EUROPEAN HEAT PUMP NEWS

The Newsletter of the European Heat Pump Concerted Action

Issue 4, February 2000

EDITORIAL

This is the fourth and final Newsletter within the project: 'Concerted Actions for the Promotion of Heat Pumps in Europe', partially funded by the European Commission as a THERMIE B activity and co-ordinated by FIZ Karlsruhe, Germany. Other participants in the project include SINTEF (Norway), NOVEM (The Netherlands), ADPM (France), Leistungsgemeinschaft Wärmepumpe (Austria) and David Reay & Associates, assisted by BG Technology, (UK).

Heat Pumps are an old technology. In 1824 S. Carnot has invented the theoretical basis of heat pumping, i.e. reversing of the natural heat flux from a higher to a lower temperature level by adding high-grade energy; the process resulting from these considerations is suitable to produce both heat and cold. In 1835 Perkins and Evans developed independently from each other the first compression refrigeration machines, and in 1855 Peter Ritter von Rittinger designed, built and operated the first MVR system in the salt production plant in Ebensee, Upper Austria; currently two centrifugal compressor-based units with an electric input of 4 MW each and COPs in the range of 12 to 16 are in operation there.

Heat pumping is a proven and reliable technology. In the case of producing cold for refrigeration, air conditioning and industrial processes it has no competitor. For producing heat as heat pumps it has to compete with conventional heat production by burning fuels, most commonly fossil fuels.

Heat pumps are an energy efficient and environmentally friendly technology. They offer the possibility to shift free energy from outdoor air, water or ground and waste heat to a temperature level required for space heating, hot water production, but also for industrial processes, adding small amounts of high-grade energy, today called exergy, to the free energy. Comparing heat delivery by means of heat pumps with conventional methods, i.e. burning fossil fuels, one can easily show that with heat pumps the primary energy consumption can be at least cut in half.

Heat pumping is a technology used world wide. Presently about 100 million units with a thermal output of 600 TWh/a are in operation, already reducing CO_2 emissions by 0.12 Gt/a. The potential for reducing CO_2 emissions with a market share of 30 % only in the building sector is about 6 % of the total world wide CO_2 emissions of 20 Gt/a. This is one of the largest CO_2 reduction potentials for a single technology. Therefore, heat pumps are one of the key technologies for reducing CO_2 emissions resulting from burning fossil fuels.

The problem is that only about 5% of these heat pumps are running in Europe, and if one concentrates on heating-only devices, the number is only in the range of 1.2 Million units. This means that concerning heat pumps Europe is a developing country neglecting the advantages of this technology. This project 'Concerted Actions for the Promotion of Heat Pumps in Europe', has taken an initiative to spread the knowledge and increase the awareness on heat pumps as an energy efficient and environmentally benign technology over Europe. However, one goal of this project has not been achieved until now - the goal to convince the politicians!

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IN THIS ISSUE

WHAT FOLLOWS NEXT? – An Overview by the Project Co-ordinator

As described in the articles elsewhere in this issue, the THERMIE B project "Concerted actions for the promotion of heat pumps in Europe" was completed at the end of February, 2000. The project was mainly aimed at supporting the market penetration by dissemination of information on nearly all aspects of heat pump technology using the following means:

- Internet page of the **European Heat Pump Network (EHPN)** (www.fiz-karlsruhe.de/hpn)
- EHPN database
- this newsletter (four issues)
- two workshops (on natural refrigerants and training programmes)

All of these products and activities have been developed and advanced respectively within the framework of this expired project. Now, the legitimate question is what will follow after. Fortunately most of the activities will be progressed in one way or another. The following information gives a short overview on the future development as far as forseeable.

FIZ Karlsruhe, the operator of EHPN, is modifying the **Internet page**. This modification is mainly aimed at the introduction of a separate homepage for the **European Heat Pump Association (EHPA)**. This not-for-profit organisation, founded in February 2000, promotes awareness and proper deployment of heat pump technology in the European market place for residential, commercial and industrial applications. The Association is open primarily to all legally constituted organisations in the European Union. Organisations in the European Free Trade Association and aspirant states to the EU may become associate members. Up to now 13 partners from eight European countries have joined the EHPA. For more information on the Association please contact the administrator (Axel Lehmann, FIZ Karlsruhe, Email: ale@fiz-karlsruhe.de)

The EHPN **database**, comprising four separate data files on organisations, manufacturers and suppliers and their products, R,D&D projects as well as sample installations, was just updated by the project partners. A condensed version of these data is published on the EHPN Internet page. The final version of the database containing information from six countries (AT, DE, FR, NL, NO, UK) will be available from FIZ Karlsruhe on CD-ROM, probably in May 2000. Interested institutions from other European countries can obtain a recent version for information and data input on request. No decision has been made so far on the future usage of this database. In case neither the EHPA nor other institutions are interested in supporting the operation of this database it would disappear from the market in a few months.

This fourth issue of the EHPN **newsletter** is the last one in this format and lay-out. The next issue will be published under the EHPA logo, the lay-out will be adapted to that of the IEA Heat Pump Centre newsletter. Beginning with the fifth issue there will be three ways to receive the newsletter regularly:

- via the homepage of the EHPN
- free of cost by e-mail
- as a supplement to the IEA Heat Pump Centre newsletter

Most probably subsequent issues will be edited by NOVEM, The Netherlands, and we think it´s the right time and place to thank the recent editor, David Reay, for the excellent job he has done during the recent months.

Reports on the two **workshops** held at Interclima in Paris last November have already been published in issue 3 and additional comments on this topic are given in other articles. The proceedings of the workshop "Heat pump training programmes – The way to certification" will be prepared by A.D.P.M., Paris and a study giving a first overview on existing training programmes is available from FIZ Karlsruhe. Due to the high importance of this subject for improving the quality of heat pump installations, follow-up activities at a European (SAVE) and national level are planned. For information on the proceedings of the workshop on natural working fluids please see the HPC article below.

All the activities reviewed above will hopefully help to make the EHPN accepted and intensively used by the European heat pump community as a **common information platform**. Especially the national heat pump associations are invited to present their activities to all European partners. Until 2001 the EHPA as well as the SAVE II project "Transforming the market for electrical heating of domestic dwellings" will provide the financial basis for maintaining the network. Thereafter, again the question "What will follow after?" has to be answered. Any form of sponsorship and other innovative ideas are highly welcome.

Axel Lehmann, Project Co-ordinator

The European Heat Pump Network – The Norwegian View of the Project

In a few days the project "Concerted Actions for the Promotion of Heat Pumps in Europe" is about to be completed. SINTEF Energy Research has been one of six participants involved in the project since the start in January last year.

The project, which is partially funded by the European Commission as a THERMIE B activity, is also a part of the European Heat Pump Network. The network was established through a similar project in 1996, and the idea is to continually work out projects building on each other and at the same time maintain the network connections.

For SINTEF Energy Research international collaboration, on this occasion in Europe, is very important. Through projects and networks we can adjust our activities to an international level, and secure first hand information about the status on similar activities in other countries. To improve a technology as well as its chances for introduction in the market, the exchange of experiences and dissemination of solutions between countries plays a vital role.

The EHPN Internet site and the European Heat Pump News are two concrete results of the CAG projects, providing interested readers information about heat pump issues. We hope that Norwegian companies and institutions use the internet site in their search for facts about heat pump systems. Regarding the newsletter we know that about seven hundred subscribers receive each number. The projects should therefor gain Norwegian interests through these actions.

In the last project, "Concerted Actions for the Promotion of Heat Pumps in Europe", easing the implementation of heat pumps into the European market has been the main objective. Emphasis is laid on clarifying hurdles and stimuli for heat pumps using natural working fluids, and also how to establish a certain standard on training programs for different heat pump actors. This means the project has not included any research in the traditional manner, but instead focused on disseminating already existing knowledge. For a research institute this kind of project is still of interest, bringing the results from laboratory research out to the end-users.

Especially in the field of natural refrigerants, SINTEF has done and still carries out a lot of research. At the same time there are serious hurdles and constraints limiting the implementation of natural heat pump systems into the market. In a long term these obstacles must be conquered if good results from research shall be transferred into a strong and efficient industry.

During the last year two organisations, European Heat Pump Association and Green Heat Pump Group have been established with support from our project. Hopefully these interest groups will increase the impact of the European heat pump industry on issues that concerns market implementation of their products. For the Green Heat Pump Group, the ongoing work with making European standards limiting the use of hydrocarbons in heat pumps has been especially focused on.

The Norwegian heat pump industry consists mostly of suppliers and only a very few manufacturers (one using hydrocarbons). The interest groups established are therefor outcome from the projects that has a limited direct impact on the Norwegian industry. Indirectly, however, European manufacturers exporting to Norwegian suppliers will benefit from these groups, and thereby also have an impact on the Norwegian situation.

In November two workshops were held in Paris as part of this latest project. Workshops like these contribute both to dissemination of information, as well as connecting people from different parts of the industry. SINTEF Energy Research therefor believe that both workshops and more generally projects in the form of concerted actions groups, gives a valuable contribution to the implementation of heat pumps into the market.

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Successful collaboration between the HPC and Europe

The Netherlands - The year 1999 was characterised by successful collaboration between the IEA Heat Pump Centre (HPC) and two European heat pump projects: A Thermie-B project – '*Concerted action for the promotion of heat pumps in Europe*' and a Save project - '*Transforming the market for electrical heating of residential dwellings*.' Joint activities included organisation of the workshop *Natural working fluids – a challenge for the future*; joint distribution of the European Heat Pump News and the IEA Heat Pump Centre Newsletter; laying the foundations for both the European Heat Pump Association and the so-called Green Heat Pump Group. The following summarises our activities in 1999, with a focus on Europe:

The IEA Heat Pump Centre

The IEA Heat Pump Centre aims to accelerate the implementation of heat pumps by exchanging information and transferring knowledge on an international level. The HPC is a world leading information centre on heat pumps and one of the largest publishers of heat pump literature. It plays a central role within the IEA Heat Pump Programme (HPP) and is supported by its member countries: Austria, Japan, the Netherlands (Operating Agent), Norway, Switzerland, the United Kingdom and the United States. The United Kingdom joined the HPC during 1999.

HPC Newsletter and Internet

The quarterly 28-page HPC Newsletter covered the following topics in 1999: “Ground-source Heat Pump Systems”; “Sorption Heat Pumps”, “the 6th IEA Heat Pump Conference/Environmental Benefits” and “Industrial Heat Pumps”. The HPC Newsletter is distributed to around 2,000 subscribers in Europe, mostly in HPC member countries. In the second half of the year, the European Heat Pump News was distributed together with the HPC Newsletter. This gave the HPC the opportunity to provide their readers with more news from Europe, while the European Heat Pump News could reach a larger audience, even outside Europe.

The HPC Internet site (www.heatpumpcentre.org) features summaries of all published articles and reports of the IEA Heat Pump Programme, global heat pump news, links to other relevant heat pump sites and much more. In 1999, the number of page requests rose by 40% compared to 1998 to 259,000 annually.

Reports published

The HPC published the following Reports in 1999:

- *The role of heat pumping technologies in a deregulated energy market*, HPC analysis study AR5;
- *Environmental benefits of heat pumping technologies*, HPC analysis study AR6;
- *International heat pump status and policy review 1993-1996*, HPC analysis study AR7, update of an earlier study on 1989-1992;
- *Natural working fluids – a challenge for the future*, proceedings (WR21) of joint European commission (THERMIE-B project concerted actions for the promotion of heat pumps in Europe) and HPC workshop, Paris, France (1999). To be issued March 2000;
- *Guidelines for design and operation of compression heat pumps, air conditioning and refrigeration systems with natural working fluids*, final report AN22-4 of HPP Annex 22;
- *Heat pump systems for single room applications*, final report AN23-2of HPP Annex 23;
- *Heat pump systems for single room applications*, workshop proceedings AN23-1 of a HPP Annex 23 workshop held in Niagara falls, Canada (1998);
- *Ab-sorption machines for heating and cooling in future energy systems*, workshop proceedings of a HPP Annex 24 workshop AN24-3 held in Tokyo, Japan (1998).

Heat Pump RD&D portal

The Heat Pump RD&D Portal will be available on the HPC website from 1 April 2000 onwards. This new section on the HPC Internet site is a concentrated list of over 30 databases, mostly available on the Internet, containing specific information on heat pumps with thousands of references. Many of these databases cover research, development and demonstration of heat pumps, thus forming an additional information source, besides that maintained by the IEA Heat Pump Centre.

Ongoing surveys

Two survey projects are ongoing:

- *Residential heat pumps and energy-efficient heat and cold distribution and ventilation systems*. This project brings together information that compares existing energy efficient heat and cold distribution systems in combination with residential heat pumps, covering air systems, ventilation and hydronic systems. Special attention is given to low-energy houses.
- *Heat pumps for retrofit.* This project aims to identify technological possibilities for and market impediments to heat pumping technologies in retrofitted residential buildings, and thus to contribute to an increased market share for heat pumps in these situations. The survey also addresses incentives and market differences in various countries.

Outlook

The HPC looks back on successful collaboration with the European Heat Pump Network in 1999. We think that during the past year an important foundation was laid for further joint projects in the future.

The IEA Heat Pump Centre

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WHY CO_2 AS A WORKING FLUID ?

Since January 1, 1996, the production of CFCs has been forbidden in the industrialised countries, and for HCFCs a phase-out schedule until 2030 - in the EU until 2015 – already exists; additionally, in the EU the use of HCFCs in new equipment will be limited by 2002. Alternatives for the HCFCs are either again synthetic substances, the chorine-free hydrofluorocarbons (HFCs) with no ozone depletion potential (ODP), but still with a high global warming potential (GWP), or “old” refrigerants, natural substances, like ammonia (R-717), the hydrocarbons (R-290, R-1270 and R-600a), water (R-718) and CO_2 (R-744). In this paper the criteria for selecting a working fluid are analysed based on the example CO_2 .

CO_2 is part of our biosphere, it is a colourless and odourless gas, it has no ODP and it offers a negligible GWP, which is the major environmental concern now. CO_2 is a high-pressure fluid (the critical data are about 31°C and 74 bar as shown in Fig. 1).

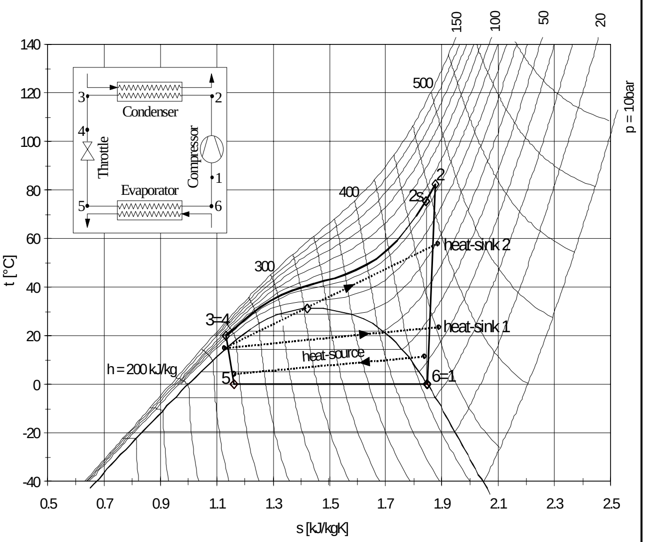

Fig. 1: Temperature-Entropy Diagram of CO_2

For CO_2 there already are and there will be in the near future several applications, which are superior to present solutions with respect to the environment and also with respect to efficiency. Examples are the change from direct evaporation systems in refrigeration to secondary loop systems for reducing the refrigerant charge, applications where refrigerant losses cannot be fully avoided, and new applications with higher efficiencies, which can be achieved by utilising this refrigerant and its cycle characteristic, respectively.

Presently CO_2 is being used as heat carrier in commercial secondary loop systems, especially in low-temperature applications, where both the sensible and the latent heat of CO_2 are being utilised. Caused by the large heat of evaporation - 316 kJ/kg at -35°C compared with 169 kJ/kg of R-502 - the power requirement of circulation pumps can be reduced significantly. Compared with brines the mass flow rate required and the viscosity, and therefore the pressure drop, are also much smaller.

But with CO_2 it is also possible to realise again direct evaporation systems by using it as refrigerant in the low-temperature stage of a refrigeration cascade. Fixing the condensing temperature at a level of –10°C, the pressure of 26,5 bar allows to use compressors an other equipment already available on the market..
One of the first applications of CO_2 taken into consideration by the late Prof. Lorentzen has been mobile air conditioning. This is an application, where refrigerant losses cannot be fully avoided, and the old refrigerant used, R-12, as well as the new chlorine-free alternative, R-134a, have a high GWP. But one has also to consider efficiency: Taking only the thermodynamic properties, CO_2 is worse compared with R-134a; however, there are some additional influences on the efficiency of a system: The pressure ratios required with CO_2 are significantly smaller than with R-134a; this means an increase of the compressor efficiency. Additionally it is possible to change the capacity by changing the pressure at the condenser side. Caused by the high working pressures the energy density becomes much higher and the size of the components can be reduced. Pressure losses within the cycle (due to losses in the evaporation temperature) are not as important; the diameters of the piping can be reduced also.

For heat pump applications with condensing temperatures exceeding 30°C the trans-critical cycle, also proposed by the late Prof. Lorentzen, with pressures up to 140 bar has to be used. This cycle is characterised by evaporation taking place in the sub-critical region, whereas heat rejection takes place in the trans-critical region. Taking the temperature-entropy-diagram this happens near the critical point. This means a heat rejection characteristic similar to the Joule-Brayton cycle, but in a region with strong deviations from ideal gas conditions; a maximum of the specific heat - infinite in the sub-critical region and at the critical point - is still existing.

This trans-critical cycle offers new possibilities concerning heat transfer or better lower heat transfer temperature losses: While the Carnot cycle is suitable for more or less infinite heat sources and heat sinks with almost no temperature glide and the Joule-Brayton cycle for limited heat sources and heat sinks resulting in large temperature glides, the Lorentzen cycle is best suited for unlimited heat sources with more or less no temperature glide and limited heat sinks with large temperature glides where the heat sink inlet temperature should be as low as possible (but at least lower than the critical temperature). Applications for this cycle are once-through hot water heaters, air heating and exhaust air heat recovery systems, and drying as well as dehumidification processes:

- Hot water production requires in the residential sector, starting from a ground water temperature of 6 to 14°C, temperatures of 60°C, in industry temperatures up to 95°C. If ground water is also used as heat source the COP which can be achieved is about 4.6; compared with R-134a the COP is significantly higher (Fig. 2).

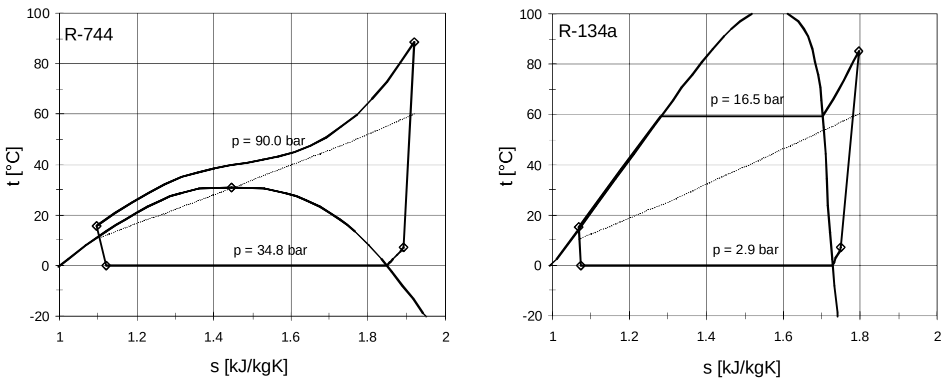

Fig. 2: Comparison of CO_2 and R-134a for water heating from 10 to 60°C

- For air heating systems the heat sink inlet temperature corresponds to the room temperature, which is in the residential sector 19-21°C and in the industrial sector 15-18°C, the corresponding maximum outlet temperatures required are 45 and 65°C, respectively. This process is less efficient than hot water production, but still better than conventional systems.
- A significant improvement can be achieved if the heat pump is part of an exhaust air heat recovery system for heating purposes combined with an air ground collector for preheating the air. In this case the heat sink inlet temperature drops with increasing load, i.e. decreasing outside temperatures, and the COPs become extremely high. Such systems can be used as the only heating system of low-heating-energy buildings with specific transmission heat loads of 10 to 20 W/m^2 heated area.
- Drying and dehumidification have the characteristic that wet air has to be cooled down to the dew-point temperature to remove the moisture; subsequently the air has to be heated up again, where both the sensible and the latent heat can be used. For laundry dryers successful theoretical as well as experimental work has been already carried out.

Carbon dioxide corresponds to the definition of a „safety“ refrigerant, and it is environmentally benign. The real problem of CO_2 is not the high-pressure technology itself, it is the availability of components produced in large scale for a reasonable price. CO_2 is not and will not be a cure-all, which solves all the problems of refrigeration and heat pumps, but for special applications it is an unbeatable solution.

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HEAT PUMPS IN LOW-HEATING-ENERGY BUILDINGS

Presently the situation in the building sector in Central Europe (3,500 heating degree days, design temperatures of about –12°C) is characterized by different types of residential buildings: Old existing buildings with poor thermal insulation of the building envelope, equipped with high-temperature heat distribution systems with radiators sized for supply/return temperatures of 90/70°C, with an annual heat consumption in the range of 300 kWh/m^2 heated area, newer buildings developed during the last decade with good thermal insulation, with heat distribution systems with low-temperature radiators or medium-temperature floor heating systems sized for supply/return temperatures of 55/45°C and 45/38°C, respectively, and an annual heat consumption of about 120 kWh/m^2 heated area, and new buildings with excellent thermal insulation, with low-temperature floor heating systems sized for supply/return temperatures of 35/30°C, with an annual heat consumption below 80 kWh/m^2 heated area, i.e. low-heating-energy buildings. The initiator for significant improvements of the building envelopes, the development of insulation systems and of better windows was tremendous:

- The brick manufacturing industry developed new products with significantly reduced U-values, down to 0.30 W/m^2 K for 0.38 m thick walls. Insulation materials based on different foams and on mineral wool entered the market with a heat conductivity in the range of 0.03 to 0.045 W/m K, most commonly offered as a package with fixing equipment and special plasters; additionally, new facade systems have been developed allowing U-values of 0,1 W/m^2 K.
- The most significant development happened in the sector windows: While old simple double-glazed windows had an u-value of 3.2 W/m^2 K, the development for double-glazed windows went down to 1.8 W/m^2 K as a result of coating, and presently to 1.0 W/m^2 K using additionally argon filling. Triple-glazed windows, originally with U-values of 2.2 W/m^2 K, went down to 0.7 W/m^2 K with argon filling and 0.5 W/m^2 K with xenon filling.

Using - at least partly - these improvements, the specific heat loads went down from originally about 150 W/m^2 heated area and more to 60 W/m^2 and less, and this reduction of the specific heat load had also a great influence on the heat distribution systems and the supply temperatures required. Floor heating systems with maximum supply temperatures of 35°C became possible, and with heat pump systems using ground-water or the ground as heat source seasonal performance factors (SPF's) of 4 and higher can be achieved.

Such buildings are energy efficient; however, there is one problem, i.e. ventilation. The way to provide the building with fresh air is the old one, it is done by natural ventilation through leaks in the building envelope. In the past, these leaks have been the windows; new windows are leak tight. This means that windows have to be opened periodically to achieve the required air exchange. As Pettenkoffer has already stated in 1858, people will not become ill from a too low ventilation rate, but they will become less resistant against other types of disease. In Sweden this problem is solved by a regulation introduced in 1986, which requires a controlled ventilation system with heat recovery in all new buildings. These regulation is based on health care and on energy conservation. In Central Europe no such regulation exists up to now.

However, taking a building with a specific heat load of 60 W/m^2, this load consists of 37 W/m^2 transmission losses through the building envelope and 23 W/m^2 ventilation losses assuming an air exchange rate of 0.8/h. Further reductions of the heat load are possible:

A reduction of the transmission losses down to 15 W/m^2 is no problem, another step is a controlled ventilation system combined with an exhaust air heat recovery system. There are different possibilities of exhaust air heat recovery, heat exchangers with energy recovery rates between 50 and 90%, heat pumps, and the combination of heat exchangers and heat pumps. With a simple cross-flow heat exchanger with a heat recovery rate of 50 %, the specific heat load can be reduced to 26.5 W/m^2 it can become significantly less if the combination of heat exchanger and heat pump is used.

Taking such a concept, the air supply temperatures required for covering the overall heat load, i.e. transmission and ventilation losses, can be calculated. Assuming 10 W/m^2 specific transmission losses and an air exchange rate of 0.8/h the air supply temperature required to cover the total heating demand at design conditions of -12°C is about 32°C, assuming 20 W/m^2 the required temperature is 50°C. This means that such houses can be heated down to low outside temperatures by the ventilation system alone, and the question arises whether a floor heating system is a suitable and economic device for covering the remaining load. In the case of omitting the floor heating system, the remaining heating demand can be covered by electric resistance heating, it can also be covered by further reducing the heat load.

Another possibility is preheating the fresh air by means of a coil in the ground; a suitable air/ground collector consists of about 60 m pipe with a diameter of 0.25 m buried in the ground in a depth of about 1.5 m around the building (Fig. 1). Using such a collector the air temperatures will be always higher than -5°C even the outdoor temperature drops below -20°C. This preheating effect is sufficient to heat the building with the heat recovery system alone.

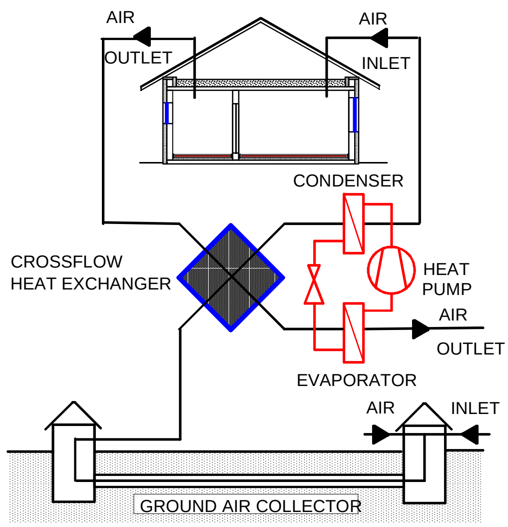

Figure 1: Fresh-air heating system consisting of air/ground collector, heat exchanger, and heat pump

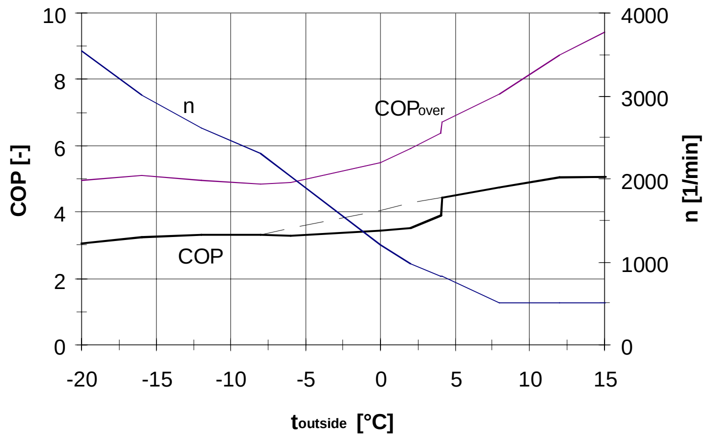

Figure 2: System efficiency and compressor speed of a fresh-air heating system
($q_{tran,-12°C}$ = 15 W/m^2, u_a = 0.8 1/h, p_{cond} = 70 bar)

The – simulated – COP_{over} for a heat pump with CO_2 as refrigerant, which includes the overall system, i.e. heat pump, heat exchanger and air/ground collector, can be expected (Fig. 2).

The systems is suitable to cover the overall heating demand of a building by using the air flow produced by the controlled ventilation system only, without circulation air and without an auxiliary heating system. This means further a significant reduction of investment cost by omitting the conventional floor heating system; the cost savings can be used for installing such a controlled ventilation system suitable for heating the building. Additionally, the hygienic situation in the building can be improved significantly compared to systems with natural ventilation and "ventilation by chance", respectively, as some people say.

But this system has some other features: it can be used for hot water production during the whole year, and it can be used for cooling or at least dehumidification during summertime, in combination with hot water production even without an additional energy requirement. This seems to be the future solution for low-heating-energy buildings. Due to the high thermal insulation standard and the controlled ventilation system, such buildings provide excellent hygienic conditions as well as high comfort for the consumer combined with a low energy bill.

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