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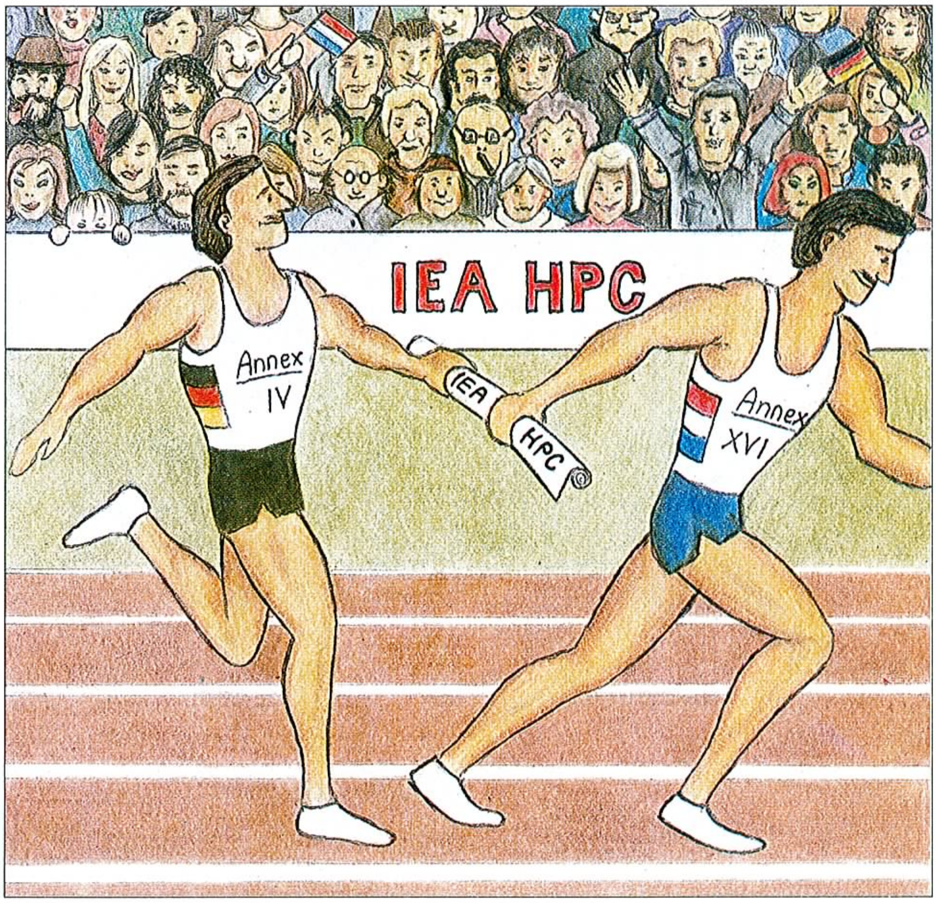

IEA Heat Pump Center Transition--Annex IV Concludes, Annex XVI Commences

This issue: Planning for the future -- national R,D&D programs, incentives, codes, and standards

Dear Reader:

This December 1989 Newsletter is the last issue published by the Fachinformationszentrum Karlsruhe, the current operating agent of the IEA Heat Pump Center. This is due to a decision made by the Executive Committee of the IEA Heat Pump Center, with the support of the majority of the member countries, to terminate the Fachinformationszentrum's operation of the Center at the end of 1989.

This, however, will not be the last issue of the Newsletter published by the IEA Heat Pump Center. The new operating agent of the IEA Heat Pump Center, NOVEM, Sittard, the Netherlands, plans to continue with a similar quarterly publication beginning March 1990. We will do our best to ensure the continued receipt of the Newsletter for those subscribers in countries which are continuing their membership in the new IEA Heat Pump Center.

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The Federal Republic of Germany is one of the countries ending its participation in the IEA Heat Pump Center. This means that, beginning 1990, German subscribers will no longer be entitled to receive a free Newsletter subscription. In Germany, however, an intensified national effort to support heat pumps and refrigeration technology is being planned and one of the activities may involve publication of a periodical in German. Current German subscribers to the Newsletter will be kept informed of future developments.

Before closing the IEA Heat Pump Center here in Karlsruhe, we would like to take this opportunity to thank all the authors, contributors, and editors for their assistance in making the Newsletter an up-to-date source of information on heat pumps. Over the last seven years the Center has published 24 Newsletter issues with more than 200 technical articles, numerous book reviews, and news from the IEA member countries and the worldwide heat pump community. With an average circulation of 5,000 copies per issue more than 120,000 copies of the Newsletter have been distributed since 1983. The Newsletter has reported on such topics as the success of heat pumps in North America, Japan, and other countries, and on the rapid increase and decline of heat pump use in Europe. In recent issues our only "major" problem in producing the Newsletter has been the receipt of too many articles often forcing us to do our best to select those of greatest interest to our readers.

A special thanks goes to our readers. Your continued interest, comments, and suggestions have been a great encouragement.

We feel that this last issue of the Newsletter comes at a time when, at least in some European countries, the interest in the use of heat pumps is again increasing. There are, of course, some problems still to be overcome.

One obstacle which remains is the CFC issue, though technical solutions are being developed or are already available. A definite opportunity for the heat pump is its contribution to more efficient heating and cooling resulting in a reduction of CO_2 emissions. Thus the heat pump is a potential technology for use in reducing the greenhouse effect which is currently one of the most serious long-term threats to the environment.

A second barrier is the present economic situation (low energy prices) which makes it difficult for heat pumps to compete with conventional heat generators. To counteract this, the attention of decision makers and the general public should be focused on a better understanding of the heat pump's environmental benefits to which a monetary value may be attached in the future.

With both the obstacles as well as the many opportunities ahead for the heat pump industry, we would like to encourage all those involved in promoting heat pumps to continue their efforts so that the full potential of the heat pump can be realized and put to use.

We wish all of our readers a joyous holiday season.

**The staff of the IEA Heat Pump Center, Fachinformationszentrum, Karlsruhe, Fed. Rep. of Germany*

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The Super Heat Pump Energy Accumulation System - Current Status of the Project

The Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI) of Japan has promoted various R&D programs on energy conservation under the name "Moonlight Project," working closely with the New Energy and Industrial Technology Development Organization (NEDO), national research institutes, and universities.

As a nation with few energy resources, Japan must promote energy conservation to maintain and develop its economy. One of the large-scale programs in the "Moonlight Project" is the "Super Heat Pump Energy Accumulation System" (SHP), which was launched in 1984 as an eight-year project (a one-year extension is expected) with a budget of about 10 billion yen. Figure 1 shows the development schedule of the SHP project.

This system will produce energy more efficiently than the conventional heat pumps by utilizing cheap electrical power during nights, storing this energy at high density, and using this stored energy during the period in the day when the demand for energy is high (Figure 2). The energy from this system can be used to air condition large buildings, to supply hot water to community districts on a large scale, for heating and cooling homes, and as a heat source for industries.

After the interim review of the master plan in 1988-1989, pilot systems combining high performance compressor-driven heat pumps with chemical heat storage units will be constructed. The coefficient of performance (COP) and the output temperature of the system are remarkably higher than those of conventional technologies. Table 1 shows the final goals for the development. These systems are expected to improve thermal efficiency, waste-heat utilization, and provide load leveling of electric power demand.

The budget of R&D of NEDO is subsidized by MITI; NEDO supervises the Technology Research Association's (TRA) R&D for the Super Heat Pump Energy Accumulation System and conducts research on topics such as optimum system configuration, control, and conceptual design of 30,000 kW class SHP system for actual application. NEDO also conducts research on the total system, including studies on

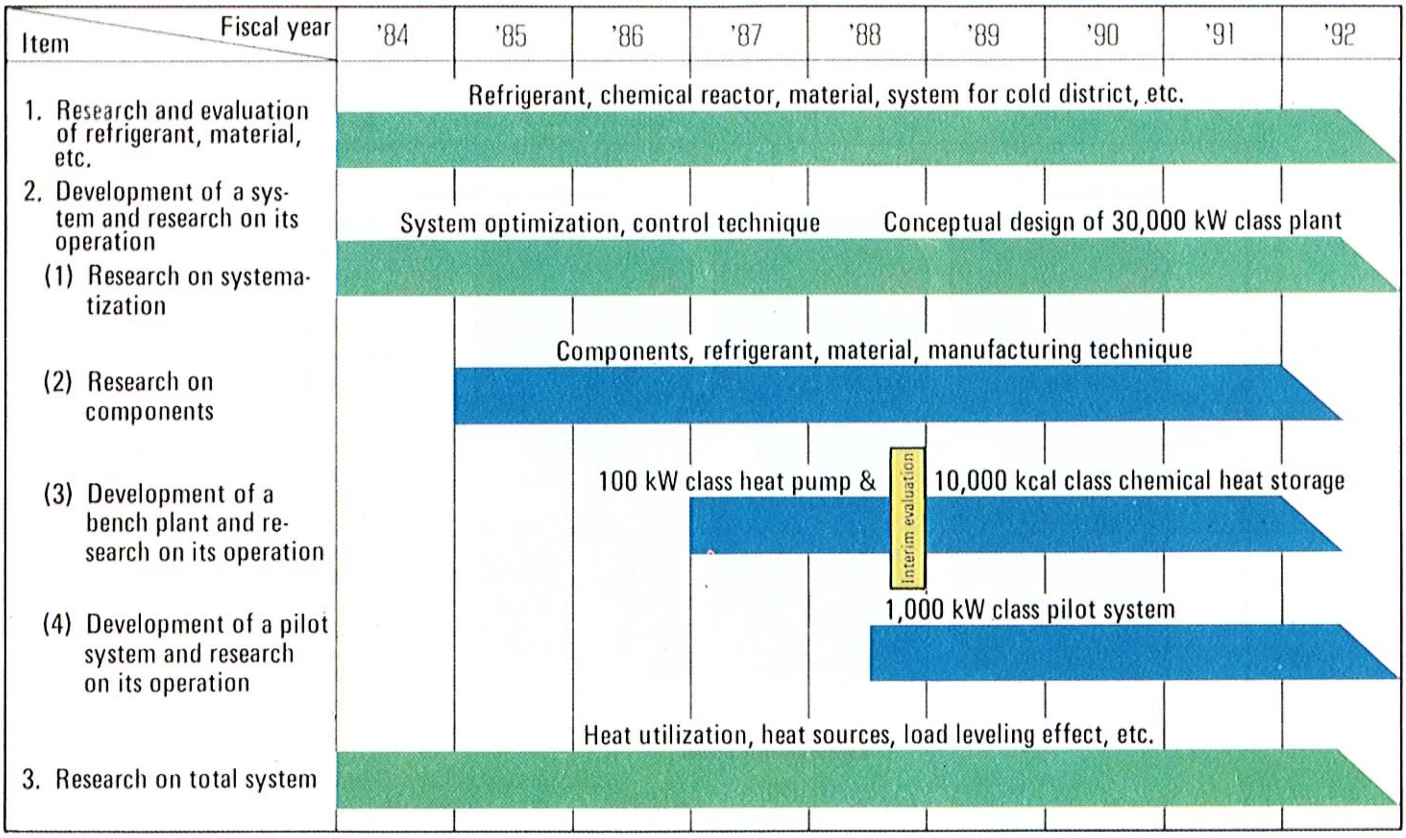

Figure 1. Development schedule for the super heat pump energy accumulation system

heat utilization, heat sources and possible effects of the incorporation of the system.

TRA consists of 17 of Japan's leading private companies and has been carrying out R&D on bench plants (small-scale test pilot plants) and on the analysis of the operation results of system components in collaboration with national research institutes studying refrigerants and materials.

Four national research institutes (Mechanical Engineering Laboratory, National Chemical Laboratory for Industry, Government Industrial Research Institute in Osaka, Government Industrial Development Laboratory in Hokkaido) have been responsible for evaluation of R&D by NEDO, in addition to individual elemental research on refrigerants, chemical reactors, and materials.

The structure of the R&D for the SHP project is summarized in Figure 3. The development of this project is periodically reviewed by the members of the evaluation committee. The final goals of this SHP project are the construction of 1,000 kW scale pilot systems, where each system will consist of a combination of a highly efficient heat pump and chemical storage unit, and the conceptual design of a 30,000 kW system. For the interim evaluation of the project, the evaluation criteria for each plant was set by the committee, taking into account the scale effect and heat loss involved in the small-scale test plants. Heat pumps and chemical heat storage systems of various bench plants which were transferable were moved to Tsukuba to evaluate the performance of interim evaluations under the same conditions. The interim evaluation results of this major Japanese project are presented below.

In one of the highly efficient heat pumps an attempt was made to produce an output temperature of 85°C and COP of 8 by adopting a multi-stage condenser system, a high performance centrifugal compressor and motor unit, and by using a nonazeotropic refrigerant mixture. As a result of the development of the 1,600 kW class test plant and research on its operation, a COP of 7.7 was obtained. The performance goal of COP=8 is expected to be reached for the 2,400 kW pilot plant.

Another highly efficient heat pump is a bifunctional-type pump for heating (output temperature of 45°C from ambient temperature [ca. 10°C]) and cooling (output temperature of 7°C from ambient temperature [ca. 32°C]) for district and large building air conditioning. Increased efficiency has been achieved by reducing the driving energy, mainly through highly efficient screw compressor with innovative rotors, adoption of a two-stage economizer system, development of a plate-fin and counter-flow type heat exchanger, and use of a non-azeotropic refrigerant mixture. Operation of a bench plant whose thermal output is 190 kW (heating) / 170 kW (cooling) with COP=5.8 (heating) and COP=6.7 (cooling) was accomplished. These values exceed the interim evaluation criteria which were COP=5.5 and 6.5, respectively. The development and operation of a 1,000 kW class pilot plant

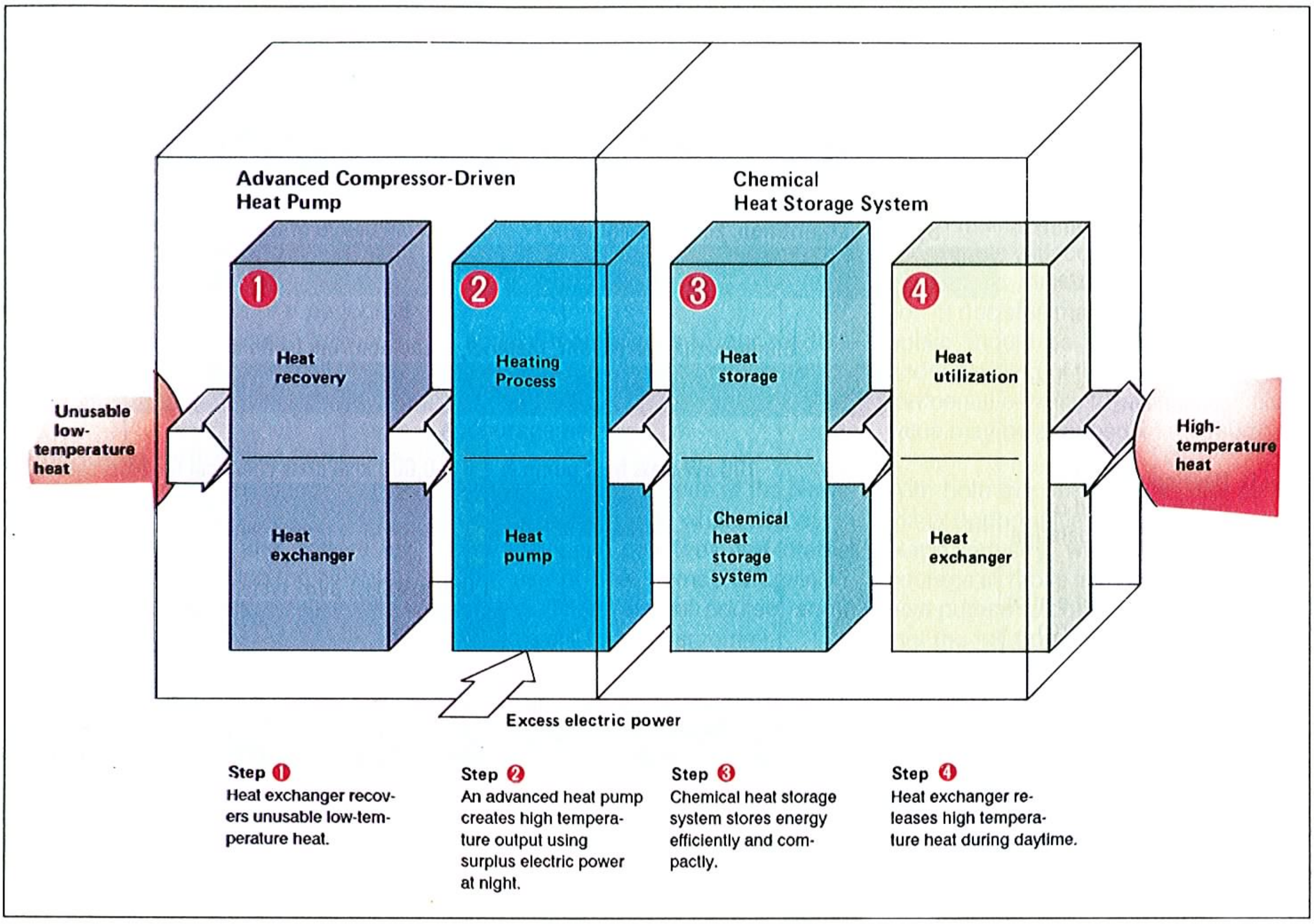

Figure 2. Conception of the super heat pump energy accumulation system for load leveling

are currently under way. Figure 4 shows this bench plant.

The second type of high performance compression heat pump is the high temperature output heat pump. One of the two developed bench plants is a large-scale screw compressor heat pump that recovers heat from low-temperature waste heat (at 50°C) discharged from a petrochemical plant or from other sources, and produces high-temperature steam (150°C), which can be utilized in various heat source fields, such as process heating for industry. This heat pump uses a thermally stable trifluoroethanol (TFE) and water mixture as the refrigerant enabling the two-stage compression system to produce high temperature output. The screw compressor -- the heart of the system -- is integrated with a biphase flow expander instead of a conventional expansion valve, thereby facilitating the recovery of power. The system also features thrust-offset structured rotors which eject vapor from both sides of the screw compressor for enhanced efficiency. The 180 kW bench plant finally attained the COP=2.8, which equals the COP set for the interim evaluation.

A high output temperature (300°C) heat pump for industrial use in oil refineries, petrochemical plants, etc., was also developed. This heat pump uses water as the refrigerant to take advantage of its thermal stability. It also utilizes a highly efficient high speed reciprocating compressor that uses a steam injection technology to realize a quasi-isothermal compression in the cylinder. In addition the pump features a turbocharger using steam from condensed water to reduce the driving power of the compressor. The effectiveness of this heat pump cycle has been verified on the 300 kW class bench plant with the achievement of a COP=2.4, which exceeded the criteria (COP=2.2) for the interim evaluation. A 1,000 kW class pilot plant is planned for construction. The results of the interim evaluation for the four high performance heat pumps developed in this project are summarized in Table 2.

The technology for components has also been developed and evaluated for the stainless steel plate-fin type heat exchanger, EHD (electro-hydrodynamic) condenser, and the flow channel reversal type evaporator for non-azeotropic refrigerant mixtures. Several kinds of non-regulated organic heat transfer medium were also developed and evaluated.

The chemical heat storage unit stores heat at either high or low temperature by utilizing chemical reactions. In spite of a number of proposals regarding chemical storage systems in chemical engineering research, to our knowl-

Item			Goals		
			Output temperature	COP	
Super high performance compression heat pump	High efficiency type	For heating[1]	85°C	8	
		For heating & cooling[2]	(heating) 45°C	6	
			(cooling) 7°C	7	
	High temperature type	For low temp. heat source[1]	~150°C	over 3	
		For high temp. heat source[3]	~300°C	over 3	
Chemical heat storage unit			Output temperature	Heat storage capacity	Heat recovery rate
	High temp. heat storage		~200°C	over 50 kcal/kg (refrigerant)	over 75%
	Low temp. heat storage		under 10°C	over 30 kcal/kg (refrigerant)	over 75%
	It is assumed that this SHP, when put to commercial use in the future, will surpass all existing systems in efficiency, applicability, load leveling effect, and other aspects of energy conservation. The goals for the pilot system are as follows:				
Pilot system (combination of heat pump and chemical heat storage unit)	Application		Output temperature	Energy efficiency	
	Office building air conditioning		(heating) 45°C	4.5	
			(cooling) 7°C	5.3	
	District heating/cooling and hot water supply		(heating) 45°C	4.5	
			(cooling) 7°C	5.3	
			85°C	6	
	Industrial process heating		150 - 300°C	over 2.3	
			Heat source temp: [1] 50°C [2] Ambient temp. [3] 150°C		

Table 1. Development goals

edge, there has been no substantial breakthrough in this field. In this project five different chemical heat storage technologies (three for high temperature storage and two for low temperature storage) have been developed. Three bench plants for high temperature storage were constructed. One plant utilizes ammonia complexes ($NiCl_2\ 6NH_3$, $NaSCN\ 3.7NH_3$) for 200°C chemical storage, another uses hydration of hydrated calcium bromide ($CaBr_2\ 2H_2O$) for 150°C heat storage, and the third one uses solvation of trifluoroethanol (TFE) / tetraethyleneglycoldimethylether (E181) for 85°C heat storage. Two bench plants for low temperature heat storage were also constructed, with one utilizing solute mixtures ($CaCl_2/LiBr$) to store 85°C heat and deliver it at 7°C when water evaporates, and another using clathrate of a mixture of water and an organic medium to store heat at less than 10°C.

The first heat storage unit will utilize the ammonia absorption/desorption reactions of ammonia complexes of $NiCl_2$ and NaSCN. This will enable the heat (200°C) produced by a heat pump to be stored at night and released during the day by using 50°C waste heat when heat is in high demand. Through the development and the operation of the bench plant with a heat storage capacity of 10,000 kcal, technical performance data has been obtained with a heat recovery rate of 38.2%, and heat storage capacity of 37.6 kcal/kg, which both exceeded the criteria of interim evaluation by 20% and 26 kcal/kg, respectively.

The second high temperature heat storage unit is characterized by the dehydration of calcium bromide hydrates by heating at 150°C derived from a compression heat pump driven by electric power at night. The process procedures also included heat storage achieved by separating the water by condensation and heat generation by the hydration of calcium bromide hydrates using water evaporated by an auxiliary waste heat source at about 70°C. The hydration reactor employs a plate-fin type reactor with an extended heat transfer surface, which is a component also developed in this project. The bench scale plant with heat storage capacity of the 10,000 kcal class achieved a heat recovery rate of 72.6% and heat storage capacity of 50.0 kcal/kg, which exceeded the targeted performance of 55% and 41 kcal/kg, respectively, in the interim evaluation for this chemical storage unit.

The third high temperature heat storage unit utilizes solvation of two types of refrigerant (TFE and E181). The TFE is evaporated using 85°C heat delivered by a compression heat pump during the night to produce a concentrated E181 solution. When heat is required the TFE which has been evaporated by auxiliary heat and compressed by a compressor is absorbed back into the concentrated E181 solution. The bench plant with a heat storage capacity of 11,000 kcal achieved a heat recovery rate of 60.5% and a heat storage capacity of 37.7 kcal/kg, which were both superior to the values of the criteria for the interim evaluation of 57.8% and 34.5 kcal/kg, respectively. Furthermore, this heat storage unit can also be used as a chemical heat pump (sorption compression type) because of its capability of raising the output temp. to between 80°C and 200°C. Figure 5 shows the bench plant with heat storage capacity of 10,000 kcal.

For the low temperature heat storage unit, the aqueous solution of the solute mixtures ($CaCl_2$/LiBr) is heated and concentrated using 85°C heat from a compressor heat pump during the night. The vapor generated goes through the hydrophobic membranes and is then condensed and stored. When low temperature heat is needed during the day, water absorbed by the concentrated mixture of the solutes collects latent heat of vaporization, and 7°C low temperature heat is created. The heat recovery rate was 60.8% and the heat storage capacity was 35.6 kcal/kg for the constructed 30,000 kcal class bench plant. The value of the heat recovery rate is almost the same as the criteria for the interim evaluation for this unit (75%); however, the heat storage capacity was below the criteria (34 kcal/kg) of the interim evaluation. This is because the heat capacity of the unit was overlooked. In fact, by taking into account the heat capacity of the container and heat transfer medium which correspond to the temperature change (from 85°C to 7°C), the heat recovery rate was estimated to be 82.0%. In the pilot plant of 250 Mcal heat capacity, this heat loss can be neglected and the targeted values for heat recovery rate and heat storage capacity can be easily attained.

The second low temperature heat storage system utilizes clathrate. Clathrate is a crystalline compound with fluidity which is formed when water is mixed with a small quantity of an organic medium and then cooled. A thermal storage system using clathrate has the following advantages: power required for low temperature heat storage is small, the heat stored per unit of volume is large, and the latent heat of fusion is nearly the same as that of ice. This compound has good heat transfer capability because clathrate is a sherbet-like crystal with excellent fluidity. The bench plant with a heat storage capacity of 30,000 kcal achieved the heat recovery rate of 64.4% and heat storage capacity of 31.2 kcal/kg, which are comparable to the criteria of the interim evaluation for a heat recovery rate of 62% and for heat storage capacity of 30 kcal/kg.

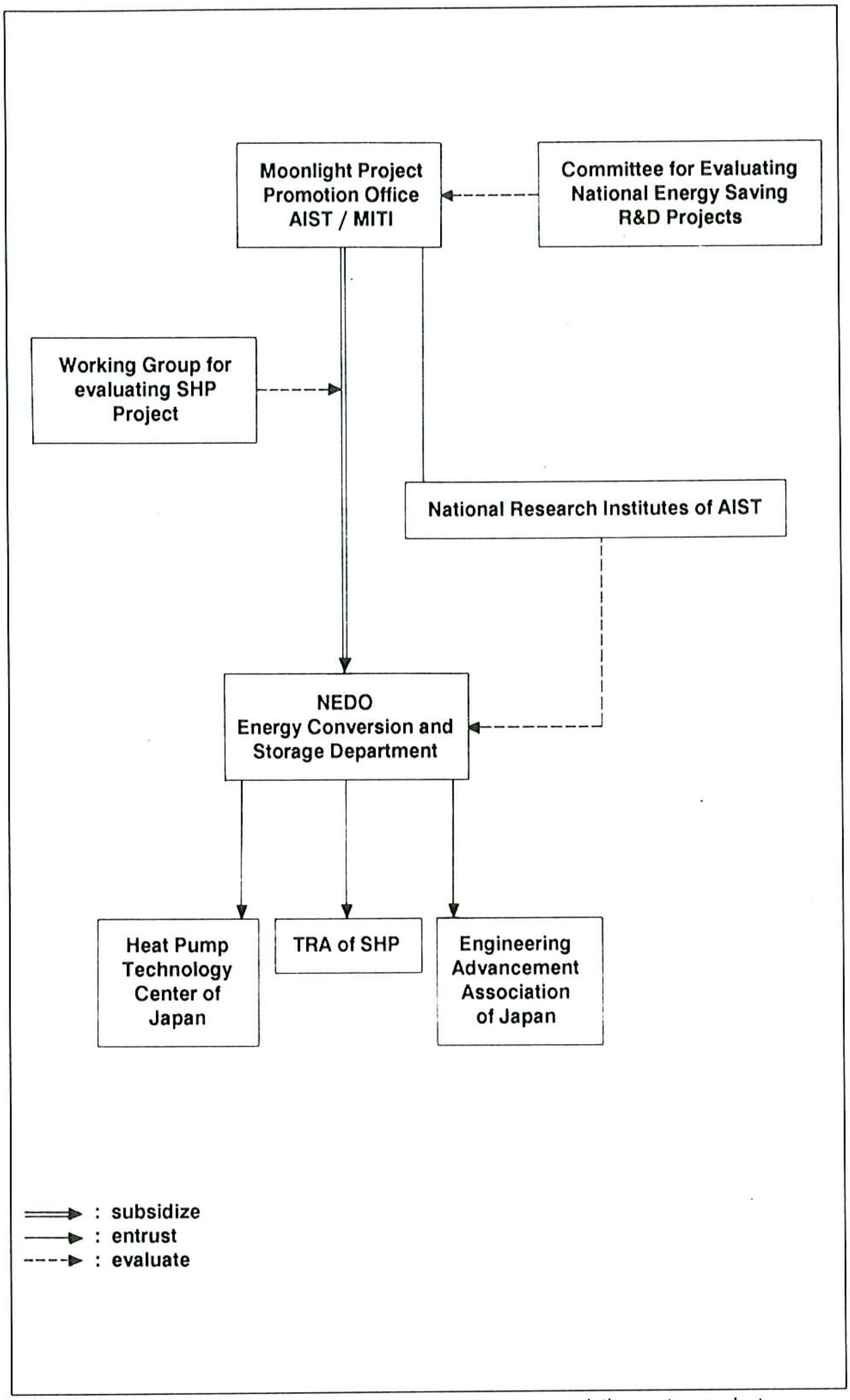

Figure 3. Organization of R&D for super heat pump energy accumulation system project

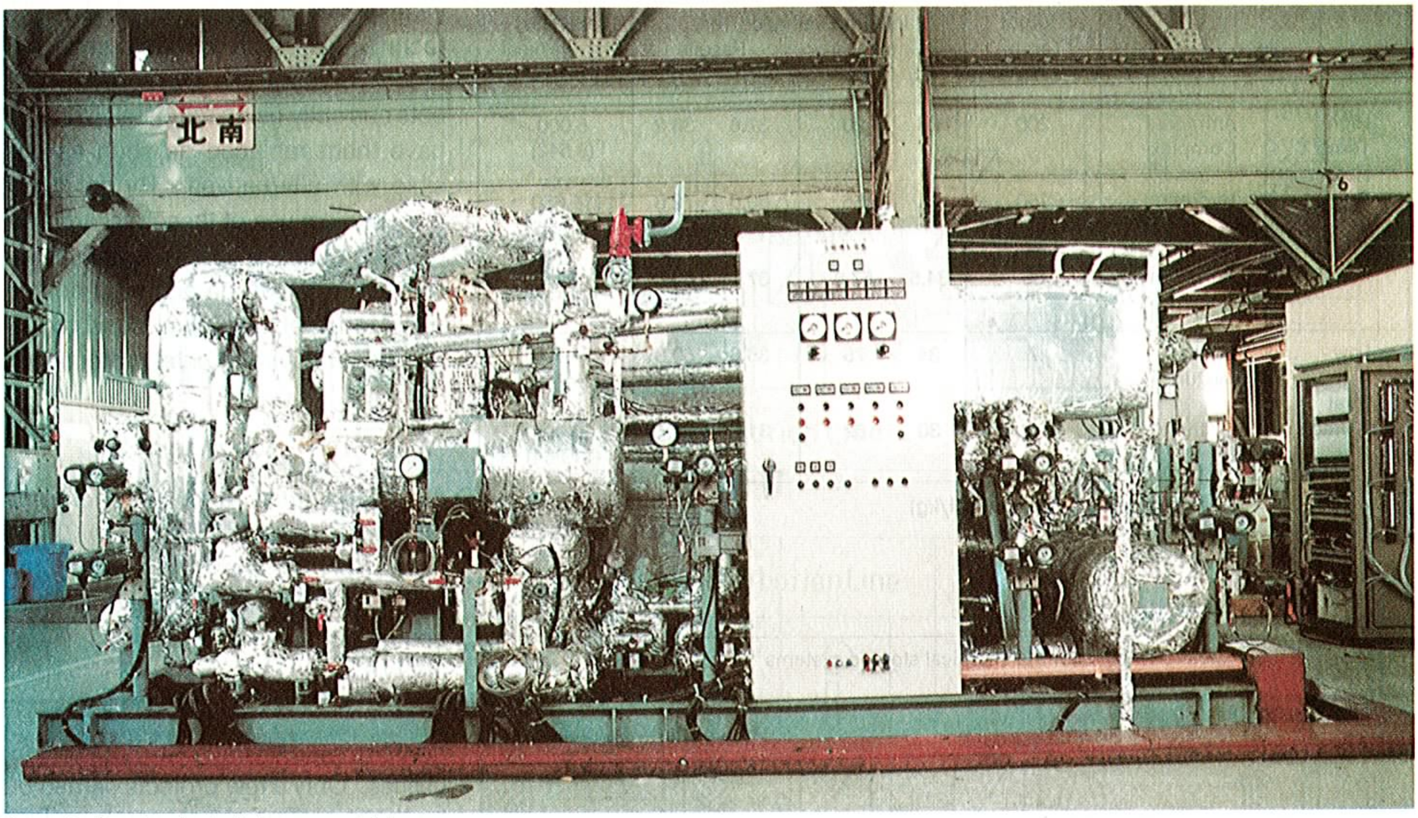

Figure 4. Bench plant of the super high performance compression heat pump for heating and cooling

The results of the interim evaluation for the five chemical storage units are summarized in Table 3.

Figure 5. Bench plant of the chemical heat storage unit of solvation type (TFE/E181) for 85°C heat storage

The interim testing of all items of each bench plant including components and new refrigerant performance were just completed. The final interim evaluation by the members of the committee for evaluating national energy saving R&D projects will be held next spring. A comprehensive report including social and economic aspects in addition to the technological aspects concerning the results of the interim evaluation for the bench plants will also be published. On the basis of successful technological advances made during this project, R&D for a pilot system combining the high performance 1,000 kW class heat pump with a chemical heat storage unit is being developed in an effort to gain

Item		Type of Compressor	Interim Evaluation Test COP		Thermal Output/kW (Result)	Refrigerant
			Criteria	Results		
High efficiency type	For heating	Turbo (centrifugal) (4-stage)	8.0	7.7*	1600 (1520)	R113/R114 (90:10 mol %)
	For heating & cooling	Screw (2-stage economizer)	5.5 (heating)	5.8	190 (193)	R22/R114 (87.5:12.5 mol%)
			6.5 (cooling)	6.7	170 (173)	
High temperature type	For low temp. heat source	Screw (2-stage)	2.8	2.8	180 (128)	TFE/H_2O (85:15 mol %)
	For high temp. heat source	Reciprocating (with a turbocharger)	2.2	2.4	300 (208)	H_2O
(*The COP=8 is expected to be achieved with the pilot plant)						

Table 2. Interim evaluation results for four high performance heat pumps

Item		Output Temp. °C	Interim Evaluation Test Criteria q	Criteria η	Results q	Results η	Total Heat Storage/kcal (results)
High Temp. Heat Storage	Ammonia Complex	200	26	20	37.6	38.2	6,000 (8,642)
	Hydration	150	41	55	50.0	72.6	11,650 (14,109)
	Solvation	85	34.5	57.8	37.7	60.6	11,175 (12,233)
Low Temp. Heat Storage	Solute Mixture	7	34	75	35.6	60.8 (82.0)*	31,800 (33,363)
	Clathrate	9.5	30	62	31.2	64.4	30,000 (31,264)

q : Heat storage capacity (kcal/kg)
η: Heat recovery rate (%)
1 cal = 4.19 Joule

*See text

Table 3. Interim evaluation results for the chemical storage systems

widespread acceptance of the SHP technology. With environmental protection becoming a global issue, projects currently using regulated CFCs will have them replaced as soon as possible with alternatives. By promoting the practical use of these research and development results, substantial energy savings can be achieved contributing to lower fossil fuel consumption and better environmental protection.

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H. Halozan*

Heat Pump System Development in Austria

Heat pump application in Europe means integration of heat pump units into heating and/or cooling systems, which have to be carefully engineered and designed to match the requirements of the customer as well as the characteristics of the heat pump. Considering these prerequisites for successful heat pump installation, cost effectiveness can be achieved in residential, commercial and industrial applications even in times of low oil prices. The most promising sector for heat pump applications is integrated energy systems. In such applications the heat pump unit is only one part of a sophisticated, carefully designed system, but it is the basic tool to realize these systems.

Introduction

The development of heat pumps in Europe was initiated by the first oil price shock in 1973, but the real market development started after the second oil price shock in 1979. Peaks in sales figures occurred in the different countries at different times according to national promotion programs; but no national program resulted in a stable market growth.[1] After a peak in sales figures all these markets stagnated or even dropped. Besides the high first cost and lack of cost-effectiveness, the unreliable operation of many heat pump systems was one of the main reasons for this market development. A second reason was that many people involved in the heat pump business did not realize that in European applications the heat pump unit itself is only part of a complex system which has to be designed and engineered very carefully.[2]

In Austria the same market development took place. But the influence of the oil price drop was not as hard as expected. There are still market niches which are the result of hard but continuous work carried out by designers, heat pump companies and distributors, and utilities. Only a few projects carried out by these groups are research projects like one ongoing even now at the Graz University of Technology and documented in reports; but many of these projects have reached a level desirable for the whole heat pump market. The systems work reliably and achieve low heating and operating costs. The customers of these plants do not really recognize that they utilize an advanced technology for heating or heating and cooling.

Residential applications

For residential applications two developments in Austria are very interesting. These are ground-coupled systems with direct evaporation and single-room heat pumps with direct condensation floor heating.

Ground-coupled systems with direct evaporation

Ground-coupled systems were introduced in applications where groundwater was not available and monovalent operation was required. Heat extraction from the ground was carried out by means of collector circuit installed horizontally in a ditch or vertically in the ground; the heat carrier was brine. Disadvantages of brine circuit systems are the temperature loss between brine and refrigerant and the power requirement

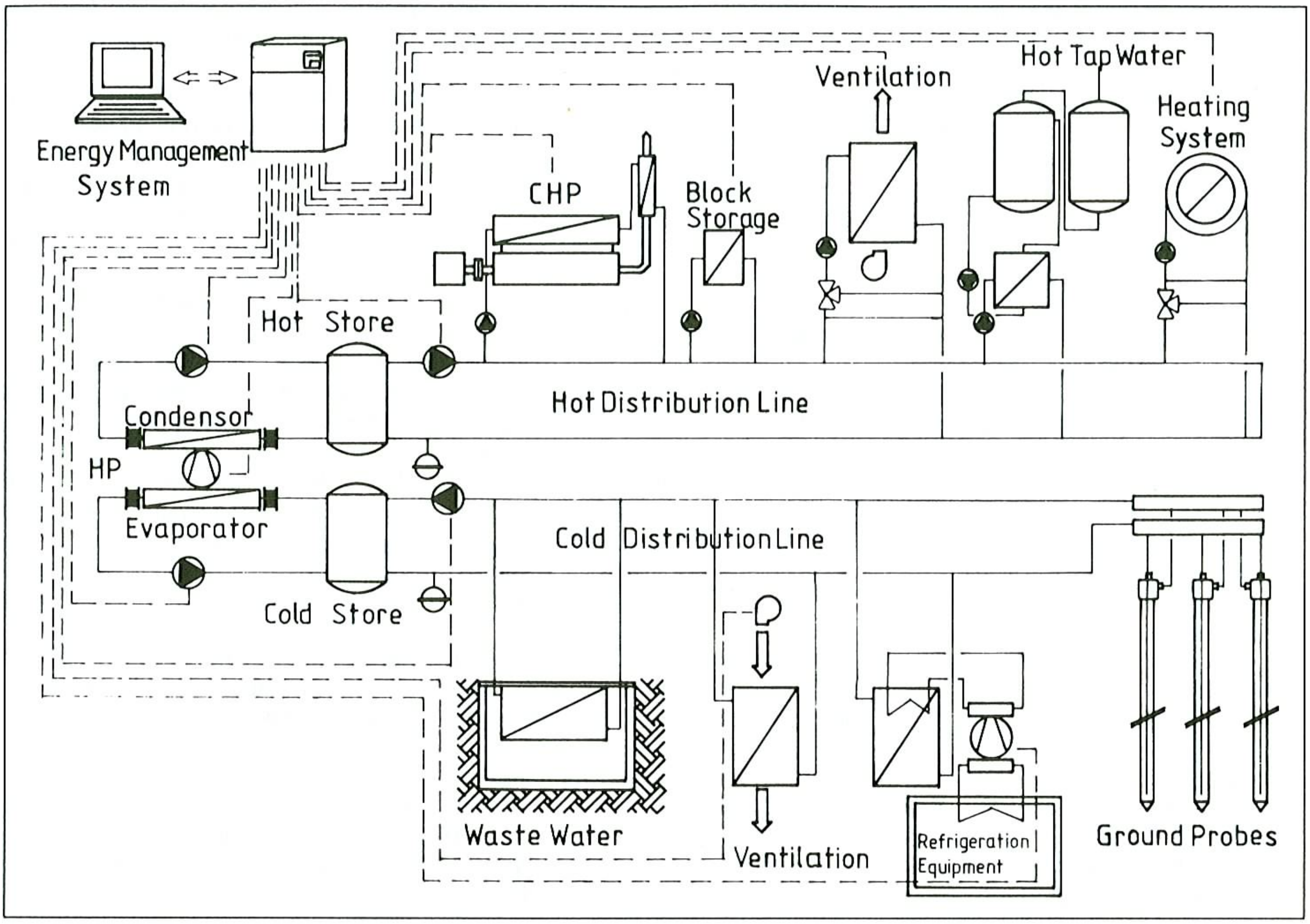

Figure 1. Integrated energy system

of the brine circulation pump especially at low brine temperatures.

Therefore the idea of direct-evaporation systems was born, where the evaporator is installed directly in the ground. Horizontally installed evaporators consist of one or more endless copper tubes with a plastic coating to avoid corrosion. Single-tube length is 60 to 75m, installation depth is about 1m, and installation costs are low. Properly sized, these systems run trouble free.

But in the case of limited space or a well-kept garden, the installation of vertical ground probes is preferable. Vertical probes are installed down to a depth of 100m. But in vertical evaporators some new aspects have to be taken into consideration: in the downcomer gravity results in a pressure and therefore an evaporation temperature increase. The evaporator has to be sized so that in the downcomer no markable pressure increase occurs and that the pressure drop in the riser is as low as possible; considering these requirements maximum efficiency can be achieved. In existing plants with vertical probes down to 60m SPFs (Seasonal Performance Factors) are in the range of 3.2.

Single-room heat pumps with direct condensation floor heating

Compared with central heating, single room heating is an efficient way to reduce the energy demand; in rooms, which are not occupied, the temperature can be reduced to reduce losses.[3]

This was the basis for a heat pump company to develop a single room heat pump system with a floor heating condenser. Endless copper tubes up to a length of 75m are installed like the tubes of a hydronic floor heating system on an insulation layer below the cement floor. The cement floor acts as a heat transfer area as well as a store. Control is carried out by a room thermostat.

The compressors are installed in the basement; up to six compressors are put into one cabinet. Each compressor is connected to one room. Heat sources are groundwater or the ground, which can be utilized by a direct evaporation, horizontally installed collector or by a vertical probe with a brine circuit. The system is sized for monovalent operation.

Integrated energy systems

In commercial/institutional applications the heat pump was originally used for cooling-only. In new systems the heat pump is used for both heating and cooling or, in other terms, for shifting energy to the two temperature levels required for heating and cooling. Figure 1 shows a heat pump connected to a cold and a hot storage tank. The cold storage tank has two functions--it supplies the cooling system and acts as a heat source for the heat pump, the hot storage tank supplies the heating system and tap water. Depending on the site, additional heat is provided by other sources and excess heat is delivered to other heat sinks. The following sections show some examples of characteristic installations.

Department store with a groundwater heat pump for heating and cooling

In a department store a heat pump system for both heating and cooling is installed. The heat pump takes heat from the cold storage tank and delivers this heat to the hot storage tank. The additional heat source in the case of predominant heating operation, respectively, the heat sink for predominant cooling operation is groundwater, separated from the heating/cooling water by flat plate heat exchangers.

The heat distribution system within the building consists of a four-pipe installation with fan-coils for heating or cooling and a floor heating system for the basement. The pipes for cooling are connected to the cold store, the pipes for heating to the hot store.

The control for the complete system is a computerized control which guarantees the temperatures in the different zones. The requirements of these zones, the outside temperature, and the operation times influence the temperatures in the two storage tanks which are provided by the heat pump.

The system is now in operation for 5 years, and some of the people have forgotten that the building is cooled and heated by a heat pump.

Office building with district heating for peak load and waste heat

The principal situation in an office building is the same as in a department store, only the internal gains caused by the computer equipment are much higher and cooling is a necessity to ensure reliable computer operation.

The installation of the heat pump is very similar to the heat pump in the department store. The amount of waste heat which can be utilized for heating purposes of the building is much higher.

An interesting solution was found for covering heating peak load and excess heat in the cooling mode: for both operation modes the district heating network is used. District heating is used for peak load heating operation, the district heating network, which has to be kept hot during summertime to avoid corrosion, acts as an heat sink. With this kind of installation no waste heat occurs, since all energy can be utilized.

Energy management system of a hospital

A requirement in hospitals and health resorts is a low energy demand to reduce operating costs. The energy demand is a result of the general demand for lighting, cooking, refrigeration, therapeutic measures, etc., and the demand for space heating, tap water, ventilation and air conditioning.

For the connection to the electric grid connection charges have to be paid once to the utility, depending on the power required. The electrical rate is split up in a demand charge based on the maximum power requirement occurring within a quarter of an hour and the working energy charge which is split up in different rates for day and night, summer and winter. The working rate is low compared with the rate in the residential sector; however, the demand charge is very high.

In a hospital many safety regulations must be fulfilled to ensure the energy supply. For electricity an emergency diesel generator has to be installed to avoid a shortage of electricity in the case of damage in the public grid. This diesel generator has to be tested each month for at least three hours to guarantee its function in the case of emergency. Furthermore, a great deal of equipment has to be installed twice.

Taking these preconditions it is necessary to install an integrated energy system with a highly sophisticated energy management system. The components of such a system are shown in Figure 1. The heat pump unit is the link between the cold and the hot side.

On the cold side waste heat is collected from waste water (which is stored in a daily storage tank), from the ventilation system, and from the refrigeration equipment. Additionally, vertical probes for heat extraction from the ground are installed.

On the hot side heat is utilized by the heating system, the hot tap water generation, and the ventilation system. Additional heat generating systems are a direct electric heater and the emergency diesel generator. This emergency diesel generator is equipped with coils for cooling water and exhaust gas, it is used as a combined heat and power plant to cover peak loads caused by electricity consumption and heating power requirement.

The main component to link these components into a system is a central computer control unit which acts as a sophisticated energy management system. This system optimizes the energy distribution within the building. Compared with conventional systems the demand charge can be reduced by 40 to 50%. Besides low operating costs compared to a conventional plant, a further advantage of this system is the reduction of emissions to a minimum. In new systems even the diesel engine, which is operated for less than 200 hours per year, is equipped with a catalytic converter.

Future systems

The final step in planning integrated energy systems is the design of regional energy concepts to minimize the demand on fuels by utilizing all sources of waste heat such as those mentioned above as well as waste heat from industry.

The successful implementation of heat pump applications can only be achieved if steps are taken to ensure that reliable and readily understood information is available to assist the prospective designer, purchaser, and installer of a heat pump system. The present high first-cost barrier of heat pumps must be overcome by appropriate information about the cost characteristics of a heat pump system. The savings in demand for commercial energy lead to reductions of investments in the energy supply system which more than compensate the extra cost for the heating system. Also the merits of energy efficient heat pump systems in reducing environmental pollution should be considered.

Conclusion

Even with the present oil price situation there are still market niches for heat pumps. In the residential sector monovalent ground-coupled systems for new buildings are competitive and the single-room heat pump seems to be very interesting. In the commercial/institutional sector heat pumps for both heating and cooling combined with heat recovery have an increasing market share.

The most promising market segment in terms of energy conservation is the field of integrated energy systems. But this means that the heat pump itself is only part of a very complex system, composed of several components, utilizing different heat sources, which has to be carefully designed and engineered. Information on such systems to support designers, installers, and purchasers is urgently required.

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M. Kaizaki*

Development of Gas Heat Pumps in Japan

Under the guidance of the Ministry of International Trade and Industry (MITI), manufacturers and gas companies in Japan are jointly commercializing and diffusing small-size gas engine-driven compression heat pumps (GHP) and absorption heat pumps (GABHP). There is also an ongoing development of Stirling engine heat pumps and Vuilleumier cycle heat pumps.

Commercialization of small gas engine heat pumps (GHP)

(1) Circumstances leading to commercialization

With a view to facilitating technical development of GHPs, the MITI invested a total of 1,500 million yen for three years, beginning in 1981. This was done due to the fact that in the energy policy implemented after the oil crisis for achieving conservation of energy, securing oil alternatives, and controlling the peak electric power load in summer, the use of gas-fired cooling was identified as a priority item. Thus technical development of the GHP was considered to be most realizable in the field of mass-produced gas-fired coolers. In the area of large units for commercial use, the diffusion of gas absorption chiller-heaters has already been facilitated.

Twelve manufacturers wanting to tap new business fields and three gas companies intending to tap demand for gas in summer organized a technology research association and carried out development of seven types of GHPs ranging in output from 1 to 10 RT (3.5-35kW) towards commercialization. Table 1 gives the initial time plan of the project leading to the results indicated. Figure 1 shows one of the GHP units.

Based on the results, advanced steps were taken for three years beginning 1984 by eight manufacturers and three gas companies towards commercialization and development of GHPs. One model was introduced on the market in 1986, and three small-capacity models were introduced beginning September 1987, thus providing GHPs in a capacity range of 1.3 to 13 RT (4.6-46kW).

Currently, 14 types of GHP units are produced by four different manufacturers. The gas engines come in three types -- gas-only original, one derived from a diesel engine, and one derived from a gasoline engine for automobiles. Two types of compressors are used -- one derived from an automotive compressor designed for R22 and a motor-driven open type.

The main technical hurdles which had to be solved for commercialization were as follows:

Small gas engines

- Increased efficiency (up 30%)
- Longer life (20,000 hours)
- Clean exhaust gas

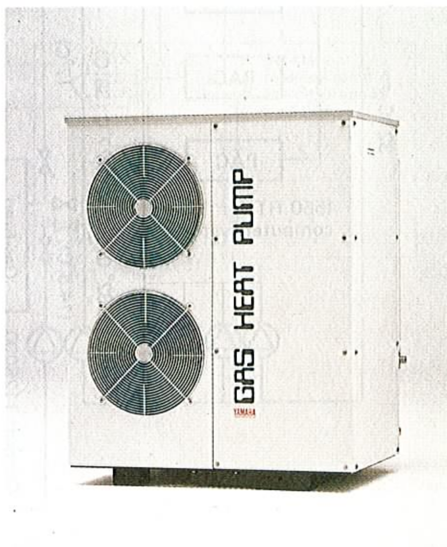

Figure 1. 4RT GHP

R22 compressors
- Longer life shaft seals for the open compressors

System
- Improved versatility, speed (rpm) control
- Effective utilization of waste heat
- Reduced noise
- Space saving
- Improved reliability and durability

(2) Products on sale

As mentioned previously, there are 14 types of GHP units available on the Japanese market. These are being installed in offices, schools, and restaurants, for the following reasons:

- Small power consumption (about 1/10 of electric motor-driven units), therefore, the received electric power capacity can be reduced

- Low running cost

- Large heating capacity resulting in short rise times

Year	1981	1982	1983
Phase	1st round of development and research on operation	2nd round of development and research on operation	Field tests
Activities	-Basic design -Trial manufacture and test of engine compressor -System test	-Design of commercial model -Trial manufacture and test of engine compressor -System test	-Design of field test unit -Construction of field test unit -Field testing
Expenditures (x 10^6 yen)	900	1,100	900
Subsidies (x 10^6 yen)	400	600	500

			Target value	Field test unit
System efficiency (COP)	Home use	Cooling Heating	0.85 1.37	0.99 1.40
	Small commercial use	Cooling Heating	0.90 1.57	0.73 1.54
Durability			10 years	To be confirmed
Maintenance			once/year	confirmed
Exhaust gas			Comparable to conventional boilers	confirmed
Noise level	Home use Small commercial use		under 50 phon under 60 phon	51 60

Table 1. Tasks undertaken by the Technical Res. Assoc., including goals/results of development

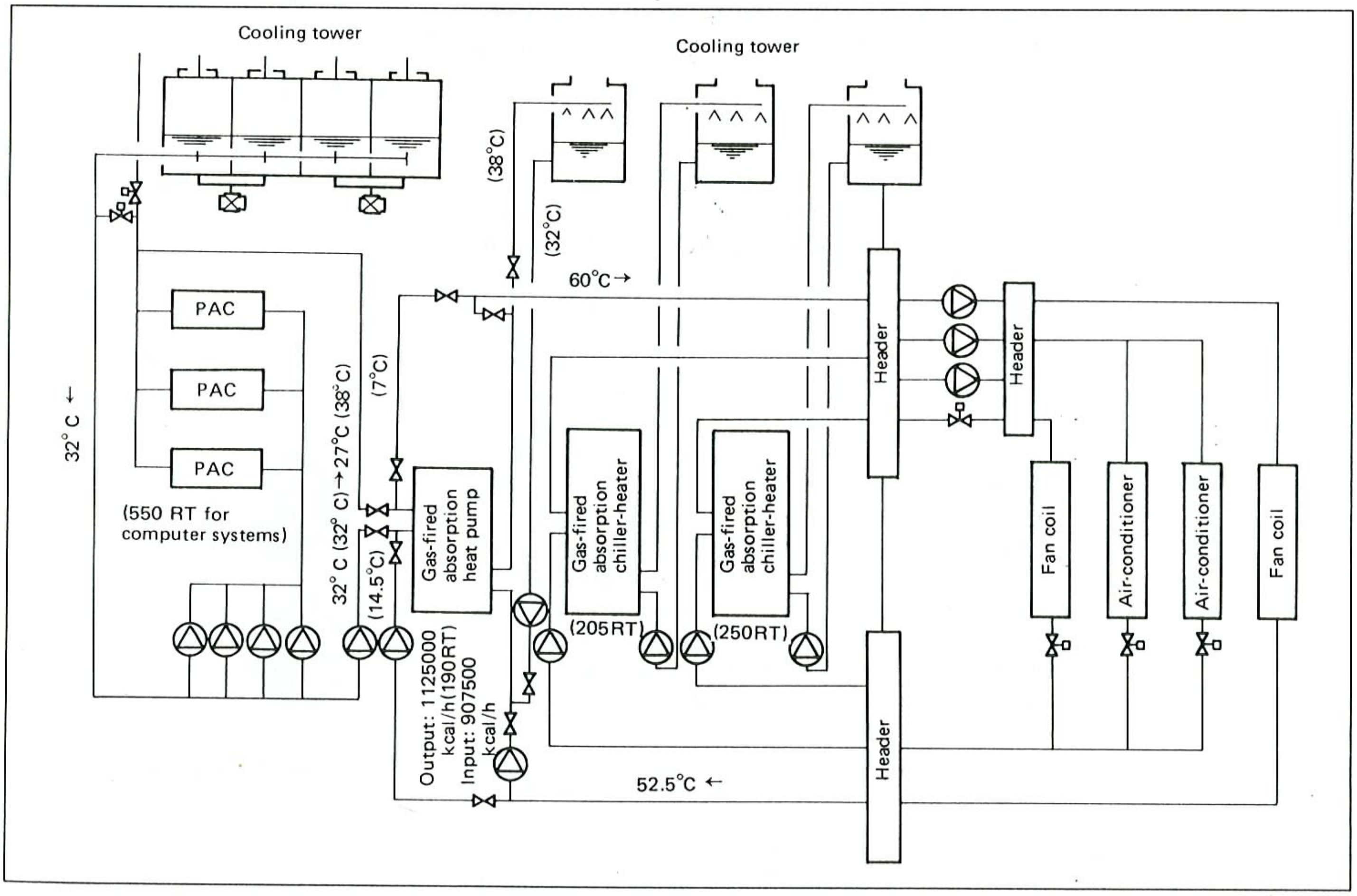

Figure 2. GABHP for a computer center

By March 1989, about 10,000 units were sold.

(3) Maintenance

A GHP requires maintenance once a year, therefore, a system for putting it into practice must be prepared. At present, maintenance is carried out jointly by service companies affiliated with the manufacturers, service centers of the distributors, and the gas companies.

(4) Future developments

In order to satisfy a variety of market needs, the line of products is expected to expand and will incorporate the following features based on technical developments:

-- Subdivided series availability of outdoor units, and expanded variation of indoor units
-- Increased allowance of head of refrigerant piping
-- Cost reduction
-- Commercialization of oil that can be used commonly
-- Extension of maintenance interval
-- Cleaner exhaust gas (NOx reductions, among others)
-- Commercialization of refrigerant heating cycle using engine waste heat for hot water production

Absorption heat pumps

(1) Circumstances leading to development

As a means of effective heat utilization and promotion of energy conservation, absorption heat pumps were taken up in 1976 by the Agency of Industrial Science and Technology (AIST), MITI, as one of main themes of R&D on waste heat utilization technology. This R&D project was included in the Moonlight Project in 1978, leading to development of a small unit for heating hot spring water. Thereafter, a gas absorption heat pump featuring direct city gas heating was developed and is widely used for cooling/heating, hot water supply, and preheating of water supplied in commercial buildings, district heating/cooling, and industrial areas.

Absorption heat pumps are manufactured by six companies also involved in manufacturing gas absorption chiller-heaters. The absorption heat pumps are water-source units using water-lithium bromide as the working fluid. They come in two types -- type 1 units of 70 to 9,000 Mcal/h in capacity and type 2 units of 150 to 4,500 Mcal/h in capacity. Type 2 serves as a heat transformer incorporated in an industrial process to deliver high temperature water or steam.

(2) Current status

Gas absorption heat pumps (GABHPs) are mainly installed in commercial

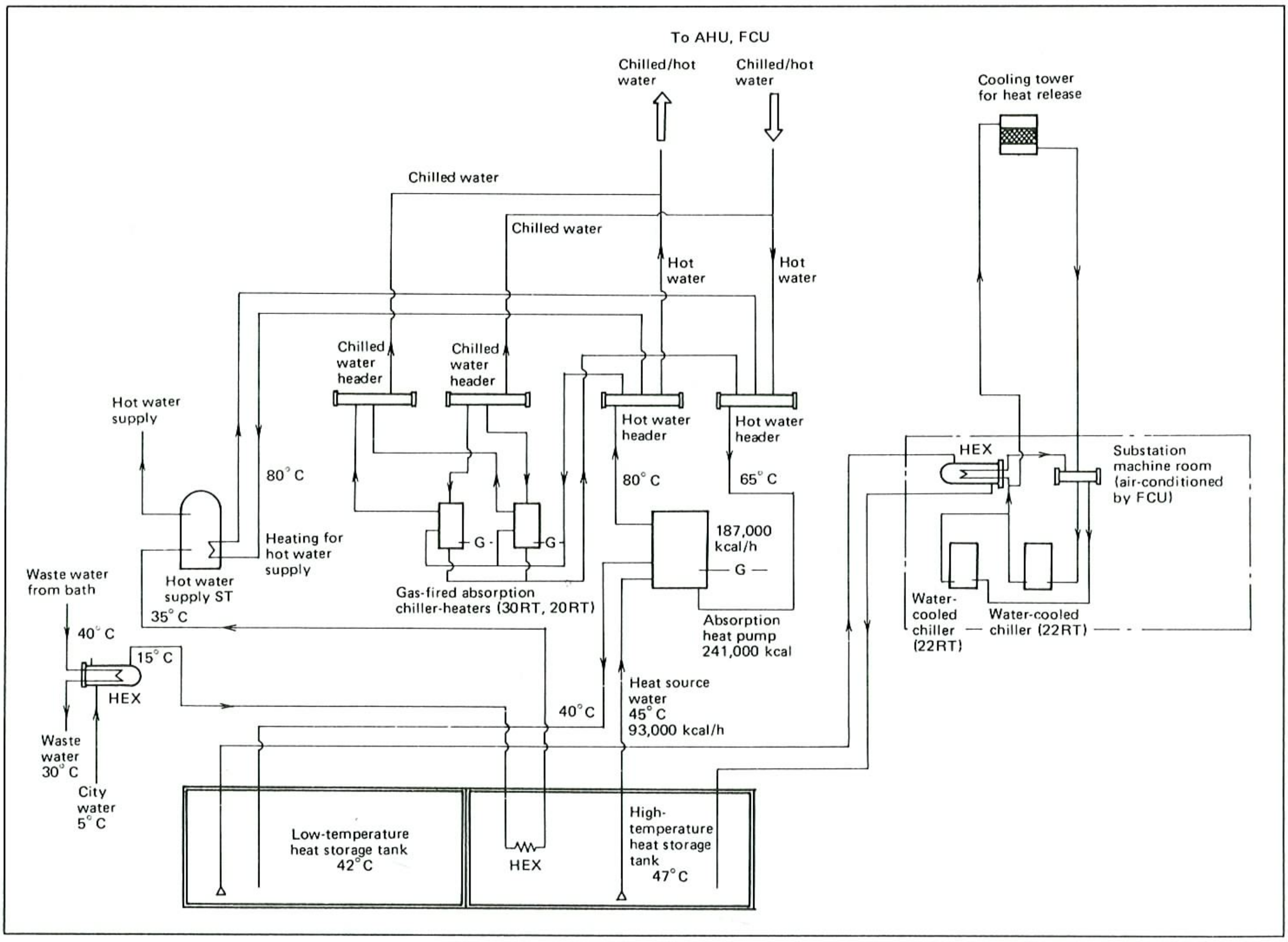

Figure 3. GABHP for a subway waste heat utilization system

buildings in Japan. Typically, they are used to collect waste heat from computers in a computer building and utilize it for office heating (Figure 2).

Recently along with city redevelopment in Metropolitan areas, GABHPs have been installed in district heating/cooling systems and subway substation waste heat recovery systems (Figure 3). Also, a GABHP unit has been put to a new type of use for hot water supply to a high-rise residential building utilizing heat from river water.

(3) Future prospects

It is expected that an increasing number of absorption heat pumps will be utilized as city waste heat recovery systems or high efficiency systems combined with cogeneration.

In view of market needs, the final goal of absorption system development is an air-source heat pump with cooling and heat pump mode selectability, heat pump operation down to -3°C outdoor temperatures (with bivalent operation at lower temperatures), a high COP comparable to double-effect units, low cost construction, and a capacity smaller than 20 RT (70kW). In order to realize these goals proper working fluids must be used. It is no exaggeration to say that the history of absorption refrigeration machines has consisted of searching for proper working fluids. On the other hand, it is also necessary to devise a compact design whose production cost is low by improving the performance of heat exchangers involving heat and mass transfer. Thus it is necessary to carry out research on the cycle, the working fluids, and the construction. It is expected that as CFC-free heat pumps, absorption heat pumps will continue to gain in importance as indicated by R&D projects underway throughout the world. The future course of development for GABHPs should be quite interesting.

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J.W.J. Bouma and P.J. Poolman

R,D&D Programs on Heat Pumps in the Netherlands

A great deal of the Netherlands annual budget for energy matters is provided through NOVEM (Netherlands Agency for Energy and the Environment). NOVEM is an organization for the management of energy and environmental programs for the Dutch government. Its most important client is the Ministry of Economic Affairs. Within the framework of government energy policy, NOVEM stimulates R,D&D and marketing of techniques, technologies and systems for energy conservation and fuel diversification. NOVEM aims at finding balanced solutions for both energy and the environment. Energy programs are at all times designed to take full account of environmental standards.

In 1990 emphasis in energy policy will be on conservation. In addition, the policy addresses diversification and further development of resources. The Ministry of Economic Affairs will spend Dfl. 634 million (US$ 315 million) on energy policy in 1990, which is 18% of their budget.

The basis for the work within NOVEM is provided by (multi) annual programs of activities in such areas as manufacturing (industry), the public utilities and the built-up environment. A separate program exists for long-term research. NOVEM drafts proposals for such programs on the basis of the policy goals set by the government in consultation with the parties in the market and outside experts, taking advantage of international developments and opportunities for international collaboration. Market parties involved are research organizations, universities, laboratories, and the private sector. This article deals with the heat pump related parts of the programs.

Energy conversion technology (1989-1993)

NOVEM's long-term research program is concerned with high risk technological developments that cannot be expected to lead to technically and economically viable applications until about the year 2000. In addition to achieving energy objectives, emphasis is on stimulation of industrial development.

Long-term research concentrates on two main areas of interest: renewable energy sources and technology development. The Energy Conversion Technologies program fits into the second area of interest. It is designed, through R&D, to increase conversion efficiencies in components, apparatus and systems and reduce flue gas emissions during heat and/or power production. The emphasis is on conversion of natural gas into heat and/or power. The program deals primarily with developments aimed at the built-up environment market sector. The nature of R&D work is applied scientific. Contractors are primarily research organizations and universities, although industrial participation is pursued in order to focus on applied research. Industry may be involved through project management and financial support. The program addresses, among other things, the problems of absorption heat pumps (40-100 kW) and a high speed integrated electric motor-turbocompressor set for heat pumps. In the period 1989-1993, Dfl. 6.2 million is available for long-term heat pump R&D. This is 31% of the total conversion technology budget.

Pre-studies are carried out to find ways to improve sorption heat pump technology. An example is the application of membranes. Sorption heat pumps may benefit from new processes in which membranes are applied, especially in the case of fluid pairs that need additional treatment after conventional distillation. An adequate membrane process would allow for omitting the additional treatment resulting in the number of potential adequate fluid pairs increasing.

Current compression heat pumps show moderate COPs (2.5-3.0). A higher performance will speed up implementation of heat pumps in the market. Therefore development of a small capacity (32 kW) high-speed electrical heat pump with high COP (>5) is supported. A Seasonal Performance Factor (SPF) higher than 6 is the target. The heat pump will be designed to produce minimum noise. The concept involves a variable high speed (60,000-100,000 rpm) electric motor, a turbo compressor and a turbo expander. Both compressor and expander use the same refrigerant, also as a lubricant.

First tests with a laboratory model were concluded successfully. At the end of 1990, an integrated module will be available for testing, followed by a prototype and production preparation.

Demonstration and implementation

NOVEM is in touch with developments in the market and maintains a close watch on technological progress. Short-term R&D and demonstrations on energy and environmental issues are embedded in market-oriented programs of activities related to sectors such as industry, agriculture and the built-up environment. Together with partners, work is performed to improve energy management, to promote the use of new systems and technologies, and to improve energy conversion. Heat pump activities concentrate on a limited number of sectors in industry. The conditions in these sectors are right for a major reduction in energy consumption. In addition, evaluation and troubleshooting studies and monitoring of installations in agriculture and the residential/commercial building sector are undertaken. The objective is to broaden the insight and improve existing installations.

Within the market sector of industry, heat pump activities mainly deal with demonstrations, supporting research, monitoring, development and market studies. Key sectors are the food industry (starch, brewery, malting) and the chemical industry. In the food industry, mechanical vapor recompression is an important option, especially for vapors other than water, e.g., acetone, methanol, as are two-stage systems. In the chemical and metal industry, attention will be paid to heat transformers. Corrosion problems that occur with a heat transformer are studied in close cooperation with the user. The outcome of the study will be used to modify the heat transformer and will also be implemented by others, e.g., metal industry (iron works), in planning and preparing adequate specifications. Demonstration of a heat transformer driven by the heat rejected from a hot strip mill is foreseen. Hot water will be produced for a cold reducing mill. The heat transformer, strip mill, and reducing mill will be located some distance from each other. One innovative aspect is that the heat transformer is linked between two different processes. Special attention will be paid to control of the system and its backup. The start of the operation is scheduled for late 1990.

Since 1986 at Randamax, a boiler manufacturer, the development of gas-fired sorption heat pumps is supported. The aim is to introduce high-efficiency, low NOx sorption heat pumps into the market in the early 90s. The range of heating capacity is 250-1500 kW. Potential markets are greenhouses (heating and CO_2-fertilization), commercial buildings and air-conditioning in Southern European countries. Development topics are inexpensive compact heat and mass exchangers, the integrated design of components, an internally driven solution pump, and a cheap and reliable heating tower for heat extraction from the ambient air.

Present development deals with upscaling and optimization of the concept. Technology has already been proven in a laboratory module. Currently a 50 kW one-stage absorption heat pump is being tested. Potential end-users and installers are involved in the development at an early stage in order to focus on the specific operating conditions in each sector. A 250 or 500 kW prototype is foreseen in 1990. It will comprise, among other things, plate fin-type very compact heat exchangers (700-1400 m^2/m^3). Development aims at minimizing manufacturing costs of the system to such an extent that investment can be justified even at the current low energy prices.

A second industrial development which is supported deals with adsorption technology. The objective is to develop a competitive chemical heat pump primarily for the residential market. The system works with sodium sulfite in water. The development aims at a high cycle frequency and high specific power output. The project and the technological achievements will be scrutinized with respect to the technical risks involved and the market perspectives before the final project stages are entered. The aim here is to build a pilot module and to commercialize it.

Knowledge transfer

Knowledge transfer on heat pumps R,D&D is a key element in the program. Transfer of knowledge and technology to target groups is realized by means of publications such as evaluation and analysis reports, market study reports, presentations and articles, and also through organizing workshops and seminars, by participation in international R,D&D programs (EC) and collaborative projects (IEA) relevant to the Netherlands program and by programs of courses and training. This is done in close collaboration with industrial and other cooperative organizations in order to reach the target groups as effectively as possible through existing channels.

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R.L. Douglas Cane*

Heat Pump Performance Standards Development in Canada

The author presents the historical development of standards for heat pumps in Canada. The impetus behind the development of standards has changed from concerns with equipment reliability, poor design and installation practice to that created by emerging new technologies, free trade and energy efficiency regulations. Canada's unique climate and energy supply infrastructure often call for standards quite different from other countries.

Heat pump systems have been commonly applied in space conditioning of Canadian buildings since the mid-1970's. At about that time, air-to-air heat pump sales reached 500 units per year. Many of these early systems experienced serious equipment reliability problems and customer dissatisfaction with performance.

These events led to the formation of a Technical Committee at the Canadian Standards Association (CSA), to draft the first performance standard for heat pumps. This standard, CSA C273.3-1977, laid down performance requirements, standard rating tests and maximum operating condition tests for both air and water source heat pumps and referenced ASHRAE Standard 37 - 1969, as the Method of Testing for Determining the Standard Ratings. While CSA C273.3-1977 was largely equivalent to Air Conditioning and Refrigeration Institute (ARI) 240 and 320, it contained the unique feature of minimum energy standards for heat pump equipment within its scope. The standard was never formally adopted by any regulatory authority. Since certification was voluntary, no equipment was ever tested and rated in accordance with the standard.

Following completion of the performance standard, the same Technical Committee undertook the development of an installation standard for air source heat pump equipment. Many of the reliability problems were thought to be the result of poor practice in installation, design, initial start-up and maintenance procedures. CSA 273.5-1980 was drafted to cover facets of design and installation such as heat pump sizing in relation to load, length of interconnecting refrigerant lines, unit location, elevation above ground, ductwork and so on. During the early 1980's, this standard was enforced by some provincial utilities as a necessary requirement before heat pump installations could receive a Canada Oil Substitution Program (COSP) grant. The installer was often reluctant to complete the paperwork which contained the installing contractors certification that he had carried out the installation and start-up in accordance with CSA 273.5-1980. Completing the form was said to be time consuming, requiring information that was considered by the industry to be superfluous to good installation requirements.

It was not until 1987 that the subject of heat pump performance standards was once again re-opened. The reason this time was Free Trade negotiations between the United States and Canada, on one hand, and looming energy efficiency legislation in Ontario on the other. Product standards were seen as potential non-tariff barriers to free trade of goods between the two countries. The United States legislature had just passed its National Appliance Energy Conservation Act which increased the Province of Ontario's interest in doing the same.

A new CSA technical committee was named and met on three occasions to review recommendations prepared by a consultant to the committee on what courses of action were available to the committee to "harmonize" with the U.S. standards. The subject standard of interest was the original heat pump performance standard CSA 273.3-1977. In the ten years since the publication of the standard, the United States Department of Energy (DOE) had managed the development of sophisticated cyclic test methods and analytical procedures to determine seasonal efficiency ratings for both air conditioners and air source heat pumps. Canadian Standards were so far behind on developments in this area that a preliminary decision was taken in September 1987 by the Technical Committee to adopt a number of the steady-state heating and cooling tests embodied in the 1979 DOE rule. However, the Committee stopped short of requiring manufacturers in Canada to undertake the two cyclic tests required to determine seasonal efficiency ratings. This was recommended in order to minimize both the cost of certification testing and the ultimate cost to Canadian consumers of Canadian manufactured heat pump equipment. The minimum levels or energy standards originally set forth in CSA 273.3 were also to be updated. Finally, a more significant decision was taken by the Technical Committee, at its final meeting in September 1987, and that was to include central air conditioning equipment within the scope of the standard. Central Air Conditioning sales have experienced phenomenal growth in regions of Canada in the latter half of the 1980's and a performance standard for central air conditioning is now seen as a very important development.

Another development in 1987 was the formation of the Canadian Earth Energy Association and a commitment by its manufacturer, distributor, and dealer members that industry standards were needed for both equipment and installation practice. CAN/CSA-C445-M89, Design and Installation of Ground and Water Source Heat Pump Systems, was published in February 1989, while CAN/CSA-C446-M89, Performance of Ground and Water Source Heat Pumps, was published in May 1989.

With the exception of the Ground Water Source heat pump provisions in CAN/CSA-C446, there was little precedence elsewhere to serve as a base for the development of the two standards. The Design and Installation standard sets forth requirements for earth-loop sizing in relation to building loads, piping materials, pipe installation and loop design. Backfilling of vertical boreholes, on-site testing, equipment design and installation, ductwork and warranty on the earth loop are other areas covered in the standard. Two Certificates are appended to the Standard and are to be completed and signed by the installation contractor as certification that the installation is in accordance with CAN/CSA-C445-M89. Copies are to be forwarded to the purchaser, electric utility and manufacturer or distributor, as appropriate. At the time of writing no regulatory authority has required that ground source heat pumps be installed in accordance with the new Standard. However, it is expected that failing regulation and inspection by electric utility or government authorities, the industry may elect to mandate compliance itself, in a similar fashion to that practiced by the Air Conditioning and Refrigeration Institute (ARI) on equipment performance in the United States.

The performance standard, CAN/CSA C446-M89, sets minimum efficiency levels for both ground-coupled and well-water heat pump cooling and heating modes of operation. The Standard requires the use of a 15% by weight methanol and water solution for all tests for equipment certified for earth-loop application. The Standard also includes an allowance for pumping energy in arriving at power input and efficiency values. This is based on a calculation which uses measured liquid static pressure drop internal to the unit and a constant external pressure loss or external head, depending on the application. The manufacturer can specify the liquid or water flow rate to be used for testing, as opposed to the fixed temperature difference approach to establishing flow rate for all tests. The intention here was to encourage innovation in heat exchanger design in the interests of overall efficiency (lower flow rates) and reduced water use in well-water systems. As of January 1, 1990, all ground and water source heat pumps for sale in Ontario must be certified to be in conformance with the standard.

Following completion of the Ground and Water Source heat pump standard in the fall of 1988, the Canadian Standard Association's Air Conditioning and Heat Pump Technical Committee turned its attention to the revision of CSA 273.3. While the original committee had taken a preliminary decision in September, 1987, to test and rate for steady-state rather than seasonal performance values, the reconstituted committee, 18 months later, decided to adopt, in its entirety, the Department of Energy rule on both central air conditioners and air source heat pumps. At the time of writing, the Committee has decided to adopt minimum levels of 9.0 for Seasonal Energy Efficiency Ratio (SEER) and 6.8 for Heating Seasonal Performance Factor (HSPF). The HSPF of 6.8 is based on a Region IV location as per the DOE rule and is an identical energy standard to that set by the United States National Appliance Energy Conservation Act for split-system heat pumps.

The SEER of 9, on the other hand, is lower than the 10 currently set for split-system central air conditioners in the U.S. regulation. The lower SEER was set in recognition of the shorter summers in Canada with fewer hours of operation. It also recognizes the concern that Canadian industry be given a longer time frame to raise generally lower levels of performance on domestically produced air conditioning equipment. At the time of writing, the standard is still undergoing revisions to accommodate the changes in the Department of Energy's final rule published in March of 1988. Several levels of approval are required before the Standard is published, likely by mid-1990. Products covered by this standard will also be regulated under Ontario's Energy Efficiency Act.

The foregoing has described the driving forces behind and the development of heat pump standards in Canada since the mid-1970's. While the initial impetus for heat pump standards was to improve equipment reliability and customer satisfaction, by the late 1980's, the renewed standards development activity in Canada has been driven by a combination of free-trade and energy-efficiency regulation initiatives. Since the Canadian industry is largely owned by United States Corporations, under "free-trade," pressures constantly exist to adopt similar if not identical standards for heat pumps to those in the United States. While it must be acknowledged that considerable, thorough background research has been undertaken in the United States in support of their heat pump standards development, the "cold" reality is that in Canada the climate and energy supply infrastructure are dramatically different to that in the continental United States. This necessitates unique performance requirements for heat pump equipment, of all types, in Canadian applications. The Canadian performance standard for ground source heat pumps is an example in point. New heat pump products are emerging on the Canadian market and will necessitate both test method and energy standard setting in the near future. Many of the existing standards will require revision to reflect advances in the state-of-the-art. Some of these new heat pump standards will, by necessity, embody unique performance and/or installation practice requirements for Canadian application.

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A. Milbitz*

CEN/TC 113 Heat Pumps

In 1993 free trade will be established between the 12 member countries of the European community. In order to take full advantage of this arrangement unified standards are needed, especially for industrial products. CEN/TC 113 is the technical committee within the European Committee for Standardization (CEN) responsible for the writing of standards for electrically-driven compression heat pumps used for space heating and/or cooling or sanitary hot water production. To date only a portion of the nine part standard designated as EN255 is nearing completion. This article describes the current status of TC113's work and gives a review of EN255 parts 1 and 2.

The European market 1993

On December 31, 1992 the free flow of goods and services will commence across the borders of the 12 member countries of the European Community. The establishment of free trade between these 12 countries will have many perceived economic advantages. The size of the combined population is 320 million people (350 million if Finland, Norway, Austria, Sweden and Switzerland, members of the European Free Trade Association, EFTA, are included) or 1.5 times the population of the United States. Presently the United States has a gross national product that is 1.5 times larger than Europe's. In part this is due to the lack of trade barriers in the United States, thus the potential for the growth of Europe's internal market once trade barriers are removed is very large.

What needs to be done by 1993?

In order to realize the full potential of a unified European market a number of activities, especially the development of unified industrial standards, must be carried out by the end of 1992. Two committees, CEN (European Committee for Standardization) and CENELEC (European Committee for Electrical Standardization), have been established to carry out a portion of this work. The scope of their activities is limited to clearly definable objects urgently requiring unified standards. If an ISO/IEC standard already exists or is being worked on then CEN/CENELEC work will concentrate on using this standard directly or as a basis for further work. Already existing international standards are thus given priority. On the other hand if a need is seen to establish standards different from already existing international standards then these will be promoted by CEN/CENELEC member countries as possible ISO/IEC standards. CEN/CENELEC members are the standards institutes of the European Community countries and the European Free Trade Association (EFTA) countries.

The actual standards writing work is carried out by specific technical committees (TC). Currently there are 212 TCs among which is CEN/TC 113 "Heat pumps and room air conditioning units." The member countries of CEN/CENELEC are bound to implement all European standards (EN) which are agreed upon and to discontinue any conflicting standards writing work in their country. These countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Sweden, Portugal, Spain, Switzerland, and the United Kingdom. It is estimated that the European Community will require the establishment of over 5000 unified standards.

Heat pump standards for Europe

CEN/TC 113 is the technical committee currently in charge of writing standards for heat pumps. These are designated as EN 255 "Heat Pumps; heat pump units with electrically driven compressors for heating or for heating and cooling." Industrial heat pumps are not within the scope of TC/113 activities. There are presently nine parts to standard EN255 as listed below:

- Part 1 - Terms, definitions and designations;
- Part 2 - Air/water heat pump units, testing and requirements for marking;
- Part 3 - Water/water and brine/water heat pump units, testing and requirements for marking;
- Part 4 - Air/air heat pump units, testing and requirements for marking;
- Part 5 - Water/air and brine/air heat pump units, testing and requirements for marking;
- Part 6 - Heat pump units for heating or for heating and cooling, requirements;
- Part 7 - Heat pump units for heating or heating and cooling and heat pump units for heating sanitary water, measurement of the emission of airborne noise, determination of sound power level;
- Part 8 - Heat pump units for heating sanitary water, definitions, testing, and requirements for marking;
- Part 9 - Heat pump units for heating sanitary water, requirements.

Current status

TC/113 held its first meeting in 1985. The secretariat is the Federal Republic of Germany acting through DIN (Deutsches Institut für Normung e.V.). The current status of each part of this standard varies. For example only part 1 is currently being implemented as a European Standard having gone through the official approval process. Each part of the standard, once it is accepted as an official European Standard, will appear in three languages (German, English, French) and can be translated into any other language as required by the individual member countries of CEN. Parts 2-9 of EN255 are still being worked on or voted on within CEN. Parts 2 and 3 will be formally voted on this year. Parts 4-9 of EN255 are in earlier stages of the standards process.

The final draft version of part 2 of EN255 will be submitted at the end of 1989 for formal voting. Part 2 contains performance tests and marking requirements for air-to-water heat pump units with electrically driven compressors used for space heating or space heating and cooling. The standard is divided into six main headings covering scope, references, terms and definitions, performance testing, reporting of results, and marking.

What are these standards like?

In order to answer this question EN255 parts 1 and 2 will be briefly outlined. In general parts 2, 3, 4, and 5 of EN255 are very similar in structure and testing requirements. Parts 6 and 9 give the minimum requirements that heat pump units must meet. Part 7 covers the measurement of airborne noise and part 8 covers the special definitions and testing requirements for sanitary hot water heating heat pumps.

EN255 part 1

EN 255 part 1, which is going into effect this year, is basically a document defining various terms used in the other parts of the standard. Annex 1 gives a listing of these terms and their definitions as given in the standard.

EN255 part 2

EN255 part 2 covers testing and the requirements for marking of air/water heat pump units. The following is a description of this standard.

The performance test section of EN255 part 2 states that the heating or cooling capacity of a heat pump is to be determined at the indoor heat exchanger by the determination of the flow rate of the heat transfer medium and of the inlet and outlet temperatures taking into consideration the specific heat capacity and density of the heat transfer medium.

The standard requires duct connected units to undergo an air leakage test. This is to be done by blocking off all air inlets and outlets to the heat pump and pressurizing the heat pump ductwork to half the maximum static pressure available from the installed air conveying device at the nominal flow rate. This is done for both positive and negative pressures. The leakage must not exceed 5% of the nominal flow rate.

The requirements for the test installation are also described in the standard. In general it must be a facility that is capable of meeting all requirements on adjustment of set values, stability criteria, and accuracy of measurement as called for in the standard. Requirements are set for the test room for the outdoor heat exchanger concerning the flow of air to the heat pump inlet and outlets and the distance of the inlet and outlet orifices from the surfaces of the test room. Temperature measuring devices and the heat pump unit itself are to be protected from direct heat radiation from any heating device in the test room. Air and water flow rates are to be set by using the maximum external static pressure difference specified by the manufacturer at the nominal flow rate. The resulting flow of water or air is considered to be the nominal flow.

Installation of the test object is to be done according to the manufacturer's instructions. For heat pumps consisting of several parts (split heat pumps) the standard requires that each refrigerant line be installed in accordance with manufacturer's instructions.

A table is given in the standard which specifies the allowable maximum values of the mean uncertainty of various measurements. For example the air dry and wet bulb temperature measurements must have an uncertainty of at most ±0.2K. The heating or cooling capacity of the heat pump must be determined to within an uncertainty of ±5% independent of the individual uncertainties of measurement.

Environmental conditions for the interior mounted units/parts are also covered in the standard. These shall be exposed to a dry bulb temperature of 15°- 25°C during the rating test. All other parts are to be exposed to the dry bulb temperature specified as the inlet air temp. The rated voltage and frequency is to be supplied to all devices.

Rating test points are defined in the standard for outside air/water heat pumps with or without defrost control and for exhaust air/water heat pumps. These are designated as T1, T2, T3, T4, T5, and T6 as shown in Table 1. The heat pump must be tested at all of the appropriate conditions given in Table 1.

The standard also describes the test procedure for determining the output of

Test condition (T)	Outside air/water heat pumps		Exhaust air/water heat pumps
	with defrost control	without defrost control	
Heating			
(T1)	A 7 (6) W 50	A 7 (6) W 50	A 20 (12) W 50
(T2)	A 2 (1.5) W 35	A 15 (12) W 50	A 20 (12) W 35
(T3)	A 15 (12) W 50	A 7 (6) W 35	---
(T4)	A -7 (-8) W 50	--	---
	If not (T4) then: A 2 (1.5) W 50	If not (T3) then: A 10 (8) W 35	
Cooling, if applicable			
(T5)	A 35 (24) W 7	--	---
(T6)	A 27 (19) W 7	--	---
A - Air W - Water			

Notes:

a. Air temperatures in brackets are wet bulb temperatures in °C.

b. All air temperatures are inlet temperatures in °C.

c. Water temperatures for the indoor heat exchanger are outlet temperatures in °C.

d. All tests carried out with nominal flow rates indicated by the manufacturer in m³/s. Where only a range of flow rates is given, tests are to be carried out at the minimum value.

e. Permissible external pressure difference and associated internal pressure difference at the outdoor heat exchanger shall be indicated by the manufacturer in Pa for appliances with duct connection.

Table 1. Rating test conditions

Measured quantity or result	Test condition See Table 1 A... W...
1) Ambient conditions	
- air temperature, dry bulb	°C
2) Electrical quantities	
- voltage	V
- total current	A
- total power input P_T	kW
- effective power input P_E	kW
3) Thermodynamic quantities	
a) Outdoor heat exchanger	
- air inlet temperature dry bulb	°C
- air inlet temperature wet bulb	°C
For duct connection	
- external or internal static pressure difference Δp	Pa
- air volume flow q	M^3/s
b) Indoor heat exchanger	
- water inlet temperature	°C
- water outlet temperature	°C
- volume flow of the water q	m^3/s
- external or internal static pressure difference Δp	Pa
c) With defrost	
- duration of defrosting time t_D	h
- duration of operating cycle	h
- capacity taken from the heating installation	kW
- heating capacity P_H or cooling capacity P_C	kW
4) Ratios	
- COP (see EN 255-1:1988)	--
- EER (see EN 255-1:1988)	--

Table 2. Test results

the heat pump at an indicated test point. For units with variable speed fans the maximum fan speed is to be used.

Since outdoor air source heat pumps usually have some type of defrosting method the standard addresses the situation of output measurements with and without defrosting of the evaporator. For operating conditions without defrosting the measurements are to be performed at the steady state condition. To insure that no frosting will take place the steady state condition must be maintained 2 hours before the start of measurements. If steady state conditions cannot be maintained for a period of 2 hours before commencing the tests then the output measurement is to be performed with defrosting of the evaporator.

With defrosting of the evaporator the operating conditions will vary continuously because of ice formation on the evaporator. Therefore the standard calls for the recording of all essential measured values at suitable intervals from which an integral mean value is to be calculated. The duration of the test under frosting conditions shall be two hours plus one defrosting cycle and shall continue for a whole number of cycles but not less than 2 hours and not more than 24 hours. During the heating phase the input temperature at the indoor heat exchanger is to be maintained constant. The resulting change in outlet temperature at the indoor heat exchanger due to icing up of the evaporator is permissible.

During the defrosting phase the standard sets permissible deviations for air inlet temperatures and water inlet temperatures taking into account the regulating capability of the test installation during non-steady occurrences. The defrosting and heating phases are to be determined by the heat pump's built in defrosting control. Any water dripping or running out from places other than those provided for this purpose shall also be recorded.

The standard sets requirements for a test report. Beyond the general information such as date, test institute, test location, test supervisor, test object and type designation and reference to the standard the results of the test at a particular rating point are to be presented as in Table 2. These values are to be mean values of measurements taken over the test period.

A durable fixed rating plate is also called for in the standard. This must be mounted on the heat pump so that it is easily readable once the heat pump is installed. The rating plate must contain the following items in addition to any information required by safety standards:

- Manufacturer
- Model number or serial number
- Type and mass of refrigerant
- COP to two significant figures at the following rating point: A7W50 or for exhaust air heat pumps A20W50
- If applicable the EER, at the cooling test point A35W7, is to be included
- Heating and cooling (if applicable) capacity in kW with one digit after the decimal comma but not more than three significant figures at the same test point as the COP.

Additional information can be provided but in the case of additional ratings only the test points given in the standard may be used.

Certification

A certification scheme for heat pumps will be established once the technical portions of EN 255 have been completed. This will be a procedure which must be fulfilled by the manufacturer so that he may affix a neutral sign to his product showing that it is in conformity with European standards. The procedure will be developed by certification experts and members of CEN/TC 113. This work will be carried out under CENCER (The CEN Certification organization). The certification procedure will most likely be on a voluntary basis and not as a forced approval procedure.

Safety standards

Within CEN there are committees dealing with safety standards. Currently the EC low voltage directive is applicable to electrical appliances such as heat pumps. CENELEC is working on harmonizing various electrical standards which will also apply to heat pumps. Mechanical safety standards in the form of a European Community directive for machinery became available in June of this year. Of additional interest is the work of CEN/TC 183 "Refrigerating systems, safety, and environmental requirements" which will tentatively be completed by 1993.

Summary

Beginning 1993 the member countries of the European Community will dismantle all border controls which hinder the free flow of goods, services, and people. To take maximum advantage of this large market, unified standards, especially for industrial products, are urgently needed. The standards activities of CEN/CENELEC are aimed at producing such standards. For the heat pump community, standards known as EN255 are being prepared by CEN/TC 113 for electrically-driven compression heat pumps for domestic heating and/or cooling. In its current form EN255 will have nine parts. Part 1 is already being implemented as a European standard. The remaining parts are approaching this same stage. EN255 part 1 contains definitions of terms used in the standard. Part 2 deals with air/water heat pump units (split type and single package) and contains the procedures and requirements for testing and marking of these units. The standard requires that the heating and cooling (if applicable) capacity, COP and EER be measured at specified test points and that this information be included in a test report and on a rating plate affixed to the heat pump unit. It is foreseen that certification of compliance with this standard will be carried out by CENCER.

Where to get copies of EN 255

Below are the addresses of three European standards institutes which can be contacted to obtain copies of EN 255.

For the English language version:
BSI British Standards Institution
2 Park Street
London W1A 2BS
United Kingdom

For the French language version:
AFNOR Association francaise de normalisation
Tour Europe CEDEX 7
F-92080 Paris-La Défense
France

For the German language version:
DIN Deutsches Institut für Normung e.V.
Burggrafenstraße 6
1000 Berlin 30
Federal Republic of Germany

References

-- Europäische Normen für 1992: Ein Leitfaden des DIN, Deutsches Institut für Normung e.V., 1988.
-- CEN TC/113 documents N159, N161, N167, N170, N172, N150, N142, N143, N136Eadd.

Annex 1: Concepts according to EN 255 part 1

Heat Pump: A heat pump is a device which takes up heat at a certain temperature and releases heat at a higher temperature. When operated to provide heat (e.g., for space heating or water heating), the heat pump is said to operate in the heating mode; when operated to remove heat (e.g., for space cooling), it is said to operate in the cooling mode.

Indoor Heat Exchanger: The indoor heat exchanger is the heat exchanger assembly which is designed to transfer heat to or remove heat from the indoor parts of the building or to the indoor hot water supplies (e.g., sanitary water).

Outdoor Heat Exchanger: The outdoor heat exchanger is the heat exchanger assembly which is designed to remove heat from the outdoor ambient environment, or to transfer heat to the outdoor ambient environment.

Heating Energy: The heating energy is the usable heat given off from the heat pump to the heat transfer medium on the indoor heat exchanger within a defined interval of time. If heat is removed from the indoor heat exchanger for defrosting, this must appropriately be taken into account.

Heating Capacity: In the heating mode the heating capacity is obtained by dividing the heating energy by the defined interval of time.

Cooling Capacity: In the cooling mode the cooling capacity is the average useful rate of heat removed to the indoor heat exchanger from the indoor parts of the building measured over a defined interval of time.

Power input: The power input of the heat pump is the total electrical power input obtained from the power consumption for operation of the compressor including defrosting, the power consumption of all control and safety devices of the heat pump, and the proportional power consumption of the conveying devices (e.g., fans, pumps) for ensuring the transport of the heat transfer media inside the heat pump. The rated input of the heat pump is the power input under rated conditions.

Coefficient of Performance (COP): COP is the ratio of heating capacity to the average power input of the heat pump measured over the defined interval of time.

Energy Efficiency Ratio in the Cooling Mode (EER): The EER is the ratio of cooling capacity to the average power input of the heat pump measured over the defined interval of time.

Range of Use: The range of use is the range of operation by the heat pump indicated by the manufacturer and limited by the upper and lower limits of use (e.g., temperatures, air humidity, voltage) within which the heat pump has the guaranteed properties.

Defrosting Time: The defrosting time is the time for which the heat pump is in the defrost mode.

**Andre Milbitz, IEA Heat Pump Center, Karlsruhe, FR Germany.* *The assistance of Mr. J. Graßmuck, Secretariat of CEN/TC 113, in providing background information for this article is greatly appreciated.*

M. Chikyu and S. Oteki*

Water-Source Split System Heat Pump and an Example of Its Application to Hospital Air Conditioning

Mitsubishi Electric Corporation, Japan, has commercialized an energy-saving, space-saving system capable of cooling/heating operation as well as heat recovery operation by connecting a number of small-capacity water-source heat pump air conditioners to a common water piping system. Recently, a split type of this water-source heat pump air conditioner has been developed by dividing it into the indoor unit and heat-source unit, and connecting them with refrigerant piping. By means of microcomputer control, indoor units differing in style can be operated as needed. The system is also equipped with various comfortable air conditioning functions. This product has been installed in a hospital in Japan. A system outline and an actual installation example are discussed below.

Background of development

In Japan, as a result of the concentration of population in cities and the development of knowledge-intensive industries, there is an increasing demand for buildings in cities, and an increasing number of buildings are being constructed. These newer buildings are being equipped with "intelligent" functions to satisfy the growing demand for a more comfortable indoor environment, energy savings, and simplified maintenance and management.

As an air conditioning system capable of meeting these requirements, air-source multi-type split heat pump systems have been most widely used. The air-source type, however, involves problems such as outdoor unit installation space, capacity loss due to the piping length, heating capacity drop in winter, cooling when the outdoor temperature is low, defrosting, and heat recovery.

In order to avoid the problems associated with the air-source type, a water-source heat pump can be used. However, water-source heat pumps have been available only as integrated systems and when installed in the ceiling of a room, such problems with noise, water leakage, and maintenance have arisen.

To solve the problems associated with the conventional air-source and water-source heat pump systems, a water-source split type heat pump system has been developed, having improved air conditioning performance, sophisticated control, and reduced noise.

Outline of the system

This system comprises a water circuit that consists of a cooling tower, heat storage tank, auxiliary heat source, and a circulating pump. To this water circuit are connected multiple heat pump heat-source units with capacities of 1 to 5 hp.

Since the heat-source unit has been designed compactly, it can be installed in the ceiling along the corridor, or near the water piping shaft space by the stairs. By connecting the indoor units to the heat-source unit through refrigerant piping, it becomes necessary to bring the compressor section (noise source) or the water piping (water leakage source) into the room space. This greatly enhances the system's flexibility and reliability. Figure 1 shows the system outline, and Figure 2 sketches the internal structure of the heat-source unit and indoor unit.

The indoor units are available as ceiling cassette type, built-in cassette type and ceiling-concealed type. The configuration of these units comes either as a 1:1 type (one heat-source unit matched with one indoor unit), a 1:2 type (one heat-source unit matched with two indoor units run simultaneously), or a 1:3 type (one heat-source unit matched with three indoor units run individually). The appearance of the heat-source unit is shown in Figure 3, and the appearance of one of the indoor units is shown in Figure 4.

Some of the main features of this system are:

1. Heat recovery operation for energy savings
   - Heat recovery through simultaneous cooling/heating operation
   - Effective utilization of industrial waste heat
2. Effective individual air conditioning
   - 24-hour operation
   - Automatic cooling/heating operation possible simply by switch selection
3. Simple to maintain/manage, and highly reliable
   - The indoor units and heat-source unit require limited maintenance
   - No water piping into the room
   - A liquid crystal remote controller with self-diagnosing functions
4. Higher comfort level

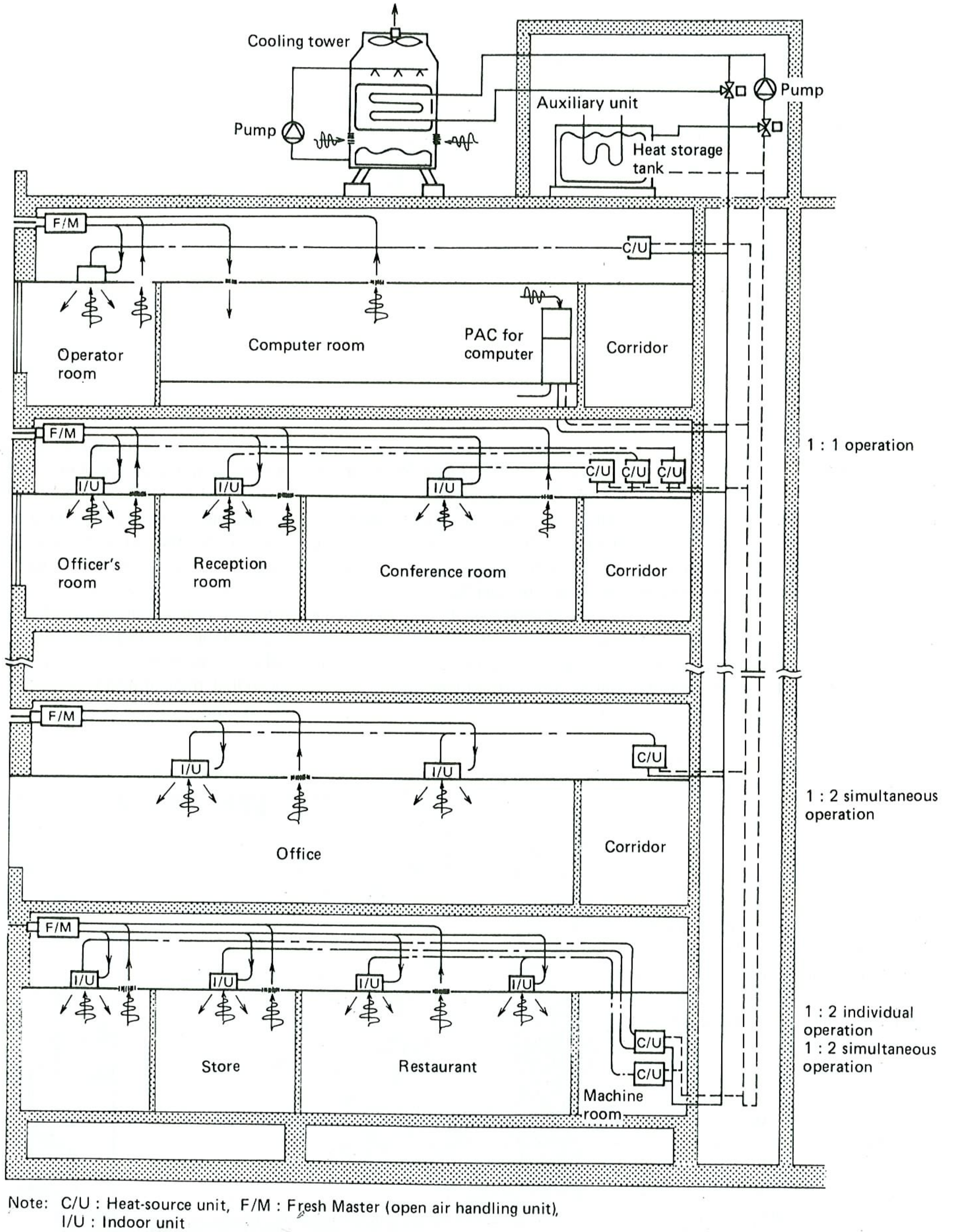

Figure 1. A system example of city multi water-source series (Note: C/U - heat-source unit, F/M - fresh master (treatment of outdoor air), I/U - indoor unit

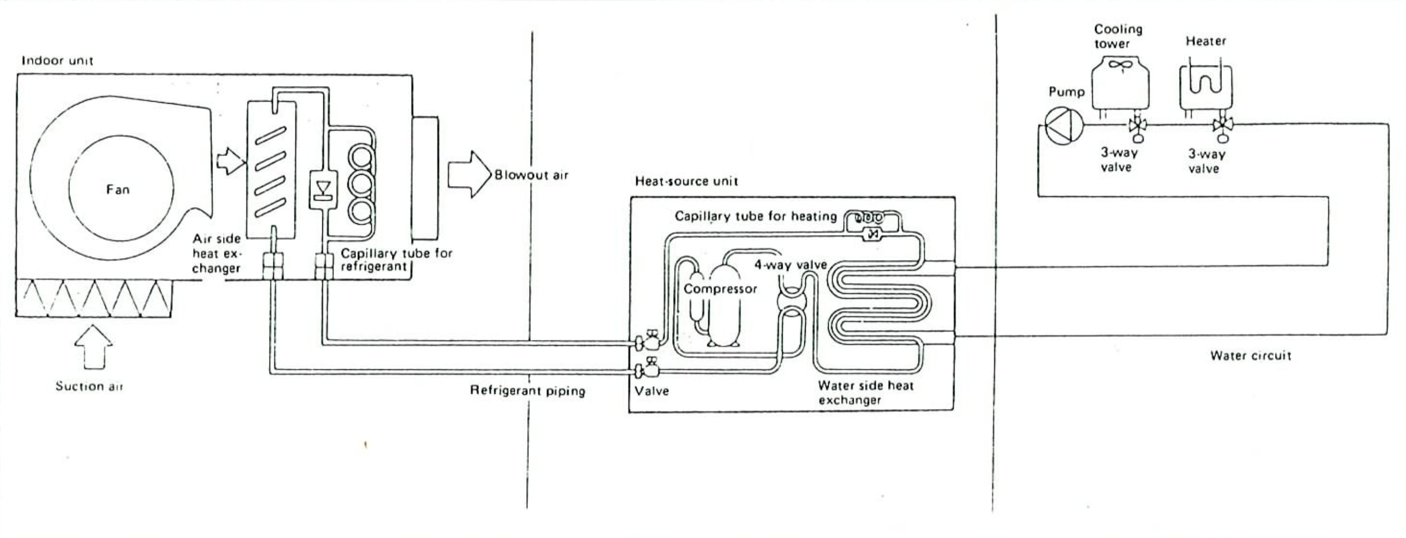

Figure 2. Sketch of internal structure

- A cassette-type free flow air supply system
- Reduced indoor unit noise
- A variety of optional components, such as filters and humidifiers
- Introduction of outdoor air by means of an outdoor air handling unit

5. Comfortable heating operation performed stably even in cold climates
6. Space savings
7. Microcomputer control
   - Control by means of a remote controller for centralized control and program timer
   - Connectable to a building control system

Installation example (at Fukushima Rosai Hospital)

An example of an installation of the water-source split heat pump system is the Fukushima Rosai (Workers' Accident) Hospital.

The main building was newly constructed, since the old facilities of this hospital were outdated after 30 years. At this hospital, air conditioning is required for different time periods between medical departments; in some departments, cooling is required even in winter. The hospital chose this water-source split type heat pump because it can effectively respond to automatic cooling/heating mode selection and partial cooling/heating load fluctuations.

The system is composed of 106 units whose compressor output ranges from 0.75 to 3.2 kW. These heat-source units are installed in the ceiling space of the machine rooms and staircases. Each room is equipped with an indoor unit connected to its heat-source unit by refrigerant piping, allowing either heating or cooling to be selected automatically. Thus, these units constitute an individual decentralized air conditioning system.

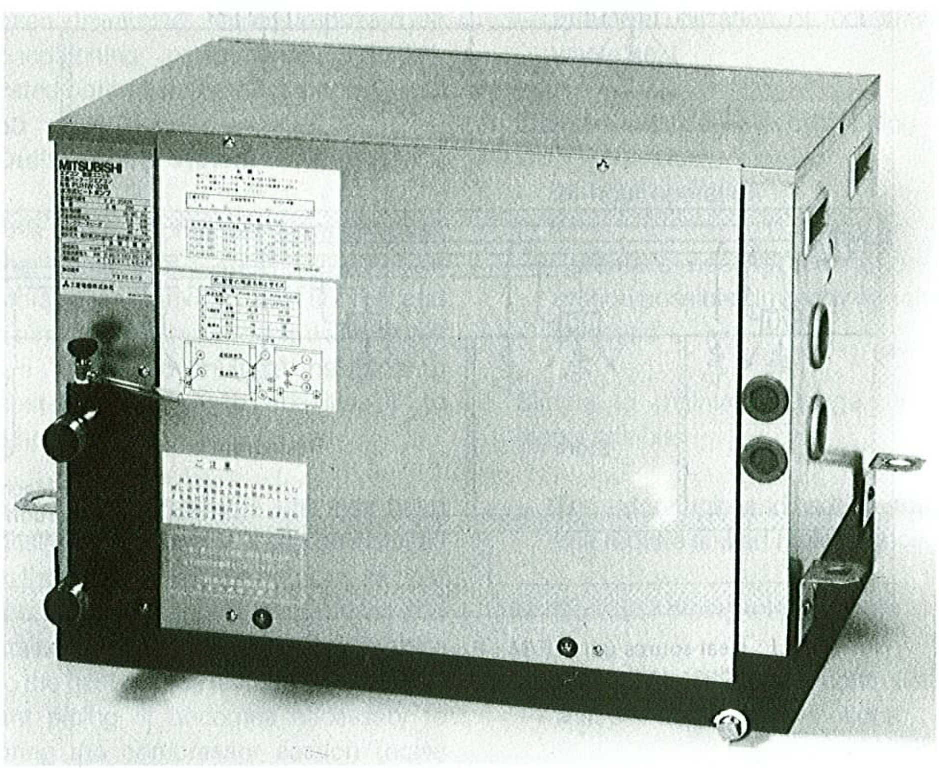

Figure 3. Heat-source unit (PQH-32A)

The heat-source units are connected through a system of circulating water piping, and the water temperature is controlled to a specified value. Heat is recovered in each heat-source unit via heat-source water. To cut down on the pumping power, two sets of four inverter pumps and two sets of cooling towers (350 RT) are installed in the primary side, and these are connected through bypass piping. Partial loads can be covered by a set of pump units. Thus, considerations are given to energy savings in the heat-source system.

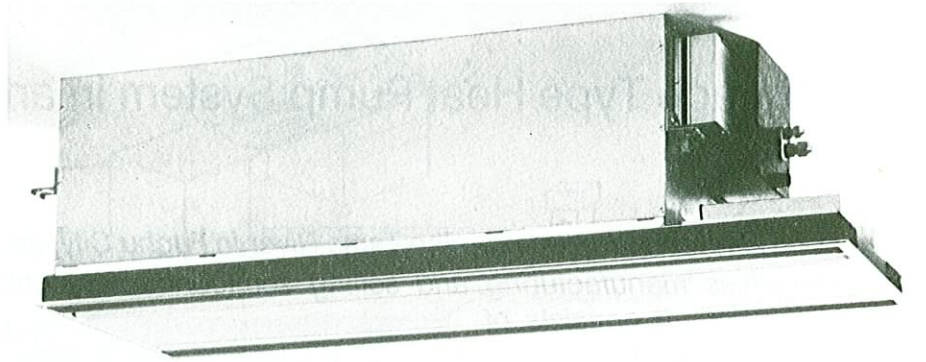

Figure 4a. Indoor unit (ceiling cassette type)

In view of the hospital functions, the air conditioning system is subject to microcomputer control that allows control from individual remote controllers, centralized control remote controllers, and a central computer.

This air conditioning system has achieved its initial goals in partial load operation concerning heat recovery performance, flexible cooling/heating mode selectability, and stability as a heat-source unit. Additionally, through this installation example, reduced noise, simplified maintenance, and improved reliability of water piping have been achieved. These are all features needed for an air conditioning system in a hospital.

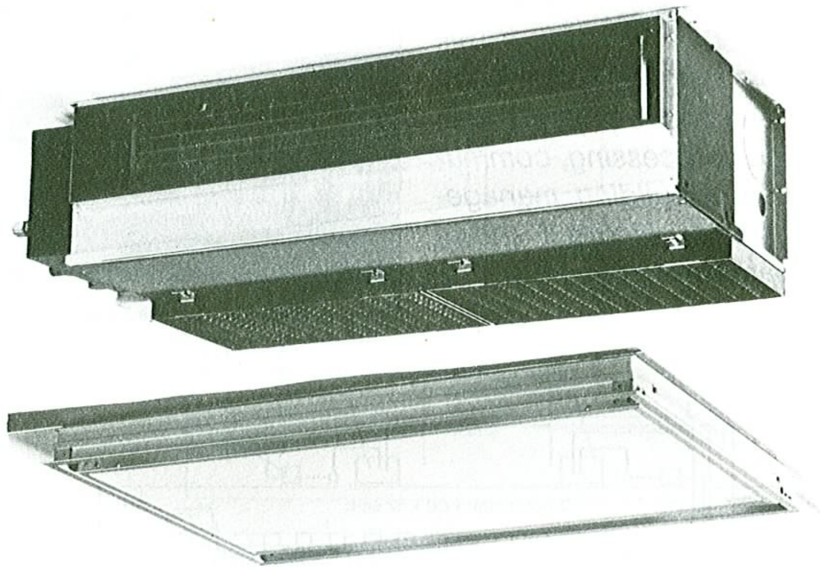

Figure 4b. Indoor unit (built-in cassette type)

Conclusion

In view of the features of the water-source split type heat pump discussed above, we feel that this system is highly adaptable to office buildings, hotels, hospitals, and buildings in cold districts. As such, it will be able to satisfy requirements for building air conditioning systems of increasing sophistication.

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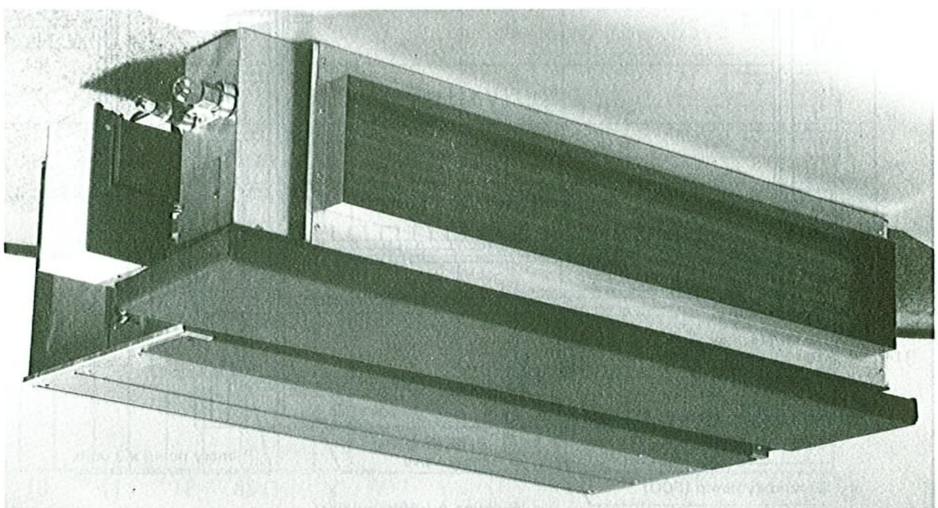

Figure 4c. Indoor unit (ceiling-concealed type)

K. Ishiguro*

Heat Storage Type Heat Pump System in an "Intelligent" Office Building

Fuchu NH Building is located near the Tama River in Fuchu City, and is occupied by international high-tech enterprises manufacturing and selling semiconductor control units, computer systems, and electronic parts. It consists of Building A (10 stories above the ground, 15,356m² in total floor area) having office and management rooms, and Building B (5 stories above the ground, 9,009m² in total floor area) comprising warehouses, a dining hall, and other facilities. This building is designed as an "intelligent" building equipped with information processing, communication and building management systems. Figure 1 shows its appearance.

Figure 1. Appearance of the building

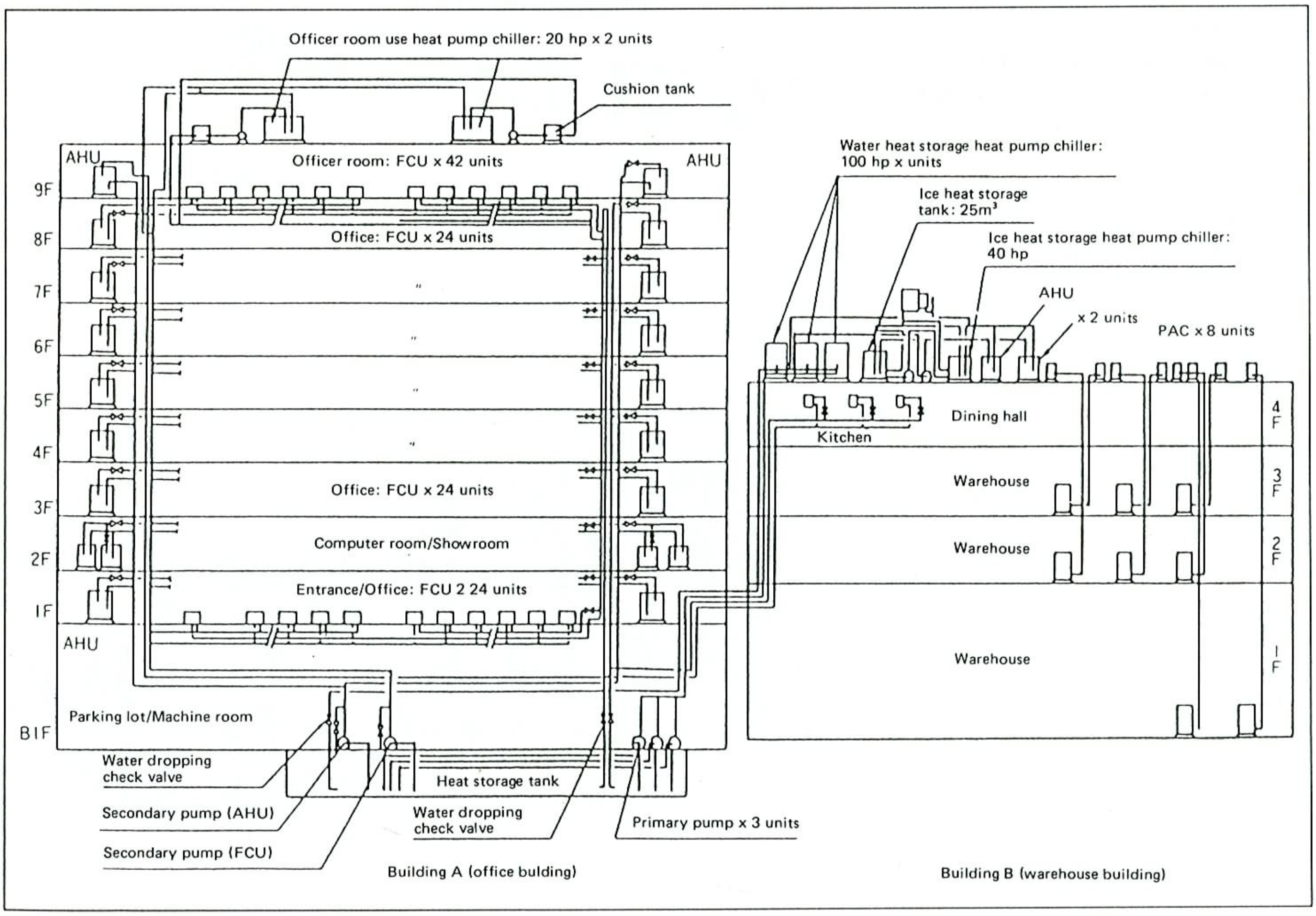

Figure 2. Heat-source system configuration

Heat-source system

With the requirement for a clean and energy-saving heat supply that satisfies demand for 24 hours, also at partial load, a fully electrical heat storage type heat pump system was installed for the major part of the building.

For Building A an air-source heat pump chiller (100 kW x 3 units) and a water heat storage tank system were installed. The chiller unit was installed on the roof of Building B. The heat storage tank has a capacity of 1,223m³ so that 50% of the total daily cooling load can be transferred to the nighttime. The two chilled/hot water pump units on the secondary side are controlled by an inverter for energy savings.

To save space and improve efficiency, the dining hall zone on the 4th floor of Building B is covered by a unit type ice storage air conditioning system that uses an air-source heat pump chiller (30 kW). This unit is installed on the roof of Building B.

The control system consists of a heat source controller with built-in prediction control and a central management system that controls the whole building, performing scheduled operation under optimum control. Figure 2 illustrates

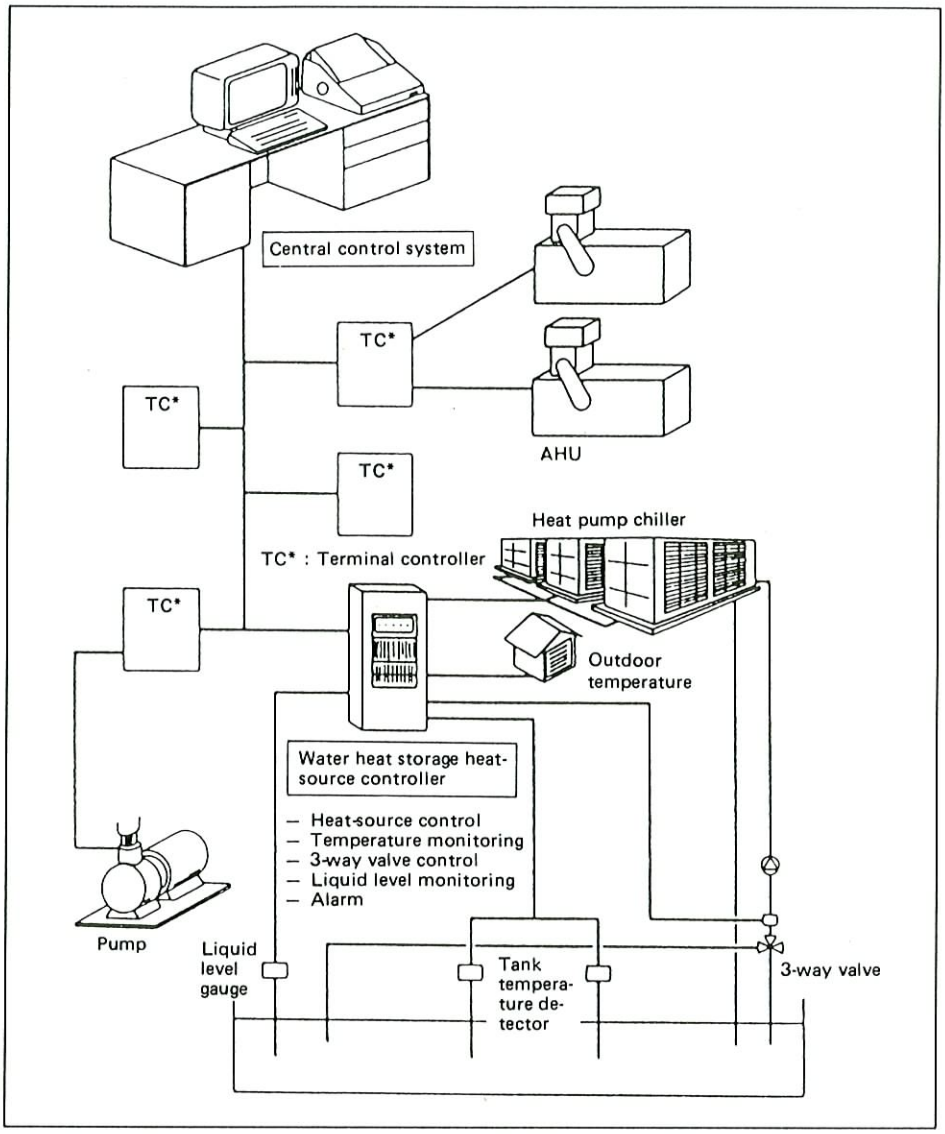

Figure 3. Control system configuration

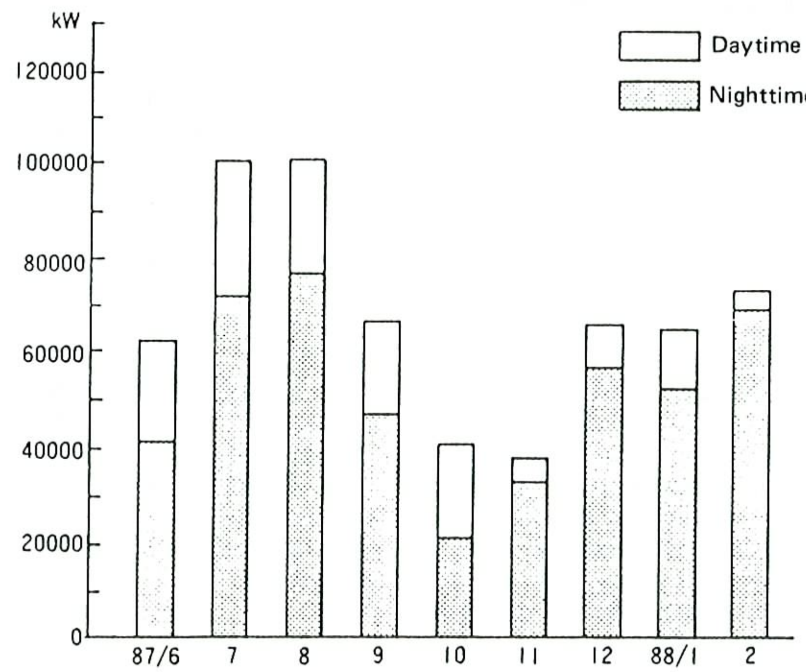

Figure 4 Day/night power consumption of heat-source unit and primary heat pumps

Month	Rate of transfer to night(%)
6	65.5
7	71.4
8	76.0
9	68.6
10	51.8
11	87.6
12	86.2
1	79.8
2	95.9

Table 1. Rate of transfer to night

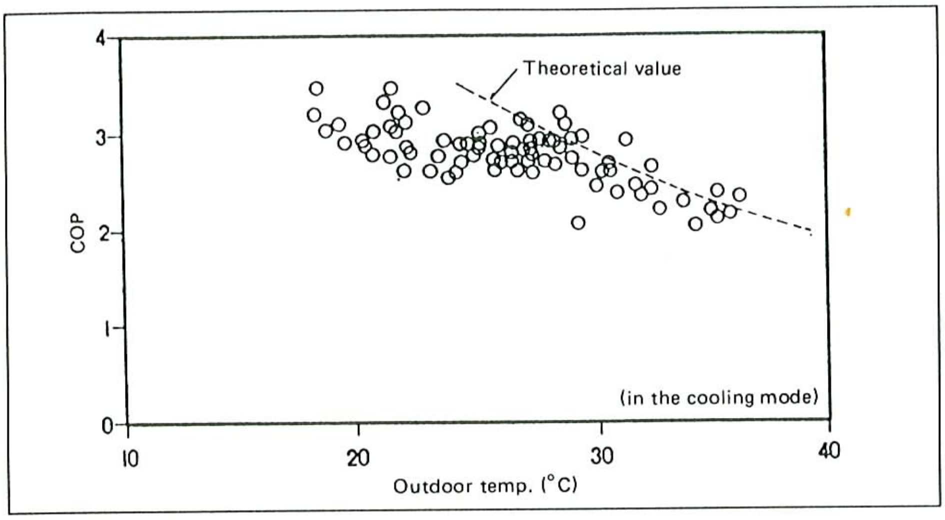

Figure 5. COP in the cooling mode

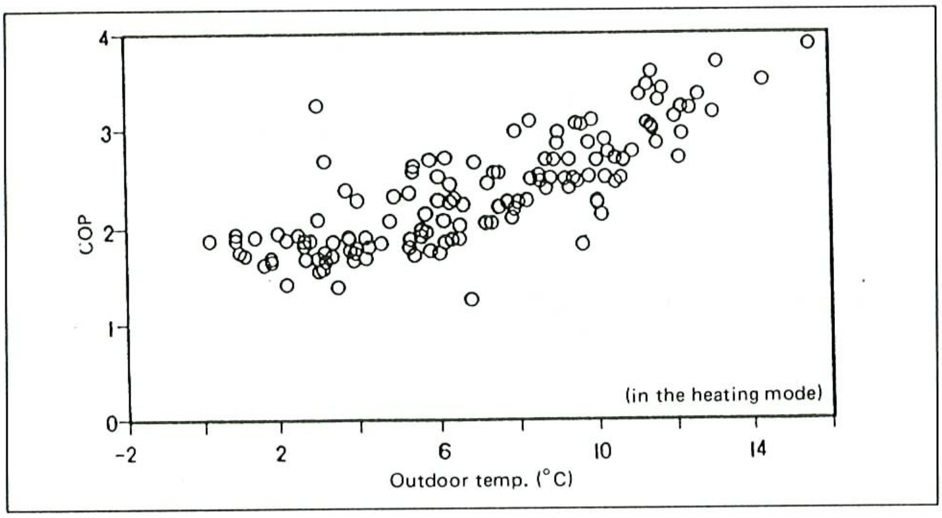

Figure 6. COP in the heating mode

the heat source system configuration and Figure 3 illustrates a control system configuration.

The air conditioning system for Building A consists of two air conditioners at each floor with the perimeters covered by fan-coil units (FCU). To save energy, each air conditioner is equipped with outdoor cooling and total heat exchangers.

Specifications

Water heat storage system for Bldg A:

Air-source heat pump chiller:
- 75 kW x 3 units
- Cooling capacity:
  - 276 kW (chilled water: 5°C)
- Heating capacity:
  - 213 kW (hot water: 50°C)

Primary chilled/hot water pump:
- 750 l/min x 30 kW x 3 units

Secondary chilled/hot water pump:
- Air handling unit system:
  - 1,290 l/min x 30 kW x 1 unit (with inverter)
- Fan coil unit system:
  - 750 l/min x 18.5 kW x 1 unit (with inverter)

Heat storage tank:
- 1,223m³ (44 tanks)

Ice heat storage system for Building B:

Air-source heat pump chiller:
- 30 kW x 1 unit
- Cold storage capacity:
  - 72 kW (brine: -6°C)
- Cooling capacity:
  - 108 kW (chilled water: 7°C)
- Heating capacity:
  - 120 kW (hot water: 45°C)

Brine pump:
- 400 l/min x 2.2 kW

Chilled/hot water pump:
- 600 l/min x 5.5 kW

Ice heat storage tank:
- 25m³
- Cold storage capacity:
  - 651 kW (quantity of ice stored: 4,000 kg)
- Heat storage capacity:
  - 256 kW

Operating data

Figure 4 shows the monthly (day/night) power consumption of the heat source and primary pumps, while Table 1 shows monthly rate of transfer to the night of the heat source and primary pumps. The rate of transfer to the night is generally high but remains low in June and October (intermediate season) when a high rate should be secured. Adjustments are underway to correct this problem.

Figures 5 and 6 show the relationship between the outdoor temperature and the COP of a heat pump chiller in the cooling mode and heating mode, respectively. For the COP in the cooling mode (Figure 5) a dotted performance curve provided by the manufacturer is shown. The COP in the heating mode is somewhat low since the calorimeter involves a piping loss and the input power includes the outdoor fan power. Therefore, it is not possible to easily compare the results with the manufacturer's values, but they generally represent favorable performance.

Conclusions

Two years have passed after completed construction of this building. As a result of adoption of the heat-source controller featuring a new type of prediction control system, it has become possible to secure about 70% transfer to the nighttime, as expected. During the nine months for which measurements were carried out, about 6,400,000 yen/year of cost savings resulted due to reduced nighttime electric rates. This is based on the assumption that all of the nighttime power consumption is transferred to daytime operation (nighttime power charges: 5.6 yen/kWh; daytime charges: 19.06 yen/kWh in summer and 17.33 yen/kWh in other seasons).

Kunimichi Ishiguro, Technical Development Department, Taisei Corporation, Japan

Bibliographic Review

Investigation of the non steady state performance of heat pump cycles. (Untersuchung des Instationären Verhaltens von Wärmepumpenkreisläufen). Upmeier, Berthold. Forschungsberichte des Deutschen Kälte- und Klimatechnischen Vereins Nr. 28, 1989. (German)

This report describes the results of experimental measurements and numerical simulation of the non-steady state performance of compression cycle heat pumps. The experimental portion of the investigation was carried out using a water-to-water heat pump and an air-to-water heat pump. The performance of these systems was measured under various operating conditions. The distribution of refrigerant within the cycle was monitored by continuous weighing of the heat exchangers. A numerical simulation program was used to perform a theoretical analysis of the non steady state performance of the refrigeration cycle. The program was modified to model the experimental set-up. Experimentally derived factors were not included in the simulation program so that it would remain as general as possible. Instead the inputs to the program were limited to component dimensions and operating conditions. The resulting differential equations were solved numerically. The results of measurements and calculations show that with typical cycle times the COP of the refrigeration or heat pump cycle during non-steady state operation does not vary significantly from steady state values. With cycle times of less than three minutes the non-steady state influences become significant. Both the experimental results and the simulation show that most operating parameters reach their steady state values within a short period of time.

3rd Informatory Note on CFC's and Refrigeration, April 1989, International Institute of Refrigeration, 177, Boulevard Malesherbes - F 75017 Paris.

This two-page notice summarizes the most important results of three UNEP (United Nations Environment Programme) meetings which took place in the Netherlands on 17-26 October 1988. These meetings were a scientific review of the depletion of the ozone layer, current status of progress towards substitutes and alternatives for CFC's and an ad-hoc working group of legal and technical experts. During these UNEP meetings four panels were set up to review available information. In particular a refrigeration expert group was formed with approximately 50 participants from around the world. Contact the IIR at the above address for more information.

NEW HEAT PUMP CENTER REPORTS

User's Handbook for Heat Pumps in Dairies: Application of standardized electrically driven compression heat pumps in dairies to heat water for washing, cleaning, space-heating, and different processes, Å. Bratt, J. Berghmans, HPC-HB-1, June 1989, 106 pages.

The User's Handbook for Heat Pumps in Dairies was written to assist decision makers in dairies in evaluating the possibility of using a heat pump in their plant. It presents the fundamentals of heat pump technology along with the types of considerations, both technical and economic, necessary to make a first evaluation of possible heat pump applications. Should this first evaluation show that it is profitable to use a heat pump, this basic knowledge of heat pumps will also enable the decision maker to communicate clearly with the heat pump contractor. As indicated by the title, the Handbook emphasizes the use of electrically-driven standardized water-to-water heat pumps in dairies to heat water used for washing, cleaning, space heating, and different kinds of processes. The suggested heat source is condensing heat from existing refrigeration plants or other heat sources. The reasons for this emphasis are that standardized water-to-water closed cycle compression heat pump units are relatively low in price, have low maintenance and service costs, are factory tested for reliability and performance, have a small refrigerant content and allows fast and simple installation. These characteristics enable the final system to have good profitability and a reasonable payback period. The Handbook is divided into 5 main sections. The first three sections cover fundamentals. Section 1 gives an introduction to the heat pump process, its performance, and its limitations. Section 2 shows how the profitability of a proposed heat pump installation can be estimated. The information obtained by using the methods presented in this section forms the basis for an initial decision as to whether or not to carry on with the heat pump project. Section 3 entitled "Project Management" presents the main requirements for a successful heat pump project. Advice on how to avoid some typical problems is given. The fourth section deals with the possible use of water-to-water heat pumps in dairies. It identifies promising heat sources and heat sinks to which a heat pump can be applied. Special emphasis is given to the use of condenser waste heat from refrigeration plants. Section five contains five examples of heat pump installations in dairies with piping diagrams and technical and economic data. Finally, a list of references is given at the end of the Handbook for further reading.

Engine-driven heat pumps, an analysis of existing systems. HPC-R-6, P. Vinz, November 1989.

The goal of this report is to make available information to individuals involved in planning of engine driven heat pump (GHP) systems so that common problems which have occurred in the past will not be repeated. The procedure used to assimilate this information was to investigate as wide a variety of existing systems as possible to get a broad overview of the types of problems encountered. In all, a total of 8 systems were investigated in the FR Germany ranging in heating capacity from 20kW to 3MW. Six of the systems are being used in the municipal sector for building heating. One of the systems is used in an industrial drying and cooling application while the eighth system is intended for residential use. Thus the conclusions and recommendations made in this report are mainly applicable to larger GHP systems used for building space heating. A detailed engineering analysis of each of the eight systems was carried out. This involved investigating the system's design, operating characteristics, and economics. Site visits and discussions with operating personnel and owners constituted the main source of information. Based on this analysis detailed suggestions for improvement of each system are made; common problems identified, and general guidelines formulated. Finally the market prospects for these systems are discussed and a number of component development needs are identified. Common problems among the systems investigated were categorized into the following areas: Preliminary design and system planning, start-up and operation, maintenance, and environmental aspects. All of the seven large scale systems were overdimensioned due to inaccurate heating load estimates. This led to excessive on-off cycling of the GHP in many of the systems causing rapid wear of components and uneconomic operation. In some systems the GHP, boiler, and thermal storage units were improperly integrated. Maintenance intervals on the investigated units varied widely for spark plug and drive engine oil changes. Pollution control equipment was non-existent on most of the drive engines. Refrigerant loss due to leakage and maintenance work was significant in all systems (average of 50 - 100kg per year). The seven larger systems all had the potential to be economic if an optimized design had been carried out from the beginning.

Some of the general guidelines to avoid problems and improve the economics of future systems are:

- Use only qualified individuals for design and planning,
- Look for opportunities to integrate heat and electricity generation and or heating and cooling,
- Have all design work examined by an independent institution experienced with these systems,
- Government grants should support only optimized systems.

The economics and market prospects of GHP systems depend on how much better they are than conventional heating systems. Thus, GHP systems must have superior operating efficiency and a lower environmental impact to remain competitive in the future. This can be achieved by optimized designs where refrigerant leakage and pollution emissions have been reduced to a minimum and designs where the potential for simultaneous electricity generation and/or cooling is used effectively. The latter designs, where cooling and/or electricity are generated in addition to heating, are competitive at today's energy prices even without government grants.

The component developments needed to make GHP systems more reliable and competitive are:

- Development of new compressor to motor coupling methods which eliminate the need for an external drive shaft and the associated refrigerant leakage through the shaft seal,
- Development of substitutes for safety pressure relief valves which presently exhaust refrigerant to the atmosphere,
- Development of an exhaust gas pollution control system with a longer service life.

News Briefs

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has finalized the technical program for the 1990 ASHRAE Winter Meeting in Atlanta (February 10-14).

The technical program consists of 14 Technical Sessions, 30 Symposia, 22 Seminars, and 36 Forums. In total, 102 sessions are scheduled with 194 published papers presented, including papers from 13 overseas countries. Of particular interest in the technical program are symposia on ground-coupled lake water heat pumps, international developments in absorption systems, and performance and reliability of unitary equipment. A forum discussing heat pump modelling needs will also be held and a number of technical papers on heat pumps will be presented.

The technical program is jointly organized with The Chartered Institution of Building Services Engineers (CIBSE). CIBSE members will present 12 papers, reporting on technology more commonly practiced in the United Kingdom and on the differences in design solutions of United Kingdom and North American engineers.

The chlorofluorocarbon (CFC) issue leads the number of sessions scheduled with 13. Papers address energy impacts, alternate refrigerants and their thermodynamic properties, issues update as well as completed research results on emerging working fluids.

The Society has also selected the Keynote Speaker for the Plenary Session February 10, Reverend William James Byron, S.J., President of the Catholic University of America. Reverend Byron's speech will reinforce ASHRAE's 1989-90 theme "Volunteers Advancing Environmental Technology." His talk is titled "Advocating the Cultural and Religious Values Needed to Overcome the Threat to Volunteerism."

Held in conjunction with the ASHRAE meeting is the 250,000-square-foot International Air-Conditioning, Heating, Refrigerating Exposition at the Georgia World Congress Center February 12-14. The Exposition is co-sponsored by ASHRAE and the Air-Conditioning and Refrigeration Institute.

To register or receive more information, contact ASHRAE Meetings Department, 1791 Tullie Circle, N.E., Atlanta, Georgia, 30329, USA, telefax 404/321-5478.

Schedule of Conferences

February 10-14, 1990

Atlanta, Georgia (USA); **Winter Meeting of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE).** Contact: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329, USA, telephone 404/636-8400, fax 404/327-5478. Advance registration deadline is January 12, 1990.

March 12-15, 1990

Tokyo (Japan); **The 3rd International Energy Agency Heat Pump Conference.** Contact in Japan: Secretariat, Heat Pump Technology Center of Japan, Azuma Shurui Bldg., 9-11 Kanda Awaji-cho, 2-chome, Chiyoda-ku, Tokyo 101, Japan, telephone 03-258-1035, telefax 03-258-1037, telex 222-4601 hptcj. Contact in North America: R.L. Douglas Cane, CANETA Research, Inc., 6981 Millcreek Dr, Unit 28, Mississauga, Ontario, Canada L5N 6B8, telephone 416/542-2890, telefax 416/542-3160. Contact in Europe: W. Hochegger, Energiesparhaus Graz, Petersgasse 45, A-8010 Graz, Austria, tel 316-822045, telefax 316-826371, telex 31-2305.

May 15-16, 1990

Columbus, Ohio (USA); **41st Annual International Appliance Technical Conference.** Sponsored by Air-Conditioning and Refrigeration Inst., Arlington, VA (USA); American Society of Mechanical Engineers, New York (USA); and the Institute of Electrical and Electronics Engineers, Inc., New York. Contact: Underwriters Laboratories, Inc., Attn: D. Grob, 333 Pfingsten Rd., Northbrook, IL 60062, USA.

June 24-27, 1990

Minneapolis, Minnesota (USA); **Annual Meeting of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE).** Contact: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329, USA.

September 24-26, 1990

Graz (Austria); **3rd International Workshop on Research Activities on Advanced Heat Pumps.** Organized by the Technical University of Graz. Contact: Doz. Dr. H. Schnitzer, Organization Committee, Workshop on Research Activities on Advanced Heat Pumps, Institut für Verfahrenstechnik, Inffeldgasse 25, A-8010 Graz, Austria, telephone 0316/7061, telex 311221, telefax 0316/77685.

September 24-28, 1990

Dresden (German Democratic Republic); **Conference of the International Institute of Refrigeration (IIR).** (Tagung des Internationalen Instituts für Kältetechnik) Contact: International Institute of Refrigeration, 177, Bd. Malesherbes, F-75017 Paris, France.

October 4-6, 1990

Nürnberg (Germany, F.R.); **International trade fair for refrigerating and air conditioning and annual meeting of Verband Deutscher Kälte-Klima-Fachleute e.V. (VDKF).** (Internationale Fachmesse Kälte-Klimatechnik (IKK) und Jahrestagung des Verbandes Deutscher Kälte-Klima-Fachleute e.V) Contact: Verband Deutscher Kälte-Klimafachleute e.V., Esslinger Str. 80, 7014 Fellbach, Fed. Rep. of Germany.

Errata

In Volume 7, Number 3, on page 37, paragraph 1. should read "The figures give the minimum COP that an electrically driven heating only heat pump must have in various countries to equal the cost of producing heat by conventional systems."

IEA Heat Pump Center Newsletter
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Heat Pump Center

The IEA Heat Pump Center (HPC) was established in 1982 as Annex IV of the "Implementing Agreement for a Programme of Research and Development on Advanced Heat Pump Systems." Operating agent for the center is the Fachinformationszentrum Karlsruhe GmbH. Presently, nine countries are members of the HPC. These are: Austria, Canada, Federal Republic of Germany, Italy, Japan, the Netherlands, Norway, Sweden, and the USA. The language used in all material published by the HPC is English.

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 Program. 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 program of collaborative RD&D consisting of 42 Implementing Agreements, containing a total of over 80 separate energy RD&D projects. IEA's address is 2 Rue André-Pascal, 75775 Paris Cedex 16, France.