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

TEST REPORT #48

System Drop-in Tests of Refrigerants N-40 and L-20 in a R-404A Ice Machine

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September 23, 2015

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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1. Introduction:

   The ice machine used for this application is the GT564RC with a remote condenser. Ice harvest is about twice per hour and information collected was throughout three cycles. Test facilities are located on site with three test rooms. Refrigerants covered in this report are R-404A, N40, and L20.

2. Details of Test Setup:

   a. Description of System

   The GT564RC ice machine with the remote condenser was the system used to test the refrigerants. The weight of ice per day for this system in 90°F /70°F conditions is 429 pounds and in 70°F /50°F conditions the production is 489 pounds. The test was run under the 90°F /70°F conditions for this system. Energy associated with this machine in the 90°F /70°F condition is at 5.14 kWh per 100 pounds. The refrigerant used for this ice machine is R-404A at a 112 ounce charge. The system uses a Tecumseh compressor (model AKA9455ZXD) with polyolester oil.

   b. Description of Modifications to System

   Initially there was a thought of changing the TXV setting for the different refrigerants. The ice produced was full and consistent in these 2-3 cycles which resulted in no change with the TXV setting for any refrigerant.

   The refrigerant associated with this ice machine is R-404A. The charge for this system is at 112 ounces. Since the system is a remote condenser the charge remained at 112 ounces for N40 and L20. There was no change in refrigerant charge when the refrigerants were removed and replaced with the next refrigerant to test.

   c. Description of Tests Conducted

   Tests were conducted in accordance with AHRI Standard 810 and ASHRAE Standard 29. Before conducting the actual test the ice machine was to run for about 2-3 cycles in order to reach steady state operation and this allowed seeing if any changes needed to be made. Test rooms were brought to 90°F ambient air, the first room for the ice machine and the second room for the remote condenser. The water temperature was set for 70°F and the ice machine was to run for 2-3 cycles to reach steady state. Upon completion the test began initially with R404A, then L20, and finally N40. Each refrigerant was tested and data recorded for three cycles after steady state was reached.

   Instrumentation used was thermocouples (.75% accuracy above 0°C and 1.5% below 0°C), pressure transducers (.25% accuracy), and software to record necessary data throughout the test. The measuring points were low and high side system pressures and evaporator superheat, compressor superheat, and condenser sub cooling. Inlet and outlet temperatures were also recorded for the remote condenser. All ice harvested was weighed

after each cycle along with duration and defrost time for that cycle. The batch weight input into the software allowed for calculation of ice production and energy usage per 100 pounds of ice.

3. Results

   a. Data Form

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: _____ Manufacturer's Notation: _____

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	N40
Alternative Lubricant Type and ISO Viscosity	Polyolester (standard)
Baseline Refrigerant and Lubricant	R404A
Make and Model of System	GT564RC
Nominal Capacity and Type of System	500# Ice Machine with Remote Air-Cooled Condenser

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)									
Compressor Type			Reciprocating	Reciprocating					
Compressor Displacement			0.07052	0.07052	m^3/min	2.49	2.49	ft ^3min	
Nominal Motor Size			3/4	3/4	hp				
Motor Speed			3450	3450	rpm				
Expansion Device Type			TXV	TXV					
Lubricant Charge			0.482	0.482	kg	1.063	1.063	lb	
Refrigerant Charge			3	3	kg	7	7	lb	
Refrigerant Mass Flow Rate					kg/min			lb/min	
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	32.22	32.22	C	90	90	F	
		wb			C			F	
	Outdoor	db	32.22	32.22	C	90	90	F	
		wb			C			F	
Total Capacity					W			Btu/hr	
Sensible Capacity					W			Btu/hr	
Total System Power Input					W			W	
Compressor Power Input					W			W	
Energy Efficiency Ratio (EER)					W/W			Btuh/W	
Coeff. Of Performance (COP)									

Other System Changes

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

Note: Cells that should not be filled in are shaded. Please fill in the blank cells, if applicable, with the appropriate information. Note that some information may not be required or even meaningful, depending on the type of equipment tested.

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: _____ Manufacturer's Notation: _____

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	L20
Alternative Lubricant Type and ISO Viscosity	Polyolester (standard)
Baseline Refrigerant and Lubricant	R404A
Make and Model of System	GT564RC
Nominal Capacity and Type of System	500# Ice Machine with Remote Air-Cooled Condenser

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)									
Compressor Type			Reciprocating	Reciprocating					
Compressor Displacement			0.07052	0.07052	m^3/min	2.49	2.49	ft ^3min	
Nominal Motor Size			3/4	3/4	hp				
Motor Speed			3450	3450	rpm				
Expansion Device Type			TXV	TXV					
Lubricant Charge			0.482	0.482	kg	1.063	1.063	lb	
Refrigerant Charge			3	3	kg	7	7	lb	
Refrigerant Mass Flow Rate					kg/min			lb/min	
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db	32.22	32.22	C	90	90	F	
		wb			C			F	
	Outdoor	db	32.22	32.22	C	90	90	F	
		wb			C			F	
Total Capacity					W			Btu/hr	
Sensible Capacity					W			Btu/hr	
Total System Power Input					W			W	
Compressor Power Input					W			W	
Energy Efficiency Ratio (EER)					W/W			Btuh/W	
Coeff. Of Performance (COP)									

Other System Changes

Each refrigerant seemed to yield well amounts of ice in terms of weight and along with the consistency of identical ice across the evaporator plate. Weight ranged from 6.7 to 7.2 pounds per harvest with L20 being at 6.7, R404A at 7.2, and N40 in the middle. Pressures at suction and discharge stayed consistent each point in the cycle (start, end, and defrost) with L20 having the slightly lower pressures at defrost and start at the discharge location. L20 also had slightly lower temperatures at the inlet and outlet of the condenser for start and end times of the cycle.

Results for the evaporator superheat, compressor superheat, and condenser sub cooling stayed consistent for that particular refrigerant but varied when compared to each other. R404A had consistent evaporator superheat with a slight increasing towards the end. L20 had a higher increasing in the end and N40 had a random spike midway through the cycle at each of the three cycles and was consistent in time with the compressor superheat for that refrigerant. Negative superheat values shown in figures are due to the pressure transducer reacting faster than the thermocouples at the beginning of the harvest stage. When the pressures spike up, the thermocouple is just warming back up.

The reasons for the results in N40 are not known and don't really match with the ice production it made for its three cycles. The pressure temperature charts of each refrigerant provided by Honeywell were used for the software and look up tables for each refrigerant. N40 even resulted in better energy efficiency than R404A. L20 results did not make it into tier 1 for energy efficiency. Each refrigerant did prove to make good ice but N40 resulted in the better energy efficient refrigerant. Figures and tables with results during the test are shown below.

Table: Comparative Performance

GT564RC	**90°F/70°F**	
	Capacity*[lb/24h]*	Energy*[kWh/100lb]*
R404a (baseline)	374.52	7.21
L-20	357.33	7.42
N-40	383.69	6.99

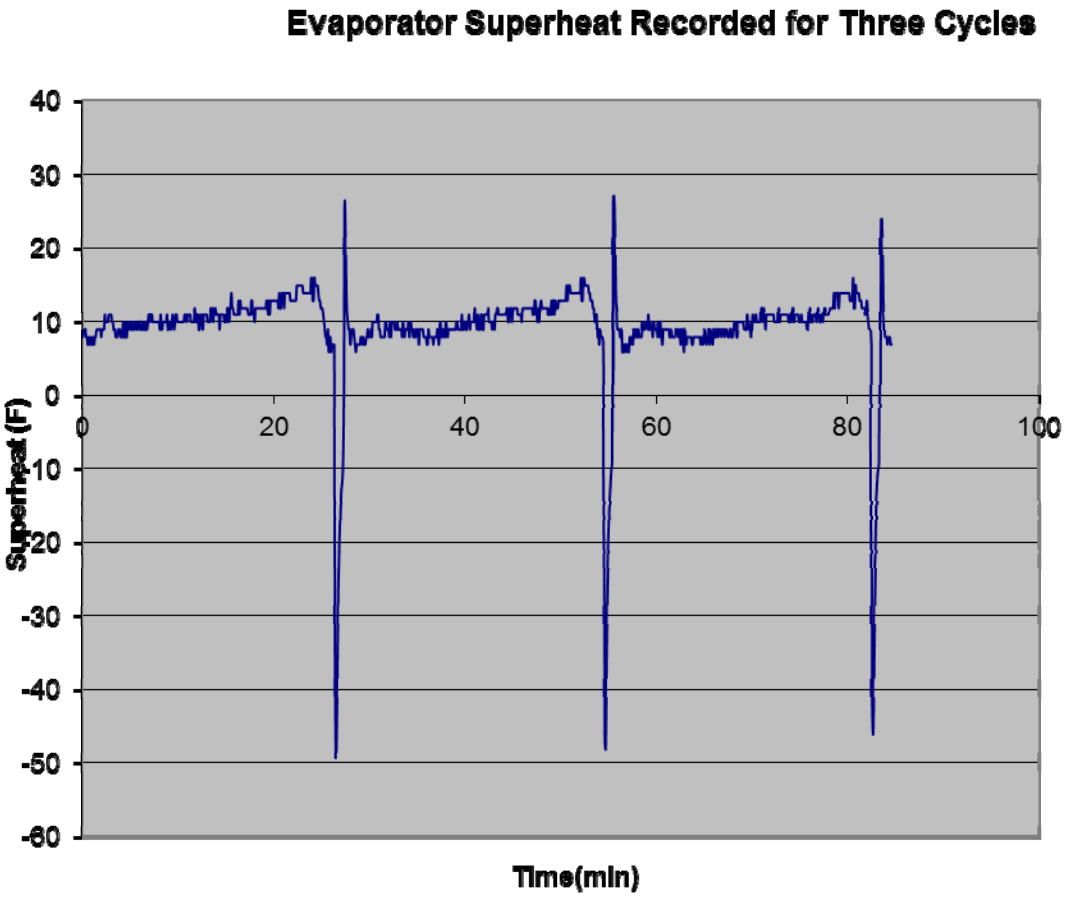

Figure 1 R404A Evaporator Superheat

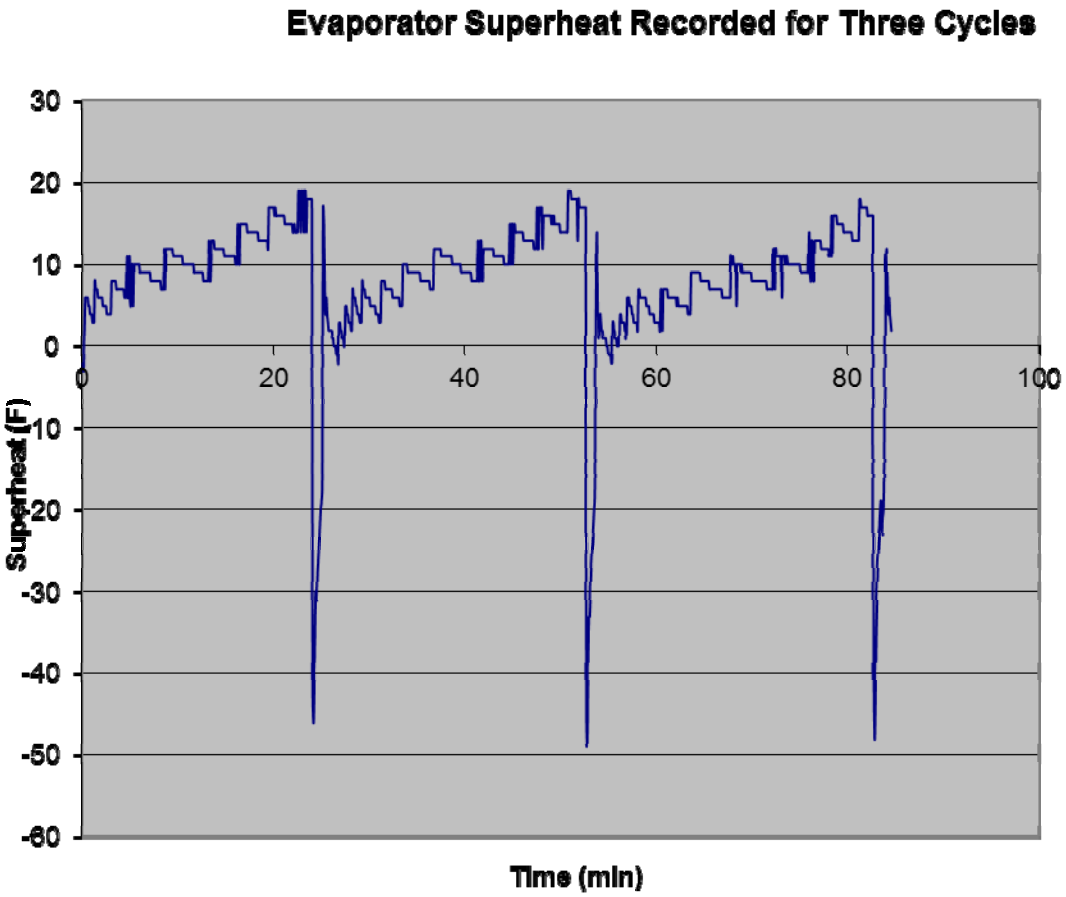

Figure 2 L20 Evaporator Superheat

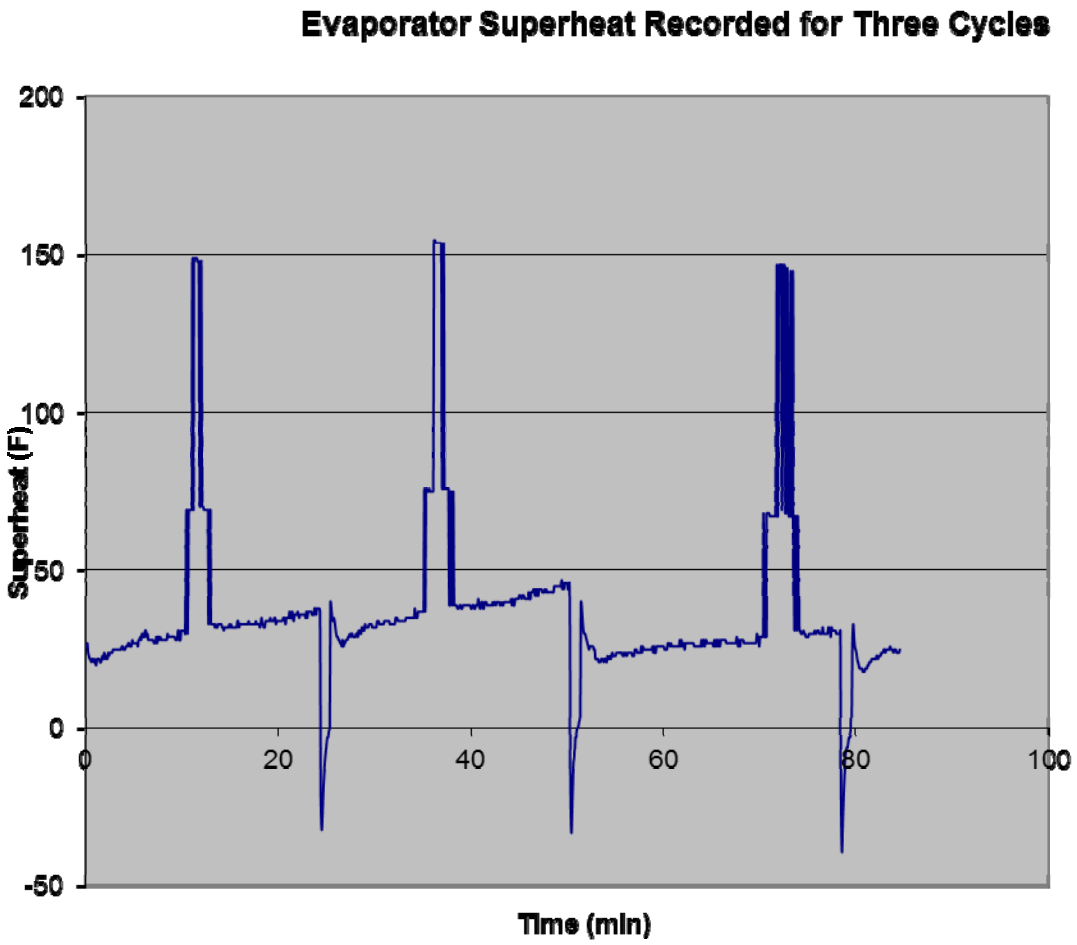

Figure 3 N40 Evaporator Superheat

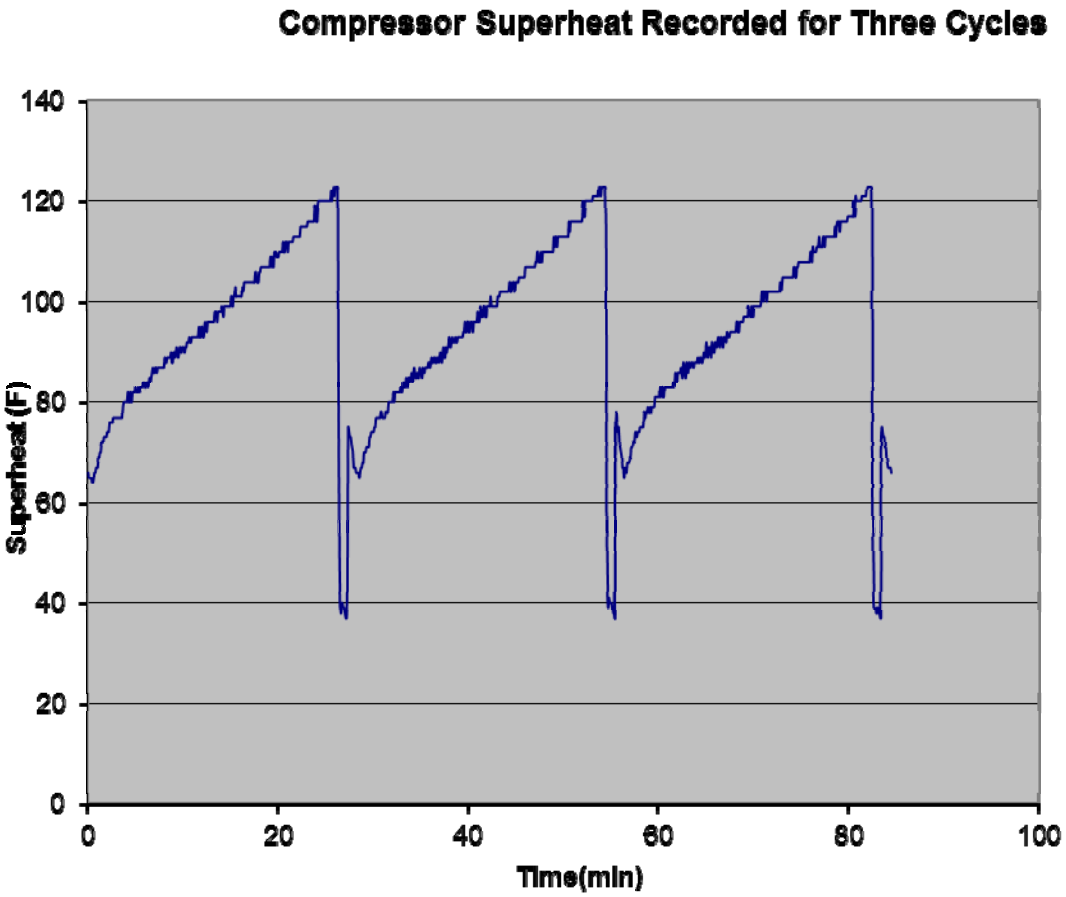

Figure 4 R404A Compressor Superheat

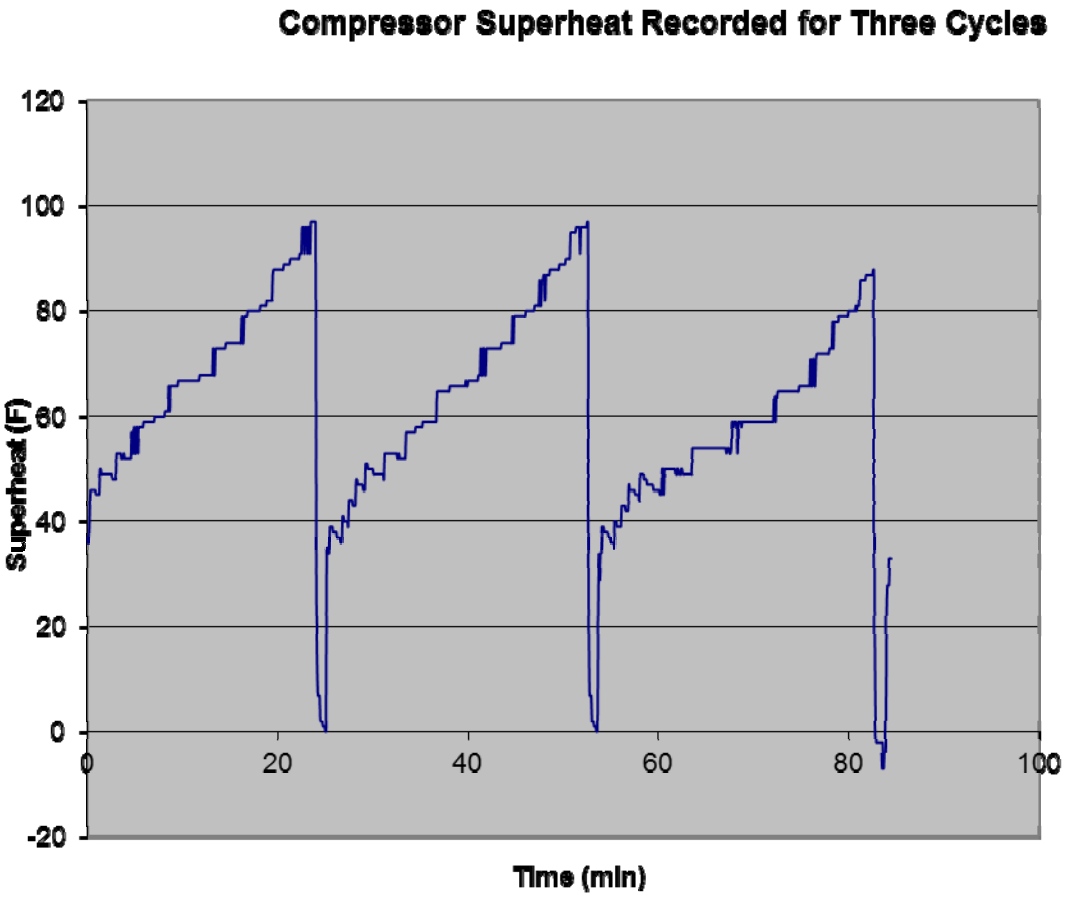

Figure 5 L20 Compressor Superheat

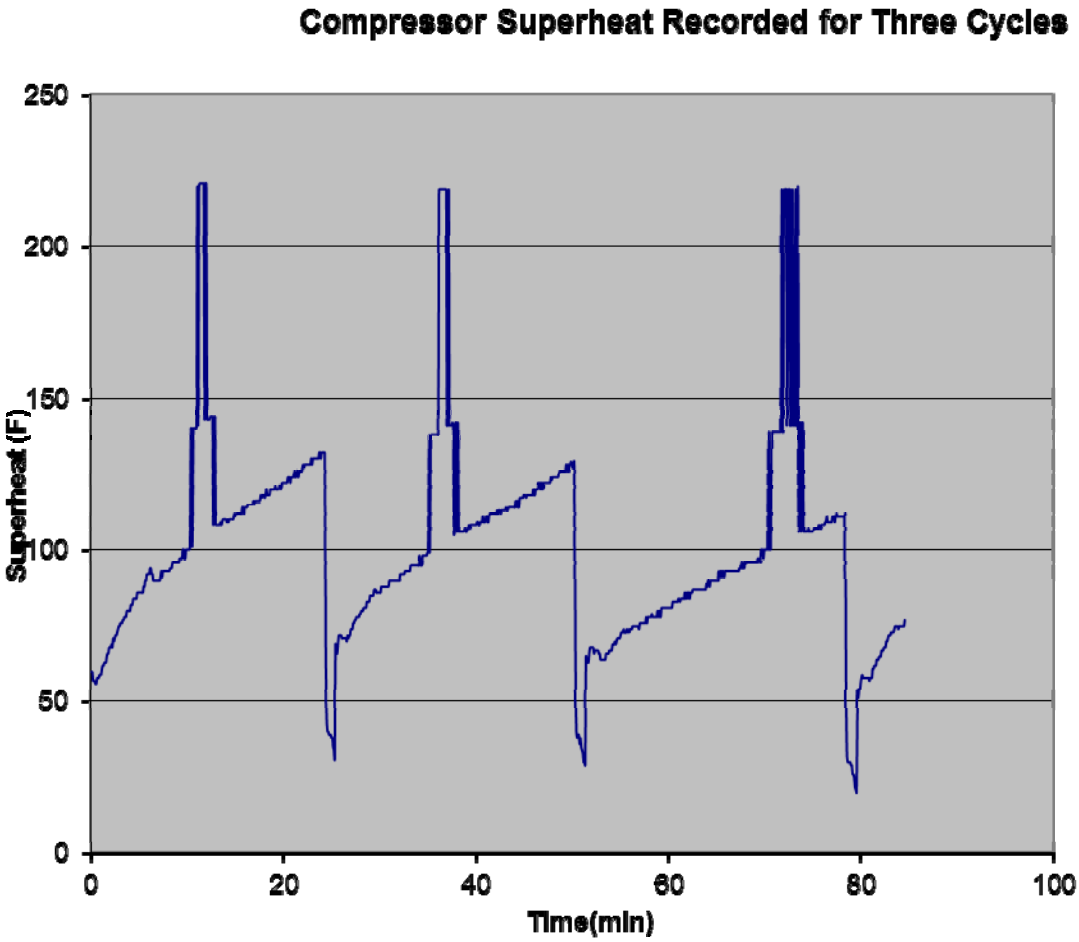

Figure 6 N40 Compressor Superheat

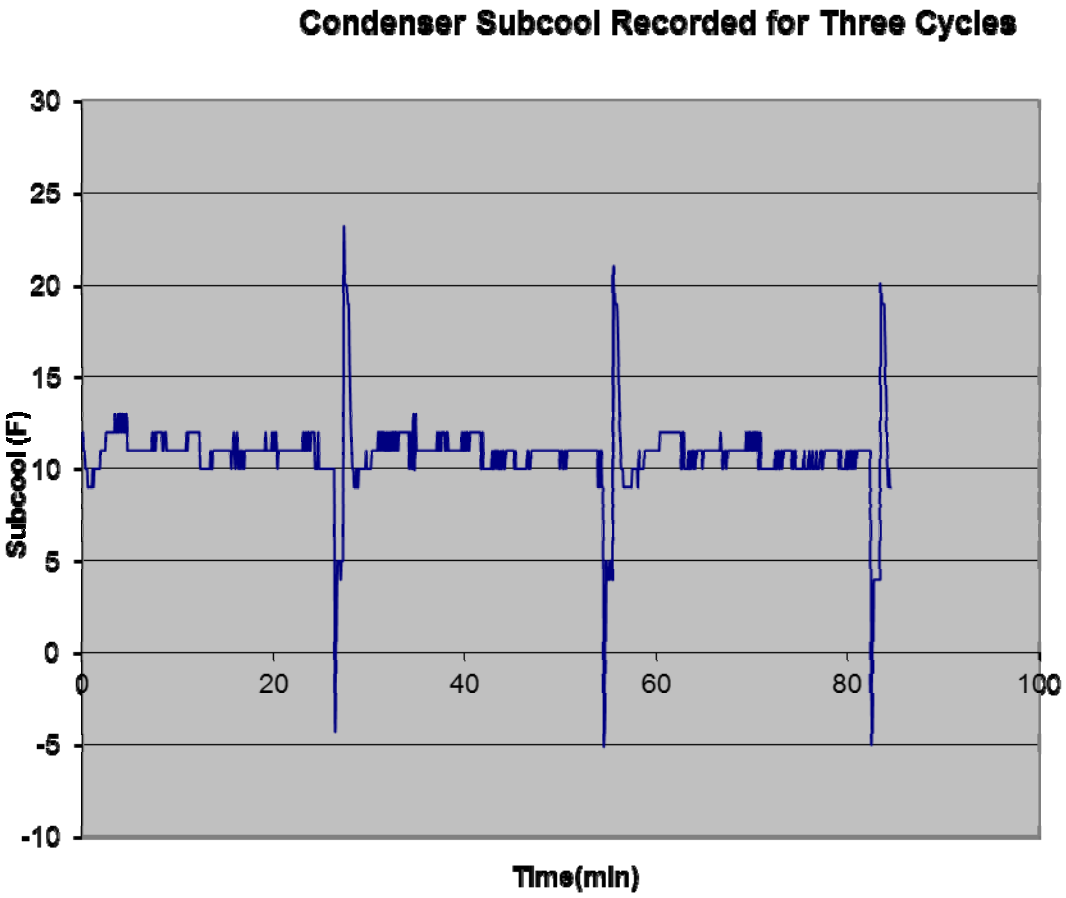

Figure 7 R404A Condenser Sub Cooling

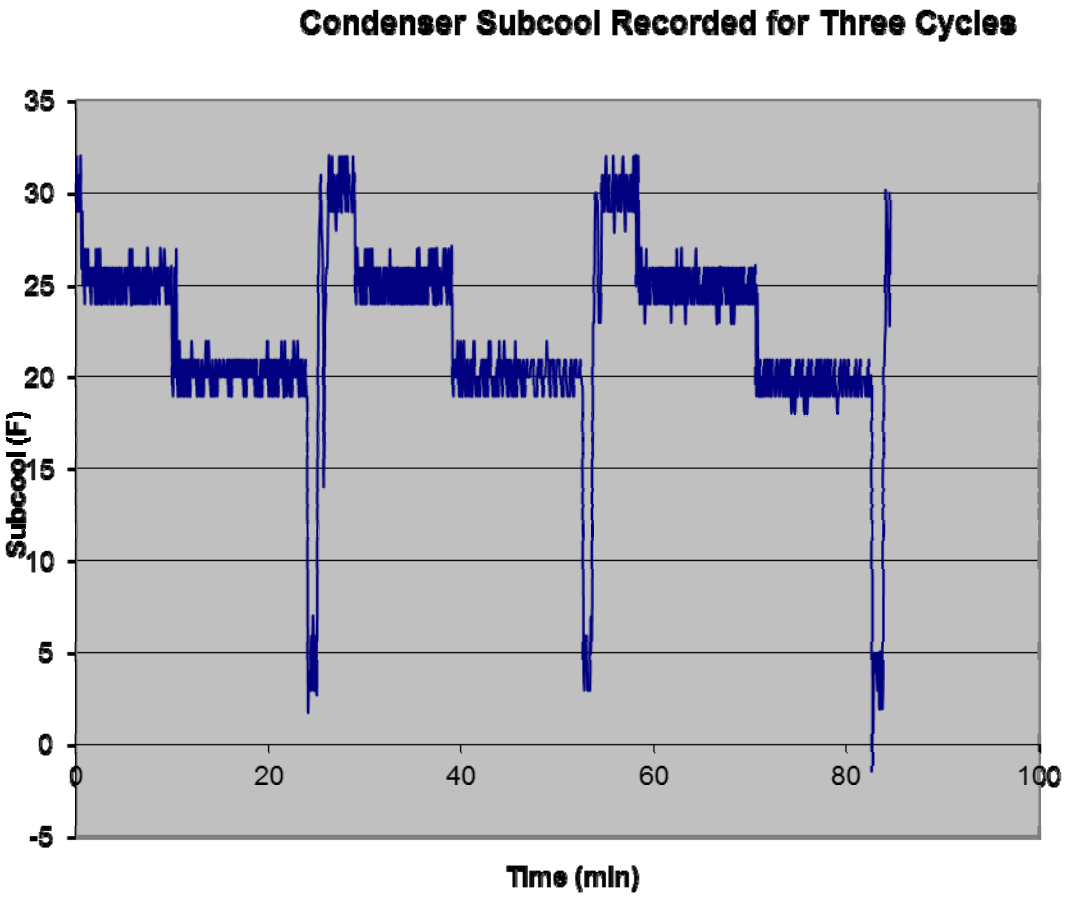

Figure 8 L20 Condenser Sub Cooling

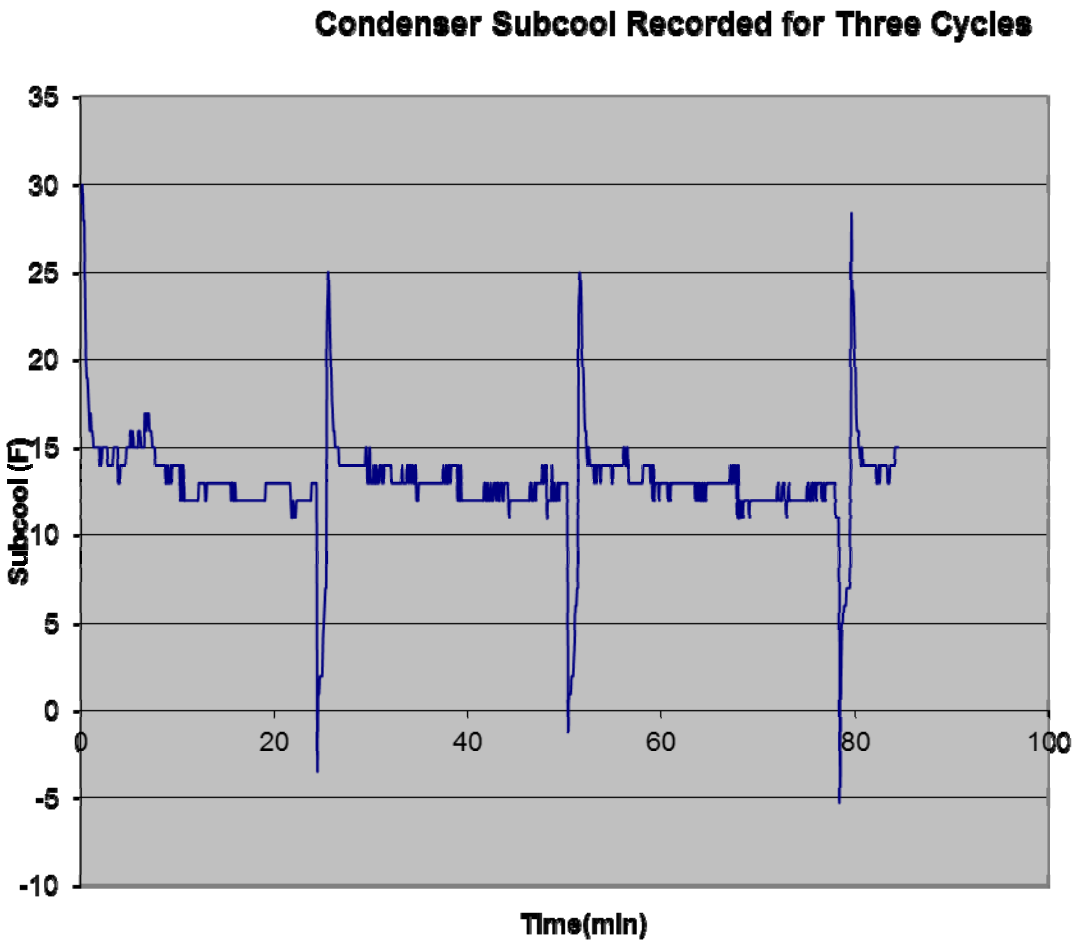

Figure 9 N40 Condenser Sub Cooling

Cycle	Suct. Press. Start (PSIG)	Suct. Press. End	Suct. Press. Defrost	Dis. Press. Start (PSIG)	Dis. Press. End	Dis. Press. Defrost
1	56	25	144	268	191	238
2	64	17	133	270	194	262
3	63	26	140	271	185	256
4	64	27	134	273	188	256

Table 1 R404A Pressure Measurements

Cycle	Cycle Time	Defrost Time	Ice Batch Weight (lbs)	Lbs/24 Hr	kWh/100lbs	Potable Water (gal)
1	T#27m16s2ms	T#55s925ms	7.2	380.24	7.03	0.971
2	T#28m8s563ms	T#56s827ms	7.13	364.83	7.39	0.965
3	T#27m56s837ms	T#55s924ms	7.13	367.38	7.36	0.967
4	T#27m43s308ms	T#59s533ms	7.21	374.52	7.21	0.986

Table 2 R404A Ice Cycle Measurements

Cycle	Cond. Inlet Temp (F)		Cond. Outlet Temp (F)	
	Start	End	Start	End
1	115	115	83	76
2	111	116	84	77
3	112	117	85	77
4	113	116	85	75

Table 3 R404A Condenser Temp Measurements

Cycle	Suct. Press. Start (PSIG)	Suc. Press. End	Suct. Press. Defrost	Dis. Press. Start (PSIG)	Dis. Press. End	Dis. Press. Defrost
1	33	21	120	240	171	216
2	53	15	115	246	179	219
3	53	15	121	247	181	180
4	54	29	128	247	174	183

Table 4 L20 Pressure Measurements

Cycle	Cycle Time	Defrost Time	Ice Batch Weight (lbs)	Lbs/24 Hr	kWh/100lbs	Potable Water (gal)
1	T#25m6s779ms	T#1m3s141ms	6.66	381.89	6.71	1.02
2	T#28m33s817ms	T#1m1s337ms	6.99	352.39	7.46	1.019
3	T#30m13s817ms	T#1m12s161ms	7.02	334.37	7.98	1.019
4	T#28m443ms	T#1m3s141ms	6.95	357.33	7.42	1.021

Table 5 L20 Ice Cycle Measurements

Cycle	Cond. Inlet Temp (F)		Cond. Outlet Temp (F)	
	Start	End	Start	End
1	96	103	68	68
2	94	102	68	70
3	94	96	70	69
4	93	102	70	68

Table 6 L20 Condenser Temp Measurements

Cycle	Suc. Press. Start (PSIG)	Suc. Press. End	Suc. Press. Defrost	Dis. Press. Start (PSIG)	Dis. Press. End	Dis. Press. Defrost
1	62	22	113	254	191	239
2	52	15	122	253	179	225
3	56	18	140	253	184	214
4	62	18	143	256	186	208

Table 7 N40 Pressure Measurements

Cycle	Cycle Time	Defrost Time	Ice Batch Weight (lbs)	Lbs/24 Hr	kWh/100lbs	Potable Water (gal)
1	T#25m22s539ms	T#58s631ms	6.92	392.69	6.94	1.018
2	T#26m1s384ms	T#1m4s43ms	6.94	384.03	7.01	1.02
3	T#28m13s79ms	T#1m10s358ms	7.1	362.32	7.39	1.027
4	T#26m14s12ms	T#1m2s239ms	6.99	383.69	6.99	1.019

Table 8 N40 Ice Cycle Measurements

Cycle	Cond. Inlet Temp (F)		Cond. Outlet Temp (F)	
	Start	End	Start	End
1	104	112	82	76
2	103	111	83	76
3	100	108	83	77
4	97	111	83	78

Table 9 N40 Condenser Temp Measurements