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

TEST REPORT #1

System Drop-in Test of R-410A Alternative Fluids (ARM-32a, ARM-70a, DR-5, HPR1D, L-41a, L-41b, and R-32) in a 5-RT Air-Cooled Water Chiller (Cooling Mode)

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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 Refrigerants' Compositions (Mass%)

ARM-32a	R-32/R-125//R-134a/R-1234yf (25/30/25/20)
ARM-70a	R-32/R-134a/R-1234yf (50/10/40)
DR-5	R-32/R-1234yf (72.5/27.5)
HPR1D	R-32/R-744/R-1234ze(E) (60/6/34)
L-41a	R-32/R-1234yf/R-1234ze(E) (73/15/12)
L-41b	R-32/R-1234ze(E) (73/27)
R-32	R-32 (100)

INTRODUCTION

This report documents tests run on a small air-cooled water chiller / heat pump in Trane's La Crosse, Wisconsin, Laboratory. Tests were run in both cooling and heating modes. The refrigerants tested are listed below:

name	order	begin testing	end testing	number of runs
R410A	1	18-Oct-2011	11-Jan-2012	44
R32	2	23-Jan-2012	09-Feb-2012	24
DR-5	3	20-Feb-2012	09-Mar-2012	29
ARM-70a	4	03-May-2012	11-May-2012	20
L-41a	5	29-May-2012	31-May-2012	18
L-41b	6	04-Jun-2012	06-Jun-2012	18
ARM-32a	7	11-Jun-2012	13-Jun-2012	17
HPR1D	8	09-Jul-2012	18-Jul-2012	20

Although ARM-32a is proposed as an alternate for R22/R407C, it was tested here because the facility was available while waiting for the HPR1D to arrive. The results are presented here only for reference and as a possible bridge between the R410A and R22 alternate testing.

TEST SETUP

The equipment being tested is a "Koolman" air-cooled water chiller / heat pump, model CGAR-0605. It has a nominal design cooling capacity of 4.4 RT (15.6 kW). The product is designed to provide chilled or hot water to apartments, offices, or small retail stores. In cooling mode, the evaporator is a brazed plate heat exchanger (BPHE); the condenser is a copper-tube/aluminum-fin coil (RTPF coil).

The production design employs R22 or R407C as the refrigerant. However, the particular unit being tested here has been fitted with a compressor and expansion valve designed for R410A and R32. Following completion of testing with alternate refrigerants proposed as replacements for R410A, the compressor will be replaced with a standard R22 compressor and testing will continue with alternate refrigerants of capacities projected to be closer to R22.

The unit came to us containing a POE 160SZ oil. This oil will be used when testing HFC/HFO refrigerants.

See Figure 1 for photos of the Koolman unit set up in the laboratory. A schematic diagram of the system with locations of instrumentation is shown in Figure 2. Key measurements include chilled water flow rate along with inlet and outlet temperatures (RTD's) and pressures, mixed air temperature, and power input to the compressor and total power to the unit. Pressure sensors are mounted along the refrigerant circuit; thermocouples are surface-mounted at corresponding locations. A list of instrumentation along with sensor accuracies is attached as Appendix A.

METHOD OF TEST

The method of test is consistent with Appendix C of AHRI Standard 550/590-2011 with operating conditions generally held within tighter tolerances. Performance is reported here as measured; no adjustments are made for fouling allowance or elevation. The cooling capacities reported are computed from the measured chilled water flow rate and the difference between the entering and leaving chilled water enthalpies. The enthalpies are computed from the measured water temperatures and pressures. Therefore, the capacity reported here corresponds to the "gross refrigerating capacity" defined in AHRI Standard 550/590-2011. Thermodynamic properties of water are computed using Trane's internal code, which is consistent with the 550/590 equations well within experimental accuracy.

Tests in cooling mode consist of:

1. Refrigerant charge sweep at nominal operating (boundary) conditions of:
   – leaving chilled water temperature = 45°F ±0.1°F
   – chilled water flow rate = 14.0 gpm ±0.1 gpm
   – ambient air temperature = 95°F ±0.15°F
   – compressor suction superheat ~ 10-12°F (TXV adjusted as needed)
   The charge for further testing was selected at maximum EER (0.5 lbm resolution).
2. Variation in leaving chilled water temperature while holding air temperature fixed at 95°F:
   – 41°F ≤ TChWo ≤ 47°F
3. Variation in ambient air temperature while holding leaving water temperature fixed at 45°F:
   – 75°F ≤ Tair ≤ 115°F (unless limited by high pressure cutout switch set at 600 psia)

This test matrix produces several measurements at the nominal operating condition to check repeatability.

The Koolman product is designed for international markets and is rated at the following conditions in cooling mode:

- ambient air temperature = 35°C = 95°F
- leaving chilled water temperature = 7°C = 44.6°F
- entering chilled water temperature = 12°C = 53.6°F
  → chilled water temperature change = 5°C = 9°F

These conditions are slightly different than those listed in AHRI Standard 550/590-2011. To expedite execution of the test matrix, several simplifications to the operating conditions were made. First, the rating point leaving water temperature (7°C) was rounded up to an integer value (45°F). Second, the chilled water flow rate was set at a fixed value of 14 gpm which produced an 8.9°F change in chilled water temperature for the baseline R410A design point run. Adjusting chilled water flow rate for a fixed temperature change is an iterative process and can become time consuming in the laboratory. Although a fixed flow rate, variable entering water temperature can affect the potential refrigerant superheat leaving the evaporator[1], a fixed water flow rate does maintain a nearly constant water-side heat transfer coefficient in the heat exchanger. These simplifications were considered to be minor compromises to maintaining conditions per a formal rating standard and are expected to have negligible impact on the ultimate comparisons of the alternate refrigerants to the baseline.

RESULTS

Overall performance results (capacity and EER), along with the key state points obtained at the nominal operating condition using the charge that maximizes EER are attached as Appendix B for each refrigerant tested. This information is also compiled in a companion Excel file.

Some relatively significant variability in performance was noted from day-to-day with several refrigerants, R32 and DR-5 in particular. The overall performance variability correlated with variability in evaporator performance (the BPHE in cooling mode and the RTPF coil in heating mode). Evidence suggests that the evaporator operating conditions were very near the lubricant/R32 miscibility point. Variations in the start-up transient from day to day likely resulted in running above or below the miscibility temperature, affecting evaporator heat transfer performance, approach temperatures, and therefore compressor suction pressure. The best performing runs are used here for comparison purposes, assuming that the lubricating oil can be formulated to maintain miscibility.

[1] The refrigerant superheat leaving the evaporator is relatively small here – roughly only half of the compressor suction superheat maintained by the TXV. The second portion of the compressor suction superheat is added by heat transfer in the switching four-way valve

A summary of the capacities, EER's, and refrigerant charges relative to performance with the baseline R410A are shown in Figure 3, Figure 4, and Figure 5, respectively. Also shown are values for the capacity and EER (COP) predicted by a simple thermodynamic cycle model. The simple model ignores line pressure drops and so assumes the evaporator pressure equals the compressor suction pressure and the condenser pressure equals the compressor discharge pressure. The model inputs (compressor suction pressure → evaporator saturation temperature, compressor suction superheat, compressor discharge pressure → condenser saturation temperature, condenser subcooling, and compressor adiabatic efficiency) were set to match those for the R410A baseline experimental data. The switching valve for cooling or heating model is assumed to behave as a heat exchanger with a temperature effectiveness of 5% (from R410A test data).

The performance predictions for the other refrigerants then simply reflect the thermodynamic properties of the fluid. Fluid properties are described by REFPROP files or property tables as supplied by the respective suppliers. For blends with glide, the average of the inlet and outlet state saturation conditions was set equal to the corresponding average saturation temperature from the R410A baseline case.

The experimental capacities are in reasonable agreement with the simple model predictions. The differences are likely due to variations in heat exchanger performance affecting the actual operating pressures and fluid specific volumes. HPR1D had the biggest shortfall by about 7%, followed by R32 at about 4.5%. At the other end, ARM-70a did about 5% better than expected.

With regard to EER (COP), the actual performance was better than model prediction for most refrigerants. The exceptions are R32 and HPR1D, each about 5% short. Again at the other end, ARM-70a was up almost 6%.

Again, ARM-32a is proposed as an R22 alternate, not an R410A alternate. However, it is interesting to note that the capacity measured for ARM-32a agrees quite well with that predicted by the simple thermodynamic model. The measured EER is a bit better than predicted. This could be a consequence of the compressor suction superheat being limited to less than the desired target. Also, as shown below, ARM-32a's inherently lower capacity makes the heat exchangers somewhat "oversized"; the consequently slightly better approach temperatures would also contribute to improved EER.

The R410A baseline test used a 12.0 lbm charge. As shown in Figure 5, less charge was needed for all of the alternate refrigerants. The charge sweeps were done in 0.5 lbm increments. The peak in the EER curve was relatively wide and flat in most cases.

The superheats at the evaporator exit and compressor suction are shown in Figure 6. The TXV controls to the compressor suction superheat. The increase in temperature from evaporator exit to compressor suction is due to heat transfer as the stream passes through the mode switching valve (seeing the stream going from compressor discharge to the condenser). The target compressor suction superheat was 10-12°F. The final reported value for DR-5 suction superheat is a bit low in part because an earlier property description was used during testing. The DR-5 data was subsequently reprocessed with an updated properties description. It should be noted that the TXV could not be adjusted to the target (TXV had reached the end of its range) when running with ARM-32a.

The condenser subcooling at the selected charge varied between 10°F (R32) and 15°F (several); see Figure 7. The charge that maximized EER for ARM-32a provided only 2-3°F of subcooling.

Determining the approach temperatures between the water and refrigerant in the evaporator (BPHE) is somewhat problematic. The water and refrigerant are in counter flow. On the refrigerant side, restrictions internal to the heat exchanger create a large pressure drop between the evaporator inlet pressure measurement point and the heat exchanger channels (to promote uniform flow rates through the channels). Therefore, the true pressure of the refrigerant entering the heat exchanger channels is unknown. It is estimated here by assuming that 85% of the total pressure drop across the BPHE occurs across the entrance restrictions. This estimate was selected by noting that it results in reasonable approach temperatures between the leaving water temperature and the corresponding refrigerant saturation temperature entering the channels for most refrigerants; see Figure 8 (first column).

The approach temperatures between the entering water and leaving refrigerant are shown by the second and third columns in Figure 8. The difference between these two columns is the evaporator exit superheat.

We see that the evaporator performance with R32 and DR-5 is very similar to its performance with R410A with DR-5 performing slightly better than R32. The other refrigerants all have slightly larger leaving water to entering refrigerant approaches, but smaller entering water to leaving refrigerant approaches. That is, except for HPR1D, which had a very large leaving water to entering refrigerant approach. This is likely due to its large glide as shown in Figure 9 compared to the other refrigerants. It appears that HPR1D's large glide (larger than the water-side "glide" in this case) might be a significant contributor to the shortfall in measured performance relative to the simple model prediction. It should be noted that the performance here (water to refrigerant) might not be representative of air to refrigerant performance.

Figure 10 provides measures of condenser performance. The entering dew point temperatures (an indication of the "excess pressure" needed to achieve the condenser heat rejection) of all the alternate refrigerants are slightly higher than the baseline R410A case. The lower value for ARM-32a might be due in part to the lower heat rejection rate because of its inherently lower capacity. The significantly higher entering dew point for HPR1D might again be attributable to its large glide and might contribute to the degraded performance relative to the simple model prediction.

The pressure drops along the evaporator to compressor suction and compressor discharge to condenser lines are shown in Figure 11. For the most part, line pressure drops are slightly lower for the alternate refrigerants compared with the R410A baseline. The pressure drops correlate with the refrigerant mass flow rates shown in Figure 12 (computed from the measured evaporator water-side heat transfer rate).

Figure 13 shows the compressor adiabatic efficiencies computed from the suction and discharge measurements and the fluid properties. It seems unlikely that the higher values obtained for several of the blends are real. Rather, it is speculated that the differences are (at least in part) a consequence of somewhat inaccurate descriptions of the gas phase specific heat (likely modeled, not measured) and therefore values of entropies and enthalpies when combined with the gas region PVT equation of state.

Finally, Figure 14 and Figure 15 show the compressor discharge temperatures reached for each refrigerant. The experimental results match the predictions quite well, except for the ARM fluids. The actual discharge temperature for ARM-70a was about 11°Fd cooler than predicted. ARM-32a was over 20°Fd cooling than predicted. As predicted, the compressor discharge temperature increased substantially for R32. HPR1D also displays a somewhat elevated discharge temperature. As with the compressor efficiency, differences between actual and modeled compressor discharge temperatures might be an indication of uncertainties in thermodynamic properties for those fluids.

NOMENCLATURE

BPHE	Brazed Plate Heat Exchanger
CAP	Capacity [RT or Btu/hr or W]
Chrg	refrigerant charge [lbm or kg]
CiDP	Condenser inlet Dew Point (dew point temperature of refrigerant entering condenser)
CoBP	Condenser outlet Bubble Point (bubble point temperature of refrigerant leaving condenser)
COP	Coefficient of Performance [ ]
dPent	ratio of the refrigerant pressure drop across the distributor entering the evaporator channels to the total pressure drop across the evaporator
EER	Energy Efficiency Ratio = cooling capacity measured from water-side of evaporator divided by electrical power input [Btu/W·hr]
EERc	EER based on power input to compressor only
EERt	EER based on total power input (compressor, fans, and controls)
RT	Refrigeration Tons
RTPF	Round Tube Plate Fin heat exchanger (condenser "coil")
Tair	temperature of the ambient air entering the condenser
TCo	subcooled refrigerant temperature leaving condenser
Tdew,lvg	saturation temperature (dew point) at the refrigerant pressure leaving the evaporator
Tref,lvg	temperature of the superheat refrigerant vapor leaving the evaporator
Tsat,ent	saturation temperature of the refrigerant entering the evaporator channels (after the inlet distributor)
Twi	temperature of the chilled water entering the evaporator
Two	temperature of the chilled water leaving the evaporator
Twtr,ent	temperature of the chilled water entering the evaporator
Twtr,lvg	temperature of the chilled water leaving the evaporator

Figure 1. Photos of the Koolman unit situated in a controlled environment chamber. Left) Water connections to BPHE. Above) Sampling tree wrapped around outside of coil.

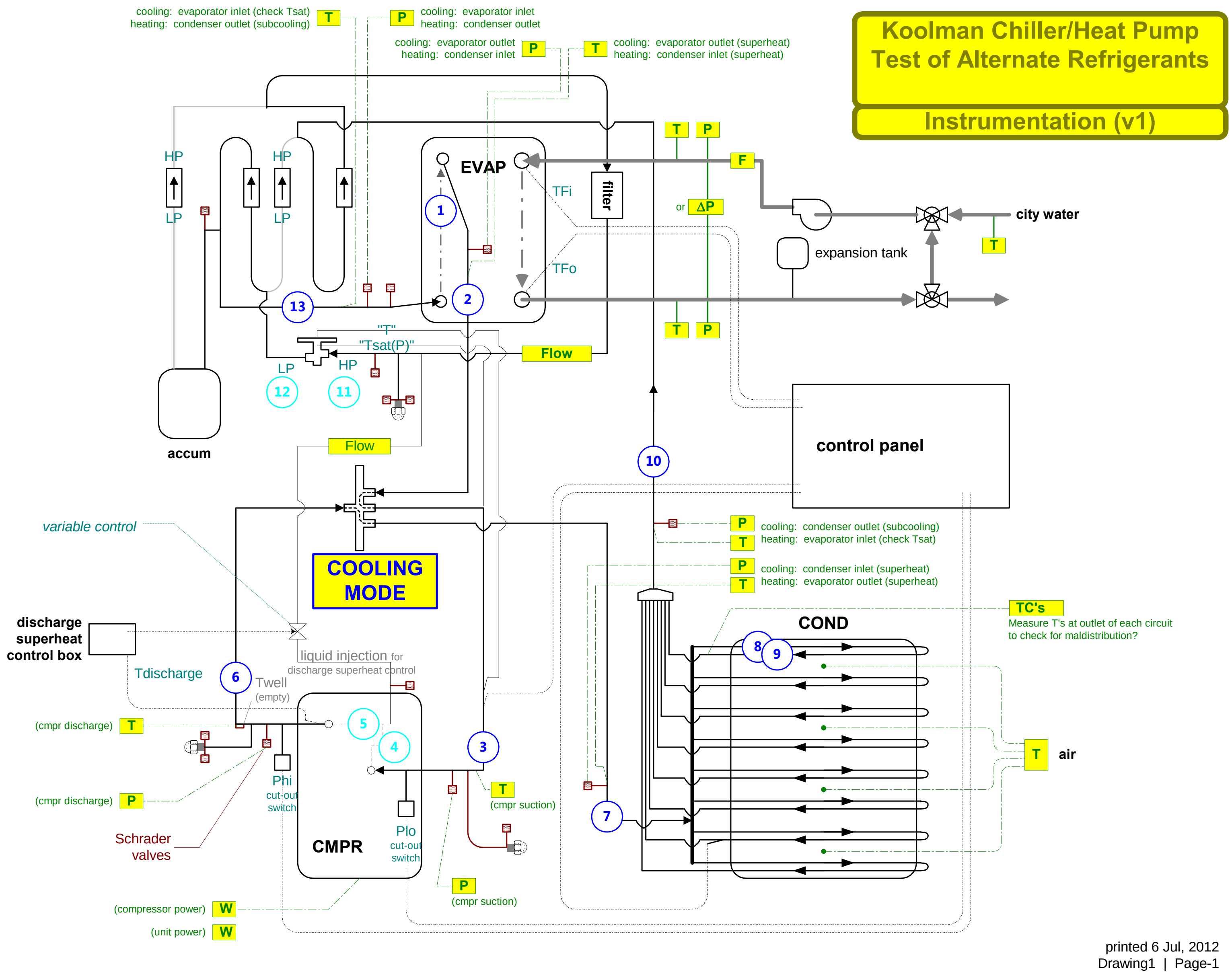

Figure 2. Schematic diagram of Koolman system showing locations of measurement points.

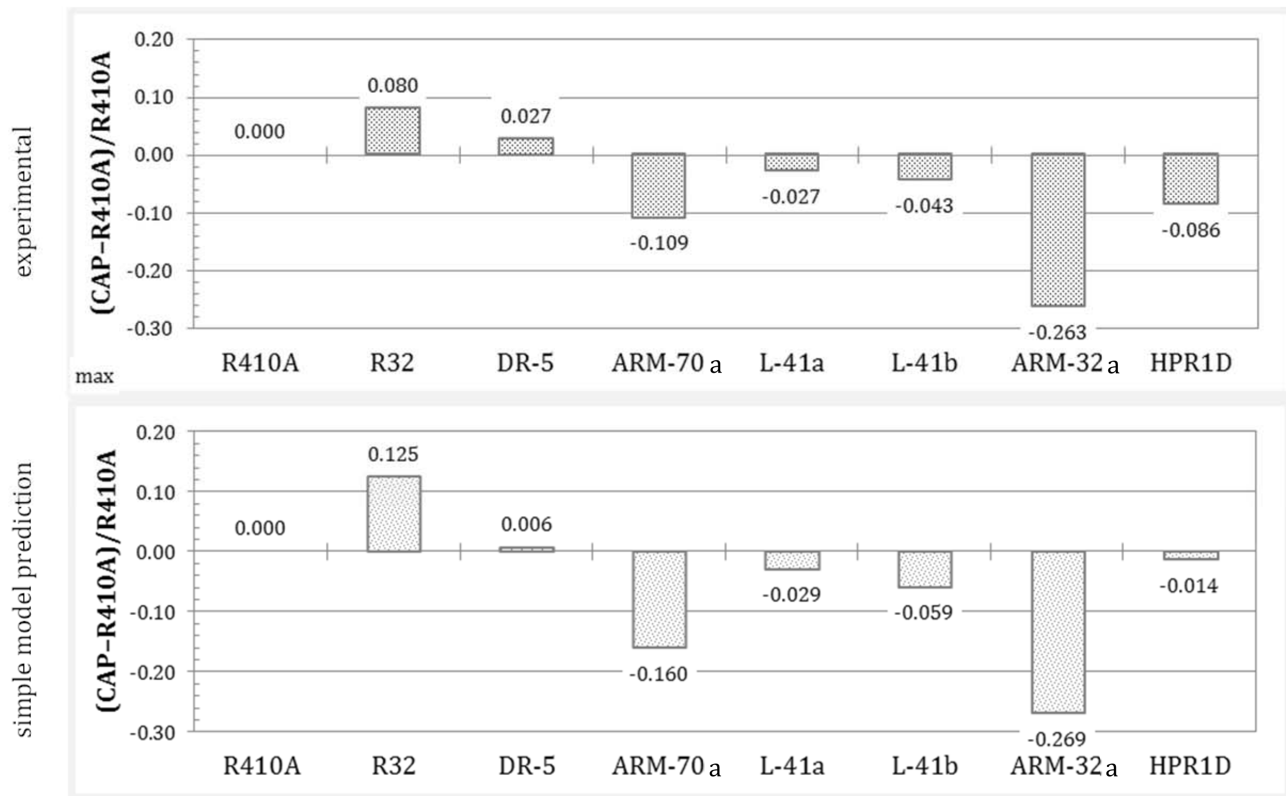

Figure 3. Capacities obtained at the nominal operating condition relative to R410A baseline.

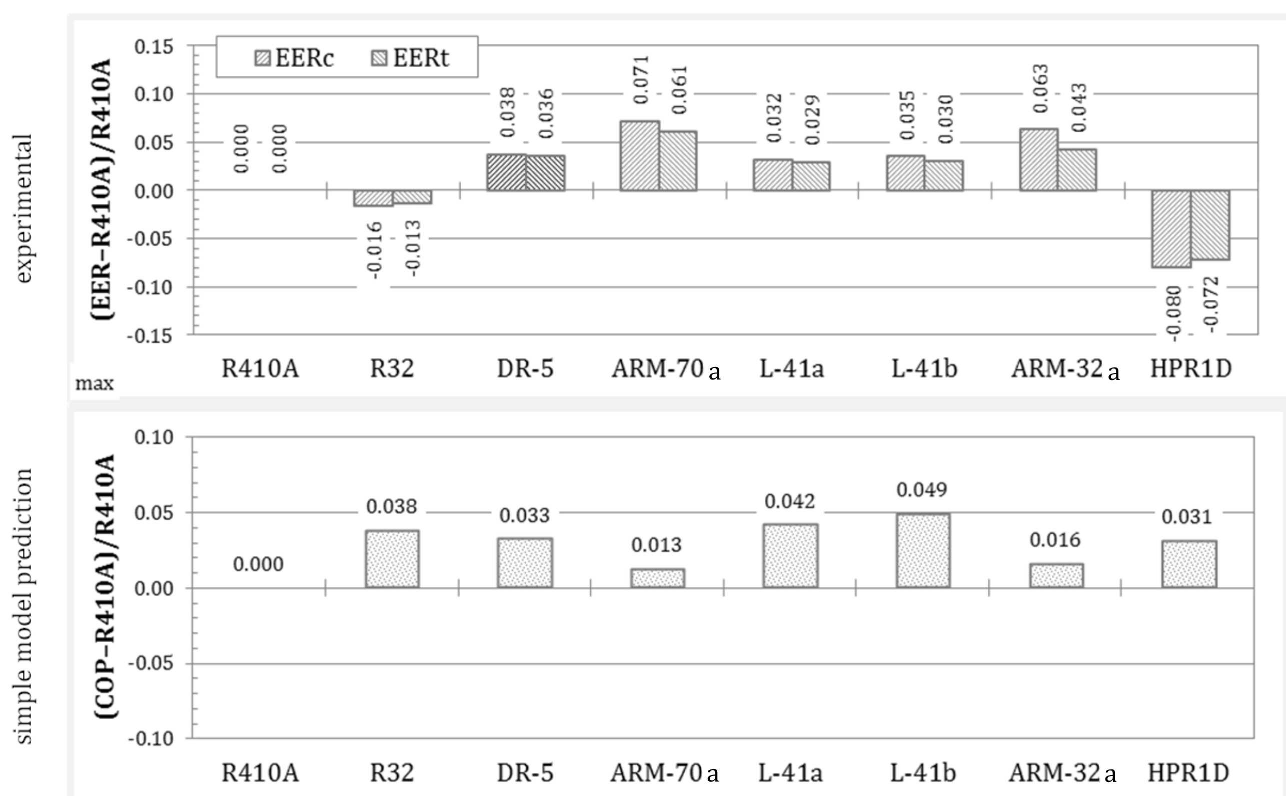

Figure 4. EER's (or COP's) obtained at the nominal operating condition relative to R410A baseline. "EERc" is based on compressor power consumption only. "EERt" is based on total power, including fans and controls.

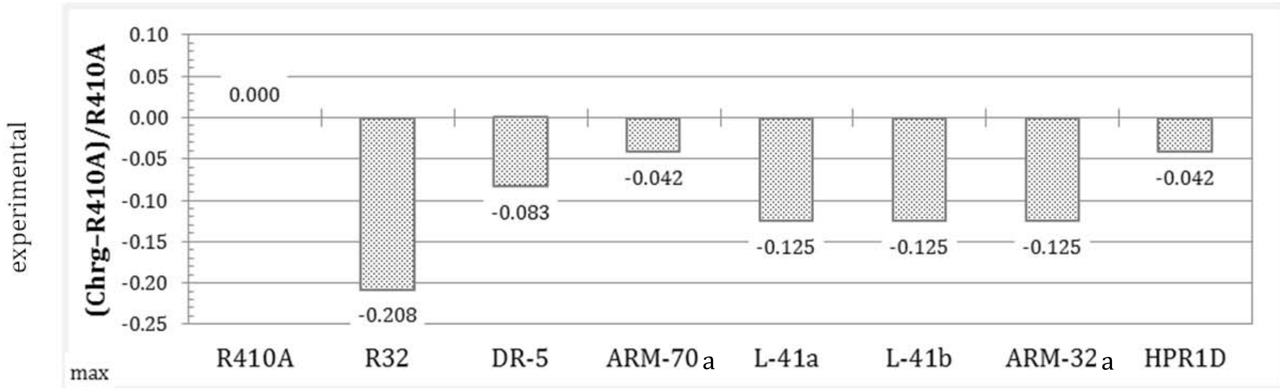

Figure 5. Charge at maximum EER obtained at the nominal operating condition relative to R410A baseline.

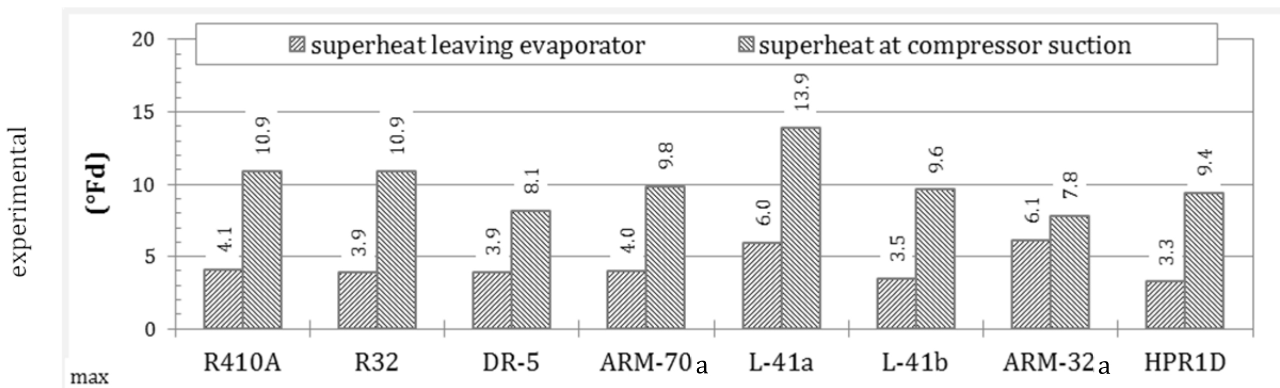

Figure 6. Superheat at the evaporator exit and compressor suction at the nominal operating conditions.

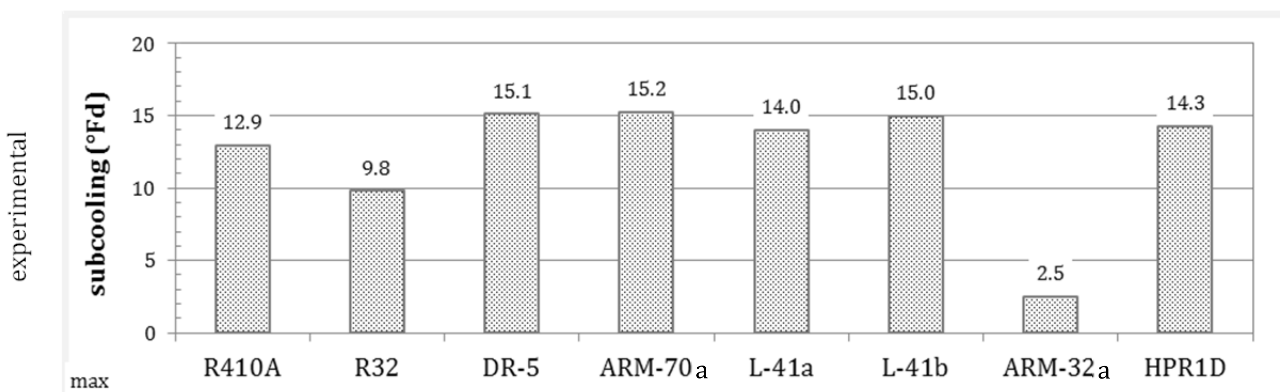

Figure 7. Condenser subcooling obtained at the nominal operating condition with the refrigerant charge that maximized the EER.

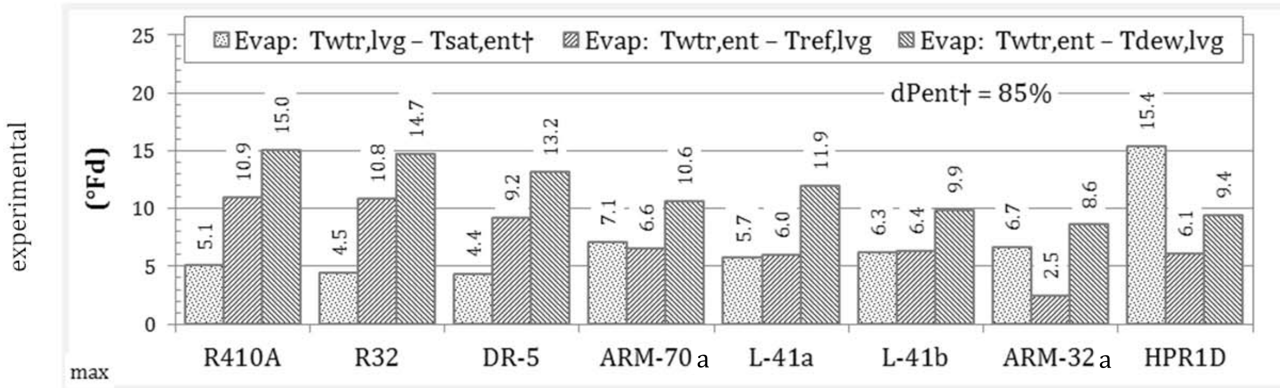

Figure 8. Approach temperatures computed for the evaporator (BPHE). It is assumed that 85% of the total pressure drop measured across the BPHE occurs across restrictions at the entrances to the heat exchanger channels.

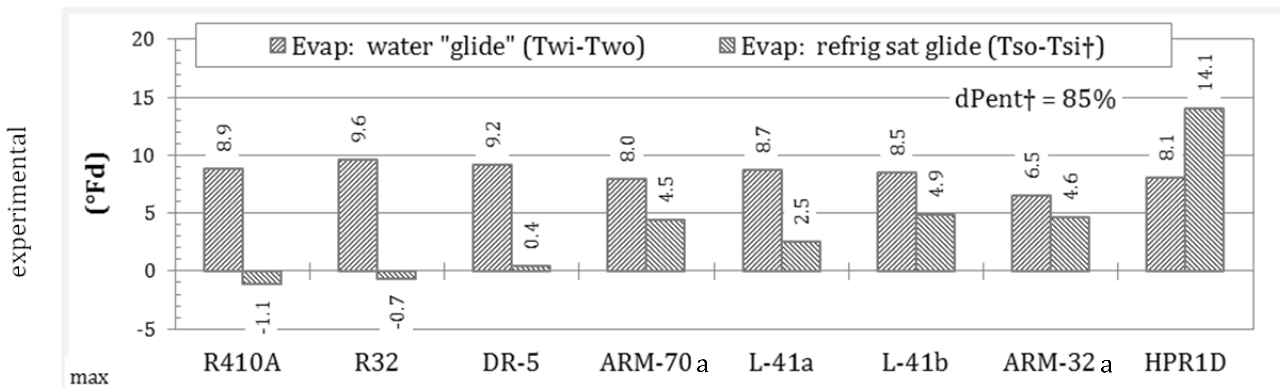

Figure 9. Changes in water and refrigerant saturation temperatures ("glides") across the evaporator (BPHE).

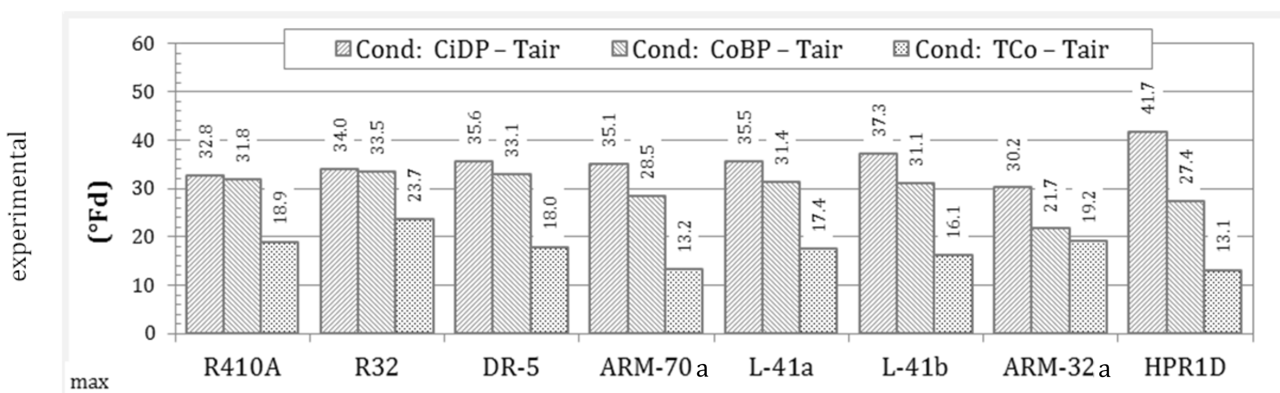

Figure 10. Condenser "approach temperatures". CiDP = condenser inlet refrigerant dew point. CoBP = condenser outlet refrigerant bubble point. TCo = condenser outlet refrigerant temperature. Tair = inlet air temperature. CiDP–CoBP (column 1 – column 2) = "glide", including the effect of pressure drop through the condenser. CoBP–TCo (column 2 – column 3) = condenser exit subcooling.

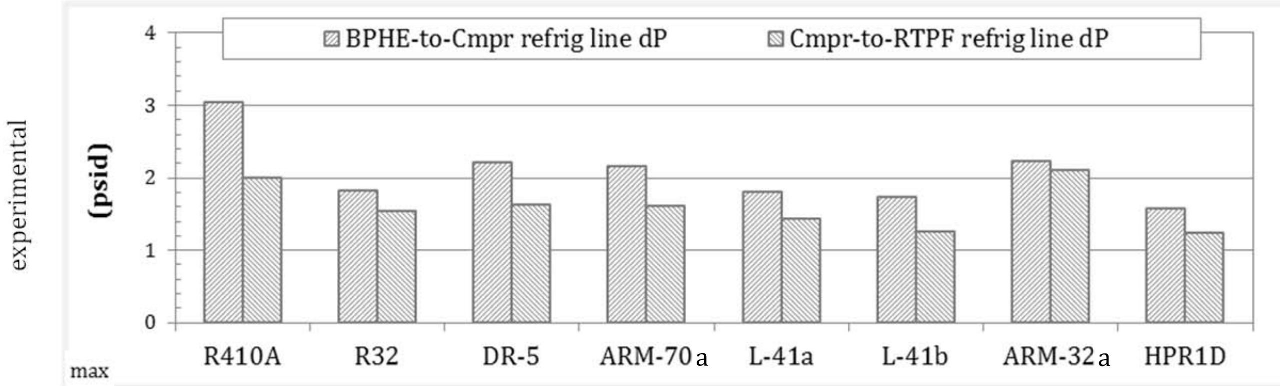

Figure 11. Pressure drops occurring along evaporator to compressor suction line and compressor discharge line to condenser.

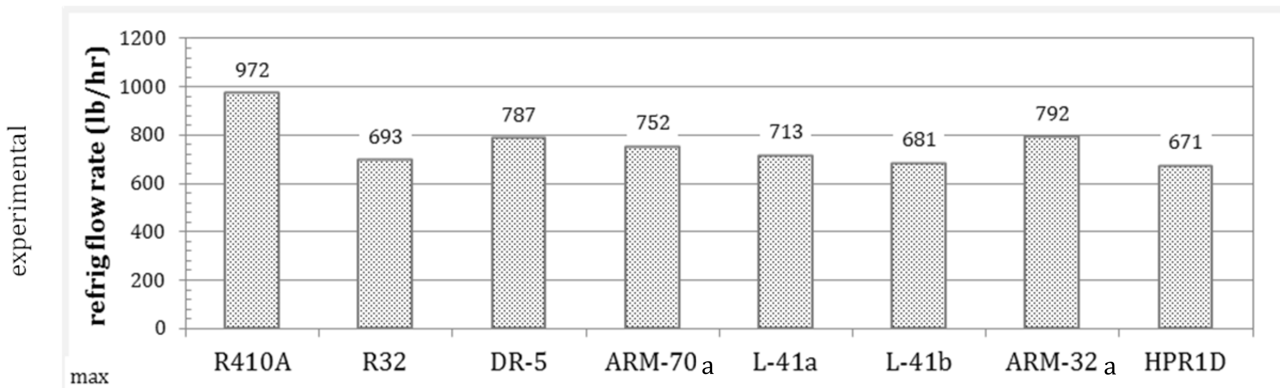

Figure 12. Refrigerant flow rate (computed from measured evaporator water-side heat transfer rate and refrigerant properties).

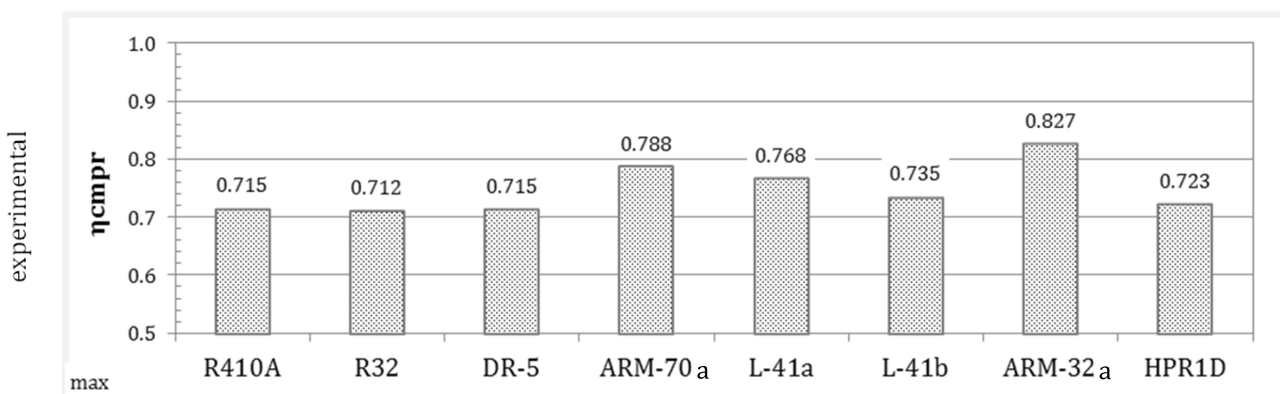

Figure 13. Compressor adiabatic efficiency computed from suction and discharge measurements and fluid properties.

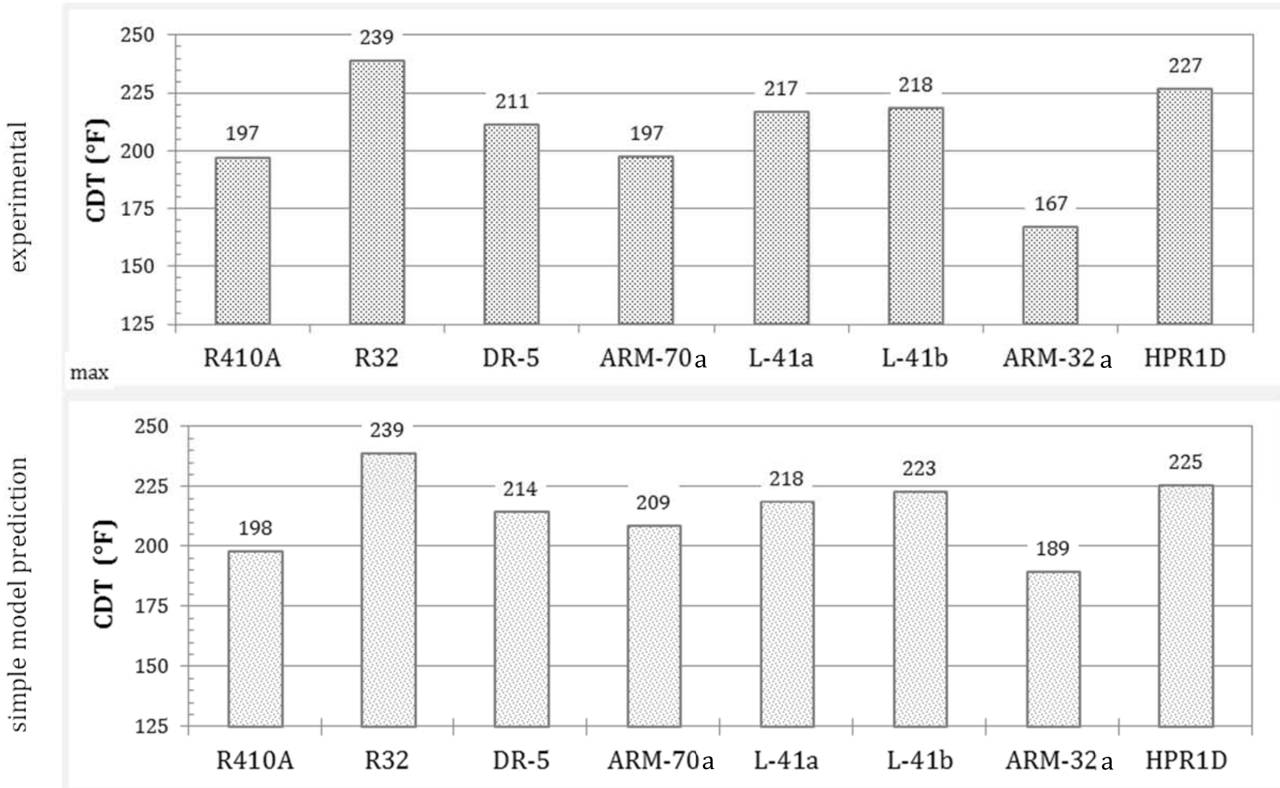

Figure 14. Refrigerant temperature at compressor discharge when running at the nominal operating condition.

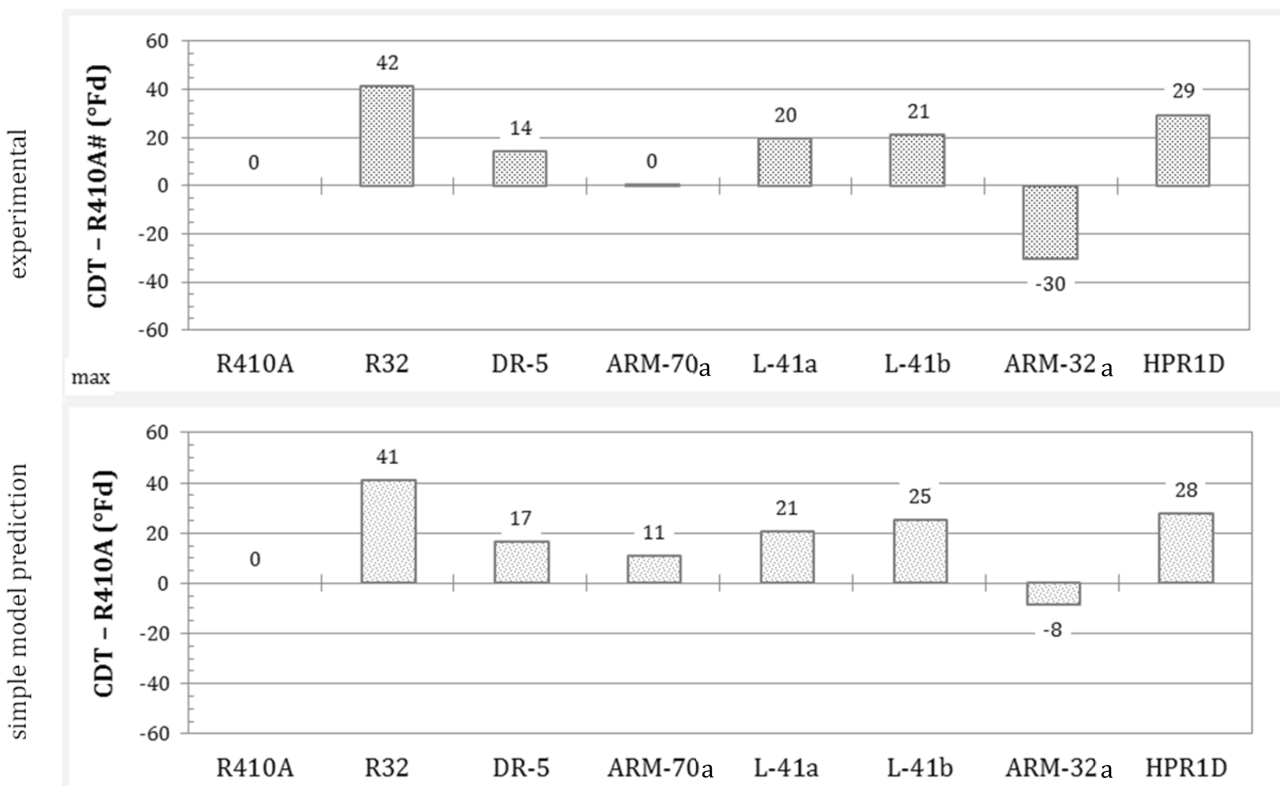

Figure 15. Difference in compressor discharge temperature for each refrigerant relative to R410A baseline.

Appendix A: Instrumentation List

ID # **	Description	Units	Stated Sensor Accuracy	Measurement Accuracy
1	BPHX Water Flow	GPM SI: m³/h	± 0.5% of Rdg	± 0.5% of Rdg
2	BPHX Waterside Delta P	psid SI: kPa·diff	0.2% of Span	± 0.054 PSID
3	Ent BPHX Water Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
4	Lvg BPHX Water Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
5	Entering BPHX Water Temp	°F SI: °C		± 0.1 F
6	Leaving BPHX Water Temp	°F SI: °C		± 0.1 F
7	Outdoor Air DB Temp	°F SI: °C		± 0.1 F
8	Outdoor Air WB Temp	°F SI: °C		± 0.5 F
9	Barometric Pressure	psia SI: kPa·abs	0.1% of FS	± 0.0157 PSIA
10	Compressor Discharge Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
11	RTPF Vapor Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
12	RTPF Liquid Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
13	Entering TXV Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
14	BPHX Liquid Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
15	BPHX Vapor Refr Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
16	Compressor Suction Pressure	psia SI: kPa·abs	0.05% of FS	± 0.375 PSIA
20	Compressor Discharge Refr Temp	°F SI: °C		± 1.0 F
21	RTPF Vapor Refr Temp	°F SI: °C		± 1.0 F
22	RTPF Liquid Refr Temp	°F SI: °C		± 1.0 F
23	Entering TXV Refr Temp	°F SI: °C		± 1.0 F
24	BPHX Liquid Refr Temp	°F SI: °C		± 1.0 F
25	BPHX Vapor Refr Temp	°F SI: °C		± 1.0 F
26	Compressor Suction Temp	°F SI: °C		± 1.0 F
30	Ent RTPF Circuit Temp #1 (cooling)	°F SI: °C		± 1.0 F
31	Ent RTPF Circuit Temp #2 (cooling)	°F SI: °C		± 1.0 F
32	Ent RTPF Circuit Temp #3 (cooling)	°F SI: °C		± 1.0 F
33	Ent RTPF Circuit Temp #4 (cooling)	°F SI: °C		± 1.0 F
34	Ent RTPF Circuit Temp #5 (cooling)	°F SI: °C		± 1.0 F
35	Ent RTPF Circuit Temp #6 (cooling)	°F SI: °C		± 1.0 F
36	Ent RTPF Circuit Temp #7 (cooling)	°F SI: °C		± 1.0 F
37	Ent RTPF Circuit Temp #8 (cooling)	°F SI: °C		± 1.0 F
40	Lvg RTPF Circuit Temp #1 (cooling)	°F SI: °C		± 1.0 F
41	Lvg RTPF Circuit Temp #2 (cooling)	°F SI: °C		± 1.0 F
42	Lvg RTPF Circuit Temp #3 (cooling)	°F SI: °C		± 1.0 F
43	Lvg RTPF Circuit Temp #4 (cooling)	°F SI: °C		± 1.0 F
44	Lvg RTPF Circuit Temp #5 (cooling)	°F SI: °C		± 1.0 F
45	Lvg RTPF Circuit Temp #6 (cooling)	°F SI: °C		± 1.0 F
46	Lvg RTPF Circuit Temp #7 (cooling)	°F SI: °C		± 1.0 F
47	Lvg RTPF Circuit Temp #8 (cooling)	°F SI: °C		± 1.0 F
50	Liquid Refrigerant Flow	GPM SI: m³/h	± 0.5% of Rdg	± 0.5% of Rdg
51	Compressor Liquid Injection Flow	GPM SI: m³/h	± 0.5% of Rdg	± 0.5% of Rdg
60	Compressor Voltage AB	V SI: V	0.2% of Rdg + ± 0.1% of Range	
61	Compressor Voltage BC	V SI: V	0.2% of Rdg + ± 0.1% of Range	
62	Compressor Voltage AC	V SI: V	0.2% of Rdg + ± 0.1% of Range	
63	Compressor Current A	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
64	Compressor Current B	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
65	Compressor Current C	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
66	Compressor Power	W SI: W	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
70	Total Unit Voltage AN	V SI: V	0.2% of Rdg + ± 0.1% of Range	
71	Total Unit Voltage BN	V SI: V	0.2% of Rdg + ± 0.1% of Range	
72	Total Unit Voltage AN	V SI: V	0.2% of Rdg + ± 0.1% of Range	
73	Total Unit Current A	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
74	Total Unit Current B	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
75	Total Unit Current C	A SI: A	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
76	Total Unit Power	W SI: W	0.2% of Rdg + ± 0.1% of Rang	~0.5% of Rdg w/ CTs
90	Ent RTPF Air Temp #1	°F SI: °C		± 1.0 F
91	Ent RTPF Air Temp #2	°F SI: °C		± 1.0 F
92	Ent RTPF Air Temp #3	°F SI: °C		± 1.0 F
93	Ent RTPF Air Temp #4	°F SI: °C		± 1.0 F
94	Ent RTPF Air Temp #5	°F SI: °C		± 1.0 F
95	Ent RTPF Air Temp #6	°F SI: °C		± 1.0 F
96	Ent RTPF Air Temp #7	°F SI: °C		± 1.0 F
97	Ent RTPF Air Temp #8	°F SI: °C		± 1.0 F
98	Ent RTPF Air Temp #9	°F SI: °C		± 1.0 F
99	Ent RTPF Air Temp #10	°F SI: °C		± 1.0 F
100	Ent RTPF Air Temp #11	°F SI: °C		± 1.0 F
101	Ent RTPF Air Temp #12	°F SI: °C		± 1.0 F
102	Ent RTPF Air Temp #13	°F SI: °C		± 1.0 F
103	Ent RTPF Air Temp #14	°F SI: °C		± 1.0 F
104	Ent RTPF Air Temp #15	°F SI: °C		± 1.0 F

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

page 1
09-Jul-2012

Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**R32**	National
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	4.31	kg	12.0	9.5	lbm	0.792
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	19,789	W	62,538	67,522	Btu/hr	1.080
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	8,397	W	7,675	8,397	W	1.094
Power to Compressor		7,334	8,043	W	7,334	8,043	W	1.097
COP or EER (total)		2.39	2.36	[]	8.15	8.04	Btu/W·hr	0.987
COP or EER (compressor only)		2.50	2.46	[]	8.53	8.40	Btu/W·hr	0.984
Refrigerant Mass Flow Rate		441	315	kg/hr	972	693	lbm/hr	0.713

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Type of System: Koolman CGAR-0605   Alternate Refrigerant: **R32**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	53.2	L/hr	14.0	14.0	gpm	1.002
T entering	12.1	12.6	°C	53.8	54.6	°F	0.8
T leaving	7.2	7.2	°C	44.9	45.0	°F	0.1
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.0	°F	-0.1
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	10.0	921	48.2	127.2	50.0	133.5
discharge	91.8	3313	114.9	3444	197.2	480.5	238.8	499.6
suction SH	6.0		6.1		10.9		10.9	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	107.7	3,434	188.4	478.5	225.8	498.0
outlet	45.5	3,267	48.2	3,413	114.0	473.8	118.7	495.0
outlet subcooling	7.2		5.5		12.9		9.8	
Expansion Device (TXV)								
inlet	45.4	3,236	48.0	3,394	113.7	469.3	118.4	492.3
inlet subcooling	6.9		5.4		12.4		9.7	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	12.0	1,008	48.1	148.8	53.6	146.2
outlet	6.0	898	6.5	933	42.9	130.2	43.8	135.4
outlet superheat	2.3		2.2		4.1		3.9	
Refrigerant Reversing Valve								
LP inlet	6.0	898	6.5	933	42.9	130.2	43.8	135.4
LP outlet	9.0	877	10.0	921	48.2	127.2	50.0	133.5
HP inlet	91.8	3,313	114.9	3,444	197.2	480.5	238.8	499.6
HP outlet	86.9	3,299	107.7	3,434	188.4	478.5	225.8	498.0

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**DR-5**	DuPont
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	4.99	kg	12.0	11.0	lbm	0.917
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	18,831	W	62,538	64,255	Btu/hr	1.027
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	7,614	W	7,675	7,614	W	0.992
Power to Compressor		7,334	7,260	W	7,334	7,260	W	0.990
COP or EER (total)		2.39	2.47	[]	8.15	8.44	Btu/W·hr	1.036
COP or EER (compressor only)		2.50	2.59	[]	8.53	8.85	Btu/W·hr	1.038
Refrigerant Mass Flow Rate		441	357	kg/hr	972	787	lbm/hr	0.809

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the
Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a
higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Type of System: Koolman CGAR-0605 Alternate Refrigerant: **DR-5**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	52.7	L/hr	14.0	13.9	gpm	0.993
T entering	12.1	12.3	°C	53.8	54.2	°F	0.4
T leaving	7.2	7.2	°C	44.9	45.0	°F	0.1
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.0	°F	-0.1
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	9.0	861	48.2	127.2	48.2	124.8
discharge	91.8	3313	99.7	3225	197.2	480.5	211.4	467.8
suction SH	6.0		4.5		10.9		8.1	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	94.0	3,214	188.4	478.5	201.3	466.2
outlet	45.5	3,267	45.0	3,192	114.0	473.8	112.9	462.9
outlet subcooling	7.2		8.4		12.9		15.1	
Expansion Device (TXV)								
inlet	45.4	3,236	44.8	3,164	113.7	469.3	112.6	458.9
inlet subcooling	6.9		8.2		12.4		14.7	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	8.8	984	48.1	148.8	47.9	142.7
outlet	6.0	898	7.2	876	42.9	130.2	45.0	127.1
outlet superheat	2.3		2.2		4.1		3.9	
Refrigerant Reversing Valve								
LP inlet	6.0	898	7.2	876	42.9	130.2	45.0	127.1
LP outlet	9.0	877	9.0	861	48.2	127.2	48.2	124.8
HP inlet	91.8	3,313	99.7	3,225	197.2	480.5	211.4	467.8
HP outlet	86.9	3,299	94.0	3,214	188.4	478.5	201.3	466.2

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**ARM-70a**	Arkema
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	5.22	kg	12.0	11.5	lbm	0.958
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	16,333	W	62,538	55,731	Btu/hr	0.891
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	6,444	W	7,675	6,444	W	0.840
Power to Compressor		7,334	6,100	W	7,334	6,100	W	0.832
COP or EER (total)		2.39	2.53	[]	8.15	8.65	Btu/W·hr	1.061
COP or EER (compressor only)		2.50	2.68	[]	8.53	9.14	Btu/W·hr	1.071
Refrigerant Mass Flow Rate		441	341	kg/hr	972	752	lbm/hr	0.773

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Type of System: Koolman CGAR-0605 Alternate Refrigerant: **ARM-70a**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	52.6	L/hr	14.0	13.9	gpm	0.992
T entering	12.1	11.7	°C	53.8	53.0	°F	-0.7
T leaving	7.2	7.3	°C	44.9	45.1	°F	0.2
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.1	°F	0.0
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	10.6	723	48.2	127.2	51.1	104.9
discharge	91.8	3313	91.9	2741	197.2	480.5	197.4	397.6
suction SH	6.0		5.5		10.9		9.8	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	86.7	2,730	188.4	478.5	188.0	396.0
outlet	45.5	3,267	42.4	2,707	114.0	473.8	108.3	392.6
outlet subcooling	7.2		8.5		12.9		15.2	
Expansion Device (TXV)								
inlet	45.4	3,236	42.2	2,688	113.7	469.3	108.0	389.9
inlet subcooling	6.9		8.3		12.4		15.0	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	6.5	823	48.1	148.8	43.7	119.4
outlet	6.0	898	8.0	738	42.9	130.2	46.5	107.0
outlet superheat	2.3		2.2		4.1		4.0	
Refrigerant Reversing Valve								
LP inlet	6.0	898	8.0	738	42.9	130.2	46.5	107.0
LP outlet	9.0	877	10.6	723	48.2	127.2	51.1	104.9
HP inlet	91.8	3,313	91.9	2,741	197.2	480.5	197.4	397.6
HP outlet	86.9	3,299	86.7	2,730	188.4	478.5	188.0	396.0

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**L-41a**	Honeywell
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	4.76	kg	12.0	10.5	lbm	0.875
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	17,829	W	62,538	60,836	Btu/hr	0.973
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	7,255	W	7,675	7,255	W	0.945
Power to Compressor		7,334	6,910	W	7,334	6,910	W	0.942
COP or EER (total)		2.39	2.46	[]	8.15	8.39	Btu/W·hr	1.029
COP or EER (compressor only)		2.50	2.58	[]	8.53	8.80	Btu/W·hr	1.032
Refrigerant Mass Flow Rate		441	323	kg/hr	972	713	lbm/hr	0.733

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Type of System: Koolman CGAR-0605 Alternate Refrigerant: **L-41a**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	52.6	L/hr	14.0	13.9	gpm	0.992
T entering	12.1	12.0	°C	53.8	53.6	°F	-0.2
T leaving	7.2	7.2	°C	44.9	44.9	°F	0.0
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.1	°F	0.0
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	12.6	806	48.2	127.2	54.7	116.8
discharge	91.8	3313	102.7	3060	197.2	480.5	216.9	443.8
suction SH	6.0		7.7		10.9		13.9	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	98.7	3,050	188.4	478.5	209.6	442.4
outlet	45.5	3,267	44.7	3,028	114.0	473.8	112.5	439.2
outlet subcooling	7.2		7.8		12.9		14.0	
Expansion Device (TXV)								
inlet	45.4	3,236	44.5	3,008	113.7	469.3	112.1	436.3
inlet subcooling	6.9		7.7		12.4		13.9	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	6.5	896	48.1	148.8	43.7	129.9
outlet	6.0	898	8.7	818	42.9	130.2	47.6	118.6
outlet superheat	2.3		3.3		4.1		6.0	
Refrigerant Reversing Valve								
LP inlet	6.0	898	8.7	818	42.9	130.2	47.6	118.6
LP outlet	9.0	877	12.6	806	48.2	127.2	54.7	116.8
HP inlet	91.8	3,313	102.7	3,060	197.2	480.5	216.9	443.8
HP outlet	86.9	3,299	98.7	3,050	188.4	478.5	209.6	442.4

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**L-41b**	Honeywell
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	4.76	kg	12.0	10.5	lbm	0.875
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	17,544	W	62,538	59,862	Btu/hr	0.957
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	7,131	W	7,675	7,131	W	0.929
Power to Compressor		7,334	6,781	W	7,334	6,781	W	0.925
COP or EER (total)		2.39	2.46	[]	8.15	8.39	Btu/W·hr	1.030
COP or EER (compressor only)		2.50	2.59	[]	8.53	8.83	Btu/W·hr	1.035
Refrigerant Mass Flow Rate		441	309	kg/hr	972	681	lbm/hr	0.700

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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Type of System: Koolman CGAR-0605 Alternate Refrigerant: **L-41b**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	52.9	L/hr	14.0	14.0	gpm	0.998
T entering	12.1	12.0	°C	53.8	53.6	°F	-0.2
T leaving	7.2	7.3	°C	44.9	45.1	°F	0.2
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.0	°F	0.0
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	11.4	771	48.2	127.2	52.5	111.9
discharge	91.8	3313	103.6	2975	197.2	480.5	218.5	431.4
suction SH	6.0		5.3		10.9		9.6	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	99.8	2,966	188.4	478.5	211.7	430.2
outlet	45.5	3,267	44.0	2,945	114.0	473.8	111.2	427.1
outlet subcooling	7.2		8.3		12.9		15.0	
Expansion Device (TXV)								
inlet	45.4	3,236	43.8	2,929	113.7	469.3	110.8	424.9
inlet subcooling	6.9		8.3		12.4		14.9	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	5.6	853	48.1	148.8	42.1	123.7
outlet	6.0	898	8.5	784	42.9	130.2	47.2	113.6
outlet superheat	2.3		1.9		4.1		3.5	
Refrigerant Reversing Valve								
LP inlet	6.0	898	8.5	784	42.9	130.2	47.2	113.6
LP outlet	9.0	877	11.4	771	48.2	127.2	52.5	111.9
HP inlet	91.8	3,313	103.6	2,975	197.2	480.5	218.5	431.4
HP outlet	86.9	3,299	99.8	2,966	188.4	478.5	211.7	430.2

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

page 1
09-Jul-2012

Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**ARM-32a**	Arkema
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor						
Compressor Displacement		15.4		m^3/hr	544		ft^3/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	4.76	kg	12.0	10.5	lbm	0.875
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	13,508	W	62,538	46,093	Btu/hr	0.737
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	5,423	W	7,675	5,423	W	0.707
Power to Compressor		7,334	5,085	W	7,334	5,085	W	0.693
COP or EER (total)		2.39	2.49	[]	8.15	8.50	Btu/W·hr	1.043
COP or EER (compressor only)		2.50	2.66	[]	8.53	9.07	Btu/W·hr	1.063
Refrigerant Mass Flow Rate		441	359	kg/hr	972	792	lbm/hr	0.815

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

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06-Jul-2012

Type of System: Koolman CGAR-0605 Alternate Refrigerant: **ARM-32a**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	53.2	L/hr	14.0	14.0	gpm	1.002
T entering	12.1	10.8	°C	53.8	51.5	°F	-2.3
T leaving	7.2	7.2	°C	44.9	45.0	°F	0.0
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.0	°F	0.0
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	9.7	629	48.2	127.2	49.4	91.2
discharge	91.8	3313	75.1	2288	197.2	480.5	167.2	331.8
suction SH	6.0		4.4		10.9		7.8	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	72.9	2,273	188.4	478.5	163.2	329.7
outlet	45.5	3,267	45.7	2,245	114.0	473.8	114.2	325.6
outlet subcooling	7.2		1.4		12.9		2.5	
Expansion Device (TXV)								
inlet	45.4	3,236	45.4	2,217	113.7	469.3	113.7	321.5
inlet subcooling	6.9		1.1		12.4		2.0	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	8.1	767	48.1	148.8	46.6	111.3
outlet	6.0	898	9.5	644	42.9	130.2	49.0	93.4
outlet superheat	2.3		3.4		4.1		6.1	
Refrigerant Reversing Valve								
LP inlet	6.0	898	9.5	644	42.9	130.2	49.0	93.4
LP outlet	9.0	877	9.7	629	48.2	127.2	49.4	91.2
HP inlet	91.8	3,313	75.1	2,288	197.2	480.5	167.2	331.8
HP outlet	86.9	3,299	72.9	2,273	188.4	478.5	163.2	329.7

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

page 1
09-Aug-2012

Manufacturer: **Trane**

Basic Information		
Alternative Refrigerant	**HPR1D**	Mexichem
Alternative Lubricant Type and ISO Viscosity	POE – 160SZ	
Baseline Refrigerant	**R410A**	
Baseline Lubricant Type and ISO Viscosity	POE – 160SZ	
Make and Model of System	Koolman CGAR-0605 – Air-Cooled Water Chiller / Heat Pump	
Nominal Capacity and Type of System	15.6 kW cooling / 17.7 kW heating (4.4 tons / 5.0 tons)	

Comparison Data		Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Mode (heating/cooling)		cooling						
Compressor Type		scroll compressor (Danfoss SH090A4ALB – egineering prototype)						
Compressor Displacement		15.4		m³/hr	544		ft³/hr	
Nominal Motor Size		7.6		kW	10.2		hp	
Motor Speed (50 Hz)		2900		Hz				
Expansion Device Type		TXV (Danfoss, TGEL, 067N3155)						
Lubricant Charge		3.0		L	6.3		qt	
Refrigerant Charge		5.44	5.22	kg	12.0	11.5	lbm	0.958
Composition (at Cmpr Suct)								
Chilled Water	Leaving Temp	7.2		°C	45		°F	
	Flow rate	53.0		L/min	14.0		gpm	
Outdoor Air	Dry Bulb	35		°C	95		°F	
	Wet Bulb	n/a		°C	n/a		°F	
Total Capacity		18,328	16,744	W	62,538	57,133	Btu/hr	0.914
Sensible Capacity		n/a	n/a	W	n/a	n/a	Btu/hr	n/a
Total System Power Input		7,675	7,554	W	7,675	7,554	W	0.984
Power to Compressor		7,334	7,284	W	7,334	7,284	W	0.993
COP or EER (total)		2.39	2.22	[]	8.15	7.56	Btu/W·hr	0.928
COP or EER (compressor only)		2.50	2.30	[]	8.53	7.84	Btu/W·hr	0.920
Refrigerant Mass Flow Rate		441	304	kg/hr	972	671	lbm/hr	0.690

Other System Changes
The unit tested was modified from original production by replacing the R22 compressor and TXV with the Danfoss prototype compressor and TXV suitable for R410A/R32. The BPHE was also replaced by one with a higher pressure rating, suitable for R410A/R32.

System Data	Base	Alt.	Ratio
Degradation Coefficient			
Seasonal Energy Efficiency Ration – SEER			
Heating Seasonal Performance Factor – HSPF			

Low GWP AREP SYSTEM DROP-IN TEST DATA FORM

09-Aug-2012

Type of System: Koolman CGAR-0605 Alternate Refrigerant: **HPR1D**

Water/Air Side Data	Base	Alt.	SI Units	Base	Alt.	IP Units	Ratio
Evaporator (BPHE)							
fluid	water						
flow rate	53.1	53.2	L/hr	14.0	14.1	gpm	1.003
T entering	12.1	11.7	°C	53.8	53.1	°F	-0.7
T leaving	7.2	7.2	°C	44.9	45.0	°F	0.1
Condenser (fin-&-tube coil)							
fluid	air						
flow rate	not msrd		L/hr	not msrd		gpm	
T entering			°C	95.1	95.0	°F	-0.1
T leaving	not msrd		°C	not msrd		°F	

Refrigerant Side	Base		Alt.		Base		Alt.	
	T (°C)	P (kPa)	T (°C)	P (kPa)	T (°F)	P (psia)	T (°F)	P (psia)
Compressor (scroll)								
suction	9.0	877	11.3	761	48.2	127.2	52.3	110.4
discharge	91.8	3313	108.1	3219	197.2	480.5	226.7	466.8
suction SH	6.0		5.2		10.9		9.4	
Condenser (refrig-to-air fin-&-tube coil)								
inlet	86.9	3,299	104.5	3,210	188.4	478.5	220.1	465.6
outlet	45.5	3,267	42.3	3,192	114.0	473.8	108.1	462.9
outlet subcooling	7.2		7.9		12.9		14.3	
Expansion Device (TXV)								
inlet	45.4	3,236	42.1	3,174	113.7	469.3	107.8	460.3
inlet subcooling	6.9		7.9		12.4		14.1	
Evaporator (water-to-refrig BPHE)								
inlet	8.9	1,026	1.6	853	48.1	148.8	34.9	123.7
outlet	6.0	898	8.3	772	42.9	130.2	46.9	112.0
outlet superheat	2.3		1.8		4.1		3.3	
Refrigerant Reversing Valve								
LP inlet	6.0	898	8.3	772	42.9	130.2	46.9	112.0
LP outlet	9.0	877	11.3	761	48.2	127.2	52.3	110.4
HP inlet	91.8	3,313	108.1	3,219	197.2	480.5	226.7	466.8
HP outlet	86.9	3,299	104.5	3,210	188.4	478.5	220.1	465.6