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ECOLOGICAL AND ENERGETICAL ASPECTS OF CHANGING-OVER REFRIGERANT EQUIPMENT OF JOINT-STOCK COMPANY "NORD" TO ALTERNATIVE REFRIGERANTS

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Abstract

In the article various criteria of valuation of introducing alternative refrigerants were considered. Results of experiments and calculations of the power characteristics of a number of working bodies were indicated. The analysis of prospects of their using into the household equipment produced by Joint-Stock Company "NORD" was made. Modified formula of ecological criterion TEWI, taking into account not only contribution in greenhouse effect caused by direct operation of the equipment, but also contribution which takes into account power cost of its devices and power costs of re-equipment and putting into operation the refrigerating equipment on alternative refrigerants,.was proposed

Nomenclature

COP	Coefficient of Performance in refrigerant cycle
GWP	Global Warming Potential
ODP	Ozone Destruction Potential
Q_v	Volumetric cooling capacity
TEWI	Total Equivalent of Warming Impact
t_0	Temperature of boiling in evaporator
t_c	Temperature of condensation

Introduction

It became obvious at present time, that using of energy effective refrigerant in the refrigerating equipment is also one of the means that promotes to reduce the rate of the Earth's climate change. Therefore a number of industrial countries have accepted the new standards on the refrigerating equipment, which provide for decrease of annual level of energy consumption. The power programs of EC JOULE-THERME and ALTENER are pursuing a policy of reduction of CO_2 emissions in the atmosphere.

CFC's direct contribution in an increase of greenhouse effect is considerable enough. Measurements show that it according to the valuation of Intergovernment Panel of Climate Change (IPCC) for the last 10 years, equal to 24% [1]. Majority of the alternative refrigerants has lesser power efficiency than R12, R502, R22 which founded wide application in the practice. Hence, resolving of many technological problems of cooling will require an additional consuming of the electric power, the main part of which is produced by burning the organic fuel.

The traditional valuation of power efficiency which is based on quantity of cooling capacity or COP is not complete in current situation. Therefore the recommendation IIR about application of new criterion TEWI should be recognized as opportune.[2]

The offered technique of TEWI has following defaults: 1) It does not consider volume of the investments that will be demanded for changing-over equipment on new refrigerant; 2) It does not take into account power consume which is necessary to create a new generation of refrigerating machines. 3) Argued method of choosing of a temporary interval for GWP that should be used at valuation of TEWI is absent.(see table 1)

Table 1

TEWI of a number of refrigerants relative to one of R22 (100%), for different time ranges: (Total contribution) / (Indirect contribution)

Refrigerant	Time ranges of GWP (years)	Temperature in evaporator t_0=-5°C	Temperature in evaporator t_0=-15°C	Temperature in evaporator t_0=-35°C
R22	500	100 / 97	100 / 97	100 / 98
	100	100 / 91	100 / 93	100 / 95
	20	100 / 79	100 / 82	100 / 88

The volume of indirect contribution in TEWI is determined by power efficiency of a refrigerating machine. It significantly exceeds the contribution in greenhouse effect from refrigerant issue in atmosphere only for pressurized systems and is quite comparable with the total volume of TEWI for conditioners and trade equipment.

It is necessary to allocate two key moments in valuation of ecological and power prospects of application of alternative refrigerants: **First,** comparison of TEWI is possible only within the framework of one type of the refrigerating equipment, at equal cooling capacity and parameters of the cycle. **Second,** offered by IIR the technique of TEWI valuation does not take into account a lot of determining factors, such as: the cost of refrigerant and refrigerating oil, metal consumption of the equipment, capital costs of machine hall building for firesafety maintenance, investments depended on development of new equipment and refrigerant production, etc. The creation of any element of the refrigerating equipment requires certain power consumption. Hence it contains a certain share of the contribution in thermal pollution of atmosphere. Therefore the TEWI account would be executed by formula:

$$TEWI = GWP_R \cdot M_R + GWP_{ba} \cdot M_{ba} + \alpha \cdot E \cdot L + \sum \alpha \cdot E_i, \quad (1)$$

where GWP_R and M_R – GWP and mass of refrigerant; GWP_{ba} and M_{ba} – GWP and mass of blowing agent; α – mass of issued CO_2 per kW hour of produced electric power; E_i – power consumption of refrigerating system devices and the service of refrigerator; L – working time.

Only the multicriterian record-keeping of power costs permits objectively to evaluate ecological prospects of the offered refrigerants. In opinion of the authors, the alternative to the stated approach is not present! Thus, if COP reflects a degree of thermodynamic perfection of the refrigerating equipment, TEWI bears in itself the information about influence of refrigerant issue and power consumption on an increase of greenhouse effect. For pressurized refrigerating systems the COP and TEWI show the close valuations of prospects of using of different refrigerants. However for half-pressurized and opened refrigerating systems (such as automobile conditioners and trade equipment, transport refrigerating installations) the conclusion will depend on accepted calculation method. Indeed the possibilities of using of a new working body in comparison with the other alternative ones basing on the classical thermodynamic approach and TEWI analysis are certain various in this case. There is no international agreement on restriction of application of ozonsafety refrigerants which have high value of GWP. However requirement of such measures is obvious whereas about 70% of all produced refrigerants were used for charging of refrigerating systems that were characterized by high level of refrigerant issue.

General Results

The ecological analysis of using prospects of alternative refrigerants for a household refrigerator is given here as an example. The calculation of parameters of a cooling cycle for various refrigerants was made for two modes of cooling: temperature of condensation: t = 40°C, one in evaporator: t = -23 °C; - temperature of condensation: t = 55°C, one in evaporator: t = -15 °C.

At definition of the ecological and power characteristics data [3, 4, 5] were used as well as results of in-operation tests of refrigerants R134a, R401 A, R134a/R152a (Tab. 2). Relative values such as Q/Q_{R12}, COP/COP_{R12}, $TEWI/TEWI_{R12}$ (100 % is appropriate values for R12) given in tab. 2 show, that all considered ozonsafety refrigerants have smaller volumetric cooling capacity than R12 and render smaller influence to an increase of greenhouse effect.

The mixtures R152a/R600a - (C1) and R134a/R152a have the closest to R12 values of Q. The last one has certain advantages in comparison with C1. At composition 0.8 R134a/0.2 R152a it is
nonflammable [6] and quasiazeotropical in the whole working interval of temperatures and pressures

Table 2

Cooling capacity (Q_v), COP, and TEWI of different refrigerants relative to R12 (100% - respective values of R12)

Refrigerant	t_0=-23 ^{0}C; t_c=40 ^{0}C			t_0=-15 ^{0}C; t_c=55 ^{0}C		
	Q_v	COP	TEWI	Q_v	COP	TEWI
R134a	93	96	72	88	95	61
R600a	54	105	63	49	108	50
R290/R600a	76	92	76	94	91	62
R152a/R600a	95	99	68	94	98	55
R134a/R152a	**89**	**96**	**70**	**91**	**102**	**56**
R401A	91	96	70	90	95	58

[5,7] contrary to azeotropical mixture C1 which is flammable and changes the concentration by 3-6% in a working interval of temperatures that hinders a procedure of refrigerant charging. Besides, the higher the boiling temperature in evaporator the lesser COP and Q of C1 are relative to this ones of R12 [4], while the mixture R134a/R152a at t_0 ≥-15°C has already significant advantage comparatively not only with R134a but also with R12. This fact shows prospects of using of this

refrigerant in conditioners and trade equipment. Results of experiments confirm the ones of calculations.

Tests of the refrigerating unit BCэ800-2-2-M show that the mixture R134a/R152a has the lowest level of condensation temperature, the one of an electric motor winding, and absorbed electric power in comparison with R134a, R12, R401A (see table 3). Mixture R134a/R152a has mutual solution ability not only in polyether oils but also in serially produced in the Russia oil XФ22 c-16 [7]. It can be referred to its certain advantage also.

Table 3

Results of carried out test of refrigerator BCэ800-2-2-M

t_0=-15 °C

Parameters	Refrigerant			
	R152a/134a	R12	R134a	R401A
Cooling Capacity (W)	384.1	469.4	341	344
Consumed Electric Power (W)	390	453	391	415
Coefficient of Performance	0.99	1.04	0.87	0.83
Temperature of Condensation (°C)	51.2	55.1	53.2	53.8
Temperature of Motor Winding (°C)	71.7	77.2	74.7	78.5
Mass Capacity (kg/h)	8.37	14.20	8.22	7.55

Insignificant quantity of combustible refrigerants R600a, R290/R600a and C1 charged in equipment can not guarantee explosion- and firesafety itself. It will be required to introduce certain changes in a design of refrigerator and to use electrical equipment in explosion-proof performance. This reconstruction will increase cost and energy expenses for producing of apart details, and hence will decrease competitiveness of the produced equipment. The low cost of combustible refrigerants in comparison with the one of R134a has no essential significance for tight refrigerating systems with small cooling capacity and the great service life.

COP of R600a is appreciably higher than one of the other refrigerants. But extremely low value of volumetric cooling capacity will require a significant increase of the compressor volume and hence its metal consumption. So new development of refrigerating unit will be required as a result. Even approximate valuation of additional power costs of development, fabrication and operation of the refrigerating equipment with flammable refrigerant R600a (the record-keeping E in the formula 1) largely eliminates its advantage (5-6 % on TEWI) in comparison with the other alternative refrigerants (see tab. 2). Flammability, the low ability to detect leakage, necessity in updating of refrigerating oil composition (for providing normative viscosity) embarrass the wide introduction of R600a.

Among all considered refrigerants there are only two — R401A and R134a/R152a that are able to be used as retrofits. Refrigerant R401A has thermodynamic properties and operational characteristics which are inferior to ones of the quasiazeotropical mixture R134/R152a.

1. R401A has a large temperature glade of boiling and condensation T=6.4°C, that hinders recharging procedure of unit and can disturb the normative modes of cooling.
2. R401A has comparatively high Ozone Destruction Potential ODP = 0.037.
3. R401A loses to R12, C1 and R134a/ R152a on power efficiency (see table 2).

Replaced in a household refrigerating equipment the refrigerant R12 has extremely high value of GWP=4500 that is equivalent to issue of CO_2 by producing 4000 kW h of the electric power. Even accounting a small weight of refrigerant, charged in refrigerator during the time of its operation, direct contribution in TEWI for R12 remains too large. For the same reason it is impossible to agree with opinion of some authors [8] on availability of introduction fluorine coal (for example, R218) in a household refrigerating engineering. It should be also noted, that CFCs containing plenty of fluorine atoms have low heat of evaporation, and hence volumetric cooling capacity. Turn to energetically inefficient refrigerating systems on fluorocarbons would result in not only preservation of ozone layer but also the increase of global warming of the Earth. Elimination of this ecological factor is practically impossible because of large life time of fluorocarbons in the atmosphere.

R134a close in thermodynamic and power properties to R12, will be a main working body in a household refrigerating engineering in the nearest years. But its essential ecological defect is high value of Global Warming Potential (GWP=1300). A number of researchers offer to mixture R134a with hydrocarbons (GWP=0) [9] or R152a (GWP=150) [5]. Thus some problems can be resolved at once: **1** It will increase solubility of a working body in cheap refrigerating oils produced industrially. **2** It will reduce the influence of refrigerant issue on greenhouse effect.. **3** It will increase power efficiency of the refrigerating equipment [5] (see tab. 2) that, as it was already marked, has more significance, than complete elimination of chemical issue [2,10,11].

Carried out tests of refrigerator "МИНСК-130-05" show that the addition of 20 % R152a to R134a increases power efficiency by 1-2 % and decreases temperature in evaporator by 0.2-0.3°C. The tests were carried out by using serially produced oil ХФ22 с-16. These tests thoroughly confirm the results of TEWI calculation for refrigerators produced by Joint-Stock "NORD". Moreover firesafety refrigerant R134a/R152a can be used both for retrofit and for charging of the refrigerating equipment that uses R134a as the working body.

Conclusion

Results of our studies show that the quasiazeotropic mixture R134a/R152a may be used as a working substance in domestic refrigerators and trade equipment.

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Calculated value of TEWI for refrigarators from the NORD series
at the turning to varios refrigerants

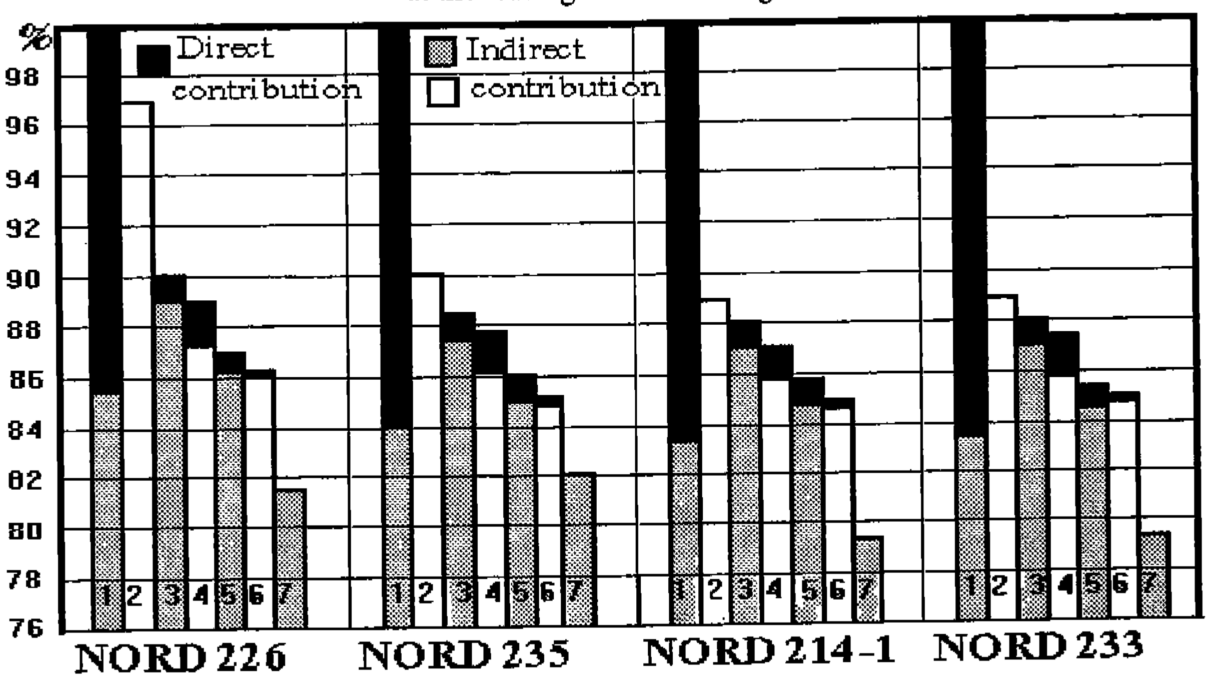

Fig. 1- R12; 2- R290/600a; 3- MP 39; 4- R134a; 5- R134a/152a; 6- R600a/152a; 7- R600a

Appendix A

Additional papers from the 1994 International Refrigeration Conference at Purdue