System Drop-In Test of R-404A Alternate Refrigerants ARM-20b and N-40c (R-448A) in Ice Maker

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1. Overview of Automatic Commercial Ice Maker
   • Basic ice maker refrigeration system and cycle
   • CVD split-system design
   • Performance requirements

2. Test Plan Objectives
   • Refrigerant selection criteria
   • Test conditions and procedures
   • Equipment selection

3. Test Results
   • Ice making capacity comparison
   • Energy use rate comparison

4. Conclusions
Freeze Cycle

Harvest Cycle

Simplified Ice Maker System Schematics
1. Harvest Valve opens
   - Discharge pressure ↓
   - Suction pressure ↑
2. HPCV goes to full bypass
3. Refrigerant in receiver boils, adding to vapor flow
4. Vapor flow into evaporator provides latent heat energy
5. Refrigerant flow leaving evaporator is highly saturated
6. Accumulator separates liquid from vapor
# Quasi-Steady State Batch Process

<table>
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<tr>
<th>Test Event ID</th>
<th>Start Date</th>
<th>Start Time</th>
<th>Test Name</th>
<th>Test Description</th>
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![Graph](image_url)
Performance Requirements

- Performance at rating condition (90°F air / 70°F water)
  - Ice making capacity [lb/24h]
  - Energy usage rate [kWh/100lb]
  - Potable water use rate [gal/100lb]

- Uniform ice slab (target of 0°F superheat) over entire freeze cycle

- Harvest cycle performance at low temperature conditions for condensing unit (-20°F air)

- Freeze cycle performance at high temperature conditions for condensing unit (120°F air)
Drop-in candidates for R-404A replacement were chosen based on ASHRAE Safety Class, GWP, and Glide at 20°F Mean Evap / 110°F Mean Condenser.

- One mildly flammable refrigerant with low GWP was selected for evaluation.
- One nonflammable refrigerant with moderate GWP was selected for evaluation.
- Both candidates have fairly high glide.
Test Conditions and Procedures

- ASHRAE / ANSI Standard 29 for Method of Test
- AHRI Standard 810 for ice machine performance
- Test sequence for drop-in refrigerants:
  - Charge optimization at -20°F air / 50°F water
  - TXV adjustment at 110°F air / 90°F water
  - Data collection at (4) operating conditions:
    - -20°F air / 50°F water
    - 70°F air / 50°F water
    - 90°F air / 70°F water
    - 120°F air / 90°F water
Equipment Selection

- Manitowoc Ice model IB1094YC-161 head section
  - Receiver located in indoor section
  - TXV expansion devices
  - Hot gas valve solenoids used for harvest

- Manitowoc Ice model ICVD1195-261 condensing unit
  - Reciprocating MBP compressor
  - POE oil
  - Head pressure control valve (225 psig setpoint)

- Manitowoc RC36 line set
  - 3/8” diameter liquid line
  - 5/8” diameter suction line
<table>
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<tr>
<th>IB1094YC / ICVD1195</th>
<th>-20°F/50°F</th>
<th>70°F/50°F</th>
<th>90°F/70°F</th>
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<td>R404a (baseline)</td>
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**Ice Making Capacity Comparison**

### Relative Performance to R-404A

- **ARM-20b**
  - -20°F/50°F: -7.7%
  - 70°F/50°F: -6.5%
  - 90°F/70°F: -3.6%
  - 120°F/90°F: 3.5%

- **N-40c**
  - -20°F/50°F: -8.2%
  - 70°F/50°F: -5.6%
  - 90°F/70°F: -6.8%
  - 120°F/90°F: 1.3%
## Energy Use Rate Comparison

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### Relative Performance to R-404A

- -20°F/50°F: ARM-20b - 1.9%, N-40c - 1.4%
- 70°F/50°F: ARM-20b - 2.9%, N-40c - 1.7%
- 90°F/70°F: ARM-20b - 1.7%, N-40c - 0.4%
- 120°F/90°F: ARM-20b - 7.3%, N-40c - 9.6%
Conclusions – Capacity and Energy Usage

- 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.
Conclusions – Refrigerant Glide

- 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.

- There were no observed issues from preferential boiling of refrigerant constituents in receiver or accumulator during harvest mode.
Questions?

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