

Low Global Warming Potential Refrigerants

A New Option for Environmental Test Chambers
That Helps Combat Climate Change



Weiss Technik North America, Inc.

White Paper
2022

Stand the Test of Time

ISO9001 Registered · ISO17025 Accredited (A2LA)

3881 N. Greenbrooke SE · Grand Rapids, MI 49512 USA · Tel 616-554-5020 · Fax -5021

© 2022 Weiss Technik North America, Inc.

Table of Contents

Summary 3

The Opportunity for a Sustainable Alternative 4

A Brief History of Refrigerants 5

The Importance of Refrigerant Selection 7

A Solution for Environmental Test Chambers 12

Conclusion 14

Additional Information 15

List of Abbreviations and Acronyms 16

References 17



Summary

R-404A and similar refrigerants have been used in environmental simulation test chambers to enable optimum performance. However, it has been determined that they have a high global warming potential, and domestic and international regulations such as the United States American Innovation and Manufacturing Act, European Union Regulation No. 517/2014, and the Kigali Amendment to the Montreal Protocol aim to phase down these types of compounds. It is expected that R-404A will see a global price increase as well as reduced availability in the upcoming years, which is why customers need an alternative.

Weiss Technik North America, Inc. has been aware of these upcoming changes and was the first environmental simulation test chamber manufacturer to develop a widespread solution for the North American market. As of 2018, environmental simulation test chambers are now available with Opteon™ XP40 (R-449A), which is a low global warming potential refrigerant, without sacrificing performance or reliability. R-449A aligns with the United States American Innovation and Manufacturing Act as well as European Union Regulation No. 517/2014 and the Kigali Amendment to the Montreal Protocol while avoiding the future availability issues of R-404A. Not only is performance preserved, but customers that transition to R-449A help combat climate change by reducing their carbon footprint.



The Opportunity for a Sustainable Alternative

Environmental simulation test chambers (test chambers) are used to test a variety of products across multiple market sectors, including circuit boards, laptops, jet engine components, natural and synthetic fabrics, and even entire hybrid/electric vehicles. The refrigerants responsible for transferring heat out of the test spaces containing these products have been synthesized to deliver optimum results, but some have been determined to have high global warming potential (GWP) values and are currently being impacted by domestic and international regulations. The price and availability are predicted to be heavily influenced by these regulations, and users need an alternative, which is why Weiss Technik North America, Inc. began investigating low GWP refrigerants.

A Brief History of Refrigerants

Refrigerants, in addition to commonly used household substances, used to be made of molecules that contained chlorine. When these gases entered the atmosphere, the ultraviolet radiation from the sun would break a chlorine atom loose from the rest of the refrigerant molecule. The chlorine atom would separate an ozone molecule (O₃) into diatomic oxygen (O₂) by bonding with one of the oxygen atoms. The amount of O₃ broken down into O₂ by a substance determines its ozone depletion potential (ODP) value, with larger values being more harmful. This is referenced against the same amount of trichlorofluoromethane, which has an ODP value of 1¹. This phenomenon was a substantial contributor to the depletion of the ozone layer, most prevalent above Antarctica.

Once the science of ODP and ozone depleting substances (ODS) was understood, the nations of the world came together and decided ODS needed to be phased out. The collaboration resulted in the Montreal Protocol, which was an international agreement signed by every member of the United Nations (UN). Every member nation agreed to phase out ODS when the agreement was finalized in 1987, and the ozone layer is now showing signs of improvement².

The Montreal Protocol was extremely successful in preventing further damage to the ozone layer, but it has been discovered that some of the new compounds (including refrigerants) that replaced older ODS over the past few decades have been contributing to the earth's rising temperatures. This is because they have high GWP values.

GWP illustrates how much energy (heat) a gas will absorb, or in other words, how much impact a compound has on Earth's rising temperatures. It is referenced against the same amount of carbon dioxide (CO₂) over a set time frame, usually 100 years³. As CO₂ is the reference, it has a GWP value of 1, which means substances with lower GWP values are more environmentally friendly. R-404A is a refrigerant commonly used in refrigeration systems for test chambers and has a GWP value of 3,922⁴. When compared with equal amounts of CO₂, R-404A is a larger contributor to global warming because it stores 3,922 times more energy. For a more direct comparison, if a 30 pound tank of R-404A was released into the atmosphere (test chambers typically have a charge of 3 to 80 pounds) it would have the same CO₂ equivalent emissions as driving 14 cars for 1 year (Figure 1)⁵.





Figure 1: CO₂ equivalent emissions from 30 pounds of R-404A⁵



The Importance of Refrigerant Selection

Test chambers use a complex refrigeration cycle to extract heat from a test space into a refrigerant and away from the system. The selected refrigerant greatly impacts the performance of the test chamber, but the refrigerant can be inadvertently released into the atmosphere when the refrigeration system is decommissioned, serviced, or charged. This makes the initial selection of refrigeration crucial because some refrigerants have a high ODP and/or GWP value, which means some are more harmful to the environment than others.

R-404A is not the only refrigerant in the industry, but it is primarily used in test chambers. Gases with similar chemical structures to R-404A are classified as hydrofluorocarbons (HFCs), and now that climate science is better understood and supported, they are being regulated because the nations of the world agreed that these high GWP substances should not be used.

The United States American Innovation and Manufacturing Act (AIM Act) initiated a mandatory domestic phasedown for HFCs, which began on January 1st, 2022⁶. This regulation is very similar to European Union Regulation No. 517/2014 (F-Gas), which is an HFC phasedown that began in 2015 for the European Union⁷. Another HFC phasedown program is the Kigali Amendment to the Montreal Protocol (Kigali Amendment), which was added to the Montreal Protocol in 2016, and set various goals for different UN regions⁸. These phasedown programs are shown in Figure 2^{6,7,8}.

The AIM Act directs the Environmental Protection Agency (EPA) to address and reduce HFC consumption by 85% before 2036 in the United States, and F-Gas has a goal to reduce HFC consumption by 79% before 2030 in the European Union, which leads to predictions of a limited global supply of R-404A and similar refrigerants^{6,7,8}. It can be expected that the price of these refrigerants will increase exponentially as the phasedown programs continue, especially since Honeywell (large R-404A manufacturer) stopped producing R-404A in Europe in 2018⁹.

While the AIM Act does not list R-404A directly, all of the individual substances used to make R-404A are impacted by the regulation¹⁰. Figure 3 shows the percentages of each individual substance needed to make R-404A.



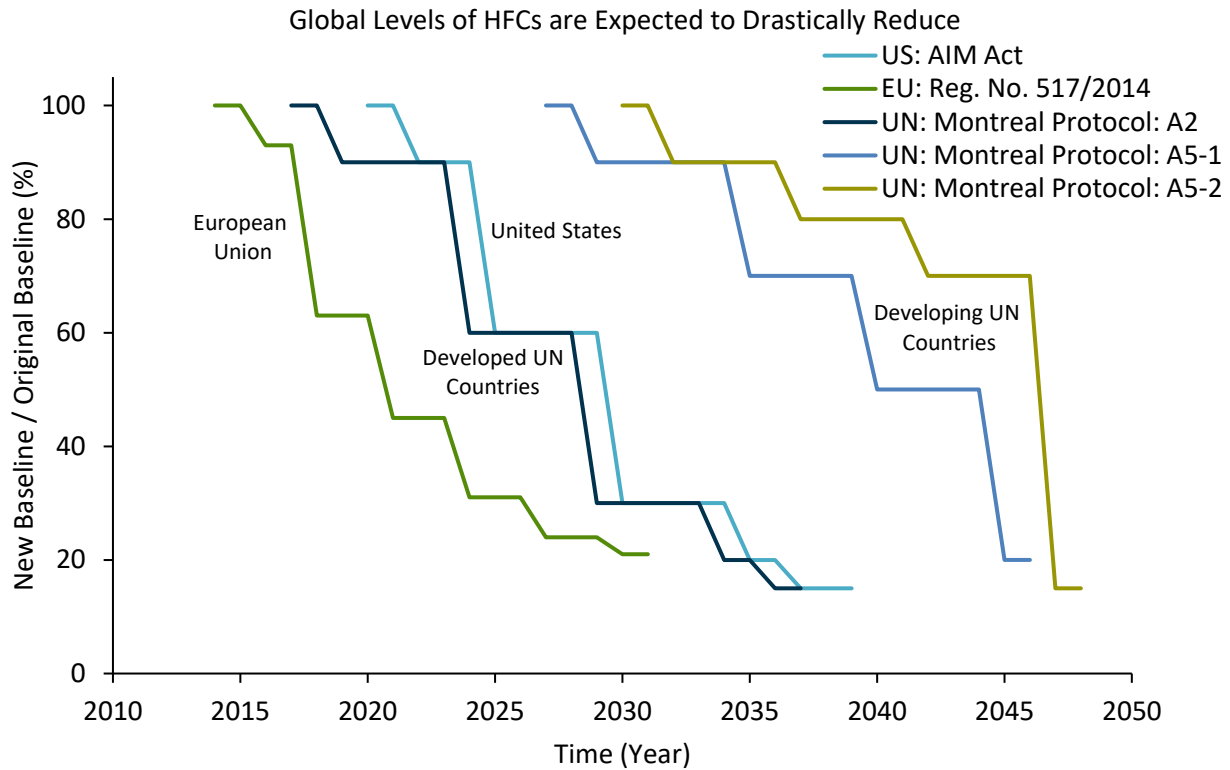
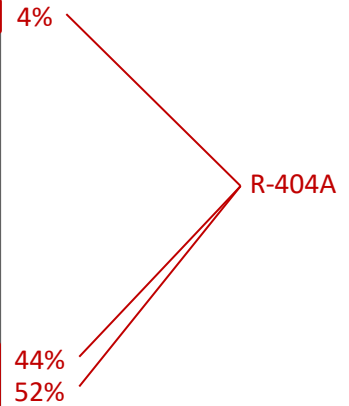


Figure 2: Global HFC Phasedown Timeline^{6,7,8}

Chemical Name	Common Name	Exchange Value*
CHF ₂ CHF ₂	HFC-134	1,100
CH ₂ FCF ₃	HFC-134a	1,430
CH ₂ FCHF ₂	HFC-143	353
CHF ₂ CH ₂ CF ₃	HFC-245fa	1,030
CF ₃ CH ₂ CF ₂ CH ₃	HFC-365mfc	794
CF ₃ CHF ₂ CF ₃	HFC-227ea	3,220
CH ₂ FCF ₂ CF ₃	HFC-236cb	1,340
CHF ₂ CHF ₂ CF ₃	HFC-236ea	1,370
CF ₃ CH ₂ CF ₃	HFC-236fa	9,810
CH ₂ FCF ₂ CHF ₂	HFC-245ca	693
CF ₃ CHFCH ₂ CF ₂ CF ₃	HFC-43-10mee	1,640
CH ₂ F ₂	HFC-32	675
CHF ₂ CF ₃	HFC-125	3,500
CH ₃ CF ₃	HFC-143a	4,470
CH ₃ F	HFC-41	92
CH ₂ FCH ₂ F	HFC-152	53
CH ₃ CHF ₂	HFC-152a	124
CHF ₃	HFC-23	14,800



* Exchange Value is numerically equivalent to the 100-year GWP of the chemical as given in the Errata to Table 2.14 of the IPCC's 2007 Fourth Assessment Report (AR4).

Figure 3: Individual HFCs Listed in the AIM Act, R-404A Breakdown¹⁰

In addition to the AIM Act impacting high GWP refrigerants, the GreenChill and Significant New Alternatives Policy (SNAP) programs are expected to increase the domestic market adoption of low GWP refrigerants, making them more affordable and commercially available.

The EPA’s GreenChill Program is a partnership with supermarkets and grocery stores, which encourages retailers to become more sustainable¹¹. Some of the current GreenChill Partners include Aldi, Kroger, Meijer, Price Chopper, Publix, Target, and Whole Foods, and the overall number of silver, gold, and platinum certifications has been steadily increasing since the program’s start in 2008^{12,13}. This trend is crucial to both test chamber manufacturers and users because supermarkets and grocery stores consume large amounts of refrigerant and have the buying power to set precedence on how and what refrigerants are used. Figure 4 shows a map of partner stores as of June 2019¹⁴.

GreenChill Partners Have Spread Nationwide

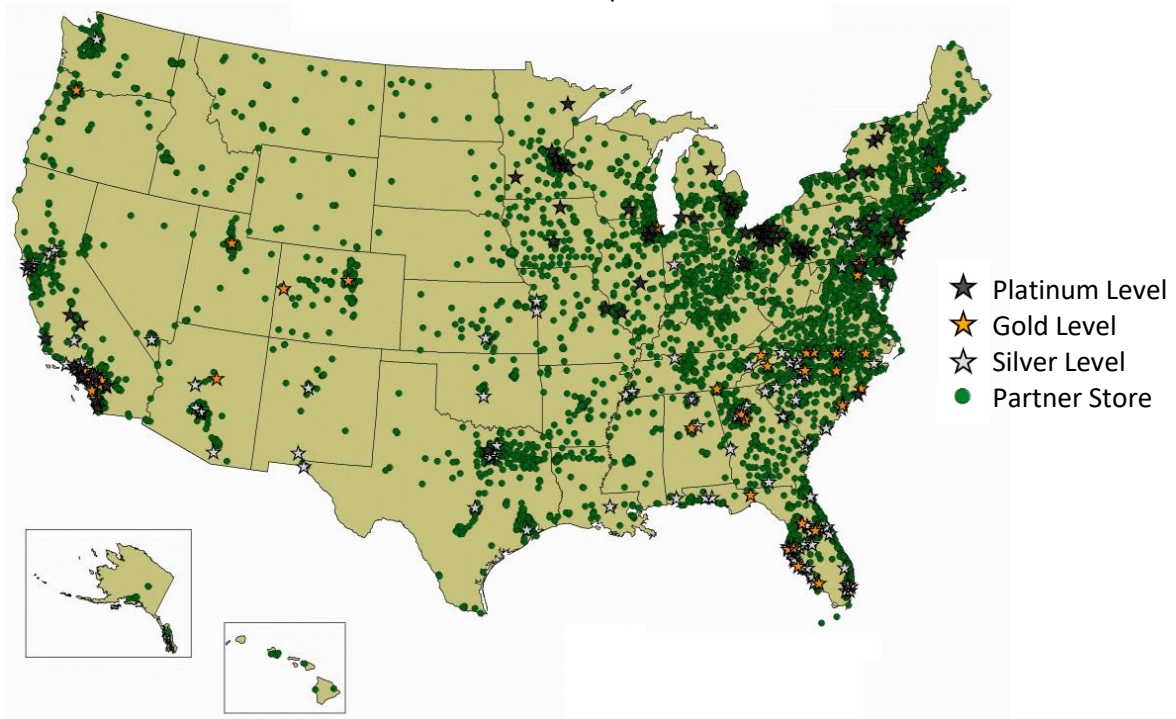


Figure 4: Location of GreenChill Partner Stores¹⁴

Considering the typical supermarket in the United States utilizes R-404A and contributes more CO₂ equivalent emissions from leaked refrigerant than from electricity consumption, the increase in certifications shows a positive trend of companies wanting refrigeration systems that impact the environment less, and retailers can drastically reduce their CO₂ equivalent emissions by transitioning to a low GWP refrigerant¹⁵.

If retailers were to switch their refrigeration systems to R-449A, which is a low GWP refrigerant (designed to replace R-404A) with an ODP value of 0, CO₂ equivalent emissions originating from leaked refrigerant could be reduced by ~65% as R-449A has a GWP value of 1,397 and R-404A has a GWP value of 3,922^{4,16}.

In addition to R-404A, R-22 is another commonly used refrigerant, but the EPA's SNAP program banned all new production of R-22 since January 1st, 2020, because the goal of the program is to promote safe replacements for ODS^{17,18}. Even though R-449A was designed to replace R-404A, The Chemours Company (manufacturer of R-449A) published a multi-year study to determine if it was a suitable replacement for R-22. The study concluded that R-449A was in fact a viable alternative to R-22 for low and medium temperature applications¹⁶.

The test chamber market needs a low GWP alternative that delivers the same performance and reliability as R-404A because the AIM Act, F-Gas, and the Kigali Amendment are expected to limit the supply of high GWP refrigerants, and the GreenChill and SNAP Programs show potential widespread use of R-449A domestically. An alternative would not only help avoid the expected price increases, but more importantly, would contribute to the global movement of environmental sustainability. Figure 5 shows 2 global temperature snapshots and reveals how quickly the earth is heating up¹⁹. Any transition from a high to low GWP refrigerant would help combat climate change by bringing the world's population a step closer to reaching the goals set by the AIM Act, F-Gas, and the Kigali Amendment.

Weiss Technik North America, Inc. tasked itself with delivering a solution. Years of collaborated research was conducted with Weiss Technik, GmbH, to fully understand low GWP refrigerants. The data guided the design and construction of prototypes, which were then optimized for industrial use. After all testing was completed, the result was successfully changing a refrigeration system's refrigerant from R-404A to R-449A, which is a low GWP refrigerant, without sacrificing performance or reliability.



Global Temperatures are Rapidly Increasing

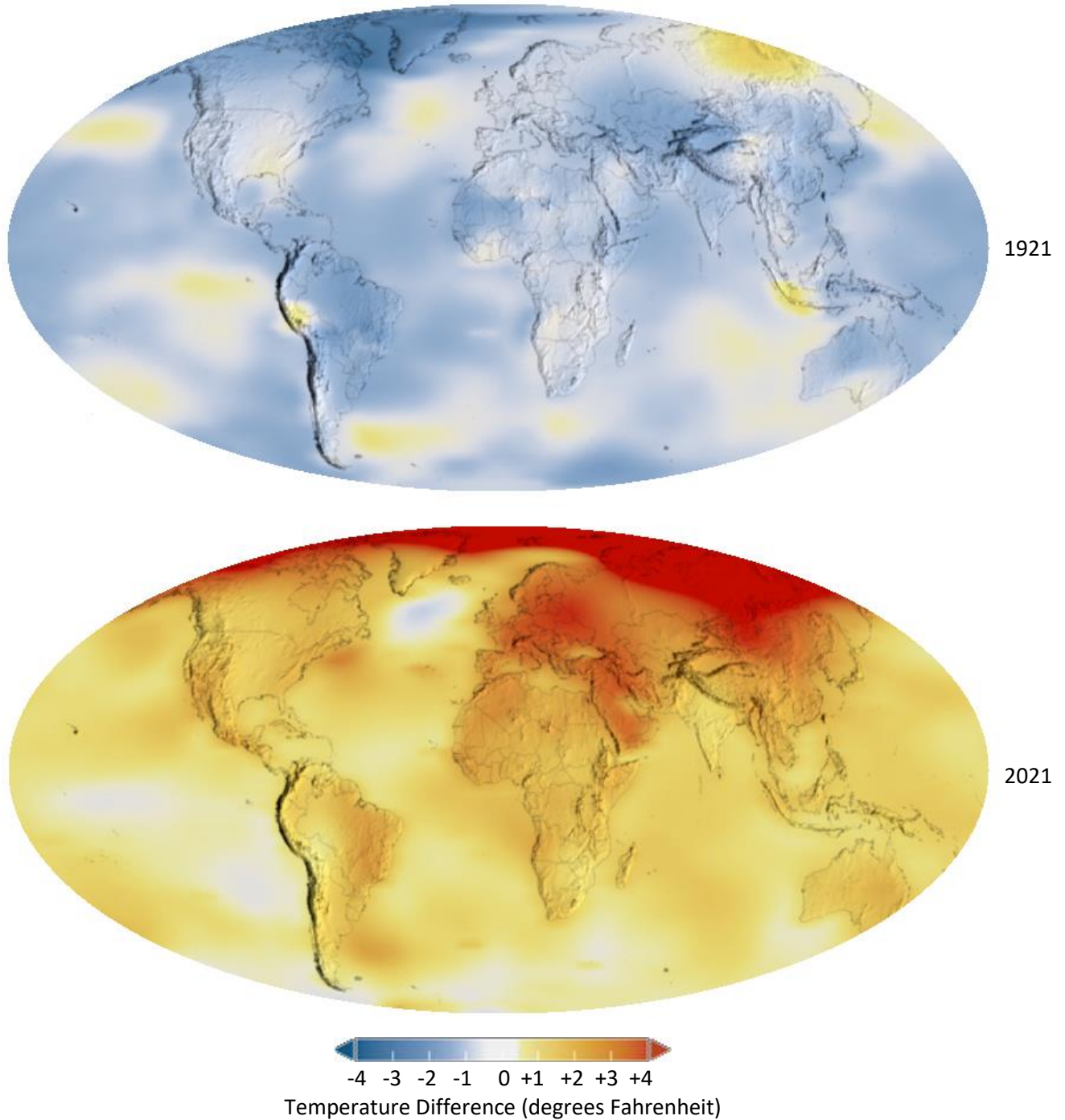


Figure 5: Global Temperature Increase from 1921 to 2021¹⁹

A Solution for Environmental Test Chambers

R-449A has been available in place of R-404A in new Weiss Technik North America, Inc. test chambers since 2018. There are no reductions in performance, and this is backed by tens of thousands of testing hours by the Weiss Group. Table 1 shows the compositional breakdown between R-404A and R-449A, and the new composition of R-449A results in a GWP value that is almost 3 times lower than R-404A (1,397 and 3,922, respectively)^{4,20}. Not only is R-449A's GWP value lower, but it also has an ODP value of 0, as well as the same non-toxic and non-flammable ratings as R-404A⁴. While the environmental benefits are considerable, users need to have access to R-449A for maintenance and servicing purposes. Weiss Technik North America, Inc. has confirmed with The Chemours Company that an authorized distribution network has been established which covers the United States, Canada, and Mexico, and most distributors have been increasingly adding stocks of R-449A for the past few years. If customers have any trouble locating a supply of R-449A, they should contact Chemours Customer Service at 1-800-441-9407.

For users that have an existing Weiss Technik North America, Inc. test chamber, there are 2 upgrades currently available featuring low GWP refrigerants. The first is a drop-in replacement, Opteon™ XP44 (R-452A) with a GWP value of 2,141, shown in Figure 6²⁰. While the change out is not complicated, internal tests have shown approximately a 10% reduction in performance. The second option utilizes R-449A. Performance is preserved but only after specifically engineered mechanical and software modifications are made to the refrigeration system. Users will need to conduct a cost-benefit analysis to determine if the simpler retrofit of R-452A outweighs the expected performance losses. Given the domestic and international regulations, it is reasonable to expect that the price of higher GWP HFCs will increase over time, making low GWP solutions even more cost-effective.

If users want to benefit from a test chamber that utilizes a low GWP refrigerant, Weiss Technik North America, Inc. recommends purchasing a new test chamber equipped with R-449A. Not only would R-449A support individual companies' initiatives to become more sustainable, but it would also help companies avoid future refrigerant availability issues as well as avoid future modification costs. Companies with both domestic and international presence would also be able to ship chambers into Europe because R-449A has a GWP value below the 2,500 F-Gas limit, shown in Figure 6^{4,20}.

Table 1: Compositional Breakdown Between R-404A and R-449A^{4,20}

Base Compound	R-404A	R-449A
R-143A	52%	0%
R-32	0%	24%
R-125	44%	25%
R-134A	4%	26%
R-1234YF	0%	25%

Weiss Technik North America, Inc. Offers Low GWP Solutions

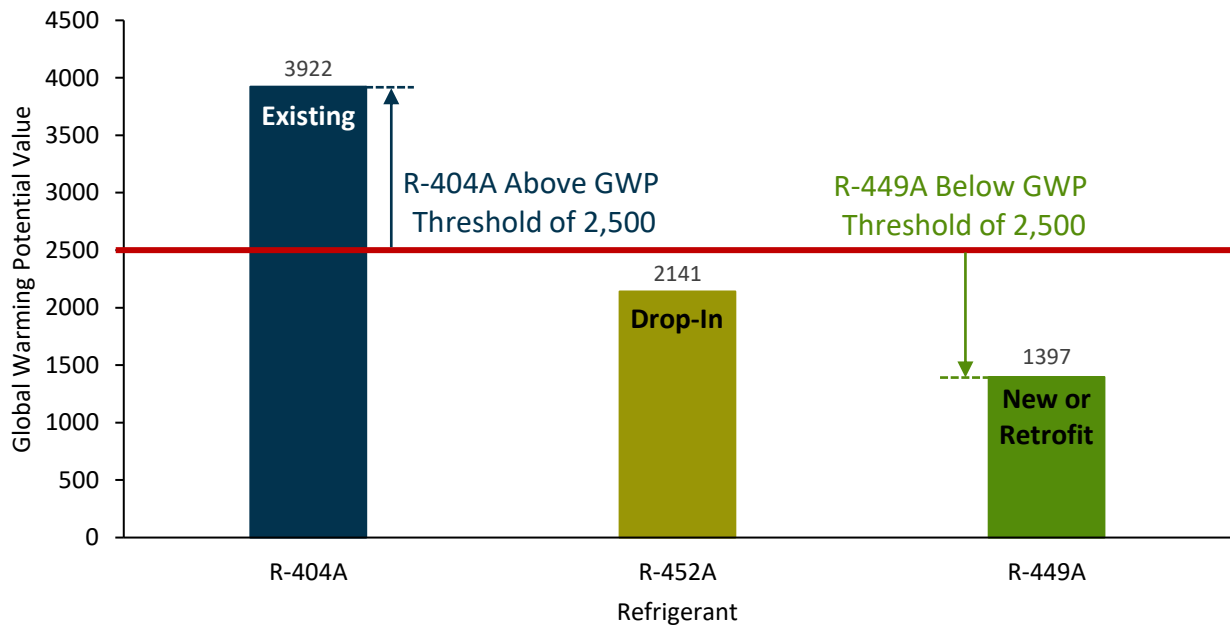


Figure 6: GWP Comparison of R-404A, R-452A, and R-449A^{4,20}

Conclusion

The AIM Act, F-Gas, and the Kigali Amendment prove that the nations of the world have agreed the practice of using and consuming high GWP refrigerants needs to stop, and the SNAP and GreenChill Programs show a domestic trend of wanting refrigeration systems that impact the environment less. R-449A has been determined to be more environmentally conscious because of its lower GWP value, and after thorough testing, it was confirmed to be a viable alternative for R-404A in test chambers. Weiss Technik North America, Inc. is proud and confident to offer its customers this option and to help lower the overall carbon footprint of environmental simulation test chambers.



Additional Information

R-449A, a low GWP refrigerant, is a more environmentally conscious alternative to R-404A for test chambers, without resulting in performance reductions. Weiss Technik North America, Inc. continues to research various refrigeration topics. Check back often as announcements of completed projects are released.

LEEF® Technology and test chambers with battery safeties are now available with R-449A. Please consult your sales representative for more information.

For any questions, please visit the Weiss Technik North America, Inc. website at www.weiss-na.com, call 616-554-5020, or email sales.na@weiss-technik.com.

List of Abbreviations and Acronyms

AIM Act	United States American Innovation and Manufacturing Act
CO ₂	Carbon Dioxide
EPA	Environmental Protection Agency
F-Gas	European Union Regulation No. 517/2014
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
Kigali Amendment	Kigali Amendment to the Montreal Protocol
O ₂	Diatomic Oxygen
O ₃	Ozone
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
R-449A	Opteon™ XP40
R-452A	Opteon™ XP44
SNAP	Significant New Alternatives Policy
Test Chamber	Environmental Simulation Test Chamber
UN	United Nations



References

- 1) National Aeronautics and Space Administration. *NASA Ozone Watch*.
https://ozonewatch.gsfc.nasa.gov/facts/eesc_SH.html
2022 (Last visited 2/24/2022).
- 2) United States Department of State. *The Montreal Protocol on Substances That Deplete the Ozone Layer*.
<https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/the-montreal-protocol-on-substances-that-deplete-the-ozone-layer/>
2022. (Last visited 2/24/2022).
- 3) United States Environmental Protection Agency. *Understanding Global Warming Potentials*.
<https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>
2022 (Last visited 2/24/2022).
- 4) The Linde Group. *R449A – Opteon® XP40*.
https://www.linde-gas.se/sv/images/Refrigerants_Brochure_R449A_EN_tcm586-175833.pdf
2022 (Last visited 2/24/2022).
- 5) California Air Resources Board. *What is Global Warming Potential?*
<https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants>
2022 (Last visited 2/24/2022).
- 6) United States Environmental Protection Agency. *Final Rule - Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act*.
<https://www.epa.gov/climate-hfcs-reduction/final-rule-phasedown-hydrofluorocarbons-establishing-allowance-allocation>
2022 (Last visited 2/24/2022).
- 7) Official Journal of the European Union. *Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014*.
<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN>
2022 (Last visited 2/24/2022).
- 8) United States Environmental Protection Agency. *Update on Kigali Amendment to the Montreal Protocol*.
http://www.epa.gov/sites/production/files/2016-11/documents/newberg_kigaliamend_122016.pdf
2022 (Last visited 2/24/2022).
- 9) Honeywell Refrigerants. *Think about tomorrow today*.
<https://www.honeywell-refrigerants.com/europe/wp-content/uploads/2017/03/honeywell-nomore404A-phase-out-information.pdf>
2022 (Last visited 2/24/2022).
- 10) United States Environmental Protection Agency. *Final Rule – Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the American Innovation and Manufacturing (AIM) Act*
<https://www.epa.gov/system/files/documents/2021-09/hfc-allocation-rule-nprm-fact-sheet-finalrule.pdf>
2022 (Last visited 2/24/2022).

- 11) United States Environmental Protection Agency. *About GreenChill*.
<https://www.epa.gov/greenchill/about-greenchill>
2022 (Last visited 2/24/2022).
- 12) United States Environmental Protection Agency. *GreenChill Food Retail Partners*.
<https://www.epa.gov/greenchill/greenchill-food-retail-partners>
2022 (Last visited 2/24/2022).
- 13) United States Environmental Protection Agency. *GreenChill Store Certification Trends*.
<https://www.epa.gov/greenchill/greenchill-store-certification-trends>
2022 (Last visited 2/24/2022).
- 14) United States Environmental Protection Agency. *GreenChill Program as of June 2019*.
https://www.epa.gov/sites/default/files/2019-09/documents/greenchillmapping_as_of_june_2019_text.pdf
2022 (Last visited 2/24/2022).
- 15) United States Environmental Protection Agency. *Profile of an Average U.S. Supermarket's Greenhouse Gas Impacts from Refrigeration Leaks Compared to Electricity Consumption*.
https://www.epa.gov/sites/default/files/documents/gc_averagestoreprofile_final_june_2011_revised_1.pdf
2022 (Last visited 2/24/2022).
- 16) International Refrigeration and Air Conditioning Conference. *Multi-Year Evaluation of R-449A as a Replacement for R-22 in Low Temperature and Medium Temperature Refrigeration Applications*
<https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2760&context=iracc#:~:text=R%2D449A%20was%20initially%20developed,and%20medium%20temperature%20refrigeration%20applications>
2022 (Last visited 2/24/2022).
- 17) United States Environmental Protection Agency. *Revised Draft Analysis of U.S. Commercial Supermarket Refrigeration Systems*.
https://www.epa.gov/sites/default/files/documents/EPASupermarketReport_PUBLIC_30Nov05.pdf
2022 (Last visited 2/24/2022).
- 18) United States Environmental Protection Agency. *GreenChill Regulatory Context*.
<https://www.epa.gov/greenchill/greenchill-regulatory-context>
2022 (Last visited 2/24/2022).
- 19) National Aeronautics and Space Administration. *Global Temperature. Time Series: 1884 to 2021*.
<https://climate.nasa.gov/vital-signs/global-temperature/>
2022 (Last visited 2/24/2022).
- 20) Tecumseh. *Guidelines for using R449A/R452A*.
https://www.tecumseh.com/globalassets/media/europe/files/guidelines-and-recommendations/r448a_r449a_r452a/tecumseh_guidelines_for_using_r452a_r448a_r449a.pdf
2022 (Last visited 2/24/2022).