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

TEST REPORT #10

System Soft-Optimized Test Of Refrigerant HFO-1234yf (R-1234yf) in a Split System Heat Pump (with Addendum)

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April 5, 2013
Updated on April 24, 2013

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

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List of Tested Refrigerant's Composition (Mass%)

R-1234yf	R-1234yf (100)

1. Introduction:

   This document reports performance testing conducted on a 3.5 Ton split-system heat pump, originally designed for operation with R410A. It was tested R410A and then modified to be able to use HFO1234yf refrigerant. This new refrigerant is a near drop-in for R-134a but significant changes were needed to the heat pump to enable useful data to be collected. The changes were:

   - Suction / Liquid Heat Exchanger Added (Packless HXR-150)
   - R134a Scroll Refrigeration Compressor Substituted (Emerson Climate ZB38KCE-PFV)
   - R134a-type Thermostatic Expansion Valves Substituted (Indoor and Out)
   - Indoor Heat Exchanger Refrigerant Circuits Increased From 6 to 12
   - Outdoor Heat Exchanger Refrigerant Circuits Increased From 6 to 9

   This testing occurred during November and December of 2012 at the Lennox Product Development and Research Center in Carrollton, TX.
   The motivation for this work was to investigate the suitability of lower Global Warming Potential (GWP) refrigerants as candidate replacements for the HFC refrigerant: R410A. These two refrigerants have GWPs (100 year basis) of:

   R410A: 2088
   HFO1234yf : 4

2. Details of Test Setup:

   a. <u>Description of System</u>

   The outdoor unit is designated as a 14HPX-042 (Lab Inventory Control # 29882). This R410A heat pump uses a scroll-type compressor (ZP36K5E-PFV) and has a thermostatic expansion valve for refrigerant flow control in the heating mode. It uses POE oil. The calorimetered sample compressor was provided by Emerson Climate Technologies.

   The indoor unit is a multi-position coil-blower. The model number is CBX26UH-042 (Lab Inventory Control #29880). This air handler uses a PSC-type direct drive blower and was tested in the upflow configuration. The air flow was set for nominal 1400 CFM (normal for a 3 ½ ton air conditioner).

   The AHRI 210/240 Directory ratings for this system are:

   AHRI #5184649

   14HPX-042-230-18 + CBX26UH-042*+TDR

   Classification: HRCU-A-CB

   Cooling Capacity (Btuh): 42500

EER Rating (Cooling): 12.00

SEER Rating (Cooling): 14.00

Heating Capacity (Btuh) @ 47 F: 45500

Region IV HSPF Rating (Heating): 8.20

Heating Capacity (Btuh) @ 17 F: 28200

This system tested 98% of "A" capacity, 103% of "A" EER and 105% of SEER.

b. Description of Modifications

A refrigerant flow meter was placed in the liquid line. Pressure taps were placed at the liquid service valve, on the compressor suction and discharge lines and on the liquid line at the inlet to the indoor expansion valve. Thermocouples were placed on the outside of refrigerant piping. Adjustable stems were placed on the expansion valves to enable some superheat adjustment. **These modifications were retained for all testing.**

When R410A testing was complete, a R134a refrigeration compressor (ZB38KCE-PFV) was substituted for the R410A compressor. Both compressors were scroll-type units and were made by the same company. However, the R134a compressor was designed for refrigeration duty and was not perfectly suited for an air conditioning application. When viewing results, this mis-application should be borne in mind. Standard 45F/130F compressor ratings:

Compressor	EER	Capacity (BTUH)
ZP36K5E-PFV	10.18	36,037
ZB38KCE-PFV	9.70	37,600

Both heat exchangers were re-circuited to provide more parallel flow paths for refrigerant flow. (There was no change to the air-side or net refrigerant-side heat transfer surface area.) This re-circuiting was advisable because the operating pressure difference of the system would be much lower.

R134a expansion valves were substituted for the R410A ones and we found that they worked reasonably well with HFO1234yf.

Preliminary testing of the modified system revealed that capacity and efficiency were both low compared to the R410A system. We found, in the technical literature, that a suction / liquid heat exchanger could boost system efficiency so we installed one (Packless HX-150) in the lines between the indoor and outdoor units (to get a boost in cooling mode). We did find a slight improvement in cooling performance (1% - 2%) so this heat exchanger was left in the system for all the testing reported here.

Note that the size of the interconnection piping between indoor and outdoor units was not changed. In a new installation scenario, larger interconnecting pipes would be used with HFO1234yf to reduce pressure drops in the system. We did not change them because most installations are retrofits and leaving them "as is" better represents what would typically happen in the field – it is often very difficult to change-out line sets in an existing home.

c. Description of Tests Conducted

The heat pump was evaluated using a pair of psychrometric test chambers. The indoor portion of the heat pump was connected to an AMCA 210 Code Tester. There are dry bulb/wet bulb temperature samplers on the inlet and outlet air streams. This enables measurement of air side capacity. A coriolis-type flow meter is used to determine refrigerant mass flow rate. With temperature and pressure sensors to establish refrigerant thermodynamic states, the refrigerant capacity can also be measured. An energy balance is determined between the two capacity measurements. The psychrometric test facility is operated as a certified satellite facility and is under an annual calibration system traceable to NIST standards. All instruments were determined to be within accuracy specifications at the conclusion of baseline testing with R410A.

The tests that have been conducted are the set of tests required to establish SEER and HSPF ratings according to AHRI 210/240. The test data from the steady-state tests are included in this report. The non-steady-state tests were also conducted but only the cyclic degradation values are included in the report.

The R410A compressor used was one that was furnished to us with calorimeter data for the 50F/100F and 45F/130F test points. We found that the performance improved after a run-in period for this compressor. Data presented is post “run-in” for both R410A and HFO1234yf systems.

The approach taken was to charge the R410A system to achieve the subcooling and superheat values that matched production verification testing of this model’s performance on the AHRI 210/240 “B” test (82F outdoor temperature). When we started the HFO1234yf testing, we charged the unit to achieve approximately the same subcooling on the “B” test. This charge level meant we used about 2% more refrigerant, by weight. We did not exhaust the possible variations in charge and TXV settings to optimize performance. When we saw that we achieved reasonable operation in the heating mode we did not do any further charge adjustment.

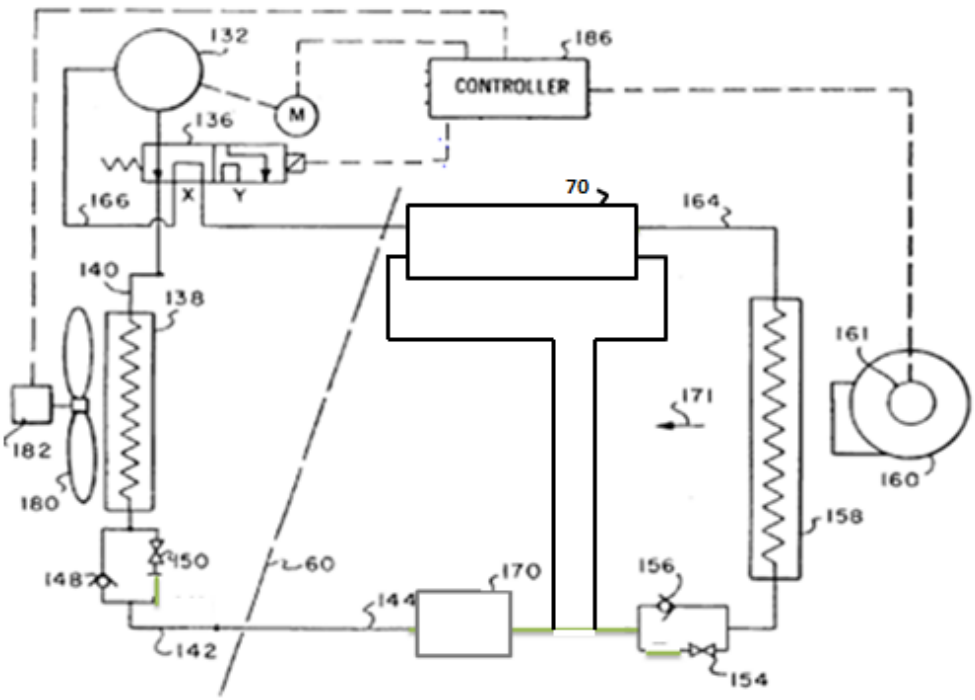


Figure 1. Diagram of Split-System Heat Pump

Legend:
60 – Separation line between outdoor and indoor components
70 – Suction / Liquid Heat Exchanger
132 – Compressor
136 – Reversing Valve
138 – Outdoor Heat Exchanger
140 – Vapor Line to Outdoor Heat Exchanger
142 – Location of Liquid Service Valve
144 – Liquid Line
148 – Outdoor Refrigerant Check Valve
150 - Outdoor Thermostatic Expansion Valve
154 – Indoor Thermostatic Expansion Valve
156 – Indoor Refrigerant Check Valve
158 – Indoor Heat Exchanger
160 – Indoor Blower
161 – Indoor Blower Motor
164 – Vapor Line to Indoor Heat Exchanger
166 – Compressor Discharge Line
170 – Coriolis-Effect Refrigerant Flow Meter
171- Conditioned Air Delivered to Air Flow Measuring Equipment
180 – Outdoor Fan
182 – Outdoor Fan Motor
186 – Low Voltage Control Panel

3. Results

This page provides information that relates to the heat pump system itself.

Subsequent pages provide information gathered from the cooling and heating mode tests.

Basic Information	
Alternative Refrigerant	R1234yf
Alternative Lubricant	3MAF-POE
Baseline Refrigerant and Lubricant	R410A + 3MAF-POE
Make and Model of System	Lennox 14HPX-042 + CBX26UH-042
Nominal Capacity and Type of System	3.5 Ton Split Heat Pump

Other System Changes
Suction / Liquid Heat Exchanger Used (Packless HXR-150)
R134a Scroll Refrigeration Compressor Used (Emerson Climate ZB38KCE-PFV)
R134a-type Thermostatic Expansion Valves Used
Indoor Heat Exchanger Refrigerant Circuits Increased From 6 to 12 circuits
Outdoor Heat Exchanger Refrigerant Circuits Increased From 6 to 9 circuits

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient (Cooling) – Cd	0.044	0.033	0.75
Seasonal Energy Efficiency Ratio - SEER	14.68	11.18	0.76
Degradation Coefficient (Heating) – Cd	0.109	0.11	1.01
Heating Seasonal Performance Factor – HSPF (region IV, min DHR)	9.07	7.26	0.80

Test Data Form for Test: "A" Test

Type of System: Split HP

Alternate Refrigerant: HFO1234yf

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	39.84	39.32	m ^ 3/min	1407	1389	CFM	0.987
Inlet Temperature	26.67/19.44	26.67/19.44	C	80.0/67.0	80.0/67.0	F	
Outlet Temperature	15.33/14.28	15.44/14.44	C	59.6/57.7	59.8/58.0	F	
Condenser							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	123.1	123.1	m ^ 3/min	4347	4347	CFM	1.0
Inlet Temperature	35	35	C	95.0	95.0	F	
Outlet Temperature	not measured	not measured	C	not measured	not measured	F	
Net Air-Side Cooling Capacity	12.24	11.65	kW	41770	39738	BTUH	

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	19.5	1067	20.3	380	67.1	154.8	68.5	55.1
Compressor Discharge	69.4	2548	58.5	1091	157	369.6	137.3	158.2
Condenser Inlet	69.4	2548	58.5	1091	157	369.6	137.3	158.2
Condenser Outlet	38.7	2484	38.9	1068	101.7	360.2	102.0	154.9
Expansion Device Inlet	38.2	2444	34.6	978	100.8	354.4	94.3	141.9
Subcooling, at expan. device	2.4		3.9		4.3		7	
Evaporator Inlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Outlet	15.3	1083	12.8	436	59.6	157	55.0	63.3
Evaporator Superheat	5.3		2.8		9.6		5	
Net Refrigerant-Side Cooling Capacity					42001 BTUH		38581 BTUH	

Test Data Form for Test: "A" Test
Type of System: Split HP Alternate Refrigerant: HFO1234yf

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			scroll	scroll					
Compressor Displacement			0.122	0.288	M^3/min	4.32	10.21	Ft ^3/min	2.36
Nominal Motor Size			n/a	n/a	hp				
Motor Speed			3500	3500	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.242	1.89	liters	42	64	fl. oz.	1.52
Refrigerant Charge			6.35	6.46	kg	14	14.25	lb	1.02
Refrigerant Mass Flow Rate			273.4	339.3	kg/hr	602.8	748.2	lb/hr	1.24
Composition, at compr. Inlet if applicable				n/a	n/a				
Ambient Temps.	In - door	db	26.67	26.67	C	80.0	80.0	F	
		wb	19.44	19.44	C	67.0	67.0	F	
	Out - door	db	35	35	C	95.0	95.0	F	
		wb	n/a	n/a	C	n/a	n/a	F	
Total Capacity			12242	11650	W	41770	39738	Btu/hr	0.95
Sensible Capacity			9059	8842	W	30910	30168	Btu/hr	0.98
Total System Power Input			3376	3947	W	3376	3947	W	1.17
Compressor Power Input			2685	3222	W	2685	3222	W	1.2
Energy Efficiency Ratio (EER)			12.35	10.07	W/W	12.35	10.07	Btuh/W	0.82
Coeff. Of Performance* (COP)			3.62	2.95					0.82

Data Source(s) for Refrigerant Properties
NIST REFPROP Version 9

Submitted By:
Uselton / Daaboul

Test Data Form for Test: "B" Test

Type of System: Split HP

Alternate Refrigerant HFO1234yf

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	39.87	39.36	m ^ 3/min	1408	1390	CFM	0.99
Inlet Temperature	26.67/19.44	26.67/19.39	C	80.0/67.0	80.0/66.9	F	
Outlet Temperature	14.94/13.83	15.33/14.22	C	58.9/56.9	59.6/57.6	F	
Condenser							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	123.1	123.1	m ^ 3/min	4347	4347	CFM	1
Inlet Temperature	27.78	27.78	C	82.0	82.0	F	
Outlet Temperature	n/a	n/a	C	n/a	n/a	F	
Net Air-Side Cooling Capacity	13.13	11.99	kW	44807	40906	BTUH	

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	18.2	1044	19.2	365	64.8	151.4	66.5	53.0
Compressor Discharge	59.4	2118	52.2	907	139	307.2	125.9	131.6
Condenser Inlet	59.4	2118	52.2	907	139	307.2	125.9	131.6
Condenser Outlet	30.7	2060	31.7	883	87.2	298.8	89.0	128.1
Expansion Device Inlet	30.6	2022	28.7	803	87.1	293.3	83.6	116.4
Subcooling, at expan. device	2.3		2.2		4.1		4	
Evaporator Inlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Outlet	15.2	1059	14.1	423	59.4	153.6	57.3	61.4
Evaporator Superheat	6.0		2.8		10.8		9	
Net Refrigerant-Side Cooling Capacity					44996 BTUH		40644 BTUH	

Test Data Form for Test: "B" Test
Type of System: Split HP Alternate Refrigerant HFO1234yf

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			scroll	scroll					
Compressor Displacement			0.122	0.288	M^3/min	4.32	10.21	Ft ^3/min	2.36
Nominal Motor Size			n/a	n/a	hp				
Motor Speed			3500	3500	rpm				1.00
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.242	1.89	liters	42	64	fl. oz.	1.52
Refrigerant Charge			6.35	6.46	kg	14	14.25	lb	1.02
Refrigerant Mass Flow Rate			174.4	211.0	kg/hr	595.0	722.9	lb/hr	1.21
Composition, at compr. Inlet if applicable				n/a	n/a				
Ambient Temps.	In - door	db	26.67	26.67	C	80.0	80.0	F	
		wb	19.44	19.39	C	67.0	66.9	F	
	Out - door	db	35	27.78	C	82.0	82.0	F	
		wb	n/a	n/a	C	n/a	n/a	F	
Total Capacity			13132	11989	W	44807	40906	Btu/hr	0.91
Sensible Capacity			9468	8941	W	32306	30508	Btu/hr	0.94
Total System Power Input			2983	3597	W	2983	3597	W	1.21
Compressor Power Input			2287	2871	W	2287	2871	W	1.26
Energy Efficiency Ratio (EER)			15.02	11.37	W/W	15.02	11.37	Btuh/W	0.76
Coeff. Of Performance (COP)			4.40	3.34					0.76

Data Source(s) for Refrigerant Properties
NIST REFPROP Version 9

Submitted By:
Uselton/Daaboul

Test Data Form for Test: "H1" Test
Type of System: Split HP Alternate Refrigerant HFO1234yf

Air Side Data	**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Evaporator							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	123.1	123.1	m ^ 3/min	4347	4347	CFM	1
Inlet Temperature	8.33/6.11	8.28/6.11	C	47.0/43.0	46.9.43.0	F	
Outlet Temperature	n/a	n/a	C	n/a	n/a	F	
Condenser							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	39.67	39.02	m ^ 3/min	1399	1390	CFM	0.99
Inlet Temperature	21.11	21.11	C	70.0	70.0	F	
Outlet Temperature	37.56	37.67	C	99.6	96.8	F	
Net Air-Side Heating Capacity	12.97	11.80	kW	44625	40264	BTUH	

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	8.3	838	7.8	303	47.7	121.3	46.0	43.9
Compressor Discharge	77.3	2830	50.2	1216	170.8	407.5	122.4	176.4
Condenser Inlet	73.9	2822	48.4	1206	164.7	406.2	119.2	174.9
Condenser Outlet	25.0	2779	27.6	1188	77.4	400.1	81.7	172.3
Expansion Device Inlet	23.4	2750	32.8	1155	74.7	395.7	91.0	167.5
Subcooling, at expan. device	20.9		12.8		36.8		23	
Evaporator Inlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Outlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Superheat	6.8		2.8		13.1		16	
Net Refrigerant-Side Heating Capacity					46214 BTUH		41861 BTUH	

Test Data Form for Test: "H1" Test
Type of System: Split HP Alternate Refrigerant HFO1234yf

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Heating						
Compressor Type			scroll	scroll					
Compressor Displacement			0.122	0.288	M^3/min	4.32	10.21	Ft ^3/min	2.36
Nominal Motor Size			n/a	n/a	hp				
Motor Speed			3500	3500	rpm				1.00
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.242	1.89	liters	42	64	fl. oz.	1.52
Refrigerant Charge			6.35	6.46	kg	14	14.25	lb	1.02
Refrigerant Mass Flow Rate			210.2	273.8	kg/hr	463.6	603.9	lb/hr	1.30
Composition, at compr. Inlet if applicable				n/a	n/a				
Ambient Temps.	In - door	db	21.11	21.11	C	70.0	70.0	F	
		wb	n/a	n/a	C	n/a	n/a	F	
	Out - door	db	8.33	8.28	C	47.0	46.9	F	
		wb	6.11	6.11	C	43.0	43.0	F	
Total Capacity			13079	11801	W	44625	40264	Btu/hr	0.90
Sensible Capacity			13079	11801	W	44625	40264	Btu/hr	0.90
Total System Power Input			3704	4129	W	3704	4129	W	1.11
Compressor Power Input			2978	3380	W	2978	3380	W	1.13
Energy Efficiency Ratio (EER)			n/a	n/a	W/W	n/a	n/a	Btuh/W	n/a
Coeff. Of Performance (COP)			3.53	2.86					0.81

Data Source(s) for Refrigerant Properties
NIST REFPROP Version 9

Submitted By:
Uselton/Daaboul

Test Data Form for Test: "H3" (17F Steady State Heating)

Type of System: Split HP

Alternate Refrigerant: HFO1234yf

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	123.1	123.1	m ^ 3/min	4347	4347	CFM	1.00
Inlet Temperature	-8.4	-8.4	C	17.0	17.0	F	
Outlet Temperature	n/a	n/a	C	n/a	n/a	F	
Condenser							
Heat Exchange Fluid	R410A	HFO1234yf					
Flow Rate (air side)	39.5	39.4	m ^ 3/min	1395	1390	CFM	1
Inlet Temperature	21.11	21.06	C	70.0	69.9	F	
Outlet Temperature	32.22	30.72	C	90.0	87.3	F	
Net Air-Side Heating Capacity	8.80	7.61	kW	30032	25980	BTUH	

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	-8.6	524	-6.5	190	16.5	76.1	20.3	27.5
Compressor Discharge	77.9	2416	43.1	969	172.3	350.4	109.5	140.6
Condenser Inlet	70.6	2410	42.0	966	159.0	349.5	107.6	140.1
Condenser Outlet	22.2	2398	25.3	953	72.0	347.9	77.6	138.2
Expansion Device Inlet	18.9	2384	25.6	946	66.0	345.8	78.0	137.2
Subcooling, at expan. device	17.6		11.7		31.7		21	
Evaporator Inlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Outlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Superheat	3.8		2.8		6.9		14	
Net Refrigerant-Side Heating Capacity					30013 BTUH		27255 BTUH	

Test Data Form for Test: "H3" (17F Steady State Heating)
Type of System: Split HP Alternate Refrigerant: HFO1234yf

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Heating						
Compressor Type			scroll	scroll					
Compressor Displacement			0.122	0.288	M^3/min	4.32	10.21	Ft ^3/min	2.36
Nominal Motor Size			n/a	n/a	hp				
Motor Speed			3500	3500	rpm				1.00
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.242	1.89	liters	42	64	fl. oz.	1.52
Refrigerant Charge			6.35	6.46	kg	14	14.25	lb	1.02
Refrigerant Mass Flow Rate			130.0	172.9	kg/hr	286.7	381.5	lb/hr	1.33
Composition, at compr. Inlet if applicable				n/a	n/a				
Ambient Temps.	In - door	db	21.11	21.06	C	70.0	69.9	F	
		wb	n/a	n/a	C	n/a	n/a	F	
	Out - door	db	-8.33	-8.33	C	17.0	17.0	F	
		wb	-9.39	-9.44	C	15.1	15.0	F	
Total Capacity			8802	7614	W	30032	25980	Btu/hr	0.86
Sensible Capacity			8802	7614	W	30032	25980	Btu/hr	0.86
Total System Power Input			3427	3600	W	3427	3600	W	1.05
Compressor Power Input			2698	2834	W	2698	2834	W	1.05
Energy Efficiency Ratio (EER)			n/a	n/a	W/W	n/a	n/a	Btuh/W	n/a
Coeff. Of Performance (COP)			2.57	2.11					0.82

Data Source(s) for Refrigerant Properties
NIST REFPROP Version 9

Submitted By:
Uselton/Daaboul

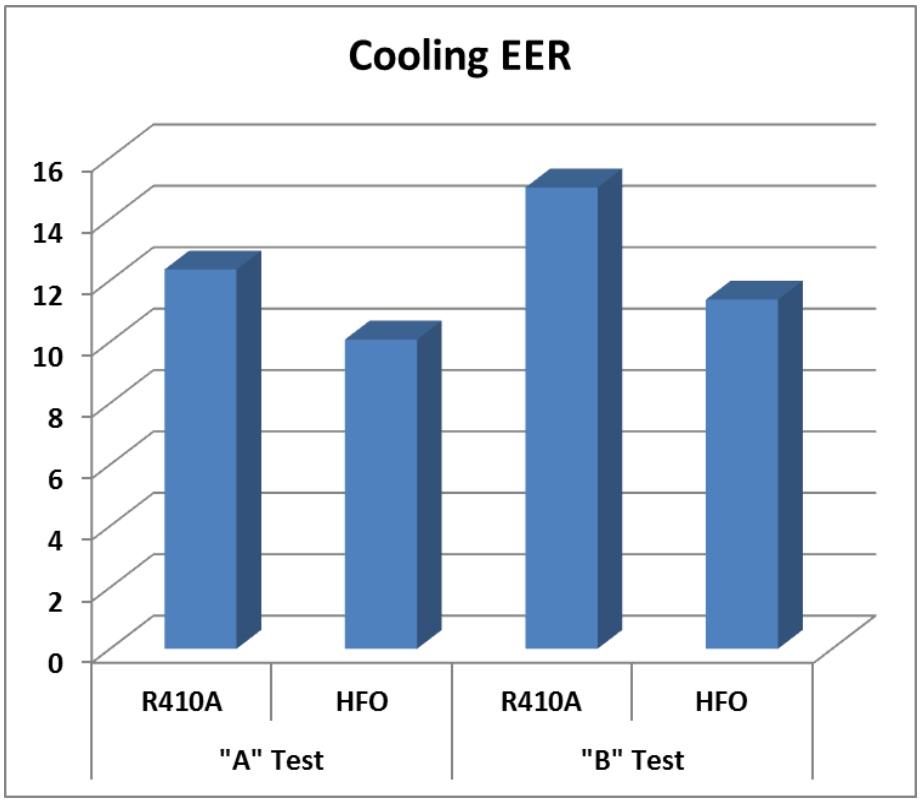
4. Conclusions

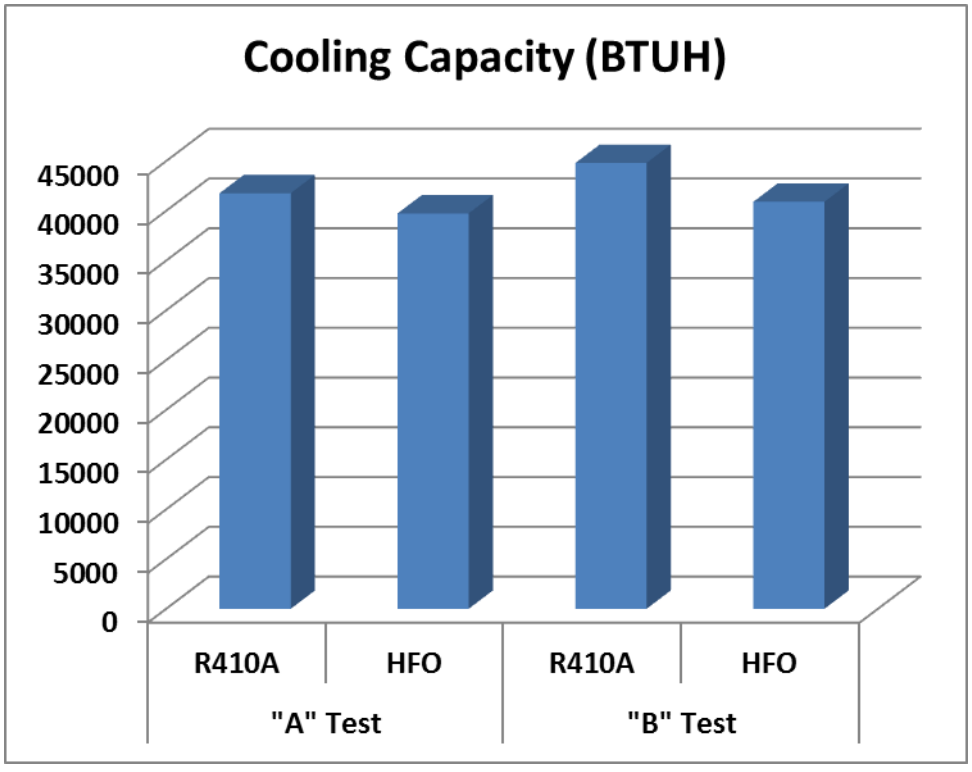
The alternate refrigerant worked successfully in this heat pump chassis, but only with significant equipment modifications. (Long-term reliability has not been established.) During testing, it was necessary to take precautions for protection of personnel and our facility since HFO1234yf is mildly flammable, having an ASHRAE A2L refrigerant designation.

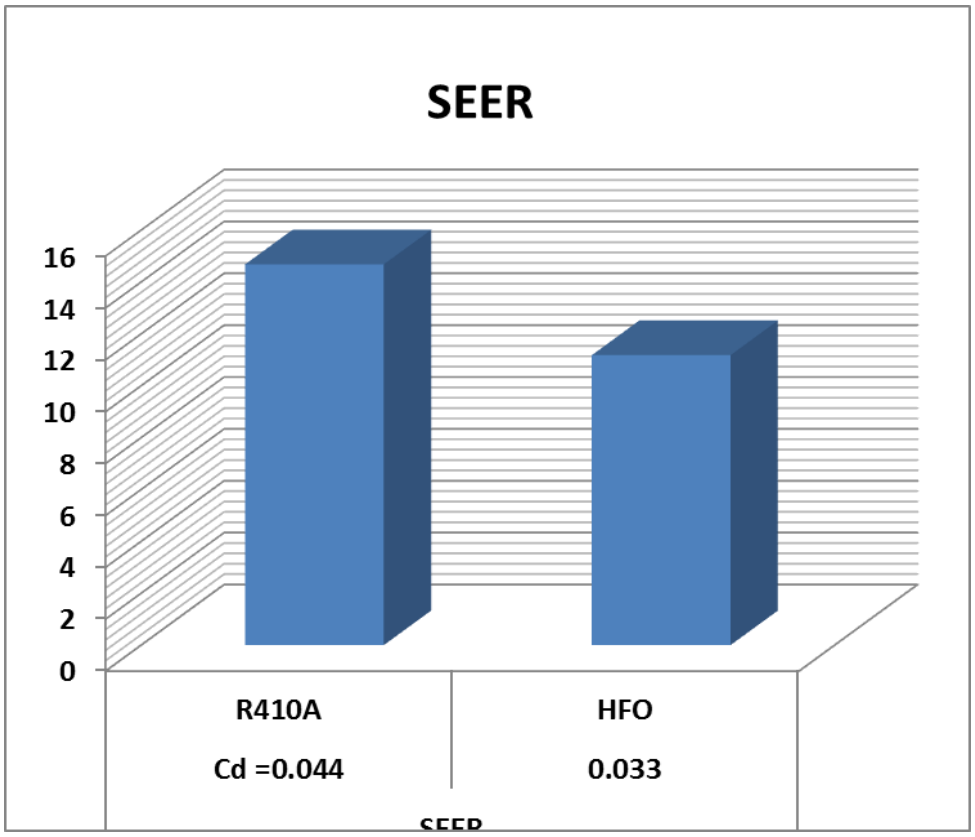
- For HFO1234yf testing, capacities and efficiencies dropped in both heating and cooling modes.
- Mass flow rates were higher and system pressures much lower.
- There is an indication that the heat transfer characteristics of the low pressure system are less favorable since we saw less cooling capacity for the same saturated evaporator temperature.
- We found that R134a thermostatic expansion valves worked pretty well with HFO1234yf.
- The compressor discharge temperatures were always very low compared to what we would see on a R410A system.
- The charge quantity for HFO1234yf was 102% of the charge quantity for R-410A. The GWP of HFO1234yf is 4. In a Life Cycle Climate Performance (LCCP) calculation, the direct warming contribution will be reduced to less than 0.5% of the contribution from R-410A for the tested system. Since the energy efficiency of this soft-optimized system was around 82% of the original system, the overall climate performance is worse due to extra energy consumed. (The AHRI LCCP HP 1.0 program was used to generate the following set of results.)

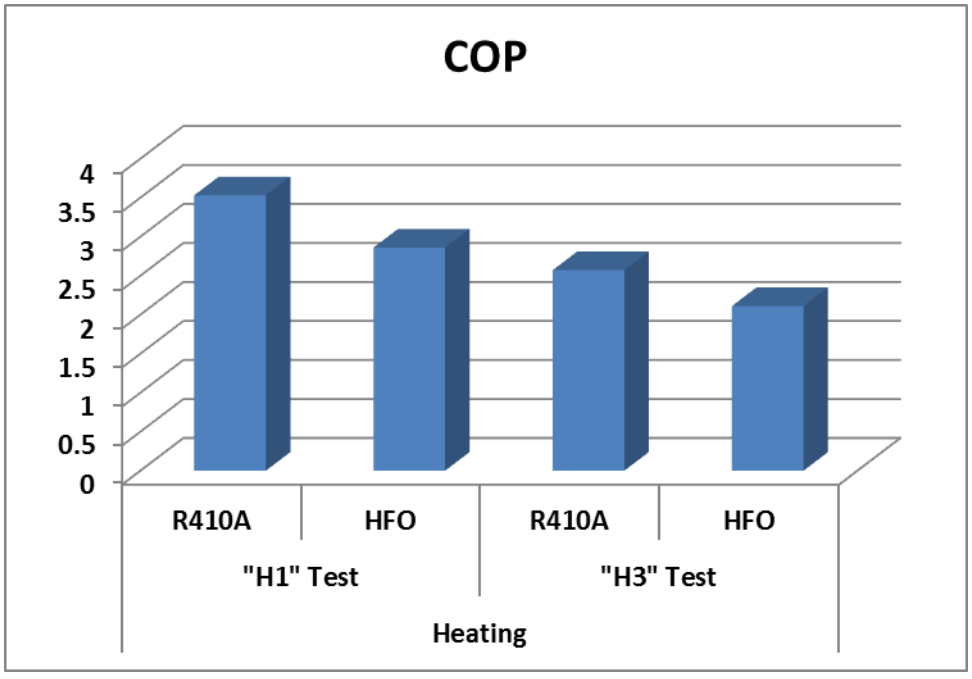
Detailed Results:

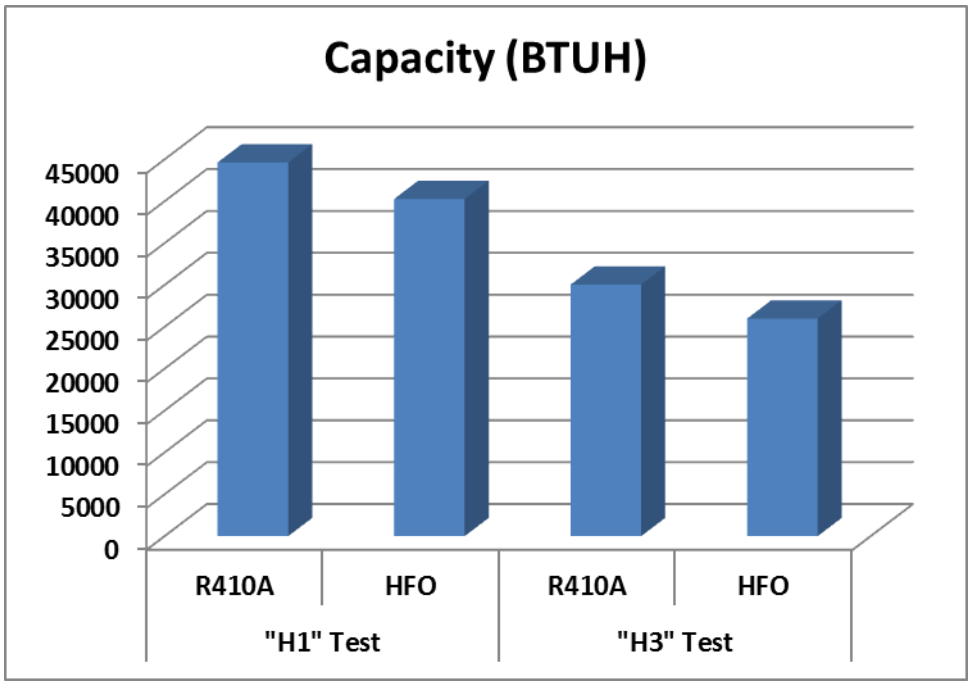
Case #		1	2
Case Name		System A	System B
HP Data Worksheet		R410A	HFO
City		DALLAS-FORT WORTH	DALLAS-FORT WORTH
Refrigerant		R410A	R1234yf
Total Lifetime Emission	kg CO2-Eq.	112332	114642
Total Direct Emission	kg CO2-Eq.	16906	77
Ref. Leakage	kg/year	0.48	0.48
Emission - Ref. Leakage	kg CO2-Eq.	14917	44
Ref. Loss at EOL	kg	0.95	0.97
Emission - Ref. Loss at EOL	kg CO2-Eq.	1989	6
Emission - Decomposition	kg CO2-Eq.		27
Total Indirect Emission	kg CO2-Eq.	95426	114565
Annual Energy Consumption	kW-hr	7580	9113
Emission - Energy Consumption	kg CO2-Eq.	94823	114006
Emission - Equipment Mfg	kg CO2-Eq.	580	536
Emission - Equipment EOL	kg CO2-Eq.	23	23
Detailed Energy Calculation			
Total Annual Energy Consumption	kW-hr	7580	9113
Annual Cooling Energy	kW-hr	4666	5829
Annual Heating Energy	kW-hr	2913	3284
Backup Heat	kW-hr		

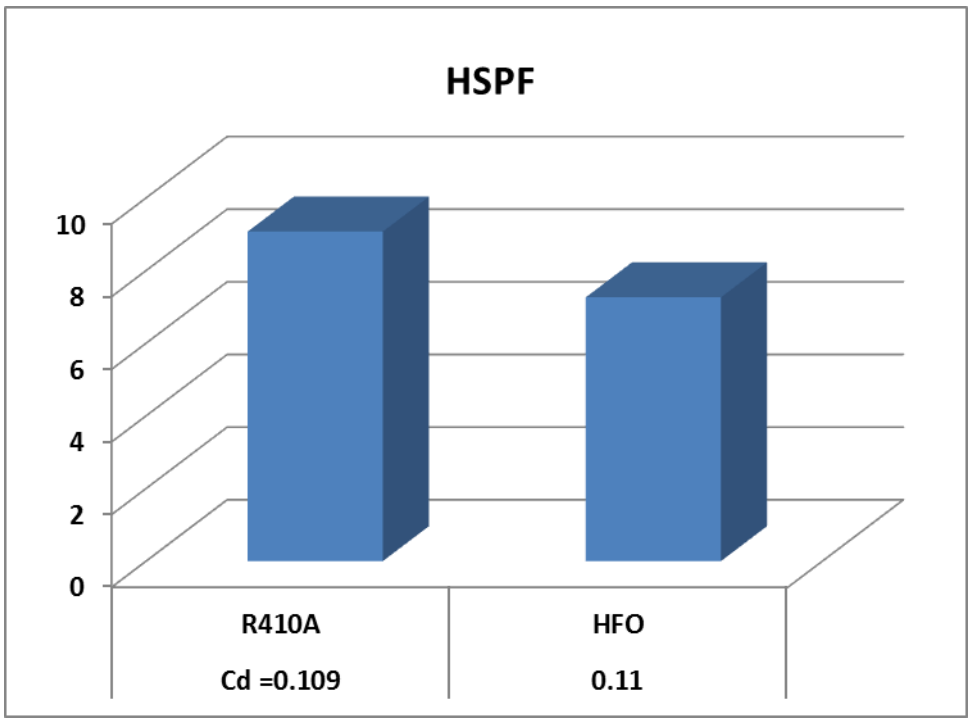

Cooling EER
16
14
12
10
8
6
4
2
0
R410A
HFO
R410A
HFO
"A" Test
"B" Test


Cooling Capacity (BTUH)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
R410A
HFO
R410A
HFO
"A" Test
"B" Test


SEER
16
14
12
10
8
6
4
2
0
R410A
Cd =0.044
HFO
0.033
SEER


COP
4
3.5
3
2.5
2
1.5
1
0.5
0
R410A
HFO
R410A
HFO
"H1" Test
"H3" Test
Heating


Capacity (BTUH)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
R410A
HFO
R410A
HFO
"H1" Test
"H3" Test


HSPF
10
8
6
4
2
0
R410A
HFO
Cd =0.109
0.11

ADDENDUM

Note: Participating companies have the option to perform additional tests at high ambient operating conditions, appropriately selected according to the equipment type. This data was collected for cooling operation at 115F (46.1C) outdoor ambient.

Test Data Form for Test: 115F Test
Type of System: Split HP Alternate Refrigerant: R1234yf

Air Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	R410A	R1234yf					
Flow Rate (air side)	39.84	39.96	m ^ 3/min	1407	1411	CFM	1.00
Inlet Temperature	26.67/19.4	26.7/19.4	C	80.0/67.0	80.0/67.0	F	
Outlet Temperature	16.0 / 14.8	15.7 / 14.8	C	60.8/58.7	60.2/58.6	F	
Condenser							
Heat Exchange Fluid	R410A	R1234yf					
Flow Rate (air side)	123.1	123.1	m ^ 3/min	4347	4347	CFM	1.00
Inlet Temperature	46.1	46.1	C	115.0	115.0	F	
Outlet Temperature	not measured	not measured	C	not measured	not measured	F	
Net Air-Side Cooling Capacity			kW	37217	37266	BTUH	

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	50.4	1103	17.1	397	122.8	160	62.8	57.5
Compressor Discharge	85.8	3269	68	1421	186.4	474	155	206
Condenser Inlet	79.4	3269	65	1421	175	474	149	206
Condenser Outlet	49.9	3200	49	1393	121.8	464	120.5	202
Expansion Device Inlet	49.1	3158	47.9	1317	120.3	458	118.2	191
Subcooling, at expan. device	2.3		2.6		4.1		4.6	
Evaporator Inlet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evaporator Outlet	16.2	1117	13.2	445	61.2	162	55.7	64.5
Evaporator Superheat	5.2		2.7		9.4		4.8	
Net Refrigerant-Side Cooling Capacity					BTUH 36985		BTUH 34363	

Test Data Form for Test: 115F Test
Type of System: Split HP Alternate Refrigerant: R1234yf

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			scroll	scroll					
Compressor Displacement			0.122	0.122	M^3/min	4.32	4.32	Ft ^3/min	1.00
Nominal Motor Size			n/a	n/a	hp				
Motor Speed			3500	3500	rpm				1.00
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.242	1.242	liters	42	42	fl. oz.	1.00
Refrigerant Charge			6.35	4.863	kg	14	10.72	lb	0.77
Refrigerant Mass Flow Rate*			276	355	kg/hr	607.4	783.4	lb/hr	1.29
Composition, at compr. Inlet if applicable				n/a	n/a				
Ambient Temps.	In - door	db	26.67	26.67	C	80.0	80.0	F	
		wb	19.44	19.44	C	67.0	67.0	F	
	Out - door	db	46.1	46.1	C	115.0	115.0	F	
		wb	n/a	n/a	C	n/a	n/a	F	
Total Capacity			10908	10922	W	37217	37266	Btu/hr	1.0
Sensible Capacity			8521	8681	W	29075	29619	Btu/hr	1.02
Total System Power Input			4115	4547	W	4115	4547	W	1.10
Compressor Power Input			3429	3863	W	3429	3863	W	1.13
Energy Efficiency Ratio (EER)			n/a	n/a	W/W	9.01	8.23	Btuh/W	0.91
Coeff. Of Performance* (COP)			2.64	2.41					0.91

Data Source(s) for Refrigerant Properties
NIST REFPROP Version 9

Submitted By:
Uselton / Crawford