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

TEST REPORT #56

System Soft-optimization Tests of Refrigerant R-32, DR-5A, and DR-55 in a R-410A 4-ton Unitary Rooftop Heat Pump-Cooling Mode Performance

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INTRODUCTION

This report documents tests performed on a 4 RT (14 kW) rooftop heat pump to evaluate the performance of lower GWP refrigerants as alternatives to R410A in unitary air-conditioning and heat pump equipment. Tests were run with, in order, R410A (baseline), DR-55, R32, and DR-5A. Compositions and GWPs are listed below in Table 1. The unit was run at the rating conditions specified in AHRI Standard 210/240 for both cooling and heating modes. In addition, the unit was run in cooling mode at ambient temperatures from 65°F to 125°F (18°C to 52°C). The tests were performed in controlled ambient chambers at Ingersoll Rand/Trane's La Crosse Development Laboratory in La Crosse, Wisconsin, from late-May through early-August 2015. *This document reports only the cooling performance; the heating performance will be submitted later.*

Table 1. Refrigerants tested, with compositions and global warming potentials (GWPs).

name	composition (%wt)	GWP (AR4)	GWP (AR5)
R410A	50% R32 / 50% R125	2088	1924
DR-55	67% R32 / 7% R125 / 26% R1234yf	698	675
R32	100% R32	675	677
DR-5A	68.9% R32 / 31.1% R1234yf	466	466

The thermodynamic properties of R410A and R32 are based on NIST's REFPROP v8.[1] The thermodynamic properties of DR-55 and DR-5A are based on REFPROP v9.1 using mixing parameters for the R32/R1234yf and R125/R1234yf pairs provided by DuPont (now Chemours).

DETAILS OF TEST SETUP

Description of Baseline System

A standard production Precedent™ packaged rooftop heat pump, model WSC048E3ROA1J, manufactured by Trane, was chosen for refrigerant testing purposes. The unit is rated at a net cooling capacity of 48,500 Btu/hr (4.04 RT, 14.2 kW) at a SEER of 13.0 Btu/W·hr (SCOPc of 3.81). The catalog refrigerant charge is 9.0 lbm (4.1 kg) of R410A. The unit is driven by a fixed speed scroll compressor (Alliance, model SXA044B2BPA, with a displacement of 0.00148 ft^3/rev or 2.56 in^3/rev (0.0419 L/rev)) lubricated with Emkarate RL32H POE oil. The indoor and outdoor heat exchangers are of aluminum-fin/copper-tube construction with fixed speed fans.

Description of Modifications to System

The original factory-installed fixed TXVs for cooling and heating were both replaced with adjustable TXVs of the same size. Additionally, a variable frequency drive (VFD, Trane TR200 P5K5) was installed to allow the compressor speed to be varied so that all refrigerants could be

[1] The descriptions of R410A and R32 have remained unchanged moving forward to later versions of REFPROP.

tested at the same capacity. Measurement of input power was made upstream of the VFD, however, the efficiency of the VFD is essentially constant over the range of power and speeds tested (cataloged as 0.97). The VFD was in place for the baseline measurements as well, so it has no effect on the comparisons between refrigerants. The original compressor lubricant was not changed.

Description of Tests Conducted

The method of test was consistent with Appendix M of AHRI Standard 210/240 with Addenda 1 and 2 (2008/2012), with operating conditions generally held within tighter tolerances. The indoor (ID) airflow rate was fixed at the catalog value of 1600 scfm for all tests.

Figure 1 shows a diagram of the Precedent unit. In this diagram, the reversing valve is in the cooling mode position. The points in the cycle at which measurements such as pressure and temperature were taken are indicated on the diagram. The accuracies of the various instrument types are listed in Table 2.

Table 2. Instrumentation accuracies.

measurement	accuracy
thermocouples (uncalibrated)	±1°F
RTD sensors (calibrated)	±0.1°F
air-side pressure differences (calibrated) Rosemount 1151DP3S12 (30 inH_2O full scale)	±0.075% of span
pressure transducers (calibrated) Honeywell DS-750 (750 psi full scale)	±0.1% full scale
refrigerant turbine meter (calibrated) Flow Technology FT4-8NE00-LEAH4	±0.5% of reading
electrical power (calibrated) YEW WT230	±0.1%

The reported cooling and heating capacities were calculated from airside flow and temperature (dry bulb and wet bulb) measurements. For confirmation, capacity was also calculated from refrigerant side measurements around the indoor coil, providing a check on energy balance. Internal property codes, consistent with ASHRAE and NIST REFPROP descriptions, were used for calculation of air and refrigerant thermodynamic properties.

Tests were first run with R410A to establish the baseline performance of the unit. Refrigerant charge was varied in 0.5 lbm (0.23 kg) increments while operating at the AHRI "A" conditions, 80°F dry bulb/67°F wet bulb (26.7°C/19.4°C) indoor and 95 °F (35°C) outdoor. The catalog charge of 9.0 lbm (4.1 kg) fell near the peak EER while producing a condenser subcooling of ~15°F (~8°C). The compressor suction superheat was ~13°F (~7°C).

For each subsequent refrigerant, a refrigerant charge sweep was also run at the "A" conditions. The optimum charge was selected to maximize unit efficiency (EER/COP) while also matching the

subcooling obtained with R410A (~15°F, ~8°C). The TXV was also adjusted during the early runs to deliver the target compressor suction superheat obtained with R410A (~13°F, 7°C).

Following selection of charge, runs were made to determine the appropriate compressor speed. The unit was run at the "A" rating conditions and the nominal 60 Hz input frequency to determine "drop-in" performance. If needed, the compressor speed was then adjusted to match the capacity obtained with R410A to within a target of ±1%. This speed was then used for all subsequent tests in both cooling and heating modes.

A series of tests was then executed at the rating points called out in AHRI Standard 210/240 for both cooling and heating. In addition, tests were also run with the outdoor temperature varying in 10°F (5.6°C) increments from 65°F to 125°F (18°C to 52°C) to examine performance over a wide range of ambient temperatures. The indoor temperature was maintained at the "A" condition specification of 80°F/67°F (26.7°C/19.4°C). These tests were run with each refrigerant, using the selected refrigerant charge, TXV setting, and AFD speed.

RESULTS

While running with R410A, the "A" point was repeated five times over the course of the test period to characterize repeatability (variability) of the test facility and unit. Shown in Figure 2, the max-to-min variation (computed as (max–min)/(2·ave)) in capacity was ±1.2% and ±0.9% for EER. With DR-55, the variability in capacity was ±1.5% and ±1.7% for EER over five runs; see Figure 3. With R32, the variability in capacity was ±0.4% and ±0.5% for EER over four runs; see Figure 4. In the interest of time, no repeat runs were made with DR-5A.

Table 3 shows the optimal refrigerant charge for each refrigerant as identified from the charge determination tests along with the TXV and AFD adjustments made to match R410A superheat and capacity at the "A" rating point. R32 required the biggest adjustment to compressor speed, as expected. The resulting EERs are also listed. All three alternative refrigerants showed similar improvements in EER at the "A" conditions over R410A.

Table 3. Refrigerant charge, TXV position, and compressor speed selected for each refrigerant, along with the average capacity and EER obtained at the "A" point for each.

Refrig	# of runs	Charge (lbm)	TXV (turns)	AFD (Hz)	CAP	wrt R410A	EER	wrt R410A
R410A	5	9.0	0	60	50,241	–	11.32	–
DR-55	5	8.2	1 CW	60	50,213	–0.1%	11.81	+4.3%
R32	4	7.25	3 CW	55	50,637	+0.9%	11.98	+5.8%
DR-5A	1	8.2	3 CW	61	50,627	+0.8%	11.84	+4.6%
CW is clockwise (in/closed), CAP is Capacity in BTU/hr, EER is in BTU/W·hr								

Although we measured and report the superheat at the compressor suction, the feedback bulb for the cooling mode TXV is located at the common outlet of the indoor coil in this unit. The superheat

leaving the indoor coil is only ~1°F with the additional superheat at the compressor suction contributed by the four-way mode switching valve located between the indoor coil and the compressor suction. A minimum of 1°F to 2°F of superheat is needed at the TXV bulb location to maintain stable operation. For R32, we needed to raise the compressor suction superheat to ~18°F (10°C) to allow the minimum superheat at the TXV bulb location because its higher compressor discharge temperature results in a larger addition to the superheat across the valve.

The performance measured at the moderate "B" conditions (wet indoor coil with 82°F/27.8°C ambient temperature) and "C" conditions (dry indoor coil) are listed in Table 4. All three alternative refrigerants showed a slight 0.5% to 1.3% reduction in capacity relative to R410A, except for DR-55's 3% increase at the "C" conditions. These can be considered to be the same within the measurement variability. As at the "A" conditions, the three alternatives all produced improved efficiencies over R410A ranging from +2% to +7%.

The cyclic "D" test was also performed for each refrigerant as described in Section 3.5 of Appendix M to AHRI Standard 210/240. The traces of cooling capacity and compressor power draw during the final six minute "on" cycle for each refrigerant are shown in Figure 5 through Figure 8. In each case, the compressor power draw eventually settles to the steady-state value obtained during the corresponding "C" test after an initial mild overshoot.

The baseline R410A capacity does not quite reach the steady value achieved during the "C" test at the end of the six minute compressor run period. With DR-55, the unit gains capacity somewhat more quickly than with R410A and is just reaching the steady-state capacity at the end of the six minute compressor run period. DR-55 also provides a little more cooling capacity during the indoor fan run period after the compressor turns off at the 30 minute mark. This contributes to DR-55's lower degradation coefficient, C_D^c, listed in Table 5 below.

Table 4. Average capacity and EER obtained at the "B" and "C" points for each.

	"B"					"C"				
Refrig	# of runs	CAP	wrt R410A	EER	wrt R410A	# of runs	CAP	wrt R410A	EER	wrt R410A
R410A	1	55,861	–	14.33	–	2	49,864	–	12.93	–
DR-55	2	55,189	–1.2%	14.77	+3.1%	1	51,467	+3.2%	13.87	+7.3%
R32	1	55,330	–1.0%	14.99	+4.6%	1	49,574	–0.6%	13.50	+4.4%
DR-5A	1	55,603	–0.5%	14.81	+3.3%	1	49,201	–1.3%	13.18	+1.9%

Although capacity with R32 reaches the steady state value before the end of the six minute run period, its ramp rate is slightly slower than DR-55's, resulting in a slightly higher value of C_D^c. The unit exhibits the quickest capacity ramp rate when running with DR-5A, eventually exceeding the "C" capacity slightly by the end of the six minute run period and resulting in a very low value of C_D^c. Combined with slightly higher EERs at the "B" conditions, the smaller degradation coefficients obtained with the three alterative refrigerants result in SEER ratings that are higher than R410A by 7% to 14%.

The integration profiles of degradation coefficient are plotted in Figure 9 where the value of C_D^c is given by the last point in each trace. These traces again show the slightly faster ramp in capacity achieved with DR-55 and R32 and the significantly faster ramp rate with DR-5A. The traces also highlight the extra "free" capacity obtained with DR-5A during the indoor fan run time after the compressor was turned off.

Table 5. SEER and related parameters for each refrigerant; SEER = $(1 - 0.5 \cdot C_D^c) \cdot EER_B$.

Refrig	"B" EER	C_D^c	SEER	wrt R410A
R410A	14.33	0.205	12.86	–
DR-55	14.77	0.134	13.78	+7.2%
R32	14.99	0.168	13.73	+6.8%
DR-5A	14.81	0.009	14.74	+14.6%

The net air-side capacity for each refrigerant as ambient temperature varies from 65°F to 125°F (18°C to 52°C) is plotted in Figure 10. The points at 95°F (35°C) represent the AHRI "A" conditions and points at 82°F (27.8°C) the "B" conditions. All three refrigerants produce capacities similar to R410A across the temperature range with a trend of delivering slightly higher capacities at higher ambient temperatures. This is consistent with predictions based on thermodynamic properties. Note that the unit's maximum compressor discharge temperature limit (250°F, 121°C) prevented operation above an outdoor temperature of 120°F (49°C) when running with R32; see Figure 12.

Unit efficiency (EER) for each refrigerant as ambient temperature varies is plotted in Figure 11. All refrigerants show similar trends, decreasing as outdoor temperature increases in accord with thermodynamic predictions. DR-55 delivers efficiencies that are 3% to 5% higher than R410A with a slight upward trend as ambient temperature increases. DR-5A's efficiency is even slightly higher, again trending higher as ambient temperature increases. R32 also shows elevated efficiencies of ~5% through about 110°F (43°C); EER appears to fall off at higher ambient temperatures.

Compressor discharge temperatures (CDT) are shown in Figure 12. Compressor discharge temperatures for DR-55 and DR-5A were roughly 6°F to 10°F (3.3°C to 5.5°C) higher than the R410A baseline, increasing gradually as ambient temperature increases. When running R32, compressor discharge temperatures were elevated by 20°F (11°C) higher than R410A at 65°F (18°C) ambient, increasing much more rapidly than DR-55 and DR-5A as ambient temperature increases. As noted above, the discharge temperature for R32 reached the 250°F operating limit at an outdoor temperature ~120°F (49°C).

SUMMARY

Performance tests have been run on a standard production rooftop unit of nominal 4 RT capacity and 13.0 SEER with R410A serving as the baseline and alternative refrigerants DR-55, R32, and DR-5A. The only changes to the unit were the replacement of the fixed TXVs with adjustable TXVs of the same size to allow matching superheats and the installation of an AFD to allow

operation of the unit at the same capacity for all refrigerants (allow matching of the compressor capacity to the capacities of the heat exchangers). No changes were made to heat exchanger circuiting.

DR-55 and DR-5A were found to be near design-compatible alternatives to R410A in terms of capacity while providing improved efficiencies of ~4.5% at the "A" rating conditions and ~3% at the "B" rating conditions. Cyclic testing suggests DR-55 and DR-5A offer additional benefits over R410A during transient operation. DR-55 and DR-5A both showed less loss in capacity (0% to +3%) and efficiency (+4% to +7%) compared with R410A at high ambient temperatures. Compressor discharge temperatures increased only modestly (10°F to 12°F) through 125°F (52°C) ambient temperature.

As expected, R32 required an 8.5% reduction in compressor speed to match R410A's cooling capacity at the "A" rating conditions. R32 produced an EER nearly 6% higher than R410A at the "A" conditions and ~4.5% better at the "B" conditions. R32 performed similar to DR-55 and DR-5A at high ambient temperatures with respect to capacity. However, R32's efficiency appeared to drop off above 110°F (43°C) ambient temperature. As expected, R32 exhibited a significantly increased compressor discharge temperature, starting +20°F (+11°C) above R410A at 65°F (18°C) ambient, increasing to +27°F (+15°C) at 95°F (35°C) ambient, and then increasing more rapidly to +44°F (+24°C) at 120°F (49°C) ambient at which point the unit's maximum discharge temperature limit of 250°F (121°C) prevented operation.

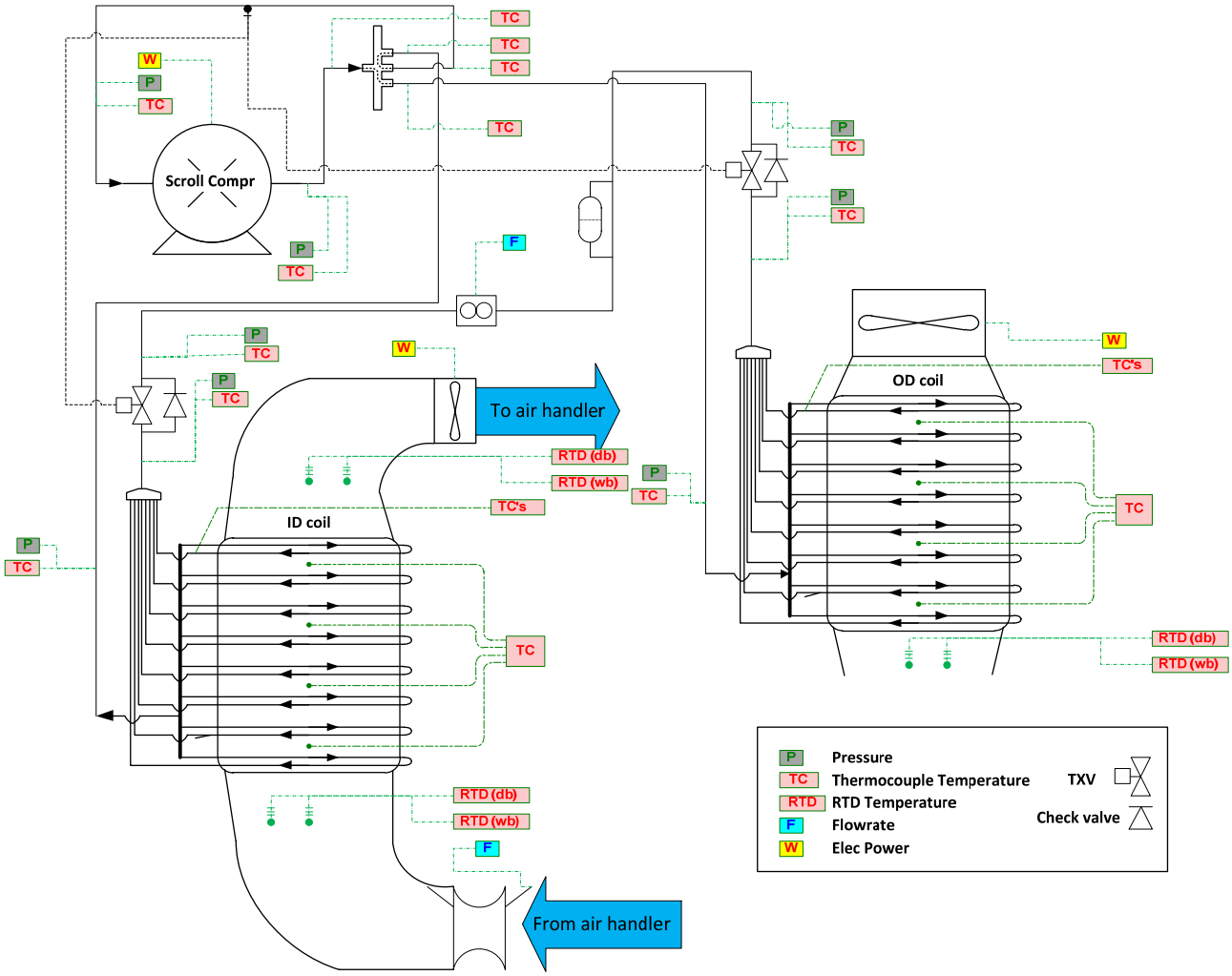
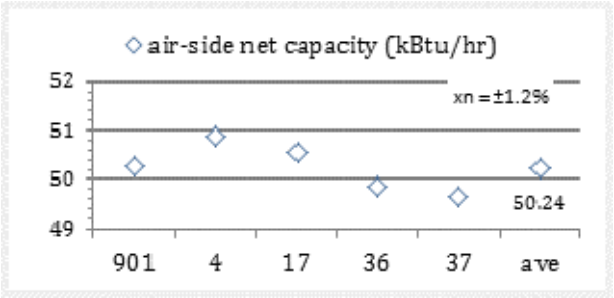


Figure 1. Precedent unit test setup indicating measurement locations.



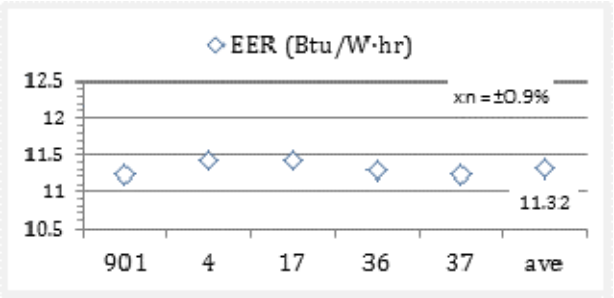
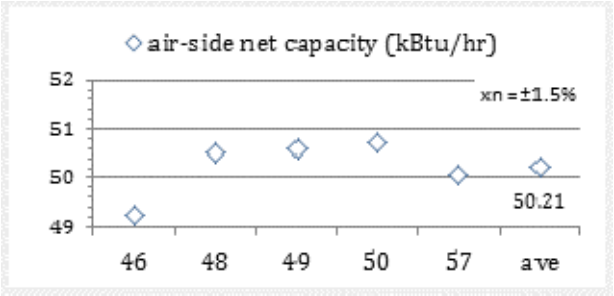


Figure 2. Repeatability of air-side net cooling capacity and EER at the "A" rating point when running with R410A.



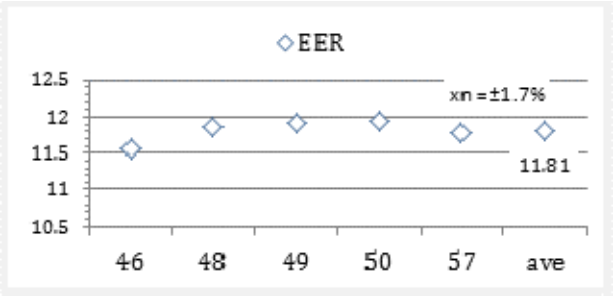
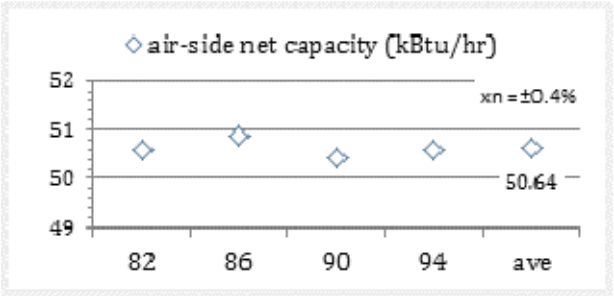


Figure 3. Repeatability of air-side net cooling capacity and EER at the "A" rating point when running with DR-55.



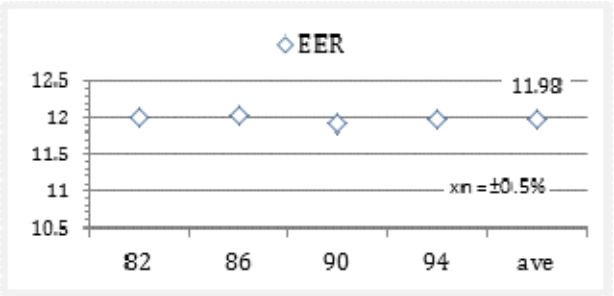


Figure 4. Repeatability of air-side net cooling capacity and EER at the "A" rating point when running with R32.

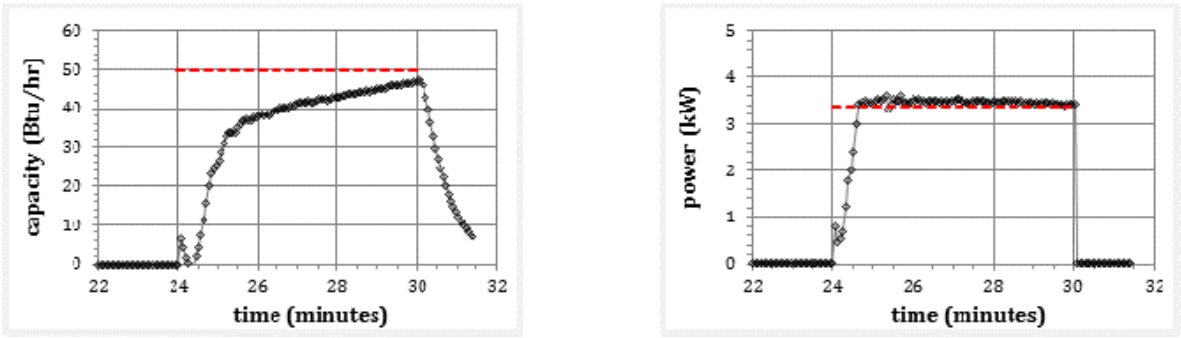


Figure 5. Cooling capacity and compressor power during final "on" cycle of the "D" test with R410A.

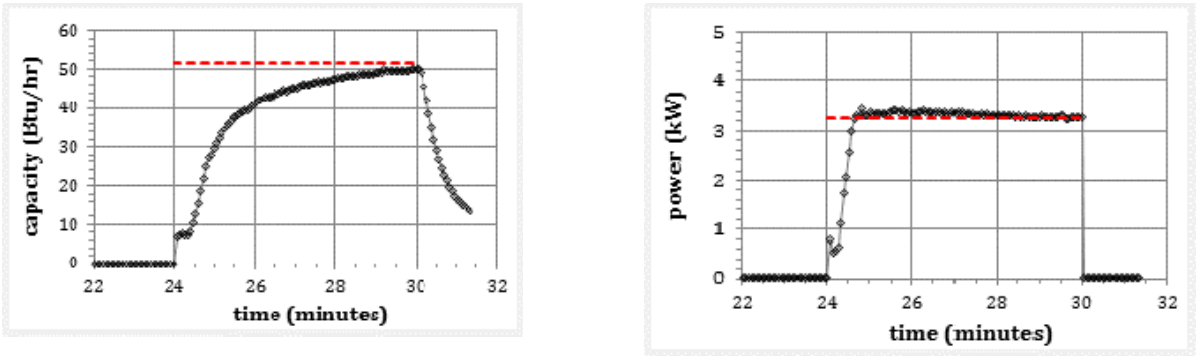


Figure 6. Cooling capacity and compressor power during final "on" cycle of the "D" test with DR-55.

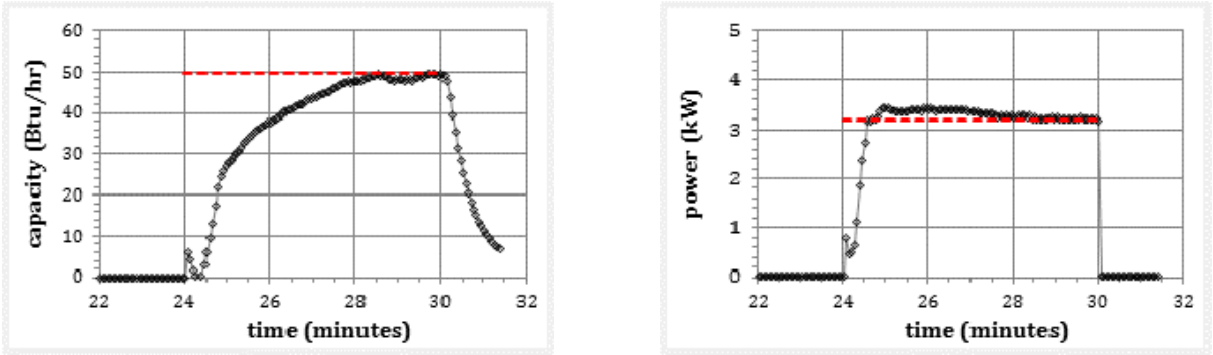


Figure 7. Cooling capacity and compressor power during final "on" cycle of the "D" test with R32.

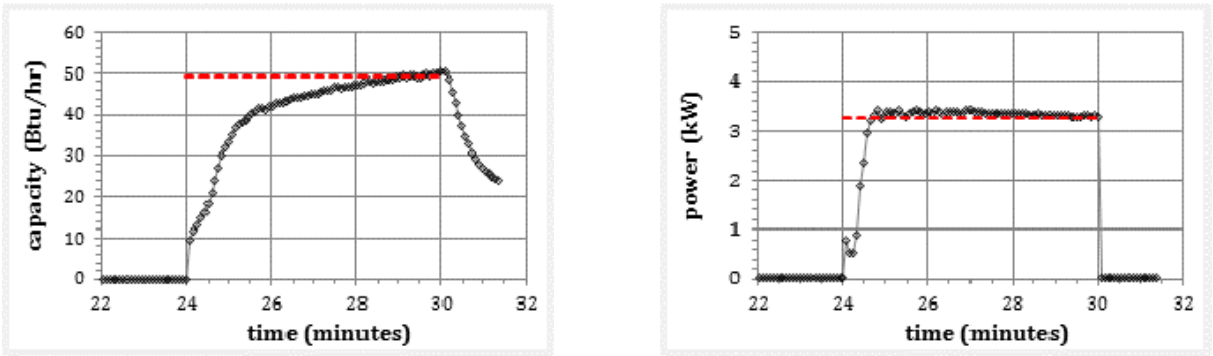


Figure 8. Cooling capacity and compressor power during final "on" cycle of the "D" test with DR-5A.

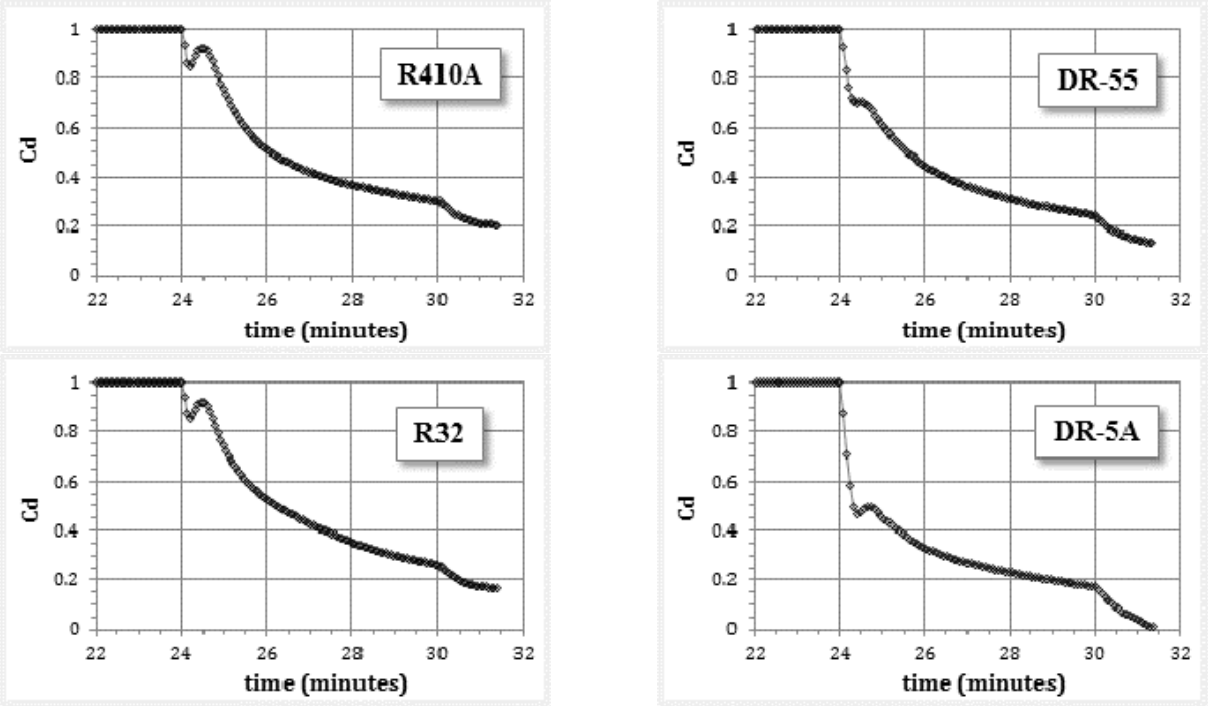


Figure 9. Integration profiles of the cyclic degradation coefficient from the "D" test for each refrigerant. The last point represents that value tabulated in Table 5.

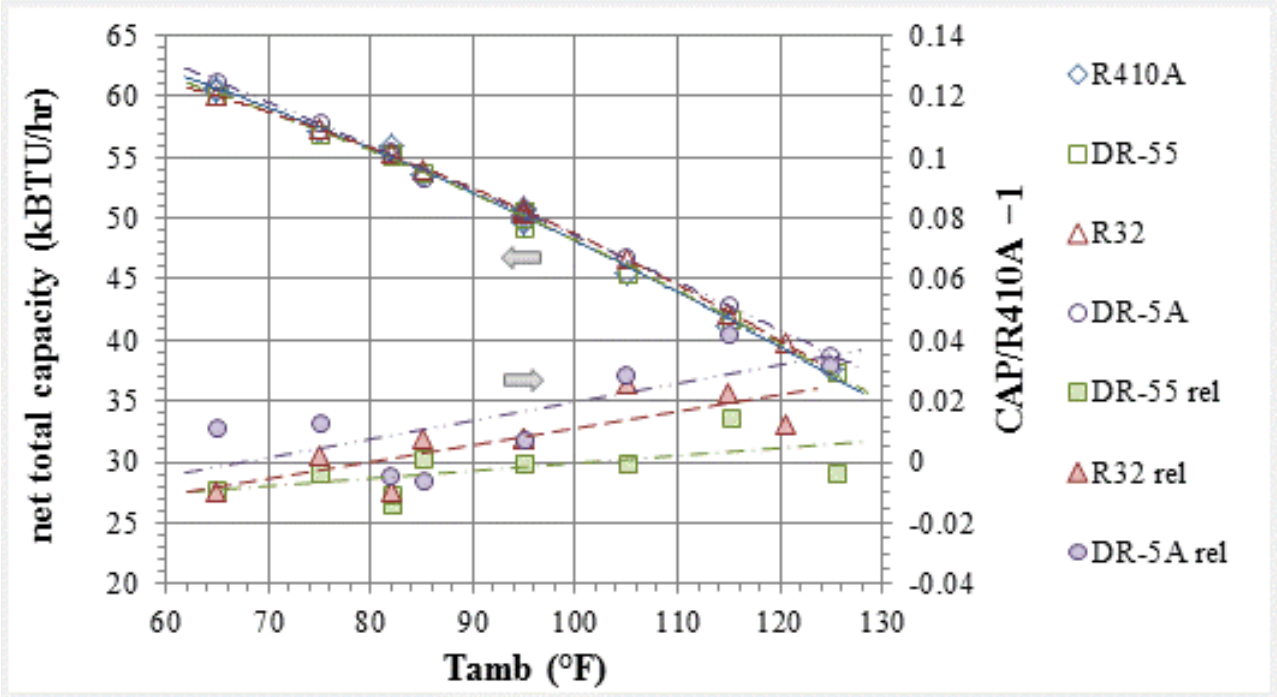


Figure 10. Left axis) Net air-side capacities for all refrigerants as ambient temperature varies. Right axis) Capacity relative to R410A at the same ambient temperature. Multiple points at the same temperature are averaged.

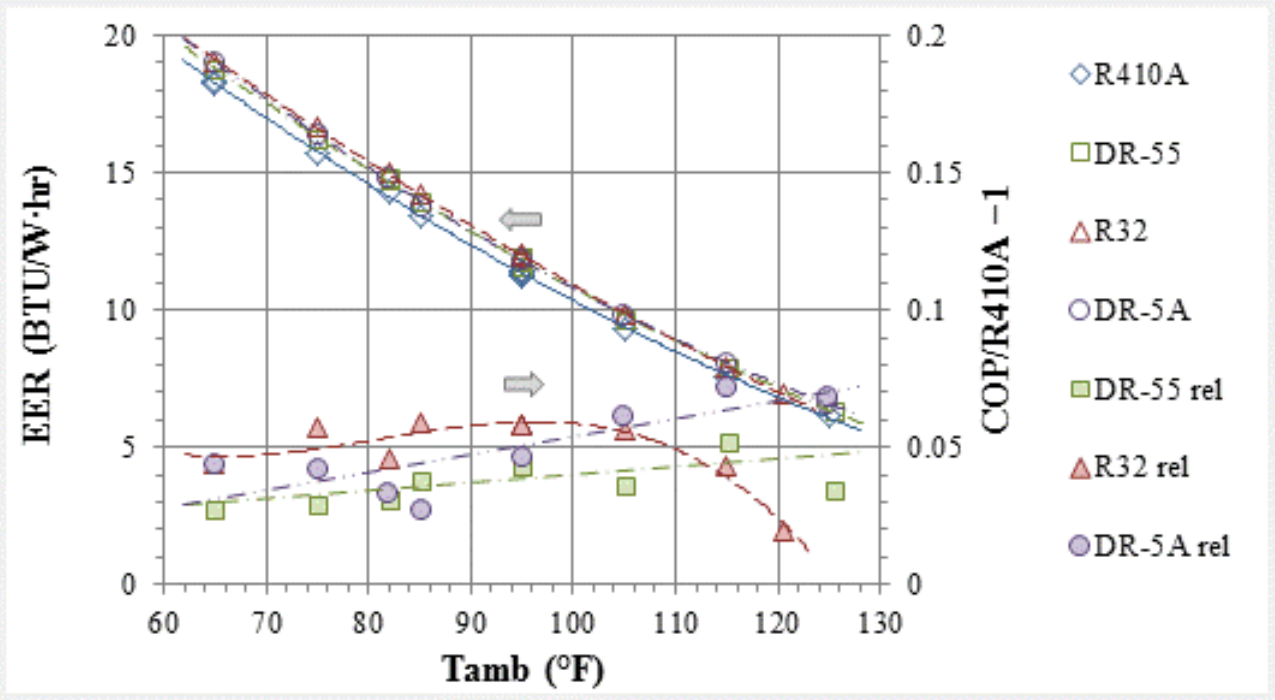


Figure 11. Left axis) EER (COPc) for all refrigerants as ambient temperature varies.
Right axis) EER (COPc) relative to R410A at the same ambient temperature.
Multiple points at the same temperature are averaged.

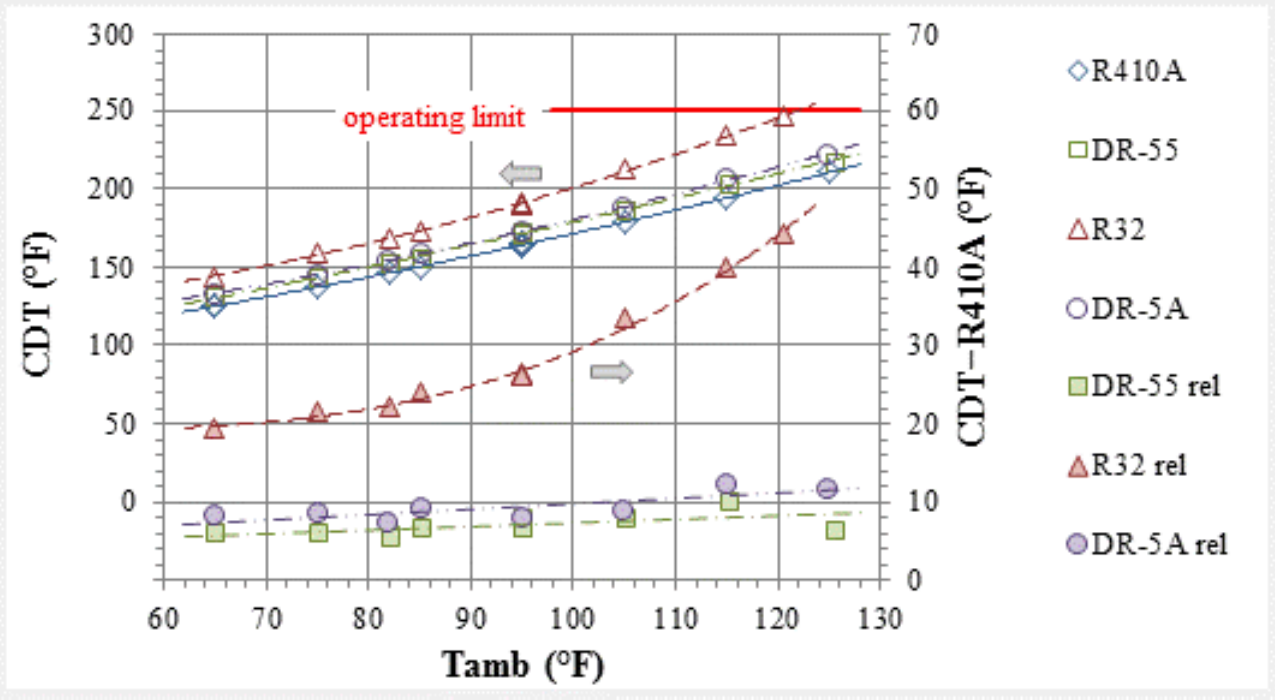


Figure 12. Left axis) Compressor discharge temperature (CDT) for all refrigerants as ambient temperature varies. The unit's operating limit is 250°F.
Right axis) Difference in CDT above R410A at the same ambient temperature.

SYSTEM INFORMATION
common to all tests

system type	packaged rooftop heat pump
manufacturer, model number	Trane, WSC048E3ROA1J catalog net cooling capacity 48,500 Btu/hr (14.2 kW) at 13.0 SEER
refrigerant, charge	R410A, 9.0 lbm (4.1 kg)
lubricant	Emkarate RL32H POE
compressor type, manufacturer, model	scroll, Alliance, SXA044B2BPA
compressor displacement	0.00148 ft³/rev / 2.56 in³/rev / 0.0419 L/rev
indoor coil type, face area	copper tube-and-aluminum fin, 7.71 ft² (0.72 m²) 5/16" tubes, 4 rows, 16 fins/inch
outdoor coil type, face area	copper tube-and-aluminum fin, 10.96 ft² (1.02 m²) 5/16" tubes, 3 rows, 16 fins/inch
cooling mode TXV	Emerson AACE4 ZW195 (adjustable)
heating mode TXV	Emerson AAE3 ZW195 (adjustable)

Data Tables for R410A in IP units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**R410A**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°F	65.0	75.0	82.0	85.0	95.0	105.0	115.0	125.0
indoor drybulb temperature	°F	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
indoor wetbulb temperature	°F	67.0	67.0	67.2	67.0	67.0	67.0	66.9	66.9
indoor air flow rate	scfm	1598	1602	1593	1603	1598	1593	1597	1597
net air-side capacity	Btu/hr	60,687	57,170	55,862	53,641	49,860	45,543	41,150	37,553
R410A/R410A −1									
net sensible capacity	Btu/hr	42,408	40,656	39,145	38,948	37,047	34,793	32,836	30,962
latent capacity	Btu/hr	18,279	16,514	16,716	14,693	12,813	10,750	8,314	6,591
sensible heat ratio	[]	0.699	0.711	0.701	0.726	0.743	0.764	0.798	0.824
compressor power input	kW	2.49	2.81	3.08	3.18	3.61	4.10	4.66	5.31
total power input	kW	3.32	3.63	3.90	3.99	4.42	4.89	5.45	6.10
energy efficiency ratio, EER	Btu/W·hr	18.30	15.74	14.33	13.43	11.29	9.31	7.55	6.16
coef of performance, COP	[]	5.36	4.61	4.20	3.94	3.31	2.73	2.21	1.80
R410A/R410A −1									
cmpr suction pressure	psia	148.2	150.8	154.0	154.8	157.8	160.5	163.4	166.3
cmpr suction sat temp	°F	46.4	47.4	48.7	49.0	50.2	51.2	52.3	53.4
cmpr suction temperature	°F	58.4	59.2	61.1	61.0	63.0	64.9	66.3	68.2
cmpr suction superheat	°Fd	12.0	11.8	12.4	12.0	12.9	13.6	14.0	14.8
cmpr discharge pressure	psia	281.3	321.3	352.2	365.4	413.2	467.0	523.8	584.0
cmpr discharge temperature	°F	125.0	136.8	146.4	149.4	163.6	178.6	193.7	210.3
condenser inlet pressure	psia	278.8	319.3	350.5	363.7	412.0	466.1	523.2	583.9
condenser inlet sat temp	°F	87.4	97.1	103.9	106.7	116.1	125.8	135.0	144.0
condenser inlet temperature	°F	121.8	133.5	142.9	146.1	160.0	174.8	189.6	205.9
condenser outlet pressure	psia	274.2	315.0	346.3	359.5	408.0	462.2	519.4	579.9
condenser outlet sat temp	°F	86.1	95.9	102.8	105.6	115.2	124.9	134.3	143.3
condenser outlet temperature	°F	69.7	79.7	87.0	90.1	100.2	110.2	120.2	129.8
condenser outlet subcooling	°Fd	16.4	16.2	15.8	15.5	15.0	14.7	14.1	13.5
subcooling at TXV inlet	°Fd	13.5	13.6	13.4	13.2	13.1	13.1	12.9	12.6
refrigerant flow rate	lbm/hr	743.6	749.9	760.4	762.9	763.6	765.9	762.2	755.0
R410A/R410A −1									
evaporator inlet pressure	psia	176.3	185.4	193.6	196.8	206.3	215.9	224.8	232.5
evaporator outlet pressure	psia	149.4	152.0	155.3	156.1	159.0	161.8	164.7	167.6
evaporator outlet sat temp	°F	46.9	47.9	49.2	49.5	50.7	51.7	52.8	53.9
evaporator outlet temperature	°F	50.3	49.5	50.4	50.7	52.0	52.7	53.8	54.8
evaporator outlet superheat	°Fd	3.4	1.6	1.2	1.1	1.3	1.0	1.0	0.9

Data Tables for DR-55 in IP units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**DR-55**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°F	65.0	75.1	82.0	85.1	95.0	105.0	115.1	125.4
indoor drybulb temperature	°F	80.1	80.1	80.0	80.1	80.1	80.0	80.1	81.1
indoor wetbulb temperature	°F	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1
indoor air flow rate	scfm	1597	1597	1592	1594	1596	1602	1599	1598
net air-side capacity	Btu/hr	60,056	56,985	55,091	53,687	50,041	45,521	41,746	37,428
DR-55/R410A −1		-0.010	-0.003	-0.014	+0.001	+0.004	-0.000	+0.014	-0.003
net sensible capacity	Btu/hr	42,168	40,654	39,431	39,059	37,299	35,445	33,328	32,714
latent capacity	Btu/hr	17,888	16,331	15,660	14,627	12,743	10,076	8,419	4,714
sensible heat ratio	[]	0.702	0.713	0.716	0.728	0.745	0.779	0.798	0.874
compressor power input	kW	2.38	2.70	2.93	3.04	3.45	3.92	4.46	5.08
total power input	kW	3.20	3.52	3.74	3.85	4.25	4.72	5.26	5.87
energy efficiency ratio, EER	Btu/W·hr	18.75	16.20	14.74	13.94	11.77	9.65	7.94	6.37
coef of performance, COP	[]	5.50	4.75	4.32	4.09	3.45	2.83	2.33	1.87
DR-55/R410A −1		+0.025	+0.029	+0.029	+0.038	+0.043	+0.037	+0.052	+0.035
cmpr suction pressure	psia	145.6	148.8	151.3	152.2	154.6	156.7	158.0	161.9
cmpr suction sat temp	°F	49.4	50.7	51.7	52.1	53.0	53.9	54.4	55.9
cmpr suction temperature	°F	61.8	62.4	63.8	64.2	65.9	67.7	68.9	67.0
cmpr suction superheat	°Fd	12.5	11.8	12.0	12.1	12.9	13.8	14.5	11.1
cmpr discharge pressure	psia	266.9	305.6	334.0	347.7	393.2	443.8	498.9	557.9
cmpr discharge temperature	°F	131.2	143.0	152.2	156.2	170.9	186.7	203.8	216.9
condenser inlet pressure	psia	265.0	304.1	332.8	346.2	392.6	443.4	498.9	557.8
condenser inlet sat temp	°F	88.5	98.3	104.9	107.8	117.3	126.8	136.1	145.2
condenser inlet temperature	°F	127.3	139.1	148.2	152.0	166.6	182.1	198.6	211.5
condenser outlet pressure	psia	261.3	300.6	329.3	342.9	389.2	440.1	495.6	554.3
condenser outlet sat temp	°F	85.2	95.2	101.8	104.9	114.5	124.1	133.7	143.0
condenser outlet temperature	°F	69.2	79.8	87.0	90.1	100.1	110.1	119.7	130.1
condenser outlet subcooling	°Fd	15.9	15.4	14.8	14.8	14.3	14.1	14.0	12.9
subcooling at TXV inlet	°Fd	13.5	13.2	12.9	12.8	12.7	12.8	13.1	12.1
refrigerant flow rate	lbm/hr	619.0	631.3	634.8	639.9	635.2	635.8	627.5	635.2
DR-55/R410A −1		-16.8	-15.8	-16.5	-16.1	-16.8	-17.0	-17.7	-15.9
evaporator inlet pressure	psia	166.6	175.5	181.8	184.7	192.2	199.5	205.2	215.4
evaporator outlet pressure	psia	146.6	149.6	152.3	153.1	155.6	157.6	159.0	162.9
evaporator outlet sat temp	°F	49.8	51.0	52.1	52.4	53.4	54.2	54.8	56.3
evaporator outlet temperature	°F	51.9	52.2	53.1	53.3	54.3	55.1	55.4	56.7
evaporator outlet superheat	°Fd	2.2	1.2	1.0	0.9	0.9	0.8	0.6	0.4

Data Tables for R32 in IP units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**R32**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°F	65.0	75.0	82.0	85.0	95.0	105.0	115.0	120.6
indoor drybulb temperature	°F	80.1	80.0	80.0	80.1	80.0	80.1	80.0	79.8
indoor wetbulb temperature	°F	67.1	67.1	67.0	67.1	67.1	67.1	67.1	67.1
indoor air flow rate	scfm	1599	1597	1598	1598	1592	1596	1599	1601
net air-side capacity	Btu/hr	59,995	57,265	55,330	54,038	50,441	46,720	42,086	39,844
R32/R410A −1		-0.011	+0.002	-0.010	+0.007	+0.012	+0.026	+0.023	+0.013
net sensible capacity	Btu/hr	42,193	40,629	39,597	39,065	37,254	35,392	33,200	31,636
latent capacity	Btu/hr	17,802	16,637	15,733	14,973	13,188	11,329	8,886	8,208
sensible heat ratio	[]	0.703	0.709	0.716	0.723	0.739	0.758	0.789	0.794
compressor power input	kW	2.33	2.63	2.89	3.00	3.43	3.95	4.55	4.91
total power input	kW	3.15	3.44	3.69	3.80	4.23	4.75	5.34	5.71
energy efficiency ratio, EER	Btu/W·hr	19.07	16.64	14.99	14.22	11.92	9.84	7.88	6.98
coef of performance, COP	[]	5.59	4.88	4.39	4.17	3.49	2.88	2.31	2.05
R32/R410A −1		+0.042	+0.057	+0.046	+0.059	+0.056	+0.057	+0.044	+0.019
cmpr suction pressure	psia	159.2	162.3	164.5	165.5	168.3	170.1	171.9	172.3
cmpr suction sat temp	°F	49.5	50.7	51.5	51.9	52.9	53.5	54.2	54.3
cmpr suction temperature	°F	66.9	68.0	68.7	69.2	70.8	74.5	76.3	77.0
cmpr suction superheat	°Fd	17.5	17.3	17.2	17.3	17.9	21.0	22.1	22.7
cmpr discharge pressure	psia	281.0	322.1	353.3	367.2	416.9	470.7	528.0	562.3
cmpr discharge temperature	°F	144.3	158.2	168.7	173.3	190.3	212.0	233.5	246.2
condenser inlet pressure	psia	279.9	321.3	352.8	367.0	416.5	470.7	528.4	562.8
condenser inlet sat temp	°F	86.1	95.8	102.6	105.5	115.1	124.6	133.8	138.9
condenser inlet temperature	°F	139.3	153.0	163.2	167.8	184.3	205.0	225.6	237.5
condenser outlet pressure	psia	276.9	318.5	350.0	364.2	413.7	467.9	525.4	559.8
condenser outlet sat temp	°F	85.3	95.2	102.0	105.0	114.6	124.1	133.3	138.4
condenser outlet temperature	°F	70.2	80.7	87.8	91.0	101.3	110.8	120.4	125.6
condenser outlet subcooling	°Fd	15.1	14.5	14.2	14.0	13.3	13.3	12.9	12.8
subcooling at TXV inlet	°Fd	13.0	12.6	12.4	12.2	11.8	12.1	12.0	12.0
refrigerant flow rate	lbm/hr	497.1	502.9	506.6	507.6	506.5	497.0	487.4	478.3
R32/R410A −1		-33.2	-32.9	-33.4	-33.5	-33.7	-35.1	-36.0	-36.6
evaporator inlet pressure	psia	173.3	180.1	185.0	187.1	193.5	198.0	202.4	203.8
evaporator outlet pressure	psia	159.6	162.7	164.9	166.0	168.6	170.5	172.4	172.7
evaporator outlet sat temp	°F	49.7	50.8	51.6	52.0	53.0	53.7	54.3	54.5
evaporator outlet temperature	°F	56.5	55.4	54.4	54.5	55.2	60.3	58.9	58.0
evaporator outlet superheat	°Fd	6.9	4.6	2.7	2.4	2.2	6.6	4.6	3.6

Data Tables for DR-5A in IP units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**DR-5A**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°F	65.0	75.0	81.9	85.0	95.0	104.9	115.0	124.9
indoor drybulb temperature	°F	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.1
indoor wetbulb temperature	°F	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0
indoor air flow rate	scfm	1602	1600	1599	1600	1597	1600	1599	1598
net air-side capacity	Btu/hr	61,270	57,926	55,603	53,348	50,627	46,845	42,877	38,765
DR-5A/R410A −1		+0.010	+0.013	-0.005	-0.005	+0.015	+0.029	+0.042	+0.032
net sensible capacity	Btu/hr	42,763	41,155	40,031	39,481	37,730	35,869	33,831	31,532
latent capacity	Btu/hr	18,507	16,771	15,572	13,867	12,898	10,976	9,046	7,234
sensible heat ratio	[]	0.698	0.710	0.720	0.740	0.745	0.766	0.789	0.813
compressor power input	kW	2.40	2.72	2.95	3.07	3.47	3.95	4.51	5.10
total power input	kW	3.22	3.53	3.76	3.87	4.27	4.74	5.30	5.89
energy efficiency ratio, EER	Btu/W·hr	19.05	16.41	14.80	13.80	11.84	9.88	8.09	6.58
coef of performance, COP	[]	5.58	4.81	4.34	4.04	3.47	2.90	2.37	1.93
DR-5A/R410A −1		+0.041	+0.043	+0.033	+0.027	+0.050	+0.061	+0.072	+0.069
cmpr suction pressure	psia	144.5	147.7	149.7	150.9	153.2	155.5	157.3	160.2
cmpr suction sat temp	°F	49.9	51.2	52.0	52.5	53.5	54.4	55.1	56.2
cmpr suction temperature	°F	63.2	64.0	64.8	65.4	66.1	67.6	70.0	71.2
cmpr suction superheat	°Fd	13.3	12.8	12.7	12.8	12.6	13.2	14.9	14.9
cmpr discharge pressure	psia	265.1	303.9	331.0	345.7	390.5	440.5	495.4	551.8
cmpr discharge temperature	°F	133.1	145.3	154.0	158.6	172.2	187.6	206.1	222.2
condenser inlet pressure	psia	263.1	301.8	329.6	344.5	389.8	440.0	495.4	551.6
condenser inlet sat temp	°F	89.1	98.9	105.3	108.6	117.9	127.3	136.8	145.5
condenser inlet temperature	°F	129.1	141.2	149.8	154.3	167.7	182.8	200.7	216.5
condenser outlet pressure	psia	259.4	298.3	326.3	341.0	386.3	436.7	492.1	548.1
condenser outlet sat temp	°F	85.3	95.3	101.8	105.1	114.6	124.3	133.9	142.9
condenser outlet temperature	°F	69.0	79.5	86.5	89.8	100.0	109.9	119.7	129.2
condenser outlet subcooling	°Fd	16.3	15.8	15.3	15.4	14.6	14.4	14.2	13.7
subcooling at TXV inlet	°Fd	13.9	13.7	13.5	13.5	13.0	13.1	13.4	13.0
refrigerant flow rate	lbm/hr	608.4	617.6	622.2	625.2	627.2	626.6	617.7	615.1
DR-5A/R410A −1		-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.19	-0.19
evaporator inlet pressure	psia	165.2	173.8	179.5	182.6	190.4	197.7	203.8	211.3
evaporator outlet pressure	psia	145.3	148.6	150.5	151.7	154.1	156.4	158.2	161.1
evaporator outlet sat temp	°F	50.2	51.6	52.4	52.9	53.8	54.8	55.5	56.6
evaporator outlet temperature	°F	53.7	53.6	54.0	54.3	54.9	55.6	56.1	57.1
evaporator outlet superheat	°Fd	3.5	2.0	1.6	1.4	1.1	0.9	0.7	0.5

Data Tables for R410A in SI units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**R410A**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°C	18.3	23.9	27.8	29.4	35.0	40.6	46.1	51.7
indoor drybulb temperature	°C	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
indoor wetbulb temperature	°C	19.4	19.5	19.5	19.4	19.4	19.4	19.4	19.4
indoor air flow rate	m^3/s	0.754	0.756	0.752	0.756	0.754	0.752	0.754	0.754
net air-side capacity	kW	17.79	16.76	16.37	15.72	14.61	13.35	12.06	11.01
R410A/R410A −1									
net sensible capacity	kW	12.43	11.92	11.47	11.41	10.86	10.20	9.62	9.07
latent capacity	kW	5.36	4.84	4.90	4.31	3.76	3.15	2.44	1.93
sensible heat ratio	[]	0.699	0.711	0.701	0.726	0.743	0.764	0.798	0.824
compressor power input	kW	2.49	2.81	3.08	3.18	3.61	4.10	4.66	5.31
total power input	kW	3.32	3.63	3.90	3.99	4.42	4.89	5.45	6.10
energy efficiency ratio, EER	Btu/W·hr	18.30	15.74	14.33	13.43	11.29	9.31	7.55	6.16
coef of performance, COP	[]	5.36	4.61	4.20	3.94	3.31	2.73	2.21	1.80
R410A/R410A −1									
cmpr suction pressure	kPa	1022	1039	1062	1067	1088	1107	1126	1146
cmpr suction sat temp	°C	8.0	8.6	9.3	9.4	10.1	10.7	11.3	11.9
cmpr suction temperature	°C	14.7	15.1	16.2	16.1	17.2	18.3	19.0	20.1
cmpr suction superheat	°Cd	6.7	6.5	6.9	6.7	7.2	7.6	7.8	8.2
cmpr discharge pressure	kPa	1940	2215	2428	2519	2849	3220	3612	4027
cmpr discharge temperature	°C	51.7	58.2	63.6	65.2	73.1	81.4	89.8	99.1
condenser inlet pressure	kPa	1923	2201	2416	2508	2840	3213	3607	4026
condenser inlet sat temp	°C	30.8	36.2	40.0	41.5	46.7	52.1	57.2	62.2
condenser inlet temperature	°C	49.9	56.4	61.6	63.4	71.1	79.3	87.6	96.6
condenser outlet pressure	kPa	1891	2172	2388	2479	2813	3187	3581	3998
condenser outlet sat temp	°C	30.0	35.5	39.4	40.9	46.2	51.6	56.8	61.8
condenser outlet temperature	°C	20.9	26.5	30.6	32.3	37.9	43.5	49.0	54.3
condenser outlet subcooling	°Cd	9.1	9.0	8.8	8.6	8.3	8.2	7.8	7.5
subcooling at TXV inlet	°Cd	7.5	7.6	7.5	7.4	7.3	7.3	7.2	7.0
refrigerant flow rate	kg/hr	337.3	340.2	344.9	346.0	346.4	347.4	345.7	342.5
R410A/R410A −1									
evaporator inlet pressure	kPa	1215	1279	1335	1357	1422	1488	1550	1603
evaporator outlet pressure	kPa	1030	1048	1071	1076	1097	1116	1135	1156
evaporator outlet sat temp	°C	8.3	8.8	9.6	9.7	10.4	11.0	11.6	12.2
evaporator outlet temperature	°C	10.2	9.7	10.2	10.4	11.1	11.5	12.1	12.7
evaporator outlet superheat	°Cd	1.9	0.9	0.6	0.6	0.7	0.6	0.5	0.5

Data Tables for DR-55 in SI units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**DR-55**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°C	18.3	24.0	27.8	29.5	35.0	40.6	46.1	51.9
indoor drybulb temperature	°C	26.7	26.7	26.7	26.7	26.7	26.7	26.7	27.3
indoor wetbulb temperature	°C	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
indoor air flow rate	m^3/s	0.754	0.754	0.751	0.752	0.753	0.756	0.754	0.754
net air-side capacity	kW	17.60	16.70	16.15	15.73	14.67	13.34	12.24	10.97
DR-55/R410A −1		-0.010	-0.003	-0.014	+0.001	+0.004	-0.000	+0.014	-0.003
net sensible capacity	kW	12.36	11.92	11.56	11.45	10.93	10.39	9.77	9.59
latent capacity	kW	5.24	4.79	4.59	4.29	3.73	2.95	2.47	1.38
sensible heat ratio	[]	0.702	0.713	0.716	0.728	0.745	0.779	0.798	0.874
compressor power input	kW	2.38	2.70	2.93	3.04	3.45	3.92	4.46	5.08
total power input	kW	3.20	3.52	3.74	3.85	4.25	4.72	5.26	5.87
energy efficiency ratio, EER	Btu/W·hr	18.75	16.20	14.74	13.94	11.77	9.65	7.94	6.37
coef of performance, COP	[]	5.50	4.75	4.32	4.09	3.45	2.83	2.33	1.87
DR-55/R410A −1		+0.025	+0.029	+0.029	+0.038	+0.043	+0.037	+0.052	+0.035
cmpr suction pressure	kPa	1004	1026	1043	1049	1066	1080	1089	1116
cmpr suction sat temp	°C	9.7	10.4	11.0	11.2	11.7	12.2	12.4	13.3
cmpr suction temperature	°C	16.6	16.9	17.6	17.9	18.8	19.8	20.5	19.5
cmpr suction superheat	°Cd	6.9	6.5	6.7	6.7	7.1	7.7	8.0	6.2
cmpr discharge pressure	kPa	1840	2107	2303	2397	2711	3060	3440	3846
cmpr discharge temperature	°C	55.1	61.7	66.8	69.0	77.2	86.0	95.4	102.7
condenser inlet pressure	kPa	1827	2096	2294	2387	2707	3057	3440	3846
condenser inlet sat temp	°C	31.4	36.8	40.5	42.1	47.4	52.6	57.9	62.9
condenser inlet temperature	°C	53.0	59.5	64.6	66.7	74.8	83.4	92.6	99.7
condenser outlet pressure	kPa	1801	2072	2270	2364	2683	3034	3417	3822
condenser outlet sat temp	°C	29.6	35.1	38.8	40.5	45.8	51.2	56.5	61.7
condenser outlet temperature	°C	20.7	26.5	30.6	32.3	37.9	43.4	48.7	54.5
condenser outlet subcooling	°Cd	8.9	8.6	8.2	8.2	8.0	7.8	7.8	7.2
subcooling at TXV inlet	°Cd	7.5	7.3	7.1	7.1	7.1	7.1	7.3	6.7
refrigerant flow rate	kg/hr	280.8	286.4	287.9	290.3	288.1	288.4	284.6	288.1
DR-55/R410A −1		-16.8	-15.8	-16.5	-16.1	-16.8	-17.0	-17.7	-15.9
evaporator inlet pressure	kPa	1149	1210	1253	1273	1325	1375	1415	1485
evaporator outlet pressure	kPa	1011	1032	1050	1056	1073	1087	1096	1123
evaporator outlet sat temp	°C	9.9	10.6	11.2	11.4	11.9	12.4	12.6	13.5
evaporator outlet temperature	°C	11.1	11.2	11.7	11.8	12.4	12.8	13.0	13.7
evaporator outlet superheat	°Cd	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.2

Data Tables for R32 in SI units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**R32**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°C	18.3	23.9	27.8	29.5	35.0	40.6	46.1	49.2
indoor drybulb temperature	°C	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.6
indoor wetbulb temperature	°C	19.5	19.5	19.4	19.5	19.5	19.5	19.5	19.5
indoor air flow rate	m^3/s	0.755	0.754	0.754	0.754	0.752	0.753	0.755	0.756
net air-side capacity	kW	17.58	16.78	16.22	15.84	14.78	13.69	12.33	11.68
R32/R410A −1		-0.011	+0.002	-0.010	+0.007	+0.012	+0.026	+0.023	+0.013
net sensible capacity	kW	12.37	11.91	11.61	11.45	10.92	10.37	9.73	9.27
latent capacity	kW	5.22	4.88	4.61	4.39	3.87	3.32	2.60	2.41
sensible heat ratio	[]	0.703	0.709	0.716	0.723	0.739	0.758	0.789	0.794
compressor power input	kW	2.33	2.63	2.89	3.00	3.43	3.95	4.55	4.91
total power input	kW	3.15	3.44	3.69	3.80	4.23	4.75	5.34	5.71
energy efficiency ratio, EER	Btu/W·hr	19.07	16.64	14.99	14.22	11.92	9.84	7.88	6.98
coef of performance, COP	[]	5.59	4.88	4.39	4.17	3.49	2.88	2.31	2.05
R32/R410A −1		+0.042	+0.057	+0.046	+0.059	+0.056	+0.057	+0.044	+0.019
cmpr suction pressure	kPa	1097	1119	1134	1141	1160	1173	1185	1188
cmpr suction sat temp	°C	9.7	10.4	10.8	11.0	11.6	12.0	12.3	12.4
cmpr suction temperature	°C	19.4	20.0	20.4	20.7	21.5	23.6	24.6	25.0
cmpr suction superheat	°Cd	9.7	9.6	9.6	9.6	9.9	11.7	12.3	12.6
cmpr discharge pressure	kPa	1937	2221	2436	2532	2875	3245	3640	3877
cmpr discharge temperature	°C	62.4	70.1	76.0	78.5	87.9	100.0	112.0	119.0
condenser inlet pressure	kPa	1930	2215	2432	2530	2871	3245	3643	3880
condenser inlet sat temp	°C	30.0	35.5	39.2	40.9	46.1	51.4	56.5	59.4
condenser inlet temperature	°C	59.6	67.2	72.9	75.4	84.6	96.1	107.6	114.2
condenser outlet pressure	kPa	1909	2196	2413	2511	2852	3226	3623	3859
condenser outlet sat temp	°C	29.6	35.1	38.9	40.5	45.9	51.2	56.3	59.1
condenser outlet temperature	°C	21.2	27.1	31.0	32.8	38.5	43.8	49.1	52.0
condenser outlet subcooling	°Cd	8.4	8.1	7.9	7.8	7.4	7.4	7.2	7.1
subcooling at TXV inlet	°Cd	7.2	7.0	6.9	6.8	6.5	6.7	6.6	6.7
refrigerant flow rate	kg/hr	225.5	228.1	229.8	230.2	229.8	225.4	221.1	217.0
R32/R410A −1		-33.2	-32.9	-33.4	-33.5	-33.7	-35.1	-36.0	-36.6
evaporator inlet pressure	kPa	1195	1242	1275	1290	1334	1365	1396	1405
evaporator outlet pressure	kPa	1101	1122	1137	1145	1163	1176	1189	1191
evaporator outlet sat temp	°C	9.8	10.5	10.9	11.1	11.7	12.0	12.4	12.5
evaporator outlet temperature	°C	13.6	13.0	12.4	12.5	12.9	15.7	14.9	14.5
evaporator outlet superheat	°Cd	3.8	2.5	1.5	1.4	1.2	3.7	2.5	2.0

Data Tables for DR-5A in SI units

Sweep of Ambient/Outdoor Temperature

Data Tables									
refrigerant	**DR-5A**			**"B" pt**		**"A" pt**			
ambient drybulb temperature	°C	18.3	23.9	27.7	29.5	35.0	40.5	46.1	51.6
indoor drybulb temperature	°C	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
indoor wetbulb temperature	°C	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.5
indoor air flow rate	m^3/s	0.756	0.755	0.755	0.755	0.754	0.755	0.754	0.754
net air-side capacity	kW	17.96	16.98	16.30	15.64	14.84	13.73	12.57	11.36
DR-5A/R410A −1		+0.010	+0.013	-0.005	-0.005	+0.015	+0.029	+0.042	+0.032
net sensible capacity	kW	12.53	12.06	11.73	11.57	11.06	10.51	9.92	9.24
latent capacity	kW	5.42	4.92	4.56	4.06	3.78	3.22	2.65	2.12
sensible heat ratio	[]	0.698	0.710	0.720	0.740	0.745	0.766	0.789	0.813
compressor power input	kW	2.40	2.72	2.95	3.07	3.47	3.95	4.51	5.10
total power input	kW	3.22	3.53	3.76	3.87	4.27	4.74	5.30	5.89
energy efficiency ratio, EER	Btu/W·hr	19.05	16.41	14.80	13.80	11.84	9.88	8.09	6.58
coef of performance, COP	[]	5.58	4.81	4.34	4.04	3.47	2.90	2.37	1.93
DR-5A/R410A −1		+0.041	+0.043	+0.033	+0.027	+0.050	+0.061	+0.072	+0.069
cmpr suction pressure	kPa	996	1018	1032	1041	1057	1072	1085	1105
cmpr suction sat temp	°C	9.9	10.7	11.1	11.4	11.9	12.4	12.8	13.5
cmpr suction temperature	°C	17.3	17.8	18.2	18.5	18.9	19.8	21.1	21.8
cmpr suction superheat	°Cd	7.4	7.1	7.1	7.1	7.0	7.4	8.3	8.3
cmpr discharge pressure	kPa	1828	2095	2282	2384	2693	3037	3416	3804
cmpr discharge temperature	°C	56.2	63.0	67.8	70.3	77.9	86.5	96.7	105.7
condenser inlet pressure	kPa	1814	2081	2273	2375	2687	3034	3416	3803
condenser inlet sat temp	°C	31.7	37.1	40.7	42.5	47.7	53.0	58.2	63.0
condenser inlet temperature	°C	54.0	60.7	65.4	67.9	75.4	83.8	93.7	102.5
condenser outlet pressure	kPa	1788	2057	2250	2351	2664	3011	3393	3779
condenser outlet sat temp	°C	29.6	35.1	38.8	40.6	45.9	51.3	56.6	61.6
condenser outlet temperature	°C	20.5	26.4	30.3	32.1	37.8	43.3	48.7	54.0
condenser outlet subcooling	°Cd	9.1	8.8	8.5	8.5	8.1	8.0	7.9	7.6
subcooling at TXV inlet	°Cd	7.7	7.6	7.5	7.5	7.2	7.3	7.4	7.2
refrigerant flow rate	kg/hr	276.0	280.1	282.2	283.6	284.5	284.2	280.2	279.0
DR-5A/R410A −1		-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.19	-0.19
evaporator inlet pressure	kPa	1139	1198	1238	1259	1313	1363	1405	1457
evaporator outlet pressure	kPa	1002	1024	1038	1046	1062	1079	1091	1111
evaporator outlet sat temp	°C	10.1	10.9	11.3	11.6	12.1	12.6	13.0	13.7
evaporator outlet temperature	°C	12.1	12.0	12.2	12.4	12.7	13.1	13.4	13.9
evaporator outlet superheat	°Cd	2.0	1.1	0.9	0.8	0.6	0.5	0.4	0.3