IEAGHG Information Paper; 2013-IP23; HCFC substitution

Recently there have been a number of policy initiatives to reduce the emissions of fluorinated or F gases. Under the Montreal Protocol gases like CFC's were phased out to reduce the depletion of the ozone layer. The CFC's were replaced by gases like HCFC-22 in refrigeration and air conditioning units. The problem with gases like HCFC-22 is that whilst they have less of an impact on ozone depletion they have high global warming potentials.

HCFC-22 contains the element Chlorine and possesses a slight ODP (ozone depletion potential) which is 0.040 compared with CFC-11, and the large GWP (global warming potential) which is 1790 compared with CO_2. Thus it was restricted by the international environmental agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer which was signed in 1987. In the Montreal Protocol, HCFC-22 was described as an interim substitute and allowed to be used until 2030 by developed countries and 2040 by developing ones.

However in recent years mounting evidence has emerged on the rapid growth in HCFC-22 production and consumption. Experts estimated that the production and consumption of HCFC-22 may have doubled by 2015 because of inefficient control measures being in place, added to by the growth in demand for air conditioning in countries like China and India. Therefore in September 2007, an amendment to the Montreal Protocol to tackle the twin challenges of protecting the ozone layer and combating global warming was ratified by governments to accelerate the freeze and phase-out of the environmental unfriendly substances like HCFCs (hydrochlorofluorocarbons).

The problem then became one of which gases to use to replace HCFC-22? In an ideal world the replacement gases will have similar compression/thermodynamic properties and have no impact on ozone depletion and have very low global warming potentials. A recent paper published in the Journal Energy has explored the potential replacement options available[1].

The potential HCFC alternatives include:

Natural refrigerant R744 (carbon dioxide) is neither flammable nor toxic, and it is cheap and widely available. The primary concerns currently for R744 refrigerating and heating systems are to simultaneously optimize the system design and improve the efficiency.
HC-290 (Propane) is another natural refrigerant that is being considered, especially in Europe. HC-290 can be considered as a suitable alternative because it has a favourable environmental character, similar thermodynamic properties and material compatibility. The decisions of using HC-290 are often more demanding owing to its safety concerns associated with wider application, while from the technical level in production process, it seems to be feasible.
R717 (ammonia) is one of the very first refrigerants to be used in refrigeration systems, with a continuous history of being used over a century. R717 can be used not only in the vapour compression refrigeration system, but also the absorption and adsorption refrigeration systems. R717 is considered as an attractive refrigerant from many technical perspectives,

To sum up, R744, R717 and hydrocarbons are the three major natural refrigerants which could be really strong contenders for dominant positions in certain applications for HCFC replacement throughout the world. The features of no harm to environment (zero ODP and extremely low GWP) and their low cost are the most obvious advantages for the natural refrigerants. While the weakness of flammability (except R744) cannot be neglected, thus the local and regional regulations will demand certain safety measures to be incorporated into the design of refrigerating and heating

[1] Zhou Zhang and XI Wu, Retrofits and options for the alternatives to HCFC-22, Energy Volume 59, September 2013, pp 1-13

equipment in order to mitigate possibility of ignition. And also the concentration limits of them are needed to be regulated

Alternative synthetic substitutes include:

R407C and R410A are traditional substituents. The efficiency of air condition units using R407C is lower than R410A, whilst R410A increases the GWP by 17% and lowers the attainable efficiency by 6% The other two traditional HCFC-22 alternatives R404A and R507, currently charged in supermarket refrigeration systems to replace HCFC-22 in many developing countries both possess the disadvantage of higher GWP's.
HFC-32 (CH_2F_2), a component of R407C and R410A mentioned above, has been recognized as a potential good candidate. Besides the efficiency and cost, HFC-32 offers an acceptable low indirect emission solution for air conditioning units with good performance (comparable to R410A regarded as a traditional substitute for HCFC-22).
The Hydrofluoro-olefin (HFO's)family are also being considered. The HFO's are not an efficient HCFC-22 alternative from a system performance standpoint without substantial redesign (larger compressor, pipeline and heat exchangers) and added cost to compensate for the high pressure drop. In addition, the manufacturing complexity and purifying difficulty leads to their higher cost. The major concerns with these new alternatives are that their thermodynamic and transport properties have not been tested completely and the harmfulness of the DP (decomposition product) has not been recognized enough.

Other options include:

Mixtures of HCs and HFCs refrigerants - these kinds of mixtures possess similar pressures with HCFC-22 may be welcomed because only small modifications are required for the primary HCFC-22 systems. Other merits (e.g. they are easy to be obtained, miscible with mineral oil if containing HC's component, simple in technology, short in developing period and acceptable in cost) are also benefits to impel these mixtures to be the feasible transitional solutions in near and medium periods, especially for most developing countries.
RE170 (DME (Dimethyl ether)), the application field of ether-refrigerants is not as wide as that of HFCs, HCs and HFOs, and the research achievements and available candidates of HFEs are limited. Major manufacturers around the world have not planned to produce it massively and the experimental data on the potential substitute is currently spare.

However, the authors indicate that at present, the best most potential alternatives with lower GWP and toxicity possess the disadvantage of flammability, which is an inescapable problem in the process of HCFCs elimination. Special security arrangement and announcements must be made when operating with the flammable refrigerants. For developing countries such as China, this may create barriers to their safe introduction.

The authors conclude that in the current situation, there are no fluids which can replace HCFC-22 perfectly in most of existing equipment. Many factors must be taken into consideration when selecting or assessing an alternative option to HCFC-22. However it is recognised that the knowledge on different substitution options is increasing rapidly. The authors state that it is increasingly important to research the flammable characteristics of refrigerants, including flammable limits, ignition energy, heat and product of combustion. Special security arrangements are needed when operating with the flammable refrigerants, covering their whole lifespan.

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