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

TEST REPORT #31

System Drop-in Test of Refrigerant R-32 in Split Air-conditioning System

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1. Introduction

To support the Low-GWP AREP as well as to find an appropriate alternative for refrigerant R410A, we carried out the performance test of R32 in cooling mode as a drop-in replacement for the baseline R410A, in a pair of rooms based on the air-enthalpy test method at Shanghai Hitachi's test center.

2. Test Setup

Testing was conducted with a split air conditioning system produced by GREE (Model KFR-72), which has a nominal capacity of 7350 W (nearly 2Ton), and it was designed for the baseline refrigerant R410A. Both evaporator and condenser in the system are tube-fin type heat exchangers.

We employed a hermetic rotary type of compressor with constant speed. The lubricant inside compressor is a POE type oil that is suitable for both R410A and R32.

On the basis of theoretical thermodynamic calculation, R32 may have a high discharge temperature which would have a negative impact on compressor's reliability. So, we added a flash-tank in the system to control the discharge temperature of R32 when necessary. In addition, two electronic valves were employed as the expansion device.

The schematic diagram and measure points' layout are shown in figure 1. Measuring points are including inlet and outlet temperature of heat exchangers, compressor suction temperature and pressure, compressor discharge temperature and pressure, and air flow rate of the indoor chamber side.

Respecting temperature measurements, we used platinum resistance sensors with errors within -/+0.1K of the quantity measured. As to pressure measurements, we used sensors with errors within ±1% of the pressure measured. YOKOGAWA DR240 Hybrid recorder was used to record the parameters measured by sensors. Other data such as capacity and EER were calculated by the testing software.

All tests here were performed in accordance with AHRI Standard 210/240. System was first run with R410A under test A condition to determine the optimized refrigerant charge. The charge increased 50g at a time to get the maximized EER. After that, test B and C were conducted with the optimized charge. Then, R410A was cleared from system, and the R32 tests were carried out in the same order.
Slight adjustments were made to the orifice diameter inside EEV1 when testing the alternative R32, to seek a better system EER.

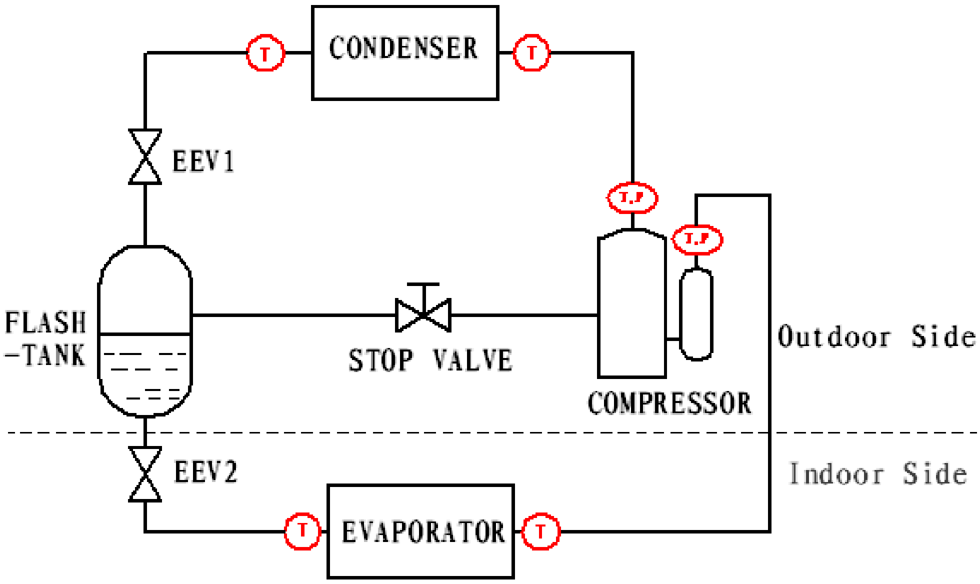

Figure1. Schematic Diagram of Testing System

3. Results

Manufacturer: Shanghai Hitachi (Compressor)
Manufacturer's Notation:
The following information on this page remains same for all the drop-in tests.

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	**R32**
Alternative Lubricant Type and ISO Viscosity	**POE68**
Baseline Refrigerant and Lubricant	**R410A / POE**
Make and Model of System	**System: GREE-KFR-72;** **Compressor: Shanghai Hitachi -ASH280***
Nominal Capacity and Type of System	**7350 W, RAC**

Other System Changes
1. A flash-tank was added in the system as figure 1 shows.
2. The diameter of orifice inside the electronic valves is adjustable in accordance with the given pulse
signal. During R32 test, EEV1 was adjusted to a smaller diameter compared with R410A system, to
seek a better performance.

System Data	**Base.**	**Alt.**	**Ratio**
Degradation Coefficient – Cd	**0.050**	**0.119**	**2.38**
Seasonal Energy Efficiency Ratio - SEER	**12.88**	**13.06**	**1.014**

Data Source(s) for Refrigerant Properties
NIST REFPROP, Version 8.0

Additional Notes
1. During the course of drop-in test, injection was off.
2. The testing system is a room air conditioner having a fixed-speed compressor and a fix-speed indoor
fan.
3. No modification was made to the heat exchangers during the test.
Some parameters of the heat exchanges are listed in following form.

	Type	**Face Area (mm^2)**	**Fin type**	**Fins per inch**	**Number of rows**
Evaporator	Fin-tube	307800 (W*H: 405*760)	Strip type	19	2
Condenser		303750（W*H:405*750）	Wavy	16	2

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

Manufacturer: Shanghai Hitachi

Comparison Data	Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)	Cooling						
Compressor Type	Rotary Type Shanghai Hitachi model# ASH280*						
Compressor Displacement	0.0803	0.0803	M^3/min	2.836	2.836	Ft ^3min	1
Nominal Motor Size	2.5	2.5	hp				1
Motor Speed	2868	2868	rpm				1
Expansion Device Type	EEV	EEV					
Lubricant Charge	0.6	0.6	kg	1.3	1.3	lb	1
Refrigerant Charge	2.15	1.6	kg	4.74	3.53	lb	**0.744**
Refrigerant Mass Flow Rate	3.09	2.26	kg/min	6.81	4.98	lb/min	**0.731**
Composition, at compr. Inlet if applicable			% wt				
Ambient Temps. In - door db	26.7	26.7	C	80	80	F	
Ambient Temps. In - door wb	19.4	19.4	C	67	67	F	
Ambient Temps. Out- door db	35	35	C	95	95	F	
Ambient Temps. Out- door wb	23.9	23.9	C	75	75	F	
Total Capacity	6847	7498	W	23369	25590	Btu/hr	**1.095**
Sensible Capacity	5008	5278	W	17092	18014	Btu/hr	**1.054**
Total System Power Input	2224	2403	W	2224	2403	W	**1.080**
Compressor Power Input	2070	2249	W	2070	2249	W	**1.086**
Energy Efficiency Ratio (EER) （total	3.08	3.12	W/W	10.51	10.65	Btuh/W	**1.013**
Coeff. Of Performance (COP) （total							

Note: 1.In the above form, the designed value of motor speed is adopted, and compressor displacement as well as the refrigerant mass flow is calculated in accordance with it.

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

Type of System: split RAC **Alternate Refrigerant: R32**

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)	18.6	18.9	m ^ 3/min	656.9	665.7	ft ^ 3/min	**1.01**
Inlet Temperature	26.7	26.7	C	80.0	80.1	F	
Outlet Temperature	13.8	13.5	C	56.8	56.2	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 Temperature	N/A	N/A	C	N/A	N/A	F	
Outlet Temperature	N/A	N/A	C	N/A	N/A	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	13.6	1037	12.7	1062	56.5	150.4	54.9	154.0
Compressor Discharge	61.8	2728	66.3	2835	143.2	395.6	151.4	411.1
Condenser Inlet	54.4	N/A	42.3	N/A	129.9	N/A	108.2	N/A
Condenser Outlet	41.8	N/A	35	N/A	107.2	N/A	94.9	N/A
Expansion Device Inlet	3.1	N/A	9.6	N/A	5.6	N/A	17.4	N/A
Subcooling, at expan. device	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Evaporator Inlet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Evaporator Outlet	10.8	N/A	10.4	N/A	51.4	N/A	50.7	N/A
Evaporator Superheat	2.3		1.8		4.1		3.2	

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

Manufacturer: Shanghai Hitachi

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Cooling						
Compressor Type			Rotary Type Shanghai Hitachi model# ASH280*						
Compressor Displacement			0.0803	0.0803	M^3/min	2.836	2.836	Ft ^3min	1
Nominal Motor Size			2.5	2.5	hp				1
Motor Speed			2868	2868	rpm				1
Expansion Device Type			EEV	EEV					/
Lubricant Charge			0.6	0.6	kg	1.3	1.3	lb	1
Refrigerant Charge			2.15	1.6	kg	4.74	3.53	lb	**0.744**
Refrigerant Mass Flow Rate			N/A	N/A	kg/min	N/A	N/A	lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	26.7	26.7	C	80	80	F	
		wb	19.4	19.4	C	67	67	F	
	Out- door	db	27.8	27.8	C	82	82	F	
		wb	18.3	18.3	C	65	65	F	
Total Capacity			7563	8108	W	25812	27672	Btu/hr	**1.072**
Sensible Capacity			5255	5525	W	17935	18857	Btu/hr	**1.051**
Total System Power Input			1953	1992	W	6666	6799	W	**1.02**
Compressor Power Input			1799	1838	W	6140	6273	W	**1.022**
Energy Efficiency Ratio (EER)（total）			3.87	4.07	W/W	13.21	13.89	Btuh/W	**1.052**
Coeff. Of Performance (COP) （total）									

Note: 1.In the above form, the designed value of motor speed is adopted, and compressor displacement is calculated in accordance with it.

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

Type of System: split RAC **Alternate Refrigerant: R32**

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)	18.7	18.8	m ^ 3/min	660.4	662.2	ft ^ 3/min	
Inlet Temperature	26.7	26.69	C	80.0	80.0	F	
Outlet Temperature	13.0	12.6	C	55.4	54.6	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 Temperature	N/A	N/A	C	N/A	N/A	F	
Outlet Temperature	N/A	N/A	C	N/A	N/A	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	15.3	981	11.0	1041	59.6	142.26	51.7	150.96
Compressor Discharge	58.9	2321	58.5	2398	138.0	347.74	137.4	347.74
Condenser Inlet	50.6	N/A	49.7	N/A	123.0	N/A	121.4	N/A
Condenser Outlet	33	N/A	34.6	N/A	91.4	N/A	94.2	N/A
Expansion Device Inlet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subcooling, at expan. device	5.2	N/A	4.1	N/A	9.4	N/A	7.4	N/A
Evaporator Inlet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Evaporator Outlet	12.3	N/A	9.5	N/A	54.2	N/A	49.1	N/A
Evaporator Superheat	5.7		1.6		10.2		2.8	

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

Manufacturer: Shanghai Hitachi

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Cooling						
Compressor Type			Rotary Type Shanghai Hitachi model# ASH280*						
Compressor Displacement			0.0803	0.0803	M^3/min	2.836	2.836	Ft ^3min	1
Nominal Motor Size			2.5	2.5	hp				1
Motor Speed			2868	2868	rpm				1
Expansion Device Type			EEV	EEV					
Lubricant Charge			0.6	0.6	kg	1.3	1.3	lb	1
Refrigerant Charge			2.15	1.6	kg	4.74	3.53	lb	**0.744**
Refrigerant Mass Flow Rate			N/A	N/A	kg/min	N/A	N/A	lb/min	N/A
Composition, at compr. Inlet if applicable					% wt				
Ambient Temps.	In - door	db	26.7	26.7	C	80	80	F	
		wb	19.4	19.4	C	67	67	F	
	Out- door	db	27.8	27.8	C	82	82	F	
		wb	13	13	C	55.4	55.4	F	
Total Capacity			6234	6619	W	21276	22590	Btu/hr	**1.062**
Sensible Capacity			5965	6287	W	20358	21457	Btu/hr	**1.054**
Total System Power Input			1924	1969	W	6567	6720	W	**1.023**
Compressor Power Input			1770	1815	W	6041	6195	W	**1.025**
Energy Efficiency Ratio (EER)（total）			3.24	3.36	W/W	11.058	11.468	Btuh/W	**1.037**
Coeff. Of Performance (COP) （total）									

Note: 1.In the above form, the designed value of motor speed is adopted, and compressor displacement is calculated in accordance with it.

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

Type of System: split RAC **Alternate Refrigerant: R32**

Air/Water Side Data	Base.	Alt.	SI Units	Base.	Alt.	IP Units	Ratio
Evaporator							
Heat Exchange Fluid	Air	Air					
Flow Rate (gas)	18.8	18.9	m ^ 3/min	662.2	666.4	ft ^ 3/min	**1.006**
Inlet Temperature	22.9	23.8	C	73.2	74.8	F	
Outlet Temperature	8.1	8	C	46.5	46.4	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 Temperature	N/A	N/A	C	N/A	N/A	F	
Outlet Temperature	N/A	N/A	C	N/A	N/A	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	881	7.2	905	45.0	127.76	45.0	131.24
Compressor Discharge	49.3	2250	55.3	2312	120.7	326.28	131.5	335.27
Condenser Inlet	43.0	N/A	46.5	N/A	109.4	N/A	115.7	N/A
Condenser Outlet	34.0	N/A	33.8	N/A	93.2	N/A	92.9	N/A
Expansion Device Inlet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subcooling, at expan. device	3.0	N/A	3.4	N/A	5.3	N/A	6.0	N/A
Evaporator Inlet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Evaporator Outlet	5.2	N/A	4.9	N/A	41.3	N/A	40.8	N/A
Evaporator Superheat	2.1		1.5		3.7		2.7	

4. Discussions

Detailed parameters obtained through tests are list in the data forms above. The optimized refrigerant charge of baseline R410A system is 2150g, while the charge amount of the alternative refrigerant R32 is 25.6% less. Test A, B and C were carried out with the opt charge of each refrigerants.

To directly compare the performance of baseline and alternative refrigerants, some parameters in test data forms are illustrated in the form of bar graphs as the following four figures.

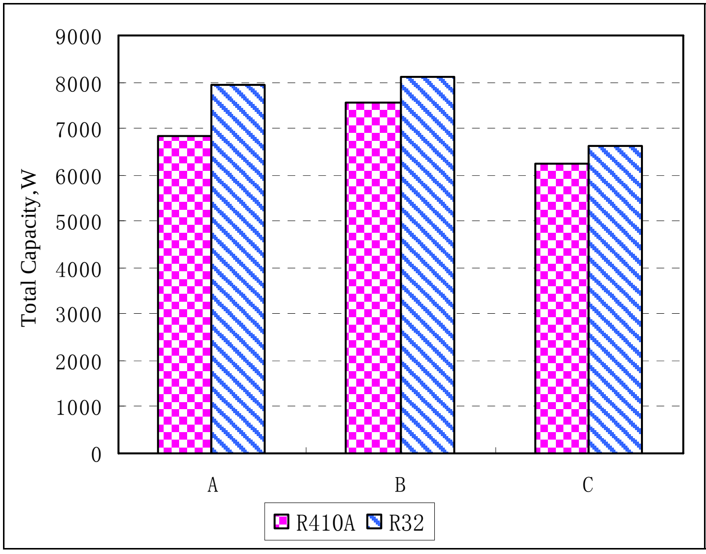

Figure 2:Capacity of R410A and R32

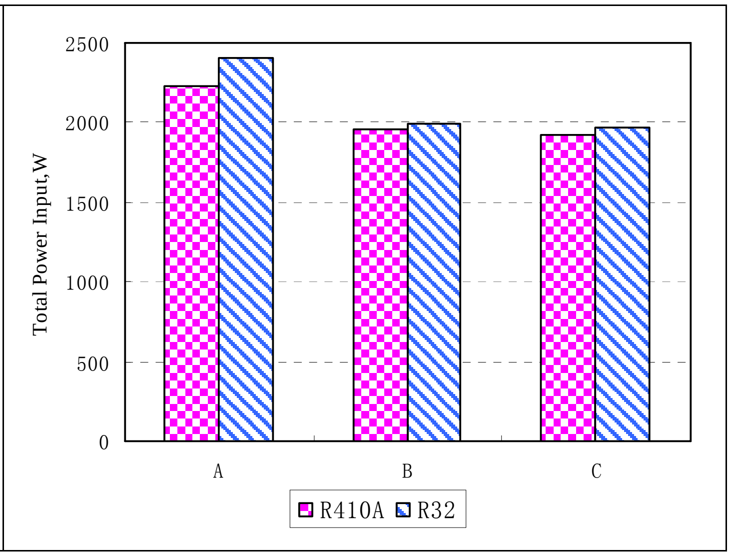

Figure 3:Total Power Input of R410A and R32

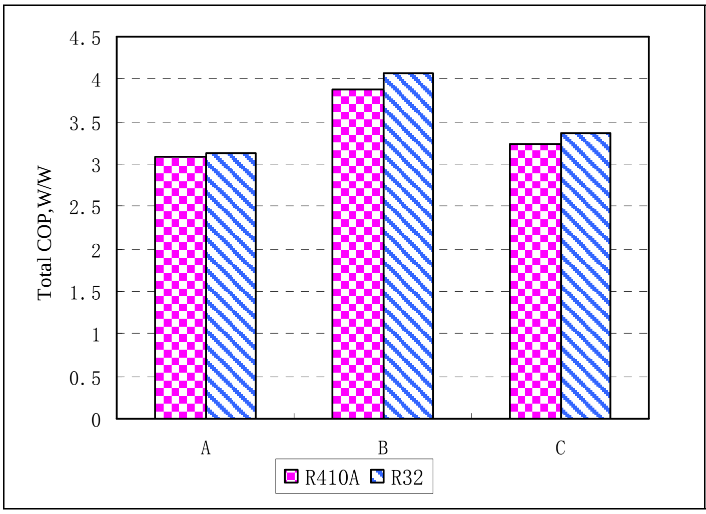

Figure 4:COP of R410A and R32

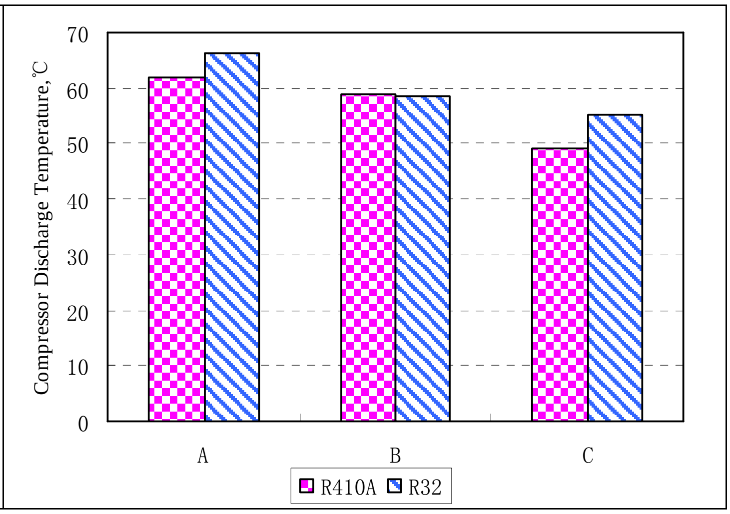

Figure 5: Discharge Temperature of R410A and R32

Figure 2 shows that in all cooling tests conditions, R32 has a better capacity over R410A, and the increment varies from 6.2% to 9.5%. However, since the total power input of R32 system rises accordingly as shown in figure 3, the increment of COP is not so well as capacity.
Figure 4 indicates that comparatively significant performance advantage over baseline system is at B condition by 5.2%, while at test A condition, R32 system has a slight 1.3% COP increment over R410A system.

At first, we worried the high discharge temperature of R32 would affect the compressor reliability, since it is nearly 20 ℃ higher than that of R410A according to thermodynamic calculation. Owing that capacity of both heat exchangers are big enough, the discharge temperature of R32 has been limited. As figure 5 shows, difference of measure discharge temperature between baseline R410A and alternative R32 is within 6℃.

Submitted by: LIU CHUNHUI