Refrigerant Conversions for Flooded Systems

Part 1. Commercial Ice Machine

Field Conversion of a Commercial Ice Making System with a Flooded Evaporator from R-404A to Opteon™ XP40 (R-449A)

Background

Many types of refrigeration equipment operating on pure refrigerant fluids such as R-22 or blends such as R-507/R-404A with minimal temperature glide, utilize flooded evaporator type heat exchangers. These designs are simple to construct and operate efficiently for pure or near azeotropic fluids. Owners of these types of systems are challenged to find service refrigerant since the production (or import) of virgin R-22 is no longer permitted and high GWP refrigerants like R-507 and R-404A are being phased down with availability of reclaimed refrigerant limited and subject to price volatility.

While there is no "drop-In" product that will perform identically to R-22 (or R-404A / R-507), the successful conversion of flooded systems using Opteon™ XP40 (R-449A), a non-ozone depleting, lower GWP, HFO blend refrigerant has been demonstrated.

This report summarizes the details of the conversion of a commercially available ice-maker machine from R-404A to Opteon™ XP40 (R-449A). While the system in this study is very typical of many others, there can be differences in design, system condition, and operating factors that make each system somewhat unique. Prior to attempting a field conversion, a detailed engineering analysis of the system is required.

The Project

A project was undertaken to understand the requirements to convert, and subsequently monitor the performance of a commercial refrigeration system (ice making), originally designed with R-404A after changing over to run on a more environmentally sustainable (non ODP, lower GWP) refrigerant blend (R-449A). The system was owned by an ice machine service vendor and the test was performed on site with engineering support from Chemours.

The goals of this project were three-fold:

1. Determine the steps and changes necessary to convert the system from R-404A to R-449A
2. Evaluate the performance (ice production) of the system after the conversion to R-449A and impacts on operating conditions (pressures, temperatures, amp draw, oil, etc.)
3. Study the refrigerant blend composition during operation at several points around the system to assess the impact of temperature glide.

The System

The system in this study was a nominal 5-ton commercial ice making system (Vogt M#P118), several decades old. The unit was operating on R-404A refrigerant with a flooded evaporator equipped with a Sporlan EBSSE-10-C TEV and a water-cooled condenser. The compressor was a Carlyle 06DM337D13250 with POE lubricant.

Conversion Process

The following steps were used converting an ice-maker machine from R-404A to Opteon™ XP40 (R-449A):

- The existing R-404A was recovered prior to charging the system with ~ 300 lbs. of R-449A. The system was started up and allowed to stabilize for a preliminary assessment using the existing power element (R-404A) on the TEV (thermal expansion valve). Measured capacity in this configuration was approximately 93% of the nominal 5 ton rating.
- Adjustments to the TEV (opening) resulted in slightly increased capacity. The receiver liquid level after the harvest cycle was observed to be lower than the operational level and fell below the sight glass at the end of the freeze cycle.
- To further investigate the effect of expansion valve selection on system capacity, an R-22 element was installed. Results indicated the original R-404A power element was the optimum choice for this application. As a result, the remainder of the testing was conducted with the R-404A element
- On the second testing day, an additional 25lbs of R-449A refrigerant was added to raise the refrigerant level in the evaporator and receiver. Four hours post refrigerant addition, ice production was measured to be 10,982 lbs (110%).
- Further tuning of the TEV resulted in production batches of 11, 073 lbs. (111%) and 11,242 lbs. (112%) with liquid level clearly visible in the receiver sight glass during both freeze cycles.

System Observations During Testing

The conversion to Opteon™ XP40 (R-449A) resulted in the following observations:

- Compressor oil management was good. Slight oil foaming was observed at the start of the freeze cycle with the site glass approximately half clear mid cycle and at the end of the freeze cycle.
- Compressor Amp Draw (averaged over three cycles)
  - L1 44.8 amps
  - L2 46.5 amps
  - L3 46.7 amps
- Compressor Suction P: average 40 psig at end of freeze cycle
- Compressor Suction P: average 77 psig at harvest cycle
- Compressor Superheat: average 26°F at end of freeze cycle
- Discharge Pressure: average 245 psig at start, average 242 psig at end of freeze cycle
- Discharge Temp: 137°F @ freeze cycle start, 165°F @ freeze cycle end
- Liquid Subcooling: average 30-35°F @ TEV
- Water make-up Temperature: ~52° F

Refrigerants

Table 1. below contains a brief comparison of the refrigerant properties.

Table 1. Refrigerant Properties

	R-404A	R-449A
Components	R-125/R-143a/R-134a	R-32/R-125/R-134a/R-1234yf
Weight %	44/52/4	24.3/24.7/25.7/25.3
Safety Class	A1	A1
GWP	3922	1397
Temp Glide	~1 R	~7 R

Refrigerant Analysis

Refrigerant samples were obtained from various points in the system (see Figure 1) and returned to Chemours central research facility for compositional analysis via Gas Chromatography. The results are presented in Table 2 below.

All samples were analyzed in triplicate with the average of three GC runs reported in the table. Predicted compositions of the R-449A at the various sample points were calculated based on a proprietary VLE model using the R-449A refrigerant blend properties and the system components, design, and operating conditions during the test.

As expected, the bulk refrigerant circulating within the system differs slightly from the nominal composition as delivered in the virgin refrigerant cylinder due to the temperature glide and the local vapor liquid equilibrium interactions within the various components.

Overall, the analytical results are in good agreement with the expected compositions, in most cases within 1-2 wt. %.

Sample points #1-3 are all expected to be the same composition as there is nothing in the system architecture that would cause fractionation between these points. For example, comparing the theoretically predicted wt. % of the R-32 component at 27.6 wt. % to the measured values of 27.1, 27.4, and 26.8 wt. % from samples #1-3, shows very good agreement between the model and samples.

Figure 1. Schematic of Ice Machine Components and Refrigerant Sample Points

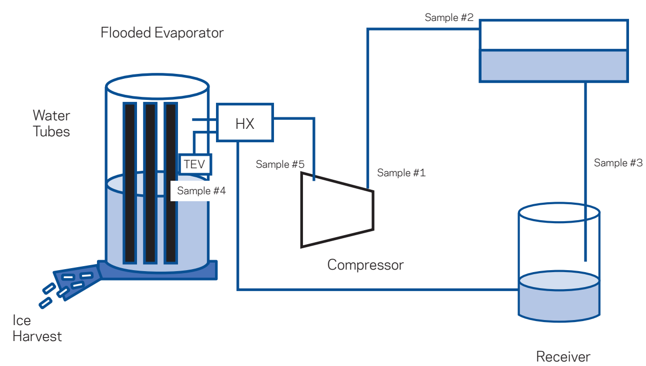

Table 2. GC Analysis and Model Predictions of Refrigerant Samples

Refrigerant Composition, wt %

	Field Test Samples				Model Predictions			
	R-32	R-125	R-134a	R-1234yf	R-32	R-125	R-134a	R-1234yf
R-449A, Nominal	24.3	24.7	25.7	25.3	24.3	24.7	25.7	25.3
Sample Points								
#1 Compressor Discharge	27.1	27.1	22.5	23.6	27.6	26.5	22.2	23.8
#2 Condenser, entering vapor	27.4	27.3	22.1	23.3	27.6	26.5	22.2	23.8
#3 Condenser, leaving liquid	26.8	27.14	22.5	23.6	27.6	26.5	22.2	23.8
#4 Evaporator inlet, liq	26.2	26.8	23.0	24.0	23.3	24.9	25.9	25.9
#4 Evaporator inlet, vap	36.5	30.7	14.8	18.0	36.9	29.8	14.1	19.2
#5 Compressor Suction	27.3	27.2	22.1	23.4	27.6	26.5	22.2	23.8

While most of the sample points were at system locations where only one phase (either pure vapor or pure liquid) was present, it is noted that sample point #4, the inlet to the flooded evaporator shell was a mixture of both liquid and vapor, which is more challenging in terms of sampling and interpretation of results.

Based on the small differences in both the low and high side compositions from the field measurements to the nominal R-449A composition, it's not surprising the system performed quite well post conversion based on the well-established performance match of R-449A to R-404A in DX systems.

Summary of Testing Results

Below is a summary of the system performance results following the conversion to Opteon™ XP40 (R-449A):

- Successful operation of a Vogt ice machine with a flooded evaporator design (originally R-404A) after conversion to low GWP blend R-449A was demonstrated
- Capacity (ice production) of ~ 112% compared to name plate (5-ton) capacity was achieved
- No component changes were required, however, adjustments to the existing TEV setting as well as refrigerant charge were critical to optimize performance
- No oil management issues noted while operating with original POE oil after conversion
- Suction/Discharge pressures, superheat, subcooling and discharge temperatures were all within system design limits
- Compositional analysis of refrigerant showed minor shifts in composition as refrigerant circulated throughout the system, in good agreement with thermodynamic models.

Conclusion:

As stated in the introduction, flooded systems are still operating today with R-22, R-404A, or R-507 refrigerants. Information on the performance of alternative refrigerants has been limited to date, however recently Opteon™ XP40 (R-449A) has been shown to successfully operate in certain systems following a detailed engineering analysis. For further guidance please contact your local Chemours representative or visit opteon.com to talk to one of our Technical Service engineers.

About Opteon™ Refrigerants

The Opteon™ refrigerants portfolio offers the optimal balance of environmental sustainability, performance, safety, and cost to help meet both regulations and business goals.

Businesses trust Opteon™ refrigerants because they offer:

Low GWP
Up to a 99% reduction compared to previous refrigerant generations.

Zero ODP
The HFO-based refrigerant family is non-ozone depleting.

Ease-of-Conversion
Minimizing conversion costs and downtime.

Excellent Capacity
A near match to many HCFC- and HFC-based technologies.

Energy Efficiency
Reduced energy use creates long-term savings over the system's life.

Long-Term Regulatory Compliance
HFO-based refrigerants can meet or exceed global and local regulatory standards.

Knowledgeable Experts
With more than 85 years of industry experience, Chemours refrigerant experts can help customers achieve both compliance and peak performance.

Visit Opteon.com/regulations for more information on HFC replacements or contact our experts.

For refrigerant related support, contact our Tech2Tech Support Team:

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