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Analysis of Alternative Refrigerants to HCFC-22

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ABSTRACT. R22 is a kind of transitional hydrochlorofluorocarbon refrigerants, which is used widespread nowadays. It will be phased out because it contains chlorine. Depicts the application of the refrigerants to the re-lated industries and the progress of phase-out of HCFC-22 of China. Thermodynamic calculation of HCFC-22、R407c、R410a、HFC134a and HC-290 are carried out, then find the best substitute of HCFC-22.

KEYWORDS: substituting refrigerants; HCFC-22; R407c; R410a; HFC134a; HC290

1. Forewords

Currently, energy and environment are the two greatest problems human bings up against. At the same time, ozonosphere and global-warming problems attract the world's attention. Both of the problems are correlative with the refrigerants which are widely used in our daily life. As the most extensively used refrigerant, HCFC-22, which is a kind of ozone depletion matter, is circumscribed by 《Montreal Protocol on Substances that Deplete the Ozone Layer》. Its substitution is one of the cores of the substitution of refrigerant. Formally see from the existence, at the present time, substitutions of HCFCs are composed of natural or artifactitious substance. Mainly have two kinds of alternative plans currently: one is choosing HFCs, such as R407C、R410A、HFC134a, as the substitutions, taking the lead by America and Japen. The other is using natural material, such as HC290、HC1270 to instead HCFCs, headed by Germany and countries in north-Europe. Based on thermodynamic calculation, several kinds of refrigeration cycle in different conditions are carried out, then find suitable substitution in the end.

2. Thermodynamic calculation of R22

2.1 Theoretic cycle

Thermodynamic calculation of R22 mainly relies on vapor compression cycle in general. Parameters of saturated cycle are shown as follows: evaporating and condensing temperatures are 5℃ and 35℃, and there are no supercooling degree and superheating degree.The results are shown as table 1.

Table1 results of thermodynamic calculation

refrigerant	refrigeration capacity [q_1] （KJ/Kg）	work consumption [Al](KJ/Kg)	condensation heat [q_2] (KJ/Kg)	coefficient of Performance[ε]	refrigeration capacity [q_v] (KJ/m^3)	compression ratio[p_h / p_l]
R22	164.23	21.05	185.28	7.80	4040.10	2.33

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2.2 Calculation of other cycles in different conditions

Other cycles mainly includes supercooling cycle, superheating cycle, variable condensing temperature cycle, variable evaporating temperature cycle, maximal pressure difference cycle, maximal power cycle. With superheating cycle for example. LgP-h diagram and parameters of superheating cycle show as fig 1.The calculation is carried out while superheating degree changes from 1℃ to 10℃.Compared with saturated cycle, increasing of refrigeration capacity per kilogram is

$$\triangle q = h_1^{'} - h_1$$

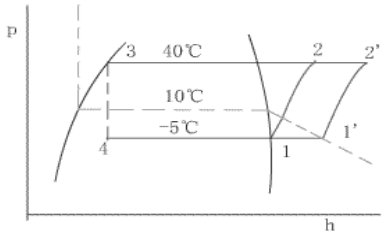


Fig 1 LgP-h diagram of superheating cycle

Calculations about cycles above are carried out. Summarizing the results, while the variety measures change 1℃, the average variety quantity of thermodynamic parameters are shown as table 2.

Table 2 average variety quantity of thermodynamic parameters

	supercooling cycle	superheating cycle	variable evaporating temperature cycle	variable condensing temperature cycl
$\Delta q_1(KJ/Kg)$	0.7980	0.5340	0.3510	-1.2750
$\Delta Al(KJ/Kg)$	0	0.2630	-0.8290	0.6380
$\Delta q_2(KJ/Kg)$	0.7980	0.7970	-0.4780	-0.6370
$\Delta\varepsilon$	0.03790	-0.0641	0.3369	-0.3040
$\Delta q_v(KJ/m^3)$	19.63	-1.2307	135.60	-31.3653

3. Thermodynamic calculation of substitutions

3.1 Results of calculations

There are many substitutions for R22. But nowadays main alternative plan mainly includes R134a, R290, R407c, R410a. With these 4 kinds of refrigerants as the main research objects, calculations of the substitutions are carried out . Parameters of cycles above are the same as those of R22. Deal with the results of substitutions in different cycles, shown as fig 2(a)-5(b).

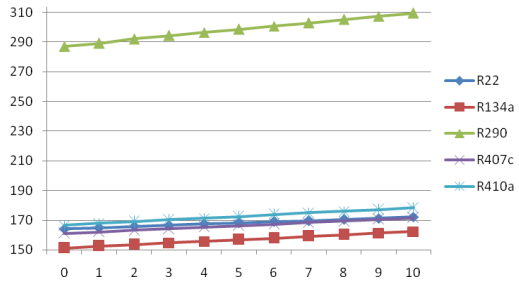


Fig 2(a) influence of supercooling degree on q_1

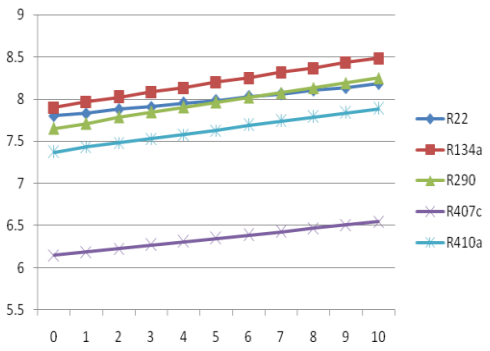


Fig 2(b) influence of supercooling degree on ε

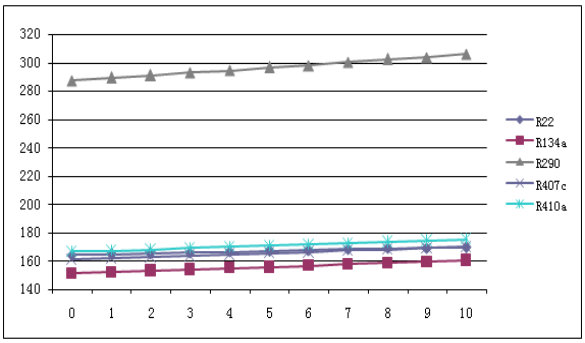


Fig 3(a) influence of superheating degree on q_1

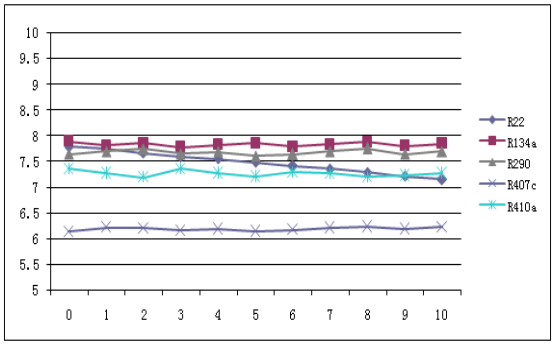


Fig 3(b) influence of superheating degree on ε

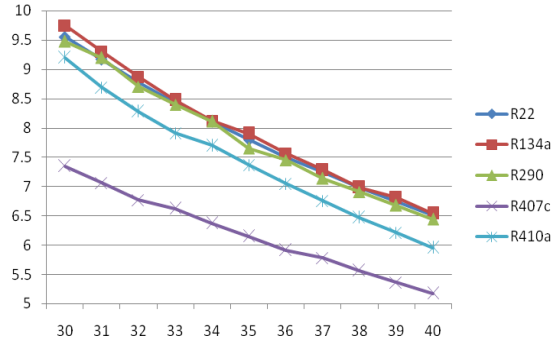


Fig 4(a) influence of condensing temperature on ε

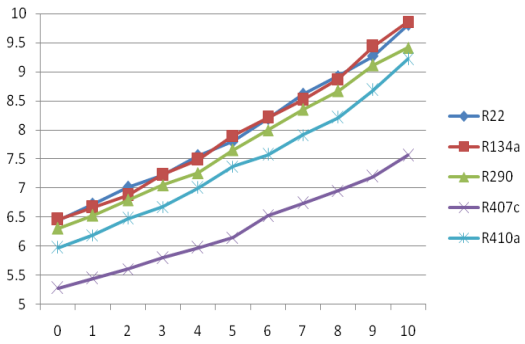
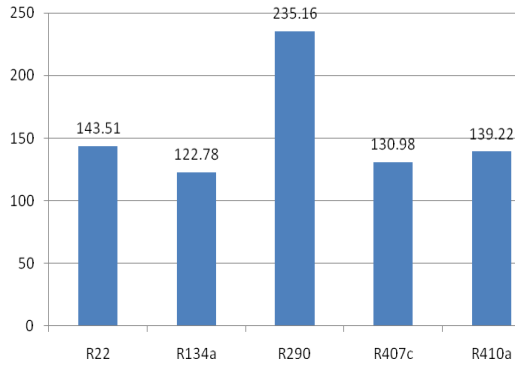


Fig 4(b) influence of evaporating temperature on ε



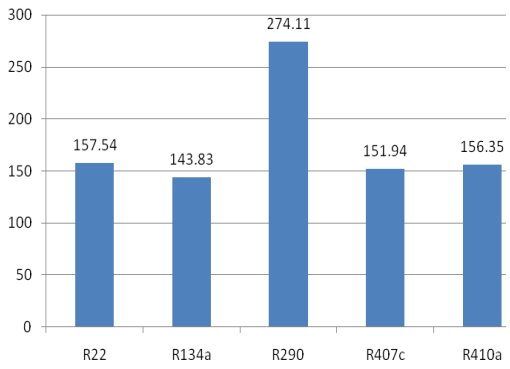


Fig 5(a) contrast diagram about q_1 of maximal pressure difference cycle Fig 5(b) contrast diagram about q_1 of maximal power cycle

3.2 Analysis of possible assessment

In supercooling cycle, while the supercooling degree changes 1℃, we can find the average variety quantity of thermodynamic parameters from the results. Seeing from the variables of refrigeration capacity, condensation heat, work consumption and coefficient of performance, R407c would suit R22 best; while seeing from the variables of refrigeration capacity per stere , only R134a would be the best substitution. Anyhow, from the influence of superheating degree on all if the thermodynamic parameters, we can educe that R290、R407c、R410a would be much more perfect to instead R22.

In superheating cycle, while the superheating degree changes 1℃, we can find the average variety quantity of thermodynamic parameters from the figs. Seeing from the variables of refrigeration capacity, condensation heat and work consumption, R134a、R407c、R410a would suit R22 better; while seeing from the variables of compression ratio and coefficient of performance, obviously, R290 would be the best substitution; or on the other way, seeing from the variables of refrigeration capacity per stere, only R410a is the most approximate to R22. Anyhow, from the influence of superheating degree on all if the thermodynamic parameters, we can educe that R290、R407c、R410a would suit R22 better.

In the same way, we can obtain the conclusions that, in variable condensing temperature cycle and variable evaporating temperature cycle, R410a may be the best choice; in maximal pressure difference cycle, R290 would suit R22 better; in maximal power cycle R407c would be the best substitution.

4. Conclusion

Through comparing and analyzing, choosing the optimal substitution for each cycle, shown as table 3.

Table 3 optimal substitution of cycles

cycle	theoretic cycle	supercooling cycle	superheating cycle	variable condensing temperature cycle	variable evaporating temperature cycle	maximal pressure difference cycle	maximal power cycle
optimal substitution	R410a	R290、R407c、R410a	R290、R407c、R410a	R410a	R410a	R290	R407c

As described above, comparatively, R410a maybe the optimal substitution for R22 although it does exist certain weakness. If can be conquered, several substitutions may could instead R22.

Though the COP of R134a and R22 are very similar, the refrigeration capacity R134a is 30％-50％ lower then R22. In order to produce equal refrigeration capacity, equipments of R134a system would be magnified about 65％, including all pipes and heat exchanger. Compressor also needs much lager exhaust and vent-pipe.

Boiling point, critical temperature and pressure of R290 and R22 are very similar, so is the saturated-steam curve. Some thermodynamic characters even exceed R22. For example, latent heat of vaporization is 84.4% higher then R22 while the evaporating temperature is seven centigrade; Under the same evaporating condition, temperature at the vent and viscosity are lower then R22; and dissolving with mineral oil much easier. Calculating results indicate that while making no changes and the mount of refrigerant is felicitous, refrigeration capacity of R290 is nearly the same as R22, and the coefficient of Performance even much higher. All of these indicate that R290 is a good substitute of R22. The combustibility of propane has been the point that the researcher considers. Exhaust temperature and electrical engineering temperature of air-conditioner using propane as the refrigerant is under 100℃; the work temperature in the system isn't likely to attain the kindling point of propane. Carrying on analysis about the combustibility ,compatibility and coefficient of performance, discover that combustion or explosion of propane needing two necessary conditions: (1) the admixture consistence with air must be 2.5%-8.9%; (2) the temperature must be higher then 810℃. While the machine’s working, the probability of above conditions achieve at the same time is hardly to appear. If appropriate safeguards in designation and running takes, such as enhancing aeration while system designing; installing annunciator in pivotal position; reducing disembosoming of propane; all electric-power appliances using flameproof type; adding non-burning substance, it’s also safe to use propane as the substitute for R22.

R407c is an admixture, and can’t dissolving with the AB type mineral oil well which is widely used in R22 system. POE polyester oil will be replaced for better lubricative characteristic, electric characteristic and security. At the same time hermetical ring should be substituted by un-corrosive material. It demands higher request to the compressor and the humidity content in the system, the numerical value should less than 0.15ml. Sometimes strainer and desiccator are necessary if workmanship can’t guarantee the vacuum in the system. As the refrigeration capacity and coefficient of Performance of air-conditioning are almost equal to to R22, R407c would be widely used in newly-produced airconditioner .

R410a , as a long-term green alternative refrigerant with zero ODP(ozone-delpeting-potential) to replace R22, commixed by R32 and R125 , has excellent heat transfer and transportation performance. Without temperature-sliping, it works as well as non-commixing refrigeration. The refrigeration capacity and coefficient of performance are similar to R22 in air-conditioning equipment, and in refrigeration equipment even 60％ higher then R22. So, inorder to produce equal refrigeration capacity, the size of compressor would 30％ smaller then that of R22. This would make refrigeration device to smaller scaled and higher

efficiency. By analysis on systemic performance, it indicates that effect of energy-saving in air-condition system of R410a is much more aboverous, especially when condensing temperature declines. We can conclude that R410a could help decrease the A/C heat exchanger size or improve the A/C operation efficiency.

5. References

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