RECENT REFRIGERANTS AND SYSTEM DEVELOPMENTS IN JAPAN

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Introduction

In refrigeration and air conditioning field, refrigerant is an important factor that influences the equipment performance. Becoming global environmental problems more serious, we must pay attention to the influence of refrigerants on the environment, especially the contribution to global warming. To maintain the global environment, it is necessary to take measures as quickly as possible.

Refrigerants are roughly classified into two groups: compounds synthesized by containing fluorine atom in the molecular structure, so-called fluorocarbons, and natural refrigerants such as carbon dioxide, ammonia, propane, isobutane, and air. Global warming substances, so-called greenhouse gases released into the atmosphere are roughly divided into carbon dioxide, nitrous oxide, methane, and HFCs, perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3), as well as others such as unsaturated HFCs and HCFCs (hydrochlorofluorocarbons), so-called hydrofluoroolefins (HFOs). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, if HFCs continue to be released into the atmosphere, the average temperature will rise about 0.4 K by 2100[1)].

Paris Agreement and Kigali Amendment

The Paris Agreement, adopted by COP21 in 2015 as a measure for the greenhouse gas issue, attempts to reduce the global average temperature rise before the industrial revolution to less than 2 K. Japan aims for a 26% reduction over fiscal 2013 by 2030. With this promise, the four gas emissions including HFCs should be reduced to less than 28.9 million t-CO_2 by 2030[2)].

The Kigali Amendment by the Parties of the Montreal Protocol on Substances that Deplete the Ozone Layer, was issued in 2019, and the consumption of HFCs in Japan, about 71 million t-CO_2 of 2011-2013, should be phased out by 85% by 2036, which means a reduction to about 11 million t-CO_2[3)].

Development of new refrigerant and reduction in refrigerant discharge to the atmosphere

In addition to restrict production of HFCs, it becomes an important key not to discharge them to the atmosphere. Furthermore it's required to develop low-GWP refrigerants and their equipment which contribute less to global warming. There is a lot of equipment with HFCs in the Japanese market (e.g., room air-conditioners, RAC: app. 100,000,000 and automobile air-conditioners: app. 80,000,000)[4)]. Due to the large amount of HFCs leakage from the refrigeration and air conditioning equipment, it is necessary to reduce

the leakage during their operation, emission at maintenance and failure, and to recover refrigerant when discarding equipment.

To promote the reduction of HFCs leakage, there are laws and regulations as follows.

☆ The Act on the Protection of the Ozone Layer through the Regulation of Specific Substances
☆ Re-commercialization of Specific Household Appliances
☆ Law on the Rationalization of the Use of Fluorocarbons and the Appropriate Management
☆ Law on Recycling of End-of-life Vehicles
☆ Global Warming Measure Plan
☆ The Action the Rational Use of Energy, etc.
☆ High Pressure Gas Safety Act

Countermeasures for global environmental problems

In order to comply with these laws and regulations, development of low GWP refrigerants, adoption of low GWP refrigerants in equipment of new and existing models, reduction of leakage during operation/maintenance of equipment, recovery from discard of equipment, reclamation of recovered refrigerant including recycle, and destruction of unnecessary refrigerant including recomposition should be promoted taking into consideration the refrigerant management circle from refrigerant production to regeneration/destruction as shown in Fig. 1.

Table 1 Target GWP and year for refrigeration and air conditioning products.

Designated products	GWP Goals	Target Year	Typical currently used refrigerants (GWP, safety code*1)	Alternative refrigerant examples	Developing situation
Household air-conditioner*2	750	2018	R 22 (1810,A1) R 410A (2090,A1) R 32 (675,A2L)	R 32 (675,A2L) R 290 (3,A3)	← In market (All products) ← Under review
Air conditioner for stores and offices	750	2020	R 22 (1810,A1) R 32 (675,A2L) R 407C (1774,A1) R 410A (2090,A1)	R 32 (675,A2L) R 410A (2090,A1)	← In market ← In market
Automotive air conditioner*3	150	2023	R 134a (1430,A1)	R 1234yf (4,A2L) R 744 (1,A1)	← In market ← Finish
Condensing unit *4 ---------- Stationary type refrigerator and refrigerating unit*4	1500	2025	R 22 (1810,A1) R 134a (1430,A1) R 404A (3920,A1) R 410A (2090,A1) ---------- R 22(1810,A1) R 404A (3920,A1) R 410A (2090,A1)	R 290 (5,A3) R 744 (1,A1) R 407H (1495,A1) R 410A (2090,A1) R 448A (1273,A1) R 449A (1282,A1) R 463A (1377,A1)	←Under review ← In market ← For retrofit ← In market ← In market ← Under development ← In market
Centralized refrigeration equipment*5	100	2019	R 22 (1810,A1) R 717 (<1,B2L) R 744 (1,A1)	R 717 (<1,B2L) R 744 (1,A1)	← In market ← In market s
Rigid urethane foam insulation*6	100	2020	R 245fa (1030,B1) R 365mfc (795,-)	R 1233zd(E) (1,A1) R 744 (1,A1)	← Under development ← Under development
Dust blower*7	10	2019	R 134a (1430, A1) R 152a (124,A2) R 744 (1, A1) DME (1)	R 744 (1,A1)	← Under development

*1: the capital letter corresponds to toxicity and the digit to flammability.
*2: Excluding floor-mounted type.
*3: For passenger cars excluding those with a capacity of 11 or more.
*4: Excluding rated compressor output of 1.5 kW or less.
*5: For newly shipped for freezing refrigerated warehouse of 50,000 m3 or more.
*6: For spray foam for house building materials.
*7: Excepting non-flammable applications.

In addition, it is recommended to take effective measures referring the refrigerant amount in the main process from flowchart [4,5)].

Development of low GWP refrigerants and equipment: Low GWP refrigerants have been developed according to the laws/regulations as shown in Table 1. However, new refrigerants are in the development process in some equipment products including non-listed products yet, e.g., medium-sized freezing and chilling, package air conditioners (PAC) and variable refrigerant flow/volume (VRF/VRV). In addition, even if it has been developed, the performance of the equipment used is inferior in terms of CO_2 emissions during operation. There may be problems with safety designated by safety code, such as combustibility and toxicity, and stability as a refrigerant. Some refrigerants become expensive for stable supply. In addition, although investigations on refrigerant mixtures in which substances are mixed as shown in Table 2 have been advanced as new refrigerants, there may be problems in handling and heat transfer characteristics in heat exchanger with respect to non-azeotropic mixtures.

Table 2 Component substances of new refrigerant mixtures

Refrigerant	Safety Code	GWP (100Yr)
R 32	A2L	675
R 125	A1	3500
R 134a	A1	1430
R 143a	A2L	4470
R 152a	A2L	148
R E170	A3	1
R 227ea	A1	3220
R 290 (propane)	A3	3.3
R 600 (butane)	A3	4
R 600a (isobutane)	A3	3
R 601a (isopentane)	A3	<20
R 1123	A2L	0.3
R 1233zd(E)	A1	1
R 1234yf	A2L	4
R 1234ze(E)	A2L	6
R 1270 (propylene)	A3	1.8

Therefore, the Japanese government have established some subsidy systems: Accelerate the introduction of energy saving natural refrigerant equipment for the early realization of a CFC-free, low carbon society with the aim of developing natural refrigerant equipment in the field of refrigeration, Fluorocarbon environmental research comprehensive promotion cost aiming at improvement of recovery rate, and NEDO business research, Development of optimization and evaluation method of next-generation refrigeration air conditioning which can achieve energy saving and low global warming effect / Regarding safety and risk evaluation concerning next-generation refrigerant. We are trying to promote the development and introduction of new refrigerants and equipment.

Since some refrigerants filled in existing equipment have very high GWP, it is important to try changing them to low GWP refrigerants, so-called retrofit and drop-in, and are being promoted in EU and the United States.

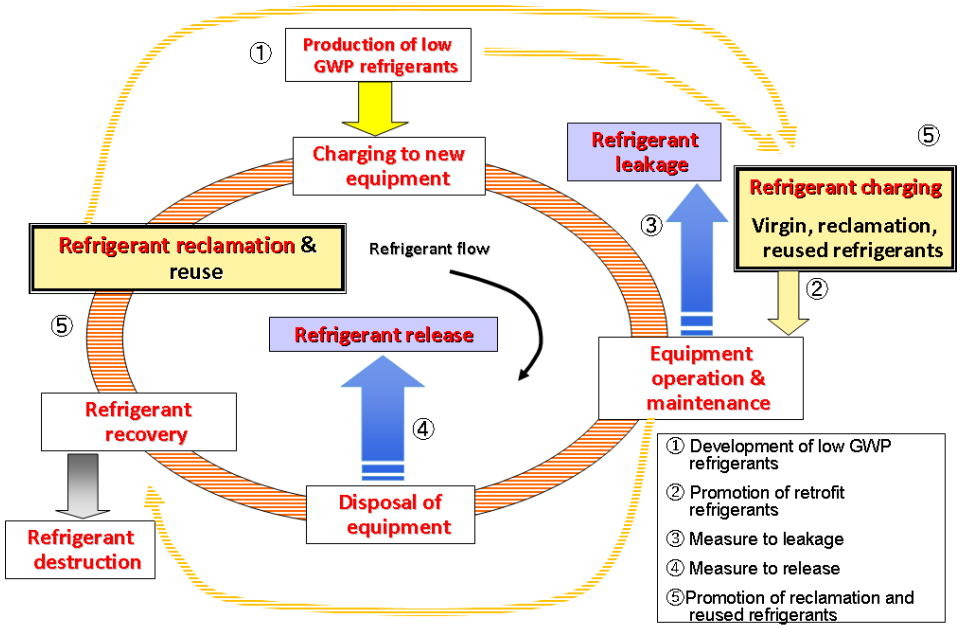

Fig. 1 Refrigerant circle from production to regeneration/destruction

Reducing leakage during equipment operation: It is necessary to investigate the cause. There are many leaks at the time of installation from connectors, etc., and leaks due to long-term operation from compressors, heat exchangers, pipes, etc.

Leakage reduction at the time of equipment disposal: It is effective to improve the recovery rate by reducing emissions. Development of the refrigerant recovery equipment and design of refrigeration and air conditioning equipment that can easily recover refrigerant are desired.

Regeneration of recovered refrigerant: Reclamation (distillation, equipment component adjustment) and recycling (simple regeneration) of the recovered low GWP refrigerant should lead to reduction of the refrigerant production amount, reduction of refrigerant leakage, and improvement of the recovery rate.

Destruction of unwanted refrigerants: Destruction, especially high GWP refrigerants, is effective. It is desirable to destroy the refrigerant and use it for the production of low GWP refrigerants or other products.

One measure to improve the recovery rate is applying economic methods. In Japan, there is currently nothing to be characterized excepting recycle tickets of automobile air conditioners and home appliances and penalties in each law and regulation, but in the future, it is desirable to take measures for the spread of reclaimed refrigerants.

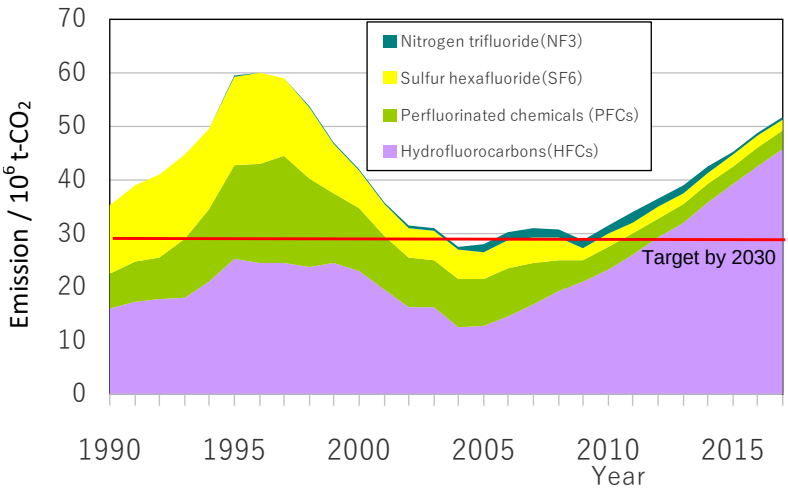

Fig. 2 Emissions of greenhouse gases

Effectiveness of measures

Not much time has passed since the legal regulations on global warming were in Japan, and there are many existing equipment with high GWP refrigerants, so no remarkable effects can be recognized. The emissions tend to increase, and the recovery rate does not improve so much (Figs. 4[6] and 5[7]). The HFCs consumption[8] was decreased from 51.5 million t-CO_2 in 2015 to 49 million t-CO_2 in 2017 (47 in 2016). The amounts of the regenerated refrigerant and the destructive refrigerant keep almost constant (Fig. 6[8]).

Conclusions

Global warming is the biggest crisis facing humanity. In order to overcome this crisis and build a sustainable world, we need to alleviate the problem. However, there seems to be a long way to go in Europe, the United States, and Japan, where laws/regulations and measures are in progress.

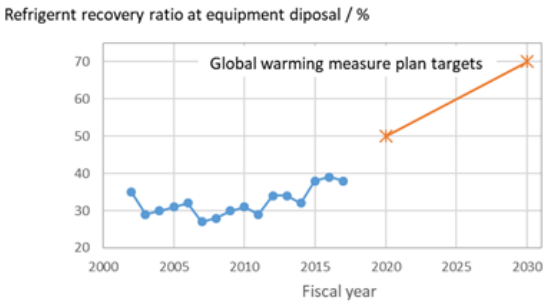

Fig. 3 Recovery ratio at equipment disposal
Commercial refrigeration and A/C only

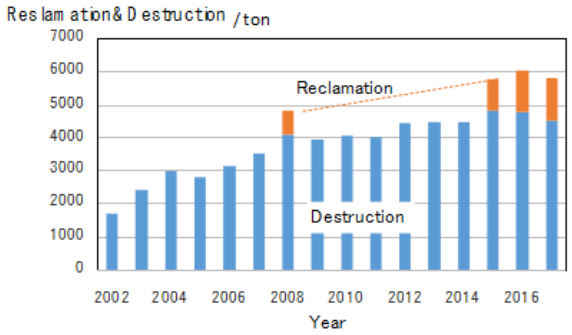

Fig. 4 Reclamation and destruction
Commercial refrigeration and A/C only

To reach the limit value and target value regarding refrigerant, the restrictions on the market input of refrigerant including total amount restriction are carried out in each country. However, the development of new GWP refrigerants for medium-sized freezing and chilling equipment, and VRF/VRV are still in their middle stages.

The environmental problems that the refrigeration and air conditioning field has are very serious. In order to solve this problem as quickly as possible, concerned parties should strive for development and cooperation in the world, and should be carried out to develop and to sustain the refrigeration and air conditioning field.

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