Options to Reduce Greenhouse Gas Emissions due to Mobile Air Conditioning

Brussels 10-11 February 2003

Summary of the discussions

Final

16 June 2003

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The different sections are also available at the MAC Summit website under "discussion" after each presentation. See
http://europa.eu.int/comm/environment/air/mac2003/programme_presentations.htm

Session 1: Environmental Challenge of Mobile Air Conditioners

Chaired by Ward Atkinson, Sun Test Engineering

Leakage of HFCs during manufacturing, operation, maintenance and end-of-life of MACS

Presented by Denis Clodic (Ecole des Mines) and Jochen Harnisch (Ecofys)

Discussion

The participants discussed the accuracy of the measurement of leakage of HFC-134a emissions during manufacturing, operation, maintenance and end-of-life of MACs. Measurement accuracy was considered to be low. Several industry representatives considered the "optimistic scenario" of the presentation the most realistic one while they considered the "realistic scenario" of the presentation pessimistic.

It was discussed, how the systems behave over lifetime, i.e. would the leakage rate increase or decrease with age.

The participants discussed what caused the regular leaks of about 57 grams (or about 8%) of HFC-134a per annum, that were found out by the study commissioned by the European Commission. The leaks arise from hoses, compressors, crimp fits, poor quality parts etc.

Some industry participants noted that the study showed that there are mobile air conditioning systems on the road, which have very low emissions. They pointed out this to be evidence that regular emissions can be very low, and that these systems would not need to be recharged.

Although no concrete evidence was put forward, the participants of the conference agreed that HFC based air conditioning systems have improved in the last years. It was discussed the total amount of refrigerant needed, before the systems needs to be refilled.

Irregular leaks due to damage to cars were touched upon. Overall while this source of leaks seems the second largest concerning MACs (being between 1.9% or higher per annum according to the consultant) it seemed that this area of leakage was least known and probably most difficult to control.

Moreover, the leaks due to “heels” in containers were also discussed noting that for industrial use, the heels are recoverable and usually recovered because this is economically sensible.

Regulators expressed concern about the quality of after sales servicing, how consumers do not go back to the retailers for servicing and how consumers are basically ignorant of how mobile air conditioners work and how much fuel they consume. Thus, they made a strong plea to improve the servicing sector and minimise emissions caused by poor maintenance and management. It was mentioned that especially small garages might cause the problems.

Some industry participants pointed out that the most effective manner to reduce leaks from MACs is that they are not serviced over lifetime at all.

It was noted that a source for leaks is also the damage done to MACs when the engine (not the MAC) is being serviced by staff who do not have the proper training to service MACs. All agreed that it would be ideal to have MACs not serviced at all. Some identified the overfilling of MACs as one problem of this approach.

A representative from fluorocarbon industry said that although they have not estimated in detail the environmental impact of mobile air conditioners, they had estimated through global atmospheric concentrations of HFC-134a that the leak rate could be 10% but in any case not more than 14% per annum.

Fuel consumption and associated CO_2 emissions due to MACs

Presented by Rob Farrington (National Renewable Energy Laboratory)

Discussion

It was noted that the largest uncertainties in the modelling of CO_2 emissions due to MACs comes from engine type, compressor type, mean radiant temperature assumptions, the vehicle and comfort models used, and the compressor's load on the engine.

It was highlighted that that the additional fuel consumption of MACs is an issue that needs to be addressed, and that there are technologies (e.g. variable displacement compressor with temperature outlet control) that can reduce fuel consumption, and related CO_2 emissions.

It was discussed weather demisting could be achieved with other means than MACs and it was concluded, that there are no real alternatives, as also the alternatives would need energy.

Biggest uncertainties with the estimation seem to be the efficiency of the engine. Another critical point of the model presented was the "customer behaviour". It was recognized that customers in the North and the South behave different. Penetration rate of MAC in northern countries is higher than in southern countries. Due to a lack of data the model needs to be seen as an estimation.

Regulatory Strategy for including MAC fuel consumption in vehicle fuel efficiency standards

Presented by Raymond Gense (TNO)

Discussion

It was recognised that while it is difficult to pinpoint what the actual increase in fuel consumption and associated CO_2 emissions are (likely to be 0.3-0.5 litres per 100 km in the EU). The presenter said that, with appropriate technology, it would be possible to half this consumption.

The participants noted that in Japan attempts had been made to include MACs to the test cycle in a very sophisticated way, but that this was abandoned. The approach proposed in the EU (labelling) seemed a plausible and cost-effective way forward. However, some participants raised questions with regard to the overall accuracy that can be achieved in simplified tests. It was also discussed, to what extend the measurements are repeatable.

Life-Cycle Climate Performance (LCCP) of MACs

Presented by Matti Vainio (European Commission)

Discussion

Concerning details, an industry representative asked why fans were included in the LCCP calculation (as fans would also be used in cars without MACs). Another industry representative responded by saying that in the presentation fans were included in the LCCP calculation for completeness, but for comparison purposes (between a car having and not having a MAC) one should not include fans. It was also noted that the definition of the boundaries of the LCCP needs to depend on why the analysis is conducted in the first place[1]. It was agreed, that clarification of definitions and system boundaries are an issue when discussing the approach.

[1] In other words, a car manufacturer might use LCCP in a slightly different manner from a policy maker.

Session 2: Response to greenhouse gas emissions from MACs

Chaired by David Smith-Tilley (Global Insight – DRI Automotive)

NGO's views

Discussion

The industry representatives questioned the optimism of NGOs in terms of using flammable refrigerants (hydrocarbons). They emphasised that the risks need to be evaluated and pointed out that potential or actual liability of using flammable refrigerants is yet to be evaluated.

Some industry participants also claimed that the NGOs views were too optimistic with regard to the commercialisation of CO_2 systems. They suggested that there are still unresolved technological issues for the design and maintenance of CO_2 systems and the higher cost is also an issue that car manufacturers need to work out.

In response, NGOs and some regulators pointed out that it is the car manufacturers that have created the problem by introducing HFCs to MACs, that they have had years to reduce these emissions to the standards of other sectors and that it would be the best to have no mobile air conditioning at all. The issue of flammability of hydrocarbons was discussed. NGOs argued that the risk for systems designed for use with hydrocarbons is likely to be negligible, and that prototypes have been developed in Japan. NGOs pointed out that hydrocarbons are widely used as drop-in replacements in standard mobile air conditioners in Australia and the United States; while neither endorsing or condemning this practice, they noted that there have been no accidents or studies indicating measurable risk increases even in these sub-optimal systems. In any case, NGOs pointed out that the industry has offered no proof to the contrary, and the main barrier is the perception of risk and fear of liability.

NGOs pointed out that CO_2 is becoming a common refrigerant in stationary sectors and has been looked into since 1992. Most importantly, research into CO_2 based MAC has been ongoing by almost all of the relevant players in the auto industry, and that commercialisation is the logical next step. This is based on information from the developers themselves. Thus, there was ground for claiming that it is realistic to move to alternative refrigerants.

Industry representatives raised the question of servicing CO_2systems but NGOs considered that it would be the responsibility of industry to sort out such details. An industry representative pointed out that there is a danger if such details are not sorted out before the policy is decided: the industry would be blamed for not sorting out the servicing of MACs even if the technological complications would be overwhelming.

Regulator's response to greenhouse gas emissions

(*Note:* Some of the discussion includes the presentations, in particular in cases when presentations were made only orally. In cases slides are available, they have been placed at http://europa.eu.int/comm/environment/air/mac2003/programme_presentations.htm.)

Discussion

Austria has made a law to phase out HFC-134a as the refrigerant in MACs and other applications from 2008 with a possible exemption up to four years. In any case existing equipment can be serviced beyond that date. Switzerland felt that something should be done for environmental reasons. Therefore, Switzerland follows a similar, but slightly different path regulating those HFCs that have a lifetime in the air of more than 2 years. A phase out is regulated through an ordinance in some cases, HFCs in MACs are allowed as long as no alternative is) available and emission reduction measures are implemented. MACs need to be controlled in a non-intrusive manner on a yearly basis.

The United Kingdom climate change programme is based on the principle that HFC emissions should not rise beyond a certain level and be kept stable. HFCs are considered not to be sustainable in the long term. The UK is waiting for the Commission's proposal for Regulation on fluorinated gases but will in the meantime put a ban on non-refillable containers and have implemented stringent and mandatory rules for the service industry.

In Denmark there is a voluntary agreement within industry to collect HFC. This schedule is beginning to cover MACs as well. There is a mandatory certification. Denmark has introduced a ban on particular uses of HFCs in new equipment (not currently in MACs). Denmark has also a tax on HFCs which also covers MACs (€17 per kilo of HFC-134a) based on global warming potential. This tax does not apply for the refrigerant of imported new cars but only for refills. CO_2 technology for MAC's should be available soon. He pointed out that the additional cost of a CO_2 system (up to €200) is insignificant compared to the price of a car. According to a small study on leakage of based on interviews in garages they found out that the IPCC default figure which is 30% per year including "regular", "irregular" and "end-of-life" leakage is appropriate for Denmark. According to these interviews even imported cars from Japan had this higher leakage rate.

The reason for high emission figures in Denmark where discussed. One reason could be that due to high vehicle taxes in Denmark much more vehicles in Denmark are equipped with after-market MAC systems, and these systems are likely to have higher leakage rates. Concerning the use of CO_2 as the refrigerant in supermarkets it was clarified that the system is a cascade one used for the freezing side and either HFC or HC is used for the cooling side. CO_2 is used as a primary fluid on the freezing side.

A participant asked whether a tax is being considered fluorinated gases. The representative from the US EPA told that in the United States, as part of the regulation of ozone depleting substances, a tax of $20 per kilo of CFC was placed. They found the tax instrumental on making it effective to recycle CFCs in the early days and having also an educational effect as people using CFCs noted the important increase in its price. The EPA believes the tax on CFCs to be one of the best of their strategies for phasing out the ozone depleting substances.

Some industry representatives asked whether the decisions for phase out were based on cost-benefit analysis. In Switzerland no cost-benefit analysis has been carried out but it is assumed that the measure is cost-effective because alternative technologies are commercially available. It was noted that any measure proposed by the California Air Resources Board in the US needs to be cost-effective.

Australia is amending its ozone legislation to also include HFCs and PFCs used as replacements for ozone depleting substances. The new legislation requires:

- importers, manufacturers or exporters of HFCs (either in bulk or in pre-charged refrigeration and air conditioning equipment) to be licensed and pay a fee of A$165 (about €93) per tonne;
- end users to handle and use HFCs and PFCs in line with legislatively backed standards and codes of practice;
- formation of a fund to pay for administration of the Act, ODS phase out programs and emission minimisation programs for HFCs, PFCs and ODS; and
- product stewardship of HFC refrigerants by importers/ manufactures. In managing ODS refrigerants, as required under the current legislation, the industry established *Refrigerant Reclaim Australia* to ensure reclamation and destruction of used ODS. This program is being expanded to collect and destroy used and contaminated HFCs and fulfil the expected new requirements

Some regulators suggested that the leak tightness of MACs would be tested regularly (e.g. either yearly or at each service or refill), ant that maintenance staff need be certified. Also all called for a ban on non-refillable refrigerant containers and making recovery and recycling mandatory. All were also in favour of having suppliers of HFCs licensed including the fact that manufacturers and importers of HFCs must assume responsibility for the life of the product.

Concerning Japan, it was asked how the leakage rates used in Japan were so much lower than what were found in the study in the EU (even for Japanese made cars). It was pointed out that the leakage rate of 15 grams of HFC-134a per annum was calculated by the industry association which has the only reliable data in Japan. It was suggested that this would be discussed in detail by experts.

France expressed the same concern as the UK: while it is possible to set the training requirements of the service staff of MACs, its difficult to get all staff trained due to their size and also they abundance.

A suggestion was made that the same measurement protocol that was used in the EU would be used also in the US or elsewhere to estimate the leakage rate of HFC-134a in other countries.

Session 3: Industry perspective on reducing direct and indirect greenhouse gas emissions from MACS: Pros and cons of the options

Chaired by Jostein Pettersen, Professor, Norwegian University of Science and Technology

Fuel-efficient, leak-tight HFC-134a systems through design and quality component

Presented by Hans Fernqvist (Volvo)

Discussion

Many participants said that it is important to develop policies that are geared towards long term emission reduction goals.

One regulator from outside the EU said that it is important to put an end to second order improvements and added that he would like to get rid of HFCs. A representative from service industry pointed out that the Kyoto Protocol aims at controlling and reducing emissions, not phasing out or banning substances.

There was a clear recommendation from representatives of the vehicle industry to make recovery/recycling of all fluorinated refrigerants (CFC, HCFC, HFC) mandatory in all EU Member States and make venting of refrigerants illegal.

Many pointed out to the fact that the level of knowledge and skills of the technicians servicing MACs was low in many EU Member States. All agreed that stringent training requirements needed to be established. It was highlighted that only good quality parts should be used both by car manufacturers and repair shops, but this was unfortunately not always the case. Some participants suggested "a life time" guarantee of MACs.

Options to reduce emission of HFC-134a during the manufacturing and distribution of the gas, during service/repair of MACs and at scrapping.

Presented by Denis Clodic (Ecole des Mines) and Jochen Harnisch (Ecofys)

Discussion

Many thought that an important source for leakage was the incorrect servicing and repair of AC systems by the technicians. A specific problem was mentioned concerning "normal" repairs of car having a side effect of damaging the MAC. Issues were also raised about how to monitor the service sector, which seems to be almost an impossible task in practice.

The cost-effectiveness of improved servicing was discussed including the question whether there is a cost in improving servicing and what are the benefits of improved service would be. Industry representatives highlighted that costs need to be available to compare measures across the sectors. However, such data was not available.

Certification of garages and technicians was highlighted as an important issue along with the need to use good quality parts. Also the emission at the end of life of vehicles noted: according to the end-of-life vehicle directive the refrigerant needs to be removed regardless the cost.

The need for training of technicians was stressed and the approach taken in the US (MAC Society) was recommended. Further, it was suggested that diagnostic tests be made a regular part of servicing.

The possibility of on-board diagnostics to detect losses was discussed. It was stated that the automatic diagnostic is difficult but work is going on in this field.

One regulator questioned why it has taken so long to realise that training of garage technicians seems neglected implying that garages are an important source of leaks of HFCs. The regulator pointed out that HFCs were introduced to cars already 8 years ago and suggested that the problems could have been foreseen then.

New technology: "HFC-152a as an alternative refrigerant"

Presented by William Hill (GM)

Discussion

Potential risks involved in mixing of flammable and non-flammable refrigerants and the possible impact on cooling performance were discussed. Industry representatives said that they had ruled out hydrocarbons as the refrigerant due to liability. On HFC-152a some industry representatives were confident that they would be able to solve the problems related to flammability and said that they will carry out the appropriate risk assessment on this. It was pointed out that, in the case of fire, any safety issues concerning the formation of hydrogen fluoride (HF) are similar for both HFC-134a and HFC-152a.

Some discussions took place around the heat of combustion of HFC-152a relative to the heat of combustion of propane. The accepted standard heats of combustion assume complete burning, and in that case HFC-152a has a third of the heat of combustion of propane[2]. One reference cited (Dupont) of actual measured heats showed HFC-152a having one seventh of the heat of combustion of propane, due to lesser complete burning of HFC-152a in that test. This is also confirmed by some work done by the US EPA. However, an academic expert contested this by stating that "realistic combustion energies" lacks scientific credibility[3] and is thus misleading since it downplays the flammability of HFC-152a incorrectly.

Some suggested that HFC-152a could be used – like systems based on hydrocarbons –with a secondary loop. A secondary loop system would add cost and reduce the efficiency gains that have been demonstrated with the direct expansion system using HFC-152a. This reduces the viability of this optional refrigerant.

[2] HFC-152a: 17.4 kJ/g versus propane: 50.3 kJ/g

[3] According to this expert there is no data available of incomplete combustion energy which is based on well defined measurements, which can be validated for HFC-152a as well as for propane, and which can be applied to car fires.

New Technology: "CO_2 as an alternative refrigerant"

Presented by Robert Mager (BMW)

Discussion

Industry representatives pointed out that leakage of CO_2 systems are not an environmental issue. Leakage is a warranty issue and has to be solved as a technical issue. While car manufacturers, component suppliers and research institutions have demonstrated that CO_2 systems perform well, their reliability needs further improvement. Many pointed out that at lower ambient temperature levels CO2 systems are more efficient than enhanced HFC-134a. On the other hand at higher temperatures (above 35ºC) the coefficient of performance of (COP) of CO_2 systems is to some extent lower than that of an enhanced HFC-134a.

Questions were raised about the availability of the systems commercially in case all technical problems would be considered as solved. It was anticipated that 4-5 years were needed to fit a CO_2 system commercially into a car. It was suggested that mass production could start by 2008

Problems with the leak detectors were pointed out: e.g. infrared technology used for leak detection was not considered to be appropriate but is used also today and systems using helium can be used for leak detection for only some CO_2 systems. One expert mentioned the spectroscopy method. Some suggested that the "bagging", "wrap-up" or "soap film" method could be used for leak detection and measurement purposes, but these would not be precise methods.

Many brought up what the impact of the introduction of CO_2 systems would be on developing countries. Some were raising the issue of possible energy penalty (due to hotter climates). Some industry representatives indicated that even under high heat load condition places the average annual MAC operating temperature is below 35ºC and CO_2 systems can have annually a lower fuel consumption when compared to actual or enhanced R134a technology. Some participants asked how (higher pressure) CO_2 systems would be serviced in developing countries. An industry representative responded that as CO_2 leakage is not an environmental issue it would be possible to construct CO_2 based MACs to allow topping up in countries with poor service personal training levels. Industry representatives pointed out that CO_2 is a cheap refrigerant compared to HFCs and is not protected by patents.

Some pointed out the higher cost of CO_2 systems. On the other hand some others pointed out to the fact that in a CO_2 system the faulty use of CFCs or HFCs could not cause a technical risk to people, because CFCs or HFCs would not work in a CO_2 system. The possibility of using in today's HFC-134a-system raises a higher hazard potential, because they do not have safety features for flammable refrigerants.

One regulator said that he has understood that while refrigerant (CO_2, HFC or hydrocarbons) plays a role in determining the fuel consumption and

related CO_2 emissions due to MACs, it seemed unclear to what direction this was pointing. In other words, it seemed that in some cases one refrigerant was doing better while in other cases another was performing better. Further, it seemed that the design of the MAC including the components (compressors, evaporators etc.) that were used seemed to have a more significant impact on the performance than the choice of refrigerant. He asked whether there was general consensus about this among the participants and got from the vast majority an affirmative response.

Summary of the discussions

The chair summarised the advantages and disadvantages of enhanced HFC-134a, HFC-152a, and CO2 mobile air conditioning systems based on the presentations.

HFC-134a systems

Advantages

HFC-134a has the advantage of being a known and established technology. Such systems are widely used, and the refrigerant is non-flammable, which from a safety point of view is important. It is also a non-toxic fluid. As demonstrated by the SAE Alternate Refrigerant Cooperative Research Project (ARCRP), there is a potential for improving the energy efficiency. In addition there are various ways to reduce direct emissions.

Disadvantages

On the negative side, however, HFC-134a has a Global Warming Potential (GWP) of 1300, and the cost of recycling and recovery of the fluid is very high. There are also costs involved in bringing about improvements to reduce leakage during manufacturing, use and disposal of the system. Even though the refrigerant is not very expensive as such, there is a tax imposed on HFC chemicals in some countries, making it quite expensive. Compared to CO_2, HFC-134a is inferior as far as heat pump operation is concerned, and it also requires larger size of components (compressor, tubing) than CO_2.

HFC-152a systems

Advantages

HFC-152a has the advantage that the system is very similar to the HFC-134a system, if direct expansion of a flammable fluid gives acceptable safety. Due to safety concerns an indirect loop may be necessary to avoid the risk of flammable refrigerant entering the passenger compartment. There is a potential for improved efficiency in direct expansion systems, but energy efficiency is likely to be reduced if an indirect system is required, due to extra temperature differences. HFC-152a has a GWP of 140, and the refrigerant charge will be lower due to lower liquid density and the emission rate may be reduced due to the HFC-152a properties.

Disadvantages

On the negative side the main problem is the flammability, giving safety concerns when using HFC-152a. The installation of solenoid valves before and after the evaporator may reduce the amount of flammable refrigerant entering the cabin through the evaporator if a leakage occurs. If this does

not provide adequate safety, an additional heat exchanger and a secondary fluid circuit will be needed. This will increase costs, and the size and weight of systems. In a fire or when it is ignited, HFC-152a can generate hydrofluoric acid gas, which is a safety concern that has to be addressed, although it is not clear whether this is a significant issue. HFC-152a would need to be recycled and recovered. Being a flammable fluid it would require changes in the production and service/maintenance, and the safety of production and servicing staff need to be considered. Training of production and servicing personnel in handling of a flammable refrigerant will be necessary.

CO_2 systems

Advantages

Carbon dioxide (CO_2) has a GWP of 1, and from an environmental point of view this is an important advantage. Some argue that the effective GWP is zero since the gas is recovered from waste. CO_2 is not flammable. CO_2 systems have shown good heating up performance at winter conditions, and more rapid pull down of temperature in cooling mode, i.e. it is able to reduce the passenger compartment temperature quicker. The size of compressor and lines becomes reduced, giving advantages in packaging. With CO_2, the refrigerant recycling cost could be eliminated. There are potential cost savings in the heating system for the car, and the fluid itself also has a low cost.

Disadvantages

On the negative side, CO_2 requires a completely new system with new components, new circuiting, and new controls. The system needs development, and also needs some safety equipment to help prevent harmful concentration of CO_2 in the passenger compartment in case of a sudden leakage. CO_2 systems are predicted to have higher production cost than the other systems, and there are still unresolved issues for the flexible hoses. The system needs an internal heat exchanger in addition to the components used in "standard" systems. Data shown earlier indicate that the weight of the system may increase somewhat, but this is uncertain. The open technical issues can be solved within the next 2-3 years according to the presentation of the CO_2 team. Then there is the discussion of efficiency, where the full potential of CO_2 systems in cooling mode needs to be demonstrated in practice. Good leakage sensing methods are needed in order to introduce CO_2 systems. Charging and maintenance procedures need to be changed, and training of personnel is required.

Comments

Chair’s comments on the advantages and disadvantages, and some key questions were:

Costs

It is important to consider the full picture in relation to costs. In addition to the analysis already undertaken we need to include cost-related factors need for:

- training
- recycling/recovery
- refrigerant charge
- refrigerant tax
- inspections
- integrated heating functions.

Once we have information on all cost-related factors then we can come to a conclusion.

HFC-134a systems

A key question here is the cost of improving HFC-134a energy efficiency and reducing refrigerant emissions (development, production, servicing, scrapping). The consequences of export of new or used cars using HFC-134a needs to be considered, even though we are discussing regulations for the EU, we need to consider whether the emission scenarios will be valid for cars exported to areas with less advanced regulations and practices. The situation is still unclear regarding irregular emissions and how they are to be controlled. Such emissions may well go unaccounted for.

HFC-152a systems

Regarding HFC-152a and other flammable refrigerants it is not clear whether car manufacturers actually will use them or not. If manufacturers are against this approach there is no point in developing this technology further. There is also the issue of whether HFC-152a will be available as a refrigerant. The fluorocarbon producers may not want to offer flammable refrigerants due to liability concerns. Perhaps the key question is whether HFC-152a needs an indirect system or could a direct expansion system offer good enough safety? There needs to be agreement on the extent of safety equipment required for HFC-152a, and what the cost implications would be.

CO2 systems

Similar questions can be posed for CO_2 regarding the safety equipment and cost implications. Also the actual figures for additional production cost of CO_2 systems in serial production needs to be evaluated. In addition we need to reach a consensus regarding the energy efficiency of CO_2 against other systems. The efficiency is not so much about the fluid but about the investment that goes into making an advanced or enhanced system. So the question of efficiency is very much about how large, complex and expensive the system is.

Finally heat pump functions are important to discuss – to what extent should these functions be taken into account. If heat pump capability is included in the analysis, the cost-effectiveness of different options is likely to change.

Discussion

One industry participant considered that the cost of the enhanced HFC-134a systems whereby the direct and indirect emissions are reduced by 50% and 25%, respectively, would be in the region of €20. He also considered recovery and recycling of HFC-134a feasible. Another industry participant stressed the problem that lay with the quality of servicing and training. He also expressed the view that, by the time cars are around 8 years old, the air conditioning system stops working, and there is no incentive for owners to maintain their systems because of the high costs of components. He agreed with that effective recovery and recycling was perfectly feasible, but, but the key lay in the training or service staff and ensuring that proper equipment are used to carry this out. Another industry participant suggested that one additional advantage of the CO_2 technology is that it could not easily be retrofitted with CFCs unlike HFC-134a systems.

One participant representing the fluorocarbon producers pointed out that the industry was willing to provide data on the environmental impact of the use of HFC-134a in MACs, but because of the nature of the distribution it is impossible to determine in which particular sector the fluid is being used. He added, that, however, there are some estimates available.

A participant from an environmental NGO was concerned that there was no opportunity to discuss hydrocarbons systems. He considered that this option should be explored so that we could understand the advantages and disadvantages of such systems.

The chair pointed out that if the safety assessment of HFC-152a systems meant that they would have to use an indirect system, then it would be right to consider using hydrocarbons?

One industry participant believed it was possible to eliminate any kind of invasive service by making certain design to the system. He also felt that using polyol ester (PE) lubricant rather than polyalkylene glycol (PAG) maybe a barrier to service, and that maybe more efficient compressors can be built with PE lubricant.

A representative from the Commission summarised the discussion. He considered that there seemed to be a consensus about a certain number of issues:

1) Leaks are inherent, but the industry claimed that enhanced HFC-134a systems could bring down fugitive emissions by 50%. This would bring down emissions from 80-90% of lifetime emission (if refrigerant was changed to HFC-152a) or 100% (if refrigerant was changed to CO2) to 50%, but emissions would still be there. It is interesting to have these systems if they do not involve servicing, but can industry envisage systems that would not need servicing for 12 or more years?

2) The price of maintenance may exceed the price of the system.I t is important to consider these costs and not just the costs of enhanced or alternative systems.

3) Greenhouse gas leaks are a risk for the environment.

4) We need to improve the standards for maintenance, through better training etc. Nevertheless, it is extremely difficult to control and monitor the quality of servicing. In the past the car manufacturers had more control over the after sale car servicing, but now that control is in the process of being diminished. Thus, there is a limit to how much can be achieved since we do not have the means to control, but we need systems that are effective and free from the danger of poor servicing.

5) Regarding increased use in developing countries and its consequences, it is not clear whether the allegation that CO_2 systems would be more difficult to operate is a view shared by all.

One industry participant claimed that it was definitely possible to design HFC-134a systems that do not need recharging for 12 years.

The Commission representative pointed out that sometimes the way the systems are designed means you have to dismantle parts of the AC system for accessing other components, which damages the AC line and you put in a replacement line which may be the wrong one, and that may end up causing a problem.

In response, the industry representative explained that this was a packaging issue in the design of the car. In placing the components, people in automotive industry and product development people know that there is a daily ongoing struggle between all the subsystems to get a place in the engine group. It might help if we get pressure to come up with an extended period warranty, but he believed there is agreement that the probability that some goes wrong increases the number of times the car goes for servicing.

A representative from the servicing sector stressed that there were no incentives for poor servicing since high labour costs push the mechanic to do efficient work and use efficient repair methods. It is economically advantageous to be well educated, well trained and well experienced in repairing and servicing air conditioning systems in cars since a consumer comes with a fixed budget and is not willing to pay for that trial and error.

One expert from academia expert was concerned about systems that may last 12 or 15 year without recharging. He said that that everything is possible in theory. If we look at thermoelectric systems for cooling there will be no leakage, but then you have to ask what type of system would be the efficient system and its costs. Everything here is based on cost-effectiveness and how much money you are willing to put into developing a system.

The chair pointed to the question raised about developing countries. He thought there were several different viewpoints. If we require 5-10 years without any servicing in the CO_2 system this would put very high demands on leak tightness and high demands on servicing to avoid any kinds or problems with the system. This might be a disadvantage if you use the system in developing countries. On the other hand, the CO_2 system uses a harmless and inexpensive refrigerant that is readily available everywhere. If you accept that and recharge the system from time to time then there is no problem.

A representative from the servicing sector believed that many of the developing countries actually have a greater need for refrigeration and therefore their craftsmen will be equally skilled if not more skilled than some of our in CO_2. Therefore, it is not a challenge to look out for servicing of these systems as long as the equipment to work with and the refrigerant are available.

One industry representative believed that cost reductions in CO_2 systems will lead us to the same number of cars and margins as we have today and the complexity of the CO_2 system will be reduced and it will be an application in EU and the rest of the world.

One regulator was worried that if we developed only HFC-134a systems there was a risk that developing countries would move back to CFCs because the refrigerant is cheaper and more readily available. He asked whether car manufacturers would be ready to offer air conditioning free of charge to the consumer for the lifetime of a car, and for the least damage to the environment. Which system would be used, assuming that the manufacturer would bear all the cost of servicing, training and so on? Keeping in mind minimum cost to the environment, what would be the preferred system applied?

In response, an industry representative agreed that in some cases they are reverting back from HFC-134a to CFC-12. In some systems that works, and in some systems the results are catastrophic because the hoses used are not compatible. The second question was interesting but his initial view was that industry would probably continue on the path we have taken on improving the present HFC-134a systems. And eventually evaluate HFC-152a for being a good alternative or not.

Another regulator doubted the claims from car producers that they can design system with no leakage for 12 years, since mechanics have been seeing a leakage rate of 12% for a number of years.

A representative from the Commission concluded this discussion point by noting that controlled losses are around 57 grams per year. According to the industry, the enhanced HFC-134a system could reduce these to 35-40 grams, which is a reduction by 30%. So even with the best system

available we still are not getting a huge reduction. Is that kind of reduction significant? If you see the whole package, is it significant?

In response, an industry representative said that there is also room for a 30% reducing in servicing emissions, which needs to be taken into account. As part of the overall package the reductions in controlled losses can then be seen as significant.

In conclusion, one regulator noted that everyone here agrees that in order to bring the next technology to market it takes 3-6 years, and in the coming years cars will have new HFC-134a systems. This will lead to a 50% reduction in direct emissions and 25% reduction in the fuel use for this system, and for a cost of about €20. On the other hand, there would be €5 or €10 from the fuel saving, and the tightness of the system would avoid at least one service procedure over the lifetime of the vehicle, which would be a €100 or more. This is looks very cost-effective, but regulators need to consider what we can do to create incentives for the new technologies to be introduced into every car sold starting immediately.

Session 4: Conclusions: The way forward

Chaired by Jos Delbeke, Director of Air Quality, Climate Change, Chemicals and Biotechnology, Environment Directorate-General

Introduction

The chair introduced the concluding session by first reflecting some of the key points that had emerged during the two days. First, the conference has been organised as part of the tradition of the Commission to involve stakeholders and come up with policy solutions. He noted that tremendous progress has been made to curb greenhouse gas emissions in agriculture, waste, industry and energy sectors: greenhouse gas emissions from these sectors are declining. However, the emissions from transport sector are continuing to rise, and rapidly. He said that the stakeholders from other sectors are constantly asking how come they have to reduce emissions while transport sector is increasing them. This is becoming politically an untenable situation.

He also pointed out that the tendency in some developing countries to go back to using CFC-12 as a replacement for HFC-134a is very alarming.

Overall, the purpose in this concluding session was to find what kinds of win-win solutions could be found for the society, and specifically what the public regulators and private sector should do to curb greenhouse gas emissions from mobile air conditioners.

When considering different policy options, the chair outlined the following five parameters to see what could constitute a good policy measure:

1) **Environmental effect** of one refrigerant compared to the other. What kinds of emission reductions are to be considered?
2) **Cost-effectiveness** has a double notion: (i) short term cost effectiveness of what we have today and (ii) the need for having long-term, long lasting solutions. New technology is needed to solve problems, and the problem at hand is a long term one. Europe has already achieved a lot to reduce greenhouse gas emissions because it has found cost-effective solutions. Solutions are required that are not only lasting in the medium and long term but are cost effective and environmentally conducive.
3) **Practicability.** Concerning MACs, it does not seem possible to have a "perfect" leak free system, and major leaks occur due to servicing of the car (or the MAC itself). Further, there is the developing country dilemma: a large share of Europe's second hand cars are exported to developing countries.
4) **Enforceability.** Is it possible to enforce policies that have been decided? Is it possible to verify them and can the emission reductions be measured accurately? It is possible to construct a "perfect" policy on paper, but if this is not enforced or enforceable, the objective or greenhouse reduction is not reached.

5) **International and trade aspects** are very important to look into. The EU embraces open markets and wants to ensure that they function. The EU is aware of the fact that car markets are global and this needs to be taken into account.

Discussion

The chair pointed out some of the key questions from the consultation paper written for the conference and suggested that some of the key questions would be deliberated in the concluding session of the conference.

Extent of the environmental problem

As the first question the chair asked *"Would it be correct to conclude that the projected life cycle climate performance (LCCP) emissions described during Day 1 are in the right order of magnitude when the impacts of different policy options are compare?"*

The representative of car industry explained that a statement about the order of magnitude will be given by responding to the consultation paper and that there is no way to receive agreement from car manufacturers on figures just presented during the conference. There was no agreement that figures for the "realistic case" should be created by just doubling the figures of the so called "optimistic case". The "optimistic case" can be assumed as the realistic case. Especially figures provided for Denmark seem to be unrealistic. There was general consensus that the orders of magnitude given during Day 1 were correct i.e. that the lifetime leakage rate was between 10% and 20%, although many pointed out that the higher range seemed unrealistically high, given also the contribution made by the chemicals industry that the leakage rate of current vehicle stock in the world is between 10% and 14%

Containing HFC-134a emissions

The chair's second question was *"What kind of incentives and policy instruments should be used to contain HFC-134a emissions?"*

All agreed that anyone handling HFCs should be competent. Thus, garages should have trained and certified staff and they should be licensed to handle the refrigerant and carry out the repairs of MACs. It was recommended that both sellers and buyers and of gas should be licensed and any sales to non-licensed operators should be forbidden. Further, all agreed that if HFCs are used, they should be recycled by certified recycling equipment and that disposable containers of HFC-134a should be phased out immediately.

It was pointed out that car owners have to accept the responsibility of operating MACs correctly. Here public education plays a big part.

The idea of the car manufacturer giving a *"life-long warranty"* for MACs was generally supported and some car manufacturers thought the merits of this idea should be further explored. However, the issue of exports of cars from the EU and raised as a problem because the warranty would become nil and void.

It was noted that economic incentives, such as taxing HFC-134a in Denmark, could be used to reinforce some other policies. In other words, economic incentives are not necessary an alternative to other policies.

It was pointed out that MACs should be checked regularly and, if technically possible, tested. It was suggested that could form the basis for a regular control tool to ensure that the existing MACs leak as little as possible.

"Refrigerant Reclaim Australia" (RRA) Limited is the not-for-profit industry funded organisation that recovers and destroys ozone depleting and synthetic greenhouse gas refrigerants. Through applying an industry-wide levy on the sale of new refrigerant RRA has established a bank of funds, held in trust, with which it pays for the collection, transport, storage and ultimate destruction of unwanted and contaminated refrigerant.

One regulator pointed to the daunting problem to deal with the tens of thousands of garages in the EU with unequal qualities. To organise the training, certification and licensing, as well as policing the system was considered a significant task. Many regulators also pointed to the need to think long term and give the right incentives to the market operators. Many participants were suggesting that regulatory guidance was needed.

It was noted by some that many of the suggestions above were equally important to mobile air conditioning in trains, ships and in stationary air conditioning and refrigeration sector, too.

Need for regulatory guidance

Finally, the chair asked the participants *"Would it be helpful if the public regulator gave the regulatory guidance by setting a environmental target and the incentives to move forward to this. Would this be helpful from engineering and design and policy points of view?"*

The responses to this question were split.

Two industry participants said that one should regulate performance and not a certain type of technology. They further said that there is no need worry, because through on-going projects (for instance under the umbrella of Society of Automotive Engineers) industry is moving forward to improving the containment of HFC-134a emissions and the energy efficiency of MACs. These representatives said that the reason for their optimism was that the competition between companies. They also claimed that a 50% reduction in regular HFC-134a emissions is good enough, and that even further reductions are possible. They also pointed out that if the regulators decided to phase out HFC-134a, one drawback would be that no one would be willing to improve these systems and no innovation would take place.

A regulator pointed out that in warmer countries than the EU, switching to refrigerants, in particular to CO_2, could trigger off an significant increase in fuel consumption and related CO_2 emissions. These could offset the

gains made by reducing HFC-134a emissions due to the phase out. He noted that the debate on fuel consumption of different systems seems to be open and concluded that no contenders should be ruled out but best ones should be promoted.

Some regulators said that the reductions forecast through improved containment of HFC-134a in MACs are not enough. The pointed out that it is very hard for regulators to monitor the servicing sector or the emissions from MACs during use. Further, even if the HFC-134a emissions per car reduced to some extent, this would be offset by the increased number of cars having MACs. In short, much more substantial reductions are needed. These regulators suggested that these issues need to be carefully considered by the top management of the companies that are responsible for placing HFC-134a systems to the market. Because of these reasons, and as there are good alternatives available in the near term, they concluded that it is evident that using HFC-134a is not a viable option in the future.

There was general consensus that regulation of the greenhouse gas emissions from MACs should be technology neutral.

Some industry participants pointed out that hydrocarbons had been looked into by the industry and considered not a viable option. They also pointed out that CO_2 technology has been developed during the past 10 years and is approaching maturity. For the industry to take the necessary steps to introduce this or any other alternative technologies, what is needed is a clear message from the regulators whether they consider the use of HFC-134a in MACs viable in the future. In sum, industry needs clarity, and in case of a transition, also a timeline e.g. to prepare the necessary training programmes.

Conclusion

The chair concluded the session by restating that it is evident that the greenhouse gas emissions from mobile air conditioners are an important problem that has to be solved. Fortunately there are solutions to this problem and they can be implemented at least at the EU level.

He pointed out that servicing and repair were one part of the problem. Some of the possible containment options included technical development of the MACs, inspection of MACs, licensing of persons handling refrigerants, levies and taxes on the refrigerant, incentives to both car manufacturers and garages to minimise leaks. He pointed out that the problem in containing HFC-134a emissions from the mobile air conditioning sector presented a considerable challenge, and it was necessary to consider the practicalities of designing a regulatory framework that would contain the problem effectively.
He closed by saying that it is very important to think in the long term and took note of the fact that many stakeholders wanted a clear signal, including a timeline, from the legislators. He highlighted once again that

the Commission is not in the business of trying to prescribe technologies and that the Commission is aware of the fact that car industry, including MAC industry, is a truly global and competitive business.