heat pump programme

IEA
OECD

Annual Report 2000

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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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 Organization for Economic Co-operation and Development (OECD) to implement an international energy programme. Membership consists of 25 of the 29 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 in developing new and improved energy technologies and introducing them into the market. Activities are set up under Implementing Agreements, which provide the legal mechanism for establishing the commitments of the participating countries and the management structure to guide the activity.

Implementing Agreements are independent bodies operating within the framework provided by the IEA, and are responsible for their individual 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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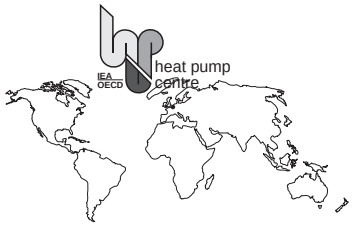
The IEA Heat Pump Programme

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*
- *European Union*

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. The participating countries are: Austria • Canada • Denmark • France • Germany • Italy • Japan • Mexico • the Netherlands • Norway • Spain • Sweden • Switzerland • United Kingdom • United States.

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 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

Chairman's Statement 2000

It has recently become clear that many countries and their politicians have not accepted the Kyoto Protocol. In the meantime we know that global warming is a fact and that we have to fight to reduce the impact of this phenomenon. This is the main reason why the IEA Heat Pump Programme has modified and extended the scope of its strategy.

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

Actions currently in place include an agreement for close collaboration with the IIR (International Institute of Refrigeration) that covers these tasks globally from a scientific perspective, a close cooperation with ASHRAE, and the strategic support of the EHPA (European Heat Pump Association) to stimulate the European heat pump market. The Programme has succeeded in organising the next IEA Heat Pump Conference in Beijing, China, in 2002, and this provides us with an excellent opportunity to transfer international knowledge on heat pumping technologies, one of the key technologies for highly efficient energy utilisation, to an extremely broad audience and rapidly developing market.

Hermann Halozan,
Chairman
IEA Heat Pump programme

Highlights of 2000

Collaboration with the IIR (International Institute of Refrigeration)

During the Executive Committee meeting in Oxford, UK, a Framework Agreement was signed between the Heat Pump Programme and the IIR. This formal agreement will enhance the existing collaboration in a wide variety of areas, such as representation, congresses and conferences, scientific cooperation, publications and the Internet. HPP chairman Mr Halozan, reflected on the long collaboration between the IIR Commission E2 and the Heat Pump Programme. He underlined the growing need for a stronger and wider collaboration. Mr Van der Ree, president of the executive and management committees, reported on the IIR organisation and signed the agreement on behalf of the IIR, sections B and E. Mr Halozan signed on behalf of the Programme Executive Committee.

New Strategy Plan
Far-reaching decisions and initiatives

In 2000 the Executive Committee approved a new strategy, and a proposal for restructuring the Heat Pump Programme. Both decisions will affect the activities of the Programme over the next five years. The Programme Strategy Plan is shown on page 4 of this report. To emphasise its role, the IEA Heat Pump Programme will now include the subtitle: International collaboration for energy-efficient heating, refrigeration and air conditioning.
To support the new strategy, the Executive Committee has decided that a strong, broadly supported information and support service is essential. The Committee endorsed the intention to introduce universal membership of this service.

COP6

To promote the environmental benefits of heat pumps, the Heat Pump Programme was represented at COP-6 in The Hague. A brochure was presented describing the environmental benefits of heat pumps and the activities of the Heat Pump Programme.

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. The conference will be organised locally and hosted by the China Academy of Building Research, with Dr Wu Yuanwei as chairman. For the first time since the inception of the Programme, a potential member country will host the conference.

The conference will provide an international overview of heat pump state of the art and create an opportunity to exchange knowledge and information about heat pumping technology, markets, applications and environmental benefits. China is a rapidly developing and emerging market for heat pumps and air conditioners, and is therefore an excellent setting for the conference.

Conference sponsors are member countries participating in the Programme, the Ministry of Science and Technology in Beijing and Chinese HVAC industry. The conference is co-sponsored by the International Institute of Refrigeration (IIR) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

Success Stories

Publications on the Internet

Since its inception in 1978, the Heat Pump Programme has generated many publications. Each article, brochure, newsletter, proceedings and report is accessible through the Heat Pump Programme bibliography of abstracts on the Internet (www.heatpumpcentre.org). The bibliography now contains over 1,800 items covering a wide spectrum of topics. This is one of the most frequently requested sections of the Heat Pump Centre Internet site.

Annex 22

The products of Annex 22 - Compression Systems with Natural Working Fluids – raised plenty of interest and many copies of the reports were sold. It reflects the need for information about natural working fluids.

Annex 24

A most successful project that came to an end late in 2000 was Annex 24, Ab-sorption Machines for Heating and Cooling in Future Energy Systems.

The final report of this Annex provides an overview of all sorption systems and the necessary tools to determine current and future economic feasibility and environmental benefits in terms of technology, applications and energy generation per country.

The products of this Annex, embedded in several reports, enable considerable progress to be made in the science and knowledge of sorption systems. The background information for the final report is contained within the workshop proceedings (Maastricht 1997, Tokyo 1998, San Francisco and Turin 1999). Researchers, designers, utilities, end-users and governmental bodies use the results of this work to assess and facilitate the development and application of sorption systems. The Annex can count many successes and the results of this collaboration are immediately usable via the workshop proceedings and final report.

International Networking

EU and IIR

Certification of heat pump technologies and installers was the title of an EU SAVE workshop that was co-sponsored by the IIR, with programme support from the Heat Pump Centre. The workshop was the final task of an EU project to develop a certification procedure for equipment and installers. The proposed European Charter for Heat Pump Systems was one of the tangible results of this project. The workshop gathered participants from heat pump associations, Eurovent Certification, the energy sector and installers. The Heat Pump Centre's involvement in the workshop was part of the EU SAVE project Transforming the Market for Electrical Heating of Domestic Dwellings, in which it participates with partners from the UK, Sweden, Denmark, Austria, Finland, Czech Republic and Romania.

The Heat Pump Centre has taken the lead in coordinating the production of the IIR Dictionary of Refrigeration chapter on heat pumps. Other areas in which the two organisations work together include reviewing Heat Pump Centre study results and publications. A highlight was the signing, in November, of a formal agreement between the Programme and the IIR for close collaboration in a wide variety of areas (see page 6). The IIR also co-sponsored a workshop in Stockholm, Sweden, that was organised as part of Annex 26 (see page 17).

EHPA

The Heat Pump Centre has developed a partnership with the European Heat Pump Association, an interest group of heat pump industry associations, installers, promotion organisations, BRE from the UK, the French agency ADEME and French utility EdF. The EHPA aims to stimulate the proper use of heat pumps and the heat pump market in Europe. One of the EHPA's initiatives concerns developing an energy efficiency label and a quality mark for heat pumps in Europe, support for which will be solicited from the EC. The Heat Pump Centre is also involved in the work of the EHPA's Strategy Committee.

The EHPA publishes a quarterly four-page newsletter, which is distributed across Europe together with the IEA Heat Pump Centre Newsletter. The EHPA newsletter can also be downloaded from the Internet (www.ehpa.org).

ASHRAE

ASHRAE has become one of the co-sponsors of the 7th IEA Heat Pump Conference in Beijing, China (see page 7). ASHRAE is an international organisation that enables members to share a wide variety of information and knowledge regarding heat pump technologies and applications. The Heat Pump Centre, through its Director, is actively involved in ASHRAE Technical Committees on heat pumps and the International Committee.

UNEP

The Heat Pump Centre was invited to participate in the 2002 assessment report for the Montreal Protocol Reassessment Process (Technical Options Committee Refrigeration, Air Conditioning and Heat Pumps). Contributions will be provided to two chapters: Unitary Air Conditioning and Heat Pumps, and Refrigerant Conservation and Containment.

Programme Workshops

In March an international workshop was held in Mexico City where the accomplishments and ongoing work of the IEA Heat Pump Programme were presented and an overview was given of Mexico's heat pump and air-conditioning activities. The workshop, which was organised in close collaboration with the Centro de Investigacion en Energia and the Comision Nacional Para el Ahorro de Energia, was attended by some 80 participants, and provided ideas for new projects under the Programme.

Another Programme workshop was held in conjunction with the autumn Executive Committee meeting in Oxford, UK. With presentations from ETSU, the UK National Team and the Heat Pump Association, an interesting overview was given of the activities, market and market impediments for heat pumps in the UK. A draft Policy Brief on UK air conditioning was unveiled and will serve as input for government decisions (see: www.mtprog.com). The Programme's activities and strategy were also presented and discussed.

Annex achievements 2000

Annex 16: The Heat Pump Centre

The participating countries in the Heat Pump Centre are Austria, Japan, the Netherlands (Operating Agent), Norway, United Kingdom and the United States.

The Heat Pump Centre plays a central role within the IEA Heat Pump Programme. The Centre was established in 1982. Using its National Team network, along with other organisations, the Heat Pump Centre 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 Heat Pump Centre is the world's leading information centre on heat pumps and air conditioning and one of the largest publishers of heat pump literature.

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Activities

The activities range from producing a quarterly heat pump magazine (the newsletter), maintaining the Internet site (www.heatpumpcentre.org), and cooperating with related international organisations to carrying out tailored collaborative projects.

The heat pump magazine features topical and non-topical articles and a news section and is free of charge in member countries. Topics covered in 2000 include Commercial and Industrial Refrigeration, Heat Pump Programmes and International Heat Pump Organisations, Refrigerants – Standards, Regulations, Safety and Liability Issues, and Heat Pump Systems for Retrofitting Space Heating Systems.

Parts of the newsletter are translated into German, French and Japanese.

The Internet website is used for information exchange and communication. The number of pages requested from the website average approx. 25,000 per month, with a total of 342,000, an increase of 30% compared to 1999. The Heat Pump Centre maintains the Programme's database of publication abstracts on the Internet, which contains over 1,800 entries such as newsletter articles, workshop and conference papers, Annex reports etc.

International collaboration with the member countries and related organisations form an important element of the Centre's work. The work programme for the following year is developed, together with the member countries, during the annual working meeting. The 2000 annual meeting was held in Amsterdam and resulted in a strong, broadly supported programme proposal consistent with the Programme's Strategy Plan.

Ties with the International Institute of Refrigeration (IIR) were enhanced. The Heat Pump Centre will play a key role in collaborating with the IIR, mainly working on the heat pump magazine and the Internet. For other international collaboration, see the International Networking section.

International assessments are vital to the work of the Heat Pump Centre, and encompass surveys and analyses on selected topics. Work on two surveys was almost completed in 2000, notably on Considerations in the Design and Selection of Domestic Heating and Cooling Distribution and Ventilation Systems and their Use with Residential Heat Pumps, and Retrofit Heat Pumps in Buildings. The first survey provides a useful overview and compilation of current distribution and ventilation systems in residences and new trends, with a focus on low-temperature heat distribution systems and low/passive-energy houses. The second survey explains the main technical and economic hurdles for retrofit heat pumps in the residential sector and points the way towards possible solutions.

Other ongoing projects include Describing Successful Heat Pump Installations (Internet), Refrigerant Recovery, Recycling and Reclamation – an International Assessment, and Users' Experience with Heat Pump Software and Handbooks. These projects will be completed in 2001.

Publications

The Heat Pump Centre is the publication channel of the Programme and the results of all Annexes are published in reports. In 2000 the following reports were published:

- Final report of Annex 24 (see page 7).
- Proceedings of a SAVE - EU workshop on Natural Working Fluids – a Challenge for the Future, held in Paris, France, and co-sponsored by the Centre.
- Proceedings of an international workshop on the Results from IEA Heat Pump Programme and Heat Pump Activities in Mexico, held in Mexico City (see page 10).

The international workshop on Natural Working Fluids identified hurdles and challenges facing the use of hydrocarbons, ammonia and carbon dioxide in small and medium-sized heat pumps and air conditioners. These refrigerants offer an alternative to HFCs in some cases, but technical solutions, information dissemination and training are required to ensure that these fluids are used safely. The workshop has improved the industry's insight into the forces that support and hamper equal opportunities for natural working fluids. There was general consensus that there is a serious

lack of both skilled installers and national training programmes. The workshop concluded with an official appeal to the European Commission that training programmes should be initiated and implemented in national education programmes for installers of equipment using natural working fluids.

Annex 24 – Absorption Machines for Heating and Cooling in Future Energy Systems

Participating countries: Canada, Italy, Japan, the Netherlands, Norway, Sweden, United Kingdom and the United States.

Annex 24 aims to further increase and promote the use of thermally driven systems, i.e. absorption systems, adsorption systems and compression/ absorption systems, for heating and cooling in future energy-efficient and environmentally acceptable energy systems. The Annex work focuses on gaining a better understanding of the current and future market opportunities for sorption systems in a global perspective, and examining how different factors (i.e. economic, political, environmental and knowledge) will affect the promotion and application of such systems in residential, commercial and industrial sectors.

The Annex benefited from multinational participation and multidisciplinary representation. The workshops allowed a healthy exchange of information provided by the country representatives and many invited speakers. The four initial workshops provided a lot of information on sorption equipment and systems together with the particular applications and marketing aspects. The amount and quality of the information is indeed substantial.

However, all this information would simply be encyclopaedic if it was not collated into worldwide conclusions on sorption systems. The last workshop in London (March 2000) was dedicated exclusively to this, and to producing the final report. The group focused on reaching general conclusions that were successfully achieved (see heat pump magazine article Vol. 18, No. 4/2000, pp. 20-22). Basically it enabled readers to predict the current and future trends of different sorption technologies, for various applications and countries, compared to boilers, mechanical heat pumps and chillers. The background information in the final report is also very useful and concise, with regard to all the contributing factors. These include the market situation in member countries, applications in residential, commercial and industrial sectors, R&D, manufacturers' information, technologies and thermodynamics of sorption systems.

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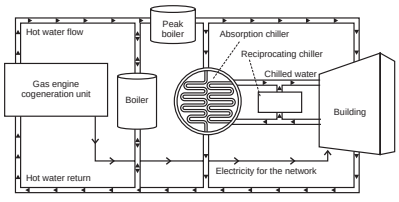

Example of CCHP installation (Courtesy Jenbacher 2000)

Further work was recommended with regard to using sorption technologies in heat recovery systems including CHP. The proposal for this new Annex has been approved by the Executive Committee, and will start later this year.

Annex 25 - Year-Round Residential Space Conditioning Systems Using Heat Pumps

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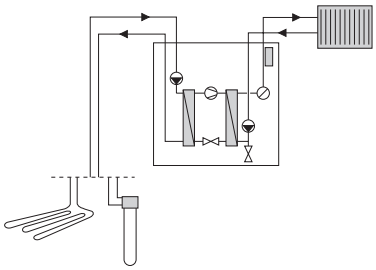
Participating countries of Annex 25: France (Operating Agent), the Netherlands, Sweden and the United States.

The Annex aims to define and show the technical feasibility of new packaged systems for year-round residential space conditioning using heat pumps. These systems (which include all the components used in a heating/cooling system, from the heat pump to the inside unit) target mainly new residences and use either water or air as energy distribution medium. The work carried out within the framework of this Annex covers low initial and operating costs, comfort provided, suitability to customer demands, design/installation requirements, performances, integration in buildings and aesthetics.



Air conditioning system using heat pump

Canada[1]

Canada has a diverse range of climatic patterns. The mini-split heat pumps reviewed in this study tended to be the air-source variety manufactured in the 'Pacific Rim' countries. However, the cost of electricity in Canada is still too low to develop a significant market for this equipment. The major incentive for ductless split systems is air conditioning, rather than heating capability in Canada.

France

France focuses on two hydronic systems (i.e. floor heating and cooling, and fan-coil units). Work has been conducted on improving the following existing systems:

- control strategies of the radiant heating and cooling floor, especially in summer, to avoid condensation;
- performance analysis of fan-coil units, to develop a new prototype for residences that is both silent and small.

Market needs and expectations were studied via several market studies and opinion surveys. They lead to avenues for new developments with aesthetics and noise levels being the most important criteria. The French

1 Canada, represented by Ontario Hydro, no longer participates in the Annex.

group will focus on a hybrid system with a radiant heating and cooling floor and fan-coil units on the first floor. This enables a more efficient cooling of the upper floor, while the radiant heating and cooling floor is restricted to the ground floor, for aesthetic and heating comfort reasons.

The Netherlands

The most important barriers to large-scale application of heat pump systems in the Netherlands are the high initial costs, integration into the building design and construction process, the low price of gas compared to electricity, and possible restrictions to using groundwater as a heat source. However, heat pumps offer a cooling function that provides a comfort benefit.

On the basis of the Dutch study, a combination that provides space heating, hot domestic water, ventilation and space cooling is a most favourable option for new private housing projects. Ongoing demonstration projects using this technology help to optimise the system and promote heat pumps.

ITHO heat pump system concept

Sweden

In order to gain a complete picture of the market requirements, various types of stakeholders were asked to give their opinions. One survey showed a service requirement for residential heat pumps and confined positive heat pump experience to Swedish houses. The most pressing barriers to domestic heat pumps and floor heating systems could be identified. Installers and architects' opinions and expectations were also documented to obtain a clear picture of market perception.

Ongoing developments concern improvements and optimisation of heat pump and heat distribution systems. In addition to customer needs, criteria such as performance, distribution losses, reliability and investment costs are taken into account.

United States

The US studies cover existing and new duct systems. These systems show an average efficiency of 43.5 to 66.2%, depending on the climate, duct location, duct leakage, and duct insulation levels. These advanced distribution systems are studied through modelling and field tests in two houses. The following improvements have been evaluated: duct sealing, improved installation and advanced distribution systems. Comparisons have been made between standard air distribution and high-velocity air distribution systems with field validation on a 156 m2 house. The distribution efficiency increases up to 85%. Another field test is being conducted in a house equipped with fan-coil units.

Annex 26 - Advanced Supermarket Refrigeration/Heat Recovery Systems

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Participating countries: Canada, Sweden, United Kingdom, and the United States (Operating Agent).

This is the first Annex within the Programme to combine refrigeration and space conditioning. Annex 26 aims to demonstrate and document the benefits of advanced systems design for food refrigeration and space heating and cooling for retail supermarkets. A specific goal is to identify advanced systems design options to reduce total equivalent warming impact (TEWI) of supermarkets. Candidate advanced supermarket refrigeration systems will be analysed and compared to other state-of-the-art systems. Concepts to be considered include:

1) secondary loop systems;
2) distributed compressor systems;
3) self-contained display cases.

Ways of integrating space heating/cooling systems with refrigeration systems are also being investigated in the analyses.

A workshop held in Stockholm, Sweden, during 2000 was co-sponsored by IIR Commission E2 (Heat Pumps) and included a wide variety of presentations covering R&D and field testing of entire systems and display cases, developments in secondary refrigerants, plus development and application of modelling and evaluation tools. Presentations originated from no less than seven countries, including Canada, Denmark, France, Norway, Sweden, United Kingdom, and the United States. A brief brainstorming session was held at the close of the workshop entitled What is most needed to improve energy efficiency of supermarket refrigeration systems? Improving display case technology to reduce system loads and improving system controls to better follow this load, were two of the main items mentioned. The workshop attracted many representatives from system and display case manufacturers, supermarket companies, and utilities as well as researchers. Workshop proceedings are being prepared in CD-ROM format by the organisers, the Royal Institute of Technology, Sweden.

The Annex participants and Operating Agent are working toward completing drafts of the Annex final report by early 2002.

Annex 27 – Selected Issues on CO_2 as Working Fluid in Compression Systems

Participating Countries in Annex 27: Japan, Norway (OA), Sweden, Switzerland, United Kingdom and the United States.

Annex 27's main objective is to bring CO_2 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.

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Projects

Japan:

Heat transfer characteristics of CO_2

As an Annex 27 research project, the University of Tokyo, Kyushi University and the central Research Institute of Electric Power Industry (CRIEPI) have agreed to exchange technological information on heat transfer characteristics of CO_2. The three organisations are experimenting independently with heat transfer, but are planning to collaborate.

Feasibility study on CO_2 compression systems

This project collects information regarding R&D activities on CO_2 compression systems for various applications in Japan. The information will be used in analysing challenges and possibilities in the future, in order to commercialise certain applications.

Norway:

Heat transfer and pressure drop characteristics of CO_2

Studies to collect experimental data on heat transfer and pressure drop data for the flow of CO_2 at supercritical and subcritical pressures in a microchannel aluminium tube have been carried out at the Norwegian University of Science and Technology. Other experiments will be carried out in the future, including studies on the effects of lubricants on heat transfer characteristics.

Selected safety issues with CO_2 as working fluid

It has been suggested that a Boiling Liquid Expanding Vapour Explosion (BLEVE) may occur when a vessel containing pressurised liquid or supercritical fluid is rapidly depressurised, e.g. due to a rupture. Tests on CO_2 have been conducted at varying initial conditions and liquid fill levels. More experiments will be carried out in the near future.

2 1 Quad = 1.055 EJ = 1 055.1015 J

Sweden:

Thermosyphons with CO_2 for transferring heat in refrigerators and freezers

This project aims to design systems for both evaporators and condensers that are driven by density difference. Projects on this topic have been carried out at the Swedish Royal Institute of Technology.

Feasibility study on CO_2 as secondary refrigerant in Sweden

A feasibility study of CO_2 as a secondary refrigerant has been carried out at the Royal Institute of Technology.

UK:

Development of a novel transcritical CO_2 compressor

The United Kingdom work relates to developing a novel compressor for use with transcritical CO_2. Design studies have been under way on applications with various refrigerants, including air, R-134a, R-410a and transcritical CO_2. Practical development is expected to start with UK Government support funding.

USA:

Feasibility of transcritical CO_2 systems for mobile space conditioning applications

Experiments have been conducted on a prototype CO_2 system operating in heat pump mode, with the heat rejection path lying entirely within the supercritical region. The prototype system is sized for a compact car, but these experiments were conducted to provide a baseline for scaling up to fit sport-utility vehicles. Further optimisation and extension of the operating range will be carried out in the near future.

Correlating the heat transfer coefficient during in-tube cooling of turbulent supercritical CO_2

The project focuses on the experimental and numerical analysis of the heat transfer and pressure drop characteristics during in-tube cooling of turbulent supercritical CO_2. Based on these analyses suitable correlations were developed for predicting heat transfer and pressure drop. The effects of small oil concentrations on the heat transfer coefficient and pressure drop of supercritical CO_2 during in-tube cooling was also quantified. The project has been completed.

Workshop

SINTEF Energy Research organised the first Annex 27 Workshop on 17-19 September 2000 in Trondheim, Norway. The workshop programme included 11 paper presentations and a group work session. In total

56 participants attended the workshop and as many as 14 countries were represented.

Internet website

An Annex 27 home page will be established to provide information exchange and publish updates of the Annex 27 activities.

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Summary of the Annexes

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

Annex	Operating Agent	Participants	Completed
14. Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps	Japan	Belgium, Denmark, Germany, Japan, Sweden, USA	1991
15. Heat Pump Systems with Direct Expansion Ground Coils	Canada	Austria, Canada, Japan, USA	1993
16. IEA Heat Pump Centre	The Netherlands	Austria, Japan, The Netherlands, Norway, Sweden, Switzerland	Ongoing
17. Experiences with New Refrigerants in Evaporators	Sweden	Canada, The Netherlands, Norway, Sweden, Switzerland	1993
18. Thermophysical Properties of Environmentally Acceptable Refrigerants	USA	Austria, Canada, Germany, Japan, Sweden, UK, USA	1999
19. Cancelled			
20. Working Fluid Safety	Belgium	Belgium, Japan, The Netherlands, Norway, Switzerland	1993
21. Global Environmental Benefits of Industrial Heat Pumps	USA	Canada, France, Japan, The Netherlands, Norway, Sweden, UK, USA	1996
22. Compression Systems with Natural Working Fluids	Norway	Canada, Denmark, Japan, The Netherlands, Norway, Switzerland, UK, USA	1999
23. Heat Pump Systems for Single-Room Applications	Canada	Canada, France, Switzerland, Sweden, US	1999
24. Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	Sweden	Canada, Italy, the Netherlands, Norway, Japan, Sweden, UK, USA	2000
25. Year-Round Residential Space Conditioning Systems using Heat Pumps	France	France, The Netherlands, Sweden, USA	Ongoing
26. Advanced Supermarket Refrigeration/Heat Recovery Systems	USA	Canada, Sweden, UK, USA (Denmark to join in 2001)	Ongoing
27. Selected Issues on CO_2 as Working Fluid in Compression Systems	Norway	Japan, Norway, Sweden, Switzerland, UK, USA	Ongoing

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