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IEA Heat Pump Centre

NEWSLETTER

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Contents

Front Cover: *In its 700th anniversary celebrations, Switzerland, the newest member of the Heat Pump Centre, used this transportable "tent" as the venue for its celebrations. Four reversible air-to-air heat pumps provided space conditioning at a COP of 6.4.*

International Energy Agency
The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme.

A basic aim of the IEA is to foster cooperation among the 22 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects. This publication forms one element of this programme.

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Editorial

This newsletter focuses on *space conditioning heat pump equipment and applications, and novel cycles.*

Information, education, stimulation, promotion, these are all important vehicles to widen the utilization of heat pumps. It is encouraging to see that neighbouring countries in Scandinavia compete in the realization of installing large numbers of heat pumps. Hopefully other countries will follow in these countries' footsteps.

This newsletter also deals with other important aspects of heat pumps, i.e. their *environmental impact.* Recently eye-catching analytical studies dealing with heat pumping technologies and the environment have been published or initiated. The US AFEAS-study deals with CFC alternative technologies and their impact on energy and global warming. The UNEP Montreal Protocol 1991 Assessment/Refrigeration Options Committee report deals with the phase-out of CFCs and the future of their replacements; this report, which is not considered in this newsletter, will be discussed in November in Copenhagen and probably help to set new regulations. The US Alternative Refrigerants Evaluation Program (AREP), established by the US Air Conditioning and Refrigeration Institute and its members, is another highly important initiative to develop and provide solutions to working fluids in heat pumping equipment. A related programme called the Materials Compatibility and Lubrications Research Program, also referred to, considers the compatibility of alternative refrigerants with the materials used in equipment.

The IEA Heat Pump Centre also deals with environmental issues. Shortly the results of the analysis Impact of Heat Pumps on the Greenhouse effect will be published.

The International Institute of Refrigeration (IIR), in particular Commission E2, and the IEA have agreed to actively collaborate in the field of heat pumps, an important step forward that will be beneficial to and strengthen both organizations, and it is a great pleasure to include in this newsletter an introduction on the IIR by its director Mr. L.Lucas.

Jos W.J. Bouma
General Manager.

Ice Thermal Storage Integrated in a Multi-Zone Space Conditioning System

*N. Kusumoto

Abstract

An ice storage system incorporated in an air cooled multi-zone direct expansion type split space conditioning system is discussed. The system consists of an outdoor unit with an inverter controlled compressor, a maximum of eight indoor units and an ice storage unit. At night when no cooling is required, ice is made using low-cost electricity. In Japan, the night-time electricity rate is about 1/3 of the daytime rate. During the day the system uses the ice to gain 35 to 40°C of refrigerant sub-cooling. As a result, with the same compressors, the cooling capacity of the system increases by 25% and the power cost decreases by more than 20%.

Introduction

In recent years, ice thermal storage has increasingly been incorporated in water chilling units for the space conditioning of large buildings. However, systems with water chilling units have the disadvantage of high operation cost at low partial load. Initial investment costs for these units are also high and it may take more than 5 years to get a return on the investment. A further drawback is the large amount of space required for the installation of storage tanks.

Air-cooled multi-zone split systems, on the other hand, have the advantage of low operation cost at low partial load and also require less space for storage tanks. In view of this, Daikin Industries decided to incorporate ice thermal storage with this system. The results show that this system has advantages over a system using water chilling units.

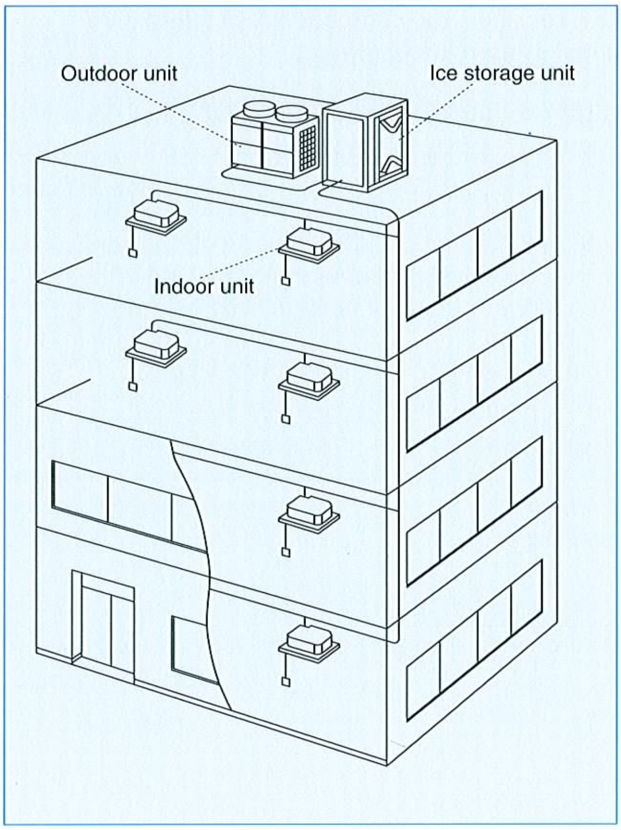


Figure 1: Air Cooled Space Conditioning with Ice Thermal Storage - Typical Example of Establishment.

System Overview

The system is shown in Figure 1. It consists of an outdoor unit with an inverter controlled compressor, a maximum of eight indoor units and an ice storage unit.

The refrigerant piping diagram is shown in Figure 2. Depending on the operating condition, the liquid refrigerant from the receiver can either go directly to indoor units or it can first pass through the ice storage tank. When space cooling is required, the heat withdrawn from the melting ice is controlled by mixing the refrigerant which has passed through the ice storage tank with the refrigerant which goes directly to indoor units. The refrigerant is sub-cooled by 35 to 40°C before going to the indoor units, with an increase in its cooling capacity of 25%.

Ice Making Operation

When the system makes ice, the liquid refrigerant is vaporized in the tubes of the tank and ice forms around the outer surface of the tubes in a concentric circle. A maximum of 50 % of the water in the storage tank can be frozen. A control system ensures that the right amount of ice is made during the night.

To establish the 'right' amount of ice to be made, the control system senses the outdoor air temperature

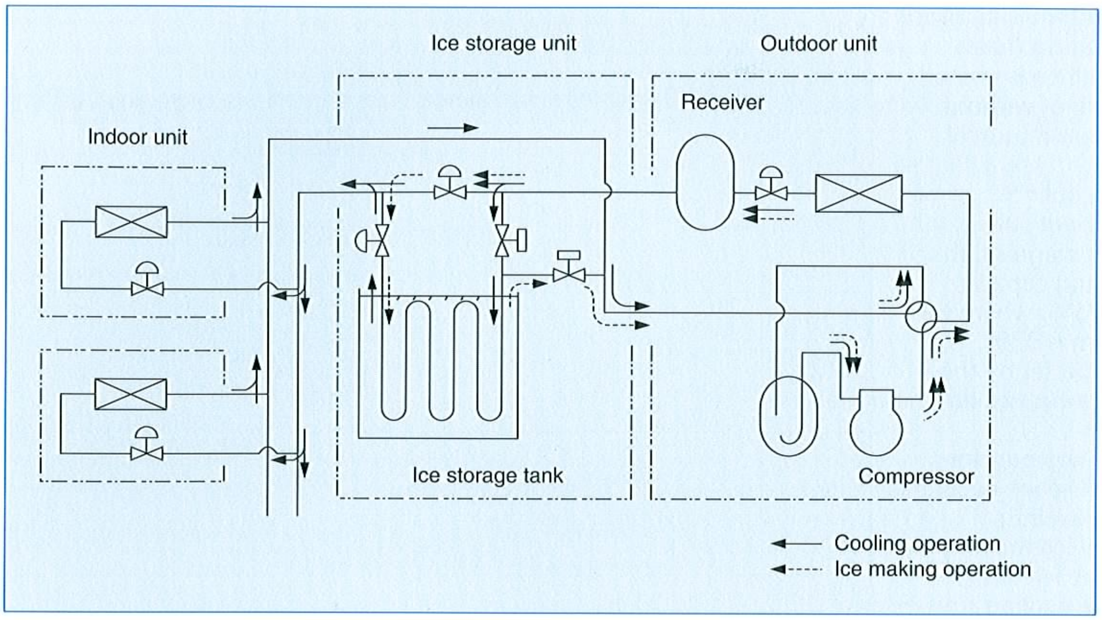


Figure 2: Refrigerant Piping Diagram.

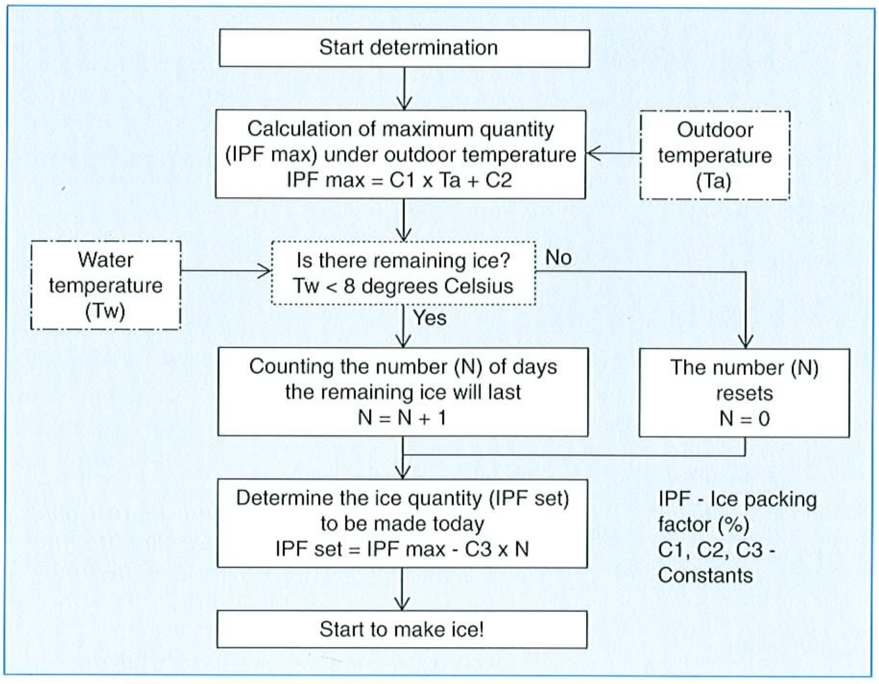
and calculates the required ice quantity to satisfy the maximum cooling demand under this temperature condition. It also measures the amount of ice already in the tank at the start of the ice making operation by sensing the water level. This amount is subtracted from the total ice requirement to determine the quantity of ice which has to be made in one night. The determination process is illustrated in the flow chart of Figure 3.

The control system subsequently calculates the most desirable lowest frequency setting of the inverter controlled compressor motor to ensure that exactly the right daily amount of ice is made in the course of the night. The compressor should be operated in the low frequency range which is around 50 Hz in the case of this system. This gives the highest efficiency, because if a compressor runs at low speed, the refrigerant flow rate decreases, with a resultant reduction in pressure difference between evaporator and condenser and thus a low compression ratio. Figure 4 illustrates the way the control system ensures that exactly the right amount of ice is made in the set time, at the lowest possible compressor frequency.

Ice Melting Procedure

It is essential to use the ice thermal storage effectively during space cooling operation. The heat extracted from the melting ice is kept constant by controlling the degrees of sub-cooling. The extracted heat is the product of the drop in enthalpy of the sub-cooled refrigerant and the refrigerant flow rate. Two electronic expansion valves control the ratio of liquid refrigerant flowing through the ice storage tank to that which by-passes the tank. The drop in enthalpy can be determined by measuring the temperature difference between ice storage inlet and outlet. The refrigerant flow rate can be calculated from compressor frequency, suction pressure and liquid refrigerant temperature. The

Figure 3: Flow Chart to Determine the Ice Quantity to be Made.



described control system minimizes energy costs by ensuring that a maximum amount of ice is melted during a day of cooling, without the ice running out prematurely.

Figure 5 shows the cooling operation with sufficient subcooling on a Mollier diagram. It shows that the cooling capacity increases by some 25%, where the theoretical maximum is 33%. The operation time can be set by the user at 8, 10 or 12 hours per day.

The system is advantageous, for both large and small space cooling demand. When the cooling demand is large, the ice melting is controlled so that the ice lasts for at least the set space cooling operation time. Sufficient cooling capacity is ensured in all circumstances. When the cooling demand is small, use of the cooling capacity of the ice storage can be maximized, by increasing the ice melting heat.

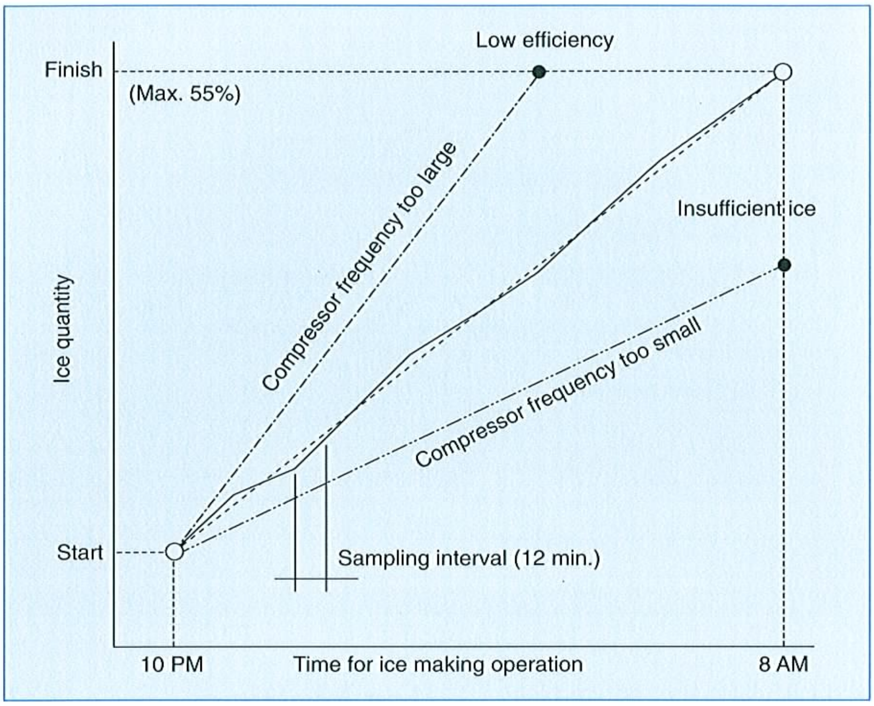
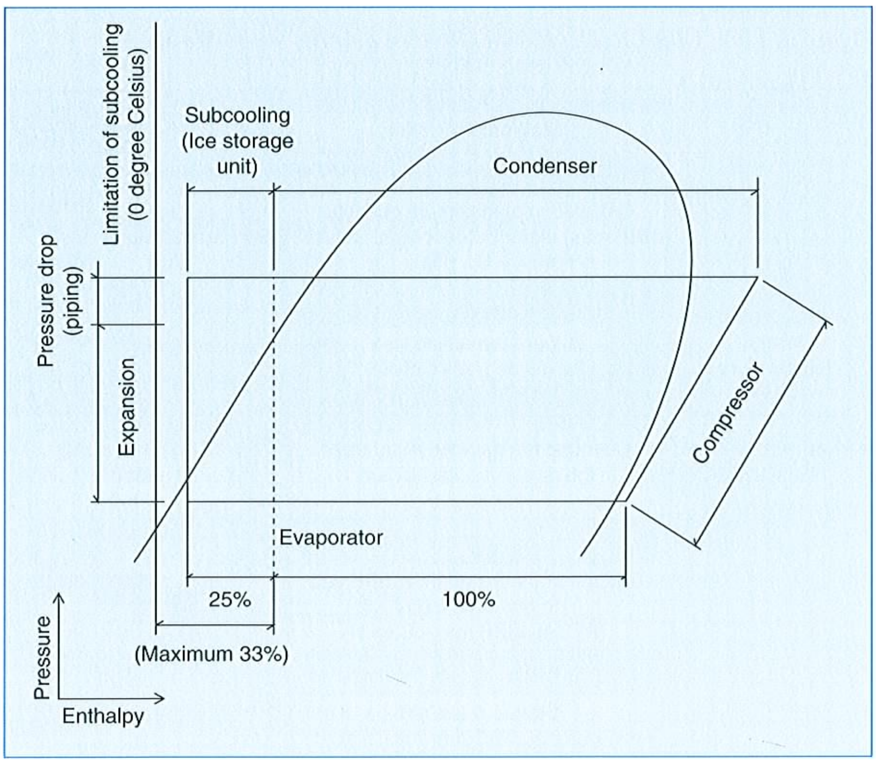


Figure 4: Ice Quantity Made vs. Ice Making Operation Time for Various Compressor Frequencies.

Conclusion

An air cooled multi-zone split system incorporating ice thermal storage subcooling the liquid refrigerant for effectively converts ice thermal storage to cooling capacity. The installation is simpler than a system using water chilling units and can be incorporated with existing air cooled multi-zone split systems.

Figure 5: Mollier Diagram of Space Cooling Operation with Ice Melting.



This system has significant merits as discussed in this paper. Yet, before further popularization of ice thermal storage as a component of an air cooled space conditioning system at least two aspects need to be improved:

- The ice storage utilization rate should be increased by more than 25%.
- The cost and size of the ice storage unit needs to be reduced.

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Advanced Control System for Multi-Zone Space Conditioning

*Y. Sato

Abstract

Today's office building is not simply a place where people work from 9 to 5 - it must serve many diverse functions over a 24-hour period, including the operation of heat generating office automation equipment. This places new demands on the space-conditioning system. Multi-zone space-conditioning heat pump systems allow different areas to be controlled separately according to demand, and offer the potential to optimize building comfort and energy efficiency.

In a large building, a multi-zone system uses so many indoor space conditioning units that individual control and monitoring of each unit is not possible with a conventional building management system. The Mitsubishi "MELANS" (Mitsubishi Electric Lossnay Air Conditioning Network System) is a sub-system for a building management system which can manage the operation of a large multi-zone system while allowing individual control. The MELANS network system is structured to limit the effects of equipment breakdown. The system is used in the NHK Broadcasting Centre at Nagoya City in Japan (see photo).

Performance Requirements

Any space conditioning control system must take account of the following performance requirements: indoor space comfort; efficiency; convenience; flexibility; reliability.

Indoor Space Comfort

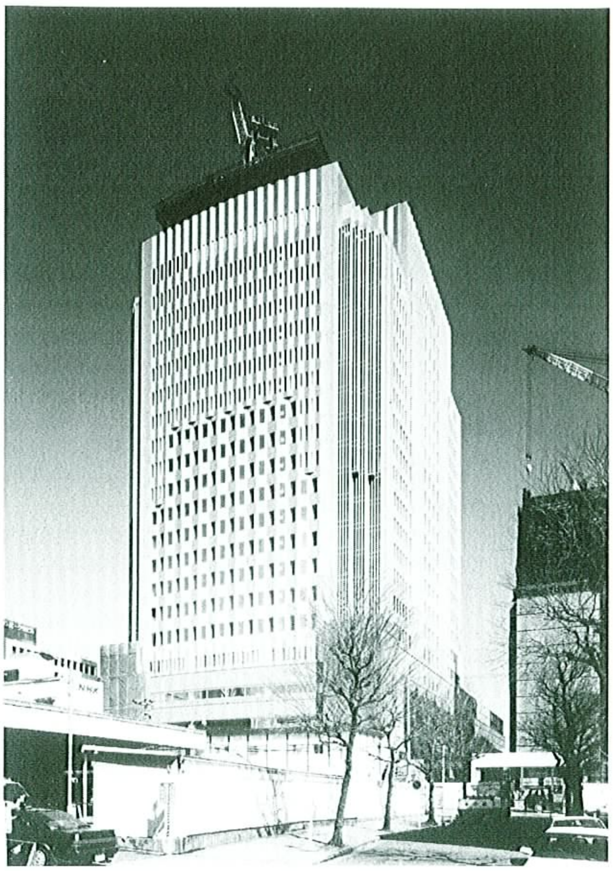
The comfort provided by a space conditioning system is determined by physical air properties, such as temperature, humidity and air current and by air quality factors such as the level of carbon dioxide, nitrous oxides, dust, airborne microbes and other pollutants. The following factors make it difficult to control physical air properties in modern office buildings:

- the increased use of heat generating office automation equipment;
- the trend from large partition-free rooms to small work-stations;
- the tendency towards multi-functional offices where working hours differ from room to room.

The recent discovery of the "sick building syndrome" indicates the importance of monitoring the air quality.

Efficiency

Efficiency can be improved by the effective utilization of building space, by the simplified design of equipment and by reducing the cost of maintenance using centralized control. The net effect will be a reduction in running costs and energy consumption.



Photograph: The NHK Nagoya Broadcasting Centre.

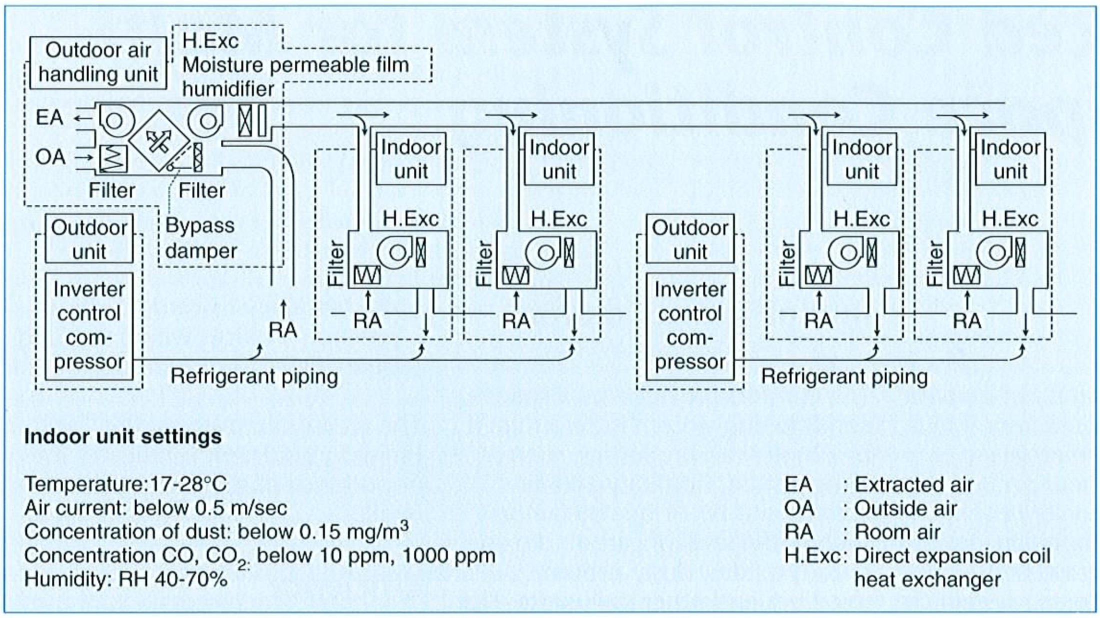


Figure 1: Schematic of Space Conditioning System Configuration.

Reliability

A large space conditioning system with many components must be designed so that a fault in one component does not cause the whole system to fail. In addition, the system design must allow full control during emergencies such as fire.

Convenience

In conventional space conditioning systems, the indoor environment is controlled to try and meet the needs of a large number of users. A multi-zone system can provide personalized space conditioning if it can flexibly configure zone temperatures in response to user controls.

Flexibility

A space conditioning system must respond to expected changes in the use of indoor space, and react to predictable changes in the heat generated by office equipment.

The MELANS Network System

The MELANS Network acts as an independent sub-system of a building management system. A schematic of the layout of a multi-zone split heat pump space conditioning system is given in Figure 1. The structure of the MELANS control and measurement system is illustrated in Figure 2. A man-machine interface supplies information to the system on the status of the space conditioning system and the cooling demand. This information includes:

- operating status of all air conditioners in the building;
- temperature settings;
- measurement settings;
- fault status;
- yearly schedule;
- weekly schedule;
- configuration of space conditioning groups;
- configuration of measurement groups.

A serial interface unit (IFU) connects the central computer of the building management system with the MELANS network system. Data exchange with the man-machine interface is via an RS-232C line. Communication with the space conditioning components is via a bus network.

A Stratified System

The network is based on a "stratified danger dispersion system" which ensures that a partial fault does not lead to a breakdown of the entire system. The IFU sends out control signals and receives measurement signals on a bus system controlled by measurement and control gateways. The system components are arranged (stratified) in several groups on each floor. The groups are physically (electrically) and functionally (i.e. in terms of software) isolated from each other. The system is configured so that a malfunctioning group is isolated to minimize adverse effects on the other groups. Even when the central control system breaks down, each space conditioner can be individually controlled.

Application in a Broadcasting Centre

The NHK Nagoya Broadcasting Centre is at the heart of a new urban centre in Nagoya City. The building comprises three types of functional space:

- an information dispatching station;
- a community plaza;

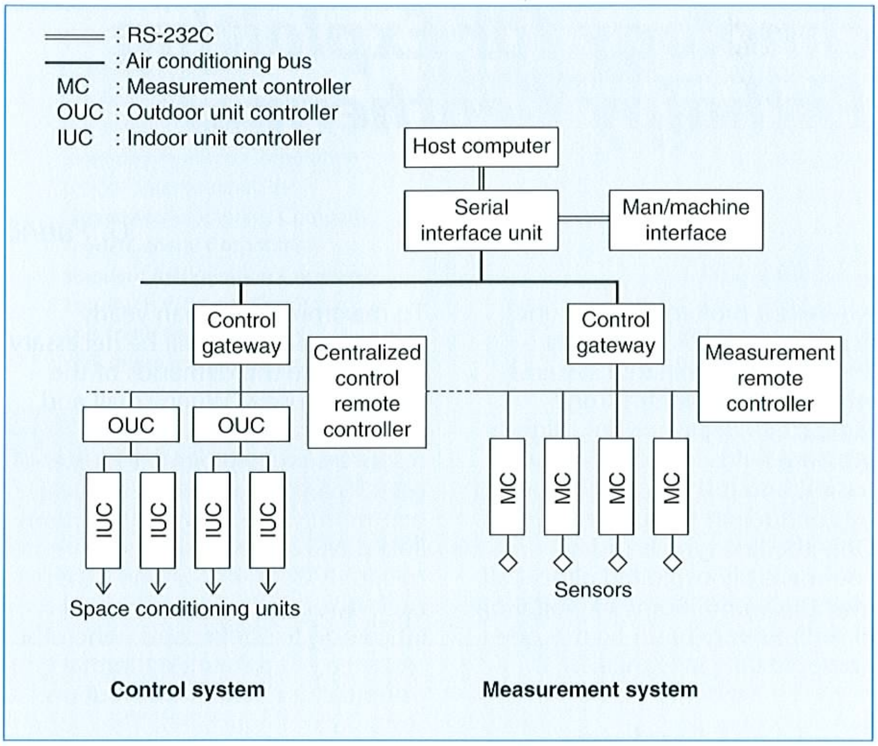


Figure 2: Stratified Structure of the MELANS Space Conditioning Control and Measurement Sub-System.

- a new business centre with futuristic office space.

Special features of the building include a huge atrium 68 m high and an elevated garden extending from the 6th floor lobby. The office zones, floors 5 to 20, are served by individual decentralized space conditioning. Each floor is divided into three spaces, freely laid out as an open space by avoiding the use of pillars as much as possible. Each space is divided into between two and six offices with each one being served by a built-in duct type indoor space conditioning unit. The indoor units feature multi-port blow-out ports with integrated lighting. Outdoor air handling and compressor units are installed on the four corners of each floor. The scroll type compressors feature inverter speed control.

Outdoor air is introduced at a sufficient rate to meet Japanese Laws (Building Control Law and Building Standard Law) on air quality in terms of levels of CO_2 and CO (from smoking) and other pollutants. The introduction of outdoor air adds additional load during heating and cooling. The ratio of outdoor air load to total load is about 1:3 when cooling and 1:2 when heating. A total heat exchanger in the outdoor units reduces the outdoor air load by recovering heat from extracted room air. A built-in by-pass damper responds to the difference in outdoor air and room temperatures and automatically selects one of three operating modes:

- cooling/heating + heat recovery;
- cooling/heating + by-pass ventilation;
- ventilation only.

The total space conditioning system comprises 450 indoor units, 99 air-handling units and 280 outdoor units. These units are used by tenants in different ways. Each unit may be individually controlled and monitored or an indoor unit and air handling unit may be governed by optimum interlocked control. With the MELANS network system, each tenant has a control gateway and is served by several space conditioning components arranged in two groups under the stratified danger dispersion system. Space conditioning for each tenant is controlled according to measurement data from indoor temperature/humidity sensors and outdoor temperature sensors (two sets per tenant).

Conclusions

By means of a man-machine interface installed independently of the building management system, the MELANS network is essentially an independent space conditioning sub-system*. It exchanges a minimum of data with the building management system via a serial interface. This includes electrical supply conditions and emergency data.

* *It allows efficient management of a large space conditioning system, enhancing safely and individual control.*

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Absorption Technology for Exploiting Low/Medium Enthalpy Geothermal Resources

*G. Panno

Abstract

This paper provides a brief discussion of the general requirement for a system which directly uses geothermal energy. It is argued that absorption heat pumps are particularly suitable for the exploitation of this resource. The argument is illustrated with a case study and the paper concludes with an economic discussion.

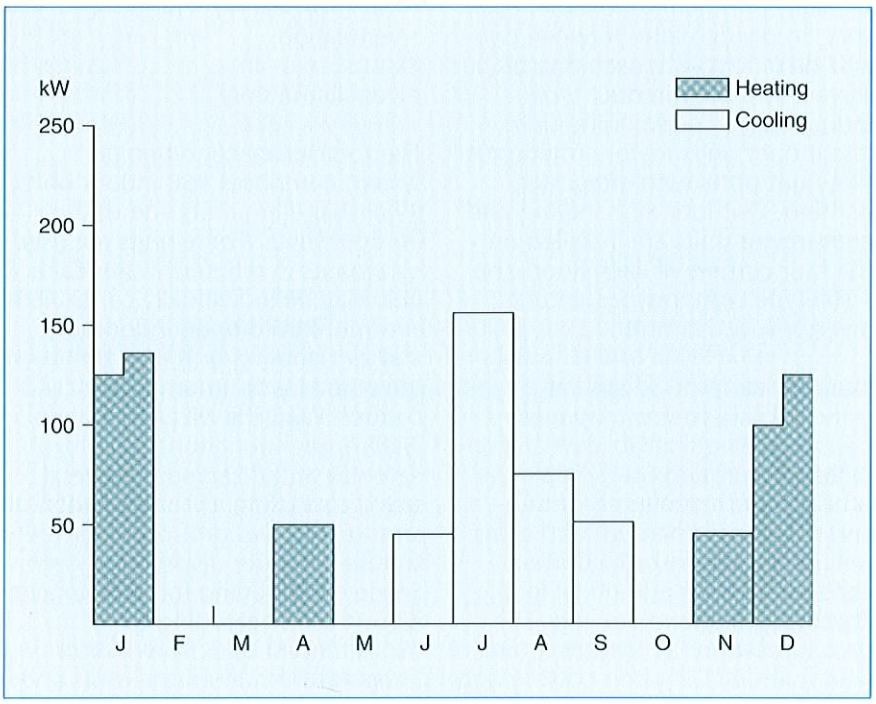
The Geothermal Resource

The use of geothermal energy for space and hot water heating dates back to the use of hot springs as baths in ancient Greece and the Roman Empire, although the first very large scale application for industrial use appeared only in the early 1940's at Reykjavik (Iceland). Nowadays the exploitation of geothermal resources in non-electric applications is developed worldwide, primarily in Iceland, but also in Hungary, Japan, New Zealand, the former U.S.S.R. and on a smaller scale in France, Italy, and the U.S.A. A boost for the use of geothermal energy was provided by the Arab oil embargo of 1973, and the consequent interest in energy-saving technologies. It is expected that in the next decades the main interest will be the application of geothermal energy for the generation of electric power, although a significant interest remains for the use of the direct heat of geofluids.
Geothermal resources can be divided into three broad classes: First of all hydrothermal convection systems, where heat is carried upward from depth by convection of water or steam. Secondly the hot igneous rock resource systems, where hot molten rock intrudes from great depth. And lastly, conduction dominated systems, where heat originates from radioactive decay, or hot, high-pressure fluids in sedimentary basins, and is then carried upward by conduction through rock.
Only the first type is today commercially exploited almost all over the world. Some exploitation of sedimentary basin heat is on-going, mainly in France.

General System Requirements

The efficient exploitation of geothermal resources requires the cascaded application of a number of energetic processes. The cost of geofluids is mainly an investment cost for well drilling, thus a high yearly utilization factor is needed. To maximize the mean yearly utilization factor it will be necessary to integrate the demands of the individual users. When small and medium sized geothermal resources are exploited, a cluster of users in a concentrated area near geothermal wells can reduce items linked with the transport of geofluids from well-head to the users and can improve thermal efficiency. In some cases, when the resource has a suitable thermal potential, a geofluid distribution system can be justified. The Reykjavik system, for instance, transmits geofluids over about 20 km. In Iceland, other applications, for which the pipeline length can reach up to 100 km or more, have been proposed. The success of these enterprises is linked with the fortunate (in this respect) meteo-climate in Iceland and the specific nature of the local geothermal resource.

Figure 1: Heating and Cooling Duty for a Hotel.



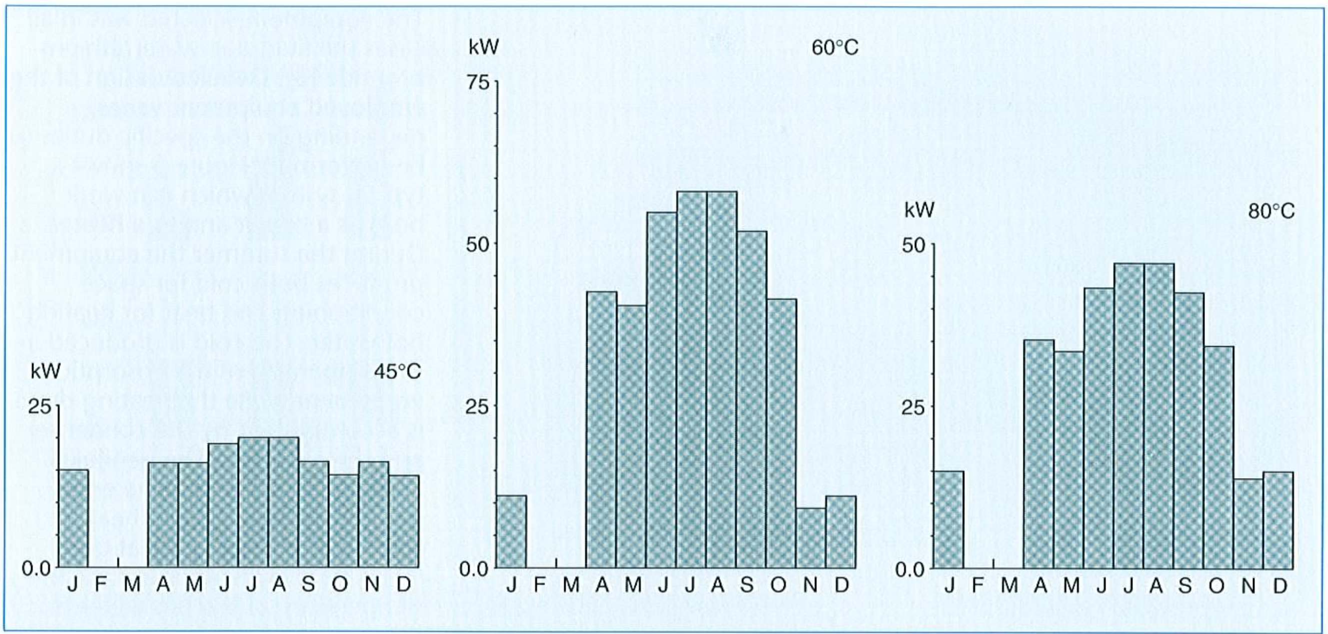


Figure 2: Hotels: Heating Duty for Hot Water Service.

The technologies employed in the past decades for direct heat from geothermal energy are also suitable for the coming years. Broadly speaking three systems are suitable for an efficient future exploitation of geothermal energy resources:

- improved vapour compression cycle heat pumps;
- absorption heat pumps (both for cooling and heating);
- absorption heat transformers.

The first technology is common today while the others are developing (mainly in Japan).

Absorption Technology with Various Fluid Pairs

The absorption system can be employed both for cooling and for heating. When heating, the system can be used either as a heat pump or as a heat transformer. If used as a heat pump, geofluids are supplied to the evaporator as heat source. If used as a heat transformer the geofluids are used in a thermal cascade combination, first as driver heat source in the expeller, then as heat source for the evaporator.

Ammonia/Water

When ammonia/water is used as a fluid pair in absorption equipment, the most suitable temperature for geofluids lies in the range 100 - 140°C. If the equipment works only as a refrigerator, the geofluids feed only the expeller. The pressure reached in the expeller is high (up to 40 bar, with a maximum temperature of 180°C). In such an extreme case a COP in the range of 1 to 1.45 can be reached, but the required pressure vessels make the equipment very heavy. A 20 kW unit can weigh as much as 320 kg. An application of ammonia/water absorption equipment for geothermal energy exploitation is currently being developed in Mexico (Columba e.a. 1990 [1]).

Lithium-Bromide

Another technology in commercial use is that using a saline solution of lithium-bromide in water. R&D in the past decade has also demonstrated the feasibility of a system using methanol/lithium-bromide. This system works at sub-atmospheric pressures and calls for a vacuum maintenance auxiliary system. Drawbacks of this system are the danger of recrystallization, chemical instability and increased susceptibility to corrosion at a high working temperature. These drawbacks have been encountered in direct-fired equipment. Further R&D is needed if a system using this fluid pair would be used for the exploitation of geothermal resources. At this stage, technology based on the use of the fluid pair water/lithium-bromide appears to be the most suitable for the exploitation of geofluids, especially considering that some units (working as heat transformers for process heat recovery) are currently already operating in industrial plants.

Other Working Pairs

Unconventional working pairs have been proven all over the world to allow the use of a geofluid of moderate temperature to feed the expeller and to enhance safety - of vital importance for domestic applications. Unfortunately these types of fluid pairs require higher flow rates of both the absorbent and the absorbate (due to their poor thermodynamic and transport properties) and, as a consequence, more pumping work, so the

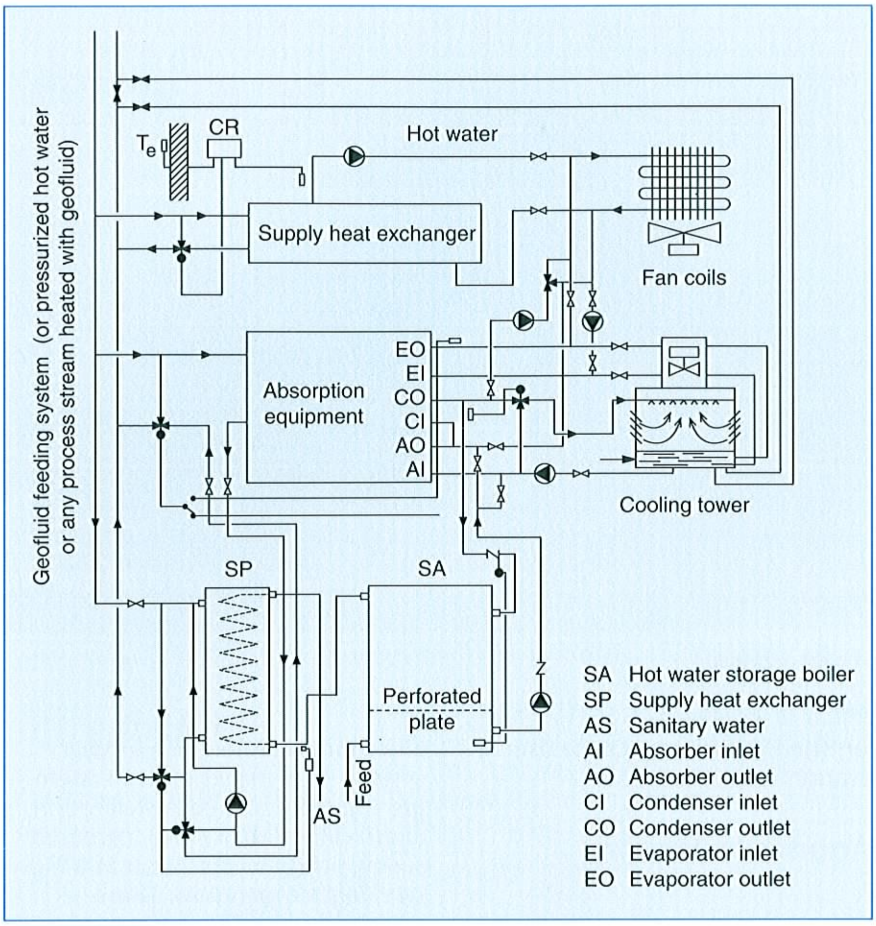


Figure 3: Geothermal Multi-purpose Plant with Absorption Equipment.

equipment can only be used for small-scale applications (Columba e.a. 1990 [2]).

A Case Study

The following case study may illustrate the perspective offered by the use of the absorption equipment for the exploitation of geothermal energy resources in the touristic and residential sector.

The application is in the Eolian Islands and is typical for the southern part of Italy. The available geofluid is pressurized geothermal brine at a temperature of about 110-120°C. The clients considered for the case study are:

- a hotel with 62 rooms, each with a private bathroom, a restaurant, meeting halls, laundry etc. The hotel is completely space conditioned and has a volume of 14,440m^3;
- a hotel with 40 rooms, all with a private bathroom and facilities as above. The space conditioned volume is 8,130m^3;
- a residence composed of three buildings each with three flats and facilities such as restaurants, meeting rooms etc. The space conditioned volume is 40,400m^3;
- 100 cottages each with a volume of 504m^3.

The buildings are spread over a large area and the mean distance from a well-head is about one kilometre. The whole complex is open in the summer, in December/ January and during the Easter holidays. Figure 1 shows a monthly bar diagram of the heating and cooling demand of the first hotel. Figure 2 shows the heating demand at the various temperature levels for the hot water service for the two hotels.

The equipment selected was in all cases the fluid pair water/lithium bromide [3]. Detailed design of the employed equipment varies, depending on the specific duties to be performed. Figure 3 shows a typical system which can work both as a cooler and as a heater. During the summer the equipment produces both cold for space conditioning and heat for heating hot water. The cold is produced in the evaporator of the absorption equipment while the heating duty is accomplished by the condenser and the absorber. The geofluids coming from the pipeline enter into the expeller (driver heat source). The rejected heat goes into a heat exchanger to raise the temperature of the hot water to the required level. In the winter the main duty is for space heating and hot water service, although some cold is required for space conditioning in the hotels. The reject brine coming out of the heat pump is used to heat the swimming pools of the hotels, so the total thermal energy of the geofluids is used. The brine returning in the pipeline is reinjected. The performance analysis of the system requires the definition of some parameters which characterize the whole process. The analysis is linked with the performance characteristics of the absorption equipment; a simple methodology can be employed (Columba e.a. 1984 [3]).

Investment Decision Analysis

Given a geothermal opportunity, an investment decision will have to be made. A key parameter in this decision is obviously the income which is expected to be generated by the investment. This income depends on the 'service rates' which users will pay when served by the system. These rates, in turn, will strongly depend on the policy of a given country concerning the price of energy products. In Italy and other EEC member states, for instance, the end cost of energy product is fixed for the final user.

Resource Type	Temperature Characteristics
1. Hydrothermal convection resource (heat carried upward from depth by convection of water or steam)	
a. Vapour dominated	about 240°C
b. Hot water dominated	
1. high temperature	150-350°C
2. intermediate temperature	90-150°C
3. low temperature	less than 90°C
2. Hot igneous resources (rock intruded in molten form from depth)	
a. part still molten	higher than 650°C
b. non-molten "hot dry rock"	90-650°C
3. Conduction dominated resources (heat carried upward by conduction through rock)	
a. radiogenic (heat generated by radioactive decay)	30-150°C
b. sedimentary basins (hot fluid under high pressure)	150-200°C
Source: D.E. White and D.L. Williams; U.S. Geological Survey Circular 726/1975.	

Table 1: Geothermal Resource Classification.

For each of the partners in the venture (resource developer, plant investor, etc.) the main investment objectives will be:

- to maximize the efficiency of the investment funds;
- to minimize the time during which the investment is at risk.

When comparing technical alternatives, the proper cost accounting both for capital and operating costs is of vital importance, as is the use of proper depreciation rates for the equipment.

The most appropriate analysis for such a venture will be a method based on a proper cash flow analysis. The sensitivity of the cash flow to variations in a number of key parameters should be analyzed.

Conclusions

The absorption technology offers significant opportunities for the exploitation of low and medium enthalpy geothermal energy. Systems can be employed to produce both cold and heat. The most attractive situation is a suitable geothermal site near a building area, which minimizes the costs for the transfer of geofluids from well-head to users. For opportunities in the residential or tourist sector, water/lithium-bromide is the most suitable fluid pair.

Opportunities are also envisaged in industrial applications. Here ammonia/water appears to be the most viable fluid pair.

R&D is required to improve system reliability, especially in view of the harsh environment in which the equipment will work.

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Optimum Use of Waste Heat and Low Cost Electricity for Space Heating - An Austrian Approach

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Abstract

Efficient energy utilization and the use of waste heat by means of heat pumps is a highly cost effective way to reduce the emission of CO_2 and other harmful gases into the environment. An Austrian company for electrical equipment and appliances has developed a concept for commercial buildings where heat recovered from waste heat by means of electrically-driven heat pumps is used to meet the base heat demand; the peak demand is covered by locally available energy sources like night-time electricity, biomass etc. To minimize energy consumption and peak demand of electricity a sophisticated computer based energy management system is of prime importance.

Several systems went into operation during the last ten years. These systems work reliably and achieve low heating and operating costs. The customers of these plants are served to the same standards of quality and reliability as they would be by conventional heat generation systems, whilst significantly reducing their costs and environmental impact (Eggen 1989).

The Concept

The aim of the concept is to use electricity in an efficient and intelligent way. To realize this aim in the context of space heating, heat pumps are used primarily for waste heat recovery and sometimes also for ambient heat utilization.

In buildings, the dominating portion of the energy used is transformed into heat, either directly for heating and hot water production, or as a result of other kinds of energy use like lighting, refrigeration or the operation of appliances. Additional heat is produced by the people living or working within the building and by solar gains. This heat leaves the building via conductivity losses through the building envelope, by ventilating losses and as waste water.

Conductivity losses are real losses; however, the energy content of the exhaust air of the ventilation system and the energy content of waste water can be recovered and shifted to the temperature level required for heating purposes and hot water production by means of heat pumps. The energy content of exhaust air consists of sensible heat and latent heat. The latent heat is increased by moisture absorption within the building. Apart from the direct heat input to the fresh air, waste heat from lighting, cooking, and other internal gains is transported by exhaust air. The temperature level of exhaust air is in the range of 21 to 24°C; in the case of indoor pools up to 32°C. By utilizing these sources, the energy input to the building can be reduced significantly. At a minimum, the base heat demand can be met by heat recovery with heat pumps.

The amount of heat which can be recovered strongly depends on the ratio of ventilating losses and waste water losses to the total losses of the building. In single-family houses this ratio is only in the range of 30 to 40%, whereas in large buildings it can be more than 60%. In buildings with a lot of internal gains caused by technical equipment it may be even higher.

Peak demand is met by energy which is locally available. This can be biomass in rural regions, or night-time electricity which can be provided for a low tariff, especially

Photo: View of the Recreation Centre Kanzelhöhe.

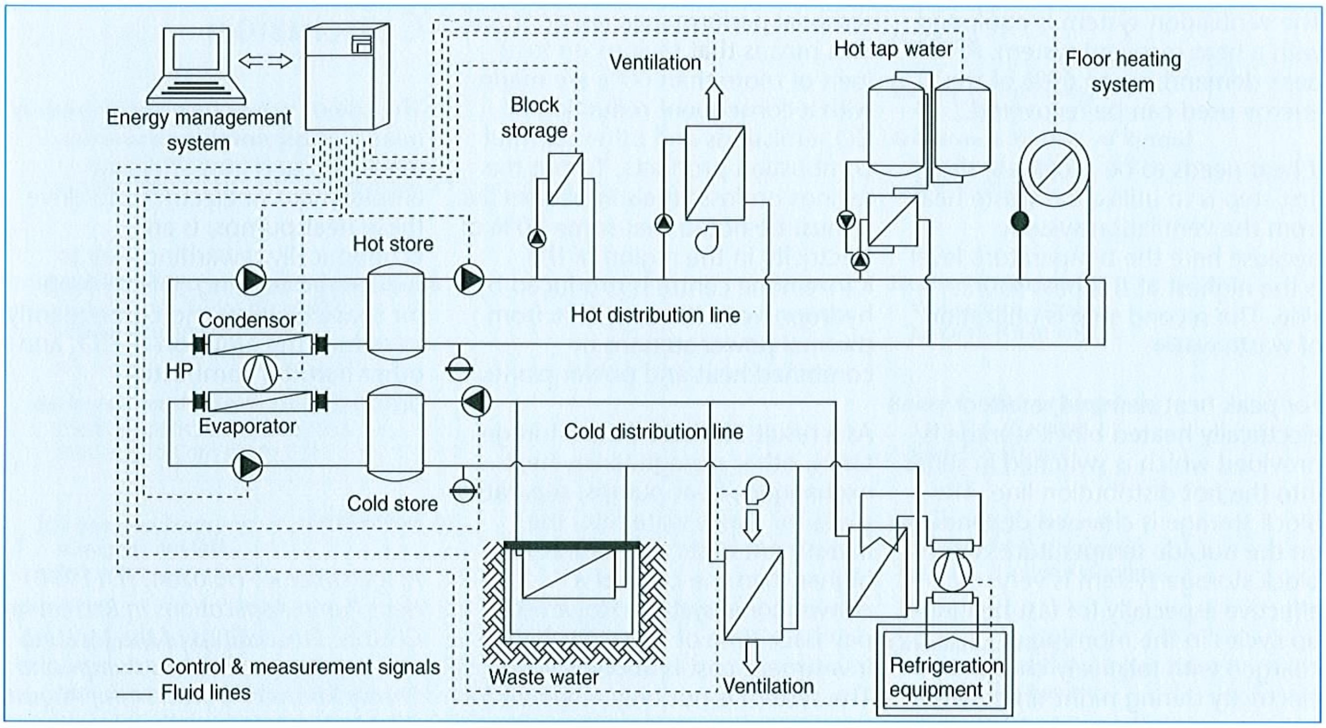

Figure 1: Flow Sheet of the Heating, Ventilating, Hot Water and Heat Recovery System Kanzelhöhe.

in skiing regions with a high peak demand during daytime.

The main running costs of the discussed heating systems are the costs for electricity. In Austria the electrical rate is split up into two charges. The demand charge has to be paid once a year and is based on the maximum power requirement occurring three times a year within a quarter of an hour. Because of the high cost of the demand charge it is necessary to achieve a uniform electricity consumption over the year without peaks. The working energy charge is based on the electricity consumption and is split up into different rates for day and night, summer and winter. The highest rate is for electricity on a winter day, the lowest rate is for a summer night.

The main component to control such a system in an efficient way is a computerized energy management system. This system optimizes the energy distribution within the whole building, and it minimizes demand peaks in electricity consumption.

An Application: Recreation Centre Kanzelhöhe

The recreation centre Kanzelhöhe (see photo) is situated on a mountain in the province of Carinthia. This province is a famous holiday region - in winter time, downhill skiing is very popular; during summer time there are lots of possibilities for walking and hiking in the mountains. In the valleys, lakes attract people for swimming, boating and sailing.

The recreation centre started operation in April 1991. The centre consists of 153 flats, space for recreation purposes, an indoor swimming pool with a sauna, a restaurant and shops. The enclosed volume is 79,000m^3 and the area is 5,400m^2.

A heating system was designed for Kanzelhöhe, in line with the concepts discussed above. The design is similar to other projects realized within the last 12 years in hospitals, other recreation centres and in office buildings (Atzgerstorfer 1990). The main components of the heating system (see Figure 1) are two heat pumps arranged in parallel with a heating capacity of about 220 kW. These heat pumps are the link between the cold side and the hot side, i.e. the side where waste heat is recovered and the side where heat is supplied.

The heat pumps are installed between a cold and a hot storage tank. In the cold storage tank waste heat is collected by means of a brine circuit from the ventilation system and from the waste water system. Waste water from showers, washing dishes, the restaurant and the indoor pool is collected in a storage tank of concrete where it is cooled down from about 25°C to 8°C before outlet to the sewage system.

The heat pumps heat the hot storage tank up to a temperature of 55°C. The heating water is distributed via the hot distribution line to a low-temperature floor heating system, the ventilation system and to the hot water system. The areas of the flats, the recreation facilities, the restaurant, the indoor pool and the sauna are heated by the floor heating system.

The ventilation system is equipped with a heat recovery system. At peak demand, up to 60% of the energy used can be recovered.

If heat needs to be provided, the first step is to utilize the waste heat from the ventilation system because here the temperature level is the highest at the heat source side. The second step is utilization of waste water.

For peak heat demand, a direct electrically heated block storage is provided which is switched in series into the hot distribution line. The block storage is charged depending on the outside temperature. The block storage system is very effective especially for fast heating-up cycles in the morning. If charged with relatively cheap electricity during night time, without increasing the peak electricity power requirement, operating costs are low.

An important part of the total system is the energy management system, which allows efficient use of electricity provided from the public grid. The system controls the total electricity consumption of the recreation centre and can switch off consumers if a peak in electricity consumption occurs. The storage content of the floor heating system as well as the building itself allows this to be done without any decrease in comfort. In this way the installed capacity of 2600 kW can be reduced down to an effective load level of 850 kW, resulting in a demand charge cost reduction of two thirds.

The realization of this optimized total energy management system, which provides not only direct energy recovery, but also utilization of passive solar energy, waste heat from lighting and technical equipment, is an important step towards economy and ecology. Only one third of the total energy demand within the building is required from the public grid to operate the system. By using electricity as the only external energy source, the energy flow in the system is realized with a seasonal performance factor of 3.5. This means that savings on fossil fuels of more than 60% are made, with a consequent reduction of CO_2-emissions and other harmful combustion products. To put the savings on fossil fuels in perspective it must be noted that some 80% of electricity in the region of the Kanzelhöhe centre is produced by hydropower with only 20% from thermal power stations or combined heat and power plants.

As a result of waste water storage tanks, other storage tanks, heat exchangers, heat pumps, separated pipes for waste water etc. the investment costs are naturally higher than the costs of a conventional system. However, pay-back time of these 8% higher investment cost is about 3 years. The system is not only a benefit for the environment, it is also cost effective.

Future Applications: Aschach and Beyond

A further step is the development of larger waste heat recovery systems. An interesting example is Aschach, a small district heating system. There, the heat source for the heat pump is waste heat from the generators of a Danube hydro power station, about 2,5 MW at a temperature level of 30°C. For peak load operation, float wood which is collected at the dam, is used. Again the system uses waste heat to meet base heat demand and locally available energy sources to meet peak demands.

Future systems will be planned for total regions and become more and more integrated, using different waste heat sources by means of heat pumps (Halozan 1989). However, such sophisticated systems can only be realized if reliable and readily understood information is available to assist the prospective planner, designer, installer and purchaser.

Conclusion

The use of waste heat recovered by heat pumps, combined with an intelligent and cost effective employment of electricity to drive these heat pumps, is an economically rewarding way to reduce the burning of fossil fuels for space heating and consequently to reduce the emission of CO_2 and other harmful combustion products.

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The Impact of Heat Pumps on the Greenhouse Effect

*A.B. Stuij

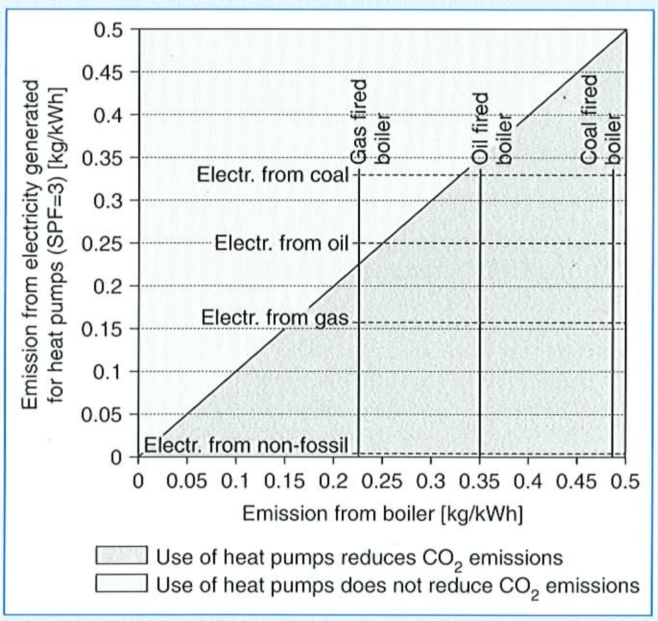
In 1990 the IEA Heat Pump Centre commissioned a major analysis of the impact of heat pumps on the greenhouse effect. The analysis, performed by ARGE Wärmetechnik of Austria, is now complete and the final report has been published. Almost fifty studies from all over the world were identified, reviewed and evaluated in the course of the analysis; the report provides a detailed overview of the current world-wide 'state of knowledge' on the issue. Apart from the final report, the IEA HPC has produced a comprehensive summary of the analysis, and a brochure which highlights the findings in the final report. The issue will remain on the agenda and is the topic of the workshop the HPC has jointly organized with the Swiss Federal Office on the 12th and 13th of October this year in Merligen, Switzerland.

The Analysis

The analysis looked at heat pumps as part of the overall energy system. Heat pumps have potentially both a positive and negative impact on the greenhouse effect.

On the one hand they can reduce the emission of the greenhouse gas CO_2. They utilize available heat (environmental heat, waste heat) as energy source - an energy source which does not require fuel combustion. And their use of electricity rather than direct combustion may be beneficial, depending on what heating system they replace and by what means the electricity is generated.

Figure 1: Average Specific CO_2 Emissions of Boilers and Electric Heat Pumps with Different Primary Energy Fuels (all Studies).



On the other hand, however, the loss of CFCs and, to a lesser extent, HCFCs during and at the end of a heat pump's working life may counteract the positive effect of reduced CO_2 emissions.

The analysis makes clear that the net effect of the use of heat pumps is a potentially significant reduction in the emission of greenhouse gases, in particular with the introduction of less damaging working fluids and the imposition of tighter regulations to prevent leakage.

As an example of an analysis result, Figure 1 shows the impact on specific CO_2 emissions of the replacement of a directly fired heating boiler by an electrically driven heat pump with a Seasonal Performance Factor of 3.

Main Conclusions

The report concludes that electrical heat pumps which replace directly fired heating boilers in general offer a significant CO_2 emission reduction potential, even if the electricity to drive the heat pump is generated with oil or gas. A significant potential remains to improve the efficiency of heat pumps where that potential for heating boilers is now virtually exhausted.

The economic potential of heat pumps for reducing the total CO_2 emissions in some countries is estimated to be up to 4%, with a technical potential of up to 9%. The report states that the greenhouse effect from the loss of working fluids other than CFCs is negligible.

Finally it is concluded that the heat pump as an energy efficient technology which benefits the environment should play an important role in an increasingly environmentally conscious world.

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Norway's National Heat Pump Programme 1989 - 1992

*U. Rivenœs

Background and motivation

The Norwegian National Heat Pump Programme started in 1989 and is scheduled to finish by the end of 1992, at a total cost of nearly NOK 30 million (USD 5 million).

The programme was initiated by the Norwegian Council for Scientific & Industrial Research (NTNF), a research management institute with an annual budget of USD 150 million.

Over the years prior to 1989, large funds had been spent on Heat Pump R&D at SINTEF in Norway, the large (2000 employees) research institute in Trondheim. A lot of heat pump knowledge had been accumulated at SINTEF, but little had been successfully disseminated - in 1989. Norway had 10,000 heat pumps, while Sweden had more than 200,000. So what could be done?

The Programme

NTNF decided that a heat pump knowledge transfer programme was required, including demonstration and international cooperation. The programme was organized as shown in Figure 1.

The two largest energy institutes in Norway, SINTEF's Division of Refrigeration in Trondheim and IFE (Institute of Energy Technology) just outside Oslo, cooperated as shown in the figure.

Target Markets

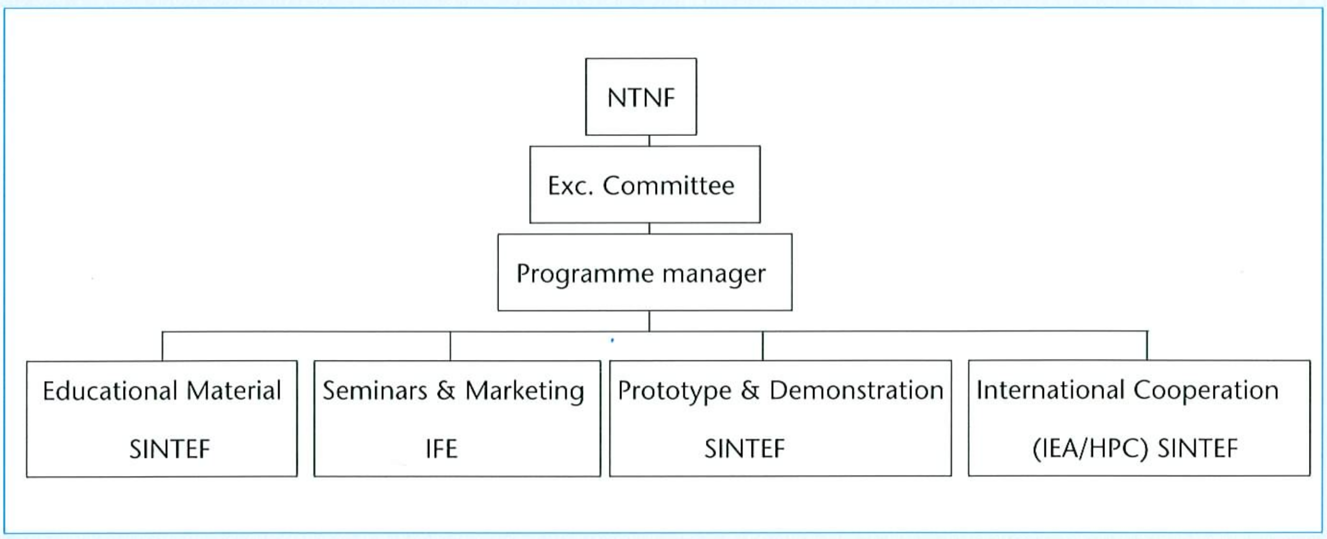
After discussions it was decided that the primary target market for the information dissemination should be the HVAC-consultants in Norway. Most building and/or property owners do use consultants whenever a new office block or building is being designed. Very few new buildings in Norway were equipped with heat pumps.

Seminars

In 1990, the programme began a series of three-day heat pump seminars throughout the country, tailored for HVAC-consultants.

Highly skilled teachers were hired and have, during the last three years, conducted almost 15 three-day seminars. The number of participants was limited to 25, with a seminar fee of USD 500. All the seminars were immediately fully booked.

Figure 1: Organization of Norway's Heat Pump Programme 1989-1992.



Educational Material

From 1989 to 1991, more than half a million US dollars were spent on producing educational books and brochures on heat pumps and their application in buildings for space heating.

Funding

The entire programme was funded by the Ministry of Energy and Petroleum and The Federation of Norwegian Electrical Utilities.

The Situation Today

The Ministry's decision to give a cash refund of up to 40% of the investment cost to anybody that installs a heat pump in Norway (air-source heat pumps are exempted) has sparked a lot of activities within the heat pump sector. The impact of this, together with the National Heat Pump Programme, is significant:

- Small companies are now selling residential heat pumps "on the doorstep" to people that do not know the difference between a vacuum cleaner and a heat pump.
- The people who are designing, operating and maintaining all state owned buildings (about 10 million sq. meters in Norway) have been specially educated by the programme as the number of heat pumps in these buildings is now increasing rapidly.
- Some electric utilities are opposing heat pumps as they affect their revenues.
- More people than can be accommodated are asking to attend seminars in 1992.

A Norwegian Heat Pump Manufacturing and Installation Association has been formed and, in cooperation with the Programme and the involved research institutes, will make educational material, and conduct courses and seminars for everybody wishing to sell and install residential heat pumps in Norway.

This material is required urgently to prevent the market from being undermined by unprofessional marketing and installation of residential heat pumps.

Demonstration and International Cooperation

The Programme has now documented the operation of 40 different heat pump types in Norway. The work will continue in the period 1993-1995 and will concentrate on the CFC-issue and the use of other working fluids.

In the international arena, Norway will try to continue the fruitful cooperation with the IEA/OECD in general and the Heat Pump Centre in particular.

The Results

This programme has clearly demonstrated that there is a market for good, educational heat pump dissemination material and seminars for HVAC-consultants and building/property owners in both the public and private sector in Norway.

The effect of this kind of targeted dissemination should last for 6-8 years, and the developed material can then be handed over to an organization that can continue the seminars on a commercial basis.

Conclusion

The National Heat Pump Programme has lifted the educational heat pump base, providing a platform from which the government could launch its subsidy programme. With the 40% investment support the number of heat pumps in Norway is now increasing at an accelerating rate.

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The IIR and its Relationship with the IEA in the Field of Heat Pumps and Related Technologies

*L. Lucas

Abstract

The IIR (the International Institute of Refrigeration - known as IIF in French) is an intergovernmental organization. Fifty seven countries are IIR members. Furthermore, there are nearly 1300 associate and/or IIR commission members (companies, universities, research organizations, individuals, etc.).

This paper deals with the activities of the IIR and its cooperation with other international organizations. The emphasis is specifically on heat pumps and related technologies.

Introduction

Every scientist or technologist knows how technical words can become misleading when commonly used. New words are proposed and definitions are agreed upon, but common usage is often more powerful. Are, for example, the terms "heat pump" and "heat exchanger" used with no ambiguity? What do people in the various parts of the world mean when they speak of "refrigeration"?

In any case, heat pumps and the related technologies which interest the readers of this newsletter need to be dealt with at an international level, on both scientific and market topics. In this respect the IIR has done quite a lot in its years of existence. It is also normal for the IEA to have taken a particular interest in heat pumps, due to their possible impact on energy consumption. I am pleased to take this opportunity to present what the IIR does, as well as the relationship which is possible and desirable between the two organizations in this field.

The IIR

The IIR's mission is to improve knowledge and technical capacities on a worldwide level in all sectors which employ refrigeration processes.

The IIR was established following an International Conference in 1908. It was the famous physicist Kamerlingh Onnes, who was to be awarded the Nobel Prize in 1913 for discovering superconductivity, who called for its establishment. The IIR's statutes were adopted after the First World War (in 1920). They have been amended regularly to keep pace with the changing scientific, economic and geopolitical situation of the world.

The IIR has nevertheless always had certain characteristics and has followed certain guiding principles:

- Its members come from all over the world: there are 57 IIR member countries (see Table 1), representing 80% of the world population, from all five continents. All of the largest countries and many of the medium-sized ones are IIR member countries. Along with these countries, the IIR is backed up by nearly 1300 IIR associate members and/or

Table 1: Member Countries of the International Institute of Refrigeration.

AFRICA	***EUROPE***
Algeria	Austria
Benin	Belgium
Burkina Faso	Bulgaria
Cameroon	Czechoslovakia
Central African Republic	Denmark
Chad	Finland
Egypt	France
Gabon	Germany
Guinea	Greece
Ivory Coast	Hungary
Madagascar	Ireland
Morocco	Italy
Niger	Malta
Senegal	Netherlands
South Africa	Norway
Sudan	Poland
Togo	Portugal
Tunisia	Romania
	Russia (Federation of)
AMERICA	Spain
	Sweden
Argentina	Switzerland
Brazil	United Kingdom
Canada	Yugoslavia
Cuba	
United States	***OCEANIA***
ASIA	Australia
	New Zealand
China	
India	
Israel	
Japan	
Jordan	
Lebanon	
Turkey	
Vietnam	

Fields of activity	Presidents
	Steimle F. (Germany)
Very low temperatures (Sec A):	***Arkharov A.M. (Fed. of Russia)***
. cryogenics, superconductivity (Com A1/2)	. Kerney P.J. (United States)
. liquified gases (LNG, LPG, air, nitrogen, CO_2, etc.) (Com A3)	. Petit P. (France)
Thermodynamics and equipment (Sec B):	***Stephan K. (Germany)***
. heat transfer, cycles (Com B1)	. Watanabe K. (Japan)
. related equipment (Com B2)	. Kruse H. (Germany)
Biological applications (Sec C):	***Bailey C. (United Kingdom)***
. medical applications (Com C1)	. Turc J.M. (Canada)
. food applications (Com C2)	. Come D. (France)
Storage and transport of products (Sec D):	***Mlynarczyk J. (Poland)***
. storage (Com D1)	. Skjeggedal O. (Norway)
. Transport (Com D2/3)	. Stera A. (United Kingdom)
Cold and heat (Sec E):	***Cavallini A. (Italy)***
. air conditioning in buildings, vehicles, industry, etc. (Com E1)	. Goldschmidt V.W. (United States)
. heat pumps and energy savings (Com E2)	. Granryd E. (Sweden)

Table 2: Scientific Council of the IIR/Sections and Commissions.

commission members. These are individuals, companies, research centres, etc., from member countries and 30 other countries. Developing countries are well represented, as are most industrialized ones.

- The IIR is wide open to the related technologies. Along with the representatives of the Management Committee, the Scientific Council of the IIR plays an important role in the IIR's activities. Three members from each of these bodies form the Management Committee of the IIR. There are currently ten IIR Commissions. These Commissions cover thermodynamics and heat transfer, but also cryogenics, liquefied gases, air conditioning, heat pumps, food processing and cryosurgery. The E2 Commission is particularly in charge of heat pumps and energy efficiency (see Table 2).

- The IIR is oriented towards science and technology. The IIR has no mandate for commercial activities, politics, or lobbying, although it is aware of the weight scientific and technical findings can have in political decisions.

IIR's Relations with other International Organizations

The IIR has long been accustomed to working with other international organizations. One has to read the list of the above-mentioned IIR Commissions to see how varied the IIR's activities are. Of course, each of the related fields involves technologies and problems outside refrigeration; such fields include magnets, medicine, food, construction, etc.

The IIR generally has corresponding bodies in its member countries, but there may exist some local international organizations for work on some particular topics. For example, the IIR has had to work very closely with the United Nations Economic Commission for Europe when that body was drawing up the Agreement for the Transport of Perishable Foodstuff (ATP). The Cryogenic Society of America chose the XVIII Congress of Refrigeration as the site of its regular meeting. Regular contacts have been maintained with the Food and Agriculture Organization (FAO), the United Nations Industrial Development Organization (UNIDO), the United Nations Environmental Program (UNEP), and the United Nations Development Programme (UNDP).

In November 1992, the Montreal Protocol on the phase-out of CFCs will be amended again, in Copenhagen. UNEP decided to send a preliminary document to all 84 signatory countries. The chapter of the "Technical Options Report" on refrigeration was prepared by a group chaired by Mr. Kuypers which carried out its task at the IIR.

IIR's Relations with IEA

Of course, energy is a major concern for most politicians, companies and scientists. After the first oil shock, the IEA was established. It was almost inevitable that the IEA would take an interest in heat pumps, due to the energy savings potential of this technology.

Many of the IEA's activities interest the various IIR commissions. The activities of the HPC are a first priority for cooperation between the two organizations.

Not surprisingly, when the IEA wanted to set up a scientific advisory board for these activities, many of the members were active in the IIR's Scientific Council and Commission E2: Prof. Fritz Steimle, Prof. Per Erling Frivik, Prof. Eric Granryd, and Mr. Gerald Groff.

Predicting how many heat pumps will be built in the next few decades is not the task of the IIR; nor is lobbying governments for favourable tax regimes. When the IEA does these things, it can save a lot of money and time in utilizing the IIR for all scientific and technical activities. Such a relationship has already started for technical papers, commission meetings, etc., to our mutual advantage.

Of course, rules for the exchange of information have to be set every time a new relationship is planned. All member countries of the IEA HPC are IIR members, but they may wish to keep some of the results of their work exclusive to themselves, although in other cases publicizing results is expected to result in a return on the money they invest in the IEA. Experience has shown that solutions can be found.

A close relationship between the IIR and the IEA has already been established thanks to people who, because of their fields of activities, are involved in both organizations. I congratulate them, and I am confident in our future work together. It will save a lot of energy.

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Energy and Global Warming Impacts of CFC Alternative Technologies in HVAC Equipment

**S.K. Fischer, P.D. Fairchild, P.J. Hughes*

Introduction

Chlorofluorocarbons (CFCs) have been used as blowing agents in foam insulation, as working fluids in cooling and refrigeration equipment, and as solvents in general and precision cleaning applications since their introduction in the 1930s. The number of applications and volumes of CFCs used grew at a tremendous pace during the 1960s and 1970s, but there have been concerns about their environmental impacts since 1973. In the mid-1980s it was confirmed that these extremely useful chemicals contribute to the destruction of stratospheric ozone and are the primary cause of the Antarctic Ozone hole. The Montreal Protocol was drafted in 1987 as an international agreement to phase-out the use of CFCs in an effort to reduce future ozone losses and to permit stratospheric ozone levels to be restored to pre-1986 levels. Amendments to the Protocol have tightened the provisions of the agreement and have accelerated the phase-out schedule in response to recent findings on ozone depletion.

CFCs have also been found to be second only to carbon dioxide as a factor causing increased greenhouse warming. It is very important that the compounds and technologies developed as replacements for CFC in an effort to protect stratospheric ozone do not result in a net increase in global warming by introducing less efficient processes and increased carbon dioxide emissions.

A study was conducted to identify those alternative chemicals and technologies that could replace CFCs in energy related applications before the year 2000, and to assess the total potential impact of these alternatives on global warming. The analysis includes an estimate of the direct effects from the release of blowing agents, refrigerants, and solvents into the atmosphere and the indirect effects of carbon dioxide emissions resulting from increased energy use for heating and cooling commercial and residential

Greenhouse Gas	Integration Time Horizon 20 years	100 years	500 years
Carbon Dioxide	1	1	1
CFC-11	4500	3500	1500
CFC-12	7100	7300	4500
CFC-113	4500	4200	2100
CFC-114	6000	6900	5500
CFC-115	5500	6900	7400
HCFC-22	4100	1500	510
HCFC-123	310	85	29
HCFC-124	1500	430	150
HCFC-141b	1500	440	150
HCFC-142b	3700	1600	540
HFC-125	4700	2500	860
HFC-134a	3200	1200	420
HFC-143a	4500	2900	1000
HFC-152a	510	140	47

Table 1: Global Warming Potentials Relative to CO_2.

buildings using non-CFC insulation, household and commercial refrigeration, building and automobile air-conditioning, and general metal and electronics solvent cleaning. The primary interest in this article is on the alternatives to CFC-11 and CFC-12 in refrigeration and air-conditioning and HCFC-22 in unitary space conditioning equipment.

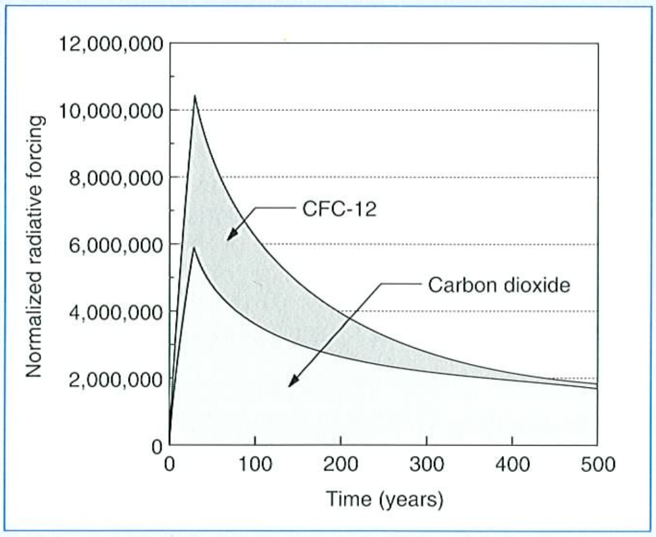
Radiative Forcing and Total Equivalent Warming Impact

The impacts that greenhouse gases have on global warming are frequently quantified and compared with each other by using indices called global warming potentials (GWPs). Tables of these values are often presented expressing the contributions of a trace gas to global warming relative to the impact of either CFC-11 or CFC-12; one of the most useful sets of values are those that express the impact of a release of a greenhouse gas relative to the impact of an instantaneous release of the same mass of carbon dioxide, CO_2. In this context the GWP of a gas is equal to the mass of $C0_2$ that would have the same net impact on global warming as the release of a single unit (pound or kilogram) of the gas in question (see Table 1).

The columns in Table 1 are labelled with different time frames, or integration time horizons. The concept of the "integration time horizon" for the GWP values is an important idea that needs to be explained in order to understand some of the results from this study. The GWPs represent a cumulative impact on global warming over a specified period of time relative to the cumulative impact of an equal mass of CO_2 over the same period of time. If that gas is removed from the atmosphere more rapidly than $C0_2$, then its GWP will decrease as the time horizon under consideration increases. An examination of CFC-11 shows that over a 20 year period, an instantaneous release of one kilogram of CFC-11 has the same impact on global warming as the release of 4500 kg of $C0_2$. Over a 100 year period, the impact is equivalent to the release of 3500 kg of CO_2 and over a 500 year period it has the impact of 1500 kg of CO_2. This decrease is a result of the fact that CFC-11 is removed from the atmosphere faster than CO_2. No single time horizon is clearly the "right" one and the choice is often controversial.

A drawback of the GWPs is that they cannot measure the impact of a system, like a refrigerator or chiller, because the GWPs do not take into account the energy used and resulting CO_2 emissions over the lifetime of the system. If a set of GWPs is used that is based on CO_2 however, a "composite" value or total equivalent warming impact (TEWI) can be computed for systems that both use a greenhouse gas as a working fluid and also indirectly cause emissions of carbon dioxide due to energy use. For example, consider a 1000 kW (300 refrigeration ton) water-cooled centrifugal chiller using 170 kg (370 lbs) of CFC-12. Such a system would consume about 190 W of electricity for each kilowatt of cooling delivered, have an annual load factor of 0.2, and would require a condenser pump and cooling tower fans and spray pumps using another 38 W for each kilowatt of cooling delivered by the chiller. The annual load factor is here defined as the annual refrigeration load met by the chiller, divided by the hours in a year (8760) times the chiller capacity. Also, historically chillers have lost about 8% of their refrigerant charge each year through leaks and during maintenance. TEWI can be compared for baseline systems using CFCs and systems using alternative refrigerants to examine the

Figure 1: Potential Radiative Forcing from Gases Associated with Operating a Centrifugal Chiller Using CFC-12.



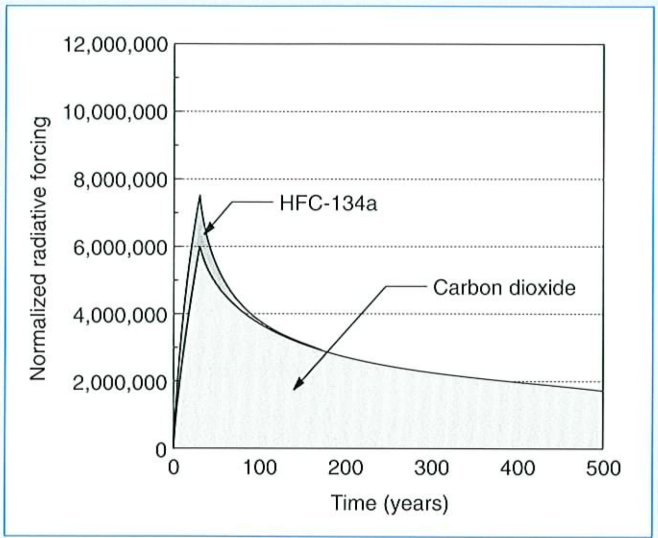


Figure 2: Potential Radiative Forcing from Gases Associated with Operating a Centrifugal Chiller Using HFC-134a.

trade offs between energy use and direct warming impacts from refrigerant released to the atmosphere.

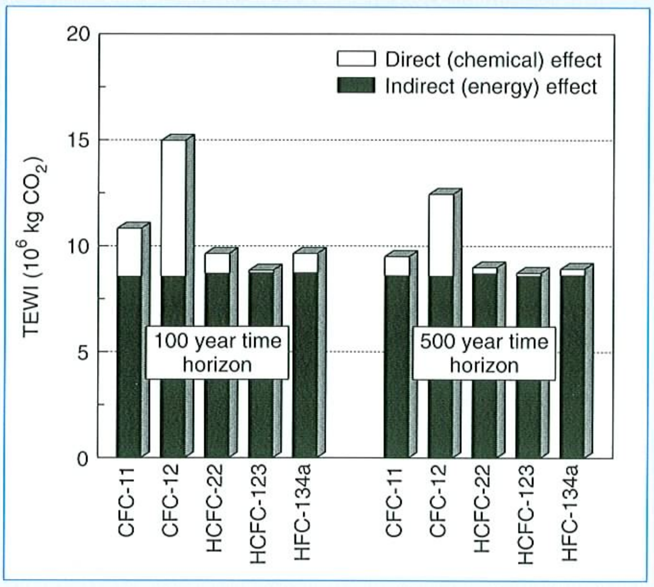
The significance of the time horizon and the relative contributions of energy use and refrigerant loss are illustrated in Figure 1. The refrigerant lost and the CO_2 both contribute to the radiative forcing in the atmosphere and impact global warming. The instantaneous radiative forcing of 1 kg of CO_2 dispersed throughout the atmosphere has been set to one and the radiative forcing of the other gases is specified relative to CO_2. Figure 1 shows the increase of CO_2 and CFC-12 from a chiller during 30 years of operation and the gradual decay as they are removed from the atmosphere through natural processes. The lightly shaded portion below the bottom curve corresponds to the effects from the CO_2 emissions from energy use and the heavily shaded portion represents the effects of the refrigerant.

The impact of the CFC-12 is significant whether the effect is considered over 50, 100, 300, or 500 years. Figure 2 has a similar set of curves using the corresponding assumptions for a chiller using HFC-134a as the refrigerant. There is a difference in energy use for the two cases based on the best available information from manufacturers, but it is insignificant to the point that it is indiscernible. The impact of the CFC substitutes in Figure 2 is much smaller than in Figure 1 and is a small percentage of the overall effect over almost any time horizon. The total effect, corresponding to the area beneath both curves in Figure 2, is less than the total effect with the CFCs in Figure 1.

The computation of the areas under the curves is an unnecessarily tedious calculation. The Total Equivalent Warming Impact (TEWI) can be calculated from the total mass of the gas released to the atmosphere, its GWP, the lifetime of the system, and the annual energy use and emissions of CO_2. The TEWI is proportional to the areas under the curves in Figures 1 and 2 and it is a very good approximation of the total impact on global warming for energy using systems (within a few percentage points of the area under the curves except when the lifetime of emissions is of the same order of magnitude as the time horizon for the GWP used). The TEWI is defined as the mass of a greenhouse gas released into the atmosphere times its GWP plus the lifetime of the system (chiller in this case) times its corresponding annual emissions of CO_2 from electric power generation for energy use. Naturally the TEWI is going to depend on the GWP and the integration time horizon chosen. For the two cases pictured in Figures 1 and 2, the 100 year TEWI for the chiller using CFCs is 15.0×10^6 kg equivalent of CO_2 while that for the chiller using HFC-134a is 9.6×10^6. The 500 year TEWIs are 12.5×10^6 and 9.0×10^6 respectively.

Figure 3 is a bar chart showing the proportion of the 100 and 500 year TEWIs due to the direct emissions of refrigerant for chillers using CFCs and possible CFC replacements. The cross-hatched portions represent the contributions from refrigerants while the darkly shaded sections correspond to the contribution from energy use. Each bar is labelled with the refrigerant used (i.e. CFC-11, CFC-12, HCFC-22, HCFC-123, and HFC-134a). The differences from energy use are not very large, while the portion of the TEWI from refrigerant loss varies a great deal. Both HCFC-22 and HFC-134a losses contribute 5 to 10% of the TEWI, depending on whether the 500 or 100 year time horizon is chosen, while the contribution from HCFC-123 is insignificant in both cases. Changing from CFC-11 to any of the non-CFC alternatives reduces the TEWI by a few percent, but replacing a

Figure 3: Comparison of TEWI for chillers using CFC Alternatives (500 year GWP Values).



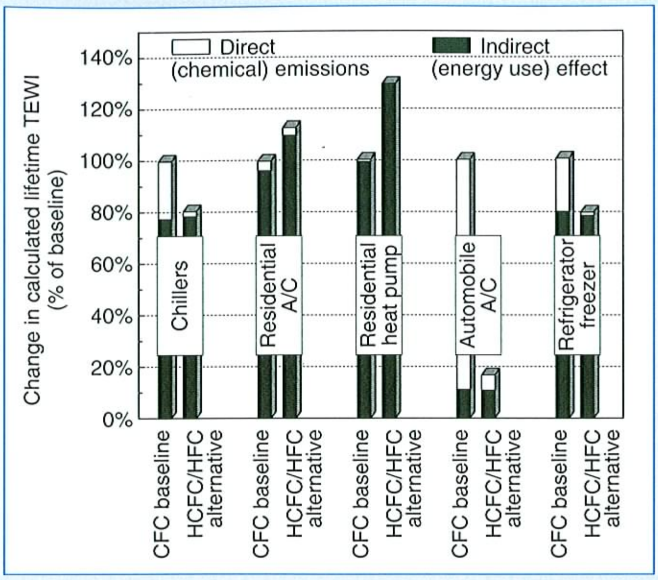


Figure 4: Comparison of TEWI for CFC Alternatives with Baseline Technologies for Five Refrigeration Applications.

CFC-12 chiller with a chiller designed to use any of the substitutes reduces TEWI significantly.

Results

Although the study looked at every major application of CFCs, household refrigeration, unitary air-conditioning, centrifugal chillers, retail refrigeration, and automobile air-conditioning were identified as the applications with the greatest global warming impacts. Each of these areas was evaluated for typical or representative equipment in Europe, North America, and Japan taking into account differences in lifestyles and customs, equipment designs, and source energy in each region.

Results for five applications are illustrated in Figure 4 using the 500 year GWP values. In this figure the TEWIs for each application have been normalized by the TEWI for the corresponding CFC baseline case. The bars for the CFC alternatives are averages of the TEWI for the most commonly proposed alternatives for each application. The results for chillers show a reduction of almost 20% going from CFC-11 and CFC-12 chillers to the alternatives with only a small portion of the TEWI due to refrigerant emissions for the alternatives. Figure 4 also shows that only a very small portion of the TEWI for residential air-conditioners and heat pumps is due to refrigerant losses and that the alternative in each of these applications, HFC-134a, result in a 10 to 20% increase in energy use. The very large direct contributions to TEWI from the high refrigerant loss rates in automobile air-conditioning show up clearly both for the CFC baseline and for the alternative. The results for supermarket refrigeration (not shown) are similar. The final set of bars, those for refrigerator/freezers, include the direct effects from both the refrigerant and the blowing agent. In this case the HCFC/HFC alternatives result in a 20% reduction in TEWI without any noticeable change in energy use and the impacts of the foam insulation blowing agent and the refrigerant are only about 1% of the total.

Several conclusions can be drawn from the information plotted in Figure 4. First, for relatively low-loss applications like refrigerator/freezers, unitary air-conditioners and heat pumps, and even for centrifugal chillers, the direct contribution of the CFC alternative is a small to insignificant fraction of the TEWI. Second, the greatest reductions of TEWI can be made by using CFC alternatives in the applications that have relatively high losses, retail refrigeration (not shown) and automobile air-conditioning where as much as 30% of the charge is lost annually. In these cases, however, the direct effect of the escaping refrigerant is still a large fraction of the total global warming impact and it may be possible to reduce TEWI even further by innovative or next-generation technologies.

Finally, recent findings are throwing some doubt on whether or not CFCs actually have a net warming effect on the atmosphere; ozone is itself a greenhouse gas and the effect of ozone loss from CFCs partially offsets the contribution to global warming from CFCs. The magnitude of this effect is still being studied by atmospheric scientists. When these new questions are finally resolved, the net effect is that the GWPs of the CFCs and HCFCs listed in Table 1 are likely to be reduced. The consequence on this work is that the energy contributions to TEWI will be even more dominant than they are now, which only emphasizes the fact that the most effective way to reduce contributions to global warming in the future will be to improve system efficiencies and reduce energy use.

Reference:

Fischer S.K., Fairchild P.D, and Hughes P.J., "Energy and Global Warming Impacts of CFC Alternative Technologies", AFEAS/DOE, 1991.

*Authors:

S.K. Fischer, P.D. Fairchild, P.J. Hughes, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

U.S. Alternative Refrigerants Evaluation Programme

*M. Menzer

Abstract

HCFC-22 has been the ideal refrigerant for heat pump applications because of its favourable thermodynamic characteristics, its miscibility with lubricants, its compatibility with most commonly used materials, and the fact that it is not flammable or toxic. It is doubtful that a replacement for HCFC-22 will possess all these qualities. To comprehensively evaluate all potential replacements a number of American, European and Japanese companies have now come together in the Alternative Refrigerants Evaluation Programme (AREP).

Introduction

Certainly, the biggest issue facing heat pump equipment manufacturers in the U.S. is the phaseout of ozone-depleting refrigerants. The uncertain future of HCFC-22 (as of this writing, Montreal Protocol revision dates for HCFC-22 have not been decided) has made it critical for manufacturers to quickly identify suitable replacements for this refrigerant. This is particularly true in the U.S., which accounts for half of the world-wide usage of HCFC-22 (Figure 1).

The Programme

Traditionally, heat pump equipment manufacturers have not undertaken cooperative research, except on the most basic level. But the lack of time available to find a replacement, and the large amount of testing to be done, have brought U.S., European, Canadian, and Japanese companies together to determine the performance of HCFC-22 replacements. They have come together in a programme called AREP, the Alternative Refrigerants Evaluation Programme. It began in January 1992 as an effort of the Air-Conditioning and Refrigeration Institute (ARI) and its members. Through a great deal of cooperation, it is eliminating the duplication of effort by ARI's members and it is serving to highlight the industry's commitment to finding environmentally acceptable alternatives to HCFC-22.

The mission of AREP is to "identify and evaluate HCFC-22 replacements for all major ARI product categories". This includes not only heat pumps, but unitary air conditioners, chillers, and refrigeration equipment. The evaluation is being conducted in an objective and open process, with inputs from all interested parties. Most project meetings are open to industry, government and others.

The transition to alternative refrigerants might be easier if all manufacturers could agree and standardize on a single replacement for HCFC-22 or at least a single replacement for a given application. However, it is illegal under U.S. anti-trust laws for a group of manufacturers to decide to use a single refrigerant to the exclusion of others.

Thus the AREP programme is not an effort to find a single replacement nor is it an effort to prioritize the results. It is only an effort to determine the performance of these alternatives and publish the results for use by individual companies.

Task Force

An ad hoc Task Force reporting to the ARI Board was established to guide this programme and a technical committee has the responsibility of recommending refrigerants to evaluate, developing evaluation procedures, reviewing the results, and generally coordinating the programme.

The Task Force is headed by ARI's Chairman Dave Goldberg and is comprised of senior executives of

Figure 1: World Use of HCFC-22 - 1991.

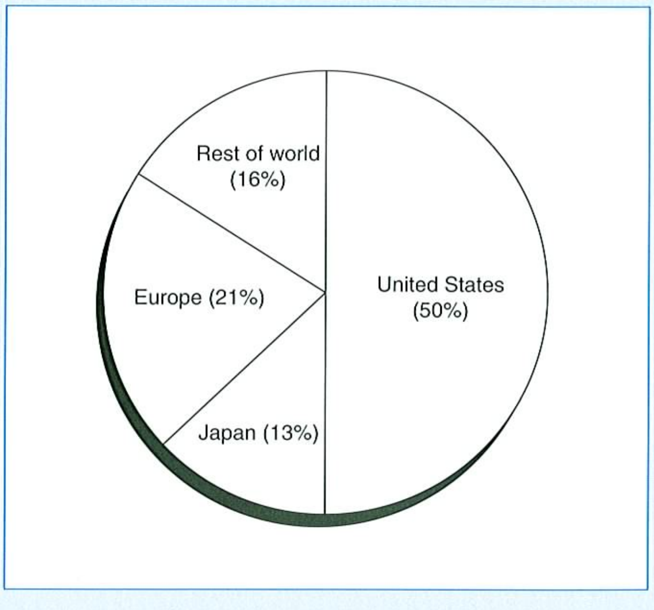


Table 1: Companies represented on the AREP Task Force.

Carrier Corporation
Copeland Corporation
Dunham-Bush, Inc.
Hussmann Corporation
Inner-city Products Corporation
Lennox International, Inc.
Rheem Manufacturing Company
SnyderGeneral Corporation
Standard Refrigeration Company
Tecumsch Products Company
The Trane Company
York International Corporation

many of ARI's major compressor and systems companies. These companies have all made a commitment to the programme - including the sharing of results.

The companies currently represented on the Task Force are listed in Table 1.

In addition, ten Japanese and eleven European companies have made a commitment to testing certain refrigerants and sharing the results, as the U.S. companies will share their results with the Japanese and European companies. The National Research Council of Canada will also play a role.

Choosing Candidates

The first step was choosing the refrigerant candidates. When the programme was announced in January 1992 all interested parties were asked to nominate candidate refrigerants. The announcement was published in air conditioning and refrigerant trade press. Almost 30 nominations from government and from industry were received. The Technical Committee met in early February to discuss the nominations, debate the pluses and minuses, and decided upon ten for further evaluation. In addition, the Committee decided to open the process for additional nominations this summer so that future candidates can be considered.

The top ten candidates chosen for further evaluation are listed in Table 2.

Of the ten there are three pure refrigerants, two azeotropic (blends of two or more refrigerants that behave like one), and five zeotropic. It is recognized that there are some special problems associated with using zeotropics in heat pump, air conditioning, and refrigeration applications. As an example preferential leaking of one component can be a problem. A system low on refrigerant may require complete purging and a whole new charge. And the need for counterflow heat exchangers may alter the way equipment is designed and manufactured.

On the other hand, the characteristics of zeotropic may allow engineers to design systems with higher efficiencies, and more comfortable supply temperatures. It may even allow for the design of heat pumps that use differing refrigerant concentrations for heating and cooling, resulting in a system that is optimized for both.

The Testing Plan

AREP is designed to be a two year programme (Figure 2) beginning with compressor calorimeter tests that are being conducted by participating companies. Currently, heat transfer testing will be performed under the sponsorship of the Electric Power Research Institute (EPRI) at various universities and laboratories. Drop-in testing will be conducted in existing systems.

The results of this testing will be put into computer simulations that will be used as a screening mechanism for refrigerants and to design components for systems. In the second year of the programme, systems will be designed, built and tested. The tests are expected to be completed by February 1994 and the results made public about 6 months later.

Other Considerations

The AREP testing is chiefly focused on performance. It is recognized, however, that factors other than performance will have to be considered before a manufacturer commits to using a new refrigerant.

Toxicity is one such concern. The equipment industry is working with a consortium of chemical companies to make sure that the toxological effects of the refrigerant candidates are understood. All but one of the component refrigerants in the list of ten have undergone or are undergoing testing; the exception is

Table 2: Alternative refrigerants; top ten candidates chosen for further evaluation.

HCFC-22 Replacement Candidates	
HFC-32/HFC-125 (azeotropic)	(60%/40% weight)
HFC-32/HFC-134a	(30/70)
HFC-32/HFC-125/HFC-134a	(10/70/20)
R-290 (propane)	-
HFC-134a	-
R-717 (ammonia)	-
HFC-32/HFC-125/HFC-134a/ R290	(20/55/20/5)
HFC-32/HFC-125/HFC-134a	(30/10/60)
R-502 Replacement Candidates (for refrigeration)	
HFC-125/HFC-143a (azeotropic)	(45/55)
HFC-125/HFC-143a/HFC-134a	(40/45/15)

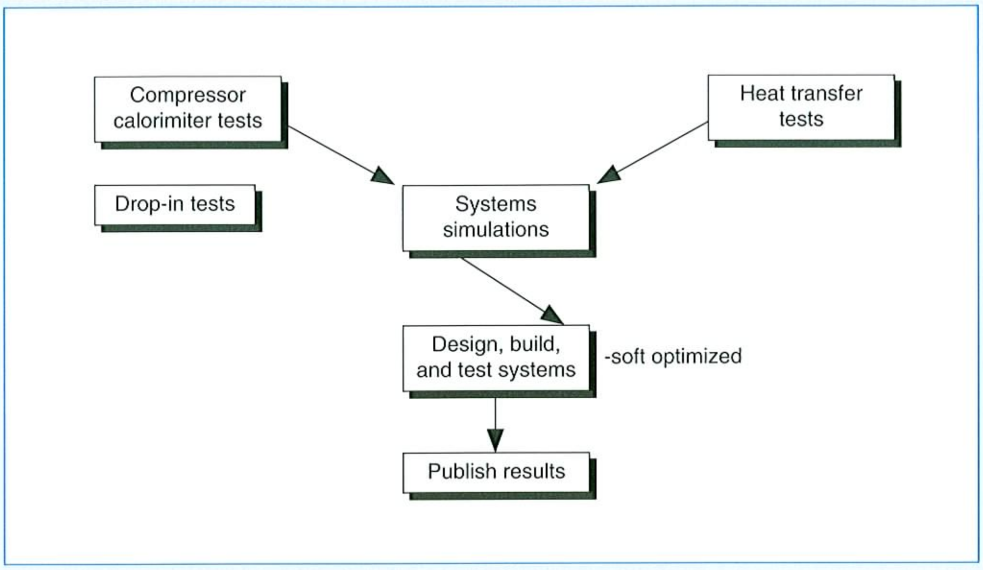


Figure 2: The Testing Plan.

HFC-143a. Some toxicity tests have been run on HFC-143a, but not the exhaustive tests conducted on the other refrigerants. The equipment manufacturers are encouraging chemical manufacturers to include HFC-143a in future testing.

Refrigerant flammability is also a concern. Certainly propane is flammable and so are some of the individual components of some blends. Underwriters Laboratories is being funded by the U.S. Environmental Protection Agency to test and assess the risk of flammability of several refrigerants.

Another consideration is the compatibility of these refrigerants with the materials used in cooling and heat pump systems. With funding from the U.S. Department of Energy and from ARI, the Air-Conditioning & Refrigeration Technology Institute (ARTI) is managing a significant programme called the Materials Compatibility and Lubricants Research programme. The first phase of the programme is underway. ARTI has contracted with independent universities and laboratories...

- to evaluate the thermal and chemical stability of refrigerants with metals, and
- miscibility of lubricants with refrigerants, and
- compatibility of new refrigerants and lubricant with
  - plastics
  - elastomers
  - motor materials
- and to provide precise measurement of thermophysical properties of these refrigerants. Precise measurements will be particularly important in the design of tomorrow's equipment.

Future MCLR work will include investigation of the compatibility of desiccant material, the solubility and viscosity of new refrigerants, and accelerated testing methods which will allow research engineers to better perform compatibility testing in the future.

Disseminating Results

As test results become available, they will be thoroughly reviewed by industry experts before being released. Results will be presented at a variety of technical conferences worldwide. And all results will be made available through the ARTI Refrigerant Database. This database is an extensive collection of citations and abstracts on CFC & HCFC substitutes and is available in PC format. The database contains information on materials compatibility, refrigerant and lubricant properties, and refrigerant performance. It is available from:

Air-Conditioning & Refrigeration Technology Institute
Attn. Refrigerant Database
4301 N. Fairfax Drive, #425
Arlington, VA 22203, USA.

Conclusion

The time schedule to find replacements for HCFC-22 is ambitious. The manufacturers of heat pump and cooling equipment in the U.S. and abroad are cooperating in the search for HCFC-22 substitutes. Parallel research efforts are being undertaken to evaluate the performance, material compatibility, lubricant compatibility, toxicity, and flammability of several promising candidates to replace HCFC-22.

**Author:*

M. Menzer, Vice President, Research & Technology Air-Conditioning and Refrigeration Institute, USA.

News and Views

Market News

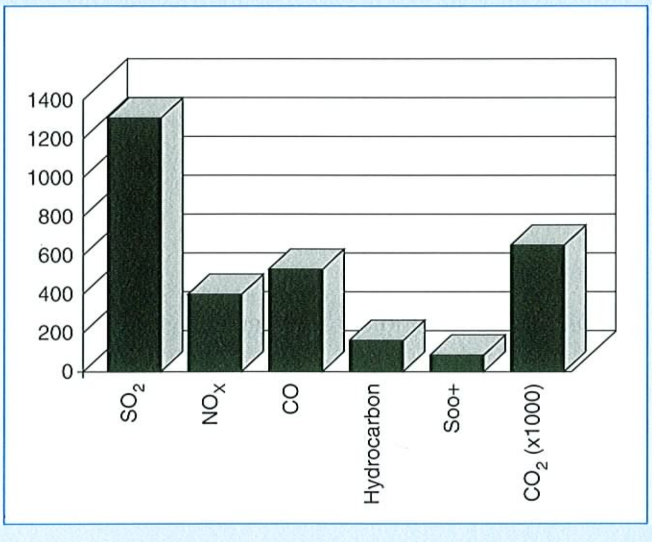
Bright Future for Gas Heat Pumps

Speaking in April at the annual meeting of the U.S. Gas Research Institute (GRI), Mr William Burnett, the institute's chief, claimed excellent prospects for both engine driven and absorption gas heat pumps in the U.S.A. He pointed out increased market penetration of absorption chillers, and recent developments such as the gas engine heat pump of the York International Corp. (see below). *(Source: The Air Conditioning, Heating and Refrigeration News, May 4, 1992)*

Manufacturer of Garden Tools Turns to Heat Pumps

Mr Burnett's confidence is seconded by the Briggs and Stratton Corp. which, in a radical departure from its core business of manufacturing lawn-mower engines, developed the single cylinder gas engine which drives York International's residential gas heat pump. The heat pump represents one of the first serious attempts to penetrate the residential heating and air conditioning market in the U.S.A. with gas fired, engine driven heat pumps. Fifty units are now installed all over the country, in a test programme which will continue through 1993. *(Source: Briggs & Stratton Corp, Milwaukee, Wisconsin, U.S.A.)*

Figure 1: Emission reductions (tonnes) in Austria in 1991 as a result of using heat pumps.



Market Trends

Domestic Heat Pumps Lose Ground in U.S.A.

In 1991, heat pump sales continued to lose ground to gas furnaces in new homes built in the U.S.A. Electric heat pumps were installed in 22% of the newly built homes. Four years earlier, the penetration was 27%. Warm-air furnaces claimed a 65% share of homes, a slight gain for the year. *(Source: The Air Conditioning, Heating and Refrigeration News, June 22, 1992)*

By contrast, a study by Prof. Gerhardt Faninger, "The Market Development of Heat Pump Technology in Austria, 1991" showed that the popularity of heat pumps in Austria is still rising. More than 100 000 heat pumps are now installed, a ten-fold increase over the last ten years. Twenty percent of the heat pumps are used for space heating, and almost eighty percent to produce warm tap-water. The installed heat pumps typically replace a directly fuelled boiler, and therefore significantly reduce the loading of the environment with harmful combustion products (see Figure 1). *(Source: Phänomenen, Kundenzeitschrift der Leistungsgemeinschaft Wärmepumpe)*

Environment

Symposium "Refrigeration, Energy and Environment" in Norway

The Norwegian NTH (National Institute of Technology) - Refrigeration Engineering celebrated it's 40th anniversary this year, with a successful symposium on "Refrigeration, Energy and Environment". The symposium was held in Trondheim, Norway, from June 22 to June 24. Eighteen papers were presented and are printed in full in the proceedings (see "Proceedings"). The third day was devoted to panel discussions.

Panel Discussion

The following questions were addressed:

1. How can we develop a more 'responsible' refrigeration technology without negative effects on the environment?
2. How can we increase the efficiency of refrigerating- and heat pump plants?
3. How can the refrigeration industry help the world in developing energy efficient and environmentally favourable energy systems?

The panel comprised Mr Steve Fisher (Oak Ridge National Laboratory, USA), Mr Erik Korfitsen (Sabroe Refrigeration, Denmark), Prof. Horst Kruse (University of Hannover, Germany), Mr Louis Lucas (International Institute of

Refrigeration, France), and Prof. Per-Erling Frivik (NTH-SINTEF Refrigeration Engineering, Norway). In response to the first question the panel emphasized the importance of 'communication'. The industry must improve its communication with decision makers and customers on the true cost and benefits of refrigeration technology. Customers must be encouraged to invest in technologies which improve energy efficiency and reduce harmful emissions. The concepts of 'fuel cycle analysis' and 'life-time economics' need to be discussed, i.e. the product's total energy consumption from construction, via operation, to scrapping.

Interestingly the panel very much agreed on the idea outlined in a Norwegian paper of pursuing the use of natural working fluids (eg. air, water, CO_2) instead of trying to fit new and complex chemical fluids in the traditional cycle. The time is now right to develop and introduce technologies which step away from CFCs, HCFCs and HFCs altogether.

On the second question the panel remarked that initial efforts must be to improve the efficiency of appliances such as household refrigerators and freezers. Since they are produced in such enormous numbers even small improvements in efficiency will yield large energy savings. Furthermore increased use of absorption technology came up as a possible contribution to improved efficiencies.

The development of absorption technology was also mentioned in the discussion on the third question. The question on the contribution of the refrigeration industry to environmentally friendly energy systems became the most contentious one for the panel, or at least the one which attracted the greatest variety of suggestions and solutions. A more detailed report on the panel discussion will be issued in due course. *(Source: Mr Rune Aarlien, Norwegian National Team)*

Working Fluids/CFCs

Japanese Phase-out Date for CFCs

Japan has said it will stop production and consumption of CFCs by the end of 1995. This new phase-out date puts Japan in line with commitments made by the United States and Europe. *(Source: The Air Conditioning, Heating and Refrigeration News, May 18, 1992)*

Dutch Recycling Tax on Refrigerators

The Netherlands have imposed an NLG 50 (USD 27) recycling tax on new household refrigerators. A new plant to capture and reprocess refrigerants and insulation from old units has been opened. Similar plants are already operating in Germany. *(Source: The Air Conditioning, Heating and Refrigeration News, May 18, 1992)*

Discussion on HCFC-22 Continues

The Institute for Energy and Environmental Research, an environmental group in the U.S.A., has petitioned the U.S. government to reclassify HCFC-22 and other refrigerants, giving them a higher Ozone Depletion Potential (ODP). To date, the Montreal Protocol does not specify a phase-out date for HCFC-22, but is expected to do so in a revision later this year. The petition charges that EPA's (Environmental Protection Agency) method of calculating ODP was inappropriate, since it averages damage to the ozone over a 200 year period, while most severe damage to the ozone will occur over the next two decades. Consequently the institute claims that HCFC-22 is 75% less ozone depleting than CFCs, rather than the 95% as estimated by the EPA.

In a separate move, Arnold Braswell, president of the Air-Conditioning and Refrigeration Institute (ARI) has argued that the phase-out dates recommended by manufacturers from Japan, Europe and America are environmentally sound and should form the basis for the Montreal Protocol revisions. The manufacturers, supported by other industry groups such as contractors and wholesaler associations, recommend 2010 as the earliest year to stop the production of equipment using HCFC-22, and 2020 as the earliest year when the refrigerant itself should no longer be produced. Mr Braswell claims that HCFC-22 will have an insignificant effect on ozone depletion, especially if used in sealed systems, and he points out that it will take some time before substitutes for HCFC-22 are found and equipment using these substitutes are being produced. *(Source: The Air Conditioning, Heating and Refrigeration News, May 4th and June 22nd, 1992)*

Systems/Installations

Production of Advanced Two-Speed GSHP Begins

In the U.S., Water Furnace International has begun full-scale production of an advanced two-speed Ground Source Heat Pump (GSHP) that is 30 to 50% more efficient than other GSHPs and offers greater flexibility in sizing systems for northern applications. Single speed GSHPs are typically sized to meet the heating load, which can result in an oversized system for the cooling load. In two-speed systems, high-speed capacity can be sized to match the heating load, and low speed capacity can be sized to meet the cooling load. The new GSHP has a COP of 4 and an energy efficiency ratio of up to 20. *(Source: The Air Conditioning, Heating and Refrigeration News, May 18, 1992)*

Water Loop Heat Pumps

In the same drive for higher efficiencies, the Trane Co. developed a new line of high-efficiency Water Loop Heat Pumps. The line was jointly developed by the Trane Company and EPRI (Electric Power Research Institute), and achieves a COP of 4.5 and energy efficiency ratios up to 15. *(Source: EPRI Heat Pump News Exchange, Summer 1992)*

Codes and Guidelines

New ANSI/ASHRAE Standard on Refrigerants Issued

The American National Standard Institute (ANSI) and the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) have issued Standard 34/ 1992, "Number Designation and Safety Classification of Refrigerants". This establishes a new classification scheme to group refrigerants by relative toxicity and flammability. A wide range of refrigerants is included, including alternatives such as HCFC-123 and HFC-134a. The standard has been approved as an American national standard. It can be ordered from Publications Sales, ASHRAE, 1791 Tullie Circle N.E., Atlanta, Ga. 30329. Telephone: +1-404-636-8400, Fax: +1-404-321-5478. *(Source: The Air Conditioning, Heating and Refrigeration News, June 22, 1992)*

IEA and Member Countries

Japan

A new national programme has started, to develop gas heat pumps (both absorption and engine driven types) for single family use. The government, four gas utilities and eleven manufacturers work together in the programme with a total budget of almost USD 30 million. The programme includes the development of an absorption type heat pump for single family domestic use. Details and intermediate results of the programme will be presented at the 4th IEA Heat Pump Conference in Maastricht, the Netherlands, next year.

Canada

Two new members from industry have been welcomed into the Canadian National Team: Mr Colin Perkins of Inter-City Products Corporation - a manufacturer of unitary air conditioning, heat pump and heating products; and Mr Ted Martin of Cimco Refrigeration - a major refrigeration equipment supplier to industry. Both companies market their products and services world-wide.

Ontario Hydro sponsored a one-day conference/workshop on Commercial Heat Pumps and Controls on June 18, in the Toronto area. Over two-hundred were in attendance. Proceedings will be available by the autumn of 1992.

The Canadian National Team hosted an invitation-only heat pump technical exchange meeting with a fifteen member Japanese delegation in Ottawa on July 7 and 8. The first day included brief presentations by all attendants. On day two, site visits were made to two large commercial heat pump installations. A joint Canadian and Japanese Heat Pump Centre National Team meeting is scheduled for October 22, 1992 in Canada. A workshop on heat pump standards is to be jointly sponsored by the United Sates and Canadian governments. The U.S. and Canadian National Teams have formed a Steering Committee and Caneta Research Inc. has been awarded a contract for technical programme development and facilitation. The workshop will be held in Canada in late autumn 1992. Participation is by invitation only.

Norway

Heat Pump Education in Norwegian Schools

One way to increase knowledge on heat pumps and their benefits is to start heat pump education at school. This may prove to be a viable means for increasing the use of heat pumps.

Within its National Programme for increased use of heat pumps, the Norwegian Government now plans to introduce heat pump education at the eighth and ninth grade in schools. The scheme will be supported by a booklet produced by Mr Einar Otterholm, a teacher, who uses easily understandable figures and sketches (see Figure 2) to support his explanations. Separate chapters explain how it is actually possible to save primary energy by the heat pump principle; the different heat sources; and the excellent conditions for heat pumps in Norway - long heating seasons, location close to the sea, relatively high sea water temperatures all year around, and clean and relatively cheap hydro-based power. The booklet also gives instructions on how to construct a demonstration heat pump in the school lab..

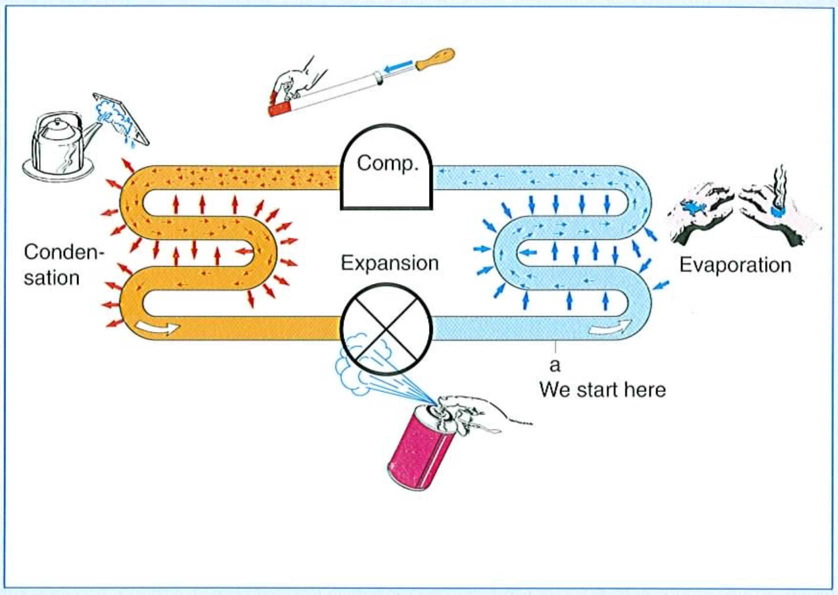
First Norwegian Sea Water Heat Pump Using HFC-134a

The Norwegian Marine Academy in Bergen will save an estimated USD 85,000 annually with a district heating system which uses a heat pump to extract heat from the sea. Annually, fuel-oil consumption will be reduced by 230m^3, and 662 tonnes of CO_2-releases will be avoided. The reduced energy consumption, 1.6 million kWh, is the equivalent of what is needed for 80 single family residences. The prototype plant, supplying hot water to several buildings in a local network, is the first in Norway where HFC-134a is used as the working fluid.

Initially, monitoring equipment was installed in all buildings in the area. Later such devices were also connected to the district heating system so energy consumption, and the savings made can be readily monitored. A state-of-the-art control system, with the possibility for remote PC-control, enables researchers in, for instance Trondheim (500 km away), to operate the plant from their offices.

Extracting heat from sea water often results in high investment costs, which often turns out to be a considerable barrier for this type of project. This project highlights the success of the Norwegian government's 40% investment subsidy scheme.

Figure 2: School Material in Norway uses Examples from Everyday Life to Explain Heat Pump Principles.



High Economic Potential for Heat Pumps in Norway

In the year 2000, the Norwegian macro economic potential for heat pumps will be roughly 25 TWh - more than 40% of the country's predicted demand of 60 TWh for heating and cooling at moderate temperatures, and more than 12% of the country's total energy consumption.

Such a massive heat pump deployment would lower the annual energy demand by 15 TWh and would eliminate the need for extra power capacity over the next 20 years. CO_2 releases would also be cut by 5%, equalling emissions from every other car in the country.

The calculations are based on an oil price of USD 0.04 per kWh and an electricity price of USD 0.075 per kWh. A 30% improvement in heat pump COP is assumed by the year 2000.

IEA Heat Pump Programme

Annex 13 - Final Report Now Out

This Annex entitled "State and Transport Properties of High Temperature Working Fluids and Non-azeotropic Mixtures" was concluded in the spring of this year and a final report has been made. Using the results of studies performed in the six participating countries, the Operating Agent in Sweden performed sensitivity analyses to evaluate the impact of state and transport properties on heat pump COP and capacity. The analysis showed that the two most sensitive parameters were:

- the evaporative heat transfer coefficient;
- the isentropic efficiency during compression.

Working fluids studied included: HCFC-22, CFC-114, HCFC-142b, HFC-152a, HCFC-123, TFE (trifluoroethanol), PFP (pentafluoropropanol) and PFO (n-perfluorooctane) and the following mixtures: HCFC-22/CFC-114; HCFC-22/HCFC-142b; HCFC-22/HFC-152a.

Annex 17 "Experiences with New Refrigerants in Evaporators"

A preliminary evaluation of data from participating countries will be presented at the final meeting for this Annex which will be held in the Netherlands in October. The final report is expected in March 1993.

Annex 20 "Working Fluid Safety"

The final meeting of this Annex will take place this autumn. The Final Report is scheduled for completion in December 1992.

Annex 21 "Global Environmental Benefits of Industrial Heat Pumps"

A questionnaire is being sent to industry and manufacturers this autumn; initial evaluation of data collected will be reviewed at the 2nd Experts meeting scheduled for November in Annapolis, Maryland (US). The meeting's aim is to develop a methodology to project market potential of industrial heat pumps (IHPs) in participating countries. Initial development of an expert computer program to assist in IHP implementation, begun in the summer, will also be reviewed.

Bibliography

Working Fluids / CFCs

NIST Refrigerant Database Updated

NIST (National Institute of Standards and Technology) has updated the Standard Reference Database 23, which is now issued as: NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Database (REFPROP), Version 3.0. The new database calculates thermodynamic properties of 26 pure refrigerants and refrigerant mixtures of up to five components as replacements for currently-used refrigerants. The database is designed to function on any MS-DOS or PC-DOS 2.0 or higher. The database can be ordered, or information obtained from: Standard Reference Data, National Institute of Standards and Technology, Building 221/Room A320, Gaithersburg, MD 20899. Tel: +1-301-975-2208, Fax: +1-301-926-0416.

ARTI Refrigerant Database

A database provides citations and abstracts of publications with information on new refrigerants including HFCs, ammonia, propane and blends made for the Air-Conditioning and Refrigeration Technology Institute (ARTI) and the U.S. Department of Energy. Contact: Mr. James Calm, P.O. Box 12014, Arlington, VA 22219-2014, USA.

Systems/Installations

Experimental Results of a Zeolite-Water Heat Pump in a Slaughter House
T. Zanife and F. Muenier, Heat Recovery Systems & CHP, Volume 12, Number 2, March 1992, pp 131-142 (English).

A two-adsorber zeolite-water heat pump has been built and tested in a slaughter house to provide hot water for washing purposes. Until now reported experiments with this type of heat pump have concerned only laboratory scale units. A satisfactory COP of 1.45 was obtained. The technology used was rather simple, and significant improvements could still be made, in particular by optimizing the sizing of the components.

Thermal Sorption Systems, Parts 1 & 2
C.H.M. Machielsen, Refrigeration & Climate Control, Number 5 (May 1992), pp 55-58, and Number 6 (June 1992), pp 21-26 (Dutch).

Two articles on research on thermal sorption systems at the Delft University of Technology (the Netherlands). The author argues that the interest in thermal sorption systems will increase as the refrigeration and heat pump industries are confronted with ever stricter limitations on the use of CFCs and HCFCs. An overview of sorption systems is provided, with particular emphasis on advanced cycles, heat transformers and so-called hybrid applications (e.g. the use of the absorption system as heat storage, or the use of a combined compression/absorption system as heat pump).

What You Always Wanted to Know About Heat Pumps
Leistungsgemeinschaft Wärmepumpe, 32 page brochure (German).

This full-colour brochure gives basic information about heat pump technology and its benefits. It provides practical data on installation requirements and includes examples of heat pump systems installed in Austria today. Copies are available (Price AUS 75) from Dr. Günter Mock, Wiedner Hauptstrasse 63, 1045 Vienna. Tel. +43-222-50105-3519, Fax: +43-222-50509-28.

IEA

Collaboration in Energy Technology: 1987 - 1990
OECD/IEA, 1992. 238 page review (English). ISBN 92-64-13599-5.

This report contains an assessment of the International Energy Agency's programme of international collaboration in energy research, development and demonstration. It makes recommendations for specific technology areas as well as general suggestions for improving such collaboration. The report outlines the progress made, summarizes new multilateral projects, and lists all the international agreements established since the IEA initiated this international collaboration in 1975.

Proceedings

Refrigeration, Energy and Environment
Symposium held June 22-24, 1992, in Trondheim, Norway, 289 pages (English) - price NOK 200.

Organized by the Norwegian Institute of Technology (NTH), and SINTEF - the foundation for Scientific and Industrial Research at NTH, on the occasion of the 40th anniversary of NTH Refrigeration Engineering. (See News and Views - Environment) Contact Mr. Rune Aarlien, SINTEF - Division of Refrigeration Engineering, Kolbjorn Hejes vei 1D, N-7034 Trondheim, Tel:+47-7-593900, Fax: +47-7-593926.

1992 International Compressor Engineering Conference at Purdue / 1992 International Refrigeration Conference - Energy Efficiency and New Refrigerants

These conferences were held in parallel from July 14-17, 1992. The proceedings (English) were printed prior to the conference and are available from Purdue University, Ray W. Herrick Laboratories, West Lafayette, Indiana, 47907-1077 USA.

Conferences

*Call for Papers

12th Conference on Heating, Ventilation, Air Conditioning: HVAC at the Turn of the Millenium
October 1-3, 1992 / Budapest (Hungary)
Contact: Wissenschaftlicher Verein für Bauwesen
Fö u. 68, H-1027 Budapest, Hungary.

Energy efficiency in Process Technology
October 19-22, 1992 / Vouliagmeni-Athens (Greece)
Organized by the Commission of the European Communities
Contact: Dr. P.A. Pilavachi, Commission of the European Communities, DG XII - SDME 3/34,
Rue de la Loi 200, B-1049 Brussels
Tel.: +32-2-235-3667; Fax: +32-2-236-3024.

Symposium on Indoor Air Quality (IAQ): Environments for People - Investigating and Evaluating Contaminants and Occupant Factors and Responses, Control and Remediation - Solutions and Recommendations
October 18-21, 1992 / San Francisco, California (USA)
Contact: ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329, United States of America
Tel.: +1-404-636-8400; Fax: +1-404-321-5478.

Symposium on Heat Pump Design, Analysis and Application
(1992 ASME Winter Annual Meeting)
November 8-13, 1992 / Anaheim, California (USA)
Contact: Keith E. Herold
Tel.: +1-301-405-5268; Fax: +1-301-314-9477.

Pragotherm '92 - International Exhibition of Heating and Air-conditioning
November 10-15, 1992 / Prague (Czechoslovakia)
Contact: INCHEBA Company Limited,
Viedenská cesta 5, 852 51 Bratislava, Czechoslovakia
Tel.: +42-801111; Fax: +42-847-982.

IGRC92 - 1992 International Gas Research Conference
November 16-19, 1992 / Orlando, Florida, (USA)
Contact: Luigi Meanti, Chairman, Policy Committee 1992 IGRC,
c/o Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, Illinois, 60631 USA
Tel.: +1-312-399-8300; Fax: +1-312-399-8170

Solid Sorption Refrigeration and Heat Pump
November 18-20, 1992 / Paris (France)
Symposium organized by Commission B1 of the IIR
Contact: Mr. Francis Meunier, LIMSI-CNRS,
P.O. Box 123, F-91403 Orsay Cedex, France
Tel.: +33-1-69-85-80-56; Fax: +33-1-69-85-80-88.

Refrigeration and Air Conditioning Conference
November 18-20, 1992 / Bremen (Germany)
Deutscher Kälte- und Klimatechnischer Verein e.V.,
Pfaffenwaldring 10, 7000 Stuttgart 80, Germany.

Conference on Air Quality Standards for the Indoor Environment
December 1-3, 1992 / Prague (Czechoslovakia)
Contact: M.V. Jokl, Society for Environmental Technology,
Novotneho lavka 5 CS-11668, Prague 1, Czechoslovakia.

International Seminar on New Technology of Alternative Refrigerants - Lubricants and Materials Compatibility
February 8 - 10, 1993 / Tokyo (Japan)
Contact: Ms. Yoshiko Miyazawa, Japanese Assoc. of Refrigeration, San-ei Bldg., 8 San-ei-cho, Shinjuku-ku,
Tokyo 160, Japan
Tel.: +81-3-3359-5231 Fax: +81-3-3359-5233

Building Design, Technology & Occupant Well Being in Cold and Temperate Climates
February 17-19, 1993 / Brussels (Belgium)
Sponsors: ATIC (Association Royale Belge Technique de l'Industrie du Chauffage, de la Ventilation et des Branches Connexes) and ASHRAE.
Contact: ATIC-CDH
Tel.: +32-2-348-0550; Fax: +32-2-343-9842.

The 4th IEA Heat Pump Conference
April 26-29, 1993 / Maastricht (Netherlands)
Sponsor: International Institute of Refrigeration
Conference Secretariat: Van Namen & Westerlaken Congress Organization Services
Tel.: +31-80-234-471; Fax: +31-80-601-159.

***Indoor Air '93 - International Conference on Indoor Air Quality and Climate**
July 4-8, 1993 / Helsinki (Finland)
Sponsors include: the IEA, ASHRAE and the World Health Organisation.
Contact: Prof. Olli Seppänen, Helsinki University of Technology, SF-02150 Espoo, Finland
Tel.: +358-0-451-3600; Fax: +358-0-451-3611.

***Cold Climate HVAC '94**
March 15 - 18, 1994 / Rovaniemi (Finland)
Organized by FINVAC, the Federation of Societies of Heating, Air-Conditioning and Sanitary Engineers in Finland.
Contact: FINVAC/Cold Climate HVAC '94, Mr Ilpo Nousiainen, Sitratori 5, SF-00420 Helsinki, Finland.
Tel: +358-0-563-3600, Fax: +358-0-566-5093

Future Issues

Vol./No.	*Topic*	*Deadlines*
10/4	Unitary gas heat pumps	**1 September 1992**
11/1	Industrial heat pumps	**20 December 1992**

New HPC Products

HPC-ASR1 The Impact of Heat Pumps on the Greenhouse Effect. This summary report is available free of charge.

HPC-AR1 The Impact of Heat Pumps on the Greenhouse Effect. This analysis report can be purchased from the IEA Heat Pump Centre.

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