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

TEST REPORT #14

System Drop-In Test of Refrigerant Blend ARM-42a in an Air-Cooled Screw Chiller

Satheesh Kulankara
William McQuade

Johnson Controls Inc
631 S.Richland Avenue
York, PA 17403

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Air-Conditioning, Heating, and Refrigeration Institute
2111 Wilson Boulevard, Suite 500
Arlington VA 22201
(703) 524-8800
www.ahrinet.org

List of Tested Refrigerant’s Compositions (Mass%)

ARM-42a	R-134a/R-152a/R-1234yf (7/11/82)

1. Introduction:

This report documents the results from the testing of ARM-42a refrigerant as a drop-in alternate for R-134a in a variable speed, air-cooled screw chiller. The tests were conducted in the air-cooled chiller test facilities of Johnson Controls located in York, Pennsylvania. Baseline tests were first conducted with R-134a. These were followed by drop-in tests with ARM-42a at the same conditions. After the drop-in tests with ARM-42a, the equipment was charged with R-134a and a limited set of tests were repeated to verify the data. All the tests were conducted using the same equipment and test facility without any modifications to the equipment, test facility or instrumentation used for measurements. The test conditions and instrumentation follows the requirements for air-cooled chiller testing specified in AHRI 550/590.

2. Details of Test Setup:

a. Description of System

- The equipment that was used for this testing is a variable speed, air-cooled, screw compressor based chiller. The test chiller has 2 independent refrigerant circuits with economizers and was configured for a nominal capacity of 175 Tons at standard AHRI 550/590 full load conditions. The chiller is designed for R-134a and uses POE oil for compressor lubrication. The evaporator of the chiller is a 2-circuit, shell and tube, hybrid falling film design with the refrigerant on the shell side. The air-cooled condenser on the chiller is made up of micro-channel modules.

b. Description of Modifications to System

- There were no modifications to the chiller between R-134a and ARM-42a testing. The chiller was first tested with R-134a to establish baseline performance. After the baseline tests. R-134a was removed from the chiller and tests were conducted with ARM-42a. The lubricating oil for both R-134a and ARM-42a tests was the same POE oil.

c. Description of Tests Conducted

Due to test lab constraints at the time of this testing, the chiller was tested in an air-cooled chiller test facility capable of testing chillers with a nominal capacity of 150 Tons. As a result, only one of the two refrigerant circuits of the chiller was operated in this testing. Both refrigerants were tested on the same independent refrigerant circuit, in the same test facility back to back. Figure 1 is a schematic of the test set-up showing the refrigerant circuit that was tested including the locations of key measurements.

Test chiller flows, temperatures, pressures and power consumption were measured with instruments calibrated in place against NIST standards. The evaporator

was instrumented with two resistance temperature detectors (RTDs) to measure the inlet water temperature, two RTDs to measure the exiting water temperature and two turbine flow meters in series to measure chilled water flow rate at evaporator inlet. The condenser was instrumented with five thermocouples (TCs) to measure the incoming air temperature. Single pressure transducers were used to measure the pressure at compressor suction, discharge and condenser outlet. A TC was used to measure the temperature of refrigerant at condenser outlet. The compressor power consumption was measured with a power analyzer designed for use with VSDs. The condenser fan power was measured separately using a second power analyzer. Redundant measurements were averaged before use in data reduction and analysis. The instrument measurement uncertainties are listed in Table 1. Both R-134a and ARM-42a were tested with the same instruments without any adjustments between the tests.

Table 1: Measurement Uncertainties

Parameter	Uncertainty
Temperature, RTD	±0.1 °F
Temperature, TC	±0.2 °F
Volume Flow Rate	±0.20%
Electrical Power	±0.15%

Data for each of the tests were recorded over a 15 minute span after the test chiller reached steady state. The speed of the variable speed compressor was held constant during each of the tests once the chiller reached steady state. Instrument data recorded over the 15 minute span was averaged for data reduction and analysis. Measurements were checked for consistency by comparing the redundant instrumentation on the evaporator water side. During testing, the readings of the two evaporator water flow meters differed by an average of 1.3 GPM. The average difference between the two RTDs reading the evaporator water inlet temperature and evaporator water outlet temperature was 0.02 °F.

Only one of the two refrigerant circuits on the chiller was tested during this work. For the full load test, the evaporator water inlet and outlet temperatures were set at 50.5 °F and 45.5 °F, respectively and the evaporator water flow rate was adjusted to get these temperatures. The evaporator water side conditions were selected based on prior testing of this same chiller with R134a in a larger test facility. During this prior testing, both circuits of the chiller were tested simultaneously at standard AHRI 550/590 full load conditions (54 °F evaporator water inlet temperature/44 °F evaporator water outlet temperature adjusted for 0.0001 hr-ft²-°F/Btu fouling factor as described in AHRI 550/590, 95 °F condenser air inlet temperature). The evaporator test conditions for the single circuit testing in this study were selected to result in a suction pressure within 1 psi of the suction pressure from the prior two circuit testing at AHRI 550/590 conditions in the larger test facility while maintaining the same tube side water velocity. For part load tests, the evaporator water flow rate from the full load test and the evaporator water outlet temperature of 45.5 °F were maintained. The same test procedure was used for both R-134a and ARM-42a testing.

3. Results

The test cooling capacity was calculated from the measurements using:

$$Q_e = V_{chw} \cdot \rho_{chw} . c_{p\,chw} \cdot (T_{chw,in} - T_{chw,out}) \quad (1)$$

The test cooling COP was calculated using:

$$COP = \frac{\dot{Q}_e}{(W_c + W_{fans})} \quad (2)$$

Table 2 below lists the results from this study including the associated uncertainties in capacity and efficiency ratios. The capacity and efficiency of the chiller with ARM-42a are normalized by the values for R-134a at the same test condition.

Table 2: Test Results

Test #	% Capacity	Capacity Ratio $\frac{\dot{Q}_{e,ARM-42a}}{Q_{e,R\text{-}134a}}$	COP Ratio $\frac{\dot{COP}_{ARM-42a}}{COP_{R\text{-}134a}}$
1	100	1.008 ± 0.039	0.967 ± 0.039
2	75	1.005 ± 0.054	0.994 ± 0.054
3*	50	0.986 ± 0.074	0.929 ± 0.075
4	25	1.063 ± 0.158	1.002 ± 0.159
5	100	0.991 ± 0.040	0.959 ± 0.040

*for Test 3, the chiller controls had different number of fans operating for R-134a and ARM-42a.

As mentioned previously, the baseline tests 1, 2 and 5 in Table 2 with R-134a were repeated after ARM-42a tests to verify data. The change in measured performance for R-134a before and after ARM-42a tests for these three tests were less than 0.8% in capacity and less than 1.5% in efficiency. The average value of the two tests with R-134a is used as the basis of comparison in Table 2 for these 3 tests.

From Table 2, it can be seen that the capacity of ARM-42a is 0.8% higher than that of R-134a near standard AHRI 550/590 chiller design conditions. However, the efficiency of the chiller with ARM-42a is 3.3% lower than that of R-134a at the same conditions. At high ambient air temperature conditions in Test 5, the capacity of the chiller with ARM-42a was 0.9% lower than that with R-134a. At the high ambient air temperature conditions, the efficiency of the chiller was 4.1% lower than that of R-134a.

It should be noted that the chiller operating conditions for Test 3 was different in terms of the number of fans that were operating. The controls on the chiller are designed to turn fans on and off depending on operating conditions. The fan control logic was optimized for R-134a and

was not changed for ARM-42a. It is likely that the efficiency for Test 3 can be improved significantly by optimizing the fan logic for ARM-42a. This change in control logic is outside the scope of this drop-in test.

Due to limitations of the test facility at the time of this testing, the ambient air temperature for Test 4 could not be maintained at the target value of 55 °F specified in AHRI 550/590 standard for 25% load for air-cooled chillers. The tests with R-134a and ARM-42a were conducted at the closest possible air temperature which allowed stable operation.

The refrigerant charge quantity for the tests with R-134a and ARM-42a were determined based on refrigerant level in the evaporator. During testing the sub-cooling exiting the condenser coil was controlled to a constant set point. The saturation temperature of ARM-42a for a given pressure is within approximately 2 °F (ranges from about 2 °F lower at the lower ambient air temperature to 2 °F higher at the higher ambient air temperature) of that of R-134a at the condenser outlet conditions in this study. Due to the relatively small difference, the sub-cooling set point calculations at the condenser outlet for control purposes for both R-134a and ARM-42a were calculated using R-134a properties. With the sub-cooling controlled, refrigerant was added until the evaporator had sufficient charge as indicated by level in a sight glass for Test 1 in Table 2. This resulted in the chiller requiring 4.5% lower refrigerant quantity (by mass) for tests with ARM-42a.

NOMENCLATURE

COP:	Coefficient of Performance (ratio of heat transfer rate at the evaporator and the total power consumed by the compressors and condenser fans)
$c_{p_{chw}}$:	Specific heat capacity of chilled water through the evaporator at average of evaporator water inlet and outlet temperatures (kJ/kg)
P_d:	Pressure of refrigerant at compressor discharge (kPa)
P_l:	Pressure of refrigerant at condenser outlet (kPa)
P_s:	Pressure of refrigerant at compressor suction (kPa)
Q_e:	Evaporator heat transfer rate (kW)
$T_{air,in}$:	Air temperature at inlet of condenser (K)
$T_{chw,in}$:	Chiller water temperature at evaporator inlet (K)
$T_{chw,out}$:	Chiller water temperature at evaporator outlet (K)
T_l:	Temperature of refrigerant at condenser outlet (K)
V_{chw}:	Volumetric flow rate of chilled water entering the evaporator (m^3/s)
W_c:	Electrical power input to compressor motor (kW)
W_{fans}:	Electrical power input to condenser fan motors (kW)
ρ_{chw}:	Density of chilled water entering the evaporator (kg/m^3)

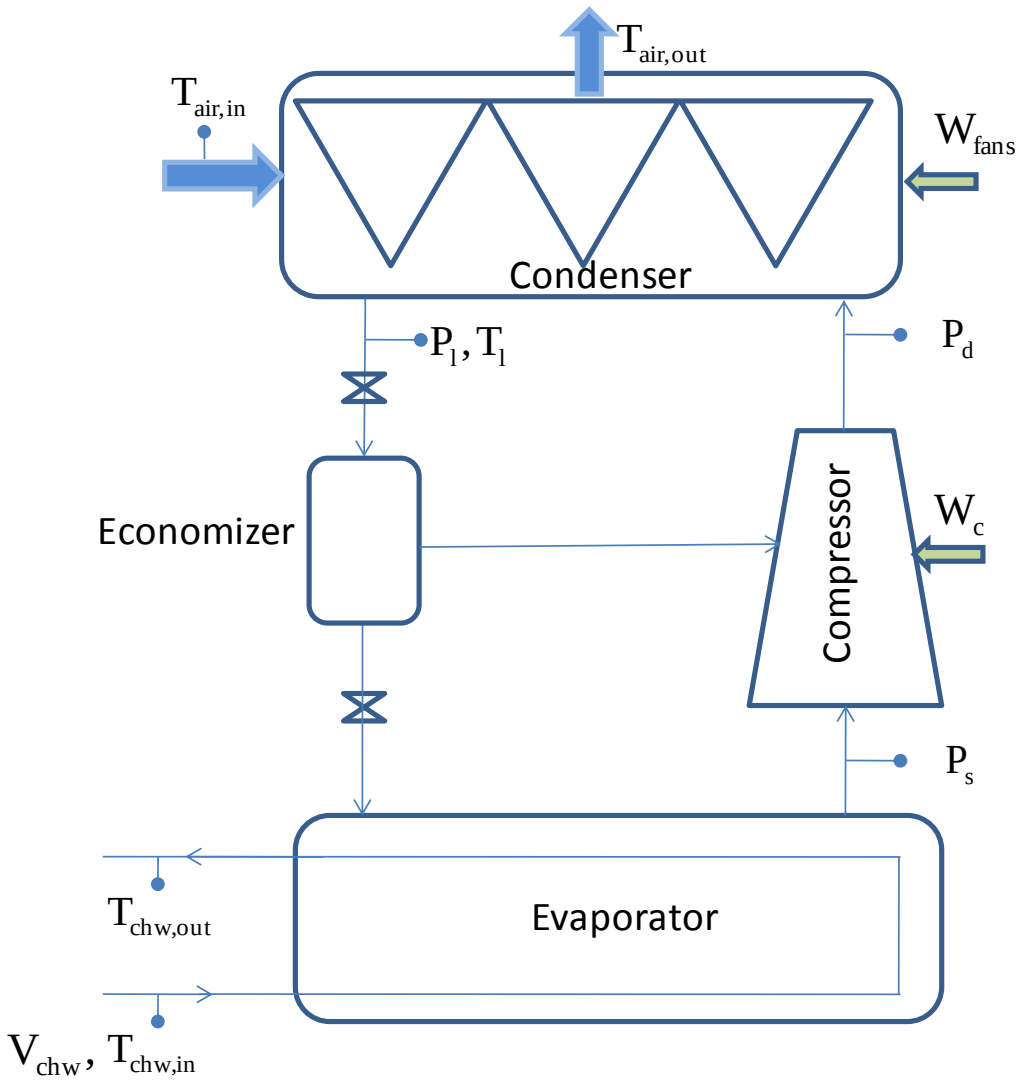

Figure 1 Schematic of the Test Chiller With Key Measurement Locations

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM – TEST #1

Manufacturer: Johnson Controls Manufacturer's Notation: YVAA

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	ARM-42a
Alternative Lubricant Type and ISO Viscosity	POE, ISO-120
Baseline Refrigerant and Lubricant	R-134a, POE (ISO-120)
Make and Model of System	YVAA Test Chiller
Nominal Capacity and Type of System	175 Tons, Air-cooled screw chiller

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling	Cooling		Cooling	Cooling		
Compressor Type			VSD Screw	VSD Screw		VSD Screw	VSD Screw		
Compressor Displacement			7.985	7.985	m^3/min	282	282	Ft ^3/min	1.0
Nominal Motor Size			240	240	hp				
Nominal Motor Speed			5100	5100	rpm				1.0
Expansion Device Type			EEV	EEV		EEV	EEV		
Lubricant Charge			9.39	9.39	kg	20.7	20.7	lb	1.0
Refrigerant Charge			90.7	86.6	kg	200	191	lb	0.955
Refrigerant Mass Flow Rate					kg/min			lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
	Out - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity			293.3	295.8	kW	83.4	84.1	Tons	1.008
Sensible Capacity			N/A	N/A	kW	N/A	N/A	Btu/hr	
Total System Power Input			104.0	108.4	kW	104.0	108.4	kW	1.042
Compressor Power Input			91.3	95.7	kW	91.3	95.7	kW	1.048
Energy Efficiency Ratio (EER)			9.6	9.3	W/W			Btuh/W	0.967
Coeff. Of Performance (COP)			2.82	2.73					0.967

Other System Changes

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #1

Type of System: Air-Cooled Screw Chiller (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-42a (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^ 3/min			ft ˆ3/min	
Flow Rate (liquid)	25.2	25.6	l/s	399	405	gal/min	1.015
Inlet Temperature	10.28	10.33	C	50.5	50.6	F	
Outlet Temperature	7.50	7.56	C	45.5	45.6	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas), nominal	1580	1580	m ^ 3/min	55800	55800	ft ˆ3/min	1.0
Flow Rate (liquid)			l/s			gal/min	
Inlet Temperature	35.0	35.2	C	95.0	95.4	F	
Outlet Temperature			C			F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction		344.7		374.4		50.0		54.3
Compressor Discharge		1435.5		1487.2		208.2		215.7
Condenser Inlet								
Condenser Outlet	39.83	1156.9	39.44	1170.0	103.7	167.8	103.0	169.7
Expansion Device Inlet								
Subcooling, at expan. device	5.1		6.1		9.1		11.0	
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
NIST REFPROP for R-134a
ARKEMA for ARM-42a

Additional Notes

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #2

Manufacturer: Johnson Controls Manufacturer's Notation: YVAA

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	ARM-42a
Alternative Lubricant Type and ISO Viscosity	POE, ISO-120
Baseline Refrigerant and Lubricant	R-134a, POE (ISO-120)
Make and Model of System	YVAA Test Chiller
Nominal Capacity and Type of System	175 Tons, Air-cooled screw chiller

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling	Cooling		Cooling	Cooling		
Compressor Type			VSD Screw	VSD Screw		VSD Screw	VSD Screw		
Compressor Displacement			5.635	5.635	m^3/min	199	199	ft ^3min	1.0
Nominal Motor Size			240	240	hp				
Nominal Motor Speed			3600	3600	rpm				1.0
Expansion Device Type			EEV	EEV		EEV	EEV		
Lubricant Charge			9.39	9.39	kg	20.7	20.7	lb	1.0
Refrigerant Charge			90.7	86.6	kg	200	191	lb	0.955
Refrigerant Mass Flow Rate					kg/min			lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
	Out - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity			220.5	221.6	kW	62.7	63.0	Tons	1.005
Sensible Capacity			N/A	N/A	kW	N/A	N/A	Btu/hr	N/A
Total System Power Input			62.5	63.1	kW	62.5	63.1	kW	1.010
Compressor Power Input			49.4	50.0	kW	49.4	50.0	kW	1.012
Energy Efficiency Ratio (EER)			12.1	12.0	W/W			Btuh/W	0.994
Coeff. Of Performance (COP)			3.55	3.52					0.994

Other System Changes

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #2

Type of System: Air-Cooled Screw Chiller (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-42a (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^ 3/min			ft ˆ3/min	
Flow Rate (liquid)	25.2	25.6	l/s	399	406	gal/min	1.015
Inlet Temperature	9.56	9.72	C	49.2	49.5	F	
Outlet Temperature	7.50	7.67	C	45.5	45.8	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas), nominal	1580	1580	m ^ 3/min	55800	55800	ft ˆ3/min	1.0
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	26.7	26.7	C	80.0	80.0	F	
Outlet Temperature			C			F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction		353.0		387.5		51.2		56.2
Compressor Discharge		1023.2		1061.1		148.4		153.9
Condenser Inlet								
Condenser Outlet	28.6	871.5	28.3	879.8	83.5	126.4	83.0	127.6
Expansion Device Inlet								
Subcooling, at expan. device	5.8		5.9		10.4		10.6	
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
NIST REFPROP for R-134a
ARKEMA for ARM-42a

Additional Notes

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #3

Manufacturer: Johnson Controls Manufacturer's Notation: YVAA

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	ARM-42a
Alternative Lubricant Type and ISO Viscosity	POE, ISO-120
Baseline Refrigerant and Lubricant	R-134a, POE (ISO-120)
Make and Model of System	YVAA Test Chiller
Nominal Capacity and Type of System	175 Tons, Air-cooled screw chiller

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling	Cooling		Cooling	Cooling		
Compressor Type			VSD Screw	VSD Screw		VSD Screw	VSD Screw		
Compressor Displacement			3.766	3.511	m^3/min	133	124	ft ^3min	0.938
Nominal Motor Size			240	240	hp				
Nominal Motor Speed			2400	2250	rpm				0.938
Expansion Device Type			EEV	EEV		EEV	EEV		
Lubricant Charge			9.39	9.39	kg	20.7	20.7	lb	1.0
Refrigerant Charge			90.7	86.6	kg	200	191	lb	0.955
Refrigerant Mass Flow Rate					kg/min			lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
	Out - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity			148.1	146.0	kW	42.1	41.5	Tons	0.986
Sensible Capacity			N/A	N/A	kW	N/A	N/A	Btu/hr	
Total System Power Input			37.7	40.0	kW	37.7	40.0	kW	1.061
Compressor Power Input			30.7	26.6	kW	30.7	26.6	kW	0.866
Energy Efficiency Ratio (EER)			13.4	12.4	W/W			Btuh/W	0.929
Coeff. Of Performance (COP)			3.93	3.65					0.929

Other System Changes

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #3

Type of System: Air-Cooled Screw Chiller (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-42a (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^ 3/min			ft ˆ3/min	
Flow Rate (liquid)	25.2	25.5	l/s	399	404	gal/min	1.013
Inlet Temperature	8.94	9.00	C	48.1	48.2	F	
Outlet Temperature	7.56	7.67	C	45.6	45.8	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas), nominal	790	1580	m ^ 3/min	27900	55800	ft ˆ3/min	2.0
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	18.3	18.	C	65.0	65.3	F	
Outlet Temperature			C			F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction		357.8		391.6		51.9		56.8
Compressor Discharge		858.4		766.0		124.5		111.1
Condenser Inlet								
Condenser Outlet	24.0	775.7	19.4	688.1	75.2	112.5	67.0	99.8
Expansion Device Inlet								
Subcooling, at expan. device	6.2		5.7		11.2		10.2	
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
NIST REFPROP for R-134a
ARKEMA for ARM-42a

Additional Notes
The chiller was tested with the chiller controls in automatic mode. Chiller controls turned off some of the fans for the baseline R-134a testing. All the fans were operating for ARM-42a testing. There is room to optimize the performance of the chiller with ARM-42a by adjusting the fan controls.

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #4

Manufacturer: Johnson Controls Manufacturer's Notation: YVAA

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	ARM-42a
Alternative Lubricant Type and ISO Viscosity	POE, ISO-120
Baseline Refrigerant and Lubricant	R-134a, POE (ISO-120)
Make and Model of System	YVAA Test Chiller
Nominal Capacity and Type of System	175 Tons, Air-cooled screw chiller

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling	Cooling		Cooling	Cooling		
Compressor Type			VSD Screw	VSD Screw		VSD Screw	VSD Screw		
Compressor Displacement			2.350	2.492	M^3/min	83	88	ft ^3min	1.060
Nominal Motor Size			240	240	hp				
Nominal Motor Speed			1500	1590	rpm				1.060
Expansion Device Type			EEV	EEV		EEV	EEV		
Lubricant Charge			9.39	9.39	kg	20.7	20.7	lb	1.0
Refrigerant Charge			90.7	86.6	kg	200	191	lb	0.955
Refrigerant Mass Flow Rate					kg/min			lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
	Out - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity					kW	20.6	21.9	Tons	1.063
Sensible Capacity			N/A	N/A	kW	N/A	N/A	Btu/hr	
Total System Power Input					kW	25.5	27.0	kW	1.059
Compressor Power Input					kW	21.4	22.9	kW	1.070
Energy Efficiency Ratio (EER)			9.69	9.71	W/W			Btuh/W	1.002
Coeff. Of Performance (COP)									

Other System Changes

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #4

Type of System: Air-Cooled Chiller (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-42a (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^ 3/min			ft ˆ3/min	
Flow Rate (liquid)	25.0	25.6	l/s	396	405	gal/min	1.023
Inlet Temperature	8.17	8.22	C	46.7	46.8	F	
Outlet Temperature	7.50	7.50	C	45.5	45.5	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas), nominal	395	395	m ^ 3/min	13950	13950	ft ˆ3/min	1.0
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	15.4	14.7	C	59.8	58.5	F	
Outlet Temperature			C			F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction		366.1		395.8		53.1		57.4
Compressor Discharge		930.1		980.4		134.9		142.2
Condenser Inlet								
Condenser Outlet	28.2	893.6	29.4	929.4	82.7	129.6	85.0	134.8
Expansion Device Inlet								
Subcooling, at expan. device	7.1		6.9		12.8		12.4	
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
NIST REFPROP for R-134a
ARKEMA for ARM-42a

Additional Notes
The chiller was tested with the controls in automatic mode. Chiller controls turned off some of the fans for this test. Both R-134a and ARM-42a tests had the same number of fans operating for this test condition.
Please note that the air inlet temperature during R-134a testing was 1.3 °F higher than that during ARM-42a testing
Due to limitations of the test facility at the time of these tests, the target air inlet temperature of 55 °F corresponding to the 25% load conditions in AHRI 550/590 could not be achieved.

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM – TEST #5

Manufacturer: Johnson Controls Manufacturer's Notation: YVAA

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	ARM-42a
Alternative Lubricant Type and ISO Viscosity	POE, ISO-120
Baseline Refrigerant and Lubricant	R-134a, POE (ISO-120)
Make and Model of System	YVAA Test Chiller
Nominal Capacity and Type of System	175 Tons, Air-cooled screw chiller

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling	Cooling		Cooling	Cooling		
Compressor Type			VSD Screw	VSD Screw		VSD Screw	VSD Screw		
Compressor Displacement			7.985	7.985	m^3/min	282	282	ft ^3min	1.0
Nominal Motor Size			240	240	hp				
Nominal Motor Speed			5100	5100	rpm				1.0
Expansion Device Type			EEV	EEV		EEV	EEV		
Lubricant Charge			9.39	9.39	kg	20.7	20.7	lb	1.0
Refrigerant Charge			90.7	86.6	kg	200	191	lb	0.955
Refrigerant Mass Flow Rate					kg/min			lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
	Out - door	db	N/A	N/A	C	N/A	N/A	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity			247.2	245.1	kW	70.3	69.7	Tons	0.991
Sensible Capacity			N/A	N/A	kW	N/A	N/A	Btu/hr	
Total System Power Input			127.7	132.1	kW	127.7	132.1	kW	1.034
Compressor Power Input			115.4	119.8	kW	115.4	119.8	kW	1.038
Energy Efficiency Ratio (EER)			6.6	6.3	W/W			Btuh/W	0.959
Coeff. Of Performance (COP)			1.94	1.86					

Other System Changes

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM– TEST #5

Type of System: Air-Cooled Screw Chiller (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-42a (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Water	Water					
Flow Rate (gas)			m ^ 3/min			ft ˆ3/min	
Flow Rate (liquid)	21.5	21.1	l/s	340	334	gal/min	1.015
Inlet Temperature	10.22	10.22	C	50.4	50.4	F	
Outlet Temperature	7.44	7.44	C	45.4	45.4	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas), nominal	1580	1580	m ^ 3/min	55800	55800	ft ˆ3/min	1.0
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature	48.0	47.8	C	118.4	118.1	F	
Outlet Temperature			C			F	

Refrigerant Side Data Temperatures & Pressures	Baseline		Alternative		Baseline		Alternative	
	T (C)	P [kPa]	T (C)	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction		341.3		370.9		49.5		53.8
Compressor Discharge		1858.1		1906.4		269.5		276.5
Condenser Inlet								
Condenser Outlet	53.8	1603.7	53.3	1621.6	128.8	232.6	127.9	235.2
Expansion Device Inlet								
Subcooling, at expan. device	4.2		6.2		7.6		11.2	
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
NIST REFPROP for R-134a
ARKEMA for ARM-42a

Additional Notes