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EXECUTIVE SUMMARIES
OF THE PRESENTATIONS

1. CFC Reductions in large refrigeration/air conditioning/heat pump equipment

Presentation by Hans T. Haukas, Div. of Refr. Eng., The Norw. Inst. of Technology, Trondheim (N)

Large size equipment is defined as unit capacities from 100 kW and upwards. It concerns industrial refrigeration, including food processing and storage, chillers for commercial and industrial buildings and heat pump systems for room heating and industrial processes. The CFC consumption (mainly CFC11 and CFC12) within this area is roughly estimated to 6-8% of total world consumption. About 1/3 of this is used for initial charge, while 2/3 is lost through leakage and in connection with service. This fact demonstrates a substantial potential for emission reductions.

Short term solutions (2-5 years) include emission reductions and a change-over to existing refrigerants with little or no ozone depleting effect in new plants.
The main reasons for emissions are rather well mapped, and reductions up to 40% is judged easily possible by IIR members in a recent enquiry. The necessary measures include better routines and improved technical standards, as well as better education and training of personnel. The industry has responded quickly to the challenge. New guidelines for plant construction, service and disposal are being developed, and educational programmes are set up in a number of countries, partly in cooperation with governmental organizations.
Reclaim of refrigerant from large systems may be economically attractive, even with today low prices of CFC, and still more so in the future. Technology and equipment are available, and standards for quality testing of the reclaimed refrigerant have been developed. (ARI).
Reintroduction of some refrigerants from the past (carbon dioxide, sulfur dioxide, methyl chloride etc.) is not of current interest (IIR enquiry). HCFC22 and ammonia, already widely used, are probably the best short term alternatives for large plants. CFC502 can and should be avoided, due to its content of CFC115, which is controlled by the Montreal protocol. CFC12 and CFC502 are to some extent chosen more from habit than due to a real need. Replacement by e.g. HCFC22 in such cases is rather straight forward. Change-over to HCFC22 whenever possible seems to be the main recommendation to the industry from its organizations.

The middle and long term prospects are characterized by possible development along different paths, HCFC22 may well become a cornerstone in the kind of equipment under consideration, or it may be subject to regulations in a future review of the Montreal protocol. No substitute for low temperature applications (replacements of CFC502 and eventually HCFC22) is under testing. FC125 is mentioned as the most likely candidate.

The intended substitutes for CFC11 and CFC123 and FC134a respectively, will probably attain a certain "market share", in spite of indisputable drawbacks as high price (especially important for large systems) and some unfavorable refrigerant properties. Other alternatives are non-azeotropic mixtures, flammable (HC)FCs and non-CFC refrigerants (in particular ammonia, and hydrocarbons). Most of these candidates are new and need further testing. Ammonia and hydrocarbons (particularly propane) are well know refrigerants, however, and represent reliable solutions. In additions they are inexpensive and superior to the CFCs concerning vital refrigerant properties, in particular ammonia.
Hydrocarbons are flammable. Ammonia can burn as well, at high concentrations and within very narrow concentration limits. It is also toxic, but its characteristic smell gives a very early warning. Precautions needed for safe operation of plants with these refrigerants are taken care of by safety codes, and years of good experience is a convincing proof of their safety in practice. Ammonia plants are today more expensive than CFC plants, partly due to the extra safety measures. With increasing prices of halogenated hydrocarbons, combined with efforts to fully utilize the many excellent properties of ammonia, this difference should turn in favor of ammonia.

Industrial refrigeration covers a very wide spectrum of applications, with temperatures from say -10°C to -40°C. Ammonia is already widely used, particularly in large food processing equipment and cold storage. Hydrocarbons are applied in e.g. petrochemical industry. HCFC22 an CFC502 have increases their "market share" for some time at expense of ammonia, particularly in the lower end of the capacity range. Elimination of CFC502/CFC12 through a change-over to HCFC22 is a question of minor technical modifications. To regain market share for ammonia is also fully possible and in fact a better solution, as this completely excludes the use of ozone depleting chemicals.

Large AC equipment consists mainly of chillers with turbocompressor and with CFC11 (lower/medium capacity range) and CFC12. (medium/upper capacity range). HCFC22 is also applied, in particular for the very large capacities. Piston and screw compressors are used to some extent. Full replacement by HCFC22 is in principle simple, by using alternative compressor types in the capacity range below the turbomachines. Low capacity turbocompressors for HCFC22 may be developed as well. Significant change in system efficiency is not expected. As substitutes for CFC11 and CFC12 are under testing, a more temporary move towards HCFC22 (in piston/screw compressors), together with measures to reduce emissions from CFC equipment, is also a possible development. Expected loss in efficiency should be kept in mind, however.
Ammonia is too light for efficient compression in today turbocompressors. On the other hand, it may easily cover the capacity range of CFC11 (up to 8000 kW per unit) in screw

compressors. Development of turbocompressors specially designed for ammonia (high speed impellers) is technologically within reach, however, and a big challenge to the industry.

As for today, hydrocarbons an flammable (HC)FC's (e.g. FC152a and HCFC142b), are better suited for this type of compressor. They represent interesting alternatives to HCFC22 in e.g. large district cooling systems, also in a shorter time perspective.

Large heat pump systems are strongly dominated by refrigerant CFC12, HCFC22 and ammonia are quite limited in use, as the conventional high temperature heat distribution systems (80°C) result in system pressures above upper limit for most standard equipment. The anticipated "drop-in" refrigerant for CFC12, CFC134a, suffers a 10-15% efficiency reduction (provisional data) compared to CFC12, a substantial drawback when energy saving is the main focus. Development of high pressure components (compressors) or, preferably, cost effective low temperature heat distribution systems are strongly needed. Compared to CFC12 and HCFC22, ammonia offers a five percent efficiency increase. The cost penalty in connection with extra safety measures is an element of uncertainty.
In large district heating systems (above 10 MW heat output) a separate building is erected for the machinery. The standards for using ammonia of other refrigerants considered hazardous may then be met more easily within economically acceptable limits. For such systems high pressure equipment (40 bar) is commercially available, and use of HCFC22 in turbocompressors is the most immediate solution. The additional cost compared to CFC12 systems is moderate and the energy efficiency is similar or slightly better. High pressure ammonia compressors are also available (pison compressors), but at a rather high price. Nor is the actual type too well suited for heat pump application. Further development is needed e.g. with respect to turbocompressors for ammonia as already mentioned.
As for large ACsystems, hyrocarbons and flammable (HC)FC's are alternatives to HCFC22 for the largest systems. Energy efficiency is expected more or less equal.
Industrial heat pumps may operate over a wide temperature range, from ambient up to 100°C or more. In such processes flammable and/or toxic refrigerants are more easily accepted. Ammonia is already introduced with good results for several applications in the lower temperature region, though HCFC22 is still more common. With components (compressors) available, ammonia may efficiently cover the whole span up to temperatures where water naturally takes over. The CFC's used today (particularly CFC114) may thereby be replaced.

2. CFC reductions in middle size refrigeration/air conditioning/heat pump equipment.

Presentation by Prof. Dr. Ing H. Kruse, Institute of Refrigeration, University of Hanover, Federal Republic of Germany.

Middle size equipment is defined as unit capacities from about 1 kW up to about 100 kW. Not covered are the domestic refrigerator and freezer sector and other applications in the fractional horsepower range of a compressor unit as well as the industrial big size equipment with unit capacities of more than 100 kW.
Refrigeration Systems in the medium capacity range are used for example in commercial refrigeration for supermarkets, for food transportation systems and in various other commercial and industrial cooling equipments. Besides R12 and R502 and R22 is used which is not mentioned in the Montreal Protocol.

Airconditioning Systems in this capacity range for small and middle size buildings are mainly unitary automatic systems, where nearly only R22 is used.

Heat pumps except those for large office and public buildings, district heating systems and large size industrial applications are within this capacity range, mainly used for one- and morefamily houses. Refrigerants are mainly R12, R502 as well as also R22. This depends mainly of the temperature of the heat sink, that means of the heating system of the building.

Potential measures to reduce the emission of ozone depleting refrigerants in the medium application field of the equipment are efforts to save these substances during installation and maintenance and by recycling processes. These efforts and processes because of the nonuniform kinds of systems and widespreaded applications are not as easily to handle like in small and large size equipment, for which they are discussed in detail. The measures discussed there are valid too for medium sized equipment but are difficult to fulfill, because of the following reasons: Whereas in small size equipment because of the high number of similar systems standardized efforts and industrial recycling processes can be an efficient measure and in large size equipment skilled people working continuously with the equipment are able to serve for efficient emission control, the medium size equipment often is not hermetically sealed and has not standing skilled supervision personnel. So a lot of efforts have to be made from the design point of view to prevent refrigerant from migration into the atmosphere during running and serving the equipment. For instance open type compressors should no more be used with CFC's because the shaft seal seems to be a main leakage source according to the results of the IIR questionnaire. Also the use of flanges should be decreased in favor of connecting the pipes and components by soldering techniques.

As the measures for saving CFC's and their potentials in emission reduction are discussed in the preparations about small and large size equipment, they will not be dealt with here in detail although they are very important measures, especially because they can be considered as short term solutions which may be realized immediately.

A second prospect to decrease the emission of ozone depleting fully halogenated refrigerants consists of the possibility of substituting them by substances with significant less ODP's. Various data base searches for alternative or substitutes showed that there is only a very limited number of fluids for refrigeration, air conditioning and heat pump systems which fulfill the necessary thermodynamic properties.Those fluids can be divided into CFC's and Non-CFC's.

Non-CFC's, which because of their thermodynamic properties could be suitable substitutes are either toxic or flammable of both. This does not necessarily exclude them as refrigerants. Large refrigeration plants are equipped with security devices, are supervised by skilled personnel and are located in special rooms, so that the use of toxic refrigerants like ammonia van be realized. On the other hand small units like domestic refrigerators and freezers are hermetically sealed and the refrigerant charge is very small. Therefore the application of flammable refrigerants like butane, propane of R152a is recently under discussion. The use of those flammable or toxic fluids in middle size equipment is impracticable for nearly all applications. As those equipments mainly are not installed in special rooms and usually are accessible for unskilled people, flammable or toxic fluids are inconvenient in the case that leakages occur.

Therefore, for middle size equipment non-CFC alternatives are less applicable than for large and small size equipments. Because of this reason and as there are good experiences in the past with refrigerants from the CFC-group for middle size equipments it is more necessary to look at non ozone depleting CFC's as alternatives to the fully halogenated refrigerants. These CFC's should be hydrocarbon derivates with hydrogen, fluorine and possibility additional chlorine, if no other solutions can be found. Fluids without chlorine do not affect the ozone layer and hydrogen gives them a limited atmospheric lifetime, so that they do not contribute too much to the greenhouse effect.

The new fluids R134a and R123 under development as substitutes for R12 and R11 are earliest available in a period of some 5 years of more from now. The toxicity tests are still running and there are various problems for example in the field of lubrication which have to be solved first. So these two fluids are only long term alternatives to R12 used in middle size systems as wording fluid and to R11 used in the insulation of those systems, respectively.

As short term alternatives up to now are only the four fluids R22, R33, R142b and R152a on the market. R22 could be a replacement for R502 which contains about 50% R115 and is mentioned by the Montreal Protocol. In this case often modifications of the plant design has to made, i.e. from one to two stage equipment. Only in some applications R22 could be also a replacement for R12, but normally the pressures and temperatures are not favorable under the same working conditions. R23 can be a replacement for the only in small amounts used R13 and R13B1.
R142b is an alternative for R114 and R152a for R12, but both are flammable and so as pure fluids alone they are not a good alternative for middle size equipments.

Mixtures of the already marketed fluids can be possible short term alternatives.

Azeotropic mixtures have the advantage that they show a pure fluids behavior. Normally they are formed both from fully and partially halogenated refrigerants. Therefore, they are not an effective alternative with the necessary small ozone depletion and greenhouse effect. But they van serve as an immediate alternative working fluid with a lower ozone depletion potential than the fully halogenated fluids. So, i.e. the azeotrope R500 is an alternative for R12 with a 25% lower ozone depletion potential, also R12/DME.

Non azeotropic mixtures can reduce the ozone depletion potential much more. They have thermophysical properties between those of their pure components depending of the composition. So, for instance the flammability of one refrigerant can be suppressed by mixing it with a nonflammable refrigerant. For example, the mixture of R22 and R142b is no more flammable at a concentration, which has a vapor pressure level similar to R12. Non azeotropic refrigerant mixtures offer further advantages especially regarding energy saving, as well as pressure and capacity adaption resp. control or in certain application fields simpler system configurations like in lower temperature applications. This is for instance the main reason that they have been used in the majority of the natural gas liquefaction plants build in the last 20 years where the mixture technique has been demonstrated successfully. Refrigerant mixtures of CFC's have now entered the smaller systems like those for low temperatures material testing chambers or capacity controlled heat pumps.

Their main disadvantages is their fractional evaporation and condensation behavior leading to certain separation effects, which need to be taken into account in the equipment design and serving. But the possibility of handling those mixtures in real plants have been demonstrated in the mentioned real applications and elsewhere.

Near azeotropic mixtures are called those blends which show a near pure fluid behavior according to a favorable composition of components.

For instance by adding only a small amount of R22 to R152a in order to achieve the pressure level of R12 to be substituted near pure fluid behavior can be achieved. In this case no separation problems occur but this mixture is still flammable. Other convenient combinations as near-azeotropic mixtures are possible.

Another family of fluid mixtures, which could be used under the aspect of the CFC-ozone problem are the refrigerant solvent working pairs. With the so called compression solution cycle the application range of a refrigerant can be extended to higher temperatures by lowering the vapor pressure in the solution. So far instance R23 and R22 could be used together with a suitable solution fluid in a temperature range, where the pure fluids would show too high boiling and condensing pressures. The equipment for such a cycle is more complex than for the normal compression cycle so that this possibility is more expensive but can be also more energy efficient like using the non azeotropic mixtures.

3. CFC reductions in small refrigeration and air conditioning equipment

Presentation by: L.J.M. Kuijpers, Philips Research Labs, Netherlands

Use of controlled CFC's (principally CFC12) for refrigeration purposes in domestic refrigeration equipment (home refrigerators and freezers) accounts for approximately 1% of the 1986 total global consumption figures for all controlled CFC's. This percentage increases to approximately 4%, if larger equipment (input up to about 2kW) is included. If the quantity of the CFC11 used in the polyurethane foam insulation in this equipment is also included, the latter percentage approximately doubles.

Most small domestic air conditionairs already apply the acceptable HCFC22 (not a controlled CFC) and therefore receive less attention in this paper.

Whereas the above refrigeration equipment, operated on CFC12, uses only a small amount of refrigerant, it represents a substantial part of the global energy consumption. The emission of combustion gases, contributing to the greenhouse effect, is directly related to energy efficiency; thus, energy efficiency is of equal importance for the environment acceptability (from the perspective of ozone layer depletion) and energy efficiency. The remainder of this summary mainly focuses on the use of CFC's for refrigeration.

A number of options exist for reducing consumption of CFC's:

1. savings in production, handling and maintenance, combined with recycling;
2. minimization of volume of the refrigeration circuit and further adaptions in designs;

3. application of substitutes/mixtures, commercially available at present, with higher environmental acceptability (ozone depletion potential significantly less than 1.0);
4. application of non-ozone depleting substances, mostly long term substitutes or other substitutes with certain drawbacks compared to the properties of the present day CFC's.

All of these options either interfere with each other, or have additional shortcomings; therefore choices have to made. A discussion of these options follows.

1. Chemical savings

In the production of refrigerations and freezers savings in the order of 10% may be achieved by careful handling of the refrigerant chemical; the industry is now actively pursuing ways and means to realize these savings.

Small equipments (domestic appliances) requires very little servicing. Larger equipment (mainly detail equipment) is routinely serviced and opportunities for leak reduction, recovery and recycle do exist. According to the results from a recent IIR (International Institute of Refrigeration) questionnaire study, improved quality in handling and equipment design could yield savings in the order of 20-30% of the total refrigerant consumption over the total lifetime of the equipment without considering recycling. By collecting the refrigerant during maintenance or replacement (at the end of the equipment lifetime) this 20-30% figure could be further enhanced.

Recycling of refrigerant used in the circuit of domestic appliances is now being strongly advocated in a number of countries. Also equipment to facilitate this recycling of refrigerant (from the circuit only) has now been developed. Recycling of the CFC11 refrigerant used in the polyutherane insulation after the scrapping af small domestic appliances is also highly desirable. It has been suggested that 30-50% of the CFC11 could be recovered. However, recovery techniques are still under development. On the other hand, it may turn out in the end that incineration would be an alternative that is economically more attractive.

This option has a very important potential, especially when taking into account the already "installed" quantity of refrigerant equipment. Recycling of the refrigerant from domestic equipment can be introduced at short term, especially in developed countries with an suitable infrastructure. However, this may require incentives from governmental organizations.

2. Minimization of Refrigeration Circuit Volume

In most refrigeration circuits savings can be achieved by a reduction of the volumes, e.g. by minimizing liquid lines and condenser geometries, or by applying different principles which induce a favorable redesign. Without noticeably influencing the energy efficiency, a reduction of the CFC consumption in the order of 10-20% of the initial charge should be achievable.

Redesigns in order to obtain this kind of saving should be feasible in the short term.
As the insulation for domestic equipment, savings in the use of CFC11 are possible (e.g. by applying carbon dioxide, which, however, implies a 35% higher conductivity). The acceptance of any proposal will have to remain contingent of overall energy consumption.

By applying the above two options, including recycling, reductions of more than 50% in the consumption of CFC's used for refrigeration are possible.

3. Use of Lower ODP Substitutes

In small equipment reductions of up 30% can be reached by using the azeotropic mixtures CFC 500 (73% CFC12, 27% HFC 152a) or CFC12/DME (87% CFC12, 13% DME); the large savings potential of the latter mixture is due to the low density of the dimethylether component. It should be noted that a still considerable percentage of the controlled CFC 12 has to be applied and that use of these mixtures can never be a final solution. Next, endurance tests are still required for obtaining a 100% reliability in the application of these mixtures.

There is, however, another problem associated with the use of these mixtures. If recycling procedures for pure refrigerants (e.g. CFC 12) are introduced, recycling of these mixtures poses additional difficulties. A separate recycling scheme for these mixtures will be required, otherwise these mixtures will likely be emitted (vented during maintenance or scrapping) as opposed to being recycled.

This is a clear case where options interfere with each other and agreements must be reached between recycling and other initiatives.

High evaporation temperature equipment (e.g. air conditioners), if operated on CFC 12, can and should switch to using IICFC 22. The equipment considered then has to be redesigned. Do, for this transition to occur HCFC22 has to be considered an acceptable solution. Taking into account the most recent data on the ozone depleting effects of HCFC22, decisions need to be taken on the long term acceptably of this chemical without uncertainty with respect to future acceptability and hence availability will impede this transition.

For low temperature food equipment using CFC12, a switch to HCFC 22 would be possible; however, it also requires the redesign of equipment and the efficiency will be lower (5-8%). For a number of cases the temperature in the compressor may become too high, therefore a switch to the azeotropic mixture CFC502 os normally recommended. It will yield a third of the ozone depletion potential (compared to the use of CFC12), due to large percentage of CFC115 in this mixture (50%, ODP 0.6).

Since the use of HCFC22, and also that of CFC 502, requires redesign, a second redesign in the near future to accommodate new substitutes currently under development, will make decision taking difficult. There is therefore a large degree of uncertainly associated with this option.

Combinations of commercially available and acceptable fluids could be applied in the form of NARM's, non-azeotropic mixtures. For their application, R&D efforts are under way. NARM's application could yield depletion potentials below 0.05 and they can be considered as rather short term substitutes.

4. Application of Non-Ozone Depleting Substances

The most promising long term substitutes for CFC 12 is HFC 134a. However, due to toxicity investigations and production feasibility studies, full application will not be likely until 1994.5. Investigations into the behavior of HCFC 134a together with lubricants have been started; special types of oil need to be developed as well. So far a decrease in the efficiency in the order of 5-6% has been established for HCFC 134a; final data are not yet available.

The CFC issue should also provide opportunities. A reevaluation of all involved with the conventional CFC properties, e.g. nontoxicity and nonflammability should be made. There are indications that, in the case of application of flammable refrigerants, e.g. HFC 152a of DME, an increase in efficiency (i.e. a lowering of the consumption) is possible without redesigning the equipment. This also applies to mixtures of these refrigerants with HCFC 22. The use of flammable refrigerants requires a critical consideration of existing standards and also of the logistics and safety provisions in manufacturing, which would require additional capital investments. Nevertheless, this aspect should be paid serious attention to.

New types of refrigerants may still be evaluated in the near future for normal of low temperature refrigeration (e.g. HCF 134 of HCF 143). Their efficiencies are probably better than that of HFC 134a, the commercial production of which is now planned. However, nothing is known about a number of other properties such as toxicity.

New blowing agents for insulation are HCFC's 123 and 141b. Material compatibility studies recently started to determine their future use. However, their insulation quality is generally lower; e.g. for HCFC 123 values of 10-15% for the decrease of the insulation quality have been mentioned recently. And, equal to decisions on long term acceptability of HCFC 22, the same holds for HCFC 123, since its acceptability is based on equal atmospheric chemistry assumption and suitability of the new refrigerants under development.

It should be emphasized, once more, that the efficiency aspect is a very important one in discrimination between options. Application of highly efficient mixtures and flammable substitutes is possible in the short ot mid term, however, final or long term choices will still depend on the acceptability and suitability of the new refrigerants under development.

Conclusions

Good practice in manufacture and maintenance and the possibility of recycling and design improvements to reduce leakage should be considered before taking final decisions on substitutes. These practices can provide reductions in the order of those set out in the Montreal Protocol. It must be recognized that options for further reductions should not be pursued concurrently, since they interfere with each other (e.g. recycling, short term substitutes, efficiency, flammability etc.).

Small refrigeration equipment is characterized by the highest requirement for reliability. Testing of new substances will take time. A considerable time period is needed and is available to make the long term "best choice" for this type of equipment. Although savings may be minor on the absolute sense, a significant effort is being made by the trade associations e.g. CECED or AHAM to study the feasibility of short term solutions. Research into new substances and/or mixtures is being initiated and supported by the International Institute of Refrigeration and many other national refrigeration associations.

4. Hermetically sealed mobile air conditioning systems

Presentation by: Messrs H. Owada, M. Hiraga and R.D. Bandeen, Sanden Corp., Sanden International Inc. and W. Bessler, General Electric Corp., U.S.A.

In recent years the percentage of automobiles that are equipped with air conditioning systems worldwide has greatly increased, for example reaching about 90-95% in the United States. These systems use CFC12 in a vapor compressor cycle and represent a significant percentage of the total consumption of this refrigerant.

As all of these systems employ compressors which are driven from the vehicle crankshaft, and are not hermetically sealed, they utilize shaft seals and static joints and seals which are a major source of atmospheric leaks of CFC12.

A hermetically sealed air conditioning system would be a natural consideration for improvement to the ozone depletion potential, for this would eliminate the shaft seal and static joints and seals. Further, the rubber hoses which serve as flexible connections to the engine mounted compressor, could be replaced by metal tubing and this would eliminate the refrigerant emissions by permeation through the hose material.

The apparent difficulties of power losses involved with the alternator and the compressor drive motor, which are not used in the current mobile air conditioning system must be minimized to make such a system possible. Even minimized losses are still additional, therefore, the total vehicle design must be reviewed to reduce the heat influx to the passenger compartment, and to given more favourable conditions to the condenser heat dissipation.

This paper discusses the feasibility of an electric system and gives preliminary test results using CFC12. And consideration to an HCFC22 system is given.

DISCUSSION

Hermetic Compressor - A semi-hermetic scroll compressor was built with a brushless CD motor. Because system efficiency is improved by controlling the pumping capacity continously to a given load, a shaft speed control method was used. The scroll compressor mechanism was chosen for its high isentropic efficiency.

System Simulation Test - In a wide range of speeds, various heat loads and air velocity conditions were imposed upon the heat exchangers to find that electric power of 2.7 kw was required at maximum to be compatible with the current "open type" system in cooling performance. The air conditioning load to the engine was calculated as 5 horsepower or more when the alternator loss is accounted for, compared with 3 horsepower for the current system.

Vehicle Heat Chamber Tests - Tests were conducted using a 1600cc passenger car and 96 volt alternator and motor. The horsepower requirement of the electric system was compared with the conventional air conditioning system, baseline, equipped with a 155cc wobbleplate type compressor, SD709.

The basic system was a thermal expansion valve type and the heat exchangers and other components were common for the two tests. The heat chamber conditions were: 38°C, 50% relative humidity, 700 KCal/h m^2 heat radiation. And 100% recirculationair mode was tested at 40 Km/h. When no modifications were made to the car, the maximum power requirement was as high as 1.6 times the baseline. With about 30% reduction of the heat influx to the passenger compartment, the maximum power requirement was reduced down to only 20% higher than that of the baseline, when the condensing capacity was improved by 70%. However, the horsepower required for the same cooling performance as the baseline was even lower than the original, and the electric power input to the compressor was about 1 kw at maximum. This indicates that, if the heat influx reduction and the use of a high capacity condenser are assured in the car design process, the hermetic system is quite feasible.

HCFC22 - can be used in this system if the compressor displacement is optimized for its higher volumetric refrigerating effect, but an improvement of condenser heat transfer is recommended to lower the discharge gas pressure.

CONCLUSION

Further development work is required to overcome the heat load increase due to fresh air introduction for ventilation, location of the compressor, impact of NVH, (noise, vibration, harshness), and possible conflict with the car design concept.
On the other hand this new technology may be able to live with the general trend of car electronics and introduction of high amperage devices, and the elimination of the accessory drive belts assisted by starter-alternator technology and may be compatible with a new way of designing a car with integrated air conditioning components and tubing design.

5. Perspectives of Demeon 13/87, a non-flammable, azeotropic refrigerant blend

Presentation by dr. Rudi Koene, Akzo Chemicals, The Netherlands

Demeon 13/87 is the trade name of a non-flammable, non-toxic, azeotropic blend of D.M.E. (Dimethyl Ether) CFC12 to be used as a refrigerant.

Introduced by Akzo Chemicals, Demeon 13/87 is meant as a temporary "drop-in" substitute for air conditioning industry.

Demeon is applicable in existing installations, so no redesign is required.

Because of its reduced CFC12 content, substitution of CFC12 with Demeon 13/87 gives an immediate reduction of CFC12 emissions and thus reduces the potential for stratospheric ozone depletion by over 20%.

In 1983 Akzo Chemicals has initiated a development programme in cooperation with T.N.O. and the technical university of Delft in the Netherlands.

The aid-programme adresses the following areas: Physical and thermodynamic properties, compatibility of materials and safety aspect.

In addition of CFC12 substitution, Demeon has shown increased refrigerating performance of approximately 7% and energy saving of approximately 5% in industrial and domestic refrigerating units.

Theoretical and experimental determination of thermodynamic properties and azeotropic behavior were subjects of study.

Compatibility tests of materials comprise metal corrosion and wear tests, protective (aqueu resistance on electrical wires and hose permeation).

Other items of study are thermal stability of compressor oils and Demeon, solubility and viscosity of blends under compressor conditions.

Safety studies refer to inhalation toxicity of Demeon and chemical decom,position on products generated under high temperatures, flammability characteristics of D.M.E./CFC12 blends with powerful ignition sources.

The aid-programme will be continued with fleet-duration tests of automobile airconditioners and behavior of Demeon under recycling conditions.
"A notice of allowance" has been received from the patent application of Demeon for the U.S.A.

6. Alternatives to CFC use in rigid foam

Presentation by: Mr. S.O. Anderson, United States Environmental Protection Agency.

Introduction

Chlorofluorocarbons are used in the production of a wide range of foam products including package materials, building insulation, and refrigerator insulation.

Industry and government in the United States are coming to the consensus that a complete phase out of CFCs and halons is necessary to protect stratospheric ozone. The Alliance for Responsible CFC Policy, representing major U.S. CFC producers and users supports a complete phase-out as alternatives become available. The Dupont Company, Allied Corporation, Pennwalt Corporation, and ICI Americas have announced goals of the complete phase-out of all fully halogenated CFCs, perhaps by the end of the century. These manufacturers of CFCs and halons represent 85% of U.S. CFC production and 90% of U.S. halon production.

The polyurethane foam industry has recently made considerable progress in adopting and developing alternative products and chemicals to replace or reduce CFC consumption. The chemical suppliers and foam manufacturers are in the process of developing alternatives, and targeting commercialization in time to allow a complete phase-out of CFCs in foam by 1993. The U.S. polystyrene foam packaging industry will voluntarily stop the use of CFCs in their food packaging by December of this year. A major polystyrene foam insulation manufacturer has also pledged to eliminate the use of CFCs. In a refrigerator sold by one of America's largest refrigerator manufacturers, vacuum foam panels containing no CFCs have already been introduced. This refrigerator is being sold in California where strict energy efficiency is required by law. However, additional technical developments will be necessary before insulation products are able to equal or better the efficiency of certain CFC-blown foam insulation applications.

This paper will discuss the use of CFC's and alternatives to their use in the polystyrene foam packaging industry, the polystyrene foam insulation industry, and the rigid polyurethane foam insulating industry.

POLYSTYRENE FOAM PACKAGING

Rigid extruded polystyrene foam sheets are used to manufacture disposable packaging products such as carry-out food containers, egg cartons, and disposable plates, cups, and bowls.

Polystyrene foam is produced by an extrusion process in which polystyrene resin is melted in an extruder and CFC12 or an alternative "blowing agent" is injected under high pressure into the extruder. The blowing agent is dispersed in the melted polystyrene. As the mixture leaves the extruder, the blowing agent volatilizes, causing the plastic to foam. Until this year, half the disposable packaging products that were produced were made with CFC's and half were made with hydrocarbon blowing agents. Today, there are a number of chemical and product alternatives to CFC12 as a blowing agent for foam packaging.

Product Alternatives

Polystyrene foam sheet competes with many other disposable packaging and single service products, including paper, cardboard, solid plastic, metal foils and laminar composites of foil, plastic film and paper. Any of these substitutes could eliminate CFC use in food packaging applications.

Chemical Alternative: HCFC22

The U.S. food service industry has developed foam food packaging using HCFC22 as a blowing agent. This new technology has equivalent costs to foam made with CFC12 and existing manufacturing plants can easily be modified to utilize this new process. HCFC22 is approved by the U.S. Food and Drug Administration (FDA) as an alternative blowing agent for use in food packaging. HCFC22 will reduce the ozone depleting effects from food packaging production by approximately 95%. The use of fully halogenated CFCs in food packaging will be completely halted in the United States by December of this year. A more detailed presentation by the U.S. Food Packaging Institute at these Hague Meetings will describe how the agreement to eliminate the use of CFC12 in food packaging production was reached between U.S. industry and several of America's leading environmental public interest organizations. The technology is available world-wide.

Chemical Alternatives: Hydrocarbons and HCFC 142b

Other existing chemical substitutes include hydrocarbon blowing agents (e.g. pentane and butane) and HCFC-142b. Hydrocarbons blown foam is virtually identical to CFC-blown foam.

Hydrocarbons are flammable and are local air pollutants, however, and thus are under stringent emission controls in many areas.

HCFC142b is a chemical which is commercially available and has been identified as a possible blowing agent alternative for foam packaging applications. Development work is necessary to determine if HCFC142b is a viable CFC12 substitute.

Chemical Alternatives: FC 134a

In the long term, stratospheric ozone would be best protected by the use of chemicals that have no ozone depleting potential. The U.S. EPA believes that HCFC22 is part of the solution to stratospheric ozone depletion, but it is not the final answer. Because HCFC22 is not fully halogenated it has a very low stratospheric ozone depletion potential and is therefore a good interim substitute for conventional CFCs. The foam packaging industry expects to find and use a chemical substitute that has no ozone-depleting potential. One likely alternative is FC134a. However, in the U.S. before use in food packaging, any alternative blowing agent will need to undergo complete toxicity testing, development, and obtain the approval of the U.S. Food and Drug Administration,.

POLYSTYRENE FOAM INSULATING BOARDSTOCK

Rigid extruded polystyrene foam is blown with CFC12 and is made into boardstock insulating material.

Product Alternatives

Current alternatives to foam boardstock as insulation include a host of product substitutes, including: fiberglass board, perlite, expanded polystyrene, fiberboard, cellular glass, insulating concrete, rock wool, vermiculite, gypsum, plywood, foil-faced laminated board and insulating brick. These substitutes require greater thickness to provide equal energy efficiency, however.

Chemical Alternatives

Dow Chemical, a major producer of extruded polystyrene boardstock, recently announced that beginning in 1989 it will substitute partially halogenated chemicals such as HCFC22, for conventional CFCs in its manufacturing process. This substitution will include all plants-domestic and international.

In the near term, manufacturers of boardstock might be able to reduce the use of CFCs by switching to chemical blends and polystyrene boardstock with a chemical substitute such as FC134a. Foams blown with FC134a may have similar insulating characteristics to those blown with CFC12. U.S. industry is also considering HCFC142b as a blowing agent for this application. HCFC142b is available in commercial quantities from Penn Corporation. The Du Pont Company has also announced plans to produce HCFC142b.

RIGID POLYURETHANE FOAM

Rigid polyurethane foams are cellular materials used primarily as insulating products. The foams are produced by the volatilization of a liquid CFC, typically CFC11 or CFC12, within a liquid plastic.
The volatilized CFC forms the cells of the polyurethane foam and the hardened plastic forms the cell walls. CFCs are an integral part of the insulating foam.
They provide the low thermal conductivity that makes the product more energy-efficient than other insulating materials of the same thickness. Most of the CFC used in this process is contained in the closed cells of the rigid foams. Thus, rigid foam slowly emits CFC over the life of the product and after disposal.

One category of rigid polyurehtane foams includes rigid polyurethane bunstock and laminated boardstock, which are primarily used as insulating materials in building and industrial construction trades. Another category includes poured and sprayed foams, which are made from the same basic materials as bunstock and boardstock. Poured foams are used to fill walls of refrigerators, freezers, refrigerated tanks, railcars, and the walls of buildings and door cavities. Sprayed foams are typically used for roofing applications and for rigid thermal insulation after construction has been completed.

Many alternative products are currently available for use as sheathing or roof insulating materials. Products such as expanded polystyrene foam beadboard, fiberglass, fiberboard, and gypsum can be used instead of polyurethane foam.In some cases, wall and roofing insulation can be made thicker to achieve the same insulating capacity as at present, but some use of CFC blown foam is likely to continue where it provides the only means of meeting a building's energy efficiency requirements.

Product and Technological Alternatives

Some product substitutes are available for poured or sprayed foam, depending upon the specific use. In applications such as packaging and flotation, product substitutes are numerous.
Combinations of plastic and non-plastic materials can provide equivalent degrees of cushioning, shock resistance, and water resistance. At present, however, no other insulation materials have equivalent ability to be poured or sprayed.

The most promising substitutes for application in the walls of insulated refrigerators and freezers are vacuum panels. Vacuum panels have the potential of doubling or tripling the insulating efficiency of CFC-blown foams, actually increasing energy efficiency. In the United States, domestic refrigerators are the largest electricity consuming appliance in the home.

They consume 5-7% of the energy used in U.S. buildings. Electricity consumption for refrigeration in developing countries may represent an even larger share of national electricity use.
The increased energy efficiency of ozone-safe refrigerators can make them more attractive and affordable.

In the United States, General Electric Company has limited capability of producing and using vacuum panels in commercially available refrigerators. These panels are then installed in refrigerator walls and foamed in place to provide rigidity and to protect the plastic membrane from failure. The foam placed around the panels need not be CFC-blown because the principle role of the foam is to strengthen the refrigerator casing.

Thus the foam can be blown with blowing agents that to not deplete stratospheric ozone. So far, General Electric is test marketing this new technology only in their most elaborate home refrigerators sold in the California market where energy efficiency standards are very stringent.

Japanese manufactures have in the past produced refrigerators using similar vacuum panels but have experienced problems with loss of vacuum as appliances age. Table 1 lists some of the companies and research groups throughout the world that have active vacuum insulation projects. The Solar Energy Research Institute in Golden, Colorado is organizing a consortium including the U.S. Environmental Protection Agency, the U.S. Department of Energy, the California Energy Commission, and several electric utilities to fund commercialization of rigid sheet metal vacuum panels using glass spacers.

Before they are widely accepted as alternatives to CFC blown foams, these vacuum technologies must still prove that they can meet performance, durability, and fabrication criteria. However, they offer the appealing advantage of significantly increased energy efficiency while at the same time protecting stratospheric ozone.

Short Term Reduction of CFC-11: Water Blown Polyurethane Foams.

Water blowing of polyurethane foams has been used to a limited extent for a number of foam applications. In water blown foam (partial carbon dioxide blowing), the amount of CFC-11 used in the formulation is reduced and compensated for by the addition of an appropriate quantity of water to the polyol blend. This water then reacts with the isocyante during foaming to liberate carbon dioxide. (ICI, 1988).

It was concluded that increasing the level of water blowing polyurethane and polyisocyanurate foams offers the most promising short term solution to extending future supplies of CFC-11. (ICI, 1988).

The initial results are very promising. A 50 molar percent reduction of CFC-11 in polyurethane foam production can produce foams with competitive initial and aged thermal conductivities processability or mechanical properties. Polyisocyanurate foams present more of a challenge, but research shows that a reduction in CFC usage by as much as 25% will still achieve excellent foam characteristics. (ICI, 1988).

Future Chemical Alternatives

HCFC-141b and HCFC-123 are both considered promising chemical substitutes for CFC-11 and CFC-12 in rigid foam production. The timing for commercialization of these chemicals is uncertain, but chemical producers currently have the capability of producing HCFC-141b in existing plants. Commercialization of HCFC-123 will require the construction of a new plant or major modifications to existing facilities. In either case, long term toxicity tests have not yet been completed. Development testing is proceeding at a quick pace.

Initial tests with both chemical substitutes show that they are viable blowing agents, but not simple drop-in replacements for CFC-11 (DuPont 1988). For HCFC-141b and HCFC-123 to be substituted successfully for CFC-11, reformulation research will be required. Many chemical suppliers and foam manufacturers have been conducting extensive developmental research to develop a firm data base that will allow for the commercialization of the new blowing agents. While some of this data is available, much of it is in a preliminary state.

Tests show that HCFC-141b and HCFC-123 can be used in all rigid insulating foam applications, including polyurethane foams used for appliance insulation, sprayfoam systems used mostly for roofing applications, and polyisocyanurate foams used in building applications. Data indicates that HCFC-141b is a more efficient blowing agent than both CFC-11 and HCFC-123. Because less HCFC-141b is necessary to blow an equivalent amount of foam as CFC 11. HCFC-141b is an economically acceptable alternative. HCFC-123 is not an efficient blowing agent and requires more chemical to blow and equivalent amount of foam as CFC-11. This makes HCFC-123 a much more costly alternative.

In comparison to CFC-11 blown foam insulation, the alternative blowing agents, as a drop-in, do not produce the same quality foam. However, reformulation and a restructure of cell size may correct many of the negative aspects of HCFC-141b and HCFC-123.

In a comparison of HCFC-141b and HCFC-123, HCFC-141b appears to be a better blowing agent. The positive aspects of HCFC-141b include: HCFC-141b requires approximately 15 wt. percent less than CFC-11 and approximately 26 wt. percent less that HCFC-123. Its projected cost is less than HCFC-123 and could be produced in a modified plant, whereas HCFC-123 may require new plant production (Mobay, 1988). HCFC-141b is a stronger solvent than CFC-11, but is less aggressive than HCFC-123.

Both compounds however caused swelling or complete dissolution of elastomers and plastics. (Mobay, Allied, Dupont, 1988). This is one of the strongest disadvantages of the alternative blowing agents. However, this can be overcome with the development of compatible materials.

Again characteristics and insulating properties of the foam blown with HCFC-141b and HCFC-123 are preliminary. There are indications that both blowing agents produce foam with a k-Factor 5-10% higher than CFC-11 blown foams. (ICI, Mobay, 1988). With reformulations and changes in cell structure, these negative characteristics may be able to be resolved.

One disadvantage of HCFC-141b is that is slightly flammable and can form explosive mixtures with air. The risks from use of a slightly flammable substance can be reduced with proper protective mechanisms. Flammability of the end foam product is also a critical factor and more research needs to be conducted to determine the combustion properties of foam blown with HCFC-141b and HCFC-123.

Overall, research conducted to date indicate that either HCFC-123 or HCFC-141b could be used technically as a CFC-11 substitute, after some reformulation of the chemical components, in the production of rigid polyurethane foams. Because of the slight flammability of HCFC-141b, HCFC-123 may be a marginally preferred option. However, HCFC-141b displays many promising characteristics for a blowing agent, and economics and availability may favor HCFC-141b. In either case, there is much research being conducted to determine the viability of both chemicals as a CFC-11 substitute.

CONCLUSION

The first voluntary phase-out of rigid foam made with CFCs will be completed by the US food packaging industry by December, 1988. Numerous product alternatives are now available that offer equal insulation and energy efficiency at comparable costs but with greater thickness. New alternatives such as vacuum panels for refrigerators may actually increase energy efficiency with energy cost savings off-selling all or part of their added cost. Short term options, such as water blown foams can reduce CFC-11 consumption by as much as 50% in some applications, without a loss of foam properties. Research has shown that HCFC-141b and HCFC-123 are still the prime contenders as eventual replacements of CFC-11. However, there are still significant technical breakthroughs and product performance and durability questions that must be answered before CFC can be eliminated in all rigid foam insulation applications.

7. Current State of Technology in Reducing Usage of CFC-blowing agents in Rigid Foams.

Presentation by Mr. M. Mann, Bayer A.G. (FRG)

Polyurethane and polyisocyanurate foam are used in a wide variety of products with primary applications as insulation material in the construction and refrigerated building and appliance markets. Although small amounts if CFC 12 are used, the primary blowing agent in the manufacture of rigid foam is CFC 11. The status of replacing CFC 11 and 12 in rigid foam formulations used in the major application areas in summarized below:

1. HCFC's 141b and 123 have not been shown to be suitable alternates to CFC 11 but they are not "drop-in" substitutes. New fromulation must be developed to optimize foam properties and system processibility.

2. Toxicity testing for HCFC's 141b and 123 is not complete and projections range from 3 - 5 year before these products will be commercially available.

3. HFC 134a si a potential alternate to CFC 12. Toxicity testing is not completed.

4. HCFC 22 is commercially available and can be used as an alternate to CFC 12 as a frothing agent in rigid foam formulations. HCFC 22 may also be useful in replacing som CFC 11. The effect of aging on the insulation value of foams containing HCFC 22 is not konown.

5. The use of water to partially of completely blow PUR/PIR foam systems is an option with the most potential for short term succes in the reduction of CFC usage in rigid foams.

6. Total substitution of CFC 11 with water is only possible in some application areas (packing, high density foams). For most applications the resulting product properties and end-use performance are not acceptable. Use of water-CFC 11 belnds as a blowing agent is presnetly the primary option for most applications.

7. In refrigerated appliance foam systems a 50 % reduction in CFC 11 usage is possible with increased water levels, but property degradation (slighly higher demould times and 2-values) should be expected. The appliance iondustry plans to begin using such CFC 11 reduced foams in 1989.

8. Formulation changes for products used in the construction industry are complicated by the many differend combustibility standards. The use of water to reduce the level of CFC 11 in the formulation in the range of 50% for some PUR formulations is possible, but an average first step reduction of 20 -30% is more realistic. In polyisocyanurate foam an average first step reduction of 10 -15% is practical. The first industry production trials are underway to determine the specific levels of CFC 11 reduction that are practical for each manufacturer.

9. ISOPA is the European Isocyanate Producers Association and a sector group of the European Council of Chemical Industry Manufactures Federations (CEFIC). ISOPA fully supports the Montreal Protocol as an encouraging international initiative. The members of ISOPA are spending in 1988 around DM 45 million (£ 14 M., $ 24 M.) on research to reduce or eliminate "hard" CFC's in polyurethane products or processes. ISOPA members are committed to replace these CFC's as fast as possible, preferably - where feasible - even at a quicker pace than the Montreal Protocol demands. This paper is supported by ISOPA.

8. Flexible foam: What are we doing to reduce our dependency on CFC.

Presentation by: Mr. C. Barkhouse, Technical Chairman CFFMA, Canada.

Studies underway to reduce and eventually eliminate emissions of CFC's in flexible polyurethane slabstock production involve all combinations of approaches. Some of these are only at the stage of evaluating published process studies, some involve evaluations of new materials just becoming available, and others are looking at process variations. None of these have reached the point of being a fully developed solution yet, and some appear to have little chance of becoming commercially viable. The following is a review of how we view the possibilities at this time.

PROCESS TECHNOLOGY: Any process for RECAPTURING CFC's used in foam making must address the fact that CFC's are evolved in two stages during the production process; partly during the foaming stage and partly during the final cure. The major obstacle is the combination of high vapor pressure of the CFC (R-11 in all cases) and high exhaust velocities. The latter are used to maintain safe levels of TDI in the workplace atmosphere. These two facts combine to require very large and expensive recovery systems.

A variety of CARBON BED ADSORPTION processes have been studied. Because of the engineering problems indicated above, none appear to be economically feasible at this time. There are some specialized developments possibly applicable to new and relatively small plants, which have addressed the problem of highly diluted, high velocity exhaust streams. These include the so-called HYPERCURE process as an add-on to VERTIFOAM technology and the E-MAX process as a variation of the standard slabstock technology. Both of these are directed to making the total volume of exhaust to be treated smaller and therefore the recovery system also smaller. Neither is adaptable to retrofitting to existing conventional foam plants. It is too early to tell how large an impact these may have.

Regardless of technical success in adsorption and possible breakthroughs in economics, there are still many other unresolved questions on process feasibility including quality of the recovered material (suitable for re-use?), difficulties in disposing of spent carbon (a hazardous waste?), generation or aqueous waste streams, and others. The economic impact of handling these has not been evaluated publicly.

CFC SUBSTITUTES: Only two non-chlorofluorcarbon substitutes have received serious consideration. One, of course is Methylene Chloride with a current major market share in the US and Canada. However, pending restrictions on emissions inside the plant atmosphere (Treshold Limit Values) and some existing local bans on outside emissions have effectively eliminated the use of this product from future consideration. The other is the generation of Carbon Monoxide from Formic Acid (the AB process from Goldschmidt) which has not caught on because of problems with toxicity and corrosion.

There are a number of new chlorofluorocarbons containing some hydrogen (to make them less ozone depleting) under development. The two most likely candidates for flexible foam are 123 and 141b. Both have been effective substitutes for R-11 in small scale machine trials. However there are some unresolved problems. These include incomplete toxicity studies as well as incomplete engineering on process development. These combine to a delay in large scale availability as well as continuing uncertainty about process economics.
Projected costs may make either of these unacceptable for general use in flexible foam. In addition there are still unresolved questions on flammability on 141b and on the allowable Threshold Limit Values in the plant atmosphere. Low allowed values would contain most of the same problems as continued use of Methylene Chloride.

CHEMICAL MODIFICATIONS: The two major uses of CFC's are to produce soft foams (at any density) and to reduce exotherm during production of low density foams which use high water levels. Work underway by the raw material suppliers include re-examination of polyol modifications, particularly, tending away from the currently favored heteropolyols (ethylene oxide and propylene oxide) and development of improved antioxidant packages.
The major reason for the development of the currently used products was improved processability and the ability to make firmer foams. Whether these efforts will succeed in permitting production of economically desirable low density products remains to be seen. Work on softer versions include variations on higher molecular weight and lower functionality polyols.
The major problem with high water formulations without any auxiliary blowing agents remains the threat of internal scorch and potential for ignition during cure.

FOAM TECHNOLOGY AND MARKETS: There is a high degree of confidence that technology for producing the whole range of firmness grades without the use of CFC's is either pending or can be developed relatively easily for the mid to high density range of products (1,5 pcf or 24 kg/m^3 and up). Possible elimination of at least some grades in the lower densities deopardizes a large volume segment of the market.

The higher cost of replacing them with higher density foams will make some of these uncompetitive with other products (such as fibers). It is this area of technology for producing low density foams which is under the most intense study.

OTHER TECHNOLOGY DEVELOPMENTS: This section includes the "sky's the limit" approaches, wholly new ideas, etc. Every major raw material supplier as well as the major slabstock foamers are actively following up their own approaches. For obvious reasons none of these have been publicized, and status as well as potential are difficult to estimate. We would hope that at least some of these will appear by mid 1989.

To summarize, there is an ongoing intensive effort in terms of time and money involving all segments of the flexible foam industry. We are in a race against time trying to develop technology which is ecologically acceptable and economically achievable. At this point there is no obvious single solution to the problem. Initial reduction of CFC use will undoubtedly be achieved, without major disruption of the market. Complete elimination will be much more difficult without conceding some significant markets to competitive product.

We hope that in a meeting in the not too distant future, we can present a more confident picture of the developments affecting the health of the flexible foam industry.

9. Technical options for the reduction of CFC use in the production of flexible polyurethane foams

Presentation by: dr. H. Creyf, chairman EUROPUR Technical Committee

Flexible polyurethane foams can, according to the production technology be divided into two wide fields : blockfoams (called slabstock) and molding products. Blockfoams are mainly used in furniture and bedding, and to a lesser (but growing) extend in technical application. Molded foams are mainly used in the automotive sector (seats) and in furniture.

The blockfoam sector is organized on a European level under the EUROPUR organization. It uses some 8000 tonnes of CFC's per annum. Molded foam producers have no European organization, and it is not known how much CFC's are used.

In polyurethanes in general, the normal blowing agent is carbon dioxide. In some cases however, the use of some extra (physical) blowing agent is necessary (e.g. when lower densities are to be made, or when extra softness is required in higher densities). Mainly two products are known : CFC 11 or, to a much lesser extend : methylenechloride (MC).

Soon after CFC's were suspected of harming the ozone layer, the flexible polyurethane blockfoamers have been involved in research to substitute CFC 11.

Some of the studies have led to technical possibilities which are at this time being evaluated further.
The situation as to the technical substitutes can be summarized as follows:

- further replacement of CFC's by methylenechloride is discouraged in Europe for technical and environmental reasons;
- in the higher density-foams, trials are being made with so called "soft-polyols";
- AB-technology : a new revised version of this technology is being evaluated by industry;
- the recovery of CFC's on active carbon beds is under further evaluation. It is now technically possible to recover some 40%;
- enhancing foam densities is another way of saving CFC's, but foam producers can only agree to lower CFC use in this field, when authorities ensure them that imports from other countries will be banned;
- on a longer term, hard CFC's could, where still applicable, be replaced by soft CFC's. Here however, foam producers are dependant on the research of their CFC suppliers.

As far as molded foams are concerned, the use of CFC's is very much function of the density. Some car companies now want to reduce the use of CFC's as much as possible, and are willing to pay the price increase involved.

10. CFC free food packaging

Presentation by: J.W. Bow, Foodservice and Packaging Institute Inc., USA.

The decision by U.S. manufacturers to phase out the use of fully halogenated CFC's in the manufacture of polystyrene foam products for foodservice is a unique case study of an industry's ability to:
1) identify a problem, 2) explore alternative solutions, 3) take concerted action within a remarkably short period of time.

Within the United States there are approximately 100 companies which manufacture disposable foodservice products serving a market valued at five billion dollars annually. About half of that market is in the area of plastic products, and only about a third of the plastic foam products had utilized CFC's. Fully halogenated CFC's were used as a blowing agent in the manufacture of polystyrene foam products such as plates, prepackaging trays, containers, egg cartons, and certain types of cups. Although the industry only used 3% of the CFC's in the US, individual companies within the industry, working with their chemical suppliers, began to accelerate research into alternatives to fully halogenated CFC's shortly after increased evidence appeared of a linkage between certain CFC's and stratospheric ozone depletion.

In the United States, many individual companies using polystyrene foam foodservice disposables sought to find substitutes for CFC-related products. This was important because of a high sensitivity to environmental matters. The problem was: 1) how to do it, 2) how to evaluate alternatives and barriers, 3) how to meet customer specifications and concerns, and 4) the time frame.

After much study, manufacturers had four options to evaluate:
1) continue to use fully halogenated CFC's, 2) go out of the business, 3) switch to hydrocarbons, or 4) switch to HCFC-22. Mounting political pressure and increasing evidence of a link between CFC's and stratospheric ozone depletion made the first option unacceptable. For many companies, the option of switching to hydrocarbons was also preceded by cost and other factors.

The US Environmental Protection Agency played a key role in facilitating the phaseout by keeping open the options of manufacturers and by highlighting HCFC-22 as "part of the solution to stratospheric ozone depletion.

11. The status of substitute solvents and processes to replace CFC-113 in the cleaning of printed circuit boards at Northern Telecom Limited.

Presentation by: Ms. M. Kerr, Northern Telecom, ltd., Canada.

Corporation profile

Northern Telecom is the world's largest supplier of fully digital telecommunications systems, with consolidated 1987 revenues of US $4.9 billion and net earnings of US $329 million.

Through its subsidiaries Northern Telecom employs nearly 50,00 people worldwide and operates 24 manufacturing plants in Canada, 13 in the United States, one in the Republic of Ireland and two in Malaysia. Research and development is conducted at nine laboratories of its Bell-Northern Research subsidiary, including three in Canada, five in the US, and one in the UK.

Northern Telecom manufactures a wide range of telecommunications equipment that includes switching and transmission systems, fiber optics and communications cable, subscriber switching systems, telephone terminals, outside plant, and other equipment for public and private communications networks.

CFC's Usage

Northern Telecom uses approximately one million kilograms per year of CFC-113 to remove soldering residue from printed circuit boards in the manufacture of its products.

The corporation is committed to a 50 percent CFC reduction in three years, and total elimination as soon as it is technically and operationally possible. That's an industry-leading position - and exceeds the Montreal Protocol or any recently proposed amendments by the EPA. Northern Telecom is building toward total CFC elimination using a full spectrum approach that encompasses new conservation techniques and several alternate processes and substitutes.

Examples of successful conservation methods (and associated cost-savings) are detailed in the paper, which demonstrates how a fast-track management approach is working to solve this problem across a decentralized corporation with global operations.

The paper then outlines the four major thrusts of Northern Telecom's elimination program - stating challenges of each application.

- low-solids fluxes
- alternate processes - aqueous
- alternate process - terpene
- alternate solvents

Also included is a discussion of the corporation's contribution to a joint government/business project (China Lake) that is working to establish reference standards for the cleaning of printed circuit boards and wiring assemblies.

The paper concludes by identifying the longer-term challenges in eliminating CFC's:

- **R&D:** joint research initiatives between government agencies and business;
- **Supplier relationships/R&D:** greater cooperation between suppliers and users in developing and testing substitutes;
- **Manufacturing design:** better co-operation in future between manufacturing process designers and environmental engineers - internally and through company-to company links;
- **International links:** a need for North American industry to establish relationships with, for example, European industry on this issue - the need to learn more about their experience with vapor containment systems.

12. Dry cleaning and metal cleaning solvents

Presentation by: P.S. Dovle, the Norwegian State Pollution Control Authority in cooperation with H. Ahmadzai of the Swedish national Environmental Environmental Board.

DRY CLEANING

The reasons for use of CFC 113

Pure CFC-113 is commonly used for dry cleaning of some textiles as well as fur and leather clothes in the Nordic countries and in some other countries in Western Europe. This review is mainly dealing with experiences in Norway concerning use of CFC-113 for dry leaning purposes.

There are two main reasons why CFC is used for dry cleaning; exposure to CFC-113 is less hazardous to health than most other solvents used and because some textiles cannot withstand the use of other dry cleaning solvents. Although CFC-113 is preferred to perchlorethylene for a number of dry cleaning purposes, only about 20% of the textiles in Norway are being cleaned with CFC-113. The remaining 80% are cleaned with perclorethylene.

Reduction possibilities:

New machines specially designed to reduce release of CFC to a minimum should be installed. There has been contact between users in the Nordic countries and the machine producers in Central Europe to improve the dry-cleaning machines and to design special devices to save CFC. Emission standards and durability standards should be considered.

An other possibility is to reduce the emissions from both existing and new equipment through implementation of better work routines for the dry cleaning process itself and better control and servicing of the machines. To improve the running of the machines, emission dude to filling of solvents should be minimized. All kind of leakages as well as overloading, too short drying time and unsuitable temperatures in any part of the process should be avoided. Routines for removal of dirt after use of the machines should also be improved.
Training of personnel is also crucial to be able to carry out the good intentions described above.
The Norwegian Dry-cleaning and Laundry Association has organized a project to reduce CFC-113 emissions.The main pillars in this project are training courses for personnel and thorough follow-up through book-keeping of CFC-use and reporting of the results to a central control group.

Tho project also supports servicing of the machinery as well as development of CFC-saving equipment and even tries to promote the producers to find alternative solvents of dry-cleaning systems.

Substitution possibilities

The alternative to CFC-113 in dry-cleaning so far is perchlorethylene, but this solvent is hazardous to health and health problems is well known among dry-cleaning personnel. This is the main reason why it is difficult to promote this solvent further as a replacement to CFC-113.

CFC-123 has been proposed as a future alternative to CFC-113, but toxicological and in-use testing have yet to be done.

METAL CLEANING SOLVENTS

The reasons for using ozone-depleting substances

CFC 113 blends and the non-regulated but still ozone-depleting substance 1,1,1 - trichloromethane (Methyl Chloroform), are used as surface cleaners to remove grease, oil and other contaminants from surfaces or parts of mechanical tools, machinery, optical parts and weapons. Cleaning is an essential part of the production or maintenance processes to prepare the surfaces for the next operation, - such as inspection, painting, coating or packaging. The cleaning equipment and system used are similar to the systems used for cleaning electronic equipment.

Loss of halogenated solvents is a function of solvent properties and equipment conditions but is generally estimated to be in the range 0,5 to 4.0 kg/m^2-hr. Enhancing costs and liabilities associated with continued use of chlorinated solvents concurrent with increasing awareness of possible health risk emanating from their use, has motivated industry to actively pursue alternative technology.

This review takes into account a number of important parameters like the ozone depleting factor, toxicity, solubility, flammability, costs etc, of the various alternatives and attempts to identify the potential substitutes and technology for the curtailment of CFC-113 and methyl chloroform in metal cleaning operations.

Reduction possibilities

Increased use of closed cleaning systems and the use of condensers to reduce the evaporation of solvent, may give a significant reduction worldwide. Further reduction may be achieved by reducing leaks and improving the overall operation of existing systems.

Reclamation of waste solvent via on-site of off-site distillation should be available, and efficient destruction of unusable waste solvents should be developed.

Through these measures it is possible to achieve a 80-90% abatement of solvent emissions.

Substitution possibilities

Metal cleaning operations generally use either aqueous or solvent based systems.

Aqueous cleaning (i.a. alkaline, acidic or emulsion based) is increasingly being identified as the most promising candidate. Actual market penetration of aqueous cleaning is estimated at 45% though maximum feasible penetration can be up to 98%.

Substitution of ozone depleting solvents by non-halogenated petroleum/alcohol solvents also has a high technical feasibility. Non-toxic methods exist to avoid the explosion hazards associated with the use of petroleum/alcohols. As such solvents are less damaging to materials and are available at modest costs worldwide, the penetration potential of non-halogenated petroleum/alcohol is estimated to be in the range 70-100%.

The envisaged substitutes CFC-123 and CFC 132b are of interest in some metal treatment operations. Their application in the short term is, however, offset by cost and availability constraint. Since their ozone depletion factors are low, but in their penetration in metal cleaning operation is lower than for the other discussed alternatives.

13. Recovery and recycling of CFC's

Presentation by: J.E. Rodgers, Allied Signal, Inc. Morristown, USA

The recovery and recycling of CFC's currently play a minor role in the overall use patters of CFC's. This is due to several factors, technical, economic and societal. Increased emphasis will be placed on this facet of CFC reduction in the future, both with the current CFC's and with the next generation.

Refrigerant Recovery and Recycling

CFC 11 and CFC 12 are presently recycled in only minor amounts < 1% in the United States. CFC 11, mainly used in large centrifugal water chillers, offers more promise since servicing is often done on a non-emergency basis. CFC 12, because of its higher storage pressure has considerably greater technical problems in recovery. These include improper filling of return cylinders, cross contamination with other refrigerants, and degradation in hermetic burnout conditions. On site recovery and return of refrigerants offers more promise. While there are currently equipment available for recovery, economics has retarded its wide spread use.

Automotive Air Conditioning, which consumed in the USA an estimated 42M kg in 1986 for recharging, is an especially attractive opportunity. Programmes are now being developed to encourage reuse of the refrigerant in this application.

Foam Blowing Agents Recovery and Recycling

The capture and reuse of CFC foam blowing agent (mainly CFC 11) from the process has been technically proven but only a few installations are known to exist worldwide. Carbon Adsorption is the present state of the art recovery technology and has been shown to capture 80-90% of available CFC.

In rigid polyurethane foam production, 90+% of the blowing agent remains in the foam so less than 10% is available for recovery. In flexible polyurethane, about 50% might be available for recovery, the remaining being lost in cutting and storage.

14. Aerosol propellants

Presentation by: Mr. R.C. Knollys, European Aerosol Association.

BACKGROUND

CFC's 11 and 12 have not been permitted in Aerosols in the USA, Norway and Sweden except for exempt products since the end of the last decade. Their use in Aerosols has also ben severely restricted in Canada. In the most significant of these markets, the USA, this has resulted in CFC propellant only being used now in some 5% of aerosols. These are principally for pharmaceutical and some industrial products where the flammability of the alternative could be hazardous.

The Aerosol Industry in the European Community has by voluntary action reduced its use of CFC's 11 and 12 by 30% since 1976. In the light of the new scientific evidence of ozone depletion the Aerosol Industry in these countries is now making rapid moves to replace CFC 11 and 12 for all but a small proportion of the market.

Elsewhere in the world use of CFC will vary according to local situations and the types of aerosol produces, but as a general rule we believe activity on a similar scale so that in Europe can be expected.

ALTERNATIVE PROPELLANTS

(a) CFC 11 and 12 have been used principally for toiletry products (e.g. hairsprays, deodorants), pharmaceutical and industrial/automotive products. They have been particularly suitable due to their low toxicity, non-flammability, good solvency and high specific gravity.

(b) CFC 114 has been used mainly in perfumes and pharmaceutical products as a substitute for CFC 11. In some conditions it is more stable but its price is higher.

(c) Hydrocarbons (propane/butane) have been used for many years for most household products, insecticides and mousses (e.g. shave foam). They are much cheaper than CFC's but are flammable and require more expensive filling plant. They are poor solvents. Odor can be a problem.

(d) Dimethylether (DME) has been used for many years in small quantities. Its performance is somewhat similar to hydrocarbon but it is a good solvent and relatively expensive.

(e) Compressed gasses (CO_2, N_2O, N_2, O_2) are cheap but produce wet sprays. They lose pressure as the aerosol is used up and total pressure loss can result if the aerosol is used at the wrong angle. N_2O is used for edible cream.

(f) HCFC 22 is similar in performance to CFC 12 but with 50% higher pressure and 2 x the cost. With an ODP of only 0.05 it has been identified as a good substitute but its toxicity has not been fully cleared and one supplier has withdrawn it for aerosol use.

(g) CFC's 123 and 134a may prove good substitutes for CFC 11 and 12 once they are cleared for toxicity in 4-5 years time. They will be expensive which may be a barrier to use.

Blends of various of these propellants is possible and used now in practice.

REFORMULATION PROGRESS

Activity can be summarized as follows:

(a) Insecticides, household products and mousses will continue to use hydrocarbon or DME.

(b) Personal products are likely to change to hydrocarbons or DME. HCFC 22 may also be used as a blend.

(c) Many pharmaceutical and industrial products will continue to use CFC 11, 12, 114 but their total consumption of CFC will be small. The possibility of use 123 and 134a will be studied once product is available.

(d) Work will continue to re-evaluate compressed gasses and the possibility of extending their use.

Factors to be managed in such changes include:

(i) Detailed attention to reformulation to ensure satisfactory and safe products in the hands of the consumer.

(ii) Investment in filling plant to cope with safe handling of new levels of flammable propellants. In some cases this may require plant relocation.

(iii) Some small fillers may be unable to cope with the costs of (ii) and leeway is needed to permit their continued activity.

SUMMARY

Aerosols world wide accounted for some 25% of the CFCs covered by the Protocol but due to the action described a very substantial reduction in the tonnages used can be expected.

15. The development of alternative fluorocarbons

Presentation by: N. Ishikawa, Prof. Emeritus of Tokyo Institute Technology, director of F&F Research Center, [illegible], Tokyo 107, Japan
Minatoku, Akasaka

Considering the charateristic physical properties of fluorocarbons, the majority of CFCs would not be replaced by non-fluorocarbon materials.
Therefore, active research works are now focussed on finding fluorocarbons which would have a low ozone depletion potential.

There are two strategies for the molecular design of these alternative fluorcarbons: 1) molecules which contain no chlorine atoms, and 2) molecules which contain chlorine atoms together with hydrogen atoms. Further, these alternatives should have appropriate physical properties matching their respective use, and they should have low toxicity and also should be available on low costs hopefully comparable to those of the present CFCs.

The most promising alternative compounds at the present time are as follows:
HFC134a - This hydrofluorocarbon contains no chlorine atoms and is expected to be safe alternative replaceable CFC12 especially as the cooling agent for car aid-conditioning. Toxicity test is incomplete.
HCFC123 and HCFC141b - These are two promising alternatives for use as the foam blowing agent for polyurathane. HCFC141b is flammable and the toxicity test for both compounds is also incomplete.
HCFC22 and HCFC142b - These two hydrochlorofluorocarbons are manufactured in large amounts, mainly as intermediates for fluoromonomers. They can be used as cooling agent in some cases. HCFC22, however, has a very low boiling point which makes this compound difficult to be widely used. On the other hand. HCFC142b is flammable giving a limited use. A mixture of these two alternatives is recommended.

The synthesis and applications of these alternatives will be overviewed

16. North American application experience with substitute chemicals

Presentation by: Mr. C.A. McCain, Du Pont.

Du Pont reactivated its programs to develop alternatives to fully halgenated chlorofuorocarbons (CFCs) in 1986 when computer model predictions of ozone change resurfaced concerns of possible ozone depletion if sustained growth in CFC emissions continued. The effort was accelerated following Du Pont's March 1988 CFC phase-out decision, which was based on the Ozone Trends Panel Report. Since announcement of a new Du Pont position in March, 1988, the company has moved up by two years plans to supply million pound quantities of three of the new alternatives. This step should accelerate the phase in of these substitutes into several major market segments.

A small number of chemicals have been identified which appear to exhibit the properties necessary to substitute for some important uses of CFCs. These chemicals include HCFC141b, HCFC123, HCFC124 and HFC134a and existing chemicals like HCFC22, HCFC142b and HFC152a. The steps to fully commercialize these substitutes include development of new processes, production of materials for application and toxicity testing, completion of needed toxicity studies for short-term and long-term exposures, completion of application studies by user industries, construction of new and restructuring of existing facilities, and phase in by the using industries.

Process development is not complete and must continue through 1990. There are many different routes to the new substitutes which must be explored before the final processes are selected. Du Pont has seven facilities dedicated to process development and production of the new substitutes. In August, 1988 Du Pont was issued a patent on new technology to co-produce HCFC123/124 in a single process.

Production of large quantities of the new substitutes has been a limiting factor in commercialization. Recognizing this critical factor, Du Pont has recently committed funds to production of commercials scale quantities of HCFC141b, HCFC142b and HFC134a. In July, 1988 it was announced that an existing commercial plant would be converted to produce HCFC141b/142b in 1989. In addition, in September it was announced that a $25MM-plus facility has been approved to produce million pound quantities of HFC134a by 1990. The commitment to produce HFC134a moved up by two years our plans to produce commercial quantities of this material.

This represents a significant financial risk since toxicity screens and user testing will not be available until just before the plant will start up. Since large quantities of HCFC123 already are available as a co-product from existing commercial facilities, there should be sufficient material available by 1990 for each of the leading candidates to complete application work at an accerlerated pace.

Toxicity studies are underway and should not be a limit to commercialization unless unexpected adverse results are discocered between now and 1992-93, when the final results from the studies are published.

Application tests are proceeding in the major market segments and these studies should accelerate as material supply increases over the next two years. These application studies will be the limit to rapid acceptance of the new alternatives. In the refrigeration segment, the critical concerns are long-term durability of machines operating with new refrigeration oils/refrigerations and the decrease in energy efficiency as the new substitutes replace the existing CFC's.

For CFC11 replacements in the blowing agent segments, work is in progress on both HCFC141b and HCFC123. However, there are concerns that either product could prove to be too toxic for this application and there are concerns about flammability and loss of energy efficiency as the new alternatives replace the existing CFC's. Because of these uncertainties Du Pont is proceeding with both products in paralell until user industries decide which products will be accepted. For other segments, Du Pont is developing products containing HCFC22, HCFC124, HCFC142b, and HCFC152a. As an example, in January Du Pont introduced Formacel (tm) S blowing agent for fast packaging and in April introduced Formacel (tm) S-Food Grade for food packaging.

As the search continues for a long-term solution in the cleaning agent segment, work has focused on emission reduction pregrams and development of interim cleaning agents with reduced ozone depletion potential. In February 1988 Du Pont introduced Freon SMT, with 25% less ozone depletion potential. Work is continuing to identify acceptable long-term candidates.

Our scientists are evaluating potential candidates to replace Halon products but it will be extremely difficult to find products with the flame extinhuishing properties and extremely low toxicity of the current compounds.

Du Pont has established a team of experts to project the capital expenditures required to restructure our facilities. In order for Du Pont to maintain the leadership position in the market, capital expenditures exceeding $1 billion will be required in just the U.S. In addition, Du Pont has spent $ 30 MM through 1987, and will spend over $ 30MM this year to fund process development, market research, and application testing. In addition, user industries will require similar expenditures to design and restructure their facilities.

Finally, after the new substitutes are being produced commercially, users will need a minimum three to five year period to change their facilities and phase-in the new alternatives. A major concern will be the demands required to phase out of the old chemicals from existing cleaning agent machines and refrigeration and air conditioning equipment. In addition to our search for entirely new chemicals to satisfy these demands we are actively purauing the use of blends and azeotropes coupled with retrofit technology and we plan to lead the way by converting Du Pont equipment to use new alternatives in the early 1990's. Currently, we have a chiller operating on one of the new alternatives and we will share this information with the industry as it becomes available.

While we are pleased with our progress to date, Du Pont's programs will be insignificant without global cooperation. We continue to believe in and support the international process and we hope all nations will work together to strengthen the Protocol to achieve a timely global phase-out.

17. Cooperative toxicity Testing Programme

Presentation by: Mr. G. Rush, Allied Signal.

In response to increasing concerns that the fully halogenated aklanes (CFCs) may be catalyzing a decrease in stratospheric ozone levels, most of the world's major producers of these chemicals have agreed to work together to evaluate the toxicity of potential replacements.

Two programs for alternative fluorocarbon toxicity testing (PAFT) have evolved, the first with HCFC123 and HFC134a, and the second for HCFC141b. While the majority of the companies participate in both groups, af few companies have elected to concentrate their resources on specific areas.

There are many advantages in this cooperative approach. It allows the scientists from each company to work together and develop a comprehensive program that reflects health and safety concerns from around the world. It eliminates duplication of programs which is costly, time consuming, and wasteful of resources. Through this cooperative effort, programs which could normally take from 6 to 7 years or more may be completed within five years.

The toxicology studies which will be performed include determination of the acute toxicity profile, the potential for genotoxicity/mutagenicity, or birth defects, and determination of any potential chronic toxicity or carcinogenicity. A program of this nature is complex, it can involve twenty or more individual studies, and may have an overall cost of DLRS 5MM for one compound, including the cost of expensive test materials. While there is a general outline, these toxicology programs are phased, with the results from one phase providing the basis for the next. Therefore, the exact timing for completing all the necessary testing cannot be predicted.
It is estimated that the initial phase of the program including the acute profile, genotoxicity studies, and initial inhalation toxicology studies will be completed within 1989. The longer term (subchronic) inhalation studies and evaluation for development effects may require some additional time. The chronic toxicity and carcinogenicity will require an additional 3,5 to 4 years.

As the various phases of toxicological evaluation are completed, the results will be made available to the public through publication in the open peer-reviewed literature and presentation at scientific symposia and meetings.

18. Halons

Presentation by: R. Mulhaupt, Executive Director, National Fire Protection Research Foundation.

The National Fire Protection Association (NFPA) is most grateful to the United Nations Environment Programme to have been offered such an active role at this first reconvening of the parties to the signing of the landmark Montreal Protocol of 1986.

Since becomming aware of the dilemma of fire protection halons and the environment only in August 1986, and then only in broad terms, NFPA has brought to bear its considerable international recources to meet the technological challanges, and to resolve the many ensuing issues.

Our messages to this Conference is twofold: First, that we are accord with, and encourage all nations who have not done so to become parties to, the Montreal Protocol. And second: We are pleased to report that the collaborative, international, public/private, multifaceted technological assault that must be waged to solve the halon/ozone dilemma is well underway.

The emergent twin goals are these: Reduce halon emissions, and improved firesafety engineering practices.

NFPA's International Standards

The NFPA firesafety standards writers responded immediately to the challenge, demanding the best new data available, and moving to reflect that understanding in new international consensus standards which are being written right now. (We note that this process is open to anyone, worldwide, who wishes to contribute or comment).

The International Halon Research project

Coordinated by the NFPA Research Foundation, literature reviews have been completed or are underway looking at hte literature in all disciplines. International research initiatives addressing Best/Essential Uses of Halon fire protection agents, improved engineering practices, alternative reliability test methods and test gases are already well underway. And industry is taking the bull byo the horns, seeking alternative extinguishing agents. We also note that the United States Department of Defense and Environmental Protection Agency are takikng active roles in research, as is the industry Halon Researchk Institute.

Public Information

And public information campaigns, initiated just as soon as the fire protection communityu became aware of the dilemma, continue to inform that community and the world about ozon-layer science and progress toward our twin goals. This last spring, the NFPA, The Brand-Verhutungs-Dienst fur Industrie und Gewerbe, the Conference of Fire Protection Associations Europe, the US Environmental Protection Agency, and Environment Canada hosted the first major International Conference on Fire Protection Halons and the Environmenmt. Participants from throughout the world felt that it was enormously successful.

The NFPA and the fire protection community are committed to achieving reduced halon emissions and improved firesafety. Let nothing I have said hint that it is an easy process, either technologically or economically.
There is much to be done. But there is light at the end of the tunnel. And we are moving toward it with increasing momentum.

19. Halogenated fire extinguishing agents transition programme.

Presentation by: Mr. W. Paslov, Assistent Secretary of Defense, USA.

The Uneited States Environment Protection Agency (EPA) published rulesat August 1st 1988 which will become effective when the United Nations' Montreal Protocol is implemented. The Department of Defense has issued a directive for each service to develop an implementing program tailored to the unique mission needs of their force structure.

The Air Force HALON fire extinguishing Agent Transition Program is typical of the programs to be implemented. This program's strategy is based on the Montreal Protocol and the EPA regulations for protection of the environment from ozone-depleting compounds. A two-step process is being used to implement the Air Force program. An implementation plan is now in final coordination. This plan brings all the various agencies involved with the use of HALON together and ensures a targeted approach to management of HALON in the air force. Agencies are then tasked to accomplish specific resposibilities related to the use, management, control and replacemnet of HALON including the issuing of design guidance, engineering technical letters and air force regulations to achieve the three objectives of the Air Force program.

1. Limit new use of current ozone-depleting agents to mission critical applications.
2. Establish a program to develop replacement agent(s) for curent ozone-depleting fire extinguishing materials.
3. Implementation of interim measures controlling non-fire suppression releases assuring continued use of current agents untill transition to replacement agent(s) is possible.

The United States Navy and Air Force have extensicve research and development afforts identified and begun in some cases, to lessen the dependance on halogenated agents and to mitigate the ozone impact where alternative appraoches are not currently practical.

The Naval Sea Systems Command through the Naval Research Laboraty is completing a study of alternative test/acceptance agents designed to eliminate the release of halogenated agents during the acceptance testing of installed systems. Operational field application is expected to begin during 1989.

The Air Force through the Air Force Engineering and Services Laboratory has identified work in four major areas of concentration;

Alternative Agents - Efforts are underway to develop a new training agent to permit firefighters to obtain critical proficiency training. this has a double benefit, the fire fighters are more effective and therefore use less actual halogenated agent. Initial work has been begun in the creation of a next generation of agents with enhanced fire suppression capability and decreased ozone impact.

Limitation of Accidental Releases - Recycling equipment has been developed to eliminate releases during required servicing and maintenance. The equipment is expected to reach Naval and Air Force field units during 1989. Work has been identified to develop enhancements for detection and control equipment to eliminate unwanted system activitations. New dispensing concepts are being considered to increase the percentage of HALON applied in fire extinguishment.

Localized, zoned, and Partial Flood System - Enhanced systems are being considered to apply agents directly to the seat of a fire rather than total flooding of an area. Such systems are being considered for the combat aircraft shelters in Europe, for electronic equipment, and special aircraft applications.

Reduction of Usage Applications - The development of computer modelling will eliminate much of the repetitive experimental testing to validate and optimize new application concepts. Advanced training techniques using computer based and other simulation appraoches will reduce the need for actual agent application during training exercises.