.90
Evaporator Superheat	0.6		0.5		1.1		0.9	

d. Tests comparison and discussion.

Tests results for the mass flow fluctuation before and after the expansion valve adjustment in the case of DR-5A with liquid receiver for a refrigerant charge of 3200g.

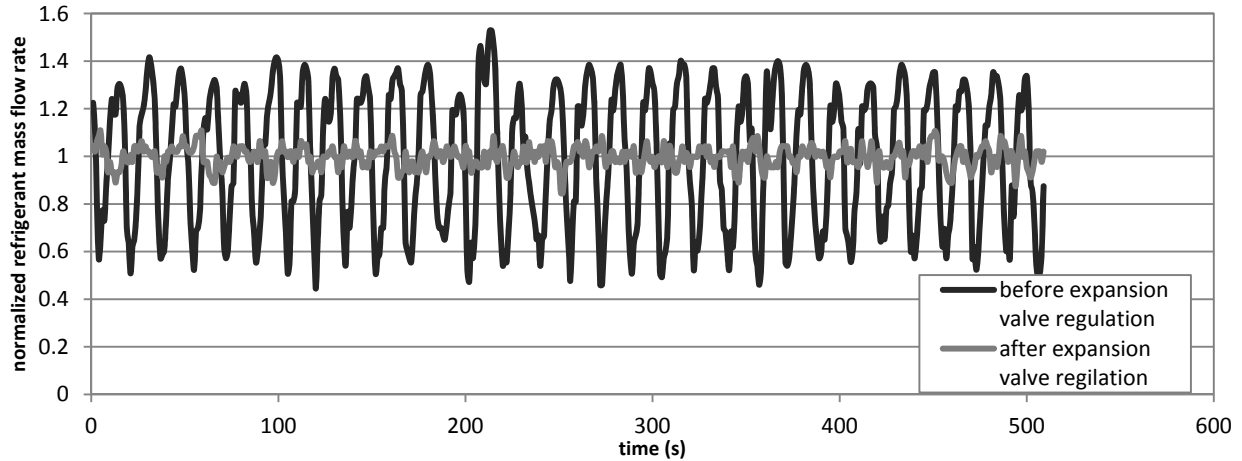


Figure 2: Mass flow relative fluctuation comparison before and after the expansion valve adjustment (DR-5A @35°C)

In the figure 2 shown above, the effect of the expansion valve adjustment on the refrigerant mass flow fluctuation is clear. Expansion valve adjustment permits to reduce refrigerant mass flow fluctuation from $\pm 50\%$ before adjustment to $\pm 15\%$ after adjustment.

Tests results for the chiller without liquid receiver and for a charge of 2700g of refrigerant.

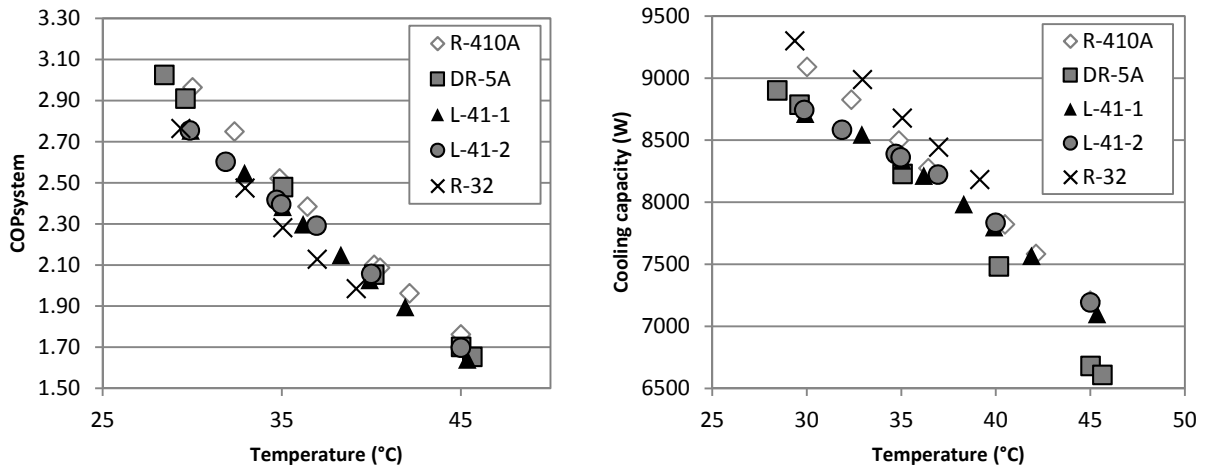


Figure 3: EER and cooling capacity (W) comparison for the chiller without liquid receiver.

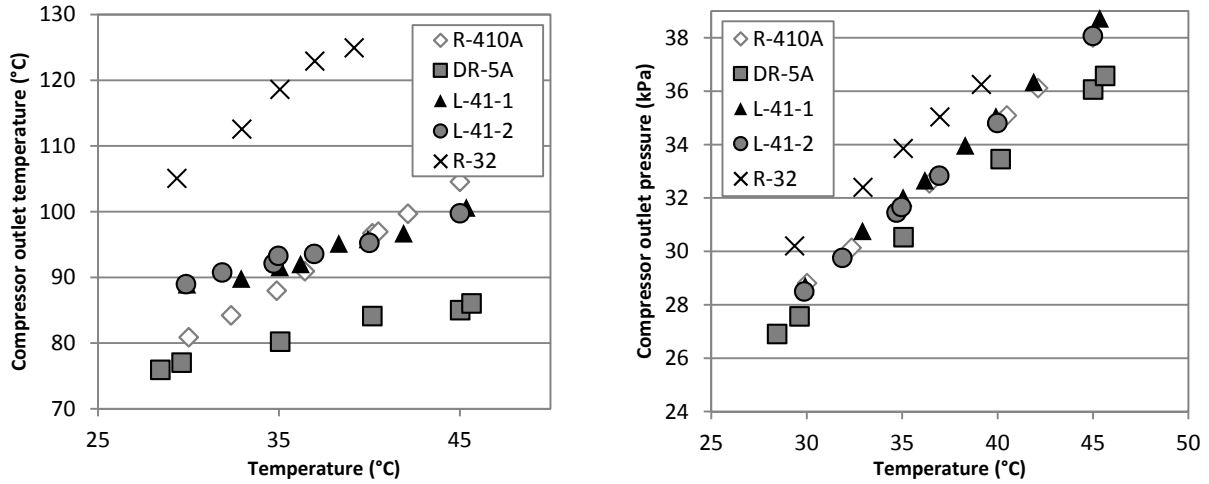


Figure 4: Compressor outlet temperature (°C) and pressure (x100 kPa) comparison for the chiller without liquid receiver.

Tests results for the chiller with liquid receiver and for a charge of 3200g of refrigerant.

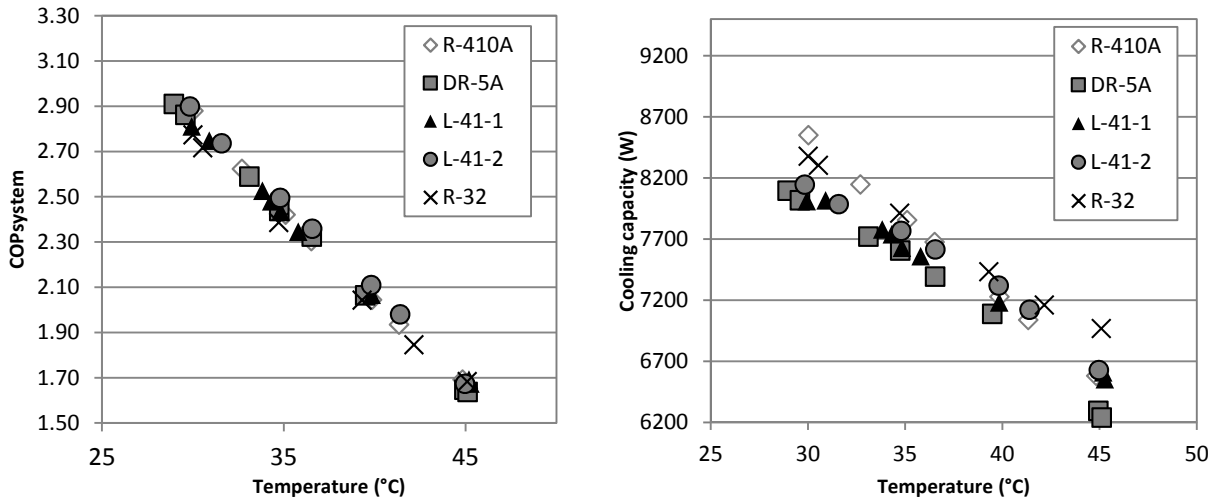


Figure 5: EER and cooling capacity (W) comparison for the chiller with liquid receiver for 3200g refrigerant charge.

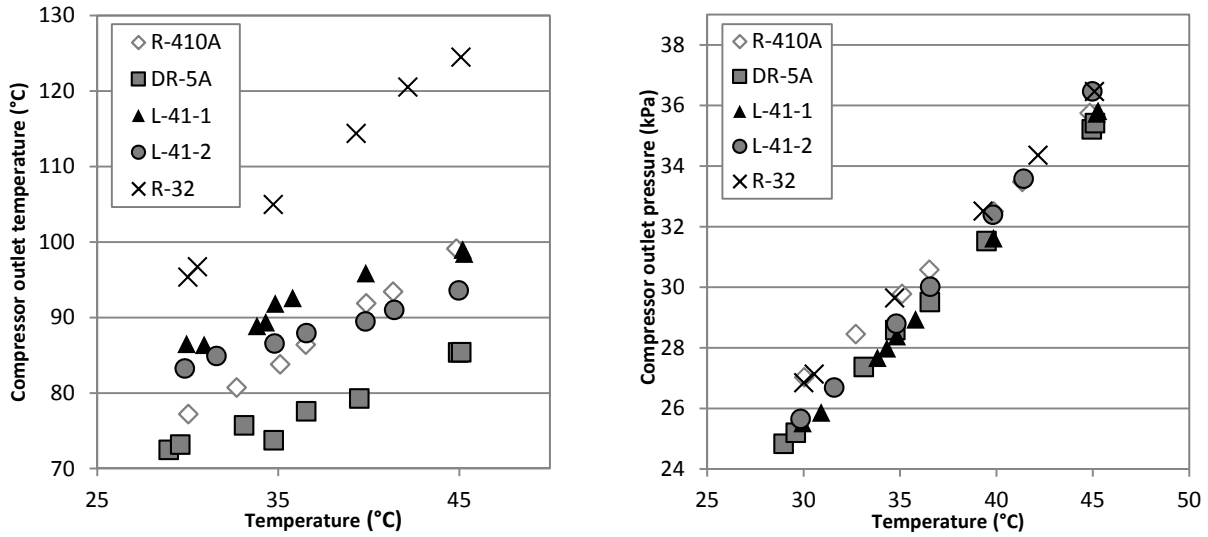


Figure 6: Compressor outlet temperature (°C) and pressure (x100 kPa) comparison for the chiller with liquid receiver for 3200g refrigerant charge.

Tests results for the chiller with liquid receiver and for a charge of 3900g of refrigerant.

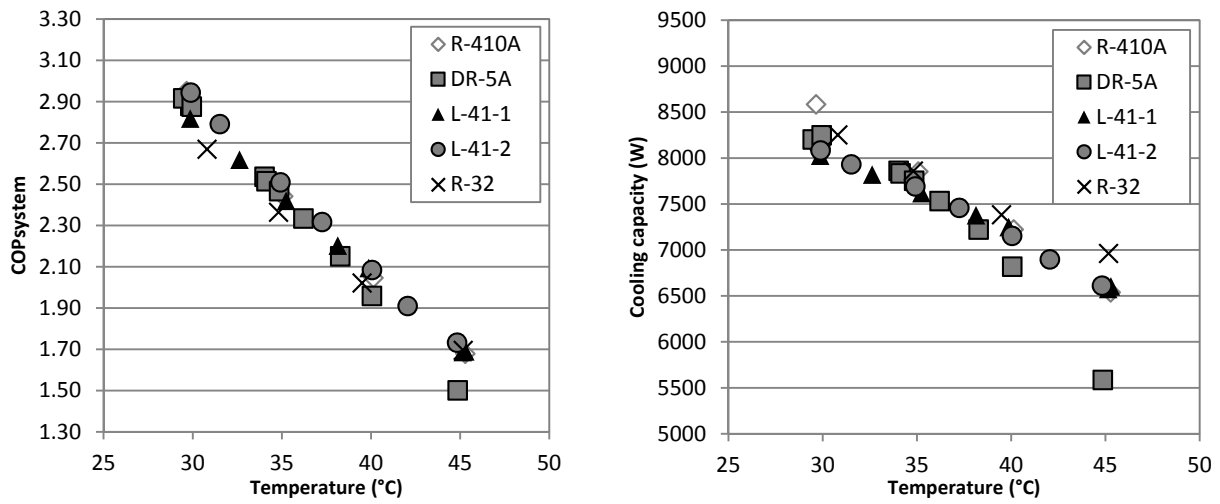


Figure 7: EER and cooling capacity (W) comparison for the chiller with liquid receiver for 3900g refrigerant charge.

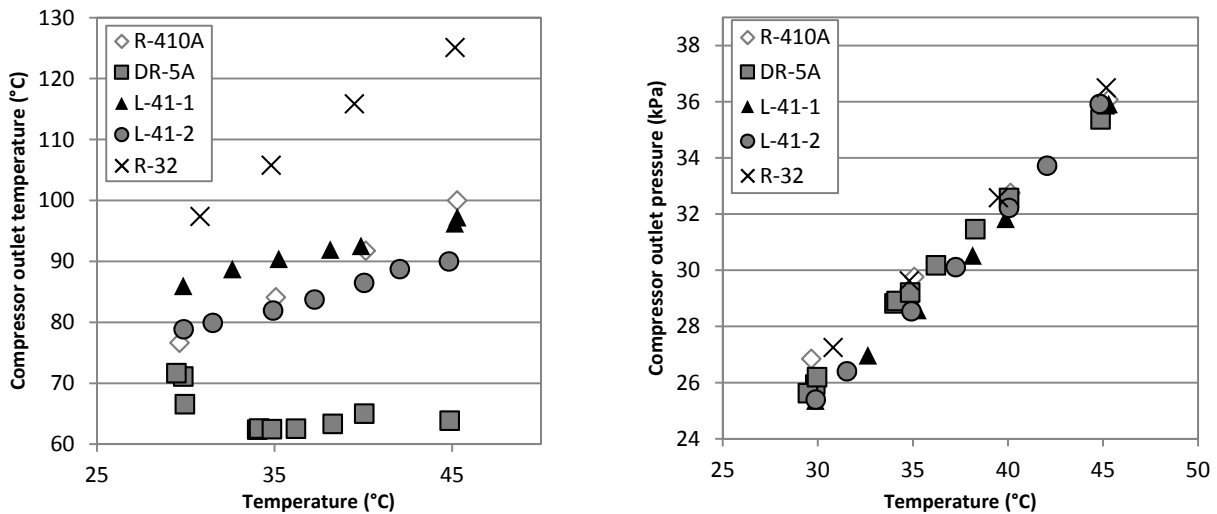


Figure 8: Compressor outlet temperature (°C) and pressure (x100 kPa) comparison for the chiller with liquid receiver for 3900g refrigerant charge.

The testing results presented in the previous figures showed, for the case without liquid receiver, that the R-410A presents a better EER than the other refrigerants, but the R-32 which presented the lowest EER provided a higher cooling capacity with very high discharge temperature and pressure. In this case, it was not possible to perform the test at 45°C ambient temperature because the 126°C limit was attained at 40°C.

When tested with liquid receiver, the performance of the chiller decreased for all refrigerants which is in coherence with study conducted by Rajapaksha and al. (Rajapaksha, 2002). This behaviour is due to a decrease in subcooling from 12°C without liquid receiver to 1°C with liquid receiver for the R-410A. In this case, for temperatures higher than 35°C L-41-1 and L-41-2 provided higher system performances and for temperatures less than 40°C they provided higher cooling capacity than the R-410A. The R-32 permitted in this case the highest cooling capacity but with lower EER than R-410A, with very high discharge temperature and pressure like in the former case. The use of liquid receiver has a consequence of reducing the high pressure leading to a lower compressor outlet temperature than the case without the receiver; in this case the operation with R-32 was possible at 45°C ambient temperature.

The results were very similar for the two refrigerant charges of 3200g and 3900g in the case of the chiller with liquid receiver. Except that for the DR-5A, the test with a refrigerant charge of 3900g showed remarked lower cooling capacity for high temperatures which seems to be related to a high fluctuations in the refrigerant flow rate probably due to an inappropriate expansion valve adjustment. It could be mentioned also that for the DR-5A under these test conditions the discharge temperature (Figure 7) showed a different behaviour in comparison with the other tests which could be due to a presence of an amount of liquid refrigerant at the suction of the compressor.

4. Conclusion

The results reported in this paper show that it is possible to replace the R-410A in water chiller by refrigerants with low GWP without causing big losses in the EER and the cooling capacity.

Under some conditions the tested candidates showed better performances than those of the R-410A and higher cooling capacity.

For the tests realized without liquid receiver, the R-32 had a EER lower than that of the R-410A by 8% to 9% with gains in cooling capacity of 1.7% to 3.2%. For this configuration, the other tested refrigerants showed EER that almost reached the EER of the R-410A especially for the DR-5A but with a cooling capacity lower by 2.9% to 7.3%. The L-41-1 and L-41-2 presented cooling capacity almost equal to those of the R-410A for ambient temperature higher than 40°C.

For the tests conducted with liquid receiver, the EER of the tested refrigerants was better in comparison of the EER of the R-410A. For the R-32 the EER was lower than that of the R-410A except for an ambient temperature that reaches 45°C and with higher cooling capacity except for an ambient temperature of 30°C. In this case the L-41-1 showed better EER than R-410A for ambient temperature above 35°C and higher cooling capacity for ambient temperature above 40°C. The L-41-2 had better EER than R-410A except for ambient temperature of 45°C and higher cooling capacity for ambient temperatures higher than 35°C.

It is remarkable that with liquid receiver the temperature and pressure discharge decreased for all refrigerants.

5. Nomenclature

GWP = global warming potential ($\text{kg}_{\text{eq}} \text{CO}_2$)

ODP = ozone depletion potential

DB = dry bulb

Q_{cold} = cooling capacity (W)

\dot{m}_w = water mass flow (kg/s)

$c_{p,w}$ = water specific heat capacity (kJ/kg/K)

T_i = water temperature at the inlet of the evaporator (°C)

T_o = water temperature at the outlet of the evaporator (°C)

W_{comp} = compressor power consumption (W)

W_{fan} = fan power consumption (W)

COP = coefficient of performance

$\text{COP}_{\text{system}}$ = system coefficient of performance

6. References

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