Use of R417A (ISCEON® 59) in Refrigeration and Air Conditioning Applications

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1. ABSTRACT

With the phase-out of HCFCs being accelerated in some regions of the World, most notably Europe, many studies have been performed on two alternatives to replace R22 i.e. R407C and R410A. However there is a third alternative emerging as a candidate to replace R22, namely R417A comprising R125, R134a and R600.

R417A (ISCEON® 59) has been primarily developed to replace R22 in air conditioning applications but has also been successfully utilised in refrigeration applications such as commercial refrigeration display cabinets. It is the only Zero Ozone Depletion Potential replacement with an A1/A1 ASHRAE classification that can be used with mineral, alkyl benzene or fully synthetic lubricants.

This paper details some practical examples of the use of R417A (ISCEON® 59) in air conditioning, refrigeration and heat pump applications.

2. INTRODUCTION

Following the ban, under the Montreal Protocol, on production of chlorofluorocarbons (CFCs) in "developed countries" in 1995, the spotlight has moved onto the next category of ozone depleting chemicals to which the phase-out legislation applies i.e. the hydrochlorofluorocarbons (HCFCs) which to the refrigeration industry mainly concerns dichlorofluoromethane (R22).

At present the Montreal Protocol specifies that production of HCFCs in developed countries will be banned from the year 2020 but there is intense pressure to bring this date forward and some authorities, most notably the European Union (EU), have passed their own legislation to phase-out production as early as the year 2010 with end use controls limiting usage well before this date.

The search for alternative refrigerants began by looking for single compounds or azeotropes with suitable properties to replace the CFCs and HCFCs but it was realised very quickly that, with the exception of 1,1,1,2-tetrafluoroethane (R134a) to replace dichlorodifluoromethane (R12), this was not achievable.

The effort was then focussed on mixing compounds which possessed some of the desired properties to produce a blend without the deficiencies of the individual components. The first blends produced were aimed at replacing the CFC R12 and the CFC containing azeotropic blend R502. These blends initially utilised HCFCs, which still allowed the use of traditional mineral and alkyl benzene lubricants, later zero ozone depleting potential (O.D.P.) blends were formulated to replace R12, R502 and R22 using hydrofluorocarbons (HFCs) but these usually required synthetic lubricants such as the polyol ester oils. The use of hydrocarbons and ammonia is also being considered.

There is no doubt that hydrocarbons and ammonia will play a role in replacing R22 but it is likely that the bulk of equipment/applications currently utilising the non flammable non toxic R22 will move to a zero ozone depleting (ODP) non-flammable non toxic alternative. Currently there are three blends with ASHRAE designations which are being proposed as potential alternatives, namely R407C (a blend of difluoromethane (R32), pentafluoroethane (R125) and R134a), R410A (a blend of R32 and R125) and R417A (a blend of R125, R134a and R600). All these blends have met the necessary criteria to be classified A1/A1 which is the lowest risk in terms of toxicity and flammability for both the as formulated composition and in the worst case leak scenario as defined in the ASHRAE standard.

R407C has physical properties similar to R22 and therefore can be used in equipment of a similar design, but R407C is used in conjunction with the new fully synthetic lubricants such as polyol esters (POE). R407C also shows a pronounced temperature glide in practice which can lead to operational difficulties e.g. in water chillers where the nominal evaporator temperature of R22 would be ~1ºC, with R407C, if the dew point condition is taken then the evaporating temperature could range from a minimum of -4ºC up to 1ºC across the evaporator with the risk of ice formation in the evaporator.

R410A also requires the use of fully synthetic lubricants and has physical properties which are very different to that of R22, e.g. saturated vapour pressure for R410A at 40ºC is almost 60% higher than R22, and therefore the equipment has to be designed specifically for use with the blend. A number of advantages have been identified when using R410A such as the unexpectedly high heat transfer coefficient and the fact that smaller compressors and pipes are required. However the critical temperature of the blend is relatively low (72ºC) which does raise questions as to the performance under extreme ambient conditions or heat pump applications where condensing temperatures of 60ºC or higher may be achieved.

R417A (ISCEON® 59), like R407C, has similar physical properties to R22 however it has been formulated to enable it to be used with traditional mineral oils or alkyl benzene lubricants. This property makes R417A (ISCEON® 59) ideal for use in existing equipment but also suitable for use in new equipment without the need to change to the more expensive and hygroscopic polyol ester lubricants.

Clearly the R407C and R410A mentioned above are potential replacements but they both require equipment changes to be made and raise the potential of new practical problems as outlined previously. This paper concentrates on the use of R417A (ISCEON® 59) in existing equipment designed for use with R22 use traditional mineral oil or alkyl benzene lubricants. This paper details independent calorimeter measurements and performance measurements in commercially available equipment for both refrigeration and air conditioning applications.

3. PERFORMANCE TESTING

3.1 Calorimeter Tests

The performance testing was performed on a blend of composition 46.6% w/w R125, 50.0% w/w R134a and 3.4% w/w R600 (R417A). The testing was performed at ILK (Institut für Luft und Kältetechnik, Dresden, Germany) on a rig comprising a semihermetic Bitzer compressor (type 4T-12.2) with B5.2 mineral oil, shell and tube condenser and a shell and tube brine fed evaporator fitted with heaters to balance against the refrigerant cooling capacity. Both R22 and R417A were tested at the following conditions;

Condensing Temperature = 40ºC Evaporating Temperatures -20ºC, -10ºC and 0ºC

The refrigeration capacity and compressor power results are shown below in figure 1 and it can clearly be seen that the refrigeration capacity of R417A (ISCEON® 59) is comparable to that of R22 with a significant decrease in the compressor power requirement. This leads to an increase of coefficient of performance (COP) between 12.5% at -20ºC to 4.5% at 0ºC. This large increase in COP has the beneficial effect of dramatically reducing the power consumption over the lifetime of the equipment and therefore the environmental impact, with regards to global warming, is also reduced.

3.2 Commercial Refrigeration

A commercially available supermarket display cabinet was tested at the Netherlands TNO Institute of Environmental Sciences, Energy Research and Process Innovation. The study was performed in accordance with European Standard EN 441 'Refrigerated display cabinets', part 4- 'General test conditions' to climate class 3 conditions i.e. dry bulb temperature 25ºC and 60% relative humidity.

The cabinet supplied by Electrolux Bedrijfskoeling B.V. was a frontloader cabinet (model EHS 250-3 Roll-in) with a remote condensing unit comprising a DWM Copeland semi-hermetic compressor (D8-LE-20X) with the standard lubricant for use with R22.

The unit was initially run on R22 for which the charge was 6.0 kg. The unit was then evacuated and charged with 5.6 kg of R417A and the expansion valve was adjusted by 1 turn to the right with respect to the reference setting. No other changes were made.

Table 1. Results from an Electrolux frontloader cabinet (Model EHS 250-3 Roll-in)

	R22	ISCEON® 59
Warmest package	13.3°C	13.8°C
Coldest package	-1.2°C	-1.4°C
Average Values		
Average all packages	4.6°C	4.9°C
Average evaporator air off temp.	0.5°C	0.5°C
Average evaporator air on temp.	7.3°C	7.4°C
Air in temp. condenser	19.7°C	19.5°C
75% of the operating time		
Evaporating temp. outlet cabinet	-2.45°C	-0.5°C
Superheat	9.2K	8.2K
Condensing temp. Inlet cabinet	33.0°C	29.7°C
Subcooling	3.5K	2.3K
Heat extraction rate	4880W	4700W

All refrigerant data taken from Refprex 5.1

The results above in table 1 show that the temperature distribution across the test packages was almost identical with both, R22 and R417A (ISCEON® 59). Similarly the evaporator air on and air off temperatures were virtually identical.

Over a 24-hour period the compressor power consumption was the same (41 kWh) even though the compressor was running 4 hours per day longer with R417A than with R22. The total time taken to defrost was also increased but only by 6 minutes per 24 hours when running with R417A (ISCEON® 59).

The typical operating conditions are shown in table 1 and it can also be seen that the heat extraction rate of the unit when operating with R417A is approximately 4% less than that of R22.

These results, proving the suitability of R417A (ISCEON® 59) in chilled applications have been complemented by experiences in the field, as the following example for a frozen application in a Swedish supermarket shows.

The system was one of two small low temperature systems delivering approximately 20kW cooling capacity each. The remote compressor was linked to four frozen food cabinets operating in the range –18 to –22 °C. After conversion to R417A the performance of the units was not noticeably different except for a marked reduction of the compressor discharge temperature.

Table 2 Comparison of R22 and R417A (ISCEON® 59) in a supermarket freezer system.

Compressor :	Bitzer S4G 12.2
Oil:	B 5.2 (Standard Bitzer oil)

Measurement	**R22**	**R417A**
Evaporating Temperature	-38.8°C	-35.5°C *
Suction Pressure	0.1 bar g	0.2 bar g
Condensing Temperature	38.7°C	39.4°C *
Discharge Pressure	14.4 bar g	12.8 bar g
Discharge Temperature	114.2°C	75.1°C
Liquid Line Temperature	33.0°C	32.5°C
Subcooling	5.7 K	4.5 K

*Average temperature.

3.3 Air-conditioning and Heat Pumps

R417A (ISCEON® 59) has been found to be particularly useful when converting systems with hermetic compressors. This has led to large numbers of split air-conditioning systems being converted but to date no formal studies such as in 3.1 and 3.2 have been conducted

One German manufacturer of specialist climate control systems for IT systems (Weiss Klimatechnik) has studied and compared R417A (ISCEON® 59) and R407C. The unit utilised three Copeland scroll compressors and was designed to be very compact. A result of this compact design was that the unit operated at high condensing conditions (55ºC). Table 3 details the results of this study.

Table 3 Performance comparison of R22, R407C and R417A (ISCEON® 59).

Parameter	Unit	R22	R417A	R407C
Condenser Air inlet	°C	36.2	35.8	35.8
Condenser Air outlet	°C	48.2	46.8	47.6
Evaporator Air inlet	°C	23.9	24.3	24.3
Evaporator Air outlet	°C	14.2	14.8	14.6
Discharge temperature	°C	98.5	72.7	88.6
Condensation pressure	bar/°C	19.5 / 52.5	18.5 / 55.5	21.3 / 55.5
Suction pressure	bar/°C	4.7 / 4.5	4.4 / 7.6	4.6 / 6
Humidity out	%	38	39	41
Humidity in	%	63	67	65
Power requirement	kW	5.1	4.6	5.4
Capacity	kW	14.7	13.8	14.6

Interview with Stephan Lang, Division Manager Research and Development at WEISS Klimatechnik GmbH

The results from table 3 show that the operating conditions are virtually identical for all the refrigerants except for two key parameters. The condensing pressure for R407C is significantly higher than for R22 and the power requirement for R417A (ISCEON® 59) is significantly lower than for R22 (-10.9%) and compared to R407C (-17.4%). Even though the capacity for R417A (ISCEON® 59) is slightly lower than for R22 (-6.5%) the C.O.P. is higher for R417A (ISCEON® 59) (3.00) than for either R22 (2.88) or R407C (2.70).

Table 4 details the results from tests performed in accordance with EN 255 on two Air/Water heatpump systems.

Table 4. Results from a Air/Water Heatpump

Conditions Outdoor/Indoor	R407C		R417A		% Change from R407C	
	Capacity/kW	COP	Capacity/kW	COP	Capacity	COP
7ºC/35ºC	9.54	2.55	9.43	3.46	-1.2%	35.7%
2ºC /35ºC	7.79	2.09	6.83	2.61	-12.3%	24.7%

The unit tested with R407C had been optimised for use with R407C but the unit tested with R417A (ISCEON® 59) was a standard R22 unit. The only modification made was to reposition the defrost controller further from the expansion valve outlet. It can clearly be seen from the results that although when used as a 'drop-in' the capacity of R417A (ISCEON® 59) is less than that of R407C in an optimised system, the C.O.P. of the R417A (ISCEON® 59) is much higher. The lower capacity would mean that the system would run for longer in order to heat the water to the desired temperature but the difference in C.O.P. is so large that the power consumption is likely to be less for the R417A (ISCEON® 59) system.

4. CONCLUSIONS

The examples given in this paper clearly demonstrate that R417A (ISCEON® 59) is a suitable candidate for the replacement of R22 for both refrigeration and air conditioning applications. In all the cases cited above the R417A (ISCEON® 59) was used as a 'drop-in' replacement i.e. no engineering changes were made to the systems and the original oil was retained.

When used as a 'drop-in' the performance testing of R417A (ISCEON® 59) has shown that the capacity is typically 5-10% lower than that of R22 and R407C but that the C.O.P. is significantly higher than R22 and particulary R407C.

Figure 1. Performance comparison of R22 and R417A (ISCEON® 59) performed at ILK (Institut für Luft und Kältetechnik, Dresden, Germany).