Development of Demonstration Unit of Residential Air Conditioner Adopting Low-GWP Refrigerant to Replace R32

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Wide-ranging regulations have been introduced to deal with global warming, and various measures have been implemented accordingly. Under such circumstances, air conditioning and refrigeration systems are required to not only have energy-saving features, but also start using alternative refrigerants with less environmental impact.

Adopting R454C refrigerant, which has an extremely low global warming potential (GWP), Mitsubishi Heavy Industries Thermal Systems Ltd. has developed a demonstration unit of a residential air conditioner with enhanced environmental properties. The global warming impact of this demonstration unit represents a reduction of more than 90% from that of our earlier models.

1. Introduction

In recent years, the reduction of greenhouse gas emissions and enhanced energy-saving features are in increasing demand from the standpoint of fighting back against global warming. The Kigali Amendment to the Montreal Protocol (2016) prescribes the international rules that developed countries will reduce, by 2036, the impact of refrigerants on global warming by 85% from the average of the actual values between 2011 and 2013, while developing countries need to achieve the equivalent reduction approximately 10 years later (**Table 1**).

Table 1 HFC production/consumption phase-down schedule in the Kigali Amendment

- The adopted Amendment adds the phase-down of HFCs (coming into effect on January 1, 2019).
- Developed countries are responsible for an 85% phase-down by 2036, while developing countries are required to fulfill a more than 80% phase-down by sometime around 2045.

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		Developing countries Group 1	Developing countries Group 2	Developed countries
Baseline	Baseline years	2020 to 2022	2024 to 2026	2011 to 2013
	Baseline calculation	Average HFC consumption	Average HFC consumption	
	HCFC included	65% of HCFC baseline	65% of HCFC baseline	15% of HCFC baseline [*25%]
Freeze		2024	2028	—
Phase-down schedule	Step 1	10% reduction in 2029	10% reduction in 2032	10% reduction in 2019 [*5% reduction in 2020]
	Step 2	30% reduction in 2035	20% reduction in 2037	40% reduction in 2024 [*35% reduction in 2025]
	Step 3	50% reduction in 2040	30% reduction in 2042	70% reduction in 2029
	Step 4	—	—	80% reduction in 2034
	Final reduction goal	80% reduction in 2045	85% reduction in 2047	85% reduction in 2036

○ Developing countries Group 1: Developing countries that do not belong to Group 2
○ Developing countries Group 2: India, Pakistan, Iran, Iraq and other Gulf countries
○ (*) Belarus, Russia, Kazakhstan, Tajikistan and Uzbekistan
HCFCs: Designated fluorocarbons including ozone depleting substances (e.g., R22)
HFCs: Alternative fluorocarbons excluding ozone depleting substances, which have a high GWP under existing circumstances and have become subject to the regulations as part of global warming prevention measures (e.g., R32)

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In air conditioners, it is particularly necessary to switch to refrigerants with a low GWP(Note 1). Nowadays, an increasing number of small-capacity air conditioners such as residential air conditioners have changed refrigerants from R410A (GWP: 2090) to R32, which offers a low GWP (675) and superior performance. However, R32 is slightly flammable. If it is applied to large-capacity air conditioners such as multi-split building air conditioners, some difficulties will arise in terms of facility design and construction. For example, safety measures such as shut-off valves are required in many cases because the refrigerant is supplied in large quantities to a single room. Since R32 is designated as a regulated substance (HFC), it has to be replaced by another refrigerant with an even lower GWP to achieve the 85% reduction in 2029. We therefore took up the challenge to develop a residential air conditioner demonstration unit, which can eventually lead us to the development of air conditioners that use unregulated refrigerants.

Note 1: GWP stands for Global Warming Potential. It is expressed relative to CO_2 (which has a GWP of 1) Lower GWPs indicate a lower greenhouse effect and superior environmental properties.

2. Selection of alternative refrigerants

As the requirement specifications in this product development, the low GWP refrigerant to be adopted should satisfy the following:

(1) Non-toxic
(2) Able to maintain a pressure high enough to be clearly considered operable at an outside air temperature as low as -15°C
(3) In the case of zeotropic refrigerants, having a small temperature glide(Note 2) in consideration of frost formation while heating using the outside air as a heat source

Table 2 summarizes the safety and environmental properties of several types of refrigerants. The candidate refrigerants satisfying the aforementioned product requirement specifications include R1234yf, R454C and R455A, all of which are comparable to R32 that is currently in use. However, considering use at an outside air temperature as low as -15°C, R1234yf was excluded because the pressure at the saturation temperature being close to atmospheric pressure would make its application difficult. **Figure 1** compares the properties of major refrigerants. Zeotropic refrigerants with a large temperature glide during the phase change process have a risk of lowering the heating capacity because of localized frost formation in the outdoor heat exchanger that works as an evaporator during heating. Therefore, in accordance with our selection criteria, R454C has been selected as a low GWP refrigerant with a temperature glide as small as R407C, which has already been used in other products.

Note 2: Temperature glide is a phenomenon in which the phase change temperature (evaporation/condensation) is not constant. This phenomenon is particular to refrigerants with a mixed composition.

Table 2 Compositions, GWPs and safety classes of major refrigerants

Refrigerant name	Composition	GWP	Safety class
R410A	R32/R125=50/50Wt%	2090	A1
R32	Single	675	A2L
R1234yf	Single	1	A2L
R454C	R32/R1234yf=21.5/78.5Wt%	146	A2L
R455A	R32/R1234yf/CO_2=21.5/78.5/3Wt%	146	A2L

Safety classification
A: lower toxicity, B: higher toxicity; 1: no flame propagation,
2L: slight flammability, 2: lower flammability, 3: higher flammability

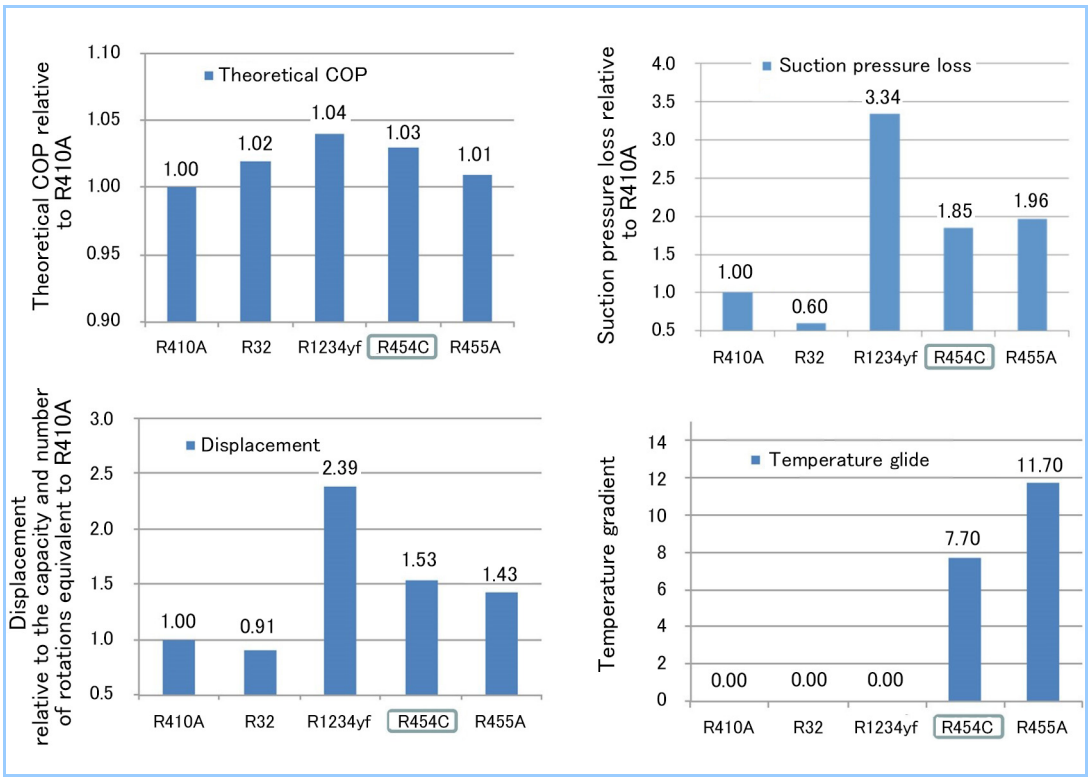

Figure 1 Property comparison of major refrigerants

3. Issues in securing performance and solution technology summary

If applied without any changes from the current model using R32, R454C is estimated to have a high specific volume because of its properties as a refrigerant, consequently decreasing the cooling/heating capacity. The following improvements in the refrigeration cycle and frost formation during heating have been made:

(1) Increased displacement (approximately 64%)
(2) Increased size of the outdoor heat exchanger (approximately 25%) and reviewed flow path configuration (number of paths) in the heat exchanger
(3) Increased size of the connected gas pipe diameter (φ 9.52 → φ 12.7) (reduced pressure loss)
(4) Increased size of the EEV diameter (φ 1.5 → φ 1.8)

These improvements have succeeded in overcoming the performance decline caused by the refrigerant properties. The test results using the demonstration unit show a 0.5% reduction in the cooling capacity and a 0.2% increase in the heating capacity (both on a calculation basis), thus indicating the likelihood of satisfying the performance regulations.

4. Major challenges for practical application

The thermodynamic properties of zeotropic refrigerants with a low GWP have a potential that is comparable to R410A or R32 in terms of environmental performance. However, their use requires larger compressors and heat exchangers than in the case of R32, increasing the size and cost. Therefore, it is necessary to achieve even higher efficiency and develop the technology for downsizing. We will continue to develop highly-efficient compressors for low pressure refrigerants (other than positive-displacement compressors) and high-performance heat exchangers that can contribute to a reduction of the refrigerant filling amount, and improve the cycle, for example, by introducing internal heat exchangers to make frost formation less frequent.

5. Conclusion

R454C has a GWP of 146. It is approximately 1/14th and 1/5th of the respective GWPs of R410A and R32, which are currently and most widely used in small-to-medium-capacity air conditioners. As a result, the global warming impact(Note 3) from the refrigerant used in the demonstration unit falls by 91.3% from the level of the current model(Note 4), which represents a

highly-significant reduction. Since 2015, the European countries, where environmental awareness is deeply entrenched, have gradually expanded regulations affecting the sale and use of global warming substances including HFCs with a GWP of 150 or higher. The development of a residential air conditioner adopting R454C is the fruit of our leading and positive response to such movements.

Going forward, we will continue to dedicate our resources to developing and marketing high-performance products using low-GWP refrigerants, thereby contributing to the protection of the global environment in markets across the globe.

Note 3: Impact of a refrigerant on global warming, which is calculated by multiplying the global warming potential (GWP) of the refrigerant by its volume

Note 4: The top-of-the-line “SRK25ZSX-S” for the European market with a piping length of 5 m, which adopts R410A refrigerant

References

(1) NEDO Environment Department Activity Report Meeting: Activities to develop technologies related to global warming prevention measures in fluorocarbon field (27 July 2017)

(2) JRAIA PAC Technical Committee: Task force of explanatory meeting increasing awareness on use of R32 for store-use air conditioners (16 March 2018)