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

TEST REPORT #45

System Drop-in Test of Refrigerant Blends ARM-20b and N-40c (R-448A) in Automatic Commercial Ice Maker Designed for R-404A

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Low-GWP AREP SYSTEM DROP-IN TEST -- REPORT FORMAT

1. Introduction:

Two R-404A alternate refrigerants were chosen for this testing to examine the effects of different refrigerant glides in the operation of a cool vapor harvest ice making system. Refrigerants were chosen based on 20°F evaporator temperature glide values listed in the Participants Handbook draft dated November 18, 2013 (Arkema ARM-20b glide listed as 8°F, Honeywell N-40c glide listed as 3.2°F). Subsequent versions of the Participants Handbook corrected a conversion error in the N-40c evaporator glide, listing it instead as 10.4°F. This resulted in this study looking at two “high” glide refrigerant blends instead of one with “moderate” glide and one with “high” glide.

Unit setup began on October 13, 2014. Testing of the system with baseline and alternate refrigerants occurred from October 14 to October 23, 2014. Testing was performed in the ice machine development and performance testing rooms located in the Engineering Lab of the Manitowoc Foodservice facility in Manitowoc, WI. The ice making unit was located in Test Room 6 and connected via line set to the condensing unit located in Test Room 1.

The refrigerants tested for this report were the baseline that the system is designed for (R-404A), the first AHRI AREP Phase II alternative (Arkema ARM-20b), and the second AHRI AREP Phase II alternative (Honeywell N-40c, a.k.a. R-448A).

2. Details of Test Setup:

   a. Description of System

   The test machine selected to use in comparing the refrigerants was a Manitowoc model IB1094YC-161 connected to a model ICVD1195-261 condensing unit using an RC36 (35 foot) line set. This unit has the ice making head section located indoors and a remote condensing unit located outside, typically on the roof. This unit is designed to fit on top of ice dispensers which are commonly used in fast food restaurants and convenience store applications. It is designed to produce a lot of ice very quietly in a customer environment. This unit uses a cool vapor harvest system, meaning that refrigerant vapor from the receiver is routed through the evaporators during harvest mode to provide the heat energy used to release the ice slab from the evaporator.

The rated ice making capacity for this system is 910 lb/24h. The rated energy usage is 4.85 kWh/100lb ice. The operating envelope that the outdoor condensing unit is designed to function throughout is -20 ºF to +120 ºF ambient.

The outdoor condensing unit is manufactured with a Bristol model R92J253ABCA compressor. The oil used is polyolester (Chemtura Everest 32BCE). The charge of refrigerant in the baseline system is 184 ounces R-404A.

b. Description of Modifications to System

The stock ice making system with R-404A refrigerant was tested without any changes to the factory built units.

Before testing was done with alternative refrigerants, the fixed superheat thermostatic expansion valves in the ice maker were replaced with adjustable-superheat thermostatic expansion valves of the same type and orifice size as the stock valves. This was done so evaporator superheat could be adjusted for each refrigerant.

Each time the refrigerant in the system was changed, the compressor oil was drained and replaced, the filter drier in the ice maker was replaced, and the suction filter in the condensing unit was replaced. The system was then pumped down overnight to ensure minimal crossover from the previous refrigerant.

c. Description of Tests Conducted

All testing was done in accordance with AHRI Standard 810 and ASHRAE Standard 29. Tests were conducted at 90/70ºF (90ºF ambient air / 70ºF water) temperatures. This is the standard AHRI rating condition, and the point used to compare the performance of the various refrigerants against each other, against baseline data, and certified data. Ice was measured in pounds of ice per freeze-harvest cycle and extrapolated to pounds of ice produced per 24 hours. Energy was measured in kilowatt hours per freeze-harvest cycle and extrapolated to kilowatt hours required to produce 100 pounds of ice. In all cases we waited for the unit to become stable at the test conditions and then recorded six ice making cycles. The results were averaged and mean data was reported. Testing was also done on the IB1094YC-161 at -20/50, 70/50, and 120/90 to see what happened to the new refrigerants when operated at other points of the equipment's design envelope.

The test sequence for the alternate refrigerants involved performing a charge optimization at -20/50 conditions to determine the minimum amount of refrigerant charge necessary for the system to operate correctly at the low end of the operating envelope. Once that amount was determined, the system was operated at 110/90 conditions so TXV adjustments could be made. Once those adjustments were completed, data was collected at the (4) operating conditions chosen for comparison (90/70, -20/50, 70/50, and 120/90).

Instrumentation used included thermocouples (T-type), refrigerant pressure transducers (Reotemp TH-P26-3B4D 0-1000psig), water pressure transducer (Reotemp TH-P26-3B4D 0-200psig), power monitor (Ohio Semitronics PTB-133D1PC), and ice and water scale (Pennsylvania 7300S).

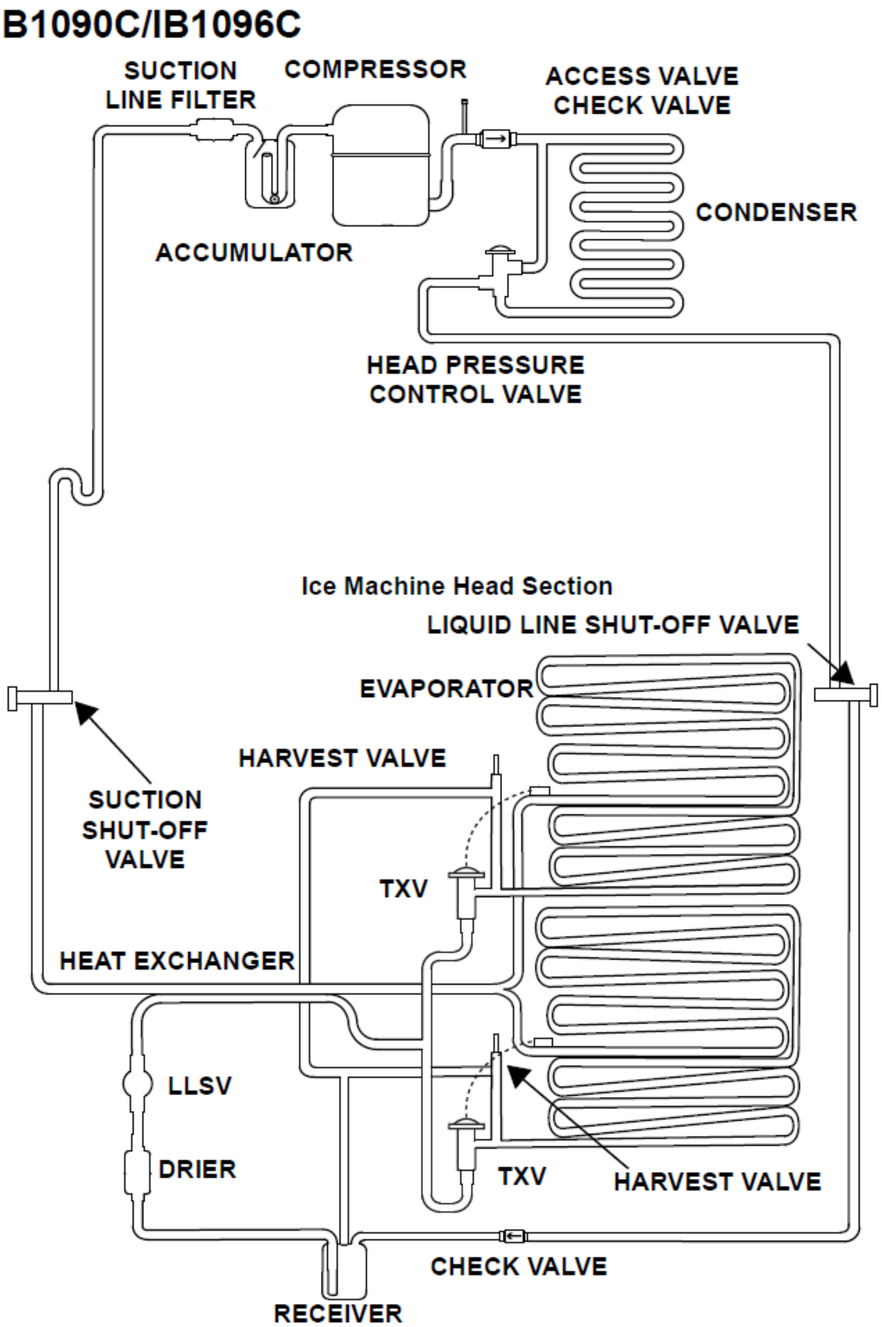

Figure 1: System Schematic

3. Results

a. Data Form

Data for the (4) operating conditions of interest is summarized in Table 1.

Table 1: Comparative Performance

IB1094YC / ICVD1195	-20°F/50°F		70°F/50°F		90°F/70°F		120°F/90°F	
	Capacity *[lb/24h]*	Energy *[kWh/100lb]*	Capacity *[lb/24h]*	Energy *[kWh/100lb]*	Capacity *[lb/24h]*	Energy *[kWh/100lb]*	Capacity *[lb/24h]*	Energy *[kWh/100lb]*
AHRI Listing					***910***	***4.85***		
R-404A (baseline)	1100	3.59	1055	4.16	941	4.77	626	7.81
ARM-20b	1015	3.66	969	4.28	877	4.85	648	7.06
N-40c	1028	3.58	996	4.22	907	4.75	634	7.24

b. Other

Both the alternate refrigerants outperformed R-404A in both ice making capacity and energy usage at the 120/90 operating condition. At all other conditions the R-404A refrigerant setup had considerably more ice making capacity and typically better energy usage.

At the 90/70 rating point, ARM-20b had a 6.8% capacity reduction from that of R-404A while N-40c had a 3.6% capacity reduction from that of R-404A.

At the 90/70 rating point, energy usage was 1.7% higher with ARM-20b than with R-404A while N-40c had a 0.4% reduction in energy usage from that of R-404A.

While using these high-glide refrigerants in this ice making application, the glide in the evaporator caused a noticeable lack of uniformity of ice slab formation across the evaporator. TXV superheat adjustments could not correct this uniformity issue. This is from evaporator temperature differences due to preferential boiling of refrigerant constituents along the length of the serpentine.

Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Arkema Manufacturer's Notation: ARM-20b

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	Proprietary
Alternative Lubricant Type and ISO Viscosity	Polyolester 32BCE
Baseline Refrigerant and Lubricant	R-404A, Polyolester 32BCE
Make and Model of System	Manitowoc IB1094YC-161 head, ICVD1195-261condenser
Nominal Capacity and Type of System	910 lb/24h capacity automatic commercial ice maker

Comparison Data			**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP UNits**	**Ratio**
Mode (Heating/Cooling)			Ice						
Compressor Type			Recip	Recip					
Compressor Displacement			0.163	0.163	m³/min	5.76	5.76	ft³/min	1
Nominal Motor Size			2	2	hp				1
Motor Speed			3600	3600	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.134	1.134	kg	2.5	2.5	lb	1
Refrigerant Charge			5.22	3.86	kg	11.5	8.5	lb	0.74
Refrigerant Mass Flow Rate					kg/min			lb/min	
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db			°C			°F	
		wb			°C			°F	
	Outdoor	db			°C			°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

Type of System: Ice Maker
(e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: ARM-20b
(and composition as charged, % weight, if not proprietary)

Air/Water Side Data	**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Evaporator							
Heat Exchange Fluid							
Flow Rate (gas)			m³/min			ft³/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature			°C			°F	
Outlet Temperature			°C			°F	
Condenser							
Heat Exchange Fluid							
Flow Rate (gas)			m³/min			ft³/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature			°C			°F	
Outlet Temperature			°C			°F	

Refrigerant Side Data Temperatures & Pressures	**Baseline**		**Alternative**		**Baseline**		**Alternative**	
	T (°C)	**P [kPa]**	**T (°C)**	**P [kPa]**	**T [°F]**	**P [psia]**	**T [°F]**	**P [psia]**
Compressor Suction								
Compressor Discharge								
Condenser Inlet								
Condenser Outlet								
Expansion Device Inlet								
Subcooling, at expan. device								
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
Supplier-Provided P-T Chart

Additional Notes

Submitted by: ______________________

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Low_GWP AREP SYSTEM DROP-IN TEST DATA FORM

Manufacturer: Honeywell Manufacturer's Notation: N-40c

Basic Information	
Alternative Refrigerant (If not proprietary, composition as Charged, % wt)	R32/R125/R134a/R1234yf/R1234ze(E) (26/26/21/20/7)
Alternative Lubricant Type and ISO Viscosity	Polyolester 32BCE
Baseline Refrigerant and Lubricant	R-404A, Polyolester 32BCE
Make and Model of System	Manitowoc IB1094YC-161 head, ICVD1195-261condenser
Nominal Capacity and Type of System	910 lb/24h capacity automatic commercial ice maker

Comparison Data			Base.	Alt.	SI Units	Base.	Alt.	IP UNits	Ratio
Mode (Heating/Cooling)			Ice						
Compressor Type			Recip	Recip					
Compressor Displacement			0.163	0.163	m³/min	5.76	5.76	ft³/min	1
Nominal Motor Size			2	2	hp				1
Motor Speed			3600	3600	rpm				1
Expansion Device Type			TXV	TXV					
Lubricant Charge			1.134	1.134	kg	2.5	2.5	lb	1
Refrigerant Charge			5.22	4.08	kg	11.5	9	lb	0.78
Refrigerant Mass Flow Rate					kg/min			lb/min	
Composition, at compr. inlet if applicable					% wt				
Ambient Temps.	Indoor	db			°C			°F	
		wb			°C			°F	
	Outdoor	db			°C			°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			

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Low-GWP AREP SYSTEM DROP-IN TEST DATA FORM

Type of System: Ice Maker (e.g., SSHP, window RAC, chiller, etc.)

Alternate Refrigerant: N-40c (and composition as charged, % weight, if not proprietary)

Air/Water Side Data	**Base.**	**Alt.**	**SI Units**	**Base.**	**Alt.**	**IP Units**	**Ratio**
Evaporator							
Heat Exchange Fluid							
Flow Rate (gas)			m³/min			ft³/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature			°C			°F	
Outlet Temperature			°C			°F	
Condenser							
Heat Exchange Fluid							
Flow Rate (gas)			m³/min			ft³/min	
Flow Rate (liquid)			L/min			gal/min	
Inlet Temperature			°C			°F	
Outlet Temperature			°C			°F	

Refrigerant Side Data Temperatures & Pressures	**Baseline**		**Alternative**		**Baseline**		**Alternative**	
	T (°C)	**P [kPa]**	**T (°C)**	**P [kPa]**	**T [°F]**	**P [psia]**	**T [°F]**	**P [psia]**
Compressor Suction								
Compressor Discharge								
Condenser Inlet								
Condenser Outlet								
Expansion Device Inlet								
Subcooling, at expan. device								
Evaporator Inlet								
Evaporator Outlet								
Evaporator Superheat								

Data Source(s) for Refrigerant Properties
Supplier-Provided P-T Chart

Additional Notes

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