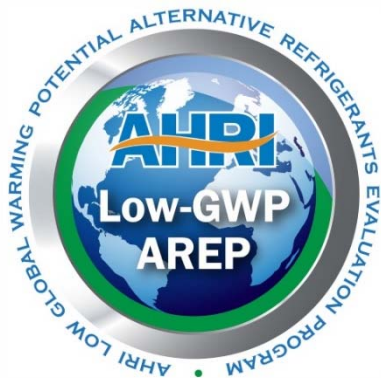


AHRI Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP)

2014 Purdue Conferences

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Air-Conditioning, Heating, and Refrigeration Institute (AHRI)



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Low-GWP AREP Introduction

- **Cooperative research & testing program to identify suitable alternatives to high GWP refrigerants**
- **Evaluation of candidates strongly desired by OEMs**
 - assess research & development needs
 - accelerate industry's response to environmental challenges
 - avoid duplicative work
- **The program is NOT to prioritize refrigerants, rather test and present objective results in a consistent manner**
- **The program started in March 2011**
 - Phase I testing was completed in 2013
 - Phase II testing is newly launched in 2014
 - new refrigerants
 - high ambient testing
- **Final reports available to the public**



Low-GWP AREP-Phase I

- **38 refrigerants were evaluated in Phase I testing**
- **Phase I was completed at the end of 2013:**

Submitted Reports	Approved	Available to the Public
41	40	40

- **Low-GWP AREP Conference was held on January 16, 2014 in New York City.**
 - 19 technical presentations from 16 test companies
 - more than 150 attendees

Refrigerants in Phase I Testing

Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP ₁₀₀
R22	ARM-32a	R-32/R-125/R-134a/R-1234yf	(25/30/25/20)	A1*	1577
	LTR4X	R-32/R-125/R-134a/R-1234ze(E)	(28/25/16/31)	A1*	1295
	D52Y	R-32/R-125/R-1234yf	(15/25/60)	A2L*	979
	L20	R-32/R-152a/R-1234ze(E)	(45/20/35)	A2L*	331
	LTR6A	R-32/R-744/R-1234ze(E)	(30/7/63)	A2L*	206
	R290	R290	100	A3	<20
	R1270	R1270	100	A3	<20
	R717	R717	100	B2L	<1

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2010.

Refrigerants in Phase I Testing

Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP ₁₀₀
R-134a	AC5X	R-32/R-134a/R-1234ze(E)	(7/40/53)	A1*	622
	ARM-41a	R-32/R-134a/R-1234yf	(6/63/31)	A1*	943
	D-4Y	R-134a/R-1234yf	(40/60)	A1*	574
	N13a	R-134a/R-1234yf/R-1234ze(E)	(42/18/40)	A1*	604
	N13b	R-134a/R-1234ze(E)	(42/58)	A1*	604
	XP-10	R-134a/R-1234yf	(44/56)	A1*	631
	AC5	R-32/R-152a/R-1234ze(E)	(12/5/83)	A2L*	92
	ARM-42a	R-134a/R-152a/R-1234yf	(7/11/82)	A2L*	117
	R1234yf	R1234yf	100	A2L	4
	R1234ze	R1234ze	100	A2L	6
	R600a	R600a	100	A3	<20
	R290/R600a	R290/R600a	(40/60)	A3*	<20

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2010.

Refrigerants in Phase I Testing

Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP ₁₀₀
R404A	ARM-32a	R-32/R-125/R-134a/R-1234yf	(25/30/25/20)	A1*	1577
	DR-33	R-32/R-125/R-134a/R-1234yf	(24/25/26/25)	A1*	1410
	N40a	R-32/R-125/R-134a/R-1234yf/R-1234ze(E)	(25/25/21/9/20)	A1*	1346
	N40b	R-32/R-125/R-134a/R-1234yf	(25/25/20/30)	A1*	1331
	ARM-30a	R-32/R-1234yf	(29/71)	A2L*	199
	ARM-31a	R-32/R-134a/R-1234yf	(28/21/51)	A2L*	491
	D2Y65	R-32/R-1234yf	(35/65)	A2L*	239
	DR-7	R-32/R-1234yf	(36/64)	A2L*	246
	L40	R-32/R-152a/R-1234yf/R-1234ze(E)	(40/10/20/30)	A2L*	285
	R-32	R-32	100	A2L	675
	R-32/R-134a	R-32/R-134a	(50/50)	A2L*	1053
	R290	R-290	100	A3	<20

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2010.



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Refrigerants in Phase I Testing

Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP ₁₀₀
R410A	ARM-70a	R-32/R-134a/R-1234yf	(50/10/40)	A2L*	482
	D2Y60	R-32/R-1234yf	(40/60)	A2L*	272
	DR-5	R-32/R-1234yf	(72.5/27.5)	A2L*	490
	HPR1D	R-32/R-744/R-1234ze(E)	(60/6/34)	A2L*	407
	L41a	R-32/R-1234yf/R-1234ze(E)	(73/15/12)	A2L*	494
	L41b	R-32/R-1234ze(E)	(73/27)	A2L*	494
	R32	R32	100	A2L	675
	R32/R134a	R-32/R-134a	(95/5)	A2L*	713
	R32/R152a	R-32/R-152a	(95/5)	A2L*	647

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2010.



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Overview of Testing in Phase I

- **Sixteen (16) U.S. companies/organizations and five (5) international companies/organizations are conducting tests**
- **Six (6) refrigerant producers supplied thirty-eight (38) refrigerant candidates**
- **Tests cover the following applications**
 - Air-conditioners and heat pumps (air-source, water-source, VRF, unitary, mini-split) (11)
 - Chillers (screw (3), centrifugal(1))
 - Refrigeration (commercial refrigerator (1), ice machine(2))
 - Transport refrigeration (1)
 - Bus air-conditioning (2)
 - Compressors (10)

Testing Methods and Conditions

- **Testing companies follow industry-wide accepted standards to conduct tests**

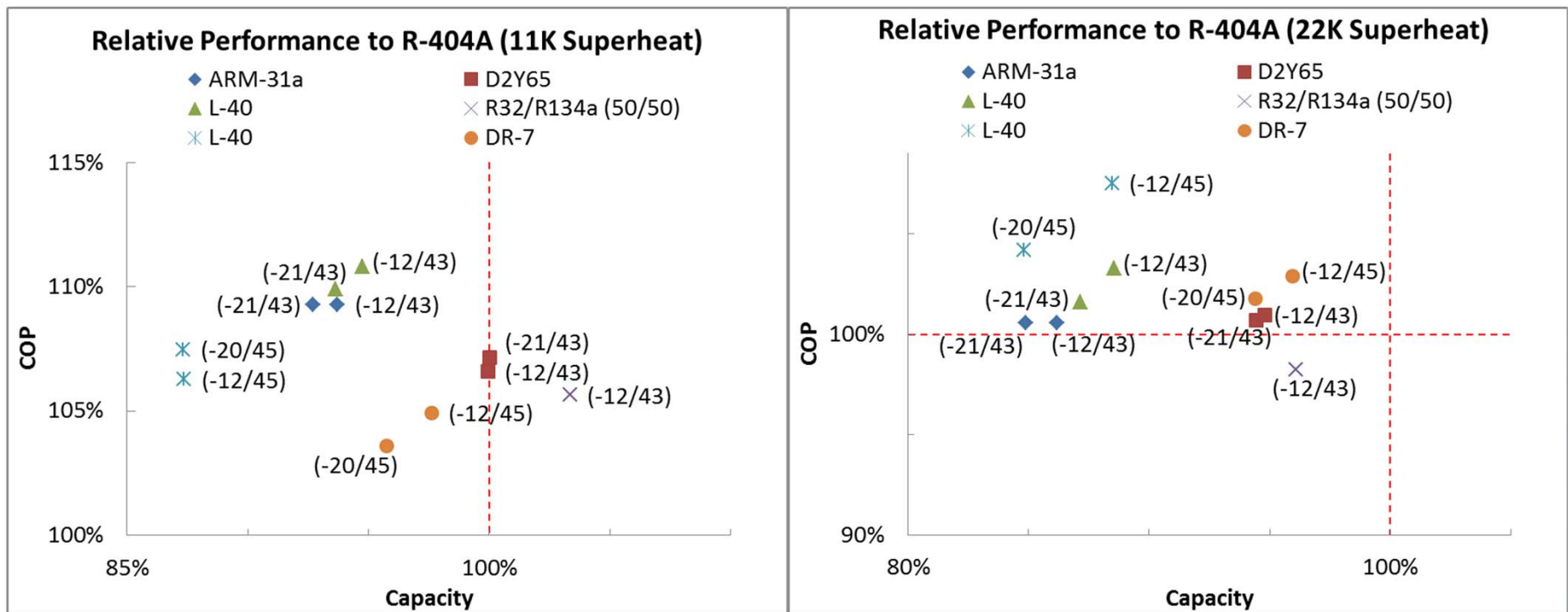
Equipment type	Method of Testing	Performance Rating
Compressor	ASHRAE Standard 23	AHRI Standard 540
Unitary Air-Conditioners and Heat Pumps	ASHRAE Standard 37	AHRI Standard 210/240
Water Source Heat Pumps	ISO Standard 13256	ISO Standard 13256
Chillers (centrifugal, rotary screw, and reciprocating)	ASHRAE Standard 30	AHRI Standard 550/590
Ice Makers	ASHRAE Standard 29	AHRI Standard 810
Commercial Refrigerators	ASHRAE Standard 72	AHRI Standard 1200/1201
Ductless VRF	AHRI Standard 1230	AHRI Standard 1230

Tests Conducted in Phase I

- **Compressor calorimeter test (18 reports)**
- **System drop-in test (20 reports)**
 - only minor modifications are allowed
- **System “soft-optimization” test (3 reports)**
 - systems are modified for the alternative refrigerants using standard production line components

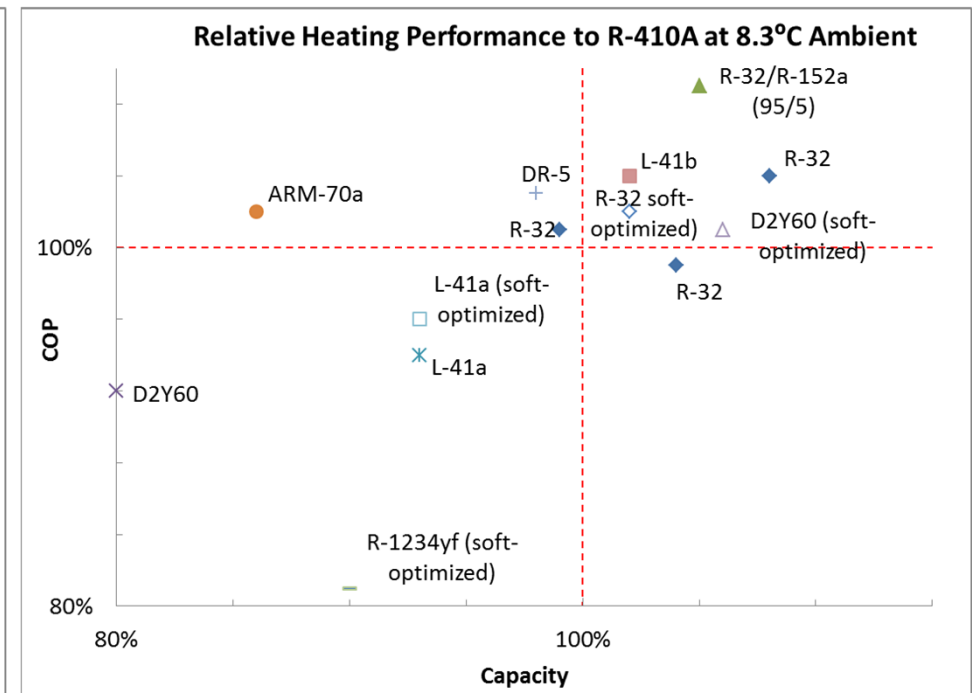
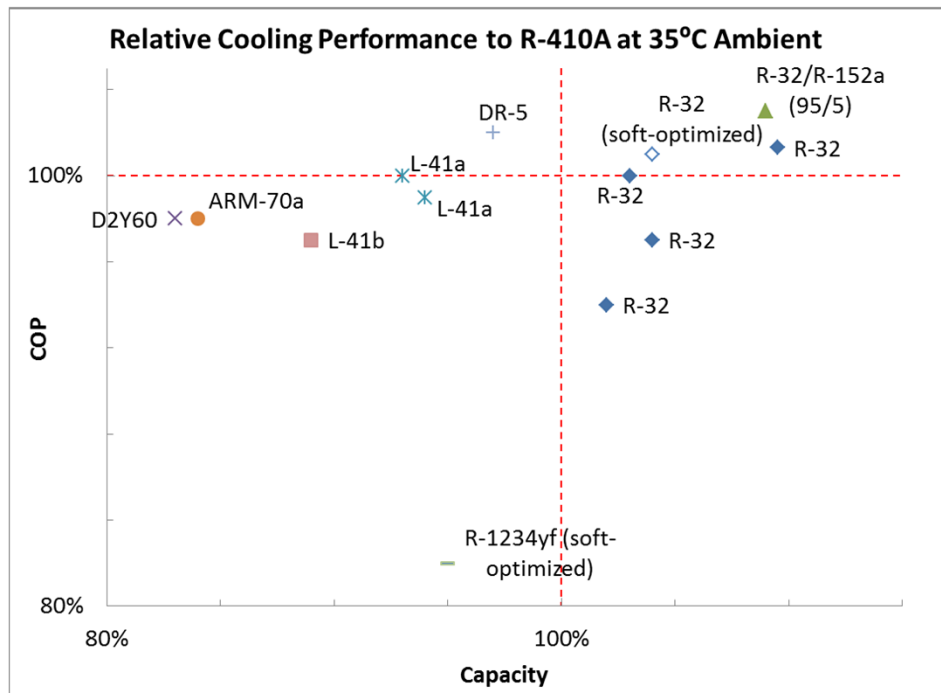
Example of Test Results in Phase I-Compressors

- Hermetic reciprocating (115V/60Hz/single phase/8.77cm³)
- Hermetic scroll (208/230V/60Hz/single phase/50.96cm³)

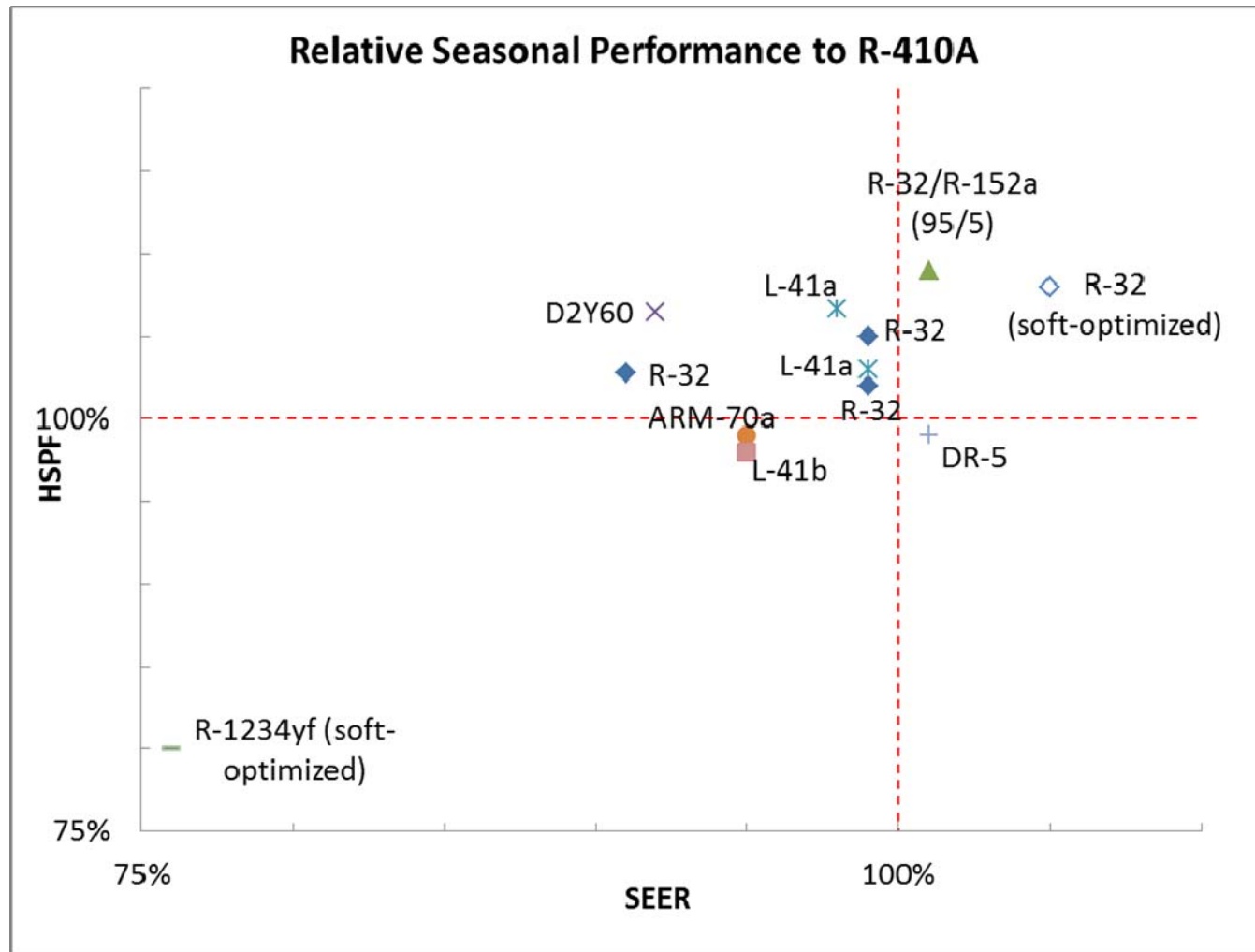


Example of Test Results in Phase I-Residential HPs

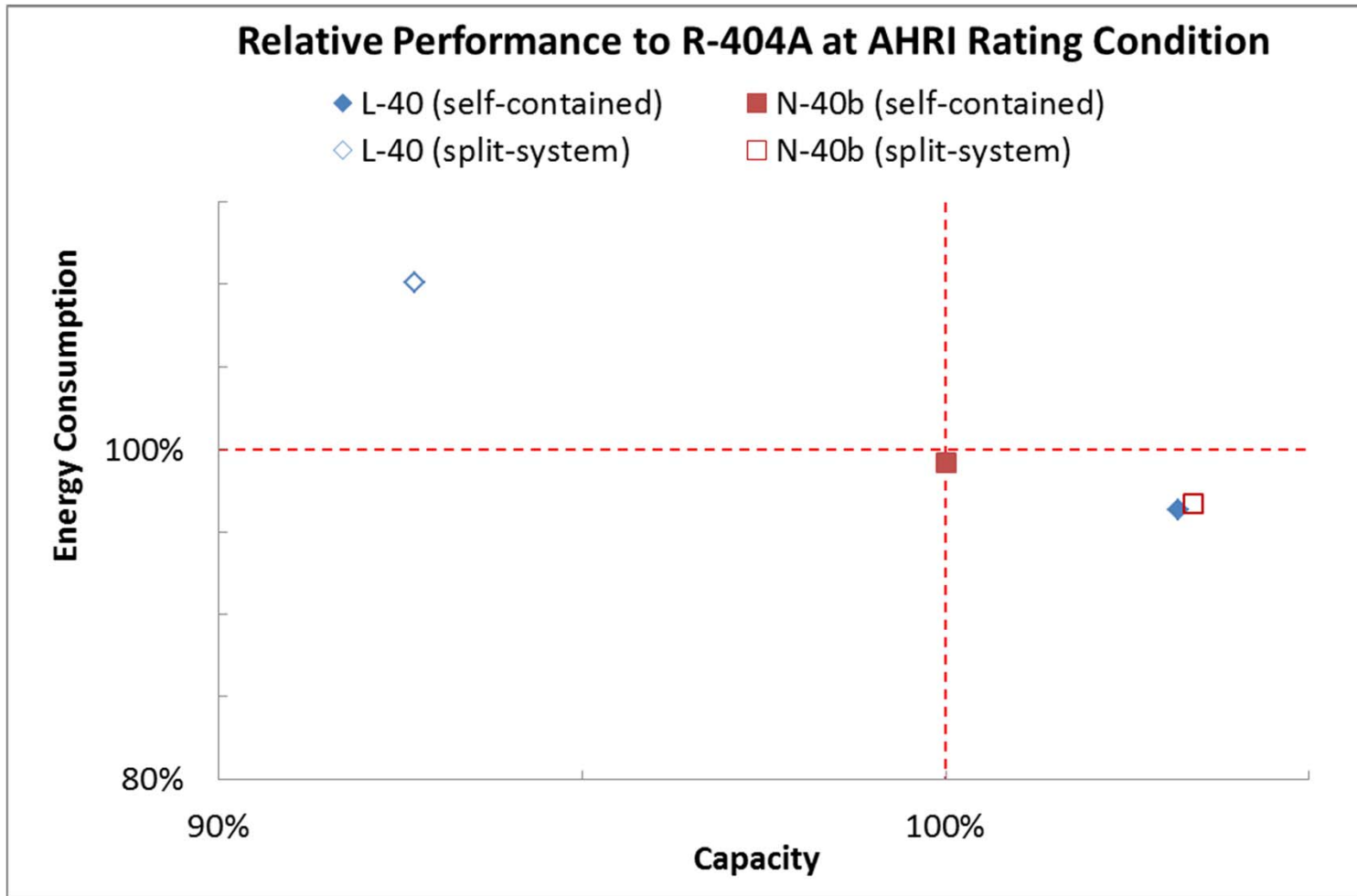
➤ Seven air-source heat pumps (2~8-ton)



Example of Test Results in Phase I-Residential HPs

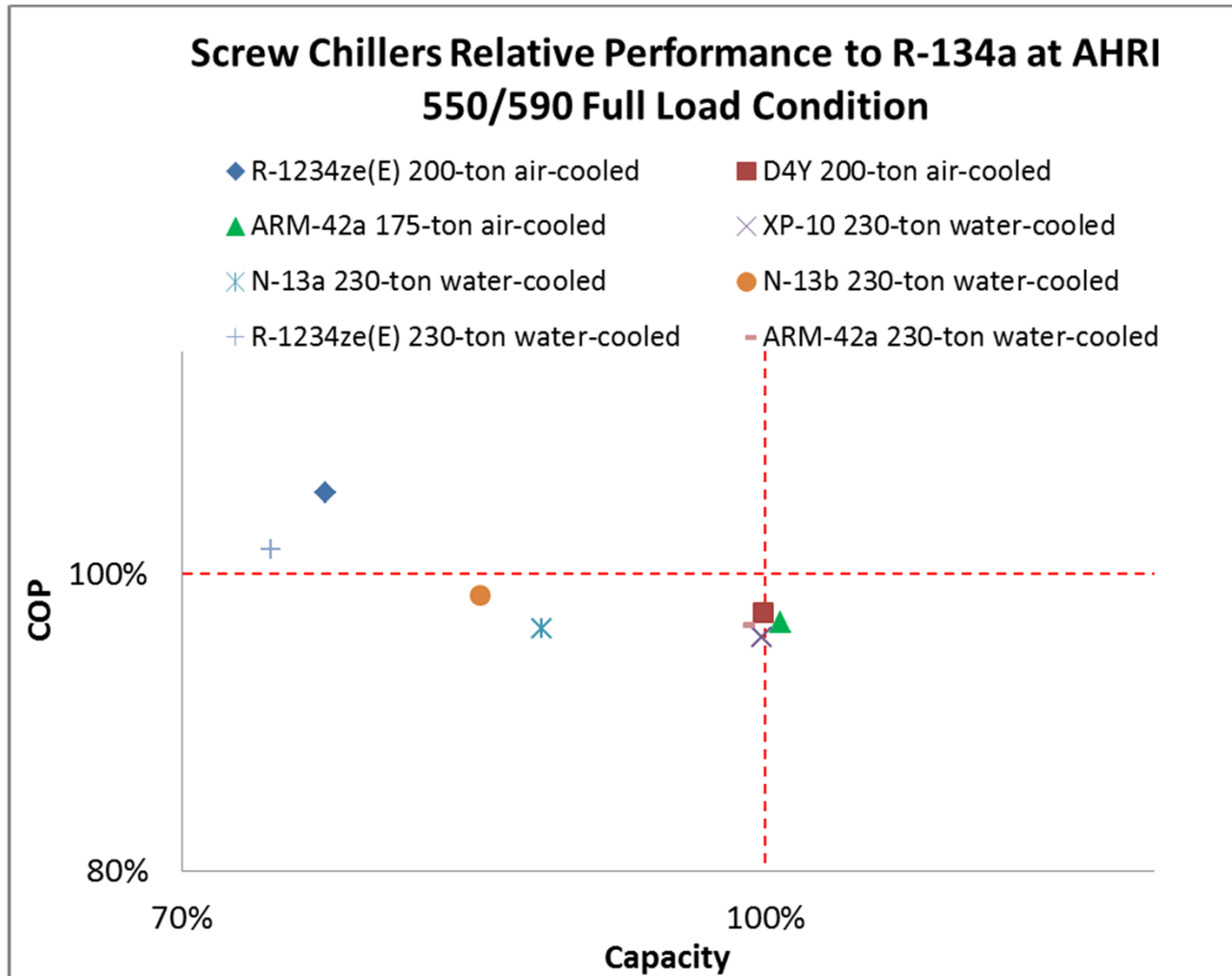


Example of Test Results in Phase I-Ice Makers



(ambient temperature: 32 °C; water temperature 21°C)

Example of Test Results in Phase I-Chillers



Conclusions and Future Work

➤ Phase I testing completed in 2013

- It appears unlikely that a single refrigerant will replace R-22, R-134a, R-404A, and R-410A.
- The results should not be viewed as universally applicable.
- Some results showed inconsistency, and warrant further investigation in the future.

➤ Phase II testing started in 2014.

- Twenty two test entities submitted their test plans.
 - Compressor (9)
 - Drop-in (14)
 - Soft-optimization (7)
- Some tests cover gaps in Phase I:
 - Rooftop unit
 - High ambient conditions

AHRI Low-GWP AREP-Phase II

➤ 25 new refrigerant candidates proposed:

Baseline Refrigerants	Alternative Refrigerant Candidates Classifications according to ASHRAE Standard 34		
	A1	A2L	A2
R-134a	BRB36		
R-404A	ARM-32b, ARM-35, D42Yb, D42Yz, DR-34, N-40c ² , R-442A ⁶	ARM-20a, ARM-20b, HDR110	ARM-25a
R-410A		ARM-71a, DR-5A, HPR2A L-41-1 ³ L-41-2 ⁴	
R-22/R-407C	ARM-32c, D542HT, DR-91, R-442A ⁶	DR-3, L-20a ⁵	
R-123	ARC-1, R1233zd(E)	LPR1A	

➤ Some samples in Phase I will also be available for testing in Phase II.

Acknowledgments

➤ Testing Entities:

- ARMINES-MINES ParisTech
- BITZER
- Bristol Compressor International Inc.
- Carrier Corporation
- Carlyle Compressor
- Climate Master
- Daikin Applied America's, Inc.
- Daikin Industries Ltd
- Danfoss
- Embraco Brazil
- Embraco Slovakia Sro
- Emerson Climate Technologies
- Friedrich Air Conditioning Company, LTD.
- Follett Corporation
- GD Midea Air-conditioning Equipment Co.,Ltd
- Goodman Manufacturing
- Hillphoenix
- Hussmann
- Johnson Controls, Inc.
- Kold- Draft International, LLC
- Lennox Industries Inc.
- LG Electronics
- Manitowoc Ice, Inc.
- Oak Ridge National Laboratory
- Shanghai Hitachi Electrical Appliances CO.,LTD
- Tecumseh Company Co.
- Thermo King / Ingersoll Rand
- Trane/ Ingersoll Rand
- University of Maryland
- WaterFurnace International Inc
- Zamil Air Conditioners

➤ Refrigerant Suppliers

- Arkema, Inc.
- ComStar International Inc
- Daikin Industries Ltd
- E.I.du Pont de Nemours&Co
- Honeywell International, Inc
- Mexichem Fluor, Inc
- National Refrigerants, Inc



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Thank you for your attention!



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