



*heat pump programme*

# Annual Report 2001

## Heat Pump Programme

Implementing Agreement  
for a Programme of  
Research, Development,  
Demonstration and  
Promotion of Heat Pumping  
Technologies

## International Energy Agency

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## Ongoing Annexes

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IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).



# International Energy Agency

The International Energy Agency (IEA) was founded in November 1974 as an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an international energy programme. Membership consists of 26 of the 30 OECD member countries.

Activities are directed towards the IEA Member countries' collective energy policy objectives of energy security, economic and social development, and environmental protection.

One important activity undertaken in pursuit of these goals is a programme to facilitate cooperation to develop new and improved energy technologies and introduce them into the market. Activities are set up under Implementing Agreements, which provide the legal mechanism for establishing the commitments of Participants and the management structure to guide the activity.

Implementing Agreements are independent bodies operating within a framework provided by the IEA, and hence take full responsibility for their work programmes and publications.

There are currently 40 active Implementing Agreements encompassing activities relating to fossil fuels, renewable energy, efficient energy end-use, fusion power and information dissemination. This publication concerns the Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies, more commonly known as the IEA Heat Pump Programme.

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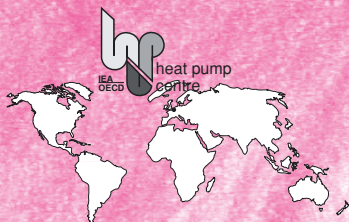
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# The IEA Heat Pump Programme

## *The Heat Pump Centre*

*The Heat Pump Centre is the central information activity of the Programme*



*The Centre links people and organisations worldwide in support of heat pump technology and communicates through National Teams in its member countries.*

*Close links have been forged with other international organisations concerned with heat pumps, including:*

- *International Institute of Refrigeration (IIR)*
- *American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)*
- *United Nations Environment Programme (UNEP)*
- *European Heat Pump Association (EHPA)*
- *European Union (EU)*

Organised under the umbrella of the International Energy Agency in 1978, the IEA Heat Pump Programme is a non-profit organisation funded by its member countries. The scope of the Programme covers heat pumps, air conditioning and refrigeration.

Participating countries: Austria • Canada • Denmark • France • Germany • Italy • Japan • Mexico • the Netherlands • Norway • Spain • Sweden • Switzerland • UK • USA.

## **Vision**

The Programme is the foremost worldwide source of independent information and expertise on heat pump, refrigeration and air conditioning systems for buildings, commerce and industry. Its international collaborative activities, which are to improve energy efficiency and minimise adverse environmental impact, are highly valued by stakeholders.

## **Mission**

The Programme serves the needs of policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers. It also works through national agencies to influence installers and end-users.

The Programme develops and disseminates factual, balanced information to achieve environmental and energy efficiency benefits by deploying appropriate high-quality heat pump, refrigeration and air conditioning technologies.

## **Strategic Objectives**

### *Environmental*

To quantify and publicise the environmental and energy efficiency benefits of heat pumps.

### *Market and Deployment*

To develop and deliver information to support appropriate deployment.

### *Technology*

To maintain and develop international technical RD&D collaboration that furthers the environmental and market objectives.

### *Information Management*

To provide effective collaboration and flow of information to, from and between stakeholders and other relevant bodies.

## **Activities**

Activities of the Programme include an information service, the Heat Pump Centre, collaborative international projects, so-called Annexes, workshops, analysis studies and a triennial international conference.

The Executive Committee held two meetings in 2001:

- \* 24-25 April in Merligen, Switzerland;
- \* 5-6 November in Leiden, the Netherlands.



# Chairman's Statement 2001

The three most important issues for the Executive Committee (ExCo) during 2001 have been the restructuring of the entire Heat Pump Programme (HPP), generation of new activities, and the 7th IEA Heat Pump Conference.

One of the critical success factors for organisations today is their willingness to change and adapt to new market constraints. The HPP is no exception. Increasing difficulties in obtaining funding for international activities have resulted in fewer participants in ongoing HPP activities (especially the Heat Pump Centre) and difficulties in establishing new projects. Against this background, a restructuring process for the HPP has been underway for the last couple of years, and will be concluded during the first half of 2002.

The autumn ExCo meeting in 2001 concluded that the HPP should still have a central information service, and furthermore, that participation in the HPP would require participation in this service. In this way, we eliminate the 'free-rider' problem (that one country pays and another country benefits), and participation in the information exchange process will mean many more members creating a broader information base and contact network. We hope that this will result in increased information exchange between the HPP member countries, and that the perceived value of being a member increases. Cost reduction for membership has been a central issue.

One of the challenges within the HPP over the past few years has been the generation of new activities (Annexes). Reasons for this could be both difficulties in obtaining funding from national sources, and a slow start-up process within the Programme. The ExCo is now taking a critical look at these problems, and is doing its utmost to stimulate the establishment of new activities. In this respect the autumn ExCo meeting (2001) gave reason for optimism, as several new proposals were submitted. With joint effort from the member countries we are optimistic that several new Annexes will be established by the 2002 spring ExCo meeting in Beijing.

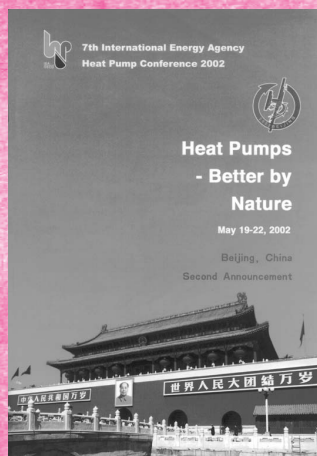
The single biggest HPP event in 2002 is the 7th IEA Heat Pump Conference, which will be held in Beijing, China, in May. This is the first time this conference has been organised in a non-member country. Already a giant in terms of manufacturing and application of heat pumps and air conditioning equipment, China is a perfect location for this conference. Preparatory work has been underway for a couple of years, and both the national and international organisation committees have made a tremendous effort to ensure a successful conference. From a professional, as well as a cultural point of view, we are looking forward to Beijing!

The existence and success of the HPP is based on contributions and efforts from many individuals around the world. On behalf of the Executive Committee, I would like to thank everyone who, in one way or another, has contributed during 2001. Finally, I would like to thank Professor Hermann Halozan for his excellent chairmanship over the past three years.



*Rune Aarli,  
Chairman Executive Committee  
IEA Heat Pump Programme*

# Highlights of 2001



## *7th IEA Heat Pump Conference 'Heat Pumps - Better by Nature'*

*The 7th IEA Heat Pump Conference will be held in Beijing, China on 19-22 May 2002.*

An attractive programme covering markets, technology and applications has been developed for this conference, the first IEA Heat Pump Conference to be held in a country that is not a member of the Programme. Prominent speakers from all over the world will present their views on a variety of interesting topics. This is the first time the conference has been split into parallel sessions, to provide participants with a choice of programme.

An entire session will be dedicated to the Chinese market situation. This is particularly interesting as the building activity in China is impressive and the application of air conditioning and heat pump equipment is growing rapidly. Heat pump technology is important in helping China achieve sustainable development of new buildings and facilities, including the Olympics in 2008.

## *Collaboration with the IIR*

The framework agreement between the HPP and the IIR has resulted in the establishment of a Liaison Committee that will further define a variety of issues, including representation, joint activities, promotion etc. This Committee has so far held meetings in Graz (Austria) and Paris (France).

Delegates of the HPP ExCo have been appointed to serve as liaison for IIR Commissions E1/E2 (Air Conditioning, Heat Pumps and Energy Recovery) and B1/B2 (Thermodynamics, Equipment and Systems). IIR/HPP contacts have also been assigned for ongoing Annexes 25, 26 and 27. An important result is that the IIR will carry out peer reviews of Programme reports, as already occurs with HPC reports. The IIR will also be invited to review new HPC and Annex proposals and promote these projects. Further collaboration is envisaged with regard to articles for IIR publications, providing input and reviewing selected IIR reports, and the respective websites. ExCo approval has been given for the Programme to become an official partner of the 21st IIR International Congress of Refrigeration, which will be held (17-22 August 2003) in Washington, DC. The Programme plans to organise an HPC workshop/seminar during the Congress.



## ***Success Stories***

### ***Annex 25***

The Annex has successfully developed new packaged heat pump systems providing year-round comfort in houses. The systems are technically feasible and combine high performance for space and domestic water heating with comfort, especially in summer, and require only a limited amount of extra energy.

### ***Annex 26***

Two user-friendly computer models have been developed. The first provides supermarket planners and equipment designers with an easy-to-use tool for making a quick comparison of energy use and environmental impact of different technical solutions for store refrigeration needs. The second assesses technical solutions, life cycle costs and environmental impact of supermarket systems.

### ***Informative Fact Sheets (IFS)***

The Heat Pump Centre has launched a new type of publication, so-called Informative Fact Sheets. These provide general unbiased best practice information about current awareness topics. Two topics were selected for 2001:

1. Hydrocarbons as Refrigerant in Residential Heat Pumps and Air Conditioners;
2. Closed-Loop Ground-Coupled Heat Pumps.

These fact sheets can be ordered (free of charge) from the Heat Pump Centre; see page 19 for address.

## *New Annex Development*

The ExCo meeting in November in Leiden, the Netherlands produced a lively discussion on topics for new Annexes. This resulted in the following selected topics that will be further elaborated into Annex proposals:

- Experiences from system integration;
- Methods for Life Cycle Cost Analysis (economics, environment);
- Ground-source heat pumps (vertical heat exchangers, recharging, surface layer, collective systems, moisture migration, heat pipe concept, market barriers);
- Total system energy efficiency performance combined with year-round comfort systems;
- Integrating heat pumps into future energy systems (heat-driven, electric, renewable energy drivers);
- Long-term performance of heat pumps (new refrigerants, monitoring standards/procedures);
- Heat pumps in relation to global warming; and
- Compact heat exchangers.

A new Annex (28) entitled 'Improving the Position of Sorption Systems (IMPOSE)' was approved by the ExCo. The Netherlands will act as Operating Agent and the following countries will participate: Austria, Belarus, China, Norway, Spain and Sweden. In an effort to raise extra funding, the Annex proposal has been submitted to the European Union's 5th Framework Programme (FP5). This Annex will build on the results accomplished by Annex 24.

The Annex covers sorption technology, with an emphasis on those applications where the technology has a clear added value with respect to energy savings, reducing greenhouse gases, economy or the diversification of energy supply. The Annex is expected to start during the second half of 2002 and will continue for three years.

A proposal from Switzerland entitled 'Test Procedure for Residential Heat Pumps with Combined Space Heating and Heating of Tap Water' has already been elaborated further and may result in a new Annex in 2002.



# Annex Achievements 2001

## *Annex 16: The Heat Pump Centre*

Participating countries: Austria, Japan, the Netherlands (Operating Agent), Norway, UK and USA.

The Heat Pump Centre (HPC) plays a central role within the IEA Heat Pump Programme. The HPC works towards the aims of the Programme by providing a worldwide, independent information exchange and knowledge transfer service. The work helps to overcome existing technical, economic and market barriers and enhances short-term and future prospects of heat pumps. The HPC is the world's leading information centre on heat pumps and air conditioning and one of the largest publishers of heat pump literature.

### **Activities**

Several projects are ongoing, including an international assessment of Refrigerant Recovery, Recycling and Reclamation Programmes in selected countries. The results of Part 1, which included Australia, France, Japan, Canada, the Netherlands and the USA, were presented at a well-attended international workshop/round table in Dubrovnik, Croatia, in August. The results served as a basis for the discussion phase of the workshop that generated additional input. More than 40 experts and participants of the IIR Refrigerants Conference attended the workshop. The report of Part 1 will be published in spring 2002.

The analysis study 'Achieving Domestic Kyoto Targets with Heat Pumps for the UK' was almost completed. The results indicate that heat pumps in the commercial/institutional building sector can contribute significantly to carbon emissions reduction in the UK for the period 2000-2020. Supplemental sensitivity calculations were in progress by the end of 2001.

A second successful workshop, co-sponsored by IIR, was organised in collaboration with the International Power Utility Heat Pump Committee (IPUHPC) entitled 'Hands-On Experience with Heat Pumps in Buildings'. The workshop was held in October in Arnhem, the Netherlands, and attracted over 100 delegates from 13 countries. The programme, which included 38 papers presented over two days, generated fruitful and lively discussions. Several suggestions for further collaborative work were made during a round-table session. CD ROM proceedings will be published in 2002.

The year 2001 marked the start of a redevelopment and restructuring of the HPC, which will begin in January 2002.

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## **Publications**

New publications launched in 2001:

- Domestic Heating and Cooling Distribution and Ventilation Systems and their Use with Residential Heat Pumps (Analysis Report AR8);
- Retrofitting with Heat Pumps in Buildings (Analysis Report AR9);
- Transforming the Market for Electrical Heating of Domestic Dwellings (report TCP99/9);
- Annex 24 workshop proceedings San Francisco/Turin - Absorption Systems (report HPP-AN24-3);
- Annex 26 workshop proceedings Stockholm (CD ROM) - Supermarket Refrigeration (report HPP-AN26-1);
- Annex 27 workshop proceedings Trondheim - CO<sub>2</sub> Technology (report HPP-AN27-1).



## Annex 25:

### Year-Round Residential Space Conditioning Systems Using Heat Pumps

Participating countries: France (Operating Agent), USA, Sweden and the Netherlands.

This Annex aims to define and show the technical feasibility of new packaged heat pump systems for year-round residential space conditioning. The work carried out within the framework of this Annex covers several items, including low initial system and operating costs, comfort, suitability to customer demands, design and installation requirements, system performance, integration in buildings and aesthetics.

#### France

EDF Research and Development carries out many on-site field tests to validate the systems and collect information on demonstration projects. The tests have shown that the costs are similar to those for boilers. The best results were obtained with ground-source heat pumps, which were installed in colder climate zones ( $COP = 3.2$  at  $30\text{kWh/m}^2$  heating demand). France focuses on a combined system consisting of fan coils and a floor heating/cooling system. Measurements have been made at a  $199\text{ m}^2$  house in the south of France.

#### The Netherlands

Specific measurements have been made on semi-detached single-family houses with multi-functional heat pump systems used for heating, cooling (passive or active) and domestic water heating. The heat source system consists of a vertical ground coil and a solar collector. Heat pump capacity can be controlled in three steps. Initial results were encouraging. Hot water could be produced at  $62^\circ\text{C}$ , without backup heating, with a  $COP$  of 3. The average system  $COP$  was 3-3.5 (heating + hot water), depending on the house.

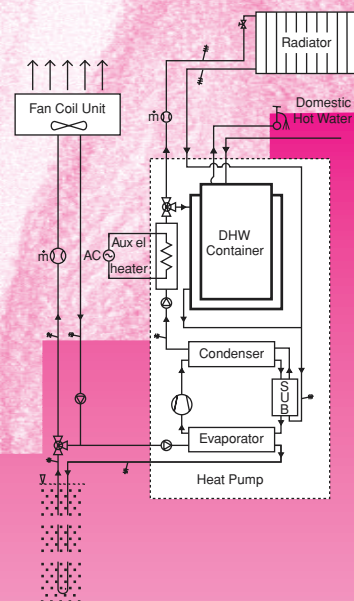
#### Sweden

The Swedish market for heat pumps mainly focuses on retrofit houses. The Swedish partner has monitored a ground-source heat pump that replaces a coal/oil burner in an existing  $190\text{ m}^2$  house. The heat pump installation provides heating (existing radiators and floor heating), domestic hot water and cooling (by fan coil). The ground source also provides passive cooling, which is still quite rare for residences.

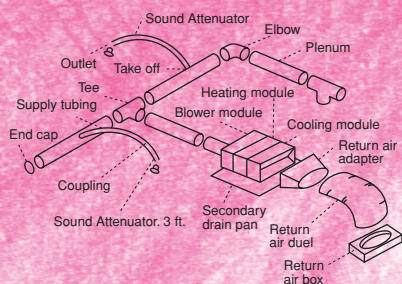
#### USA

A large survey (focusing on air distribution in new constructions in the USA) has revealed large potential energy savings in single-family homes. Two advanced distribution systems, hydronic and high-velocity air distributions, were studied and compared through modelling and field tests on two houses.

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Schematic lay-out (Sweden)



*High velocity air distribution system (USA)*

A field validation on a 156 m<sup>2</sup> house has been initiated to complete the study of high-velocity air distribution and measurements have confirmed the simulation results. The distribution efficiency has clearly increased up to 85%.

Another field test was conducted on a 400 m<sup>2</sup> house equipped with hydronic distribution and fan coil units. The distribution efficiency varies from 88-93% (versus 44-66% for a conventional air system). These results illustrate the potential energy saving by replacing standard duct distribution with efficient solutions, such as high-velocity or hydronic distribution.

### **Initial conclusions**

Although the systems are quite different from one country to another, depending on economic, climate or cultural differences, similar conclusions can be derived from the partner contributions, i.e.:

- the feasibility of these new and improved heat pump systems has been demonstrated;
- they enable high performance for both space and domestic water heating, providing considerable energy savings;
- the comfort provided has clearly improved, especially in summer, and with limited extra energy consumption.



## **Annex 26:**

### **Advanced Supermarket Refrigeration/Heat Recovery Systems**

Participating countries: Canada, Denmark, Sweden, UK, and USA (Operating Agent).

Annex 26 plans to demonstrate and document the benefits of advanced system designs for food refrigeration and space heating and cooling for retail supermarkets. A specific goal is to identify advanced system design options to reduce the total equivalent warming impact (TEWI) of supermarkets.

#### **Canada**

Three systems are being field-tested: one conventional and two advanced multiplex systems. Initial tests in 1999-2000 showed that both advanced approaches achieved around 6% lower specific energy consumption compared to the baseline store.

A technology showcase will be installed in a Montreal supermarket late in 2002. This technology showcase is expected to demonstrate how the integration of several technologies can meet the supermarket's heating, ventilation, air conditioning and refrigeration requirements.

#### **Denmark**

A small Danish supermarket has had the old refrigeration plant replaced by a cascade plant. Propane is used as the high-temperature refrigerant (-14/+30°C) while carbon dioxide is used at the low-temperature level (-32/-11°C). Total energy consumption fell by 10% due to the new plant. A second propane/carbon dioxide demonstration plant has been installed in a medium-sized supermarket, which started operation towards the end of 2001.

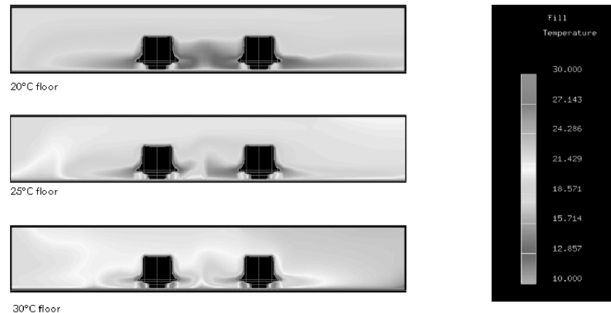
#### **Sweden**

Field tests of advanced systems in three supermarkets (floor area ranging from 720 to 2,700 m<sup>2</sup>) are underway. Two of these use cascaded secondary-loop system designs with R-404A primary refrigerant and a potassium formate brine solution as the secondary refrigerant. The third system uses individual secondary-loop refrigeration units in each display case, which are all connected to a central building chiller for heat rejection. A significant result is that night coverings tested in one of the stores resulted in 10-20% lower system energy consumption with only 70% of the case coverings operative.

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## UK

### CFD Analysis of Cold Aisle



- Floor temperature of 30°C gives acceptable conditions

Four case studies are underway. These include an evaluation of the economic and environmental viability of combined cooling, heating, and power schemes for supermarkets; a comparison of various secondary-loop system concepts against standard direct expansion systems; analytical and experimental investigation of the effect of various HVAC systems on case performance (including cold aisle issues), and analytical and experimental investigation of three different defrost strategies.

## USA

Two systems are being field tested - a distributed compressor refrigeration system and a baseline multiplex refrigeration system. The distributed system uses a glycol loop for heat rejection and includes water-source heat pumps that reclaim the reject heat for store heating. Test results from the first winter indicated that the distributed system had higher average energy consumption than the baseline system (by around 14%). The distributed system manufacturer has provided correctly sized condensers and the loop operation problem has been corrected.

A spreadsheet-based analysis model of supermarket refrigeration systems has been developed. Future work includes validating this model against field data from the Annex field demonstrations and conducting some analytical comparisons of advanced system approaches.



## ***Annex 27:***

### ***Selected Issues on CO<sub>2</sub> as Working Fluid in Compression Systems***

Participating countries: Japan, Norway (Operating Agent), Sweden, Switzerland (UK, partly for 2001) and USA.

Annex 27's main objective is to bring CO<sub>2</sub> technology closer to commercialisation, by adding critical issues of both a basic and applied character. It is important to involve industry, especially manufacturers, as well as research organisations.

During 2001 the various participants more or less completed the projects under this Annex. A website has been set up ([www.egi.kth.se/users/thermo/samer/www/annex27/](http://www.egi.kth.se/users/thermo/samer/www/annex27/)), where the results from the work are presented. The website also contains information on the various projects, a news section with information relating to CO<sub>2</sub>, and a CO<sub>2</sub> equipment database. The remaining work basically consists of writing the final report and organising the second workshop of the Annex. The latter will probably be held during the second half of 2002. The results of this Annex were presented at the Nordic Refrigeration Meeting in Copenhagen, August 2001.

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# Summary of the Annexes

Annex	Operating Agent	Participants	Completed
1. <i>Common Study of Advanced Heat Pumps</i>	Germany	Austria, Belgium, Canada, Denmark, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, UK, USA	1980
2. <i>Vertical Earth Heat Pump Systems</i>	Sweden	Austria, Canada, Denmark, Sweden, USA	1983
3. <i>Heat Pump Systems Applied in Industry</i>	Belgium	Austria, Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Sweden	1984
4. <i>IEA Heat Pump Centre</i>	Germany	Austria, Belgium, Canada, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, USA	1990
5. <i>Integration of Large Heat Pumps into District Heating and Large Housing Blocks</i>	Sweden	Denmark, Germany, Italy, Sweden	1986
6. <i>Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems</i>	Sweden	Austria, Denmark, Finland, Germany, Japan, USA	1986
7. <i>New Development of the Evaporator Part of Heat Pump Systems</i>	Sweden	Canada, Denmark, Finland, Norway, Sweden	1989
8. <i>Advanced in-ground Heat Exchange Technology for Heat Pump Systems</i>	Canada	Canada, Germany, Switzerland, USA	1992
9. <i>High Temperature Industrial Heat Pumps</i>	Belgium	Belgium, Germany, Finland, Japan, the Netherlands, Sweden, Switzerland, USA	1990
10. <i>Technical and Market Analysis of Advanced Heat Pumps</i>	USA	Sweden, USA	1991
11. <i>Stirling Engine Technology for Application in Buildings</i>	USA	Japan, Sweden, USA	1989
12. <i>Modelling Techniques for Simulation and Design of Compression Heat Pumps</i>	USA, Italy	Austria, Belgium, Germany, Italy, Japan, Switzerland, USA	1992
13. <i>State and Transport Properties of High Temperature Working Fluids and Non-Azeotropic Mixtures</i>	Sweden	Canada, Germany, Japan, Norway, Sweden, USA	1992



Annex	Operating Agent	Participants	Completed
<i>14. Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps</i>	Japan	Belgium, Denmark, Germany, Japan, Sweden, USA	1991
<i>15. Heat Pump Systems with Direct Expansion Ground Coils</i>	Canada	Austria, Canada, Japan, USA	1993
<i>16. IEA Heat Pump Centre</i>	The Netherlands	Austria, Japan, the Netherlands, Norway, UK, USA	Ongoing
<i>17. Experiences with New Refrigerants in Evaporators</i>	Sweden	Canada, the Netherlands, Norway, Sweden, Switzerland	1993
<i>18. Thermophysical Properties of Environmentally Acceptable Refrigerants</i>	USA	Austria, Canada, Germany, Japan, Sweden, UK, USA	1999
<i>19. Cancelled</i>			
<i>20. Working Fluid Safety</i>	Belgium	Belgium, Japan, the Netherlands, Norway, Switzerland	1993
<i>21. Global Environmental Benefits of Industrial Heat Pumps</i>	USA	Canada, France, Japan, the Netherlands, Norway, Sweden, UK, USA	1996
<i>22. Compression Systems with Natural Working Fluids</i>	Norway	Canada, Denmark, Japan, the Netherlands, Norway, Switzerland, UK, USA	1999
<i>23. Heat Pump Systems for Single-Room Applications</i>	Canada	Canada, France, Switzerland, Sweden, US	1999
<i>24. Ab-Sorption Machines for Heating and Cooling in Future Energy Systems</i>	Sweden	Canada, Italy, the Netherlands, Norway, Japan, Sweden, UK, USA	2000
<i>25. Year-Round Residential Space Conditioning Systems using Heat Pumps</i>	France	France, the Netherlands, Sweden, USA	Ongoing
<i>26. Advanced Supermarket Refrigeration/Heat Recovery Systems</i>	USA	Canada, Denmark, Sweden, UK, USA	Ongoing
<i>27. Selected Issues on CO<sub>2</sub> as Working Fluid in Compression Systems</i>	Norway	Japan, Norway, Sweden, Switzerland, UK, USA	Ongoing

*Publications from all these Annexes are available from the Heat Pump Centre:*

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