The 2nd Asian Conference on Refrigeration and Air-conditioning ACRA2004

-New Contribution to Asian Sustainable Development-

PROCEEDINGS

Beijing, China

May 12-13, 2004

Sponsors: Chinese Association of Refrigeration

Beijing Association of Refrigeration

Co-Sponsor: International Institute of Refrigeration

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Foreword

On behalf of Chinese Association of Refrigeration (CAR) and its Organizing Committee of the 2nd Asian Conference on Refrigeration and Air Conditioning (ACRA2004),it is great pleasure for me to warmly welcome you all for your participation to the ACRA2004 to be held in Beijing,China,on May 12,2004.Strengthening the exchange and co-operation between nations and regions is very important to the development of the relative nations and regions.Refrigeration and air conditioning is playing and active role to the improvement of economy and societies,the human life quality enhancement,and the sustainable development.

Initiated by Japan Society of Refrigerating and Air Conditioning Engineers(JSRAE),The Society of Air-Conditioning and Refrigerating Engineers of Korea,and Chinese Association of Refrigeration,the 1st Asian Conference on Refrigeration and Air Conditioning (ACRA2002) was held in Kobe,Japan,2002.Then ACRA has been paid attention to by many colleagues in the refrigeration and air conditioning field.This conference will be followed by a series of ACRA in two-year interval even in the future.

At this ACRA 2004,we have received 112 abstracts and more than 90 papers submitted from nine nations and regions.In addition,89 papers are published in Proceedings of the 2nd Asian Conference on Refrigeration and Air Conditioning.It can be noted that the number of the papers submitted by Chinese experts and scholars has grown greatly.Refrigerants,energy efficiency improvement of refrigeration,indoor air quality,and the application of new technologies are the commonly interesting issues on the refrigeration and air conditioning promoting the sustainable development.The Scientific Committee of ACRA2004 has arranged six parallel sessions according to the main topics of the papers submitted.

I do hope you all will find this ACRA2004 a valuable forum to exchange our updated knowledge and views among the participants so as to make new contribution to the Asian sustainable development.

Finally,I would like to acknowledge the co-sponsorship from the International Institute of Refrigeration(IIR),the additional co-sponsorship from Beijing Association of Refrigeration.The generous financial supports kindly provided by several leading industries in China are also highly appreciated.

He Jihai

President of Chinese Association of Refrigeration(CAR)

President of China General Chamber of Commerce

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Keynote Speeches

One Word, Different Voices, One Issue, Many Options

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Abstract

Hydrofluorocarbon (HFC) compounds have been essential substitutes for Ozone-Depleting substances (ODS) in the implementation of the Montreal Protocol. However, HFCs are included in the basket of global warming gases for control by the Kyoto Protocol, leading to different voices about applications of HFCs in the world. The paper describes the different situations concerning usage of HFCs, especially the proposal of European Union (EU) Commission and the statements of Partnership and ICARMA. In fact, it is concerning on how to evaluate completely the climate change of HFC emissions. Therefore, LCCP has been introduced as an important and recognized procedure to assess climate change impact of refrigeration and air conditioning systems in the paper. The other important question is how to select of refrigerant for refrigeration and air conditioning system. The paper introduces the refrigerants and their applications in the present, and predicts the trends in the near future. At last, the paper indicates that hydrochlorofluorocarbons (HCFCs) are still required for developing countries. Any more rapid phaseout of HCFCs could actually slow the transition from CFCs.

1.Background

The main challenges and the opportunities for air conditioning and refrigeration industry are the global environmental issues: Ozone Layer Depletion and Global Climatic Change.

1.1 Ozone Layer Depletion

The ozone layer depletion is one of the global environmental issues.

The area of the ozone holes in both hemispheres reached a record 27~28 million km^2 in early Sept. 2000. Since then, ozone hole is decreasing but just not as fast. The World Meteorological Organization (WMO) (OzonAction, 2003a) said in statement on Oct. 16, 2003 that the hole had declined to an area of less than 18 million km^2 during the first weeks of Oct. 2003. Scientists indicate that recovery of the ozone layer may be expected by around 2050 if no further ODS are released to the atmosphere. So Klaus Toepfer, UNEP's Excutive Director(9.16,2003) said: "We must remain vigilant and more needs to be done before we can say that problem is solved for good" (OzonAction, 2003b).

1.2 Global Climate Change

The global climate change is also another one of the global environmental issues.

The IPCC (2001) revaluation report said(indicated) that the 90s of 20^{th} Century were the warmest ten years and the 1998 was the warmest one in the 90s from the record results.

In the Kyoto Protocol, HFCs were included in the comprehensive "basket" of greenhouse gases (GHG) along with carbon dioxide, methane, nitrous oxide, PFCs and SF_6. The protocol requires developed countries

to first eliminate any growth in their GHG emissions that took place over the two decades (since 1990) and then collectively to further reduce their emissions 5.2% below 1990 levels on average over the 2008 to 2012 time period.

The global GHG emissions are broken down in Figure 1 (Little, A.D. 2002). Carbon dioxide emissions are 89% of the total while PFCs, SF_6 and HFCs are only 1%, only half of which in HFCs in 1997. The warming impact of projected HFC emissions in 2030 is only 2.4% of the total. A recent report by Climate Action Network (CAN Europe, 2002) provides longer range, estimates of HFC emissions, it shows that, on a global basis, relative contributions of HFCs emissions compared to total GHG emissions are in the range of 2% to 4% in 2050.

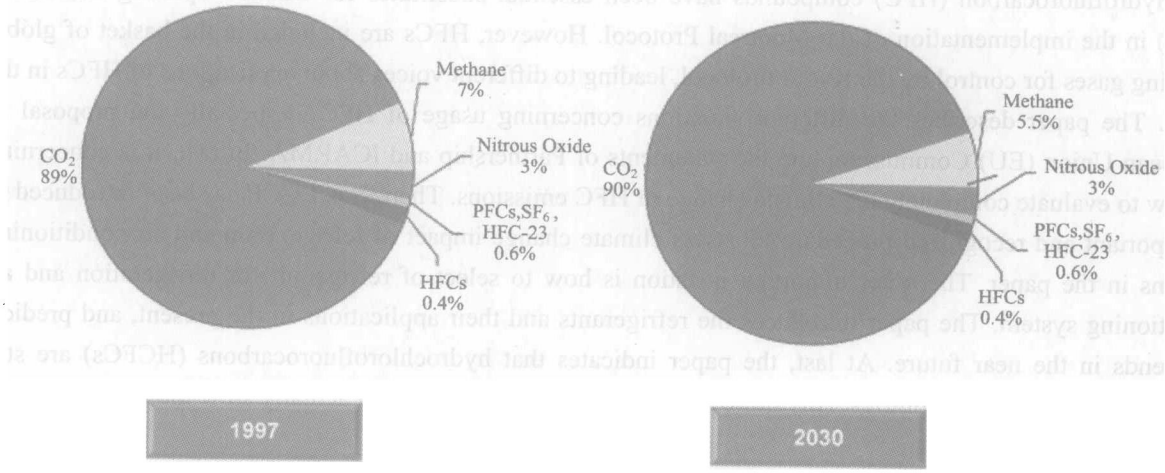

Fig.1 Breakdown of Global GHG Emissions

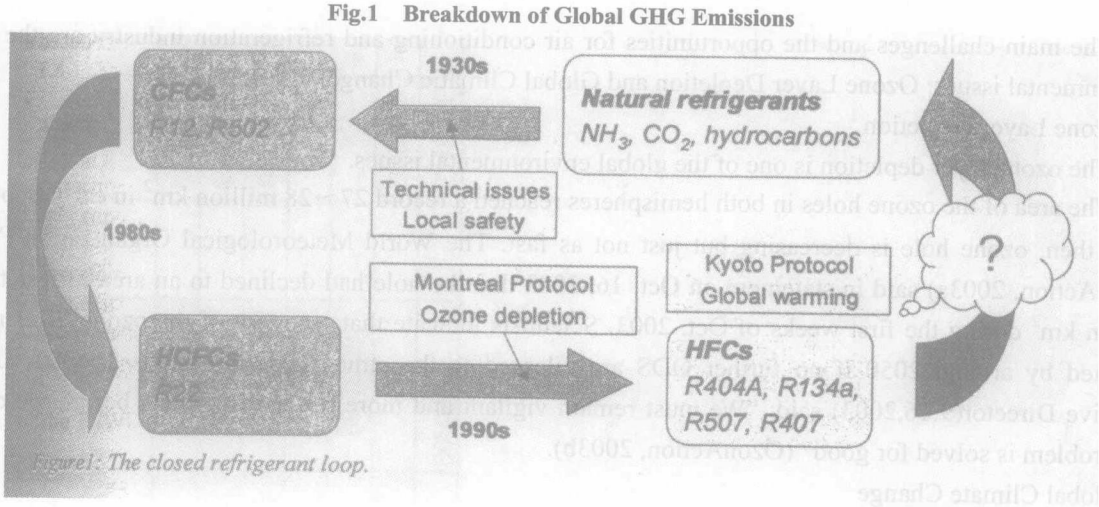

Fig.2 The closed refrigerant loop

HFCs are a very small part of GHG emissions and an important factor in successful implementation of the Montreal Protocol. However, HFCs are included in the basket of GHG for control by the Kyoto Protocol, leading to uncertainty of some countries and organizations about future HFC applicability. Some groups point to low GWP of natural refrigerants as the primary criteria for refrigerant selection.

It seems to be formed as a closed refrigerant loop showed in Figure 2 (Christensen, K. G., 2004). Northern Europe started using HFCs 5-7 years ago. These countries are now looking for applicable natural refrigerants in a broad range of applications. Southern Europe is lagging a bit behind this development.

2.Different situations concerning usage of HFCs

The situation concerning usage of HFC refrigerants differs greatly world-wide. It is one of main distinguishing features of current status for refrigerants.

Europe is at the cutting edge of development due to the differences in legislation locally and in EU.

On the European situation, several countries already ban HFC refrigerants in a number of applications and impose sequenced phase-outs from some uses. At least some imposed very high taxes (roughly $20 and $30 per kilogram for HFC-134a) and more than ten countries have laws that will strictly limit or phaseout HFC refrigerants in the next decade.

Austria has made a law to phase out HFC-134a as the refrigerant in mobile air conditionings (MACs) and other applications from 2008 with a possible exemption up to four years (EU Commission Conf., 2003).

Switzerland follows a similar, but slightly different path regulating those HFCs that have a lifetime in the air of more than 2 years (EU Commission Conf., 2003).

Denmark has introduced a ban on particular uses of HFCs in new equipment from Jan. 2007 and has also a tax (about $20 per kilogram of HFC-134a) on HFCs based on GWP on 1 March 2001 (EU Commission Conf., 2003).

Norway has also introduced tax on HFCs from 2003, and that tax is 80% higher than in Denmark (EU Commission Conf., 2003).

In UK, HFCs are considered not to be sustainable in the long time. The UK is waiting for the Commission's proposal for Regulation on fluorinated gases (F-Gas) but will in the meantime put a ban on non-refillable containers and have implemented stringent and mandatory rules for the service industry (EU Commission Conf., 2003).

France expressed the same concern as the UK (EU Commission Conf., 2003).

Germany is also working on new national regulations. A recent report by the German environmental agency shows that a full replacement of HFC-134a by CO_2 in MACs will be implemented from 2007 (Nekso, P., 2004).

The EU has proposed the "F-Gas" regulation to limit HFC uses. On March 7, 2001, EU Presidency Statement on sustainable development said that "Countries should avoid the use of HCFC, and where feasible HFC, by converting directly to substances or technologies that are not ozone depleting nor have adverse climate effects (EU Presidency Statement, 2003). The European Commission has adopted a proposal for a regulation to reduce emissions of fluorinated greenhouse gases on August 12, 2003 (EU Climate Change, 2003). The proposal has four main elements:

- Provisions to improve the containment of fluorinated gases;
- Reporting requirements to strengthen the monitoring of emissions;
- Marketing and use restrictions where containment is not feasible or the use of fluorinated gases in inappropriate;
- Phase-out of HFC-134a in air conditioning systems of new vehicles.

The proposal introduced a flexible system based on transferable quotas to gradually phase-out the use of

HFC-134a in new vehicle air conditioning systems over the period 2009 to 2013. Alternatives having a GWP value less then 150 are accepted in this proposal. This means that the options are covered by CO_2 and the flammable alternatives HFC-152a and HCs. The proposal by EU Commission has been sent to European Parliament and Council of European Union. On March 16, 2004 the European Parliament's Environment Committee has already adopted its opinion on draft EU Commission controls on climate altering fluorinated gases. The committee voted to ban "F-Gases" (essentially HFCs) in MACs in new vehicle models from 1 Jan. 2009. The ban should apply to all new vehicles from 1 Jan. 2014. One of the committee's key interventions was to reject a proposed quota system for "F-Gases" use in MACs in favour of a ban. In a related change, the committee voted to include in the ban all "F-Gases" used in MACs with a global warming potential over 50, rather than 150 as proposed by the EU Commission (Environment Daily, 2004a). This will exclude use of "F-Gases" mixtures or HFC-152a, i.e. it means the main potential alternatives are natural refrigerants such as CO_2 etc. Of course, the proposal by the committee will be waited for the discussion and decision by European Parliament and Council of EU, then the EU Regulation will enter into force in 20 days. During the period, the Mobile Air Conditioning Summit, sponsored by European Commission, US EPA, the Australian Greenhouse Office, and the Japan Ministry of Environment will take place in Washington, D.C., USA April 14-15, 2004. It will be an important meeting in addressing reduced emissions of HFCs from MACs.

Besides EU, Australia is amending its ozone legislation to also include HFCs and PFCs used as replacements for ODS. The new legislation requires importers, manufacturers or exports of HFCs to be licensed and pay of fee of A$165 per tonne (EU Commission Conf., 2003).

Obviously, lots of organizations, societies, groups, and government etc. have expressed or are expressing the different voices. The European F-gas manufacturers group EFCTC regretted the committee's decision to ban use of HFCs with global warming potential above 50 in MACs. It said that this would "force the introduction of carbon dioxide systems which are far from ready today". The European Partnership for Energy and Environment (EPEE) also described the situation as "unnecessarily complicated and impractical" (Environment Daily, 2004b).

Before then, The UNEP Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol on Substances that Deplete the Ozone Layer concluded that HFCs are important to the current safe and cost-effective phaseout of CFCs in developing countries. They are essential substitutes for highly important uses of ODS and are also technically and economically necessary for phase out of HCFCs in developed and developing countries. The report of the TEAP HFC and PFC Task Force Oct. 1999 also stated: "Use of HFCs as substitutes for ODS is not likely to impede Parties to the Kyoto Protocol from meeting emission reduction obligations because HFCs are a very small part of national emission targets" (TEAP, 1999).

The Intergovernment Panel on Climate Change (IPCC) Third Assessment Report (IPCC, 2001) concluded that alternatives are not technically and economically feasible for some HFC applications.

A partnership has been formed by the United States Environmental Protection Agency (EPA), the United Nations Environment Programme (UNEP), and the Alliance for Responsible Atmospheric Policy. "Responsible Use Principles for HFCs" was announced by this partnership at the Earth Technologies Forum, Washington, D.C., March 25, 2002. The responsible use principles stated that "HFCs are used in important applications in both developed and developing countries", "HFCs are necessary for an orderly phase out of ODS under the Montreal Protocol", "HFCs are low in toxicity, cost-effective, safe to use and in many applications provide high energy efficiency",etc.. The principles include:

- Select HFCs for applications where they provide health and safety, environmental, technical,

economic or unique societal benefits

- Design and operate HFC-producing plants with the goal of zero HFC emissions
- Engineers, operate and maintain HFC using systems to minimize emissions and maximize energy efficiency
- Recover, recycle, reclaim and/or destroy used HFCs where technically and economically feasible.

The responsible use principles mentioned above are list on the UNEP website: http://www.uneptie.org/ozonaction/sector/hfcuse/htm.

The International Council of Air-Conditioning and Refrigeration Manufacturers' Associations (ICARMA) is a membership organization. Its' current members are: ABRAVA, the Brazilian Refrigeration, Air Conditioning and Ventilation Industry Association; ARI, the Air-Conditioning and Refrigeration Institute; CRAA, the China Refrigeration and Air Conditioning Industry Association; EUROVENT/CECOMAF, the European Committee of Air-Handling, Air-Conditioning and Refrigeration Equipment Manufacturers; HRAI, the Heating, Refrigerating and Air-Conditioning Institute of Canada; and JRAIA, the Japan Refrigeration and Air-Conditioning Industry Association. ICARMA has also announced the "Responsible Use Principles for HFCs" (Http://www.icarma.org/policy/hfc.shtml). The principles are very similar to that by partnership mentioned above. They stated that "Industry supports the global use of HFCs in applications that meet important environmental and societal needs", "HFC-producing and using industries have determined that HFCs are viable and proven global long-term solutions to the problems addressed by the Montreal Protocol and Kyoto Protocol processes. These refrigerants are energy efficient, low in toxicity, cost-effective, and can be used safely." The principles include:

- Minimum HFC emissions during manufacture and use based on cost-effective technology
- Optimize the amount of HFCs needed for the application
- Produce, transport, handle and use HFCs in a manner that assures workers and community safety
- Design HFC-producing plants with the goal of achieving zero emissions
- Provide HFC-related products where their signification societal value justifies their environmental impact, or which have favorable Life Cycle Climate Performance (LCCP).

On Nov. 17, 2003, Thomas E. Bettcher, 2003 ARI Chairman also said:"We continued our defense at home and abroad of HFCs as the long-term replacement for refrigerants that are being phased out of production. Our partner in Europe, EPEE, worked with our support, on provisions that enhance containment and re-use of HFCs, while providing manufacturers the option of using a safe, energy efficient refrigerant in numerous equipment applications" (Beffcher, T.E., 2003).

From above, we can see that there are very different voices concerning usage of HFCs from different countries and regions in the world.

In fact, the responsible use of HFCs as well as HCFCs and natural refrigerants like as two principles proposed by the Partnership and ACARMA mentioned above is the most important, even though major EU controls are inevitable and the situations about HFCs are very different.

3.LCCP

Another important question is concerning on how to evaluate scientifically and completely the climate change impact of HFCs as well as HCFCs and natural refrigerants. Some groups have called for the

elimination of HFCs on the basis of GWP values; however, this is a one dimensional, incomplete view of the climate charge issue.

As described in the principles, the correct procedure for evaluating climate change impact of refrigeration and air conditioning systems is LCCP. The LCCP analysis methodology is rigorous and is recognized by UNEP, USEPA, IIR, ACARMA, Alliance, ARI, EPEE and some other organizations in the world.

The LCCP accounts for warming impacts due to direct GHG emissions from the product and to indirect GHG emissions associated with the energy consumption of the product over the entire life cycle of refrigerant and equipment including inadvertent emissions from chemical manufacture, energy embodied in components, and emissions at the time of disposal or recycle. The lower the value, lower the environmental impact.

A recent publication (Little, A.D., 2002) provides LCCP calculations for the major categories of refrigeration and air conditioning applications with the inclusion of HFC refrigerants, ammonia, hydrocarbons, and CO_2 as appropriate.

The LCCP calculating equation is

$$\text{LCCP}= N \times E_{\text{ann}} \times \beta + (GWP + E + F)[L \times N + m(1-\alpha_{\text{rec}})]$$

here, N is the operating time of equipment, [year]; E_{ann} is the energy consumption, [kWh/year], β is the CO_2 emissions per kWh, [kg CO_2/kWh]; GWP is the global warming potential, [kg CO_2/kg], E is the embadied energy, [kg CO_2/kg]; F is the fugitive emissions, [kg CO_2/kg]; L is the refrigerant emissions per year , [kg/year]; m is the refrigerant charge amounts of equipment, [kg]; α_{rec} —the recovery amounts of refrigerant, [kg]. The values of E and F have been summarized in Appendix A (Little, A.D., 2002).

In Figure 3 the LCCP has been compared for residential unitary air conditioning include HFC blends (primarily R407C and R410A), propane (HC-290) and HCFC-22. LCCPs have been calculated for a typical application in Atlanta, GA, USA, at three efficiency levels-seasonal energy efficiency ratio (SEER) levels of 10, 12 and 14 Btu/Watt·hr.

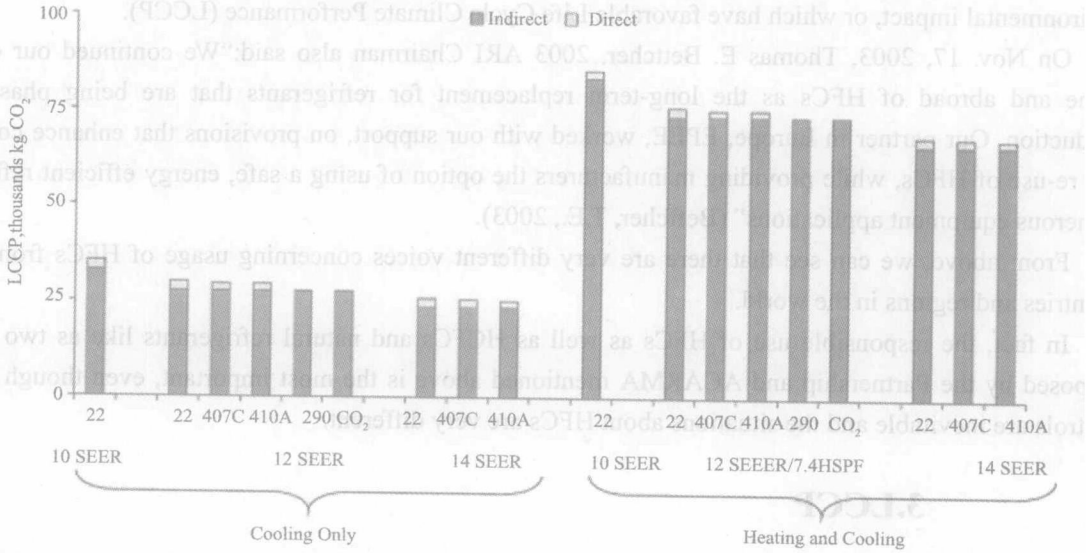

Fig.3 LCCP for Residential Space Conditioning in Atlanta (3 ton)