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R. Yajima  
*Daikin Industries*

K. Kita  
*Daikin Industries*

S. Taira  
*Daikin Industries*

N. Domyo  
*Daikin Industries*

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# R32 AS A SOLUTION FOR ENERGY CONSERVATION AND LOW EMISSION

Ryuzaburo Yajima  
Koiti Kita  
Shigeharu Taira  
Nobuo Domyo

Daikin Industries, Ltd.  
Kanaoka 1304, Sakai, Osaka, Japan  
E-Mail [ryuuzaburou.yajima@daikin.co.jp](mailto:ryuuzaburou.yajima@daikin.co.jp)  
[kouichi.kita@daikin.co.jp](mailto:kouichi.kita@daikin.co.jp)  
[shigeharu.taira@daikin.co.jp](mailto:shigeharu.taira@daikin.co.jp)  
[nobuo.domyou@daikin.co.jp](mailto:nobuo.domyou@daikin.co.jp)  
TEL +81-722-50-0900 FAX +81-722-59-9283

## ABSTRACT

We selected the low GWP refrigerant R32, as a promising refrigerant candidate in the air conditioning field, which has a potential of economically satisfying the requirements for safety and environmental protection. We investigated its performance and TEWI of a 16kW prototype with a variable speed compressor driven by a motor controlled by DC inverter. The test analysis shows that the COP of R32 is higher than that of R410A not only under the rated capacity but even under the capacity reduced by compressor speed control. The analysis also shows that its heating COP at a low ambient temperature and its cooling COP under the overload condition are superior and the refrigerant charge can be reduced by adoption of smaller diameter heat transfer tubes for heat exchangers. As a result, if a R32 system is operated during the specified seasonal period in Tokyo area, its TEWI drops by 18% in comparison with that of R410A and direct impact portion in case of R32 decreases to 7% of the total impact. Since the international standard for safe use of flammable refrigerants is currently under drafting, its superiority in performance and low impact on warming may enhance the future refrigerant change.

## INTRODUCTION

For protection of ozone layer, in Japan, since early 1997 the air conditioning equipment with HFC refrigerant has been launched into the market and the whole air conditioning industry is on the move to complete the refrigerant change of its major products by the end of 2003. In November 1997, for prevention of global warming the Kyoto Conference agreed to establish a target for emission control of greenhouse gas in the advanced countries and the restriction also applies to the emission of HFC refrigerants.

Table1 Properties of Refrigerants

	Merit				Subject (compared with R22)			
	Flamm- ability <sup>*1)</sup>	Toxi- city <sup>*1)</sup>	ODP <sup>*2)</sup> R11=1	GWP <sup>*3)</sup> CO2=1	Theo. <sup>*4)</sup> COP [%]	Capacity <sup>*4)</sup> [%]	High <sup>*4)</sup> Press. Mpa]	Dis.Temp <sup>*4)</sup> [degC]
R32	Low	Low	0	880	95	159	3.14	83
Propane	High	Low	0	3	97	82	1.71	54
R410A	Non	Low	0	2340	91	140	3.06	69
R22	Non	Low	0.055	1900	100	100	1.94	69

\*1) by ASHRAE Standard

\*2) Ozone Depletion Potential

\*3) Global Warming Potential, IPCC 98, 100 years

\*4) Te/Tc/SC/SH=5/50/3/0 [degC]

\*5) Thermo Properties by NIST REFPROP V6

Up to now, R407C and R410A are selected within the framework of selecting the candidates among the non-flammable refrigerants of which safety is already verified. On the other hand, some reports are published from the past regarding the superiority of slightly flammable R32 in energy efficiency<sup>1), 2)</sup> and its risk assessment<sup>3)</sup>. However, R32 is currently excluded from the candidates, since the consensus about the results of safety assessment is not yet achieved. However, recently R32 is reviewed from the viewpoint of its low GWP and high energy efficiency and some reports are published regarding assessment results of TEWI of the air conditioning equipment by making comparison with other refrigerants<sup>4), 5), 6)</sup> and the performance when mixed with hydrocarbon<sup>7)</sup>.

In general, the higher the non-flammability of a refrigerant is, the larger its GWP and the lower its energy efficiency. Therefore, from the viewpoint of global warming prevention it is desirable to clarify the range of safe application of slightly flammable refrigerants instead of adhering to non-flammability and open a gateway to its adoption within this range. The range of charge amount for safe use of flammable refrigerants is currently being discussed at the meetings related to the international standard such as IEC and ISO and the drafting of the standard is to be completed in the near future. When the standard is established, the move toward the practical use of slightly flammable refrigerant will be made.

From the above mentioned reasons, we selected the low GWP refrigerant R32 as an alternative refrigerant candidate which has a potential of economically satisfying the requirements of safety and environmental protection in the air conditioning equipment industry. To clarify it, we tested and analyzed its performance and TEWI of a 16kW prototype with a compressor driven by DC inverter controlled motor.

### REFRIGERANT PROPERTIES

Table 1 shows the characteristics of R32, R410A and propane. As for the features of R32, its GWP is low, high system COP can be expected and it is possible to reduce the amount of refrigerant charge because of its low-pressure drop. The tasks to be taken on are slight flammability and high discharge temperature.

#### GWP and Flammability

Fig.1 shows the relation between GWP and the combustion heat per unit weight of each refrigerant. There are many indexes to indicate combustibility such as the lower flammable limit, the difference between upper and lower flammable limit, the combustion speed and the minimum ignition energy. In this figure the combustion heat per unit weight which is adopted by ASHRAE is used.

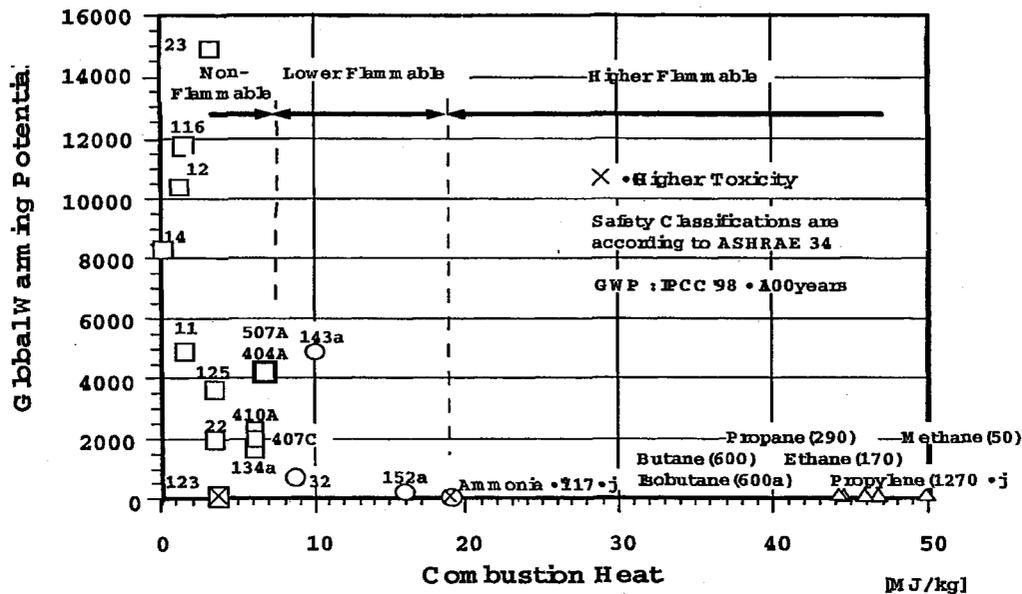


Fig.1 GWP and Flammability of Refrigerants

Though this index does not always indicate the combustibility of ammonia in nitrogen compound, it well indicates the combustibility of fluorine-based compound and hydrocarbon. Classification of non-flammable, slightly flammable and highly flammable is in accordance with that of ASHRAE. What can be roughly said from this figure are,

1) The lower the GWP of refrigerant, the higher the combustibility.

Since hydrocarbon such as propane does not contain fluorine, its GWP is low. However, since the performance and the cost must be sacrificed for its safe use, its application to the air conditioning equipment is not practical. On the other hand, if a refrigerant verified as non-flammable is used, though there is no risk of fire accident, global warming impact of the refrigerant emitted into the atmosphere without being recovered cannot be reduced.

2) R32 is near the boundary between non-flammable and slightly flammable

Among the slightly flammable refrigerants, R32 exists near the range of non-flammable. Therefore, there is a great potential of using R32 safely by restriction or reduction of refrigerant amount to be charged into the air conditioning equipment. In addition, since the GWP can be reduced to approximately 1/3 in comparison with R410A, the global warming impact of refrigerant can be reduced to a great extent.

From the above 1) and 2), we selected R32 as the refrigerant, which can decrease the global warming impact without sacrificing the performance and the cost.

## RESULTS

### Test Unit

Table 2 shows the specification of prototype. Using the latest R22 model with DC inverter as a mother unit, the compressor, heat exchanger and motorized expansion valve are modified for R32 application. The heat exchanger adopts grooved tubes of 6.35mm in diameter for the outdoor unit and 6mm for the indoor unit. The test of this prototype was conducted with both R32 and R410A for comparison of their performance.

**Table 2 Spec. of Prototype**

		R32 and R410A Systems
Base Unit	Model	Super Inverter (R22)
	Type	Split
Compressor	Capacity	Cooling 6 • 14kW, Heating 6 • 18kw
	Type	High Pressure Side Scroll (Optimum Cylinder Volume for R32)
Indoor Heat Exchanger	Motor	Direct Current Driven
	Lubricant	Ether Oil (VG68)
Outdoor Heat Exchanger	Pipe Dia.	6mm
	Pipe Type	Grooved
	Path Pattern	Counter (Cooling)
Expansion Device	Pipe Dia.	6.35mm
	Pipe Type	Grooved
	Path Pattern	Counter (Cooling)
Connecting Pipe	Type	Electric Driven Exp. Valve (Optimum Needle Dia.)
Connecting Pipe	Dia.	Gas 3/4inch, Liquid 2.5/8inch
	Length.	5m

### Results and Discussions

By adoption of smaller diameter tubes for heat exchangers, with R32 the refrigerant charge amount can be reduced to 57% of that of R22 mother unit and with R410A to 62%. As for the heat exchanger performance, both the condensing and cooling heat-exchanging capacity increase and the COP

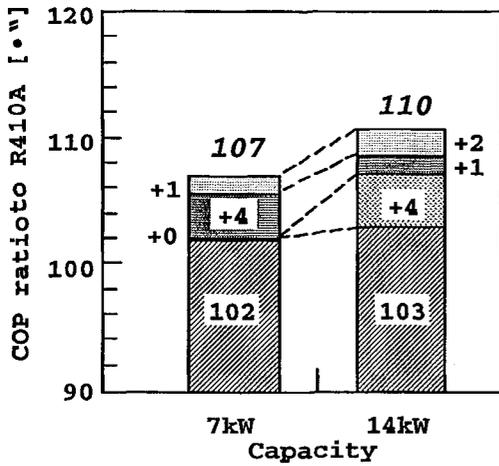


Fig. 2 Standard (Cooling)

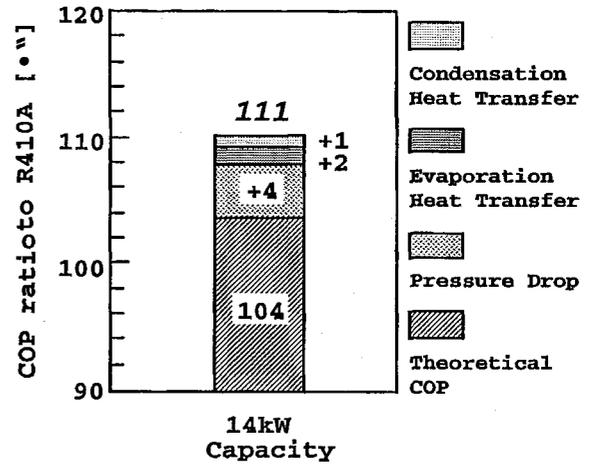


Fig. 4 Overload (Cooling)

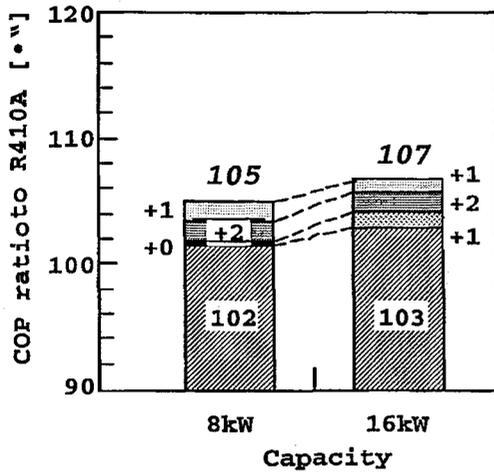


Fig. 3 Standard (Heating)

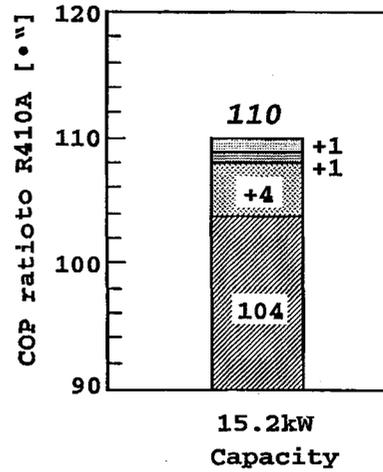


Fig. 5 Low outlet Temp. (Heating, -20°C)

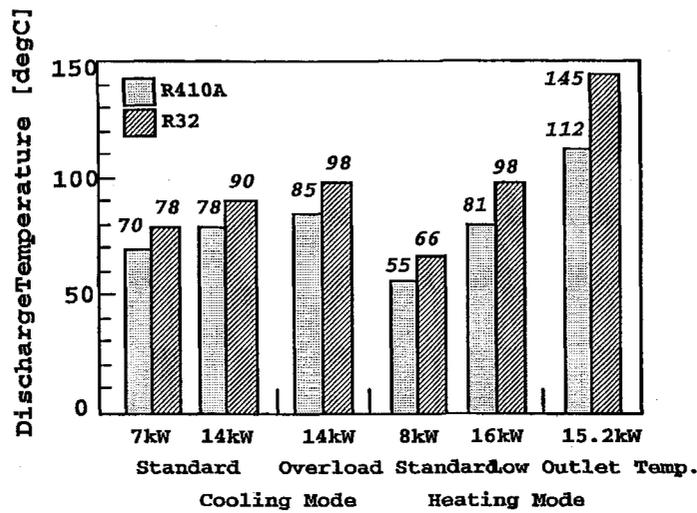


Fig. 6 Discharged Gas Temperature

improves by adoption of smaller diameter tubes. On the other hand, the evaporator capacity drops with R410A due to increase of refrigerant pressure loss caused by adoption of smaller diameter tubes. Since we conducted the test with the small diameter heat exchanger having the same number of paths, the pressure drop of R410A was unreasonably large. We, however, considered that the heat exchanger temperature drop due to pressure drop of each refrigerant must be equivalent. Therefore, we compensated the COP of R410A so that it may be fairly judged. Its values were compensated from +4 to +6%. The following data show the measured values with compensation added.

Fig. 2 and 3 show the comparison of COP when the capacity is changed by inverter control. The factors for improvement of performance with R32 obtained by the test data analysis are shown in these figures. The bars on the right show the performance under the rated capacity and those on the left show the performance under the capacity reduced to 1/2 by rotation speed control. Under the rated capacity, due to improvement in theoretical COP and heat transfer of evaporation and condensation and reduction in pressure loss, the COP improves by 10% under cooling operation and 7% under heating operation in comparison with those of R410A.

Usually the operation under the capacity reduced to 1/2 occurs more frequently in the field than that under the rated capacity. Therefore, the COP value under this condition has a significant meaning when we discuss about the efficiency during the specified seasonal period of the air conditioning equipment with inverter control. Under the capacity reduced to 1/2, the COP improves by 7% under cooling and 5% under heating.

Since the test unit is a split type, the suction side pressure loss under cooling is larger than that under heating. Therefore, the R32 system that has small pressure loss is more favorable under cooling. If the capacity is reduced to 1/2, as the pressure loss is by nature small, the effect of reduction in pressure loss cannot be taken into account. However, due to improvement in heat transfer effect and theoretical COP, the COP mentioned above is obtained. According to some reports<sup>8)</sup>, the evaporation heat transfer coefficient of R32 is more favorable than that of R410A particularly in the low mass flux range. When the capacity is reduced to 1/2, as the mass flux is in this low range, the superiority in heat transfer coefficient of R32 on refrigerant side brings benefits to COP.

In addition, it is necessary to evaluate the COP under the cooling overload condition, because depending on the installation the ambient temperature may rise higher than the outdoor temperature.

Fig.4 shows the COP ratio of R32 to R410A under the cooling overload condition in Japan (ambient temperature 43°C). The COP ratio under the rated capacity is 110% (Fig.2) and that under the overload condition is 111% (Fig.4). Therefore, even under the overload condition, the COP of R32 exceeds that of R410A. If the ambient temperature further rises, the theoretical COP ratio also increases, which means that if the equipment is used beyond the overload condition still R32 is superior to R410A.

Though the temperature scarcely goes below 0°C in Japan except for the northern areas, we investigated the low ambient temperature of -10°C for global application. Fig.5 shows the comparison at -10°C ambient temperature. The effect of reduction in refrigerant pressure loss (+1.3 to +4.1% [Fig.3, Fig.5]) is large in comparison with that under the rated standard heating condition and the COP ratio is 110% (Fig.5). Therefore, even under this condition R32 is superior to R410A.

Fig.6 shows the discharge temperature under each condition. Under the cooling and heating standard conditions and the cooling overload conditions, the discharge temperature is 8 to 17deg higher than that of R410A. And under the heating low ambient condition whose evaporating temperature is low, it is 33°C higher. Refrigerants such as ammonia and R32 of which latent heat is large and performance is highly efficient have a tendency of discharge temperature getting high. Therefore, the know-how for applying the material technology and the control technology becomes important.

### **Global Warming Impacts**

In order to evaluate TEWI of air conditioners with inverter control, we estimated the annual power consumption using the data shown in Fig. 2 - Fig. 5. It is assumed that the air conditioner is installed in a store in Tokyo. Fig.7 shows the specified seasonal performance factor calculated CSPF, HSPF and APF. For propane application, in order to prevent the refrigerant leak into the room, indirect expansion systems must be used instead of direct expansion system. If an indirect system is used, due to

the heat exchange between the heat medium, COP drops 20% compared with a direct system.

Fig.8 shows comparison of TEWI of packaged air conditioners with those refrigerants. Recovery rate is assumed to be 50% in all refrigerants. We can reduce TEWI by 18% in comparison with R410A. The direct warming impact decreases down to 7% of TEWI in case of R32. The drop in efficiency by adoption of indirect expansion system diminishes the merit of propane. Consequently, TEWI of propane is almost equivalent to the value of R410A. From the viewpoint of seasonal performance and TEWI, R32 can be considered as the most promising candidate.

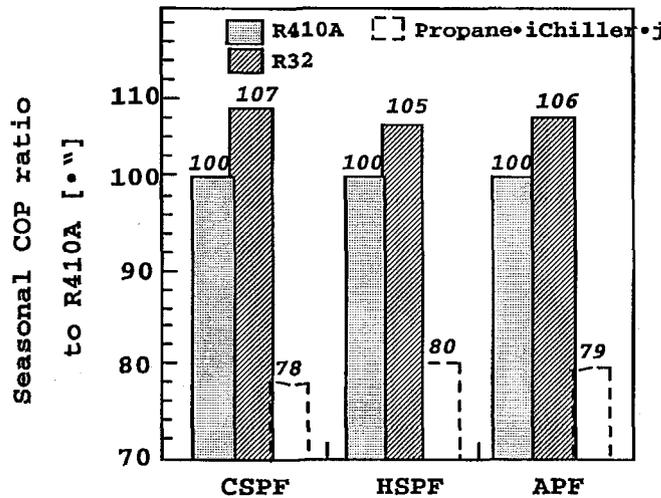


Fig. 7 Seasonal Performance

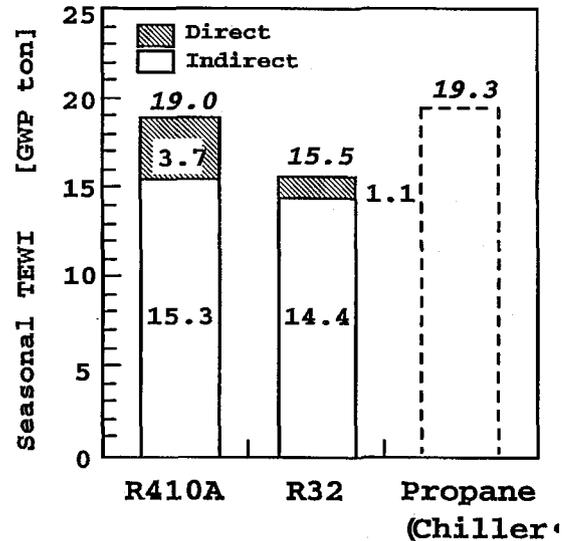


Fig. 8 Seasonal TEWI Evaluation

### FUTURE PROSPECTS

An example of refrigerant change in the history of air conditioning industry is the change from R12 to R22. This change took place not because of the restriction to the refrigerant but the change took place, advanced and spread throughout the market because of the driving force generated by the inherent performance difference of the refrigerant itself. Since restrictions are something that greatly depends on the politics and public opinion on the global environmental issues of the times, they cannot become a definite standard. However, since the inherent difference of refrigerants is something that does not change over the times, it can become a standard when we consider the future refrigerants.

Fig.9 shows the transition of refrigerant for the air conditioning equipment. The ratio of COP improvement obtained when the refrigerant was changed from R12 to R22 is +7% if we estimate it from the theoretical COP and the pressure loss. If we consider the COP improvement

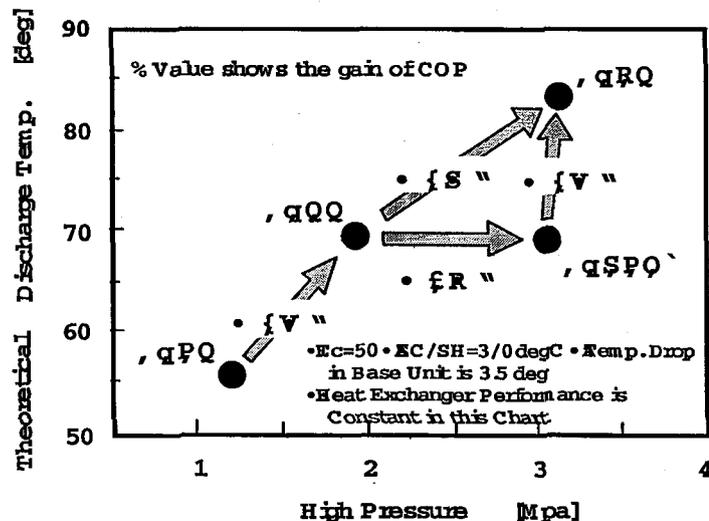


Fig. 9 Transitions of Refrigerants

ratio as the driving force for promoting the refrigerant change, from the past history we can make a hypothesis that if the COP improvement ratio is 7% or more, the change of refrigerant will be promoted.

If we estimate the COP improvement ratio between R32 and R410A, it is +7% even if we don't take into account the difference in heat exchanger performance of these refrigerants. Therefore, judging from the above hypothesis, it is not too much to say that there is a possibility of future refrigerant change. In addition, the energy saving effect obtained from the refrigerant change will definitely contribute to improvement of COP, miniaturization of equipment and improvement in profitability.

The standard for use of flammable refrigerants are currently being discussed at the IEC/ISO joint working group meeting and most probably the upper limit of refrigerant charge will be stipulated for security of safety. Committee members including those from Japan are working hard for preparation of the standard and it is said that discussion among the members on the draft of the standard has been finalized. As mentioned before, R32 is a slightly flammable refrigerant among the flammable refrigerants. Therefore, the upper limit of refrigerant charge amount is likely to be specified within the practically applicable range.

There is no impeccable refrigerant, which satisfies all the requirements for inflammability, low GWP and high-energy efficient performance. Technology and society need to supplement its shortcomings. It is a desirable thing that the above international standard is currently being discussed to probe the range for safe use of slightly flammable refrigerant and establish the rule for practical application. It is true that the consensus of safety to R32 is growing and that is something we hope for.

Since R32 has a potential to economically satisfy the requirements of safety and environmental protection simultaneously, R32 is likely to become the major refrigerant for the future air conditioning equipment.

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