# Cost-Effective Replacements for HCFCs in Refrigeration and Air Conditioning

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**Abstract:** Under the European ODP regulations HCFCs (the transitional replacements for CFCs) are now being rapidly phased out. This paper describes, with case history examples, a family of safe to use zero ODP refrigerants which can be used in existing refrigeration and air-conditioning systems without the need for expensive changes of the oil type, facilitating the move away from ODSs.

**Background:** The EU has been at the forefront of environmental legislation in recent years. The EU adaptation of the Montreal Protocol (which regulates the use of Ozone Depleting Substances – leading to an eventual phase out of their production and trade for non-essential and chemical processing and feedstock uses) has been more stringent and with earlier phase out dates than the Montreal Protocol requires for countries with developed economies. The EU regulation 2037/2000 "on substances that deplete the ozone layer" imposes actual use bans on ODSs within the EU together with an accelerated phase-out of the use of the substances (HCFCs) still permitted under the Montreal Protocol in developed economies outside the EU.
The "use" (broadly defined as the physical transfer of the fluid into, for example, a refrigeration system) of CFCs has been prohibited in the EU for several years.
HCFCs, which have been used as an interim replacement for CFCs in many applications, are banned in the EU for use in new systems and their use for servicing refrigeration systems is due to end shortly. Newly manufactured HCFCs will be banned for use for servicing existing refrigeration/air-conditioning equipment from the beginning of 2010 and the use of recovered HCFC fluids from the end of 2014. Based on current recovery rates for refrigerant fluids it is very clear that the vast majority of systems in use today will have to be converted away from HCFCs to use non-regulated refrigerants (substances with zero Ozone Depleting Potential) well before the 2014 deadline.

Climate change is another environmental issue with global consequences. Carbon Dioxide released to the atmosphere from fossil fuels (burned to generate energy) is the major contributor to global warming, however fluorocarbon fluids used as refrigerants are also contributors. The ODSs (CFCs and HCFCs) being phased out under the Montreal Protocol are Green House Gases, as are their replacements the zero ODP HFCs. It is important to note that, over a typical refrigeration or air-conditioning system's operating lifetime, the energy it consumes is the major contributor to the system's environmental impact. Hence the strong interest from regulators in energy conservation and system energy efficiency. Releases of HFC refrigerant fluids from systems are a significant contributor to climate change, however to a much lesser degree than system energy consumption. There is a growing focus in Europe (and, indeed, globally) on refrigeration/air-conditioning system energy efficiency.

**Refrigerant Application Issues**

Fluorochemicals have been widely used as refrigeration working fluids for over 70 years because of their safety and performance characteristics. The application range of refrigeration and air conditioning systems has developed in the intervening years and specific refrigerant fluids have been developed to help optimise systems for a variety of temperature applications. The early (CFC) refrigerants worked well in compressors which used hydrocarbon based oils as lubricants. The use of the HCFC refrigerant R-22 had become widespread by the late1980s. In the early 1990s R-22 and specifically developed HCFC based blends to replace CFCs were very widely used, particularly in air-conditioning and in commercial refrigeration. HCFC systems also use standard, hydrocarbon based, compressor lubricating oils.

HFC refrigerants were developed, in the 1990s, as non ozone depleting replacements for CFCs and HCFCs. Due to their reduced solvency characteristics with the standard hydrocarbon based compressor lubricating oils, HFCs required the development of a new type of oil for refrigeration/air-conditioning applications. Polyol Ester (POE) lubricants have become the standard lubricant used for stationary refrigeration and air-conditioning systems using HFCs. (A related family of lubricants, the PAG lubricants, are used in automobile air-conditioning systems). Conversion of existing refrigeration and air-conditioning systems (using CFCs or HCFCs) to HFCs requires a change of oil to POE. The conversion procedure to standard HFC refrigerants requires a flushing procedure to ensure the removal of residual mineral oil from the system. A target residual mineral oil level in the POE oil of 5% maximum has become the accepted practice to ensure satisfactory system performance after conversion.

One disadvantage of POE and PAG lubricants over hydrocarbon-based ones is that these products are hygroscopic – they have a high affinity for moisture and will absorb and retain moisture when exposed to the normal atmosphere. Moisture cannot be removed by conventional vacuum techniques. (The use of an appropriate desiccant will remove moisture from these oils, however.) Great care has to be taken during servicing of systems which use POE (and PAG) lubricants to minimise the ingress of moist air.

**Refrigeration and Air-conditioning Systems in Europe – the Problem**

It is estimated that there is currently a “pool” of close to 200,000 tons of (primarily HCFC with a small residual amount of CFC) ozone depleting substances in working refrigeration and air-conditioning systems in Europe. This represents several millions of systems dependent on refrigerant fluids which will not be allowed to be sold into the market from the first of January 2010. Conversion of these systems to conventional HFC refrigerants represents a formidable task in terms of manpower requirements and of course cost. Many of these systems are critical to their users and cannot be shut down for long periods of time to allow complex conversion procedures.

**The Solution**

The development of a family of zero ozone depleting potential (HFC based) refrigerants (Isceon®), that can be used with hydrocarbon-based compressor lubricating oils, it is an excellent solution at this problem.

The new Isceon® Refrigerants and their main characteristics and applications, are shown in the Tab. 1

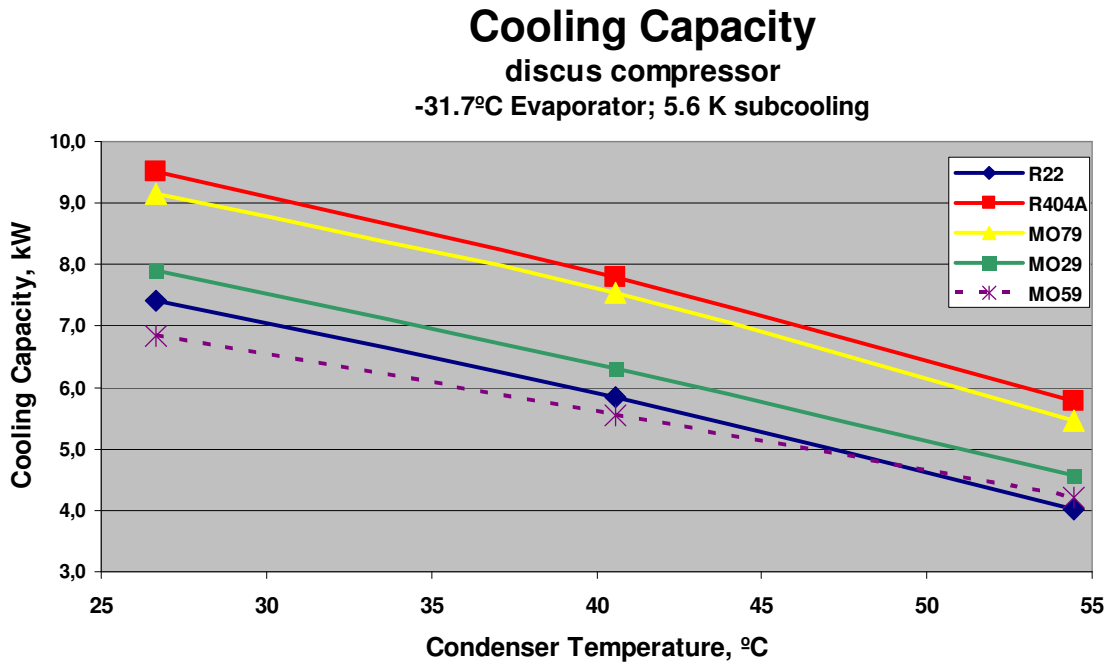
**Tab. 1 – Refrigerants DuPont™ ISCEON®**

| Refrigeranti | n° ASHRAE | Sostituisce | Per RETROFIT DEFINITIVI | Componenti | P.eboll. a P.atm. (C°) | Temp. Critica (°C) | Pressione a T=55°C bar (a) | Temp. Glide (°K) | Classe di Sicurezza |
|---|---|---|---|---|---|---|---|---|---|
| DuPont™ISCEON® MO29 | R-422D* | R-22 | R22 in "Water Chillers" | R125 65,1 %<br>R134a 31,5 %<br>HC 3,4 % | -43 | 79,6 | 23,4 | 3,0 | |
| DuPont™ISCEON® 39TC® | R-423A | R-12 | Per compressori centrifughi | R134a 52,5 %<br>R227 47,5 % | -24 | 79,5 | 13,6 | 0,5 | A1 |
| DuPont™ISCEON® MO49 | R-413A | R-12<br>HCFC blends | Condizion. auto e refrigerazione | R134a 88,0 %<br>R218 9,0 %<br>HC 3,0 % | -33 | 98,5 | 16,8 | 3,0 | A1/A2 |
| DuPont™ISCEON® MO59 | R-417A | R22 | Aria condizionata. | R125 46,6 %<br>R134a 50,0 %<br>HC 3,4 % | -39 | 87,0 | 20,7 | 3,5 | A1 |
| DuPont™ISCEON® MO79 | R-422A | R-502<br>R-22<br>HCFC blends | Refrigerazione BT | R125 85,1 %<br>R134a 11,5 %<br>HC 3,4 % | -46 | 71,7 | 26,2 | 1,5 | A1 |
| DuPont™ISCEON® MO89 | | R-13B1 | Refrig. BBT (-50/-60°C) | R125 86,0 %<br>R218 9,5 %<br>HC 5,0 % | -53 | 64,2 | 30,7 | 1,0 | |

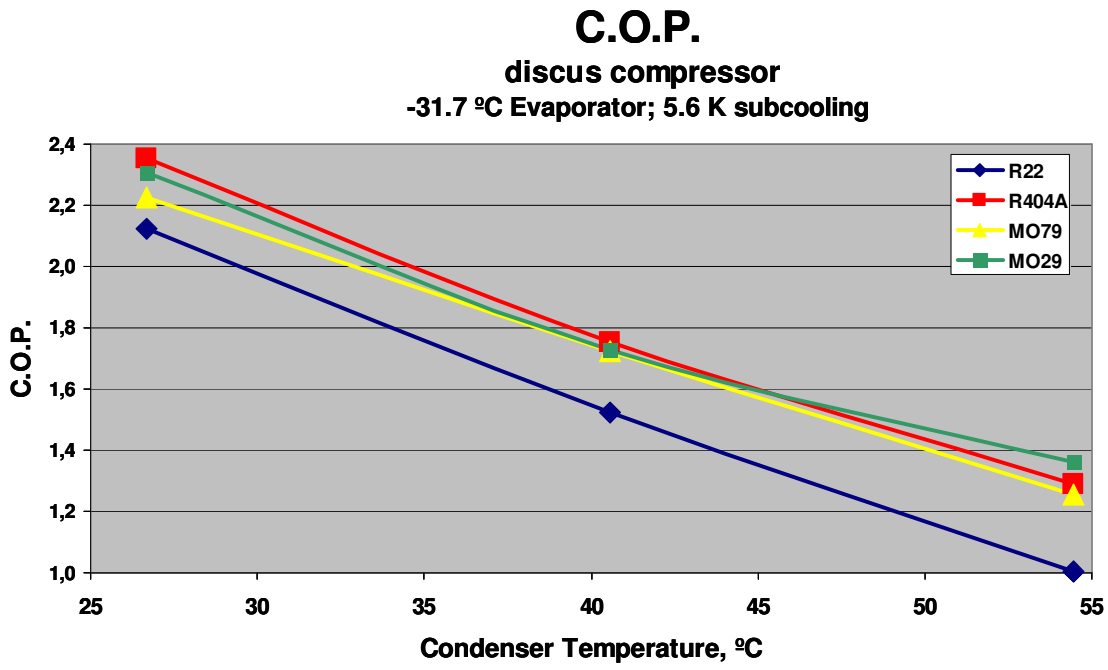
**Comparisons: Refrigeration Capacity and COP**

The following Tables show the Refrigeration Capacity and the COP of the most important Isceon Refrigerants, compared with R-22. In the Tab. 2 and 3 the data are related to refrigerant conditions of Low Temp., while in the Tab. 4 and 5 the graphics are related to Normal Temp.
Particularly, in Low temp., Isceon MO29 allows to improve the Refrigeration Capacity and the COP, in comparison to R-22; the use of Isceon MO79 is suggested, as substitute of CFC 502, or other HCFC substitutes of R-502, as R-402A, or R-409A, since, in this case, the changing of expansion valve is not required (it is normally necessary if we change R-502 with MO29).
On the contrary, the use of the Isceon MO29 or MO59 to replace R-22 (in air conditioning or in refrigeration) doesn't require the expansion valve change.

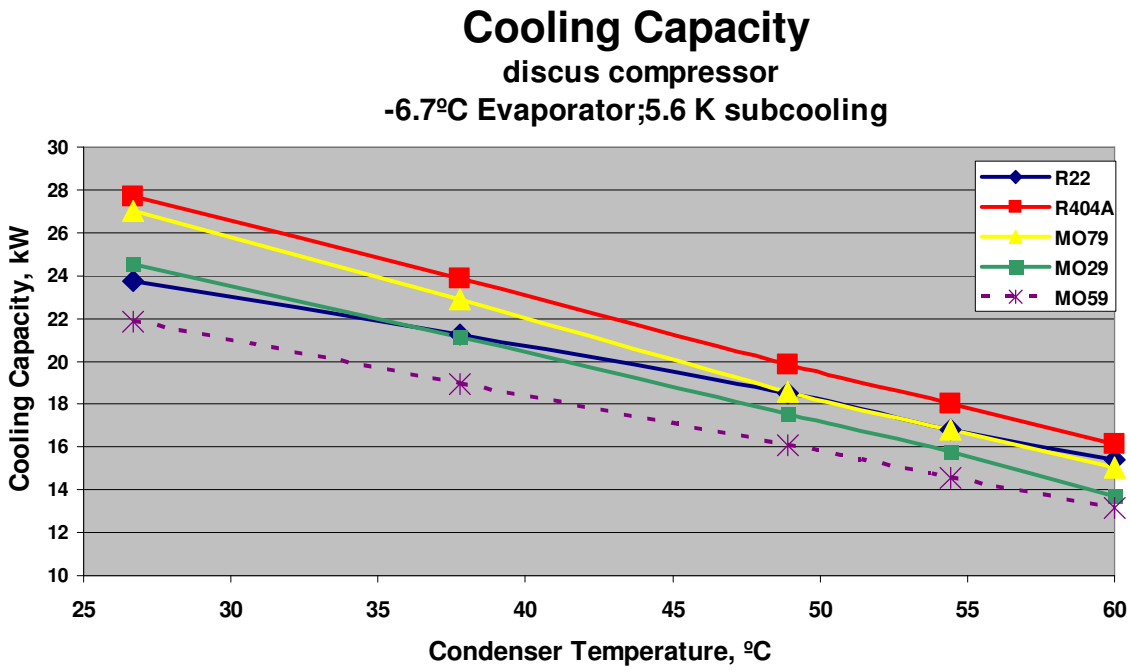
Tab. 2


Cooling Capacity
discus compressor
-31.7ºC Evaporator; 5.6 K subcooling
Cooling Capacity, kW
10,0
9,0
8,0
7,0
6,0
5,0
4,0
3,0
25
30
35
40
45
50
55
Condenser Temperature, ºC
R22
R404A
MO79
MO29
MO59

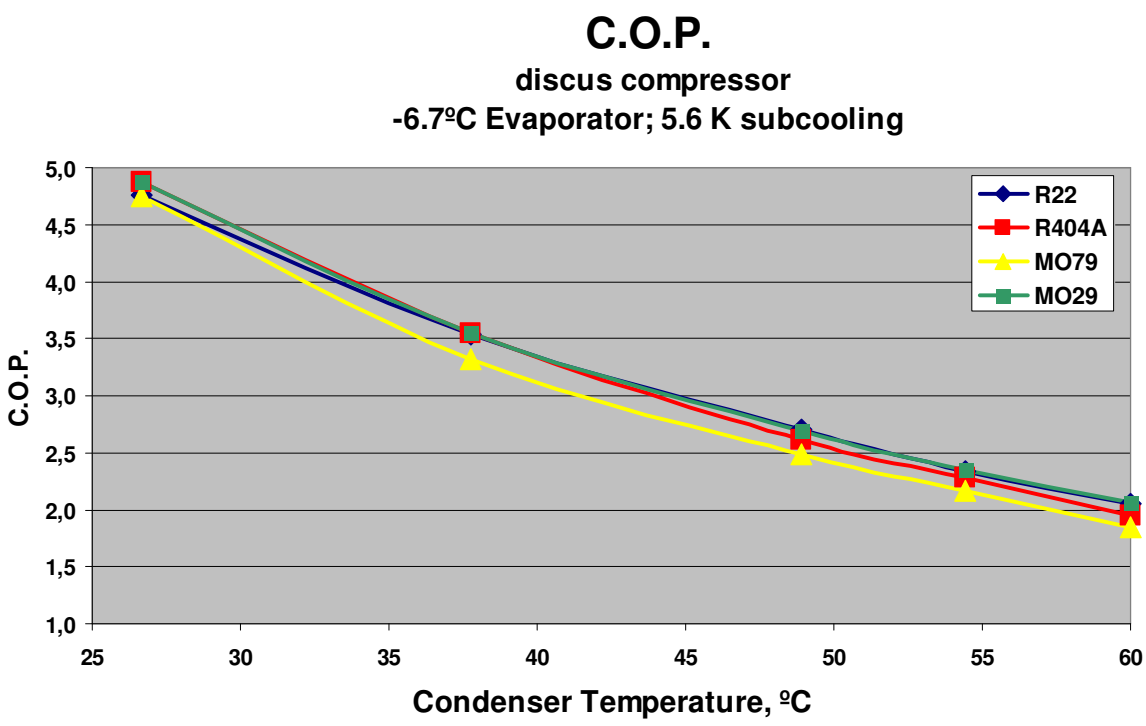
Tab. 3


C.O.P.
discus compressor
-31.7 ºC Evaporator; 5.6 K subcooling
C.O.P.
2,4
2,2
2,0
1,8
1,6
1,4
1,2
1,0
25
30
35
40
45
50
55
Condenser Temperature, ºC
R22
R404A
MO79
MO29

**Tab. 4**


Cooling Capacity
discus compressor
-6.7ºC Evaporator;5.6 K subcooling
Cooling Capacity, kW
30
28
26
24
22
20
18
16
14
12
10
25
30
35
40
45
50
55
60
Condenser Temperature, ºC
R22
R404A
MO79
MO29
MO59

**Tab. 5**


C.O.P.
discus compressor
-6.7ºC Evaporator; 5.6 K subcooling
C.O.P.
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
25
30
35
40
45
50
55
60
Condenser Temperature, ºC
R22
R404A
MO79
MO29

With the Isceon Refrigerants already a great number of conversions have been carried out and many “Case histories” are available and they show as follows:

- The replacement of R-22 with Isceon MO29 in chillers, or in refrigeration systems at normal or medium-low temperature, allows to have a Refrigeration Capacity similar to R-22, and to achieve a better energetic efficiency.
- Using Isceon MO79 in Low temp. refrigeration systems, it’s possible to have a good improvement of Refrigeration Capacity and COP (with a sensitive reduction of the electric consumption)
- With the use of Isceon MO59 or MO29, instead of R-22, in air conditioning systems or in medium Temp. refrigeration systems, we note that the discharge temperature of the compressor is remarkably lower (from -15° to -30°C) than the temperature of R-22: this is a great advantage, as it reduces the compressor wear and the lubricant deterioration.
- The same advantage of discharge temperature reduction is noted also in the low temperature applications, in which, substituting R-22 with Isceon MO29, it is possible to avoid the “Liquid injection”, improving furtherly the refrigeration capacity of the system.
- Isceon MO29 is a particularly versatile refrigerant, as it can be used in all the application fields of the R-22:
    - Chillers (except the units with centrifugal compressors)
    - Air conditioning systems
    - Normal Temp. Refrigeration (T. evap. -10 / 0°C)
    - Medium-Low Temp. Refrigeration (T. evap. -25 / -10°C)
    - Low Temp. Refrigeration (T. evap. -35 / -25°C)

**Conclusion**

The problem of the R-22 substitution in the refrigeration and air conditioning systems can be easily solved using refrigerants gases with O.d.P=0, that don’t need lubricant change, neither system cleaning; for these reasons the conversions can be made by frigorists in short time, with no need of special instruments or technologies; besides, the retrofits made show that the new refrigerants allow to have the same refrigeration capacity with a reduction of the energetic consumption.