Vol. 10, No. 1, March 1992

IEA Heat Pump Centre

NEWSLETTER

IEA
OECD
heat pump
centre

Contents

Front Cover: The front cover shows the Technorama building in Düsseldorf, Germany, at which both heat and cool storage is applied. More information is available in the article on page 4.

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

A basic aim of the IEA is to foster cooperation among the 21 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources and energy research, development, and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of 42 Implementing Agreements, containing a total of over 80 separate energy RD&D projects. This publication forms one element of this programme.

Editor: *Rosemarie Smith*
Production Team: *Lucinda Maclagan / Roswitha Muyres / Heleen Smeets.*
Technical Editing:
Jos Bouma / Léon Wijshoff / Mike Steadman.
Illustrations:
Offermans EPS, Maastricht.
Printers:
Huntjens Drukkerij, Stein.

ISSN 0724-7028

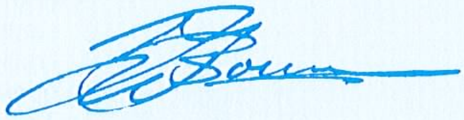
Editorial

The theme of this Newsletter is *Heat Pumps and Heat/Cold Storage*. Thermal storage of heat and cold are important ways to improve energy efficiency, not only in industry but also in the residential and commercial buildings sector. Combining heat and/or cold storage with heat pumps can further increase energy efficiency, not only providing benefits to end-users (lower energy cost) but also to electric utilities (load levelling). With heat pumps both heating and cooling can be provided with little extra investment cost. Thermal storage can also provide operational benefits for the heat pump system.

Usually, when writing this editorial I address the theme of the Newsletter and highlight related key issues, headlines and trends. However, on this occasion I would like to focus on another aspect of current awareness, dealt with in this issue, namely Fuzzy Logic in relation to control of air-conditioners and heat pumps.

Fuzzy (or vague) Logic is not dealt with as an article but is presented in the form of an interview with an expert of one of Japan's leading companies which applyies Fuzzy Logic in consumer products. Japan was the first to bring the fuzzy-type artificial intelligence straight into the market, an avenue previously indicated by US scientists but only recently followed by industries in Europe and the USA. Fuzzy Logic was first applied in controls, a logical step because control is required almost everywhere. Fuzzy Control imitates human experience, enabling a process to become more flexible and in particular controlled more quickly. Fuzzy Logic, or Fuzzy Interference, is not a solution to all technical problems. It provides, however, an excellent opportunity for increased heat pump performance and user comfort.

Developing Fuzzy Logic applications in heat pumps and related technologies, especially for the diversified European market, should be a spear-head activity. Typically, these are the advancements in technology needed to achieve high performance heat pumps which are being accepted widely as environmentally benign products.



Jos W.J. Bouma
General Manager.

Seasonal Cold Storage in the Ground Using Heat Pumps

*B. Sanner, V.G. Chant

Introduction

Energy use for cooling, based primarily on electricity, is rapidly increasing in North America and Europe. Especially important in commercial buildings, cooling is increasingly needed because of heat generation from computers and other appliances. In addition, the emphasis on energy conservation in the past two decades has decreased air infiltration in buildings contributing to an increased requirement for cooling. Increasing awareness of the benefits from improved indoor air quality and occupant comfort also leads to increased demand for cooling.

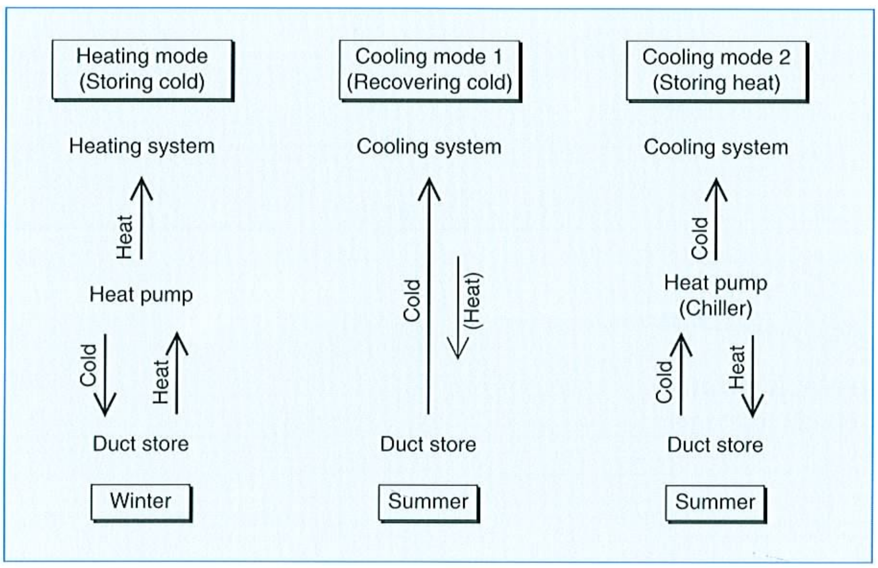
Thermal storage systems for cooling applications, or for combined cooling and heating, can result in energy savings, cost savings and reduced adverse environmental impacts when compared to conventional energy systems.

Within the IEA Implementing Agreement "Energy Conservation through Energy Storage" (ECES) a collaborative R&D work programme targeted on thermal storage for cooling has been established as Annex 7. Work regarding national reviews of "state-of-the-art" of storage technologies and applications commenced in 1990 in the participating countries (Canada, Germany, Netherlands, Sweden). The reviewed projects include existing plants as well as feasibility studies, in buildings and industrial applications, and systems with and without heat pumps.

Operation Principles

As a storage medium, aquifers with ground-water, or the ground itself (soil, rock), can be used. Aquifer stores are most suited to high capacity systems. The projects reviewed ranged in size from less than 50 to over 10,000 kW. The average project cost decreases with project capacity from about USD 400/kW (for 50 kW systems) to about USD 200/kW (for 10 MW systems).

Figure 1: Basic Operational Principles for Seasonal Cold Storage in the Ground Using Heat Pumps.



The basic operational scheme of a ground-coupled heat pump with seasonal cold storage is shown in Figure 1. During heating operation, the ground or ground-water is cooled, while heat is supplied to the building. At the end of the heating season, enough cold is stored to run a cooling system directly (mode 1) with cold ground-water from the injection well or cold brine from earth heat exchangers. For peak cooling loads, a back-up system using the heat pump in reversed mode can be operated (mode 2). After continuously running the heat pump for space cooling for more than a few hours, temperatures in the ground may be too high for mode 1 cooling. The system should then be operated only as a conventional heat pump plant, storing heat in the ground until the beginning of the next heating season. The most cost-effective and optimum energy performances can be obtained by running the system in heating mode and cooling mode 1 only.

It is evident that the cost-effectiveness of seasonal storage depends significantly on the thermal and seasonal characteristics of the load. Storage for cooling is more cost-effective for cooling systems with relatively high operating temperatures (up to 15°C) than for the more conventional temperatures (6-8°C). Operating at higher temperatures, storage for cooling has reduced thermal losses, increased loading availability in winter, and reduced climatic influences on performance.

Table 1: Technical data of the Linden and Düsseldorf plant.

Name Location	Geotherm admin. and shop Linden, Germany	Technorama Düsseldorf, Germany
Earth probes •Number •Individual length	 5 40 m	 77 35 m
Type	HDPE-U-tube in drill holes	Steel tubes with inner pipe
Heat pumps •Number •Total heating capacity	 1 15 kW	 6 190 kW
Heating temp. Heat load	40/30°C 14 kW	45/35°C 190 kW
Cooling temp. Cooling load Annual heat from store Annual cold from store	14/18°C 11 kW 19 MWh 11 MWh	14/19°C 40 kW installed 1990 60-80 kW planned ~ 200 kW max., with HP 254 MWh 120 MWh installed 1990

Installation Examples

Germany

A small commercial building in Linden, Germany, has been equipped with a ground-coupled heat pump using stored cold for space cooling in summer. Technical data about this plant is given in Table 1, the operational modes can be seen in Figure 2.

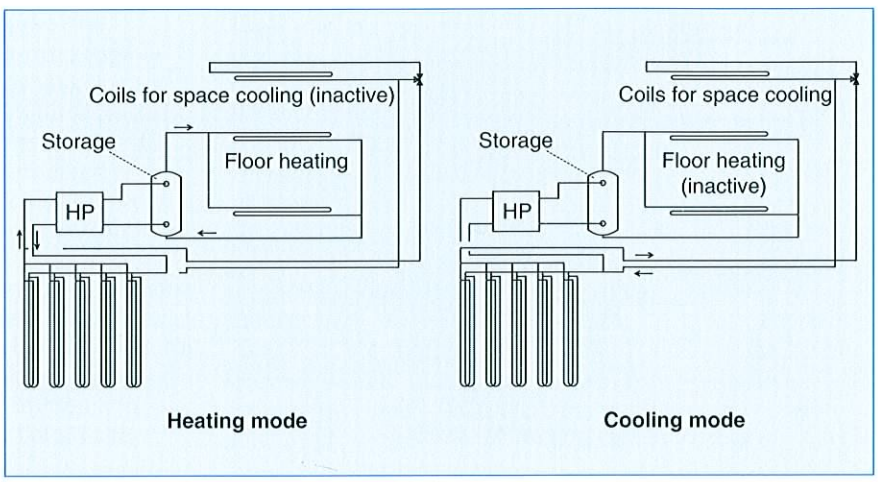
The building is a conventional type of architectural design. The offices and shops within it are heated, but only the offices are cooled. Thus, compared to the heat load, the energy required for cooling is low and is run for approximately 1,000 hours only. The cold in the ground is sufficient to cover the total cooling load, and no additional system or reversible heat pump is provided. To cover the peak heat load, a burner for natural gas has been installed. The plant has been in operation since spring 1990.

The cold is distributed with coils in the ceiling. Brine is circulated through these coils. The undisturbed ground temperature at the beginning of heat pump operation was on average 9.8°C. On January 30, 1991, during the heating season, the brine temperature which ran the heat pump for one hour was 4.5°C supply and 1.7°C return. On July 11, 1991, while the outdoor air temperature was 34°C, an office room was kept at 23.7°C. A reference room, which had no cooling, had an air temperature of 27.9°C. Cold brine from the ground entered the system at a temperature of 14.5°C. Continuous monitoring of the system is planned.

A somewhat different approach has been applied in Düsseldorf at the Technorama building, and uses the "passive solar" system, see front cover. Transparent insulation of the outer shell and the roof of a large atrium provide substantial solar gains. Hence, the annual heating load is reduced, but the cooling of office rooms and laboratories is essential during the summer-time in addition to shading. Computer facilities also need to be cooled most of the time.

The local ground consists of sand and gravel from the Tertiary age. The store consists of 77 earth probes, grouped into four clusters with an individual manifold for each group. For technical data see Table 1. In each cluster, the steel tubes have been arranged in a radius with a dip angle of approximately 45°C (see Figure 3). The earth probes are of the coaxial type, brine flows down through a plastic pipe inside the steel tube and comes up through the annulus.

Figure 2: Linden Plant in Heating Mode, Winter (left) and Direct Cooling Mode, Summer (right).



Six heat pumps are working in parallel, all connected to one manifold on the "earth side" and to two buffer tanks on the "building side". These heat pumps feature a small pressure drop in the evaporator and condenser, and the cycle can be reversed for the cooling operation in a similar way as shown in the basic scheme in Figure 1. To meet reduced heat demands in the spring and the autumn (and on sunny days during the winter), heat pump units are shut off. A computerized energy management system in the building ensures adaptation to the actual heating/cooling requirements.

The plant has been in operation since November 1990. During the first two months, increased heating was required to dry the new building, and heat pumps were operated almost continuously. Brine temperatures went down to 0°C and below. Once the building was completed internally and in full use, the heat demand reduced. Although the monitoring system is not yet available, the first cooling season in 1991 can be considered a success.

Sweden

In Sweden, storage systems based on porous aquifers, ground-water in fractured rock and heat exchangers in rock are under construction or being studied; heat exchangers in clay soil are in operation for heat storage only. Excellent conditions for aquifer stores are found in so-called "Eskers", a type of glacial-fluviatile sediment which consist mainly of gravel, are good hydraulic conductors and have a well-defined area. The formation of eskers are typical of northern countries which are affected by ice-age glaciation.

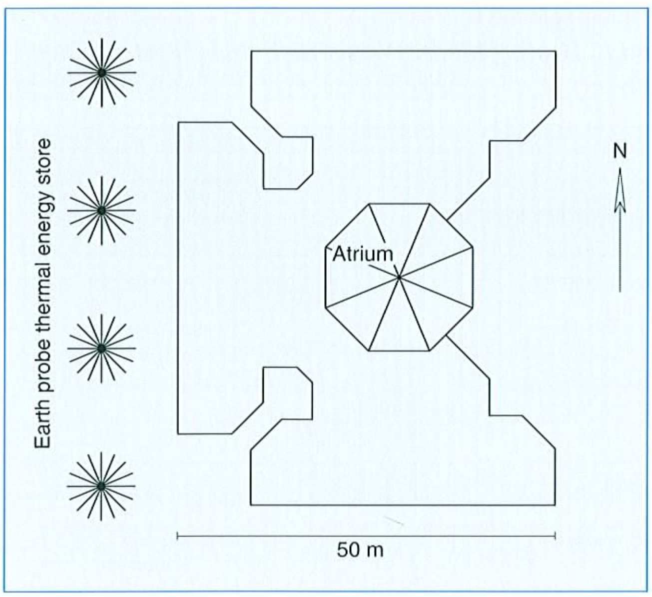
A new 80,000 m² area buildings' project on such an esker, will be heated and cooled with heat pumps, using the aquifer as the heat source and sink. The freezing demands of an ice rink will provide an additional heat source.

The most prominent project of this type is located in the SAS Head Office at Frösundavik north of Stockholm, Sweden. The building with 64,000 m² floor area is situated above an esker-aquifer, which is used for thermal energy storage by using three "cold" and two "warm" wells. Figure 4 shows the principle flow scheme of this system, which was put into operation in 1987. During 1990, the production of heat in the Frösundavik plant was 3.41 GWh, while 2.96 GWh was produced for cooling. For the production of this amount of thermal energy (6.37 GWh) the system used 1.02 GWh electrical energy. No serious problems with ground-water chemistry have occurred in the circulated water.

The use of an aquifer in fractured rock has been realized in the Traingeln Trade Centre in Malmoe, providing 1.7 GWh for heating and 1.0 GWh for cooling annually. Eight production and eight injection wells at a distance of 150 m, drilled in limestone, supply a maximum ground-water circulation of 58 m³/h. Two heat pumps with a total heating output of 900 kW are backed-up by the local district heating system for peak heating load. Cooling is mainly provided directly from the aquifer, backed up by 200 annual running hours of heat pump operation to cover the peak cooling demand.

A storage system with heat exchangers in rock has been realized in the GLG centre in Upplands Väsby, Sweden, where 64 boreholes in crystalline rock, each 120 m deep, provide the heat source for a ground-coupled heat pump. The cooling capacity of this system is 480 kW.

Figure 3: Plan of Technorama, Düsseldorf, and showing the thermal store.



Netherlands

The majority of projects in the Netherlands concern cooling plants without heat pumps. Ground-water is cooled by air-to-water heat exchangers during winter-time, and used directly for process or space cooling during the summer. A planned project for the heating and cooling of a shopping mall in Eindhoven includes heat pumps for heating, but mainly for cooling purposes. At maximum cooling load during the summer, 1.6 MW of heat will be discharged to the

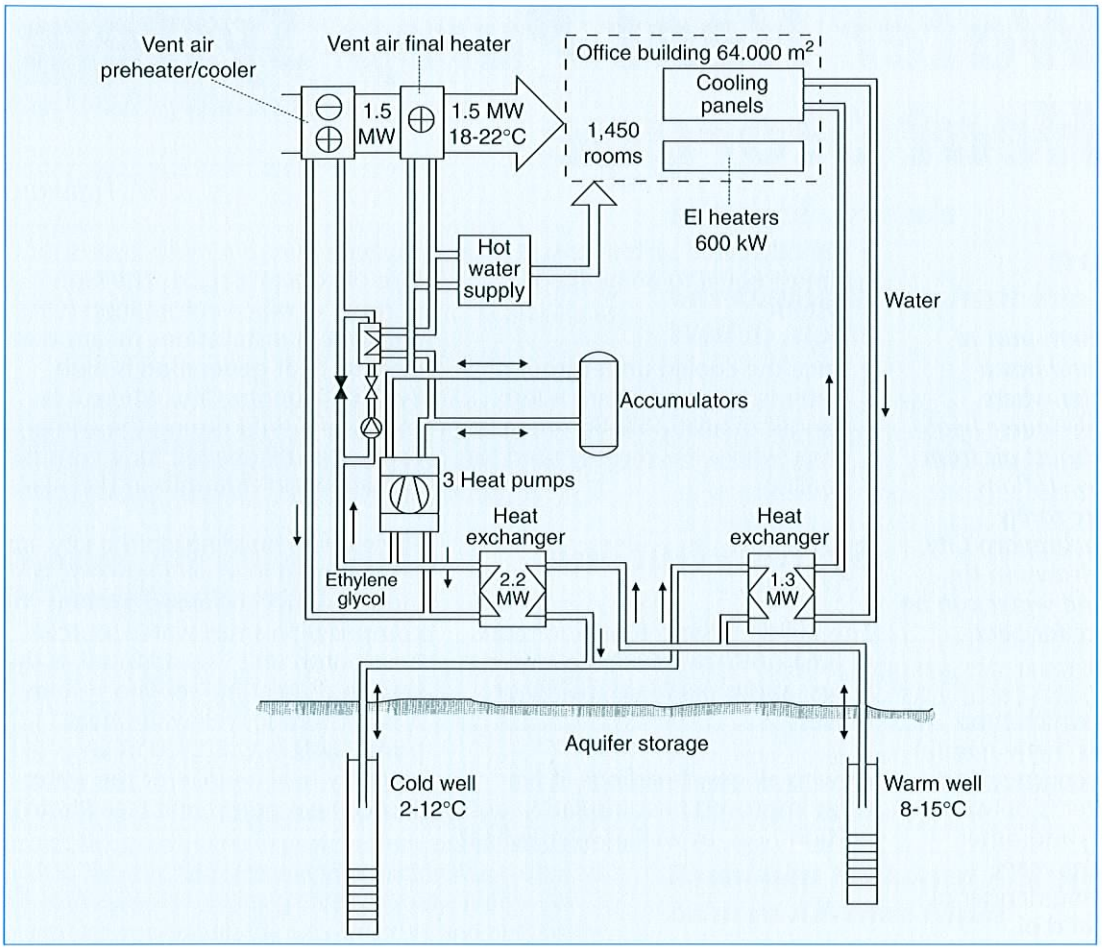


Figure 4: Principle flow scheme for the heating and cooling system at Frösundavik plant.

aquifer. After a few years the ground-water temperature will rise to about 30°C, and the ground-water can be used directly to pre-heat ventilation air during the winter. For further details see News and Views on page 31.

Conclusions

Ground coupled heat pumps with a space cooling option are numerous in North America. Some of them, using ground-water as a heat source/sink, apply natural cooling by circulating the cold ground-water as a cold carrier directly.

Ground heat pump operation lowers temperatures in the ground, and the resulting cold can be used for space cooling. The more frequently cold is used directly, the more efficient the system becomes. Heat pump operation for cooling should be reduced to short peak periods. Using the ground system for both heating and cooling improves economy and energy efficiency; however, proper layout and sufficient knowledge of the sub-surface conditions are crucial.

Feasibility studies for projects that have not been implemented indicated that cost-effectiveness is the most frequent reason for not proceeding. Other reasons include lack of experience with the concept and control systems, scheduling conflicts with the primary project, and uncertainty about hydro-geological characteristics at the site. Cold storage can also imply start-up problems. Therefore, start of operation in the autumn is preferable.

The merits of seasonal cold storage systems, with or without heat pumps, have been demonstrated in actual operation. Electrical energy consumption and peak demand, and thus energy costs, can be reduced considerably through seasonal cold storage.

Acknowledgements

The authors wish to record their sincere thanks to those who contributed to this paper: Olof Andersson of VBB VIAK, Malmö, Sweden; Anders Eriksson and Sam Johansson of AIB Anläggningsteknik AB, Solna, Sweden; Gerd Euler of Geotherm GmbH, Linden, Germany; Jörg Reichmann of Kaiser Bautechnik, Duisburg, Germany; Aart Snijders, IF Technology, Arnhem, the Netherlands.

** Authors:*
Dipl.-Geol. Burkhard Sanner, Institute of Applied Geosciences, Giessen University, Giessen, Germany;
Dr. Verne G. Chant, Hickling Corporation, Canada.

Well Water Heat Pump System with Heat Storage

*Y. Fujiwara

Introduction

Situated in the northern part of Japan, Hokkaido Island has a snowy and cold winter where, apart from special air-source heat pumps which use exhaust air from underground railway stations, room heat pumps are rarely utilized. However, in Sapporo City, attention has been drawn to the fact that underground water can be used as a heat source for heat pumps.

The Toyohira River, which runs through the city, has many natural underground water courses. This readily available water is pumped up for use in cooling and other applications. In recent years, however, an increasing danger of ground subsidence and of contamination of underground water has arisen. Thus, the municipal authorities stipulated a guideline to save water which included prohibiting direct use of underground water for cooling and recommending the use of water-saving sanitary appliances, etc.

The "Sumitomo Shoji Fukamiya Odori Building" opened in April 1989. A heat storage type well water heat pump system is used for heating and hot water supply. It uses low tariff electricity at night for contracted heat storage.

Although initial costs are marginally higher than for conventional oil- or gas-fired systems, the advantages of this type of system include:

- there is no danger of polluting the ambient air;
- it can be safely and stably operated 24 hours a day;
- it can utilize off peak electricity at night;
- the calculated system cost is almost equal to an oil-fired system;
- since the cooled underground water is returned, there is less danger of heat pollution than in cases where it is directly used for cooling.

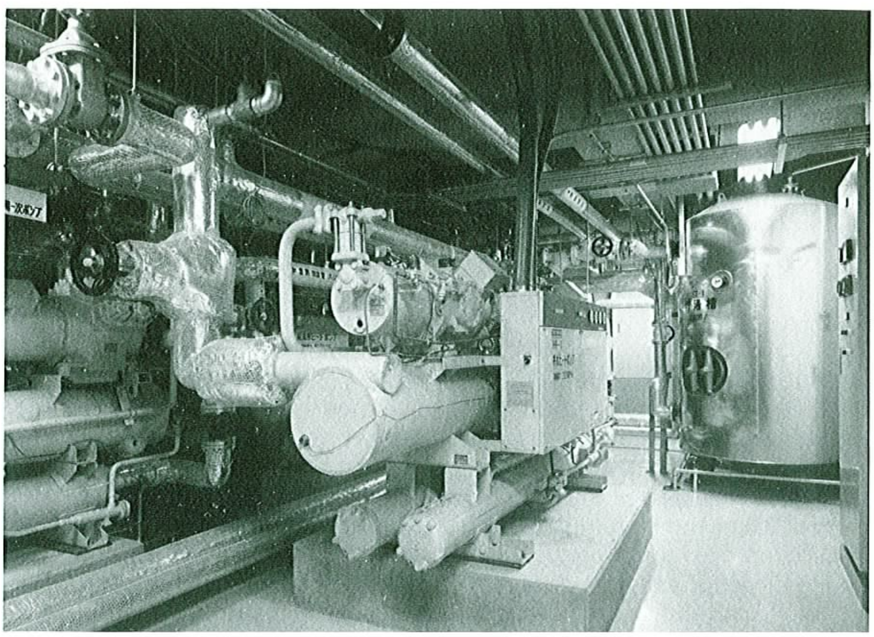
System Outline

The building has a total floor area of 8,617.691 m² divided over ten floors, and is made up mainly of offices.

As with all new buildings, it features improved heat insulation and air-tightness, as well as a large heat capacity due to a multi-layer structure of concrete slabs. The high number of office automation (OA) equipment installations means that internal heat generation is high. Even in Sapporo City, where it is snowy and cold during the winter, cooling is still needed for a considerable period throughout the year.

Since office buildings in the city are often rented in small segments, an individual decentralized system comprising a small water-source heat pump unit was adopted as the building's heating/cooling system. A heat storage well water heat pump system was used as an auxiliary heat source for the water-source heat pump unit (see Photo).

Well-Water Source Heat Pump Unit.



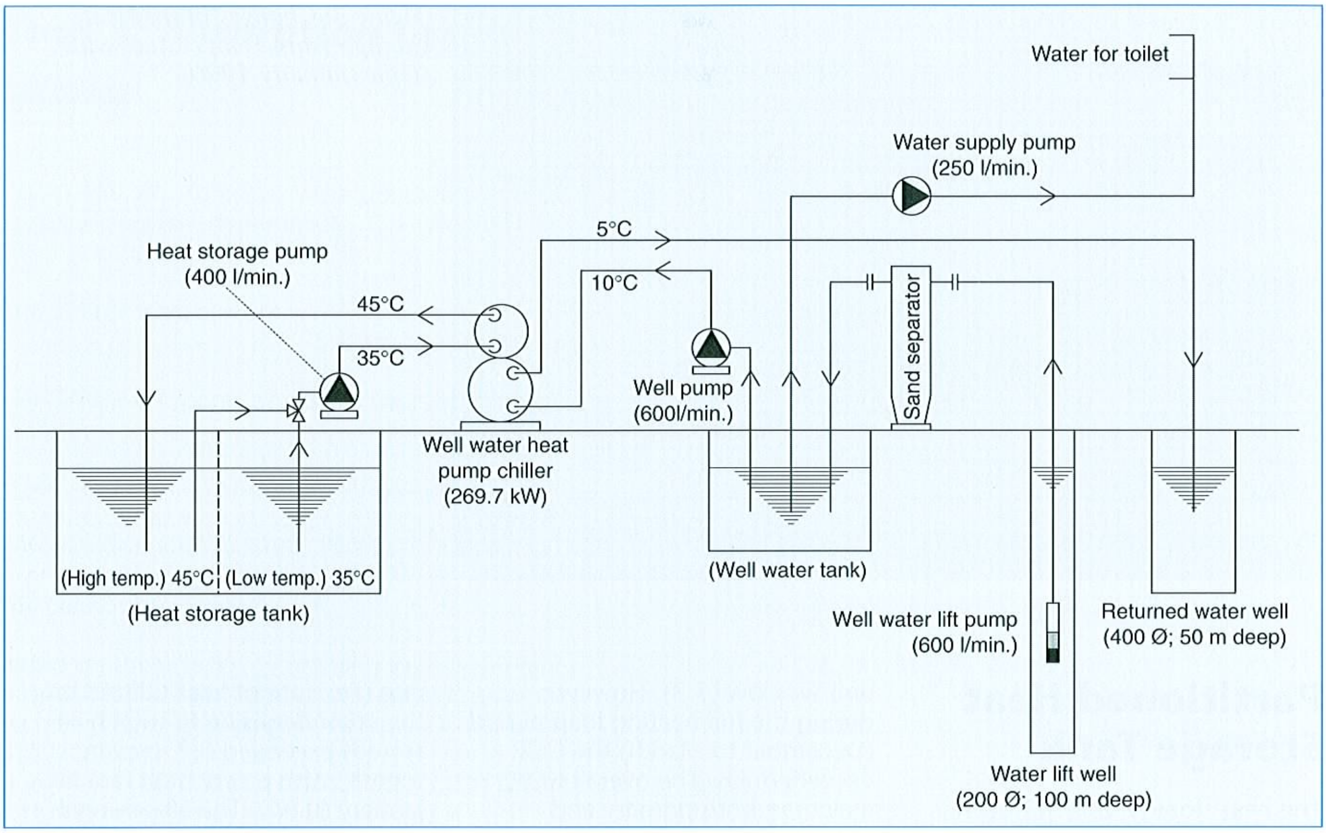


Figure: 1: The Well Water Heat Pump System - A System Flow Diagram.

System Operation

As shown in Figure 1, well water at 10°C is pumped up, heat is extracted in the heat pump and the water is returned to the well at 5°C. On the secondary side of the heat pump, water from the low temperature side of the heat storage tank, is increased in temperature by 10°C and returned to the high temperature side. The capacity of the heat pump and that of the heat storage tank were set by taking the following into account:

- the peak load and daily load obtained using an unsteady heat load calculation ;
- the expected quantity of internally generated heat, insolation and other building data.

Although the maximum calculated heating load is about 580 kW the actual heat source capacity installed is 269 kW.

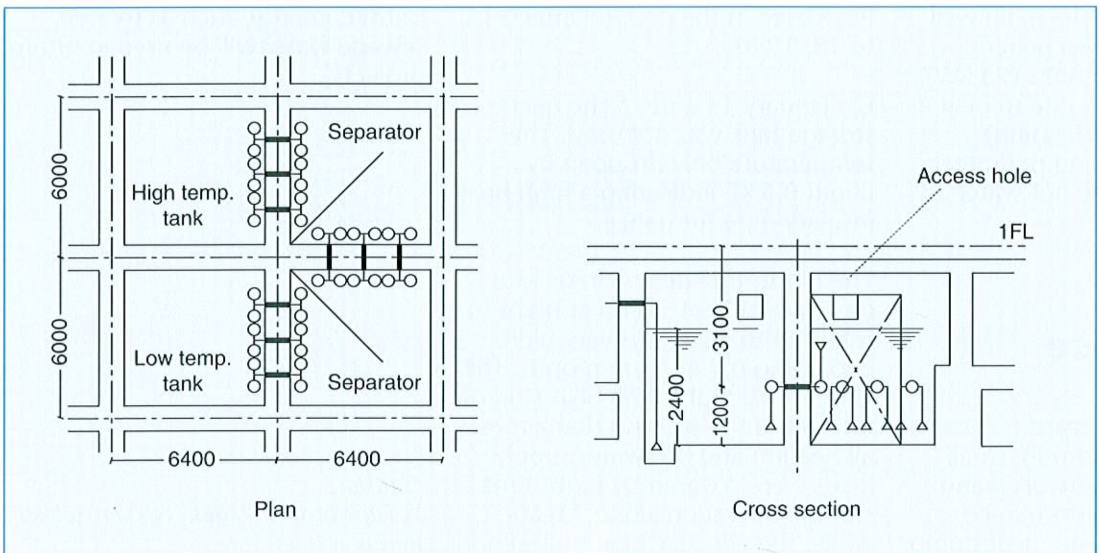


Figure 2: The Plan and Cross-section of the Heat Storage Tank.

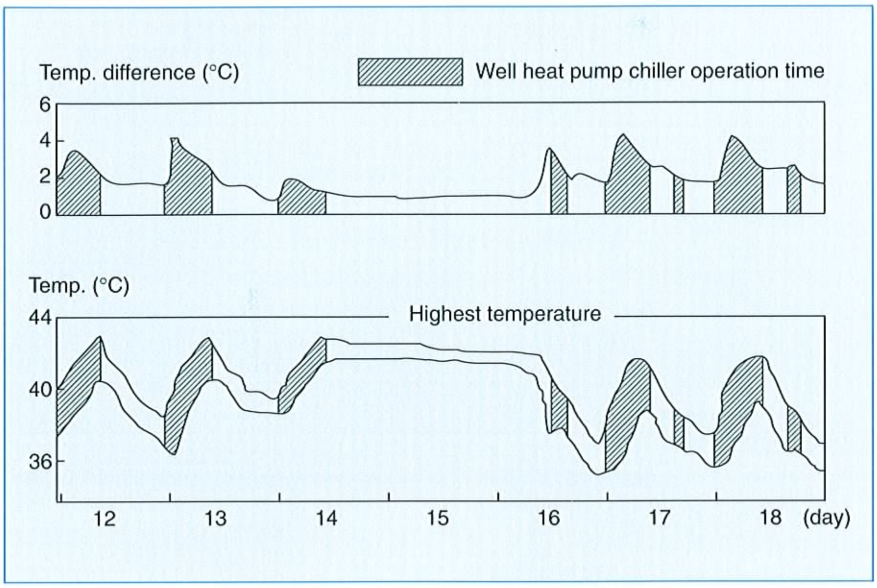


Figure 3: Changes in the Heat Storage Tank Temperature with Time (January 1990).

Partitioned Heat Storage Tank

The heat storage tank has been installed under the ground floor, (see Figure 2). It comprises a number of partitioned storage units connected together in groups of four by 300 mm diameter tubes. The tank capacity is 240 m^3 and the walls are insulated by 50 mm thick hard urethane foam. Separators are used to ensure an even temperature flow between the high and low temperature tanks.

Back-up

In order to back-up the main well water heat pump, two general-purpose heat pump units (93 kW) have been installed - one to heat a hydronic (hot water heating) system for the building perimeter, and the other for the hot water supply.

System Performance

In the intermediate seasons (October, November and April), small quantities of heat were used and the Coefficient of Performance (COP) of the well water heat pump unit was low (3.3). However, during the full heating load period (December to March) the COP exceeded 3.6. The overall COP, including both primary and secondary circulation pumps, was 2.96 ~ 3.18, proving that the sys-tem operated under good conditions.

The all-seasonal COP was 3.73 for the well water heat pump unit and 3.03 for the overall system.

Heat Storage Tank Performance

Figure 3 shows how the high and low storage tank temperatures fluctuated in the period January 12 to 18, 1990.

On January 14 and 15 the heat storage tank was not used. The temperature only dropped by about 0.5°C, indicating a high heat insulating performance.

The night-time heat storage rate (i.e., rate of heat stored at night to total stored heat) was very high, exceeding 0.9 in every month. The all-seasonal night-time heat storage rate was 0.97, proving that almost all heating and hot water supply loads were covered by night-time storage operation alone. Meanwhile, the effective heat utilization rate (i.e., rate of heat utilized on the secondary side to total heat stored) exceeded 0.7 in every month, with a very high rate in January (0.95). The all-seasonal effective utilization rate was 0.83, thus indicating that the heat storage tank functioned very effectively.

Conclusion

By introducing the heat storage system, a highly efficient system utilizing low-tariff late-night electricity has been realized. Since it is difficult to utilize underground water as a heat source in urban areas in Japan, it is expected that other sources of unused energy, such as treated sewage water will be used in future projects.

**Author:*
Y. Fujiwara, Hokkaido Nikken Sekkei, Japan.

SWEAT - a Chemical Heat Pump for Heat or Cold Storage

*H.A. de Beijer, J.W. Klein Horsman

Introduction

The SWEAT (Salt and Water Energy Accumulation or Transformation) system is a solid-gas absorption system for storing heat or cold. Its applications include the storage of low temperature heat from solar systems, district heating systems, industrial systems and car engines.

This system allows for heat or cold to be produced at a later stage by using the chemical (absorption) heat pump function.

The basic problems with earlier comparable systems were:

- *poor stability and side reactions of the working materials;*
- *low power output;*
- *low efficiency.*

Recent research in the Netherlands has considerably improved the chemical heat pump storage systems, and has resulted in a 'tube-like' heat pump module being built.

Working Principle

The system is based on a discontinuously working absorption heat pump which incorporates a storage function, the operating principle of which is as follows (see Figure 1):

Two chambers, I (the accumulator) and II (the condenser/evaporator) communicate with each other. Chamber I contains a vapour absorbing salt (Na_2S) while chamber II contains a fluid (H_2O). The system is evacuated so that the only remaining gas is water vapour.

The discharge process works by absorbing heat in chamber II as the latent heat of evaporation. At the same time, heat is released in chamber I as fluid vapour is absorbed by the salt. The water vapour is taken up as water of crystallization in the dry crystal structure of the salt. Part of the absorption heat is called the salt latent heat of condensation. The rest is released in the form of chemical bonding energy, as follows:

$$nH_2O + Na_2S \Leftrightarrow Na_2S.nH_2O + \text{heat}.$$

The result is that chamber II is cooled as the fluid evaporates whilst chamber I is heated as the fluid vapour is absorbed by the salt.

The temperature difference between the warm and cold chamber in pressure equilibrium, i.e., when no heat is taken from or supplied to the warm chamber, is 55°C.

In order to recharge the system, heat must be supplied to chamber I at a higher temperature than the equilibrium temperature.

If the connection between the chambers is closed, the chemical energy can be stored for an indefinite period without losses. The salt used in the SWEAT system, Na_2S, is very stable, and can undergo many hydration and dehydration cycles.

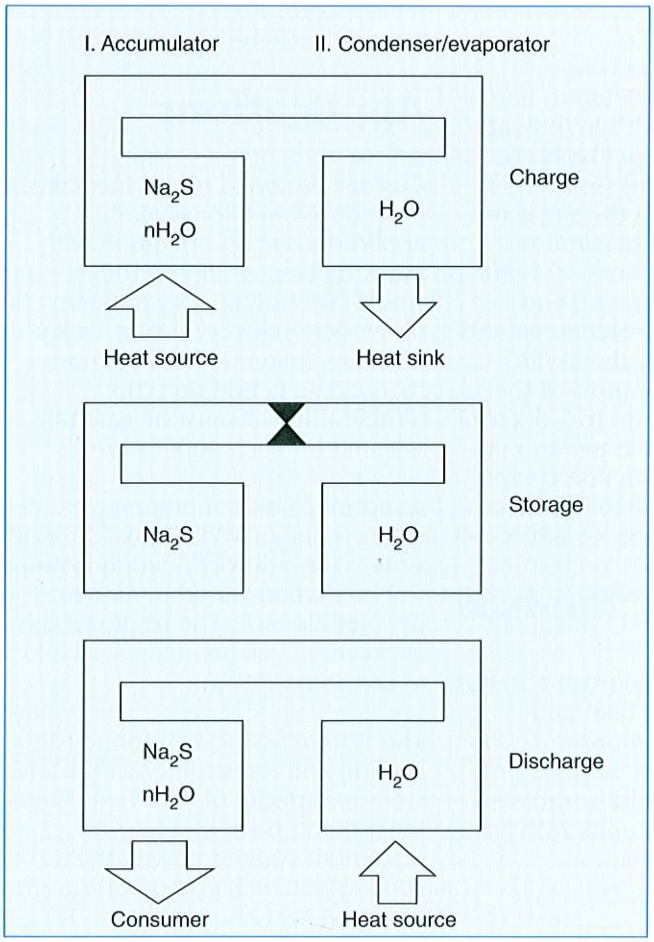


Figure 1: Operating Principle.

Heat and Mass Transfer

The rate of transfer of heat and mass has considerable influence on the reaction kinetics of solid-gas absorption processes. The rate at which water vapour flows into the solid crystal determines the reaction speed, and depends on the porosity of the crystals. This can be controlled by the crystallization method.

In conventional solid-gas absorption systems, thermal conductivity is generally low. A large amount of absorption (bonding) energy has to be transferred right through the crystal to a heat exchanger. In the SWEAT system, the heat exchanger is integrated into the salt during crystallization, improving the overall thermal conductivity. This method achieves high power densities and short cycling times.

Storage Capacity and Power

At 0-2°C, the SWEAT system has a storage capacity of 1.1 kWh heat and 0.75 kWh cold per kg Na_2S. Conventional systems (using heat exchangers in which the salt is not integrated) achieve maximum power densities of about 40 Watt per kg salt. By integrating and optimizing the heat exchanger and the crystal structure, the SWEAT system has greatly improved the power density with up to 1.5 kW of heat and 1 kW of cold per kg salt. By using different reaction chemicals it is also possible to produce cold at -30°C and heat to 350°C.

The SWEAT Module

The tube-like module (Figure 2) has a capacity of 5 kWh heat and 3 kWh cold, and comprises a complete heat pump. These mass produced modules can be combined in custom designed units with a wide variety of capacities.

The SWEAT system costs approximately NLG 100/kW compared to conventional cooling systems which cost NLG 250/kW.

Advantages of SWEAT

The SWEAT system can save energy costs by utilizing waste heat or by storing energy from low-tariff off-peak electricity. Its advantages include:

- lossless store of both heat and cold;
- production of cold from heat;
- raising the temperature from 20°C to 75°C in one stage (Na_2S);
- low investment costs;
- high energy density: 1.1 kWh/kg dry salt (heat);
- high power density: up to 1.5 kW of heat or 1 kW of cold per kg dry salt;
- no noise;
- no CFCs;
- no power consumption;
- easy to control;
- modular design.

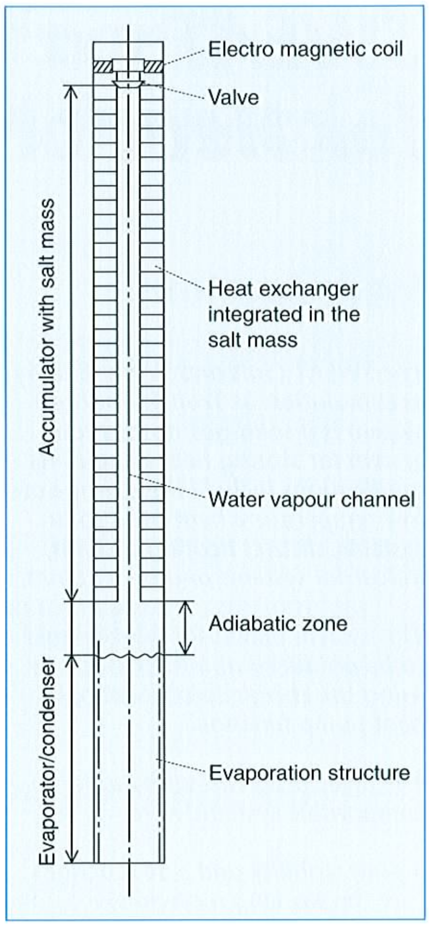


Figure 2: The SWEAT Module.

Applications

Custom-designed prototypes have been developed for several applications in co-operation with industry. Depending on the specifications (capacity, power, dimensions) the cycle time varies from less than one hour to more than a day. In addition, the temperature lift must be carefully selected for each application.

A prototype air-conditioning system using a SWEAT heat storage system for a district heating system will be demonstrated in Almere, the Netherlands. The results of this experiment will be made available at the end of 1992.

The system features continuous cooling and recharging with a storage capacity of 8 kWh and a maximum power of 4 kW. At maximum cooling power, the cooling and recharging parts are switched every hour.

Further demonstration projects for the SWEAT system include:

- the storage of low temperature heat with a capacity of 1 MWh, and production of cold for industrial applications in the Netherlands;
- the use of engine waste heat from cars for interior cooling and heating, or for engine heating, has been investigated in co-operation with a German company.

**Authors:*
H.A. de Beijer, J.W. Klein Horsman,
De Beijer RTB B.V., Arnhem,
the Netherlands.

District Heating/Cooling System Uses Thermal Store and Recycled Heat

*H. Yoshida

Introduction

The New Makuhari Urban Centre is an area selected by the administration of Chiba Prefecture to grow into a new international city with advanced research, business, education, culture, administrative services, etc. In creating such a city, the energy supply system for the city is considered paramount. With the purpose of energy saving, improved energy efficiency, and safe and pollution-free operation, a recycling district heating/cooling (DHC) will be adopted, featuring:

- *hot and cold water storage;*
- *heat recovery;*
- *heat pumps utilizing treated sewage.*

The cooling load in the area is expected to be significant, requiring highly efficient refrigerating machines and a heat recovery heat pump system for recovering the cooling load in winter. A recycling-type DHC system is ideal for this situation. By using a thermal storage tank, the electric peak load can be reduced in summer by exploiting low-tariff off-peak rates at night. The system thus also contributes to the reduction of power supply costs.

According to the current plan, the buildings in the business/R&D facility area will include 900,000 m² of heated floor area. The heat load of the planned commercial area is about 30 to 40% of that supplied to the business/R&D area. The DHC supply plant will be installed close to the commercial centre, in a high-rise building complex.

The System

The system features heat pumps utilizing waste heat from treated sewage. These heat pumps produce hot water (47°C) and chilled water (7°C) which is supplied through distribution pipes to consumers within the service area all year round. In Table 1 a technical specification of the proposed heating/cooling equipment is given.

The heat generating equipment includes three types of heat pumps, and water-to-water heat exchangers. Heat sources for the heat pumps include treated sewage water and ambient air. Figure 1 shows the equipment set-up for summer operation.

Thermal Storage

The thermal storage system is the most important component of the plant. The functions of the storage system include:

- providing chilled water;
- selective chilled/hot water operation.

The thermal storage system consists of two chilled/hot water tanks (1,995 m³ each), a chilled water tank (250 m³) and a hot water tank (220 m³). The chilled/hot water tank is used selectively according to the season, in some cases it can be used separately to provide chilled or hot water, or as a heat source water tank and a hot water tank. In Figure 1, the chilled/hot water tanks are combined with the chilled water tank.

Although the chilled water storage system is inferior in heat storage density to an ice storage system, it offers a high system efficiency and cuts down on running costs by using low-tariff electricity at night.

At night, two heat pumps of 1,250 RT each, may be connected in series to produce chilled water of below 1°C. This improves the heat storage capacity by 35%.
During daytime operation, these heat pumps are operated in parallel for standard (5°C) operation.

Utilization of Treated Sewage

Treated sewage is thermally very stable and its flow rate is almost constant all year round. It may safely be utilized as a heat source for heat pumps and can deliver a higher energy efficiency than air-source heat pumps. The expected treated sewage temperature is

Table 1: Heating and cooling equipment for the DHC system.

Equipment	No. of units	Capacity Cooling (RT)	Capacity Heating (MW)
Heat recovery heat pump	2 1	750 1500	3.2 5.8
Sewage-source heat pump	2 4	1250 3000	5.0 11.1
Refrigerating machine	1	3000	-
Total		20500	66.4

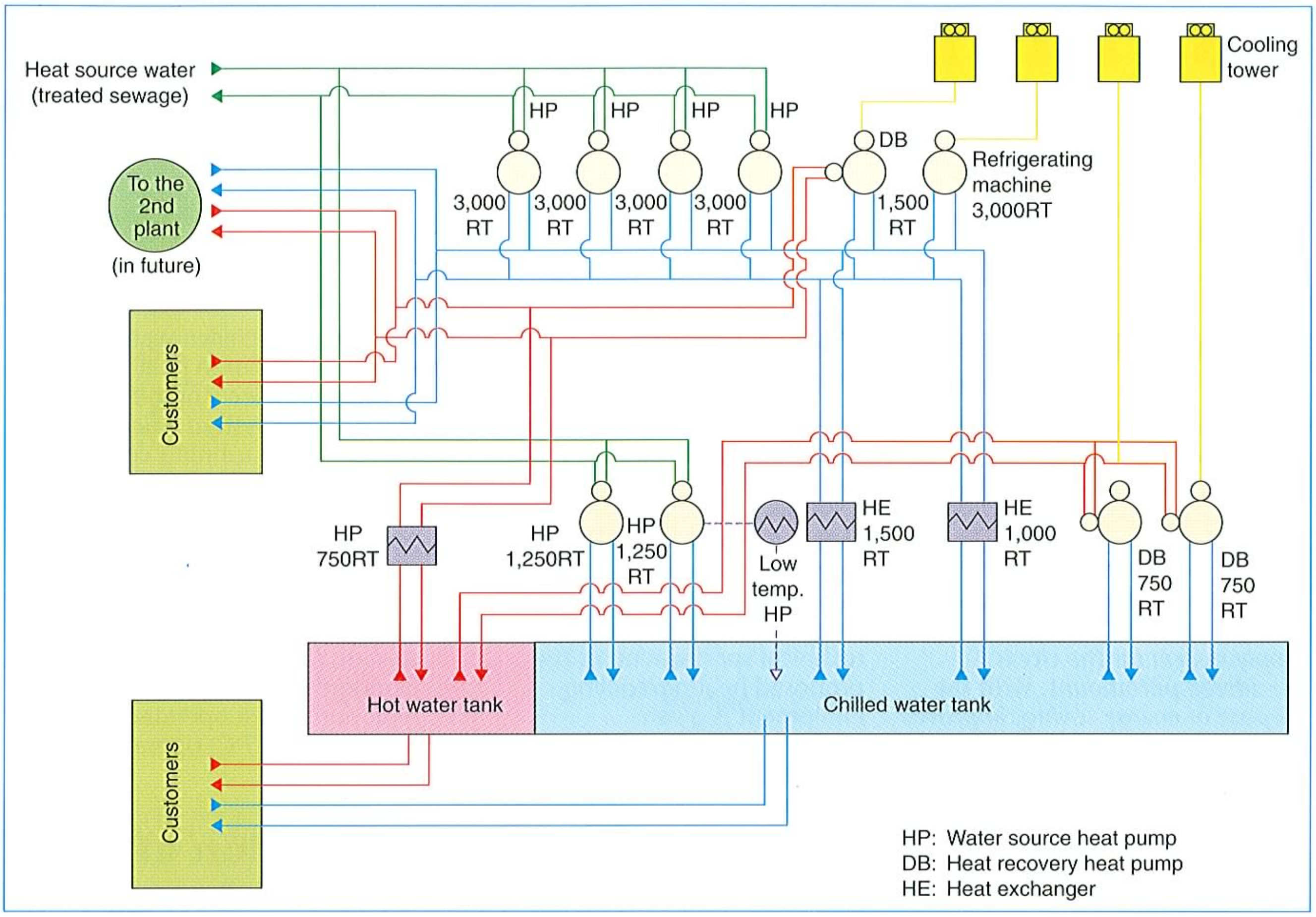


Figure 1: The DHC System in Summer Mode.

about 25°C when used as cooling water in summer, and about 15°C when used as a heat source water in winter. Compared to air-source heat pumps, the evaporation temperature is about 15°C higher in winter and no defrosting system is needed. In the summer, treated sewage can be used as a heat sink, providing a 7°C lower sink temperature than a cooling tower. These advantages significantly improve the efficiency of heat pumps. In order to improve the overall system efficiency, emphasis has been placed on the selection of advanced heat generating equipment, reduction of electricity demand, and overall system simplification. As a consequence, power savings of 15% during the summer and 40% during the winter are possible, compared to air-source heat pumps.

Corrosion-proof tube materials were investigated with the result that de-acidified copper was selected. This material is physically advantageous and most suitable in terms of cost and function. Additionally, since staining of the tube surface is very likely to cause galvanic corrosion, an automatic strainer and tube washing unit is incorporated. Although almost no solid substances are present in the secondary treated water circuit, an automatic strainer is installed. The strainer brushes the surface automatically and solid substances caught by it are intermittently returned by a drain pump. The automatic tube washing unit incorporates a flow reversible brush washing system. In addition, corrosion resistant nylon-coated steel pipes and valves are applied in the secondary circuit.

Conclusion

It is hoped that this project will lead to an increased use of heat pumps to recover the waste heat that is readily available in cities. By accommodating the seasonal variations in heating and cooling demand, the thermal storage system adopted for this scheme makes efficient use of low-tariff electricity, making this scheme highly attractive as a model on which future recycling DHC systems can be based. The widespread use of DHC systems with heat recovery will greatly contribute not only to ensuring a stable supply of cheap heat and creating a clean, comfortable urban environment, but also to a decrease in thermal pollution and energy consumption.

**Author:*
H. Yoshida, Tokyo Electric Power Company, Japan.

An Interview with Dr. Moriyoshi Sakamoto of Toshiba

Fuzzy Logic-Controlled A/Cs and Heat Pumps

*G. Meijer

In the autumn of 1990, all Japanese manufacturers suddenly brought fuzzy logic controlled air-conditioners and heat pumps onto the market. Claimed features were smoother operation, increased comfort, and energy savings. Dr. Moriyoshi Sakamoto, General Manager of the Air-Conditioners and Appliances Engineering Laboratory of Toshiba Corporation, and Member of the Advisory Board of the IEA HPC, explains what fuzzy logic control is all about.

Fuzzy logic implies vagueness. What is the principle behind it?

"Fuzzy logic is based on a mathematical theory, established in 1965 by L.A. Zadeh of the University of Berkeley, California, USA. I will summarize the principle in simple terms, so do not consider this as scientifically correct in all aspects.

Let me begin as follows. In daily life we normally say that it is cool in a room, instead of saying that the temperature in the room is 19°C. Moreover, at 19°C, some people would feel cool, whereas others would say that it was warm. Therefore, other than working with exact numerical data as a conventional control scheme does, people describe their knowledge about situations in linguistic terms such as *cool*, *warm*, words which are ambivalent or *fuzzy*.

Fuzzy logic control is a digital control method working with this ambivalent linguistic information. So-called ***membership functions*** are used to interpret measured data and translate them into linguistic variables such as *cool* or *warm*. It also takes into account that a specific temperature is valued by some people as *cool* and by others as *warm*. Therefore, a measured temperature can, to a certain degree, say 30%, fall in the category *cool* and for 70% in the category (or temperature set) *warm*.

Figure 1 depicts the shape of a ***membership function***. Between 15 and 18°C, 100% of the people would feel *cool*. Therefore, temperatures in this range are categorized 100% as *cool*. However a temperature of 20°C would belong, for 20%, to the category *cool* and 80% to the category *warm*. The temperature set, or ***membership function***, is called ***fuzzy*** because the boundary between *cool* and *warm* is not defined, but varies between 18 and 21°C. A conventional control system working with the criterion of 18°C as being the boundary between cool and warm would identify a temperature of 17.8°C as *cool* and a temperature of 18.2°C as *warm*. Most people would not notice this slight difference. One can therefore say that *fuzzy logic* is a digital control method which simulates human thinking and incorporates human knowledge of physical systems. For the design of a conventional controller one needs to develop a mathematical model

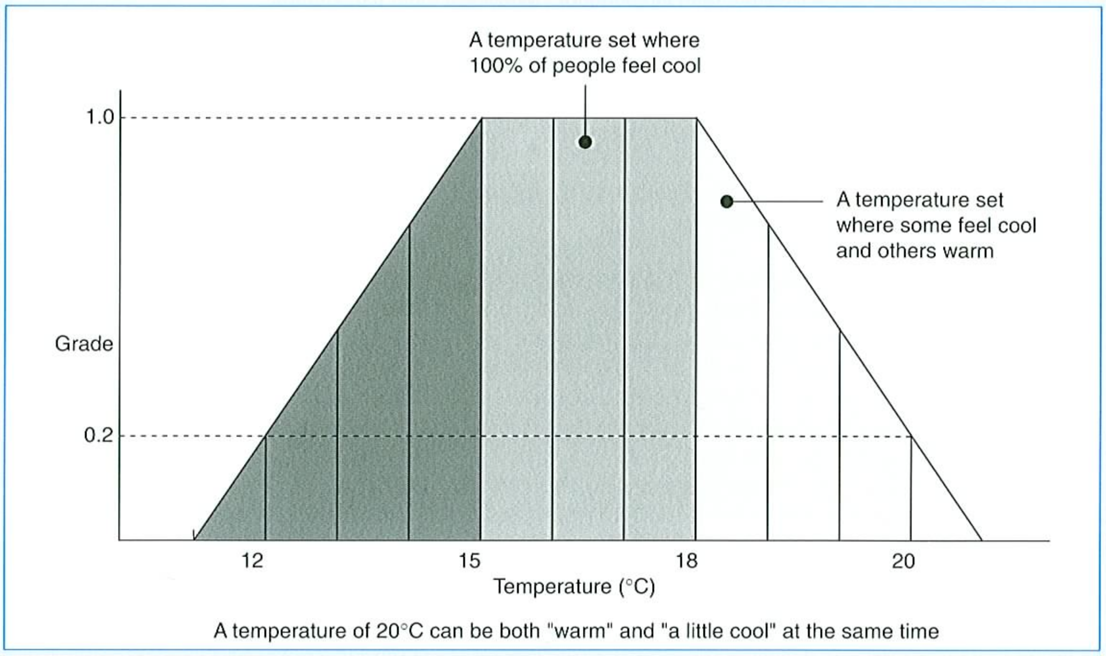


Figure 1: Membership Function.

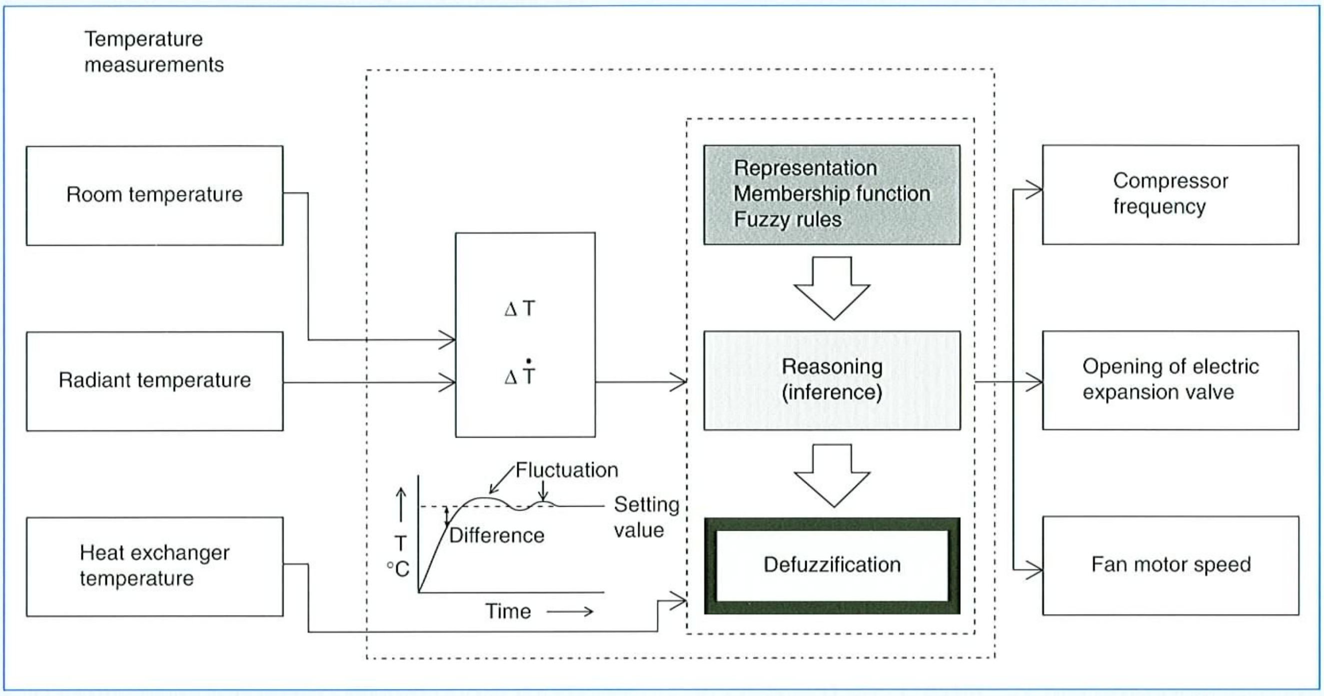


Figure 2: Control Block Diagram of an Air-Conditioner.

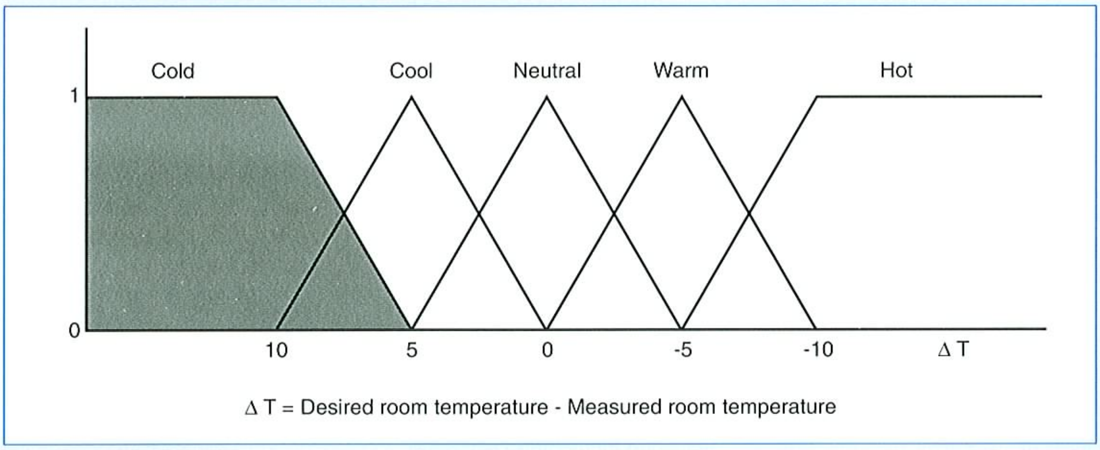


Figure 3: Membership Function for ΔT.

of the process, whereas for the design of a fuzzy logic controller, an expert knowledge base is required."

How is this principle applied to devices such as air-conditioners and heat pumps?

"Figure 2 shows a block diagram of the control scheme of an air-conditioner/heat pump. In addition to the room temperature, the radiant temperature, that is the temperature of the walls of the room, is also measured. If the measured room temperatures are lower than the desired temperature - i.e., when it is *cold* or *cool* - then I will denote the ΔTs as being *positive*. The heat exchanger temperature is also measured but for explanatory purposes one has to limit oneself to the room and the radiant temperatures.

The fuzzy logic controller incorporates three steps:
- representation;
- reasoning, and
- defuzzification.

We shall go through each of the steps.

Representation:
This step handles the representation of measured data into linguistic variables such as *cold, cool, moderate, warm*, and *hot*. Membership functions can have different shapes, for instance, trapezoidal as shown in Figure 1, but also triangular or parabolic. The ***membership functions*** for the difference between the desired temperature and the actual room temperature are shown in Figure 3.

Reasoning:
In this step, also called ***inference***, the direction is determined into which the process must be controlled. This is done by a number of ***IF-THEN*** rules

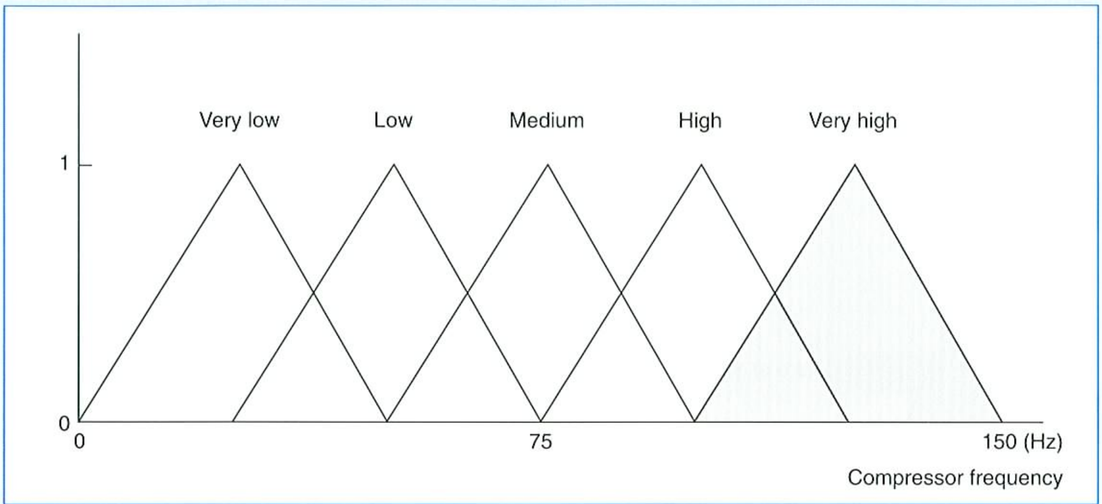


Figure 4: Membership Function for Compressor Frequency.

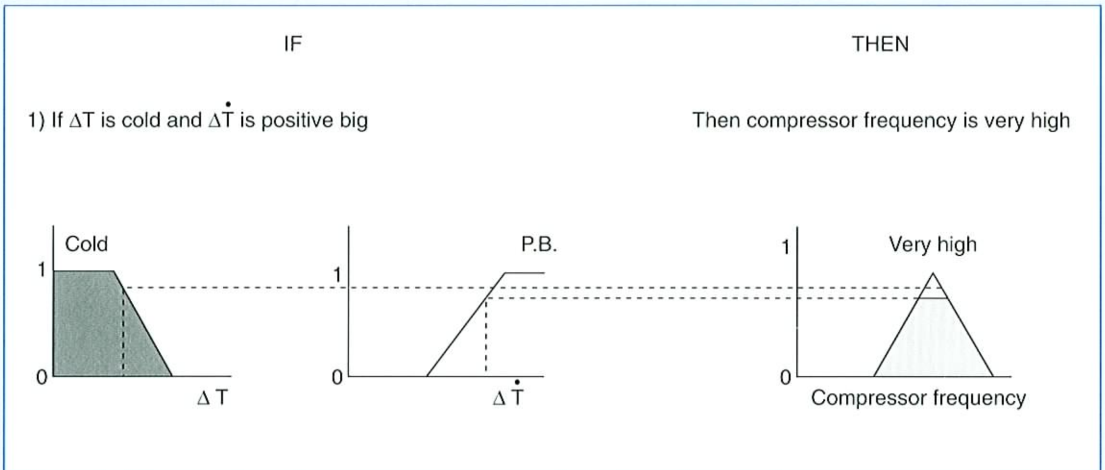


Figure 5: Fuzzy Rule.

Representation

$\Delta\dot{T}$ \ ΔT	Cold	Cool	Neutral	Warm	Hot
NB *					V.L.
NS				L	
ZO			M		
PS		H			
PB	V.H. **				

* N = Negative
P = Positive
S = Small
B = Big
ZO = Zero

** V.H. = Very high
H = High
M = Medium
L = Low
V.L. = Very low

Defuzzification

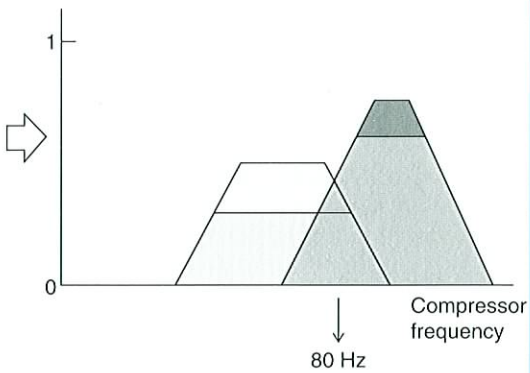


Figure 6: Process of Representation/Inference/Defuzzification.

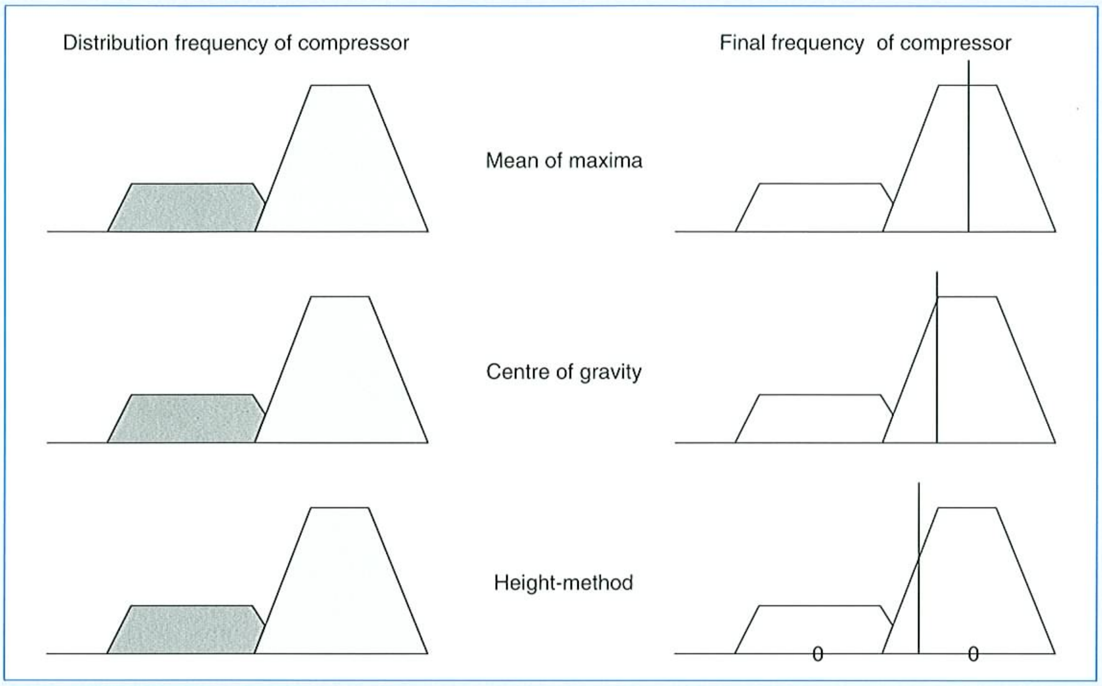


Figure 7: Defuzzification of Rule Outputs.

which are programmed in the controller. For instance, ***IF***, at the beginning of a heating service, the room is very cold, ***THEN*** the compressor should operate at its highest frequency and the air flow should be maximized in order to rapidly heat up the room with warm air. Figure 4 shows the ***membership functions*** of the compressor frequency (or compressor speed) and Figure 5 exemplifies how fuzzy rules are applied. The upper interrupted line indicates a relation between a room temperature being represented as *cold* and the desired compressor frequency.

It will not be clear yet what one can do with the right-hand figure of Figure 5, but it is important to note that since it is not 100% *cold*, the indicated line does not run to the top of the *very high* frequency ***membership function.***

The middle figure of Figure 5 indicates a ***membership function*** of the time variation of the difference between the measured temperature and the desired one, $\Delta\dot{T}$. Let us suppose that the measured temperature is lower than the desired temperature. When the temperature difference increases $\Delta\dot{T}$ is *positive*, while when it decreases $\Delta\dot{T}$ is *negative*. And when the temperature changes very quickly, the size of $\Delta\dot{T}$ is called *big*, while when it changes slowly it is called *small*. Hence, when the temperature difference is quickly increasing, $\Delta\dot{T}$ is called *positive big*. Here the ***IF-THEN*** rule is also that if the temperature difference variation is "positive big" then the compressor should run at a high frequency. The lower interrupted line shows the inference. As in the case of the room temperature difference, it also cuts off a part of the top of the triangle. Now, it is customary to use the smaller trapezoid in the next step, (i.e., the lighter grey area).

Figure 6 shows the *so-called* ***look-up*** table in which the ***IF-THEN*** rules are stored. The dark grey block indicates that if the variation temperature difference is *positive big* and the room is *cold* then the compressor frequency should be *very high*. Note that, in the above example, two variables (*cold* and *positive big*) are combined in one ***IF-THEN*** rule. A real *look-up* table contains hundreds of ***IF-THEN*** rules. The other grey blocks indicate that the situation in the room is represented as both *cold* and *cool*. Also, the temperature difference variation is, to a certain degree, *positive big* and partly *positive small*. The resulting compressor frequency distribution figure after applying the fuzzy rules is shown on the right-hand side. Now, this figure has to be ***defuzzified.*** As indicated in Figure 6 the ***defuzzification*** leads to a compressor speed of 80 Hz (4,800 rpm).

Defuzzification:
Figure 7 shows how ***defuzzification*** is done. One of three methods is usually applied. One can take the mean of the maximum frequencies of the frequency distribution figure (top), determine the centre of gravity (middle) or determine the average height (bottom). I will limit myself to showing the principle; it would be too much detail to discuss which method should be used when."

According to the claims of the Japanese A/C manufacturers the fuzzy logic control leads to a better performance of the device. Can you illustrate this; and can you explain, in general, what the strength of fuzzy logic control is?

"When starting the heating system, a fuzzy logic-controlled heat pump reaches the desired temperature considerably faster than a Proportional, Integral and

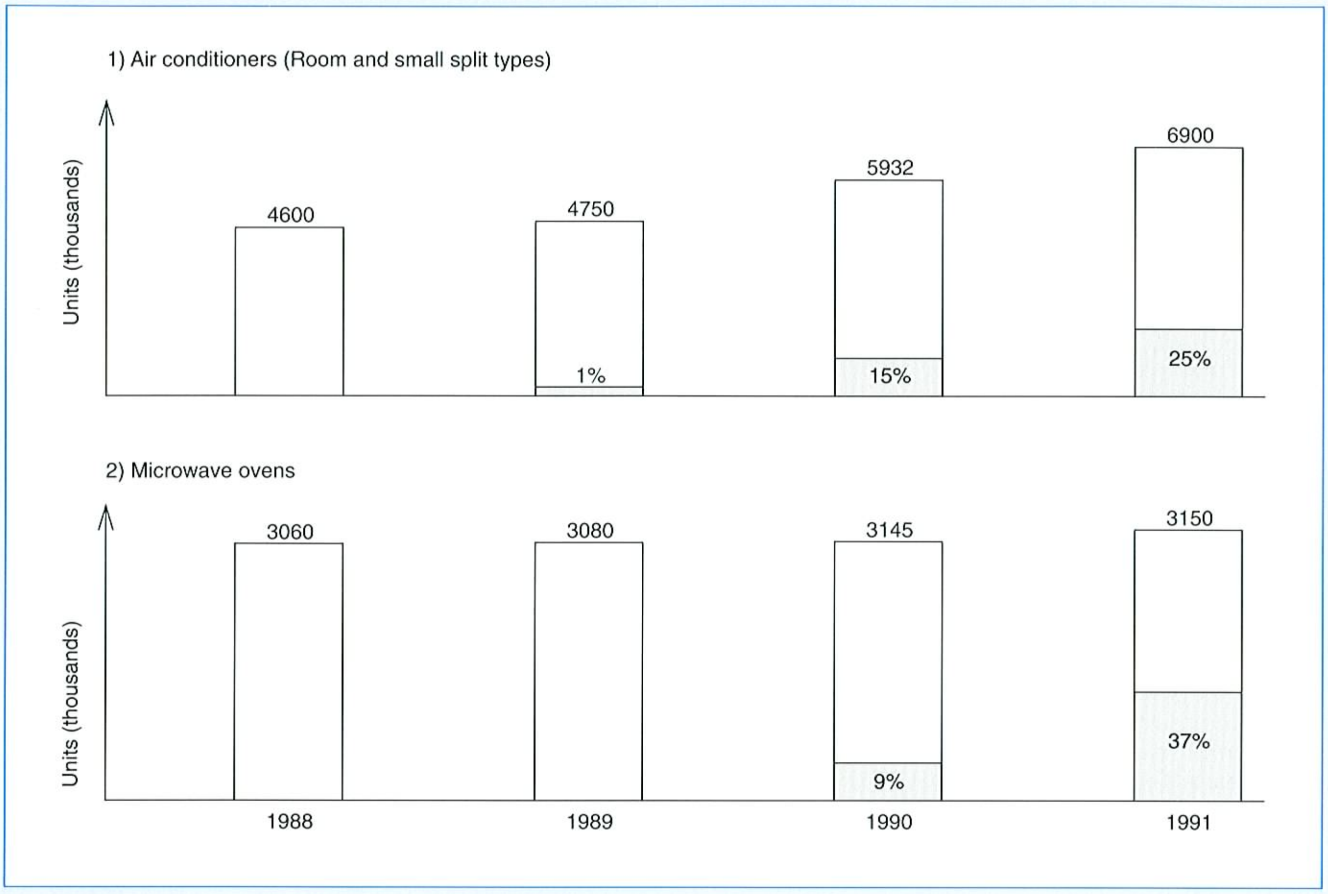


Figure 8: Growth of Fuzzy Controlled Products.

Derivative (PID) controlled one. Over and undershoots in room temperature, which with classical controllers, are usually in the order of 3°C (peak to valley height) can be almost completely avoided.

It has been demonstrated that a fuzzy logic-controlled compressor operates very smoothly, while a PID-controlled one runs with frequent "on-off" cycles. The smooth operation of the compressor accounts for the stable temperature control. Data indicates that the energy saving due to minimizing "on-off" operation of the compressor amounts to about 20%.

Fuzzy logic is very well suited to A/C systems due to the following reason. As already mentioned, a classical PID controller requires a mathematical model of the process. An A/C and heat pump system, including the space to be heated, is physically difficult to describe. Therefore, development of a good physical model is expensive and the manufacturer has to put a great deal of effort into fine-tuning, due to the inaccuracy of the models. The fuzzy logic controller uses rules from experience (so-called *heuristic* rules) which, of course, have to be developed as well, but fuzzy logic allows the knowledge to be expressed imprecisely. The PID controller requires an accurate measurement of the process, whereas for a fuzzy logic system the accuracy requirements are more relaxed, allowing the use of inexpensive sensors.

In general, fuzzy logic is most suited in cases dealing with non-linear, time-variant or ill-defined systems; systems that cannot be easily represented by a simple mathematical model; or if a control system should meet different purposes.
Its strength can be summarized as follows:

- fuzzy logic has the ability to translate imprecise/ vague knowledge of human experts;
- the technology is easy to implement and transfer from product to product;
- requirements about accuracy are relaxed;
- the behaviour of the controller is smooth and robust;
- the rule-based systems can be analyzed and fine-tuned;
- fuzzy logic has the ability to control unstable systems;
- it can use inexpensive sensors;
- it improves performance."

Does fuzzy logic control increase the cost of the devices?

"The answer is clearly: No!

The reason for this is that the data, including fuzzy rules, are usually tabled and installed in the ROM of a micro-computer which is also being used for conventional systems. In most cases, current micro-computers have sufficient space or capacity to process fuzzy logic control at no or little additional costs. If not, then fuzzy control can be applied by increasing the capacity from 4 to 8 KB. This entails only USD 3 to 7, when one uses a micro-computer for home appliances."

What is the key factor enabling Japanese manufacturers to bring applications on the market?

"After the first symposium held in 1972 by Japanese researchers, and the start of research in the late 1970s, the success of fuzzy logic was widely recognized in 1987 when it was used to control the braking of an underground railway train in a manner assuring minimum discomfort to train passengers. This was a typical example of a situation in which the control system had to meet two different criteria:

- bringing the train to a stand-still at a given location;
- minimizing discomfort to the passengers.

In 1989, Mitsubishi Heavy Industries was the first to apply fuzzy logic in air-conditioning systems, and in 1990 it was widely used in home appliances in Japan. However, one cannot say that, from the outset, scientists in Japan had a clear and strong perception about the practical possibilities of fuzzy logic; for instance, I myself had my doubts. But it was something new. Therefore, R&D continued."

So, a year after Mitsubishi introduced fuzzy logic in A/Cs, all other Japanese manufacturers could apply the system in their products. The technology must have been common knowledge, then?

"In Japan, manufacturers compete very strongly in the market place. Generally speaking, we do compete less in the field of scientific development. It appears to be more efficient to exchange and share science with others. In many cases, researchers from many different manufacturers tend to co-operate when working on an infant technology such as fuzzy logic, in order to exchange information on a specific subject."

How are sales of fuzzy logic controlled products going?

"Fuzzy logic-controlled product sales are booming. Figure 8 shows the growth in room air-conditioners (window and small split-types) and in microwave ovens. Microwave ovens use 600-800 W and it is important to increase their energy efficiency. My personal opinion is that it is booming because 90% of all various kinds of appliances are digitally-controlled by micro-computers which have sufficient memory to implement fuzzy logic control and, moreover, no, or only minor hardware modifications are required to replace a PID controller. Furthermore, manufacturers who can meet customer demand for new features have an edge over competitors."

Finally, what is your opinion on fuzzy logic's future?

"Fuzzy logic has proved to improve the performance of a range of products, e.g., rice cookers, A/Cs, camera and tape recorders, washing machines, etc.. Although customers may not yet be fully aware of the advantages, fuzzy logic-controlled products are beginning to attract their attention. This in turn will encourage manufacturers to develop and market new applications. In parallel, standards are being reviewed regarding the quality of fuzzy-controlled appliances. The development of a compact fuzzy chip will certainly accelerate the diffusion of this technology into the motor car and machine tool industries."

**Interviewer:*
Gerard Meijer, IEA Heat Pump Centre, the Netherlands.

Industrial Process Waste Heat Recovery

*F.J. Pucciano

Introduction

Heat is added to or removed from most industrial processes, and is added to or removed from rooms or spaces for HVAC and refrigeration purposes. World events and environmental concerns dictate that we halt current waste through all forms of conservation . For heating and cooling, that means heat recovery.

This heat recovery can be accomplished with industrial or recovery heat pumps, but in some cases straight heat exchange is all that is necessary. The thought process of heat exchange first, heat pump second, should always be applied before picking a final design.

Removal of heat from many process effluent streams will sufficiently reduce the temperature of the effluent to protect the environment and improve the effectiveness of the bacteria used to break down the solids in the effluent. Removal of heat from stack gases can result in reduced emissions of harmful chemicals.

Heat recovery will in many cases provide attractive economic solutions to both environmental and productive problems.

Dryers and Ovens

Dryers and ovens are frequently used on industrial processes for curing, cooling and water removal. Current design usually calls for a forced-air natural gas heater to supply large volumes of heated air. The amount of heat that is actually absorbed in the product is usually between 5 and 10%, resulting in a 90 to 95% energy loss through the stack. Standard heat exchangers and condensing heat exchangers can be used to preheat the dryer make-up air and/or combustion air, thereby delivering back to the process - typically 25 to 35% of the energy.

Figure 1 shows how a recovery chiller or heat pump can be used to recover additional amounts of this heat by boosting the make-up temperatures. A typical system like this can recover another 10 to 20% of the exhausted heat. However, this system would need to supply heat to loads outside the dryer to recover all or most of the heat lost from the stack. The external loads could include space heating or clean-up water heating.

Perhaps the real benefit of these systems is not the energy savings, but rather the "cleaning" of the dryer

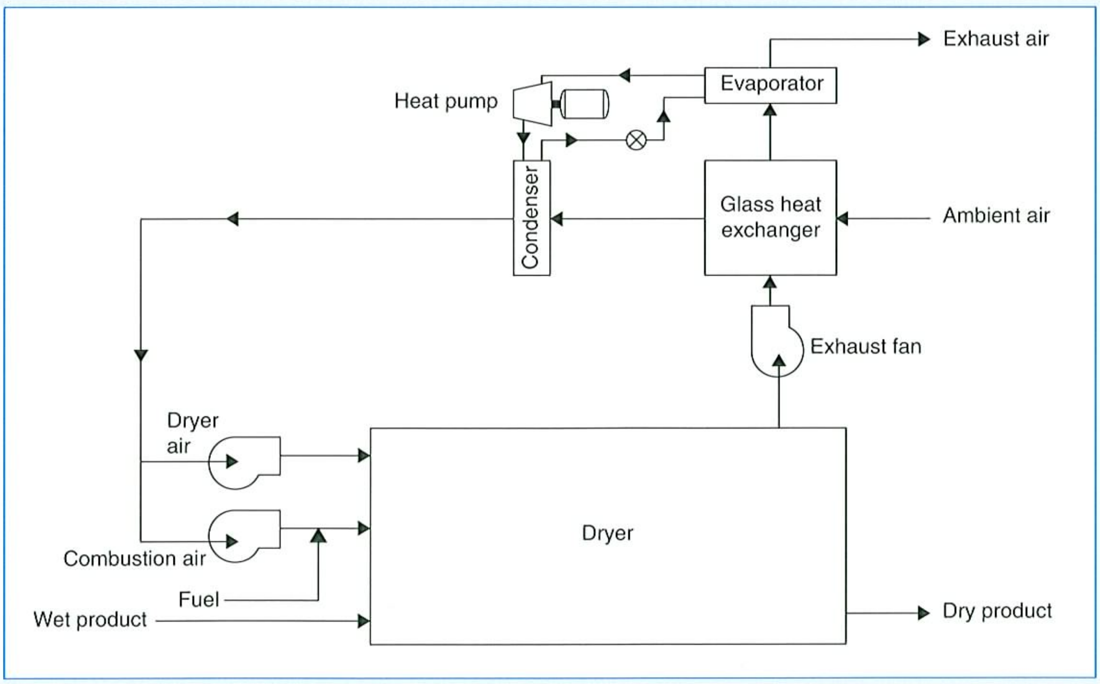


Figure 1: Food Processing Plants - Dryer Heat Recovery.

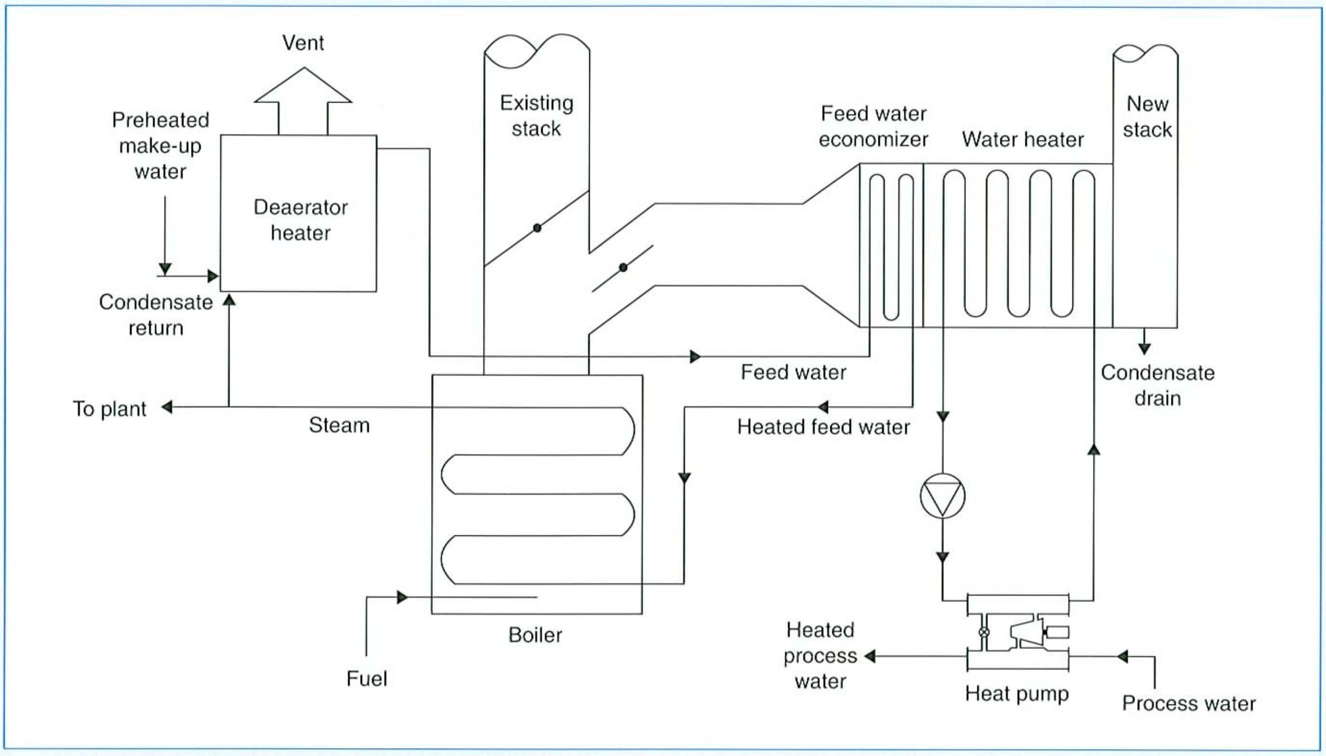


Figure 2: Industrial Boiler - Economizer and Heat Pump Water Heater.

exhaust. Oils, fibres and chemicals which are exhausted in the stack can frequently be entrapped in the recovery system. They can then be recycled or disposed of in an effective manor.

Boilers

Boilers offer a tremendous heat recovery potential since about 20% of the heat energy burned is exhausted. Combination economizer and condensing heat exchangers can be used to recycle this heat and reduce the net losses down between 5 and 10%. Figure 2 shows how the combination system can be modified when higher temperatures are needed and the need to preheat make-up water is small. This system uses only one condensing heat exchanger, with the water heated supplying a heat source for a recovery heat pump. This design is most suitable when the boiler has a large volume of condensate

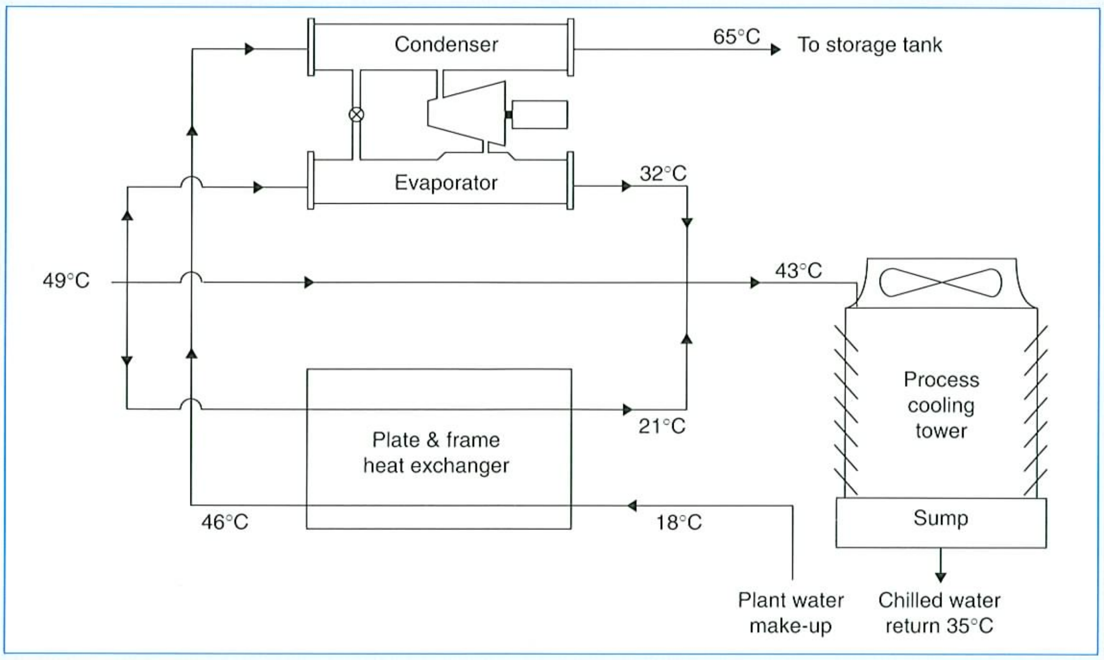


Figure 3: Cooling Tower - Recovery Heat Pump System.

return - and thus a small amount of make-up water, and when a hot water heater is located near the boiler.

Reduced pollution benefits derived from this type of system are growing as awareness and penalties for air pollution grow. CO_2 pollution is reduced in two ways with this system - the improved efficiency of the boiler itself, and the displaced steam requirement now supplied by the heat pump.

Process Cooling Towers

Process cooling towers work just like HVAC towers, only, the temperature requirements are usually somewhat higher. A plate-and-frame heat exchanger can usually be installed to recover some of the heat exhausted at the tower. In many cases the tower water can only be used to preheat process water to about 38°C to 49°C. Figure 3 shows how a recovery heat pump is used to boost the output temperature for those cases where higher temperatures are desired.

Whether a heat exchanger or both a heat exchanger and a heat pump is used, a very big side benefit is the resulting tower load reduction. This results in less water evaporated at the tower - and less sewer charges, since most administrations assume what goes in comes out. It also means less chemical consumption to treat algae and calcium build up.

Dealing with Effluent

Process effluent is a necessary evil to many processes, and is cause for concern for many plants. High effluent temperatures can cause problems with water treatment facilities and can result in fines or even plant shut-downs. Effluent conditions dictate how heat is recovered because the waste water can be fairly clean or contain many solids, it can have a balanced ph or be very corrosive.

In food processing plants waste water flows through several levels of solid removal, including a screening process to remove bones, gristle or vegetation and a decanting process to remove fats and oils. The water after these two processes is fairly clean, but still has substantial heat. Figure 4 shows a system using a plate-and-frame heat exchanger and a heat pump to further cool this waste water. Waste water treatment can be substantially improved as these systems can be designed to provide a constant temperature effluent.

Some waste waters like textile effluent offer specialized requirements. In this case lint, thread, nuts and bolts and just about anything else you can imagine find their way into the effluent. Plus, the effluent contains caustics and other harmful chemicals. A specially designed continuous-tube heat exchanger is used to prevent fouling, and the entire system is made of stainless steel to prevent corrosion. These heat exchangers are used to preheat two different water requirements - warm and hot water.

Effluent temperatures even after the heat exchanger system are quite high - about 49°C - because the amount of hot water required is only about half the waste water flow. Figure 5 shows how careful arrangement of two recovery heat pumps can be used to heat smaller volume of water to a higher temperature. The system can be designed for the desired final effluent temperature, or the desired make-up temperature.

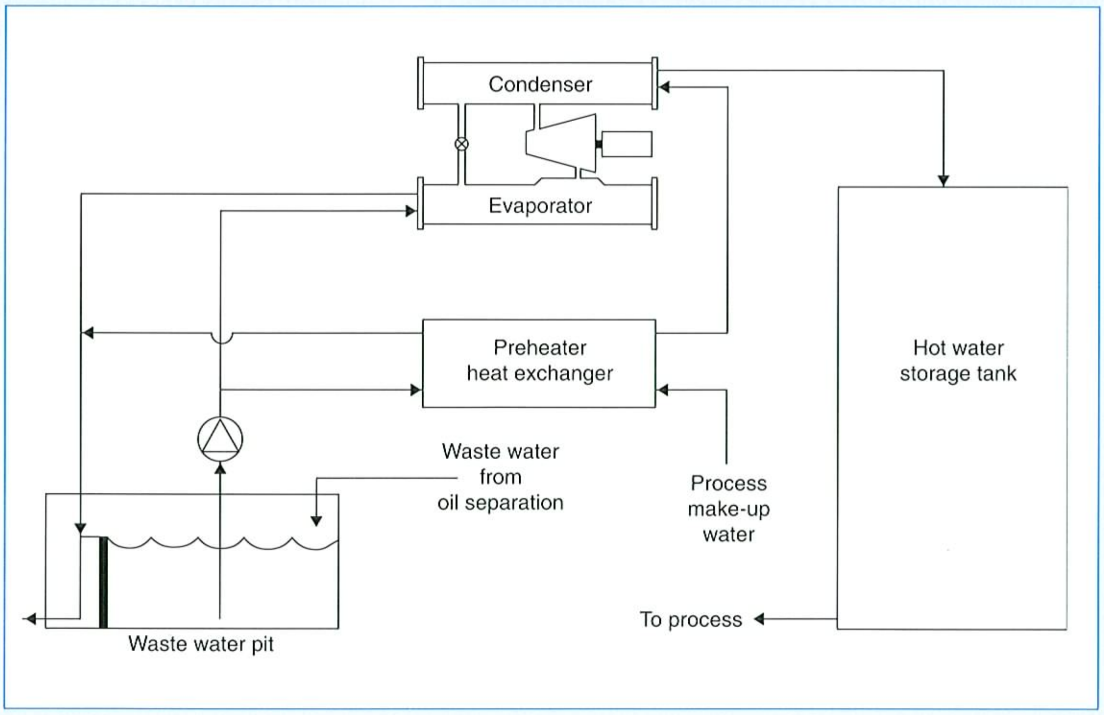


Figure 4: A Typical Food Processing Plant - Waste Water Heat Recovery System.

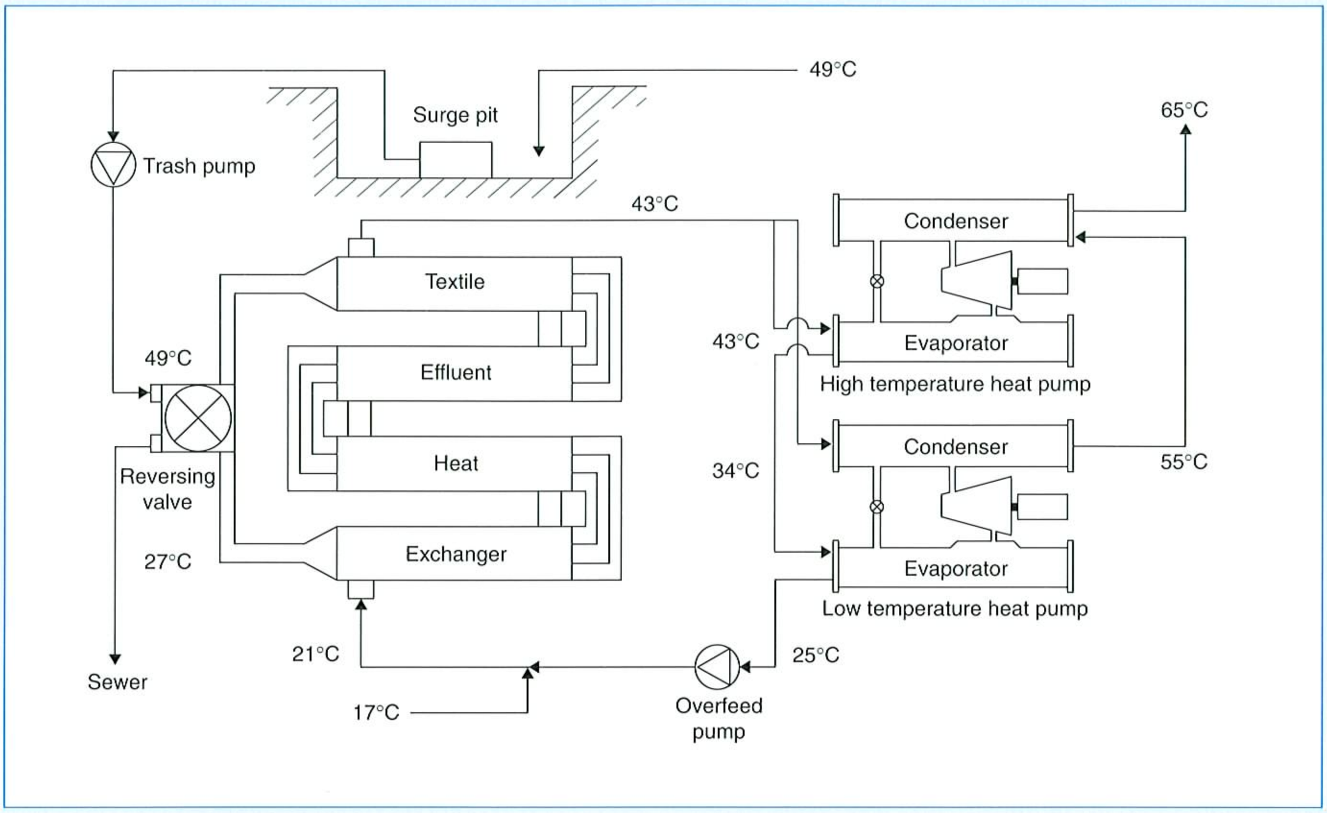


Figure 5: Textile Dyeing & Finishing Plant - Effluent Heat Recovery System using High & Low Temperature Heat Pump.

This system frequently results in four major benefits to the plant. Control of the effluent temperature and the small volume high temperature heating effect brings the plant down to allowable effluent temperatures and results in less water consumption in the plant. The hotter supply water increases production by reducing cycle times since the water is preheated ahead of time. The hotter supply water also provides a better rinse which improves on product quality. And finally, the energy savings alone will frequently provide one to two years simple paybacks (US conditions).

Dehumidifiers

Space dehumidification is necessary in many processes to protect the product and to improve working conditions. Conventional systems use a refrigeration

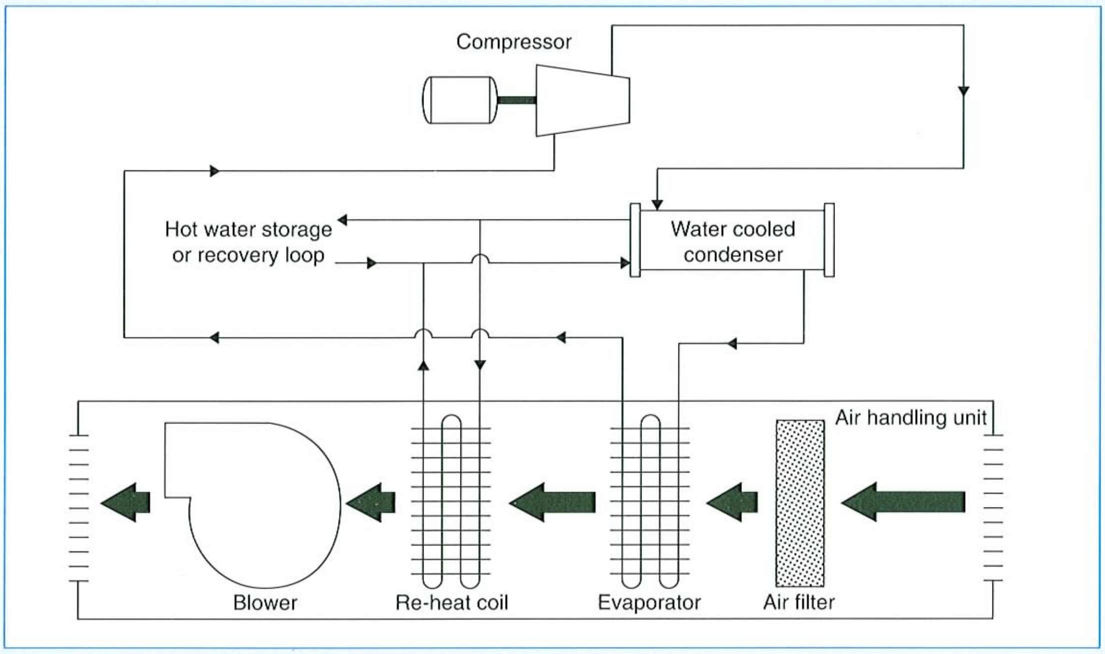


Figure 6: A Typical Food Processing Plant - Heat Pump Dehumidifier.

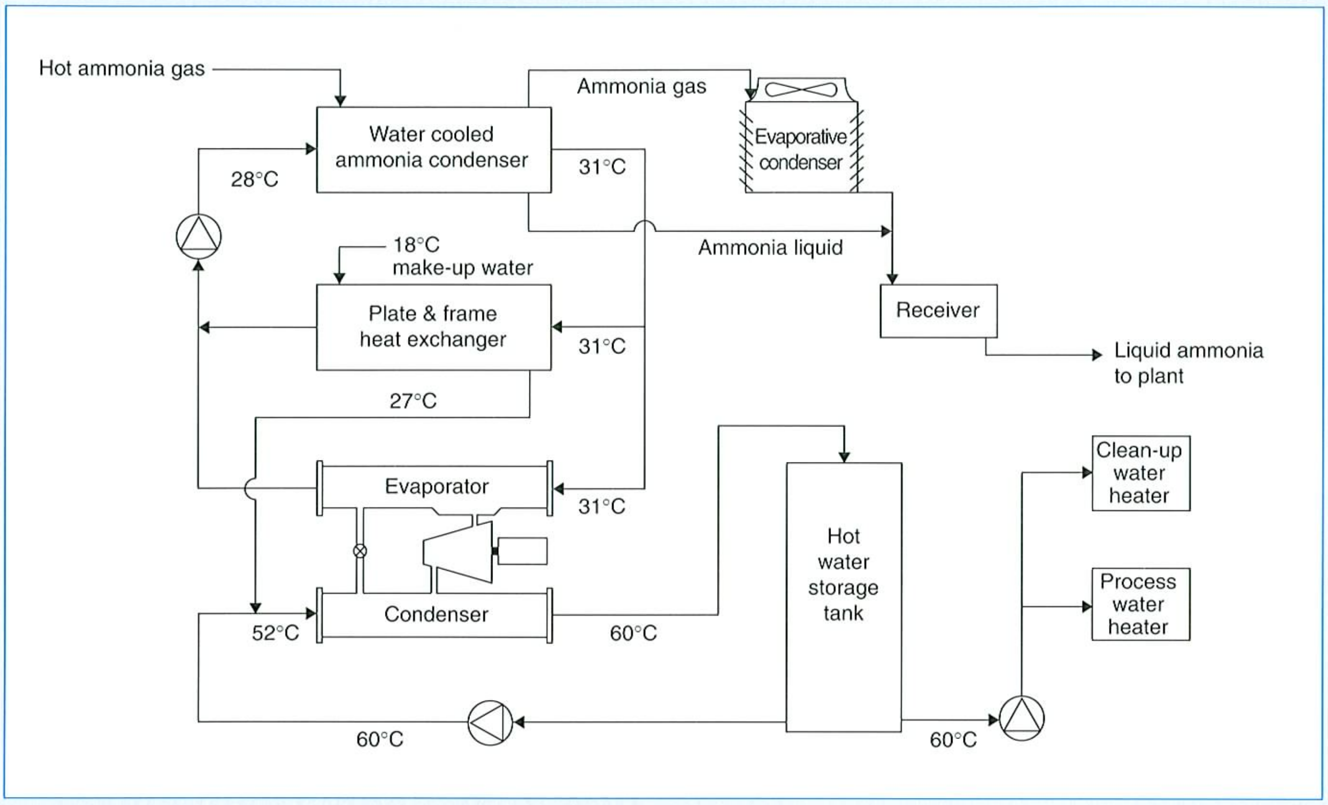


Figure 7: A Typical Food Processing Plant - using Heat Recovery from Refrigeration.

cycle to remove moisture from the air and to reheat it before it is returned to the space. Figure 6 is a system that works like the conventional system during the winter when warming of the returned air is needed. However, during the summer months the heat is rejected to a recovery system to make hot water for the process and the supply air is air-conditioned for the employees benefit.

Most benefits of this system result from the fact that there is less water build-up on pipes and equipment in the process area. This reduces maintenance costs as rust and corrosion are reduced.

Refrigeration

Refrigeration systems found in most food processing plants are perfect heat sources. The heat is fairly easy to recover and there is usually large hot water requirements. The actual size of the hot water requirement will dictate the selection of one or two systems.

If a small volume of hot water or a large volume of warm water is needed, then a combination of condenser and "desuperheater" is suggested to recover low grade heat from the refrigerant gas.

However, if a large volume of hot water is required then a heat pump is added to the system as shown in Figure 7. This system uses most or all of both the sensible heat and latent heat of the refrigerant as a heat source. The heat pump is used to heat the water up from 52°C to 60°C. The side benefits of this system are tremendous. The recovered heat unloads the evaporative condensers, which are commonly the limitation to the plant's refrigeration capacity. It also reduces the water and resultant chemicals used in the towers. The hot water supplied to the plant can provide better control for processes such as scalding, resulting in better quality product. Reductions in steam requirements reduce stack gas emissions, blow down pollution and boiler chemicals.

Conclusion

Large amounts of heat wasted in industrial process applications can be recovered to reduce energy cost and consumption. Real end-user benefits include reduced tower load, reduced water and water treatment requirements, and improved process production and product quality. The problem is how to make industry understand these benefits and spend limited capital to take full advantage of these systems.

**Author:*
F.J. Pucciano, Senior Power Engineer,
Georgia Power Company, USA.

Annex XIV - Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps

*T. Saito

Introduction

In the mid-temperature range, absorption heat pumps driven by heat are considered to be the optimum for using waste heat. The heat sources used for heat pumps are water and air. However, air-source heat pumps are more widely applicable than water-source heat pumps. Therefore, it was decided to focus on advanced air-source absorption heat pumps in Annex XIV of the Implementing Agreement on Advanced Heat Pumps.

The objectives of Annex XIV were:

1. *to collect and evaluate data on working fluids and transport phenomena in components for advanced absorption heat pump systems;*

2. *to offer appropriate proposals for future developments in this field;*

3. *to recommend future research and development programmes.*

Participating Countries

The countries which participated were Belgium, Denmark, Germany, Japan, Sweden and the USA. The Operating Agent was the Heat Pump Technology Center of Japan.

Activities

The work performed was limited to the context of the following types of advanced absorption heat pumps:

- compact high performance water-source heat pumps;

- air-source heat pumps.

To accomplish the objectives, the participants undertook a jointly funded study on a task-sharing basis. Each participant was responsible for surveying literature about the following topics in its own country and that of it's neighbouring countries:

- working fluids

- transport phenomena

- absorption cycles.

Each report has been summarized in the form of a review sheet and some were also discussed in workshop meetings. To process and analyze the data, three tasks were set up by the Operating Agent:

Task 1: Working Fluids Survey

About 500 publications covering thermophysical properties, advanced absorption cycles and transport phenomena were selected and reviewed, referring to previous reports and data bases of relevant literature. The number of papers collected was approximately 260 on thermophysical properties, 130 on absorption cycles, and 100 on transport phenomena. The references were reviewed by the participants on a task-sharing basis. The contents of the collected review sheets were entered into a data base. Numerical equations about thermodynamic properties were collected. Additional examples using numerical expressions are required. As to the transport properties, such as viscosity, diffusion coefficients, and thermal conductivity, experimental investigation is still necessary as well as the development of estimation formulas. Experimental data about chemical instability, toxicity, and corrosion characteristics of mixtures are also needed.

Task 2: Transport Phenomena Survey

This task surveyed mass transfer, heat transfer, momentum transfer, and interaction. The effects of surfactants and waves generated at the interface are considered important items for study. Two-phase flow pattern and analytical thermodynamic modelling of the absorption process are required.

Task 3: Absorption Cycles Survey

Approximately 70 cycles were selected and were evaluated thermodynamically. The selected cycles were examined under the following conditions.

Evaporator temperature:	5°C for refrigeration cycle -5°C for heat pump cycle.
Condenser temperature:	35°C for refrigeration cycle 50°C for heat pump cycle.

Multi-effect cycles and multi-stage cycles were investigated as well as single-effect cycles in combination with working fluids such as Water/LiBr, Ammonia/Water, FTE/NMP, etc. Single-effect cycles still cannot be ignored.

Based on these tasks, future developments were proposed. R&D of high performance absorption technology, which obtains high temperatures by utilizing lower temperature heat sources to drive heat pumps, will benefit the environment. This technology includes new cycles, such as heat transformers or temperature amplifiers, and hybrid systems.

Publication

All investigations were assembled and published in a two-volume Final Report:

- Vol. I: Final results
- Vol. II: Proceedings of the Seminars on Advanced Absorption Heat Pumps.

This report is restricted to the countries which participated in Annex XIV.

**Author:*
Dr. T. Saito, Professor, Faculty of Engineering, University of Tokyo, Japan.

News and Views

A New Connection

The Heat Pump Centre now has its own fax machine, for easier communication with National Teams and all interested in Heat Pump Centre activities. Our new fax number is: +31-46-510-389.

Market News

New Gas Engine Heat Pumps from Italy

CLIMAVENETA, an Italian heat pump manufacturer, has launched a new line of gas engine heat pumps in the refrigeration range 100 to 170 kW. These heat pumps recover additional heat from the water jacket and exhaust system. A micro-processor checks fault indicators and motor operation and gives indications about maintenance (filters spark plugs, oil, etc.). Additionally, the units are remote-controlled by a serial data line via modem or radio-bridge. These heat pumps also feature low emission and noise levels. *(Source: Italian National Team.)*

Italian A/C Manufacturer ROBUR Gains US Foothold

ROBUR S.p.A., an Italian firm in the field of air-conditioning systems, with affiliate companies in London, Frankfurt and Strasbourg, acquired, in May 1991, a division of DOMETIC Society (U.S.A.), which was formerly controlled by the Electrolux Group.

The new ROBUR Corporation plans to invest USD 15 million over the first three years in the manufacture of non-CFC gas-driven absorption air-conditioners, using ammonia/water as working pair. *(Source: Italian National Team.)*

Pilot Production of High-Efficiency WSHPs

US company Trane will begin a pilot production run this summer of a new water-loop heat pump with higher efficiency, lower noise, and better air handling capability than existing units. Jointly developed by Trane and EPRI, the new water-source heat pump (WSHP) offers cooling energy efficiency ratios over 14 and heating coefficients of performance close to 5.

The new WSHP achieves its high efficiency through several advanced components, including:

- scroll compressors that are more efficient and should be more reliable than existing reciprocating compressors;
- thermostatic expansion valves, which replace fixed devices, to allow optimum control of superheat;
- micro-electronic controls that are compatible with building-automation computer programs to provide better system management.

The new 1.5- to 4.5-ton line of horizontal WSHP units are well-suited for both retrofit or new construction applications. *(Source: EPRI Heat Pump News Exchange, Autumn 1991.)*

Development of Turbo Heat Pump System

Tokyo Electric Co. (TEPCO), and Mitsubishi Heavy Industries, have jointly pursued development of a turbo heat pump system for district heating/cooling or large building air-conditioning use. At the end of March 1991 they finished tests with a 200 RT pilot system. The main technological features are:

- "magnetic bearing" system which floats the rotor by magnetic force and controls operation. No lubricating oil mechanism is needed;
- high frequency inverter for 10,800 rpm operation without speed-up mechanism;
- energy loss on the bearing has been reduced to less than 1/10 (i.e., 7.9 to 0.7 kW in terms of electric power). Combined with a high efficiency operation system, the new system reduces power consumption by 30%.

Other improvements are:

- noise reduced by about 7 dB;
- vibrations reduced to about 1/10;
- compact and simplified system;
- simplified maintenance.

The system will be commercialized by MHI. *(Source: JARN, October 25, 1991.)*

Ice/Hot-Water Heat Accumulating Heat Pump Unit

Toyo Engineering Works Ltd., Tokyo has developed, the "Heat Sum" heat pump unit. The "Heat Sum" is an air-conditioning system which uses ice and hot-water for heat storage. The heat accumulating heat pump unit combines an air-source and water-source heat pump with a thermal storage tank. Its operation is as follows:

To begin heating, hot water is directly utilized to respond to the large load required during rise-time. As the temperature of hot water in the tank drops, the system uses lower temperature water for operation as a water-source heat pump. During the day when the outdoor temperature rises and the system load is low, the operation mode is changed over to that of an air-source heat pump unit.

The unit features a new type of ice-making coil, which improves the ice-making rate by 50%. As a result, the ice storage tank size has been reduced to about 1/9 of the conventional size. Using low-tariff electric power, heat is stored during night-time operation, and the stored low/high temperature heat is delivered in the day-time to operate the system.

A micro-computer provides automatic control of heat storage and discharge, and the two-stage heating operation. The "Heat Sum" comes in two models - 30 and 40 RT in nominal cooling capacity. *(Source: JARN, October 25, 1991.)*

'Dramatic Growth' in Spanish Air-Conditioning Market

Between 1988 to 1990, the Spanish market for packaged air-conditioning has seen a dramatic growth. Sales of packaged units have leapt by about 50%, from 200,000 units in 1988, to an estimated 300,000 in 1990.

This is one of the key findings of an in-depth report on the Spanish air-conditioning market, recently published by the Building Services Research and Information Association, as part of its European Building Services Study. It provides detailed information on the size, structure and outlook for the various product categories within the air-conditioning sector, and highlights the 'barriers to entry' into the marketplace, invaluable for companies seeking to penetrate the booming market.

In the packaged sector, today, demand is focused on consoles and cassette units, which now share 75 to 80% of the market. In terms of the capacity/size of units being sold, almost all are less than 9 kW, and the majority less than 7 kW. Heat pumps, although used to a degree for air-conditioning, generally form part of the separate heating market in Spain. Looking to the future, the report predicts continued growth, with a doubling of the market forecast. Over the next five years, the main growth area is expected to be split systems.

For further details contact:
BSRIA, Tel.: +44-81-6887788, ext. 3444.
(Source: Refrigeration and Air-Conditioning, October 1991.)

Toshiba Gears up for Full-Scale Production in the UK

The first Toshiba air-conditioning units to be manufactured on British soil are now rolling off the production lines at the company's new plant in Plymouth.

To begin with, existing products from the Toshiba range will be manufactured, but the company plans to move on to use the research and development facilities at the site to develop products specifically for the European market. *(Source: Refrigeration and Air-Conditioning, November 1991.)*

Market Trends

Gas Engine-Driven Heat Pumps Selling Well in Japan

Since demand for cooling expands explosively during the summer, electric power supply at this time has become increasingly stringent. In these circumstances, demand for gas engine-heat pumps (GHPs), is rapidly growing on the commercial A/C market in Japan. Preferential gas charges and gas engine speed control corresponding to load, have lowered running costs considerably for GHPs.

GHPs are mainly used by corporate and government offices, schools, factories, hospitals, etc., but they are also utilized in various other types of fields such as stores, temples and banquet halls. Nationwide demand for GHPs (both city gas and LP gas driven units) increased from 20,000 units in ref. year 1990, to about 50,000 units in the following year. *(Source: JARN, October 25, 1991.)*

Room and Packaged A/C Shipments Achieve All-Time Highs

According to the Japan Refrigeration & Air Conditioning Industry Association (JRAIA) HVAC & R products for ref. year 1991 (October 1990 to September 1991) showed a more than two-digit percentage growth, see Table 1. Shipments of room A/Cs went up 19.6% over the preceding year. The rapid growth is largely attributable to the amazing growth in demand for the first half of ref. year 1991 largely due to a high demand from the still-booming construction industry.

Table 1: Japanese Domestic Shipments from October 1990 to September 1991

	No. units	% change
Room A/C	7,092,363	+19.6
Cooling only	1,749,508	+3.6
Heat pump	5,342,855	+25.9
Packaged A/C	1,080,644	+16.2
Cooling only	221,468	+8.0
Heat pump	859,176	+18.5

(Source: JARN, November 25, 1991.)

Refrigerants/CFC's

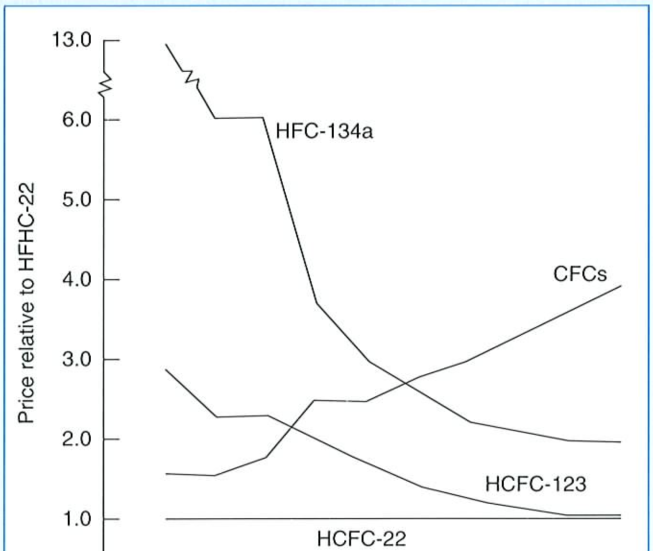
New Test Facility for CFC Alternatives

ICI is planning to build a pilot factory in Widnes, United Kingdom, for the production of HFC-32, or KLEA-32 as it is called by ICI. This refrigerant is specifically aimed at low temperature applications. The development of KLEA-32 is part of ICI's research programme to find a replacement for CFC's and HCFC's.

York Re-affirms its Support for R-123 Equipment

Despite current health safety fears, York Applied Systems will continue producing equipment using R-123 as an alternative to R-11 where it is economically justified. According to York, their R-123 chillers operate with an exposure level well below 10 ppm and therefore allow safe operation. With regard to future costs of the two main alternatives to R-22, (see Figure 1), York expects R-123, now about three times as expensive as R-22, to come to within about 10% of it by 1991. However, by the end of the decade, R-134a will still be about twice as expensive as R-123.

Figure 1: Estimated Refrigerant Prices.



(Source: Air Conditioning, Heating & Refrigeration News, October 14, 1991.)

Refrigerant Manufacturers Support Accelerated Phase Out of CFCs

Four major refrigerant manufacturers have recently announced their support of an accelerated phasing out of CFCs. This action was based on new atmospheric findings from the 1991 UNEP Scientific Assessment of Stratospheric Ozone. The four companies are: E.I. duPont de Nemours, Atochem North America Inc., ICI Americas Inc., and Allied-Signal Inc.. DuPont intends to stop selling CFCs to developed countries by the end of 1996 and to developing countries by the year 2000.

The other companies do not give specific dates but support UNEP's call for phasing out CFCs in advance of the earlier year 2000 deadline. The four companies - all of which manufacture HCFCs - support the use of HCFCs as interim replacement refrigerants for CFCs. *(Source: ASHRAE Journal, December 1991.)*

Systems/Installations

Soil Data for GSHP Design

EPRI has entered into an agreement with Oklahoma State University (OSU) to obtain long-term data on the thermal properties of soils. The data will be used to assist system designers in reducing the size and installed cost of ground coils used in ground-source heat pumps (GSHPs). EPRI's investigation will be "piggy-backed" onto a larger, collaborative project called MesoNet - The Oklahoma Mesometeorology Network - being created to monitor meteorological, agricultural, and hydrological conditions throughout the state.

Operation was set to begin in late 1991. MesoNet will consist of 107 permanent, automated weather stations. EPRI plans to participate by adding its own sensors at a select number of sites to gain information on soil temperature, moisture, and thermal resistivity. In addition, soil type and density will be determined at these locations. The need for information on soils has already been identified at the IEA Heat Pump Centre Workshop on GSHP held in August 1991 in Montreal. It is now expected that the Mesonet project will make a substantial contribution to the further application of GSHPs. For more information on the MesoNet project contact Powell Joyner, EPRI Residential Program, Tel.: +1-415-855-2580. *(Source: EPRI Heat Pump News Exchange, Autumn 1991.)*

Field Test of Residential Gas Heat Pumps Shows High Efficiency

An 18-month field test of ten residential natural gas heat pumps in the USA shows promising efficiencies for both heating and cooling, reports the Gas Research Institute. COPs of 1.0 to 1.2 for cooling and 1.2 to 1.4 for heating were reported for the units, which operated over 39,000 hours in a variety of climates. The units feature single-cylinder reciprocating engines and reduce nitrogen oxide emissions down to 300 ppm, through lean-burn combustion. When commercialized, the units will be offered in capacities from 2.4 to 4 tons. Further information is available from the Gas Research Institute, 8600 W. Bryn Mawr Avenue, Chicago ILL, USA. *(Source: Air-Conditioning, Heating & Refrigeration News, October 21, 1991.)*

First Gas Absorption Heat Pump Utilizing Treated Sewage

Sanyo Electric Co., and Tokyo Gas Co., have jointly developed the world's first unit that serves both as an absorption chiller and absorption heat pump by effectively utilizing treated sewage - an energy source which has remained unused - as a heat source. Its advanced temperature lifting absorption system (ATLAS) saves about 30% energy compared to conventional systems. Due to these combined functions, the system can deliver both chilled and hot water. By utilizing treated sewage it achieves a cooling COP of 1.2. The gas absorption heat pump uses water as refrigerant and lithium bromide as absorbent. *(Source: JARN, November 25, 1991.)*

Shopping Centre Applies Heat Pumps and Aquifer

A plan for a shopping centre in Eindhoven, the Netherlands, includes the use of an aquifer for energy storage and heat pumps for heating and cooling. The heat pumps will be connected to a circulation line which by means of a heat exchanger extracts heat or cold from the aquifer. Each shop will have its own heat pump to allow individual control of climate and energy costs. *(Source: Koude Magazine, November 1991.)*

New Air-source Gas Engine Heat Pump in Germany

In October, 1991, the 5th centralized heating-only gas engine heat pump installation developed, installed and operated by Thyssen Bauen und Wohnen, was put into operation in Germany. The proven concept features a so-called *power tower* heat source installation and an underground machine room providing minimum noise and optical pollution and optimized integration of stack and fanless air coils. The design of the *power tower* is highly acceptable from an architectural point of view. The installation includes two units comprising proven engines and screw compressors, and a separate cogenerator providing electricity for the heat pumps. Gas furnaces assist the heat pumps at low ambient temperatures. R-12 is still used as a refrigerant but R-134a is being considered as a replacement for the short-term. The retrofit installation is located at the heart of a 600-house settlement in Duisburg.

Thyssen Bauen und Wohnen is a large housing corporation and is now preparing to market new installations on a commercial basis using this successful concept, based on the 'know-how', developments and field experience gained during many years as a user and designer. Thyssen also states that gas engine heat pumps are now considered proven technology.

Codes and Guidelines

Japan Awards Superior HP Systems

The Heat Pump Technology Center of Japan (HPTCJ) will award heat pump systems which contribute greatly to saving energy by designating them as superior heat pump systems.

At present there is a similar qualification award for standard air-conditioning units, mainly for domestic use.

Nowadays, heat pumps are often applied in large-scale systems for heating, cooling, drying, hot water supply, etc., in large buildings, district heating & cooling installations or in industrial processing. In such cases, evaluation of the system as a whole is very difficult but important for the potential replicators. Therefore, a neutral and authorized organization should evaluate the system to qualify it as superior.

Thus, HPTCJ - a semi-governmental, neutral organization, has taken on this task which it begun last year. It established a committee of neutral members from universities and national laboratories, and then invited manufacturers, constructors and other interested parties to enter projects for the award. The committee evaluated the applications and selected 12 qualified systems. These superior HP systems will be announced to the mass-media as recommended systems for future implementation.

IEA and Member Countries

HPC to work with Austrian Heat Pump Association

The association represents ten manufacturers, distributors and specialists in the area of heat pump technology in Austria. Its main aim is to support their members by exchanging research results and market developments, and by promoting the application of heat pumps through seminars and brochures.

For more information contact:

Leistungsgemeinschaft Warmepumpe
c/o Bundeswirstschaftskammer
Dr. G. Mock
Wiedner Hauptstrasse 63,
1045 Wien, AUSTRIA
Tel.: +43-222-50105-3519
Fax : +43-222-50509-28

By forming links with the Austrian Heat Pump Association, the Heat Pump Centre will have access to a valuable information source.

Visit Japanese Gas Engine Heat Pump Study Group

On November 4-5, 1991 a team of Japanese heat pump experts visited the Netherlands to discuss gas heat pump/cogeneration standards for equipment, installation and maintenance. The group consisted of representatives from the High Pressure Gas Safety Institute of Japan, Kimmon Manufacturing Co., and MITI. The visit included the NMB bank building installation, incorporating three cogeneration units of 450 kW power each, and the gas engine heat pump installation with screw compressor in the World Trade Centre building, both located in Amsterdam. Views and information on the topic were exchanged in a constructive and beneficial meeting organized by the Dutch National Team. The group continued its tour to Germany, France and England.

European Community

Call for Proposals for Joule-II

The Commission of the European Communities has recently published its research and technological development programme for non-nuclear energy, which is an extension of the JOULE programme. Joule-II (1991-1994) aims to contribute to the development of new energy options that are both economically viable and environmentally safer. The programme includes energy saving technologies and specifies heat pumps as an option. Proposals for R&D projects can be submitted in accordance with the guidelines and format from the EC.

For more information contact:

Commission of the European Communities
Directorate General for Science, Research and Development
Directorate E Non-Nuclear Energy Programme
Rue Montoyer 75, B-1040 Brussels, Belgium.

Bibliography

Refrigerants/CFCs

The Greenhouse Effect and CFC Substitutes in Refrigeration

Helmot Lotz, Ki Klima-Kälte-Heizung, 10/1991, pp 405-409 (German).

This report discusses the impact of CFC reduction legislation in Germany and the EEC on refrigeration systems. It compares a wide range of refrigerants with regard to ozone depletion and their contribution to the greenhouse effect. In addition, several refrigeration systems are examined regarding their indirect effect on greenhouse gases, through energy consumption, and their more direct effect through refrigerant leakage.

The Oil Behaviour of the Chlorine-Free Refrigerants R-23, R-143a and R-152a

Manfred Burke, Horst Kruse, Ki Klima-Kälte-Heizung, 9/1991, pp 348-351 (German).

As part of the global effort to reduce CFC levels, the Institute of Refrigeration and Applied Heating Technology at the University of Hanover is investigating several currently available chlorine-free CFC substitutes. One important aspect in determining their suitability for refrigerating systems is their behaviour in conjunction with the oils used in these systems. This article compares the behaviour, especially miscibility, of a number of oil refrigerant mixtures over the operating temperature range.

Refrigerant R-227

Ewald Preisegger, Ki Klima-Kälte-Heizung, 11/1991, pp 456-460 (German).

R-227 (1, 1, 1, 2, 3, 3, 3-heptafluoropropane) could partially replace the halogenated refrigerant R-114 in air-conditioning and heat pump applications. This paper considers the current known chemical, toxicological and ecological properties of this substance, and describes its miscibility behaviour with compressor lubricants. The thermodynamic properties of R-227 are compared with R-134a and R-114 using theoretical heat pump processes, with particular attention to the promising effects of R-227 on COP in practice.

Environment

Environmental Consequences of New Energy Technology

Torbjörn Svensson et al, Swedish Council for Building Research, 72 pages (English).

The planned phasing out of nuclear power generation in Sweden has concentrated Swedish research on the change-over to new energy forms. But new energy technologies bring with them new environmental problems.

This report examines the environmental consequences of using solar energy, heat storage and heat pump technologies for heating in the built environment. The basic concepts of environmental loading, environmental effect and environmental consequence are outlined and used to make systematic descriptions of the full environmental impact of these new technologies.

Systems/Installations

Heat Pumps for Industry - Take Another Look

24 page brochure (English) prepared for the US Department of Energy, Office of Industrial Technologies, by the National Renewable Energy Laboratory.

Illustrated with real life industrial situations, this brochure shows how heat pumps can reduce energy consumption in industry, and describes the basic concept of heat pump technology. The brochure also shows how pinch analysis can optimize the use of heat exchangers and heat pumps in an industrial process.

Research & Development

Thermophysical Properties of New Working Fluid Systems for Absorption Processes

U. Nowaczyk and F. Steimle, Universität Essen, Germany, Int. Journal of Refrigeration, 1992, Vol. 15 No. 1, pp 10-15 (English).

This report summarizes research into working fluid pairs for absorption heat pumps. The refrigerants investigated were trifluoroethanol (TFE) and hexafluoroisopropanol (HFIP). They were combined with solvents of the group of organic heterocycles. Experimental data are presented on solubility, heat of mixing and vapour-liquid equilibrium. Comparison with conventional ammonia-water and TFE-NMP systems highlight the advantages of these new working fluid systems.

Cold Air Refrigeration Machine With Mechanical, Thermal and Material Regeneration

A. Henatsch and P. Zeller, Hochschule für Verkehrswesen "Friedrich List", Dresden, Germany, Int. Journal of Refrigeration 1992, Vol. 15 No. 1, pp 16-30 (English).

In the light of recent restrictions on CFCs as refrigerants, the potential of cold air refrigeration machines has been re-examined. This report summarizes the technical, energy and operational aspects of these machines and analyses the following aspects: the irreversible Joule process, a modified Joule-Ericson process, and the effects of thermodynamic regeneration. Computer modelling predicts performance coefficients of 1 and higher, suggesting a new lease of life for this 19th century invention.

Computer Model for Absorption Systems in Flexible and Modular Form

Grossman, Gommed and Gadoth of the Israel Institute of Technology. Prepared for Oak Ridge National Laboratory, USA. 102 pages (English).

This report describes a simulation program which can predict the performance of a wide range of absorption heat pump designs. The modular structure of the program makes it possible to investigate various cycle configurations with different working fluids. The report details the equations and codes used to model heat pump components and material properties, and shows the results of a number of modelled systems.

Absorption Heat Pumps and Heat Exchangers

R. Hölscher-Schmidt, pp 60 (German).

Within the European Community's research project EUREKA a co-operative effort known as PACA has been established between German, French and Dutch companies to continue development of industrial heat pumps and heat exchangers for market implementation. The main application is industrial heat recovery and energy saving for heating and cooling. The report describes phase 2 of the study consisting of the basic research. For further information please contact: FachinformationsZentrum Karlsruhe, InformationsZentrum Wärmepumpen & Kältetechnik, Leopoldshafen 2, D-7514 Eggenstein, Germany. Reference IZW berichte 2/91.

IEA

The Air-Conditioning Equipment Market in Southern Europe

Published by the IEA Heat Pump Centre - Report No. HPC-R7 (English).

This HPC report summarizes an analysis performed by Annex X of the IEA Implementing Agreement on Advanced Heat Pumps which carries out technical and market analysis of heat pumps. The analysis looks closely at the market situation in Italy, France and Spain, and assesses the interest in new heat pump technologies. This report is available to all countries participating in the IEA Implementing Agreement on Advanced Heat Pumps (price NLG 60) and marks the beginning of a new role for the HPC as producer of docu-ment-ation concerning other advanced heat pump annexes. The USA and Sweden participated in Annex X, which has now been completed.

IEA greenhouse gas R&D programme

November 1991 saw the launch of two publications from this newly formed IEA programme. **"Greenhouse gases bulletin"** is a bi-monthly current awareness journal that provides details of the most relevant items from the world's literature on greenhouse gases and fossil fuels. **"Greenhouse issues"** is a free newsletter on information related to the IEA greenhouse gas R&D programme. Contact Deborah Norman at IEA Coal Research, Gemini House, 10-18 Putney Hill, London SW15 6AA, UK.

Proceedings

Symposium on Ground-Source Heat Pumps

Held in October 1991, at the Convention Centre of Glessen University, Germany (German with English abstracts).

Organized by the Institute of Applied Geosciences of Giessen University and the Information Centre for Heat Pumps and Refrigeration, this symposium brought together 72 experts from eight countries to discuss 22 paper presentations on the state-of-the-art of ground-source heat pumps in Europe.

The proceedings are available, price DEM 29, from Fachinformationzentrum (FIZ) Karlsruhe, D-W7514 Eggenstein-Leopoldshafen, Germany.

Conferences

Innovative Cooling Strategies Workshop
May 12-14, 1992 / Birmingham (UK).
Organized by Oscar Faber under the auspices of the Energy Conservation in Buildings ExCo. Contact Mr S. Irving, Oscar Faber Applied Research Ltd., Marlborough House, Upper Marlborough Road, St. Albans, Herts AL1 3UT, UK.

ASHRAE Annual Meeting
June 27-July 1, 1992 / Baltimore, Maryland (USA)
Contact: Meetings Co-ordinator ASHRAE,
1791 Tullie Circle, NE, Atlanta, GA 30329, USA.
Tel.: +1-404-636-8400; Fax: +1-404-321-5478.

Symposium Ground-Source Heating & Cooling Systems
June 27 - July 1, 1992 / Baltimore, Maryland (USA)
To be held at the same time as the 1992 ASHRAE Annual Meeting, TC 6.8 (Geothermal Energy Utilization) and TC 9.4 (Applied Heat Pump, Heat Recovery Systems) intend to organize the above-mentioned symposium. Contact: Steve Kavanaugh, University of Alabama, P.O. Box 870276, Tuscaloosa, AL 35487-0276, USA..

1992 International Refrigeration Conference - Energy Efficiency and New Refrigerants
1992 International Compressor Engineering Conference
July 14-17, 1992 / West Lafayette (USA)
Short courses on above subjects will be held July 12-14 '92
Contact: Phyllis Hurst, Conference Secretary,
Purdue University, 1077 Ray W. Herrick Laboratories,
West Lafayette, IN 47907-1077, USA.
Tel.: +1-317-494-0117; Fax: +1-317-494-0787.

International Congress COLD '92
September 7-9, 1992 / Buenos Aires (Argentina)
Organized by Commissions B2, C2 and E2 of the IIR.
Contact: International Congress COLD '92, CC5109, Correo Central, 1000 Buenos Aires, Argentina
Telex 22421 INARG AR; Fax:+54-1-11-1984.
Tel. +44-81-784-5784; Fax: +44-81-784-5700.

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

Future Issues

Vol./No.	*Topic*	*Deadlines*
10/2	Utilities and heat pumps	**1 March 1992**
10/3	Servicing and maintenance	**1 March 1992**
10/4	Space conditioning heat pump equipment and applications, including novel applications	**1 September 1992**
11/1	Unitary gas heat pumps	**20 December 1992**
11/2	Industrial heat pumps	**1 March 1993**

NB: Volume 10, numbers 2 and 3 might be combined.

New HPC Products

HPC-WR8 HPC Workshop Proceedings on Ground-Source Heat Pumps - Advancements Towards Cost Reduction (available to Member countries for NLG 60.)

HPC-R7 Summary Report of an Analysis Performed under Annex X - The Air-Conditioning Equipment Market in Southern Europe (available to IEA Implementing Agreement countries for NLG 60.).

Name

Company

Address

City / Postal Code

Country

☐ My country participates with the IEA Heat Pump Centre. Please send me my free copy of the HPC Newsletter each quarter.

☐ My country does not participate with the IEA Heat Pump Centre, but I would like to subscribe to the HPC Newsletter. (Annual subscription charge NLG. 90, including postage).

☐ Please cancel my subscription to the HPC Newsletter as of the next issue.

Date

Signature

Austria
Mr. H. Halozan, TU Graz
Inffeldgasse 25
A-8010 Graz, Austria
Tel.: +43-316-873-7303
Fax: +43-316-873-7305

Canada
Mr. D. Cane, CANETA Research Inc.
6981 Millcreek Dr., Unit 28
Mississauga, Ontario, Canada L5N 6B8
Tel.: +1-416-542-2890
Fax: +1-416-542-3160

Italy
Mrs. L. Manduzio, ENEA - C.R.E. Casaccia
Via Anguillarese, 301
00060 S. Maria di Galeria, Rome, Italy
Tel.: +39-6-3048-6445
Fax: +39-6-3048-6306

Japan
Mr. Y. Igarashi, Heat Pump Technology Center Japan
Azuma Shurui Bldg. 9-11 Kanda Awaji-cho 2-chome,
Chiyoda-ku, Tokyo 101, Japan
Tel.: +81-33-258-1035
Fax: +81-33-258-1037

The Netherlands
Mr. P. Oostendorp, TNO
Department of Heat and Refrigeration Technology
P.O. Box 342, 7300 AH Apeldoorn , The Netherlands
Tel.: +31-55-493-493
Fax: +31-55-419-837

Norway
Mr. R. Aarlien, SINTEF
Norwegian Institute of Technology
Division of Refrigeration Engineering, N-7034 Trondheim, Norway
Tel.: +47-7-593-929
Fax: +47-7-593-926

Sweden
Mr. B. Bäckström
Chalmers Teknikpark
S-41288 Göteborg, Sweden
Tel.: +46-31-724-226
Fax: +46-31-418-056

USA
Mr. M.A. Broders, Oak Ridge National Laboratory
Building 3147, P.O. Box 2008
Oak Ridge, TN 37831-6070, USA
Tel.: +1-615-576-2731
Fax: +1-615-574-9338

IEA Heat Pump Centre
Swentiboldstraat 21, 6137 AE Sittard
P.O. Box 17, 6130 AA Sittard, The Netherlands
Tel.: +31-46-595-236
Fax: +31-46-528-260

STAMP

IEA Heat Pump Centre
P.O. Box 17
6130 AA SITTARD
THE NETHERLANDS

For your subscription please use the attached card.

The IEA Heat Pump Centre Newsletter will be published quarterly.

Subscribers from countries participating with the IEA Heat Pump Centre (see list above) will receive the newsletter free of charge.

Subscribers from other countries will be charged Dfl. 90, a year, which includes postage.

Cancellation of the subscription must be made at least one month before the end of the subscription year.