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

TEST REPORT #3

System Drop-in Test of R-32/R-152a (95/5) in a 5-ton Air Source Heat Pump

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Table of Contents

ABSTRACT……...3

1. INTRODUCTION…….3

2. TEST SETUP…….3

3. RESULTS ……..5

Cooling Test A……6

Cooling Test B……8

Cooling Test C……..10

Heating Test H1……12

Heating Test H2……14

Heating Test H3……16

4. RESULTS SUMMARY……...18

5. CONCLUSION……21

APPENDIX……...23

ABSTRACT

As a contribution to the AHRI Low-GWP Alternative Refrigerants Evaluation Program (AREP), this study compares the alternative refrigerant R32+R152a (95%+5%) to the baseline refrigerant R410A. A drop-in test was performed to evaluate the performance of the alternative refrigerant in place of the common refrigerant R410A in a 5-ton commercial heat pump system. The two refrigerants had similar performance with EER differences ranging from -1.76% to +8.61%. A post drop-in test was conducted, reintroducing R410A to the heat pump to see if the alternative refrigerant mixture impacted the system. The system performance exhibited negligible change when R410A was reintroduced to the system after operation with R32+R152a.

1. INTRODUCTION

This report investigates the performance of candidate refrigerant R32 95% + R152a 5% as a drop-in replacement for the baseline refrigerant R410A in air-source heat pumps. R32/R152a is a mixture of R32 (difluoromethane) and R152a (difluoroethane) and has a GWP of 648. R410A is a mixture of R32 and R125 (pentafluoroethane) and has a GWP of 2088. The single zone air handler (Model #: AHX60D3XH21A) and the outdoor unit (Model #: THGD60S41S4A)are supplied by Johnson Controls Inc. Heating and cooling tests were conducted under the AHRI standard 210/240-2008, the Air-Conditioning, Heating, and Refrigeration Institute's standard rating tests for air-source heat pump equipment. Heating and cooling tests were conducted in the Building Technologies Research and Integration Center (BTRIC) at Oak Ridge National Laboratory. Each test lasted an average of 41 minutes with the shortest test taking 15 minutes and the longest taking 55 minutes.

2. TEST SETUP

Figure 1 illustrates the schematic of the heat pump system in heating mode. The heat pump system consists of two units from Johnson Controls Inc. The system has a 5 ton nominal capacity. The baseline refrigerant is R410A with a charge of 14.0 lb, an average refrigerant flow rate of 10.38 lbs/min, and a PVE lubricant. No changes were made to the system for the drop-in tests.

To the left of the dashed line is the indoor chamber, which contains a heat exchanger that will act as a condenser or an evaporator depending on what mode the heat pump is running in. To the right of the dashed line is the outdoor chamber, which contains another heat exchanger, to serve as the evaporator or condenser, a receiver to prevent liquid from getting into the compressor, the compressor, and a reversing valve, which facilitates the switch between cooling and heating mode. There is a thermal expansion valve (TXV) attached to the indoor coil, which serves as the expansion device for cooling. For heating, the expansion device is a fixed orifice on the outdoor coil. Thermocouples, pressure transducers, and a mass flow meter are also indicated at their measuring points.

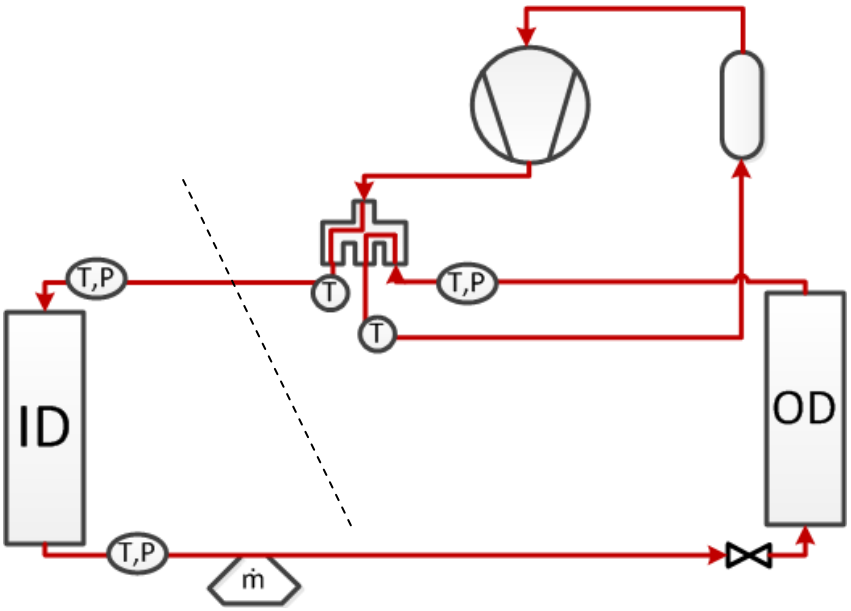

Figure 1: Heat Pump Schematic Diagram in the Heating Mode.

3. RESULTS

The following information is the same for all the tests listed below:

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	R32 95% + R152a 5%
Alternative Lubricant Type and ISO Viscosity	PVE, 80 cSt at 40°C
Baseline Refrigerant and Lubricant	R410A, PVE
Make and Model of System	Johnson Controls, Indoor Unit: AHX60D3XH21A Outdoor Unit: THGD60S41S4A
Nominal Capacity and Type of System	5 ton, Air Source Heat Pump

Other System Changes
No changes

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd	0.15	0.15	1.00
Seasonal Energy Efficiency Ratio - SEER	16.51	16.67	1.01
Heating Seasonal Performance Factor - HSPF[†]	8.55	9.32	1.09

Data Source(s) for Refrigerant Properties
NIST- REFPROP; Lemmon, E.W., Huber, M.L., McLinden, M.O. NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 9.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, 2010.
Lubricant density provided by ROCOL Lubricants
Lubricant viscosity; http://www.machinerylubrication.com/Read/213/iso-viscosity-grades

Additional Notes
Total capacity is air-side heat capacity
EER is air-side EER
Refrigerant Side Evaporated Inlet is calculated not measured
Negative values for the evaporator superheat with the alternative refrigerant indicate 2-phase outlet due to using the R410A TXV or undersized outdoor heat exchanger.

[†] HSPF was calculated based on DHRmin with CD = 0.2

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM - Test A

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio Alt./Base.
Mode (Heating/Cooling)			Cooling						
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6					
Compressor Displacement			9.8	9.8	m^3/min	346	346	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			R410A TXV	R410A TXV					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	1
Refrigerant Charge			6.35	6.58	kg	14	14.5	lb	1.04
Refrigerant Mass Flow Rate			5.96	4.14	kg/min	13.15	9.12	lb/min	0.69
Composition, at compr. Inlet if applicable			N/A	N/A	% wt				
Ambient Temps.	In - door	db	25.8	25.9	C	78.5	78.6	F	
		wb	18.6	19.6	C	65.4	67.2	F	
	Out - door	db	36.7	37.1	C	98.0	98.8	F	
		wb	19.3	19.3	C	66.8	66.8	F	
Total Capacity			18405	20078	W	62799	68505	Btu/hr	1.09
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			4456	4703	W	4456	4703	W	1.06
Compressor Power Input			3727	3975	W	3727	3975	W	1.07
Energy Efficiency Ratio (EER)						14.09	14.57	Btuh/W	1.03
Coeff. Of Performance (COP)			4.13	4.27	W/W				1.03

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—Test A

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	49.2	48.7	m^3/min	1737.96	1719.35	ft^3/min	0.99
Inlet Temp.	26.9	26.8	C	80.4	80.3	F	
Outlet Temp.	14.1	14.5	C	57.3	58.1	F	
Condenser							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	N/A
Inlet Temp.	35.0	35.1	C	95.0	95.1	F	
Outlet Temp.	37.4	37.1	C	99.2	98.8	F	

Refrigerant Side Data	Baseline		Alternative		Baseline		Alternative	
Temperatures & Pressures	T [C]	P [kPa]	T [C]	P [kPa]	T [F]	P [psia]	T [F]	P [psia]
Compressor Suction	13.9	N/A	14.1	N/A	57.0	N/A	57.4	N/A
Compressor Discharge	72.8	N/A	89.5	N/A	163.0	N/A	193.1	N/A
Condenser Inlet	71.6	2695.8	87.4	2701.9	160.9	391.0	189.3	391.9
Condenser Outlet	39.9	2590.6	39.0	2641.8	103.7	375.7	102.3	383.2
Expansion Device Inlet	24.9	2528.4	10.6	2604.8	76.8	366.7	51.1	377.8
Subcooling, at expan. device	2.67		5.39		4.8		9.7	
Evaporator Inlet	8.8	N/A	38.2	N/A	47.9	N/A	100.8	N/A
Evaporator Outlet	11.7	1050.9	10.6	1057.0	53.1	152.4	51.1	153.3
Evaporator Superheat	2.78		0.56		5.0		1.0	

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM—Test B

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Cooling	Cooling	NA	Cooling	Cooling	NA	NA
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6	NA	Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048U 1LP6	NA	NA
Compressor Displacement			9.8	9.8	m^3/min	346	346	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			R410A TXV	R410A TXV					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	
Refrigerant Charge			6.38	6.58	kg	14	14.5	lb	1
Refrigerant Mass Flow Rate			5.98	4.08	kg/min	13.18	8.99	lb/min	0.68
Composition, at compr. Inlet if applicable			N/A	N/A	% wt				
Ambient Temps.	In - door	db	25.83	25.77	C	78.50	78.39	F	
		wb	19.49	19.53	C	67.09	67.16	F	
	Out - door	db	29.92	30.30	C	85.85	86.54	F	
		wb	12.78	12.78	C	55.00	55.00	F	
Total Capacity			20072	21013	W	68486	71698	Btu/hr	1.05
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			3928	4066	W	3928	4066	W	1.04
Compressor Power Input			3192	3333	W	3192	3333	W	1.04
Energy Efficiency Ratio (EER)						17.43	17.63	Btuh/W	1.01
Coeff. Of Performance (COP)			5.11	5.17	W/W				1.01

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—Test B

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	49.23	49	m^3/min	1738.67	1730.37	ft^3/min	1.00
Inlet Temp.	26.72	26.67	C	80.1	80	F	
Outlet Temp.	14.45	14.11	C	58.01	57.39	F	
Condenser							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	N/A
Inlet Temp.	27.78	27.85	C	82	82.13	F	
Outlet Temp.	30.27	30.53	C	86.48	86.96	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	14.5	N/A	13.5	N/A	58.1	N/A	56.3	N/A
Compressor Discharge	63.3	N/A	77.1	N/A	146.0	N/A	170.8	N/A
Condenser Inlet	62.4	2278.44	75.4	2285.61	144.3	330.46	167.7	331.5
Condenser Outlet	33.1	2173.16	32.0	2228.39	91.7	315.19	89.5	323.2
Expansion Device Inlet	32.4	2052.78	31.3	2193.77	90.4	297.73	88.3	318.18
Subcooling, at expan. device	0.8		5.2		1.5		9.4	
Evaporator Inlet	8.7	N/A	8.8	N/A	47.7	N/A	47.9	N/A
Evaporator Outlet	12.7	1047.93	10.1	1026.22	54.9	151.99	50.1	148.84
Evaporator Superheat	3.9		-0.1		7.0		-0.2	

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM—Test C

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Cooling						
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6					
Compressor Displacement			9.8	9.8	m^3/min	346.08	346.08	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			R410A TXV	R410A TXV					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	1
Refrigerant Charge			6.38	6.58	kg	14	14.5	lb	1.04
Refrigerant Mass Flow Rate			5.41	3.76	kg/min	11.92	8.29	lb/min	0.70
Composition, at compr. Inlet if applicable				N/A	% wt				N/A
Ambient Temps.	In - door	db	26.07	25.73	C	78.93	78.32	F	
		wb	16.02	15.68	C	60.84	60.22	F	
	Out - door	db	29.71	30.14	C	85.47	86.25	F	
		wb	N/A	N/A	C	N/A	N/A	F	
Total Capacity			18648	18702	W	63363	63810	Btu/hr	1.01
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			3911	4010	W	3911	4010	W	1.03
Compressor Power Input			3181	3281	W	3181	3281	W	1.03
Energy Efficiency Ratio (EER)						16.2	15.91	Btuh/W	0.98
Coeff. Of Performance (COP)			4.75	4.66	W/W				0.98

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—Test C

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)	49.07	49.1	m^3/min	1733	1734.12	ft^3/min	1
Inlet Temp.	27.0	26.8	C	80.6	80.2	F	
Outlet Temp.	11.0	10.6	C	51.8	51.0	F	
Condenser							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	N/A
Inlet Temp.	27.7	27.8	C	81.8	82.1	F	
Outlet Temp.	29.7	30.4	C	85.5	86.7	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	11.5	N/A	6.7	N/A	52.7	N/A	44.0	N/A
Compressor Discharge	64.9	N/A	75.6	N/A	148.8	N/A	168.0	N/A
Condenser Inlet	63.4	2224.11	73.1	2237.97	146.7	322.58	163.6	324.59
Condenser Outlet	32.1	2133.65	31.7	2188.88	89.7	309.46	89.0	317.47
Expansion Device Inlet	31.6	2083.04	31.0	2158.54	89.0	302.12	87.9	313.07
Subcooling, at expan. device	2.19		4.86		3.9		8.7	
Evaporator Inlet	5.7	N/A	5.8	N/A	42.3	N/A	42.4	N/A
Evaporator Outlet	9.1	956.79	6.4	935.89	48.4	138.77	43.5	135.74
Evaporator Superheat	3.27		-0.77		5.9		-1.4	

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM—H1

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Heating						
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6					
Compressor Displacement			9.8	9.8	m^3/min	346.08	346.08	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			orifice	orifice					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	
Refrigerant Charge			6.38	6.58	kg	14	14.5	lb	1
Ref. Mass Flow Rate			4.34	3.43	kg/min	9.56	7.57	lb/min	0.79
Composition, at compr. Inlet if applicable			N/A	N/A	% wt				
Ambient Temps.	In - door	db	21.66	20.8	C	70.98	69.44	F	
		wb	16.71	16.17	C	62.08	61.1	F	
	Out - door	db	8.22	7.81	C	46.79	46.05	F	
		wb	3.72	3.72	C	38.7	38.7	F	
Total Capacity			17339	18159.94	W	59162	62022	Btu/hr	1.05
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			5163	4983	W	5163	4983	W	0.97
Compressor Power Input			4403	4219	W	4403	4219	W	0.96
Energy Efficiency Ratio (EER)						11.46	12.45	Btuh/W	1.09
Coeff. Of Performance (COP)			3.36	3.65	W/W				1.09

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—H1

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	NA
Inlet Temp.	8.5	8.4	C	47.4	47.1	F	
Outlet Temp.	7.8	7.5	C	46.1	45.5	F	
Condenser							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	48.8	48.9	m^3/min	1725	1726	ft^3/min	N/A
Inlet Temp.	21.7	21.1	C	71.0	70.0	F	
Outlet Temp.	41.8	41.8	C	107.2	107.3	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	7.2	N/A	2.8	N/A	44.9	N/A	37.0	N/A
Compressor Discharge	92.0	N/A	87.5	N/A	197.7	N/A	189.5	N/A
Condenser Inlet	85.3	3067.8	78.9	2814.9	185.5	445.0	174.1	408.3
Condenser Outlet	27.4	3028.0	31.1	2784.7	81.3	439.2	88.0	403.9
Expansion Device Inlet	26.5	3001.3	30.0	2765.8	79.7	435.3	86.0	401.1
Subcooling, at expan. device	22.9		16.4		41.2		29.6	
Evaporator Inlet	-0.4	N/A	1.9	N/A	31.3	N/A	35.5	N/A
Evaporator Outlet	4.9	790.8	2.7	829.9	40.8	114.7	36.9	120.4
Evaporator Superheat	5.2		-0.6		9.3		-1.0	

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM— H2

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Heating						
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6					
Compressor Displacement			9.8	9.8	m^3/min	346.08	346.08	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			orifice	orifice					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	
Refrigerant Charge			6.38	6.58	kg	14	14.5	lb	1
Ref. Mass Flow Rate			3.78	2.9	kg/min	8.34	6.39	lb/min	0.77
Composition, at compr. Inlet if applicable			N/A	N/A	% wt				
Ambient Temps.	In - door	db	21.52	20.66	C	70.73	69.18	F	
		wb	16.38	16.17	C	61.49	61.1	F	
	Out - door	db	1.34	1.26	C	34.41	34.27	F	
		wb	-0.94	-0.94	C	30.3	30.3	F	
Total Capacity			14963	15271	W	51054	52105	Btu/hr	1.02
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			4745.36	4550.85	W	4745.36	4550.85	W	0.96
Compressor Power Input			3974.31	3779.83	W	3974.31	3779.83	W	0.95
Energy Efficiency Ratio (EER)						10.76	11.45	Btuh/W	1.06
Coeff. Of Performance (COP)			3.15	3.36	W/W				1.07

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—H2

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	NA
Inlet Temp.	1.9	1.7	C	35.4	35.1	F	
Outlet Temp.	1.0	1.2	C	33.8	34.2	F	
Condenser							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	48.9	48.9	m^3/min	1728	1726	ft^3/min	1.0
Inlet Temp.	21,77	21.1	C	71.2	69.9	F	
Outlet Temp.	38.8	38.4	C	101.9	101.1	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	0.3	N/A	-2.9	N/A	32.5	N/A	26.7	N/A
Compressor Discharge	85.8	N/A	82.8	N/A	186.5	N/A	181.1	N/A
Condenser Inlet	78.3	2688.3	73.1	2490.9	173.0	389.9	163.5	361.3
Condenser Outlet	27.5	2658.2	31.6	2468.8	81.5	385.5	88.9	358.1
Expansion Device Inlet	26.2	2637.1	29.7	2455.1	79.2	382.5	85.4	356.1
Subcooling, at expan. device	17.6		11.8		31.7		21.2	
Evaporator Inlet	-4.9	N/A	-3.4	N/A	23.2	N/A	25.8	N/A
Evaporator Outlet	-2.0	682.7	-3.0	694.0	28.4	99.0	26.7	100.7
Evaporator Superheat	2.8		-0.8		5.0		-1.4	

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM—H3

Manufacturer: National Refrigerants, Inc. Manufacturer's Notation: R32 95% + R152a 5%

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Heating						
Compressor Type			Danfoss Model # HRH048 U1LP6	Danfoss Model # HRH048 U1LP6					
Compressor Displacement			9.8	9.8	m^3/min	346.08	346.08	ft^3/min	1
Nominal Motor Size			0.25	0.25	hp				1
Motor Speed			850	850	rpm				1
Expansion Device Type			orifice	Orifice					
Lubricant Charge			0.88	0.88	kg	1.94	1.94	lb	
Refrigerant Charge			6.38	6.58	kg	14	14.5	lb	1
Ref. Mass Flow Rate			2.8	27.93	kg/min	6.18	61.57	lb/min	9.96
Composition, at compr. Inlet if applicable			N/A	N/A	% wt				
Ambient Temps.	In - door	db	21.59	20.21	C	70.86	68.37	F	
		wb	16.61	15.73	C	61.9	60.32	F	
	Out - door	db	-8.79	-8.8	C	16.17	16.16	F	
		wb	-12.39	-12.39	C	9.7	9.7	F	
Total Capacity			10673	11124	W	36418	37954	Btu/hr	1.04
Sensible Capacity			N/A	N/A	W	N/A	N/A	Btu/hr	N/A
Total System Power Input			4221	4031	W	4221	4031	W	0.95
Compressor Power Input			3448	3254	W	3448	3254	W	0.94
Energy Efficiency Ratio (EER)						8.63	9.42	Btuh/W	1.09
Coeff. Of Performance (COP)			2.53	2.76	W/W				1.09

Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM—H3

Type of System: ASHP Alternate Refrigerant: R32 95% + R152a 5%

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	N/A	N/A	m^3/min	N/A	N/A	ft^3/min	NA
Inlet Temp.	-8.0	-8.3	C	17.6	17.0	F	
Outlet Temp.	-8.1	-8.9	C	17.4	16.0	F	
Condenser							
Heat Exchange Fluid	Air	Air		Air	Air		
Flow Rate (gas)	48.9	48.9	m^3/min	1727	1726	ft^3/min	N/A
Inlet Temp.	22.1	21.1	C	71.8	69.9	F	
Outlet Temp.	33.8	33.2	C	92.9	91.8	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	-14.0	N/A	-12.2	N/A	6.8	N/A	10.0	N/A
Compressor Discharge	72.7	N/A	79.9	N/A	162.8	N/A	175.8	N/A
Condenser Inlet	62.0	2176.5	66.6	2129.9	143.6	315.7	151.9	308.9
Condenser Outlet	28.8	2159.1	32.3	2114.5	83.9	313.2	90.1	306.7
Expansion Device Inlet	26.8	2148.8	30.8	2102.5	80.2	311.7	87.4	304.9
Subcooling, at expan. device	8.5		4.3		15.3		7.7	
Evaporator Inlet	-15.0	N/A	-13.0	N/A	5.1	N/A	8.7	N/A
Evaporator Outlet	-14.0	482.3	-12.3	503.9	6.8	70.0	9.8	73.1
Evaporator Superheat	0.8		-0.8		1.5		-1.5	

4. RESULTS SUMMARY

The detailed results presented in section 3 above are summarized below to give a general overview of the system performance. Furthermore, the H1 test was repeated with R410A after running R32/R152a mixture to investigate system performance.

Overall cooling results summarized in Table 1 below indicate that the suggested mixture has better performance than R410A in higher temperature lift cases. Efficiency during was greater than R410A by about 3.34% and 1.13% for Cooling Tests A and B respectively. However, for the Cooling Test C, the system performance was slightly reduced by -1.76%. The results also show that the discharge pressures of the alternative refrigerant were similar to that of R410A. Finally, it is shown that the alternative refrigerant has higher volumetric capacity, lower pressure drop through heat exchangers, and higher overall system capacity.

Table 1: Summary of Cooling Test Results

Cooling Test	Discharge Pressure (PSIa)			Air-Side Heat Capacity (Btu/h)			EER (Btu/W·h)		
	R410A	R32/R152a	% Diff	R410A	R32/R152a	% Diff	R410A	R32/R152a	% Diff
A	390.99	391.88	+0.23%	62799	68505	9.09%	14.09	14.57	+3.34%
B	330.46	331.50	+0.31%	68486	71698	4.69%	17.43	17.63	1.13%
C	322.58	324.59	+0.62%	63363	63810	0.71%	16.20	15.91	-1.76%

Overall heating test results summarized in Table 2 below indicate that the suggested mixture has better performance than R410A in all heating conditions. The results also show that the alternative refrigerant has lower discharge pressures although the system was charged with 3.6% more charge than that of the R410A system. However, it should be noted here that the system had a large receiver which would render such change in system charge of negligible effect on the system performance. Finally, it is shown that the alternative refrigerant has higher volumetric capacity, lower pressure drop through heat exchangers, and higher overall system capacity.

Table 2: Summary of Heating Test Results

Heating Test	Discharge Pressure (PSIa)			Air-Side Heat Capacity (Btu/h)			EER (Btu/W·h)		
	R410A	R32/R152a	% Diff	R410A	R32/R152a	% Diff	R410A	R32/R152a	% Diff
H1	435.30	401.14	-7.85%	59162	62022	4.83%	11.46	12.45	+8.61 %
H2	382.48	356.08	-6.90%	51054	52105	2.06%	10.76	11.45	+6.42 %
H3	311.65	304.94	-2.15%	36418	37954	4.22%	8.63	9.42	+9.14 %

The refrigerant mass flow rate for R32/R152a's H3 test was not determined due to 2-phase flow conditions at the coriolis mass flow meter. The system was run for a second time after adding 23.6 oz more charge than the baseline. Despite the increase in charge, the results from the second test matched the first and the 2-phase flow conditions at the coriolis mass flow meter persisted. Table 3 shows a summary of this second H3 test as well as percent differences comparing these results against R410A H3 heating test data.

Table 3: Summary of Second H3 Test for R32/R152a

Discharge Pressure (PSIa)	% Difference	Air-Side Heat Capacity (Btu/h)	% Difference	EER (Btu/W·h)	% Difference
306.39	-1.69%	38837	+2.33%	9.62	+2.17%

Pressure-enthalpy (P-h) charts for R410A and the alternative refrigerant are shown in Figure 2 and 3 respectively. These charts indicate that the alternative refrigerant has slightly lower pressure, higher critical pressure, and larger specific heat capacity than R410A. The difference in pressure affected the performance of the R410A TXV used in the cooling mode. Furthermore, the higher specific heat capacity was not well matched with the outdoor heat exchanger used as an evaporator during the heating mode. This resulted in negative values for the refrigerant superheat at the evaporator outlet.

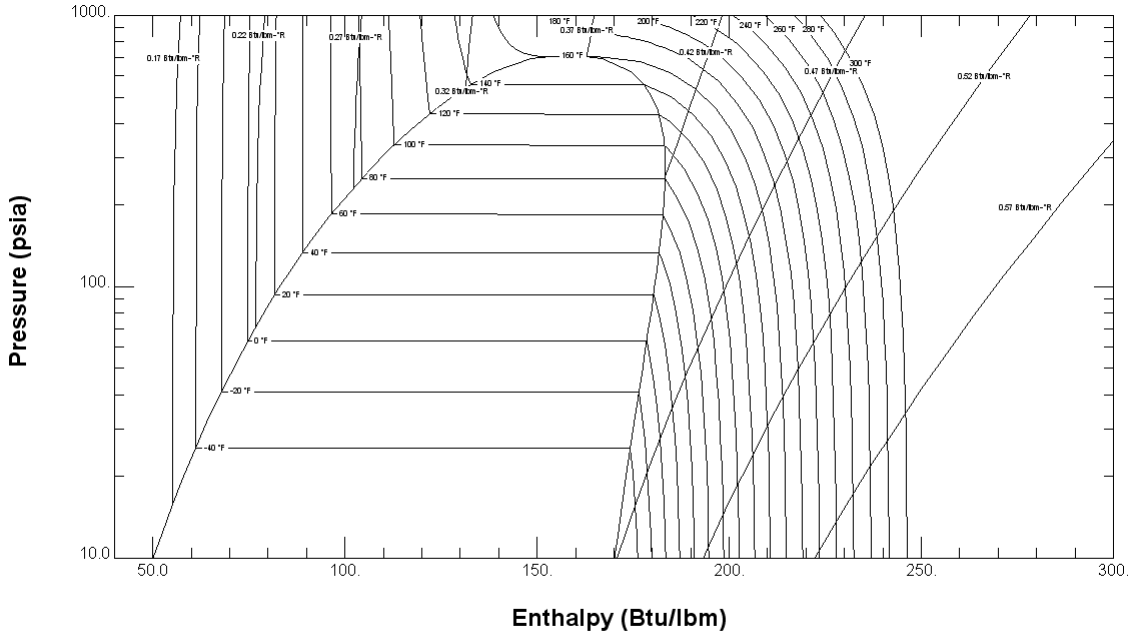

Figure 2. P-h chart for R410A

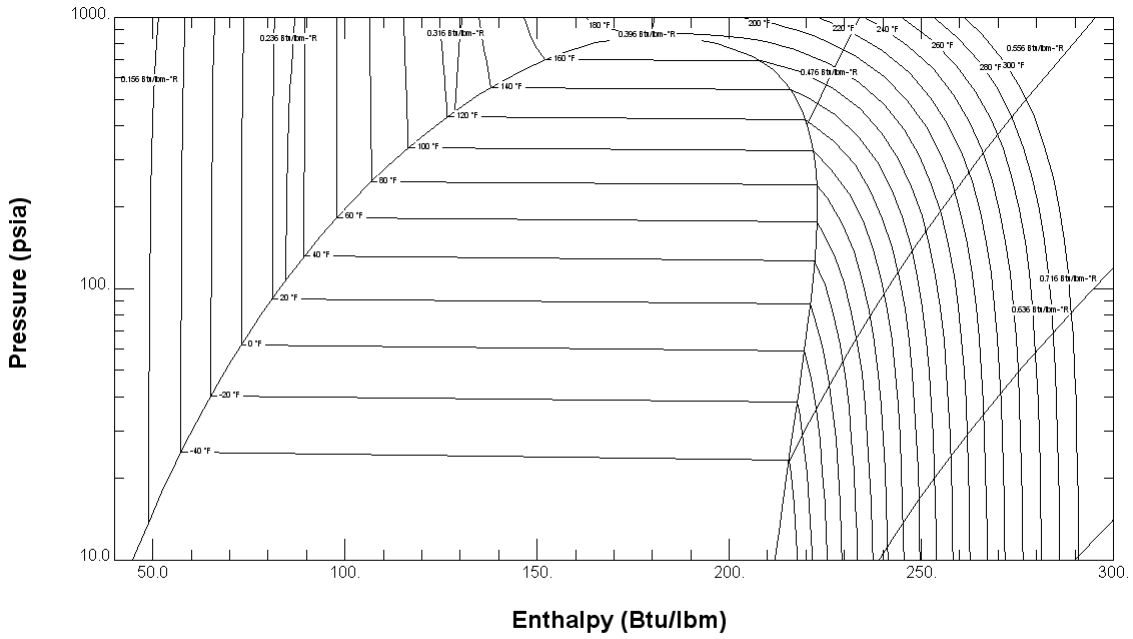

Figure 3. P-h chart for R32/R152a mixture (95.22/4.78)

Side by side comparisons of system EER, discharge pressure, total power consumption and air-side capacity are illustrated in Figure 4 through 7 respectively. The figures indicate that the alternative refrigerant can be considered as a drop in replacement for R410A.

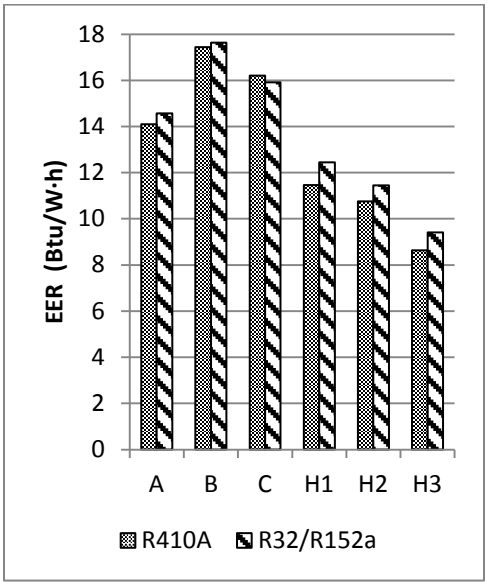

Figure 4: EER of R410A and R32/R152a

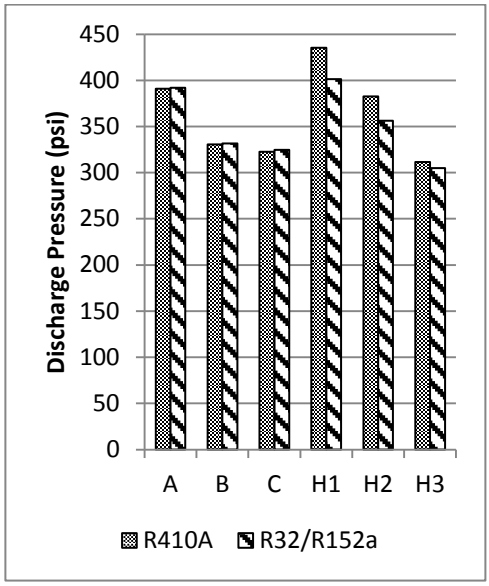

Figure 5: Discharge Pressure of R410A and R32/R152a

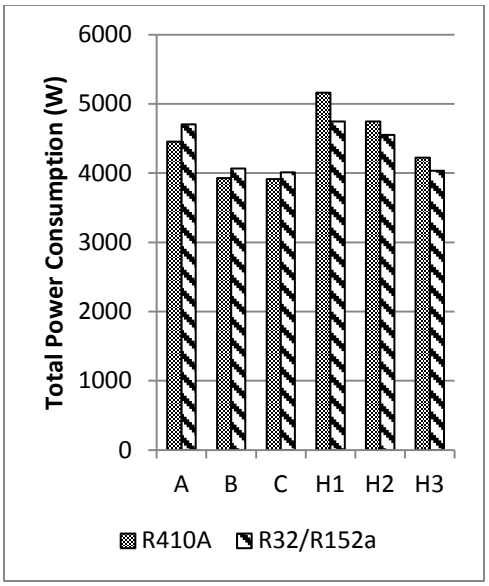

Figure 6: Total Power Consumption of R410A and R32/R152a

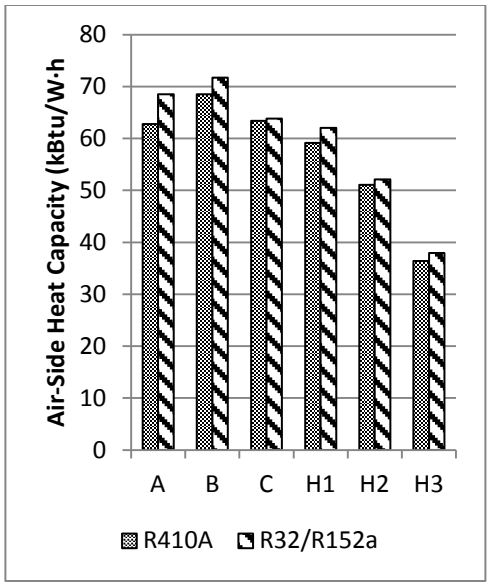

Figure 7: Air-Side Heat Capacity of R410A and R32/R152a

Finally, the compressor discharge temperatures for the 6 tests were compared for both the R410A and the alternative refrigerant mixture. Figure 8 below show the summary of this comparison. During the cooling mode; the alternative refrigerant mixture resulted in 20 – 30°F higher discharge temperature compared to when the system was run with R410A. This might have a slight impact on the compressor performance and reliability. During the heating test, the difference in compressor discharge temperature varied between -8 to +13°F. The higher increase in the air conditioning modes and the H3 heating mode can be attributed to the flatter isentropic lines for the alternative refrigerant mixture compared to that of R410A as indicated in Figure 3 and 2. However, the lower compressor discharge temperature in the H1 and H2 heating tests are attributed to the lower discharge pressure compared to the R410A system operation.

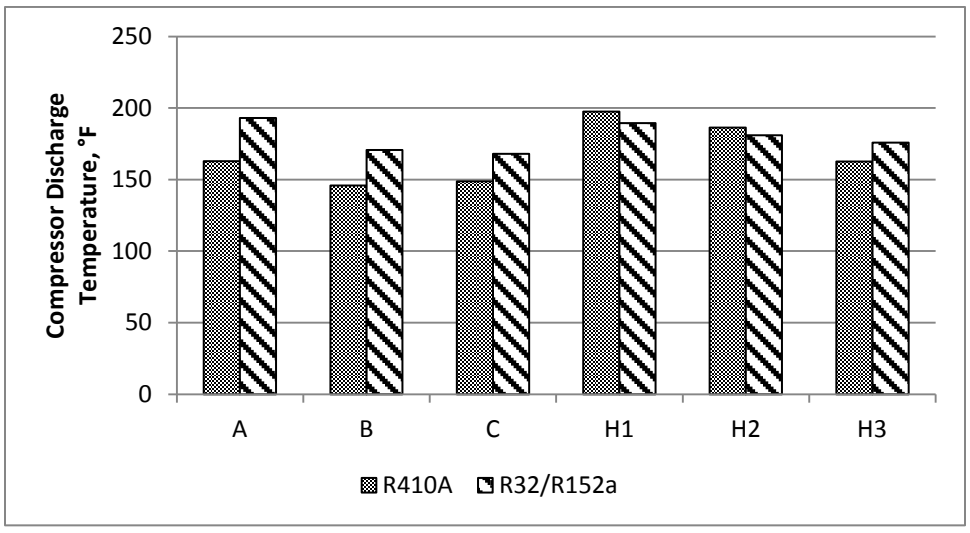

Figure 8: Compressor Discharge Temperature of R410A and R32/R152a

After the R32/R152a had been cleared from the system, R410A was reintroduced and another H1 test was run. The results of the second H1 test, which are summarized below in Table 4, were very similar to that of the first, meaning the R32/R152a had no negative effects on the heat pump. The results show that the system was slightly undercharged and hence the lower discharge pressure.

Table 4: Summary of Second H1 Test Run with R410A

	Discharge Pressure (PSIa)	Air-Side Heat Capacity (Btu/h)	EER (Btu/W·h)
Baseline	435.30	59162	11.46
After performing testing with alternative refrigerant	413.08	58640	11.88
% Difference	-5.10%	-0.88%	+3.67%

5. CONCLUSION

A drop-in test was performed for an air source heat pump at Oak Ridge National Laboratory. In this test; a mixture of R32/R152a (95.22/4.78 by mass) was used as a drop-in replacement to R410A in a 5-ton heat pump unit. The results indicated that the alternative refrigerant has higher volumetric capacity and lower pressure drop through heat exchanger. The performance results showed that R32/R152a mixture has higher efficiency compared to R410A at high temperature lift conditions and slightly lower efficiency for small temperature lift applications (1.2% and 1.78% drop in EER for Cooling Test B and C respectively). The alternative refrigerant also exhibited higher or similar system capacity for all test conditions. However, the results show that the alternative refrigerant mixture results in 20 – 30°F higher compressor discharge temperatures for all cooling tests as well as the H3 heating test.

A post drop-in test revealed that the system operated at similar capacity and efficiency after the alternative refrigerant mixture was cleared from the system and the original R410A charge was used. This indicates that the alternative refrigerant mixture did not impact the performance of the unit. Overall, the results show that the refrigerant mixture R32/R152a performs just as well as R410A in the test system.

Appendix A. Instrumentation:

Indoor unit air flow measurement
FAN-E Airflow Measuring Station: A multi-point, self-averaging Pitot traverse station with integral air straightener-equalizer honeycomb cell, capable of continuously measuring fan discharges or ducted airflow with an accuracy of ±2% or better. Calibration data available upon request.

Refrigerant mass flow rate (liquid line)
ELITE Peak Performance Coriolis Flow and Density Meters: CMF025 calibrated in forward and reverse direction within ±0.5% of reading. Calibration data available upon request

Pressure measurement:
Omega PX409 with ±0.08% Full scale of BSL with ±1% span shift over compensated temperature range. Calibration data available upon request.

Indoor Airside temperature measurements Temperature and Relative Humidity:
Vaisala HMD60Y with ±1.5% RH and ±0.15°C. Calibration data available upon request.

Refrigerant side temperature measurements:
Omega in-stream T-type thermocouple is ±1°F. All thermocouples were calibrated against NIST traceable temperature measurement device.

Outdoor Airside measurement:
T-type thermocouple grid ±1°F.

Power measurement: Ohio semitronics PC5 series.
Compressor → PC5-059CX5 0-20 kW ±0.5% F.S.
Outdoor Fan → PC5-002CX5 0-1 kW ±0.5% F.S.
Indoor Blower → PC5-107CX5 0-500 W ±0.5% F.S.

Uncertainty propagation for the R410A Cooling Test A based on air side performance is:

Q=62933 [Btu/hr] ±4194 (±6.7%)
EER=14.12 [Btu/hr-W] ±0.9934 (±7.0%)