ISSN 0724-7028

NEWS LETTER

IEA heat pump center

PERIODICAL OF THE
IEA HEAT PUMP CENTER

VOL 3, NO. 1/2, JULY '85

500 m^2 of unglazed absorbers for a heat pump heating system on a factory roof in Engen (W.-Germany)

Contents

Contents	Page

Editorial by K. Holzapfel*

Canada - Newest Member of the IEA Heat Pump Center

In 1985 Canada has decided to participate in the IEA Heat Pump Center. Therefore, 8 countries are now supporting this important activity: Austria, Canada, Federal Republic of Germany, Italy, Japan, the Netherlands, Sweden, and the USA.

Detailed information about the heat pump situation in our newest member country, Canada, will be presented in the next issue of this newsletter. However, some figures presented by J.M. Bell of Ontario Hydro, Toronto, Canada at the IEA Heat Pump Conference in Graz, May 22-25, 1984 can give a first impression about the Canadian heat pump market [1]. 4000-5000 degree days in the densely populated areas result in a significant heating load, 50% of which occurs at temperatures above -2 °C. These significant heating requirements in combination with low electricity prices and governmental subsidies, provided the conditions for a successful introduction of electric heat pumps in residential buildings. By the end of 1982, a total of about 33000 heat pumps for space heating purposes had been installed, and recently the annual sales increased to 10000 units per year.

One reason for the governmental subsidies and the extensive heat pump research, development and demonstration program was that 20% of the oil consumed in the 1970s was imported. A substitution of these imports by electricity, domestic fuels, and energy conservation measures shall phase out this dependence by 1990.

A survey among home owners, [2], published in March 1984, showed that most of the heat pump owners were satisfied with their systems. The main advantage of heat pump systems was stated to be the low fuel costs, whereas the survey showed that the high noise level was the main disadvantage of heat pumps.

A variety of heat pump development and demonstration projects have been supported by the Canadian government and by the utilities in the past. Information about these projects shall be added to the HPC's R, D & D database and will be reported in the next update of the R, D & D Report.

We hope that a fruitful cooperation with our new member country will take place, and that the forum of experience exchange provided by the HPC will benefit all participants.

References

[1]Current Situation and Future Prospects, IEA Heat Pump Conference, Graz, Austria, May 22-25, 1984

[2]Heat Pump Owners Attitudinal Manual, Department of Corporate and Consumer Affairs, Final Report, Canada, March 1984

K. Holzapfel, IEA Heat Pump Center c/o Fachinformationszentrum Energie, Physik, Mathematik GmbH, D-7514 Eggenstein-Leopoldshafen 2

H. Nakajima*

Residential Heat Pump Floor Heaters

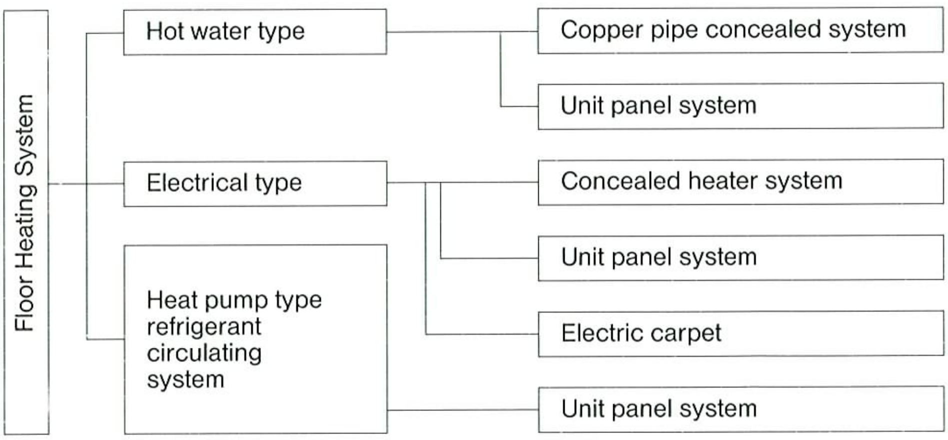


Fig. 1 Types of Floor Heating Systems

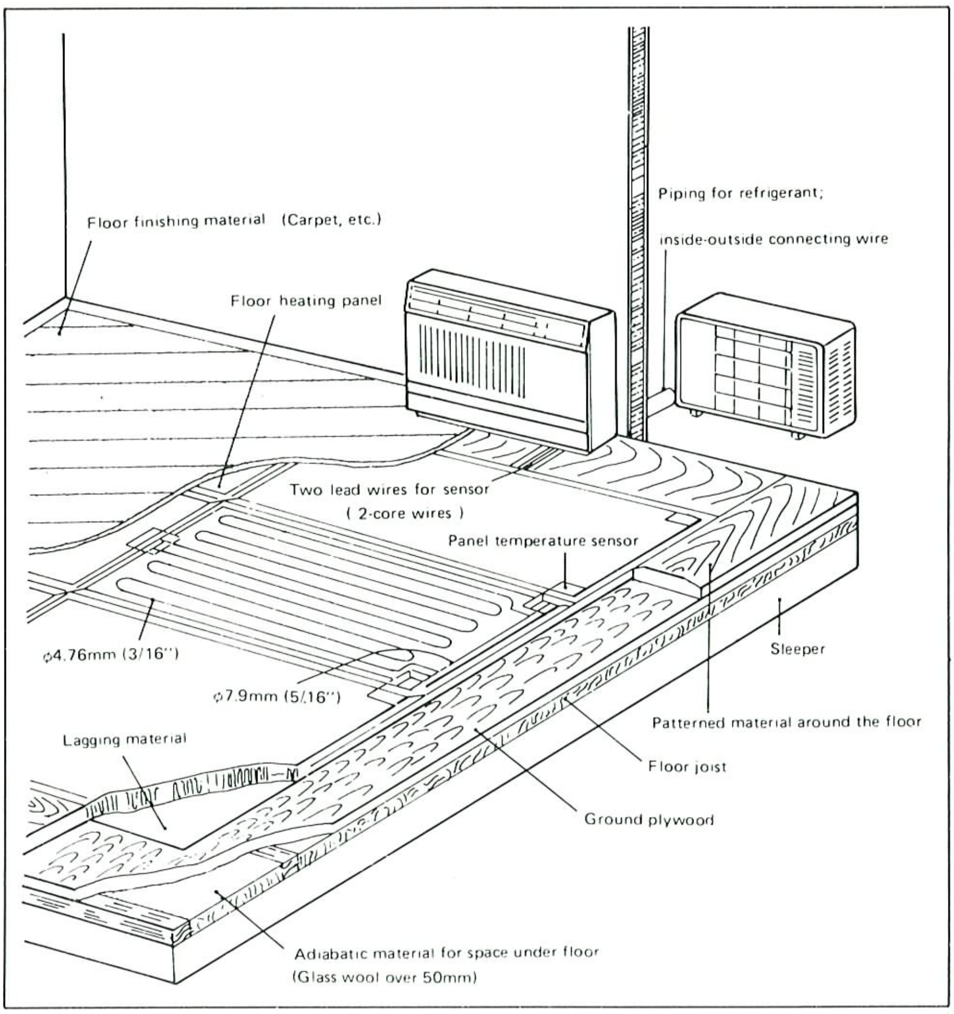


Fig. 2 Heat Pump Floor Heating System

Various types of floor heating systems are presented in Figure 1. Heat pump floor heaters that directly send the refrigerant R22 through the floor heating panel have the following advantages compared with conventional floor heating systems:

1) The heater is a heat pump heating system, which is highly efficient and energy-conserving.

2) When part of the floor surface radiation is obstructed, radiation from the remaining part is increased. The floor temperature remains low at all times.

3) The heat pump outdoor unit can also be used for cooling.

4) It can be installed without difficulty and rarely needs maintenance work.

1. System Configuration

The system consists of an indoor unit, an outdoor unit, and floor heating panels. These are manufactured in the factory and installed at the operating site using pipes to connect the heating panels.

If the area of the floor heating panels is about 70% of the total floor area of a room, the panels can produce sufficient heat for the room without utilizing an auxiliary heater.

The indoor unit contains the control system, which includes a switch for selecting the heating or cooling operation mode, a thermostat, a timer, etc.

The room heating panels are installed as shown in Fig. 2. They are connected to one another by brazing and covered with a floor finishing material such as carpet.

It is very important to use sufficient thermal insulation below the panels in order to avoid heat losses to the space below the floor.

Fig. 3 shows the refrigeration cycle of the floor heating system.

The size of a heating panel is 1.7 x 0.85 m, and its thickness is either 12 or 8 mm. It is constructed so that it is strong enough for use as a flooring material. Fig. 4 shows its cross section.

A hard polyethylene foam with a honeycomb structure gives strength and insulating properties to the floor heating panel. Aluminum-plated steel sheets cover the top and bottom of the panel to ensure thermal uniformity and improve the surface strength. The refrigerant tube is thermally connected to the surface material via the filler material. The thermal mass of this system aids in maintaining the uniformity of, and avoiding abrupt changes in, the surface temperature.

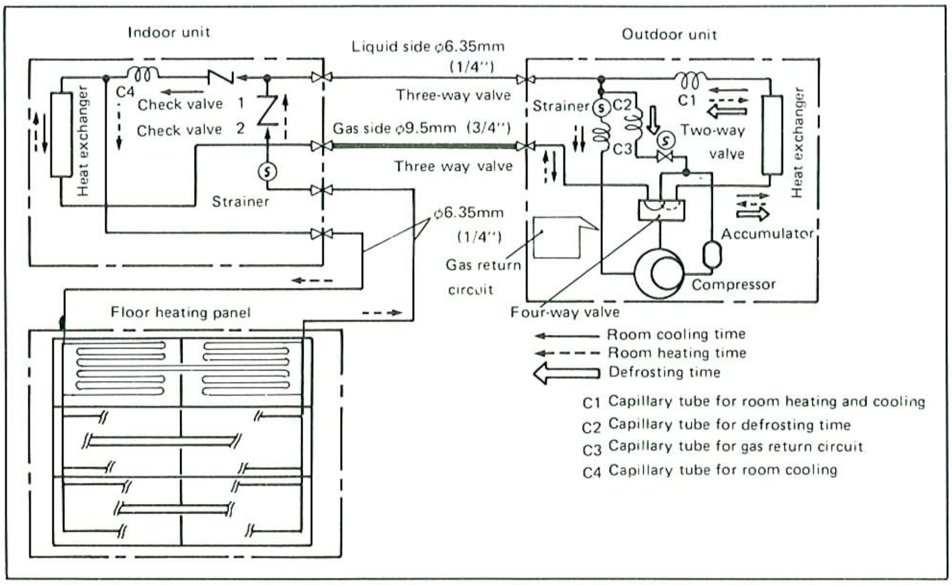


Fig. 3 Diagram of Refrigeration Cycle

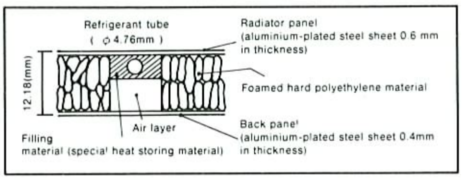


Fig. 4 Cross-Section of Floor Heating Panel

2. Heating Capacity of the Floor Heating Panel

Since this space conditioning system utilizes a heat pump, its heating capacity diminishes as the outside air temperature drops. However, the floor heating panel functions satisfactorily until the outside air temperature drops below -3 °C. Table 1 lists an example of specifications for the floor heating panel and Figure 5 gives the relationship between heating characteristics and outside air temperature.

It takes about 2 to 2.5 hours for the room temperature to reach 16 °C and the floor surface temperature to reach 25 to 30 °C. When operating this heat pump system, the time is preset by the timer built into the indoor unit. The floor surface temperature can be adjusted within the range of 18-32 °C by means of the thermostat built into the indoor unit.

3. Economic Comparison

Tables 2 and 3 compare a heat pump floor heating system with a conventional system in terms of initial cost and monthly energy cost.

4. Manufacturers

The heat pump type floor-heating systems are sold by the following three manufacturers:

1) Matsushita Electric Industrial Co., Ltd., Air Conditioning Division, Nojimachi 2275-3, Kusatsu, Shiga 525, Japan
2) Hitachi, Ltd., International Sales Corp. 2, Kanda-Surugadai 4-6, Chiyoda, Tokyo 101, Japan
3) Toshiba Corp., Intl. Operation-Consumer Products, Shibaura 1-1-1, Minato, Tokyo 105, Japan

Hiroyuki Nakajima, Marketing Development, Engineering Division Tokyo Electric Power Co., Ltd., Tokyo, Japan

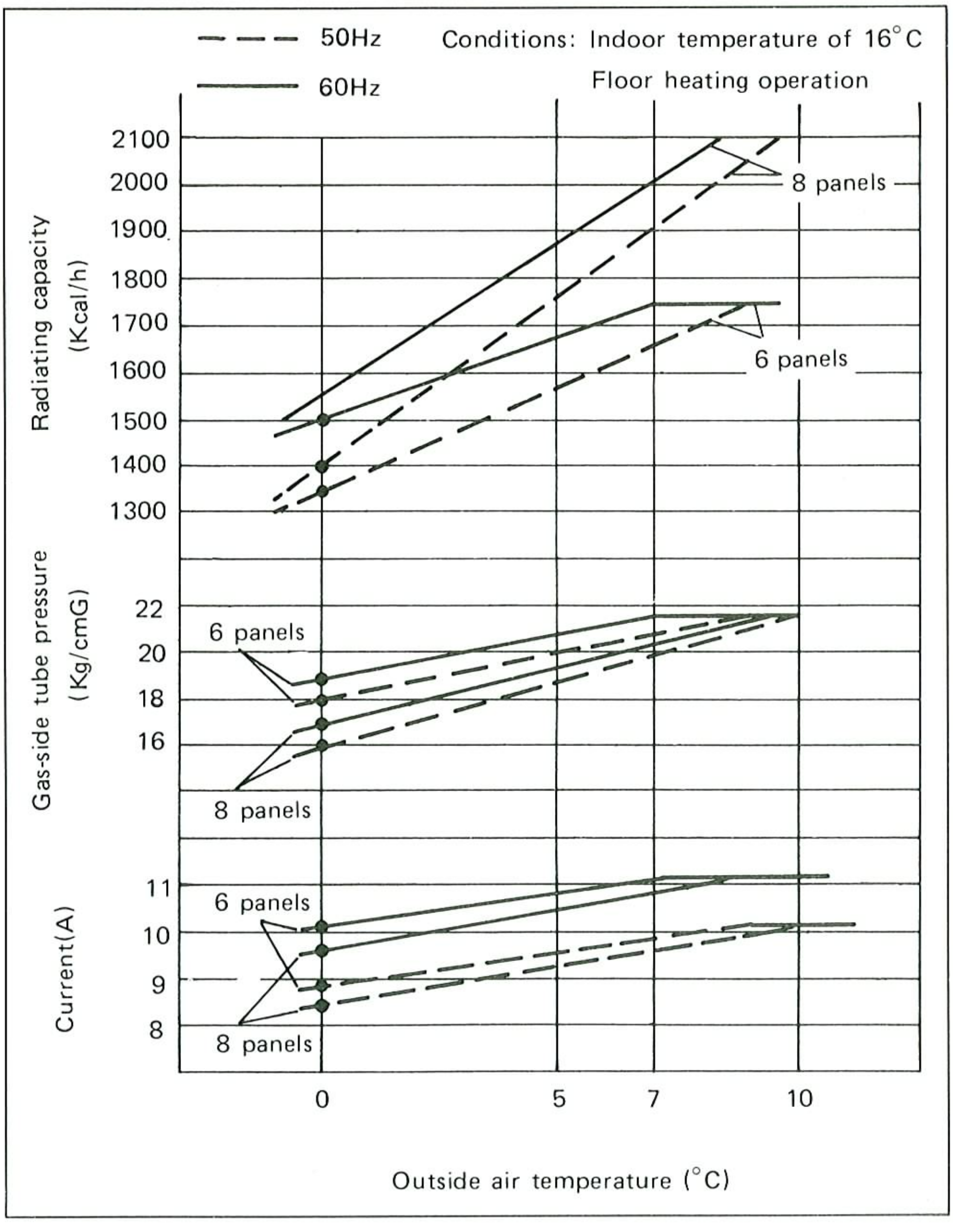


Fig. 5 Heating Characteristics of Floor Heating Panel

Number of panels / Item	Power supply	Room cooling: Room cooling capacity	Room cooling: Power consumption	Room cooling: Power factor	Room heating capacity: Room cooling capacity	Room heating capacity: Power consumption	Room heating capacity: Power factor	Compressor output	Area of air conditioned room
		kcal/h	W	%	kcal/h	W	%	W	m²
6	φ 100V	2020/1240	860/1050	92/99	1650/1700	900/1100	92/99	750	6 – 10
8	50/60Hz	2000/2240	860/1050	92/99	1900/2000	970/1050	92/99	750	
10	φ 200V	3150/3550	1410/1740	90/99	2250/2500	1310/1610	91/99	1100	12 – 16
12	50/60Hz	3150/3550	1410/1740	90/99	2500/2800	1270/1570	91/99	1100	

Table 1 Example of Specifications for Capacity

EQUIPMENT			
Heat Pump	286,000	Air Conditioner	216,000
6 Floor Panels Y 39,000/panel	234,000	6 Floor Panels, controller type	291,900
Subtotal	520,000	Subtotal	507,900
INSTALLATION			
Floor Heating Panels and Heat Pump	50,000	Air Conditioner	20,000
Electrical Work,	15,000	Electrical Work Air Conditioner	15,000
		Floor Heating Panels	30,000
		Electrical Work, Heating Panels	25,000
Subtotal	65,000	Subtotal	90,000
TOTAL	585,000	TOTAL	597,900

Table 2 Comparison of Initial Costs for a Room 13.2 m^2 in area (costs in Yen)

	Units	Heat Pump Type	Electrical Heating Type
Heating Load	kcal/month	360,000	
Required Electrical Input	kcal/month	171,429	360,000
Energy Cost	Yen/month	5,526	11,636
Comparison of Energy Costs	%	100	210

Table 3 Comparison of monthly Energy Costs

Swedish Heat Pump Training Program (VPU-83)

The accomplishments in heat pump installations during 1984 were largely a result of the ongoing heat pump training program, which began in 1983. Through the end of 1984 about 2500 people involved in various aspects of heat pumps were trained in the courses. This article briefly describes the training program.

The energy supply in Sweden relies heavily on imported oil. Heat pumps have proved themselves to be useful in reducing dependence on imported oil because of access to inexpensive electricity from hydroelectric and nuclear power stations. At present (January 1985) some 90,000 heat pumps have been installed in Sweden.

In order to realize the heat pump installations in Sweden it has been necessary to train the involved personnel. A special training project, VPU-83, was established to provide specialized information on heat pumps and to allow for the exchange of experiences related to heat pump use. The project is being financed by the Swedish State Power Board and the Swedish Council for Building Research and is intended to be active for a three year period. The Swedish Society of Heating and Air Conditioning Engineers and the Swedish Association of Plumbing, Heating and Ventilation Contractors are collaborating on the project and will use their existing project planning experience and information channels.

The VPU-83 project was started in 1983, and its focus is described in the following:

Analysis of training requirements and methods for coordinating the required training programs.

Preparation of the necessary technical training and information materials.

A large number of organizations are involved in the actual implementation of the training and information activities. These organizations will use the material prepared by the VPU project and will operate within the planning framework developed by VPU. The cost and implementation of the specific tasks are primarily the responsibility of the participating organizations.

Target Groups for VPU Training

At present, about 2,500 individuals have participated in the courses. There are a variety of training packages that are tailored to the needs of different target groups. Example target groups are:

- Property owners
- Consultants
- Installation firms
- Operating and maintenance personnel
- Energy advisory personnel
- Heating, ventilation and air conditioning inspectors
- Energy planning personnel
- Teachers, lecturers
- Health and environmental control inspectors

Example of Courses

Some of the various training courses offered are listed below:

- Exhaust air heat pumps in apartment blocks
- Heat pumps in apartment blocks
- Planning for heat pumps in group centrals
- Installation of heat pumps in private houses
- General heat pump technology
- Heat pumps and the environment

Heat Pump Training School

The heat pump courses have been offered in a school in central Sweden equipped with about 20 different heat pumps. Therefore, it has been possible to carry out extensive experiments and laboratory work in addition to theoretical studies.

The official education authorities are also preparing to introduce courses on heat pumps into the normal high school curricula.

Source: Swedish State Power Board, Swedish Council for Building Research, Stockholm, Sweden.

R. Lazzarini*

Absorption Heat Pump Demonstration Project in Italy

Absorption heat pump applications for space heating have great importance in countries such as Italy, where an increase in natural gas availability is planned. In order to promote efficient use of this source with advanced energy conserving technologies, some demonstration projects were financed to test the actual performance of absorption heat pump equipment.

The first experimental results on an absorption heat pump application are now available for a plant at "Musile di Piave" (Venice), where an ammonia/water absorption heat pump (water to water type, 25 kW nominal capacity) was integrated with a 100 m^2 energy roof.

The tests were carried out in April and May, 1984, under exceptionally unfavorable meteorological conditions for the season. As natural gas distribution is not yet available at the site, the heat pump was fed with LPG, using proper nozzles applied to the burner.

The results obtained from more than 500 measurements can be summarized as follows:

- The COP of the unit (excluding burner efficiency) ranges between 1.4 and 1.63 (Table 1), with an average value of 1.53, while the corresponding PER (Primary Energy Ratio) ranges between 1.11 and 1.32.
- The heating capacity amounts to 18 kW (Fig. 1), thus being lower than the 25 kW stated by the manufacturer.
- The unit is reliable and no maintenance was required during the test.

During the next winter season the plant will be monitored again to confirm the preliminary results.

*R. Lazzarini, Istituto Fisica Tecnica, Facolta di Ingegneria, Universita di Padova (Italy)

No. Hours	Qu (kWh)	COP	COP (with pump)	LPG (kg)	PER	PER*
18	285	1.45	1.41	16.3	1.25	1.17
7	119	1.63	1.58	8.0	1.42	1.32
17.5	259	1.40	1.36	15.6	1.19	1.11
6.5	100	1.48	1.44	5.7	1.26	1.17
49	763	1.46	1.42	43.6	1.25	1.17

* - With electrical energy evaluated at 2500 kcal/kWh

Table 1 Useful thermal energy, Qu (kWh), thermal COP, LPG consumption (kg), and Primary Energy Ratio (PER) during measuring periods

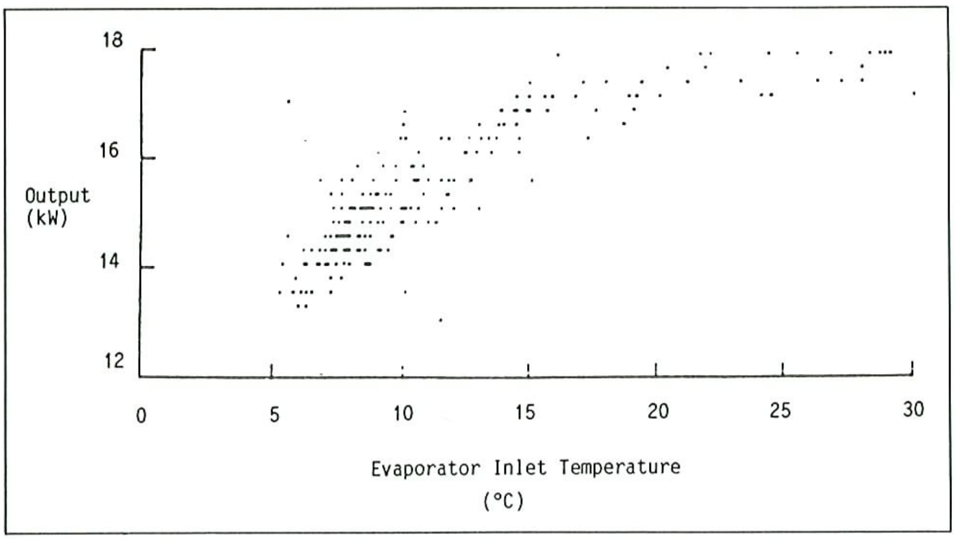


Fig. 1 Useful Thermal Output vs. Evaporator Inlet Temperature

Low Pressure Air Cycle Heat Pump

A prototype of an air cycle heat pump was recently presented to the press in Filderstadt near Stuttgart (West Germany).

This new concept uses air both as working medium and as heat transfer medium in an open cycle. Air with ambient temperature and pressure is sucked in by a piston machine, and expanded to a low pressure and low temperature. This cold air is moved to an absorber (the black plastic tube in photograph 1) where it absorbs heat from the environment. In a second piston machine it is recompressed to atmospheric pressure and thereby heated up to a useful temperature. This hot air is now released to the space to be heated. Both piston machines are working on the same shaft, which is driven by an electric motor (in the prototype presented). During the presentation, the heat pump was set into operation, and soon released a continuous air flow of 40-50 °C to the room operating at about 0,5 bar in the low pressure part.

Wilhelm Häberle, the inventor, claimes a COP of about 6 for his prototype at air temperatures about 5/40 °C. He is convinced that considerably higher COPs will be attained in a series development.

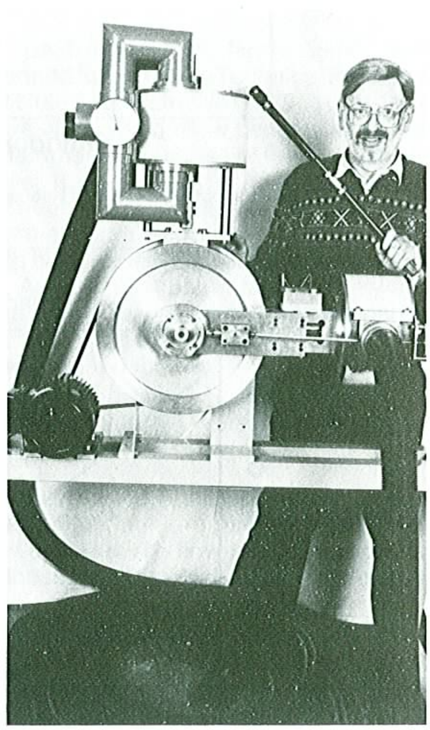


Photo: 1 Prototype of a low pressure air cycle heat pump and its inventor.

Further information from IEA Heat Pump Center, D-7514 Eggenstein-Leopoldshafen 2.

C.E. Bullock*

Recent Performance Investigations of Heat Pumps

Introduction

The electric, air-source heat pump has established itself as a highly efficient and reliable heating and cooling system, and increasing product sales have reflected its acceptance by consumers. Most of the information regarding the actual installed performance that can be expected from such units has been developed for all-electric, single-speed, single-compressor systems, however. Information on the more advanced designs is vitally needed by consumers, manufacturers, utilities and even legislators in order to properly evaluate various heat pump systems and to compare them with alternative heating and cooling systems. In response to this need, field studies have been conducted in order to monitor forced-air as well as hot water (hydronic) systems, dual-fuel (electric/gas, electric/oil) as well as all-electric systems, single as well as dual-capacity heat pumps, and domestic water heating units.

The present paper describes four of these field studies that are of particular interest and provides information concerning the selection and proper application of these heat pumps. The emphasis will be on heating performances.

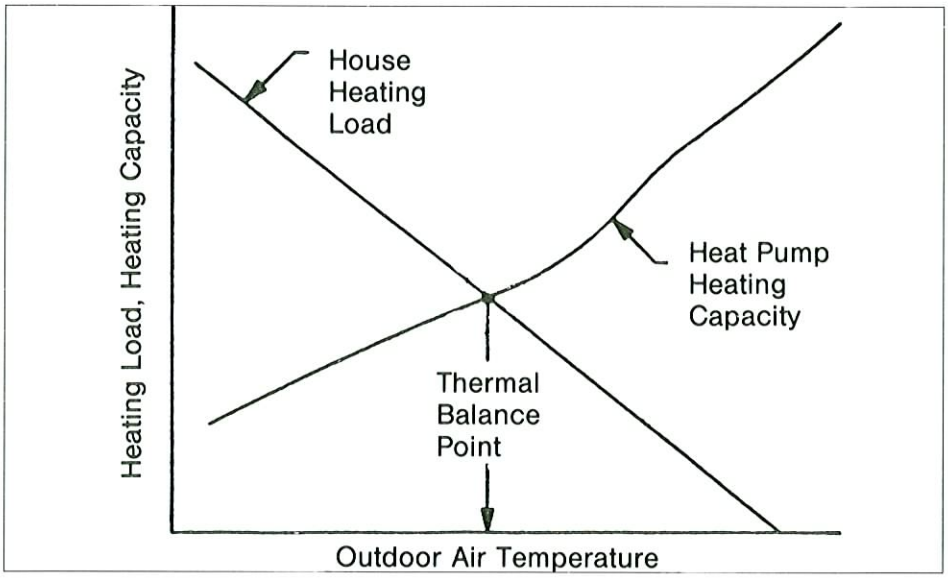


Fig. 1 Thermal Balance of the Heat Pump Heating Capacity with the House Heating Load

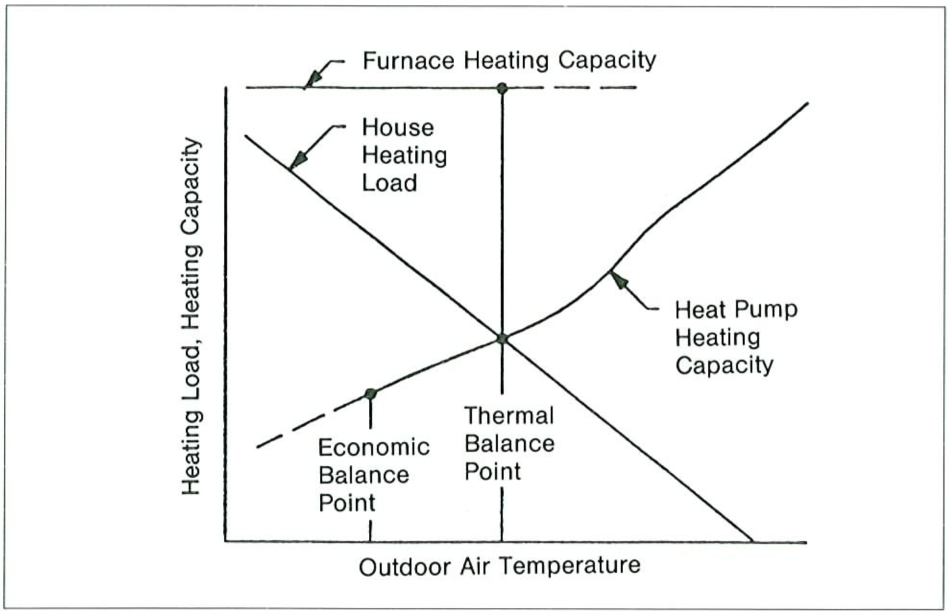


Fig. 2 Economic Balance Point of a Dual-Fuel System

General Features of Heat Pump Heating Systems

Fig. 1 illustrates a typical heat pump heating capacity characteristic, superimposed on a building heating load characteristic. The intersection of the two curves defines the thermal balance point for that heat pump/building combination. At this point the heat pump unit just meets the building heating load without need for supplemental heat. At higher outdoor temperatures, the heat pump has capacity in excess of the building requirement (and does not run continuously). At lower outdoor temperatures, the heat pump essentially runs continuously, and supplemental heat, typically from electric resistance heaters, must be provided to satisfy the building heating load.

An important parameter describing the efficiency of heating systems is the heating seasonal performance factor (HSPF), defined simply as the ratio of the total seasonal heating output (Btu) to the total seasonal energy input (Wh). The total heating output as well as the total energy input must include contributions from the heat pump and from supplementary heat sources. In the case of all-electric systems, the heat pump will have a high performance factor (typically 6-10 Btu/Wh) while electric resistance heaters will have a low performance factor (3.4 Btu/Wh). Thus the HSPF will be influenced by two independent factors:

1. The efficiency of the heat pump; and

2. The portion of the heat load provided by supplementary heat, which is mainly at low outdoor temperatures.

The first item relates directly to equipment design. The second item, on the other hand, is affected by the sizing of the heat pump. A larger, less efficient heat pump, which will require less supplementary heat, can develop a higher HSPF than a smaller, more efficient heat pump, which requires more supplementary heat. The second item above is also significantly affected by climate and the number of hours at low temperatures in particular. A heat pump sized for a given thermal balance point will have a much lower HSPF in the northern U.S. than in the southern U.S.

With dual-fuel systems, the situation is only slightly more complicated. As depicted in Fig. 2, the heating capacity (and efficiency) of the fossil-fuel furnace (or boiler) is not significantly affected by the outdoor temperature. At temperatures below the thermal balance point, the furnace (or boiler) and heat pump can either operate simultaneously or alternately, depending on the design of the control system. Because of the differences in energy costs and in heating efficiencies, the cost of one unit of heating output energy will generally be different for the two systems. Since the efficiency of the heat pump decreases as the outdoor temperature drops, an outdoor temperature can generally be found at which the cost of one unit of heat is the same from either system. This is referred to as the economic balance point (EBP) for that equipment combination. The EBP may be below or above the thermal balance point, depending upon energy costs and equipment efficiencies. At outdoor temperatures below the EBP, the heat pump is shut off, typically with an outdoor thermostat.

Hot water (hydronic) heating systems involve some special considerations. In this type of system, the heat pump and boiler are essentially in series, with the heat pump always upstream of the boiler. Fig. 3 shows a simplified schematic of one possible arrangement. The boiler is generally sized to match the design heating load of the building with an outlet water temperature of 160 °F to 180 °F. Radiators (or convectors) are likewise sized for this condition, which may occur only a few times each year. The heat pump is generally sized to achieve a specified thermal balance point with an outlet water temperature of approximately 120 °F to 130 °F. This lower water temperature has been shown by field and computer studies to be appropriate at outdoor temperatures above the thermal balance point since the required heating output from the radiators is much lower than the design load.

Field Instrumentation

A unique instrumentation system developed by the Carrier Research Division was employed to obtain the detailed equipment, system, and environmental measurements needed to characterize and assess the performance of the heat pump systems. The instrumentation system features on-site recording of approximately 20 channels of continuous data onto a magnetic tape cassette. Tape cassettes are changed monthly by each homeowner, who sends them directly to Syracuse for processing and analysis. Considerable detail regarding the capabilities of this instrumentation procedure has been published elsewhere [1] and is not, therefore, repeated in this paper.

Results of Field Monitoring

Site No. 1 is in Minneapolis, Minnesota. The test residence is a single-story ranch-style house with a full basement and is occupied by a family of four. The original forced-air heating system employed an all-electric heat pump with a single-speed compressor in the outdoor unit. Analysis of the results indicated that the original unit was undersized for the building, resulting in the use of more strip heat than necessary and in a relatively low HSPF value of 4.1 Btu/Wh. (Remember that this is in Minneapolis where low HSPFs are expected because of the severe heating season). Subsequently, a larger, more efficient, three-piece heat pump (with compressor indoors) was installed. Placement of the compressor in a separate indoor compartment has significant advantages for northern climate installations because it improves operation at low outdoor temperatures, while also simplifying any compressor servicing that may be required. The larger heat pump lowered the thermal balance point from 25 °F to 14 °F, reducing the need for resistance heat by roughly one-half. Coupled with its higher efficiency, total electric consumption was reduced by 30%, raising the HSPF to a more respectable 5.9 Btu/Wh. These results illustrate the point made earlier, i.e., that the system HSPF can be increased by either improving the efficiency of the heat pump or by increasing its heating capacity at lower outdoor temperatures.

Although it is generally true that increasing the heat pump size for a given house will increase the system HSPF, this should not be carried to the extreme. A larger heat pump will have the positive effect of reducing the auxiliary heat requirement at low outdoor temperatures but will have the negative effect of increasing the on/off cycling losses at high outdoor temperatures. In a properly installed system, the on/off cycling losses are a relatively small part of the overall picture so that the heat pump could theoretically be increased in size until no auxiliary heat would be needed, at which point the HSPF would be a maximum. Larger sizes than this would have lower HSPFs because of increasing on/off

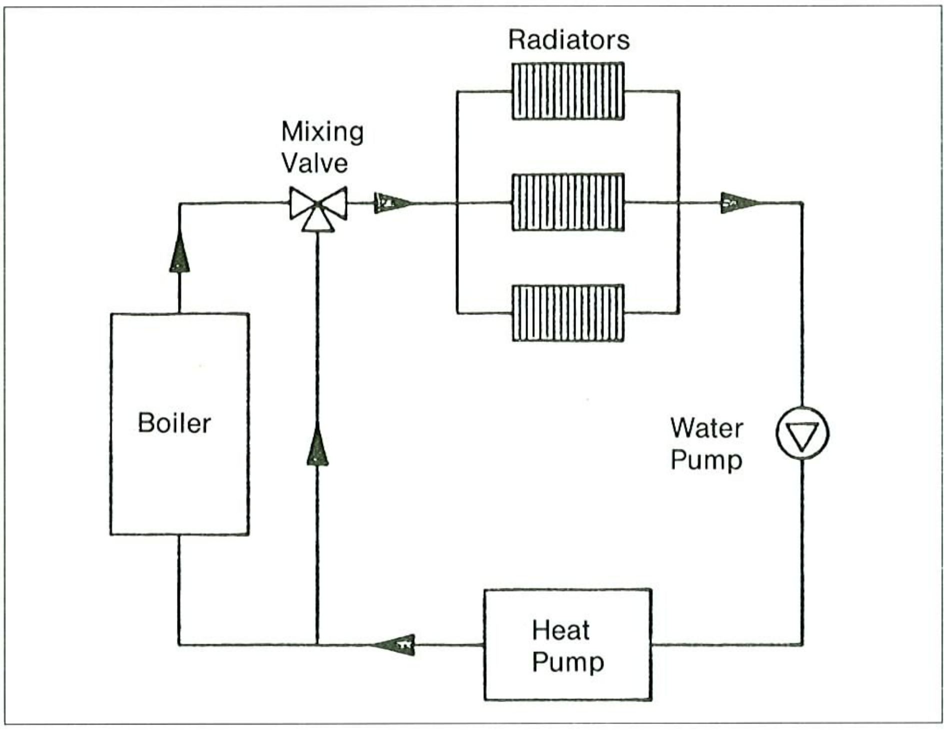


Fig. 3 Schematic of a Dual Fuel Hydronic System

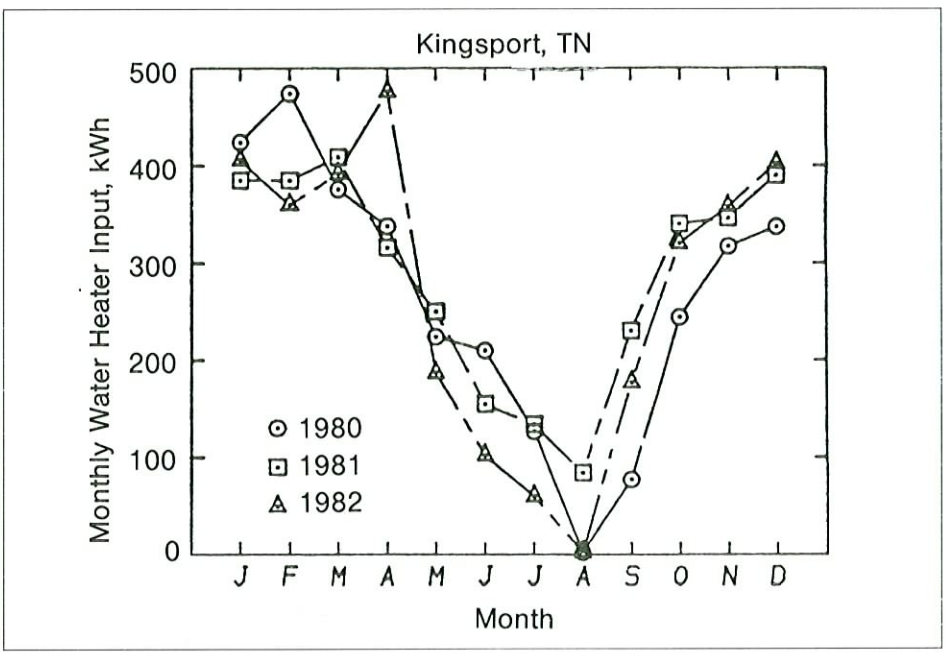


Fig 4 Monthly Water Heater Input

cycling losses. However, it would be found that such a large heat pump would not be practical because of its high first cost and also poor indoor temperature control at light loads. A rule of thumb is that the heat pump should be sized to meet the house design cooling load and also provide approximately 90% of the total heating requirements. The final choice, however, should be made by comparing total ownership costs (installation plus operating costs) for several units, using local equipment, labor and energy costs. Many heat pump dealers now have microcomputer programs which will perform this analysis quickly and accurately.

The larger heat pump also benefited the local electric utility by reducing the heating peak electric power demand under heavy load conditions. For example, at -12 °F (heating design temperature for Minneapolis) the original unit had a power requirement of 15.5 kW, including strip heat. The larger unit, reduced this peak to approximately 14.5 kW, thus reducing the strain on the utility generating equipment and distribution grid by about 1 kW.

Site No. 2 is in Kingsport, Tennessee. This site features a single-story ranch house with an underfloor crawl space, where the heat pump compressor, the indoor fan and coil, and the hot water heat recovery unit are located. The main electric water heater tank is located in an attached garage approximately 50 feet away. A family of three occupies the home. Of special interest at this site is the performance of the heat recovery unit and its effect on the main water heater. The heat recovery unit is a tube-in-tube (coaxial) refrigerant-to-water heat exchanger that is inserted into the compressor discharge line. Insulated water lines connect the unit to the main water heating tank, and a self-contained pump provides circulation. The unit can only operate when the heat pump is providing space heating or cooling and then only when the compressor discharge temperature is sufficiently high. Fig. 4 shows the monthly water heater electrical energy consumption for three consecutive years. During the peak heating months of December, January, February, and March, the low outdoor air temperature keeps the compressor discharge temperature relatively low. The heat recovery unit is thus not able to deliver much water heating in this condition. During the primary cooling months of June, July, August and September, however, the compressor discharge temperature is much higher, yielding substantially more heat recovery. In fact, there is little or no metered electrical input to the main water heater in August. The annual savings attributable to the heat recovery unit are approximately 30-40%, a very significant benefit.

The heat recovery unit increases the total heat transfer surface on the condenser side which, in theory, should improve the overall heat pump cycle capacity and efficiency. Analysis of the field data as well as separate computer studies indicate, however, that the net improvements on the heat pump cycle are small, probably less than 5%. The heat pump thus provided space heating and cooling with efficiencies that would be expected from a conventional unit. The principal result from this site, therefore, was the demonstration that significant portions of the domestic water heating load can be provided at little or no extra operating cost by conventional heat pumps to which a compressor heat recovery unit is added. Heat pumps presently on the market have this heat exchanger already built in, thus minimizing the additional first cost.

Recent changes have been made at this site in order to improve the performance of the heat pump and the heat recovery system. A new, higher efficiency heat pump with a factory-assembled, integral desuperheater coil was installed directly adjacent to the main water heater tank, thus eliminating the connecting line heat losses and improving the overall efficiency. Preliminary results indicate that additional "free" water heating is indeed being achieved, particularly in the milder months.

Site No. 3 is a two-story colonial style frame house with basement, in Syracuse, New York. The house is heated and cooled by a two-piece air-source heat pump. Supplementary heat is provided by a gas furnace with a rated output of 100,000 Btu/hr thus making this a dual-fuel, forced-air system. Controls are set to switch between the heat pump and the gas furnace at the house thermal balance point, 25 °F. Measurements over a one-year period showed that the heat pump operated for 1648 hours with an HSPF of 7.4, while the furnace operated for only 310 hours with a seasonal efficiency of 58%. Note in particular that the heat pump achieved a high overall efficiency, since it operated only at higher ambients. This dual-fuel system, because it operates the heat pump under the most favorable conditions, is attractive for a wide variety of climates, both south and north. Heat pump reliability will also be very likely improved. Another attractive feature is the freedom of choice of fuels. It should be noted that neither the heat pump sizing nor the heat pump/furnace switchover point have been optimized at this site. An economic analysis is needed to assess both of these items.

Site No. 4 is a single-story, ranch style house with basement in Central Square, New York (approximately 20 miles north of Syracuse). The hydronic heating system is comprised of an electric air-to-water heat pump supplemented by an oil-fired boiler. The control to switch between the heat pump and the boiler is set at 23 °F, which is above the house thermal balance point, 16 °F. Measurements showed that the average temperature of water supplied to the room baseboard convector units was approximately 130 °F, which is very compatible with heat pump requirements. Over a one-year period, the heat pump operated for 1169 hours with an HSPF of 6.9, while the oil boiler ran for 221 hours with a seasonal efficiency of 49%. Note again that, for this dual-fuel system, the heat pump efficiency is high because of its operation primarily at the higher outdoor temperatures. The heat pump sizing and the heat pump/boiler switchover point also need to be analyzed at this site in order to identify possible improvements.

Conclusions

Field tests at four separate sites have demonstrated that several efficient heat pump systems are presently available, each offering unique benefits to the consumer. Single-speed, single-compressor systems have established a good record for reliable and efficient space heating and cooling. Competition among manufacturers has steadily improved their efficiencies and reliability and will continue to do so in the future, making them very difficult to beat. Dual-fuel systems further enhance the heat pump heating performance by operating it only at higher outdoor temperatures.

With forced-air heating systems, proper heat pump sizing is important. In all-electric systems, a rule of thumb is that the heat pump should be sized to provide approximately 90% of the seasonal heating needs, in order to minimize the use of expensive resistance heating. With dual-fuel systems, sizing is influenced by electricity and fuel costs. Rules of thumb are not of much use here. Equipment selections are best done using local energy costs and climate data. Local heating equipment dealers now have accurate, easy-to-use computer programs which take much of the guess work out of equipment selection.

With hot water (hydronic) heating systems, heat pumps have been shown to operate very well with existing or new boiler systems. In order to be able to utilize a heat pump, a hydronic heating system must have radiators or convectors which are able to meet the house heating loads with water temperatures at or below about 130 °F over a significant range of outdoor temperatures. Because radiator and convector systems are generally sized for extreme heating load conditions, this does not appear to be a serious limitation. The sizing of the heat pump follows essentially the same guidelines as for forced-air systems.

In addition to proper sizing of heat pumps, the use of proper installation practices is very important in order to achieve all of the performance advantages and reliability improvements that are available. In particular, adequate indoor air flow (or water flow) must be assured, refrigerant lines must be properly sized and the outdoor coil section must be located so that unusual wind patterns or snow accumulations cannot occur. Also, adequate safety controls, in order to protect the compressor from unusually high or low refrigerant temperatures or pressures should be added if they are not built into the original unit.

Future improvements in heat pump designs will likely involve one or more forms of capacity modulation, such as multiple compressors or variable speed compressors, in order to achieve better load matching as well as additional capacity at high load conditions. Since domestic water heating can account for as much as half of the heating energy consumption for a household, future heat pump designs will likely include integrated water heating coils which will be able to provide much of the domestic hot water even when space heating or cooling is not needed. Further improvements will also be made in microprocessor control designs to improve overall system efficiency and reliability as well as to provide better control of peak electric power demands, such as during periods when the electric utility has its peak loads or during recovery periods following room thermostat night setback.

Acknowledgement

The field monitoring activity described in this paper was supported by the Niagara Mohawk Power Corporation and Electric Power Research Institute, whose help is gratefully acknowledged.

Reference

[1]G.C. Groff, W.R. Reedy, "Investigation of Heat Pump Performance in the Nothern Climate Through Field Monitoring and Computer Simulation", ASHRAE Transactions, Vol. 84, Part I, 1978.

*C.E. Bullock, Carrier Corporation, Research Division, Syracuse, New York.

R. Brandner*

Heat Pumps in Austria

The residential heating situation in Austria is still characterized by a high dependence on imported oil and therefore by strong efforts for conservation of all energy forms and for oil substitution [1]. These aims, particularly the second, can be furthered by the utilization of heat pumps. In recent years, the application of heat pumps for residential space and tap water heating with air, ground water, or ground as the heat source has been of primary interest in Austria. For heating capacities greater than 20 kW and as large as several hundred kW, gas/diesel engine-driven heat pumps are being utilized. Absorption heat pumps have not yet been used in residential applications.

Heat Sources

Ambient air is used as the heat source most frequently, because it is often not possible to use ground water. Generally, heat pumps are operated in the bivalent mode together with a conventional heating system. In the case of operation below +5 °C outdoor air temperature, defrosting of the evaporator is required. Air-source units for single-family hot tap water supply have increased in sales in recent years and now have the greatest share of the heat pump market. These units have an input electric power range from 0.6 to 1.0 kW, have heating capacities up to about 3 kW, and are coupled to a 200-500 liter water tank containing an auxiliary electric heating coil. Brine-to-water heat pump systems coupled to fanless ambient heat absorbers (energy roof, stack, fence, block, etc.) use air as a heat source but transfer the heat via an intermediate brine circuit. A number of such installations utilize tubes installed in concrete walls, balcony railings, garden walls, etc. ("Massiv-Absorber").

Ground water varies little in temperature over the year and therefore is a preferred heat source if sufficient water is available and if its utilization is permitted. The procedure for obtaining permission to use ground water for heating purposes is administered in different ways by appropriate local authorities. Areas with a high ground water level are the main river valleys, e.g. the Danube River valley.

Ground source heat pump systems have been successful in regions with low ground water levels and low average annual air temperatures (e.g. Muehlviertel, Oberoesterreich) [2]. These systems utilize horizontal or vertical ground absorbers, and the systems can employ direct evaporation or use an intermediate brine circuit between the absorber and heat pump.

R, D & D Effort

Current research activities in Austria were described in the HPC Newsletter of December 1983 [3]. Emphasis is placed on:

- design and sizing of ambient heat absorbers that can utilize heat from solar radiation and precipitation, and their integration into the heat pump system either with an intermediate brine circuit or with direct evaporation;
- development and testing of seasonal storage systems combined with collector systems to charge the storage during summer operation;
- design of compact units to facilitate the installation of the heat pump into the heating system;
- integrated control of entire system.

More details on heat pump projects in Austria are available to parties from countries participating in the IEA Heat Pump Center from the R, D & D database [4].

Sales

Whereas in 1980 the total number of heat pump installations in Austria was 5,800, at the end of 1984 more than 33,000 electrically-driven heat pumps were in use, about 76% for tap water heating, 18% for space heating, and 2% for swimming pool heating; 4% are combined systems for both space and tap water heating [5].

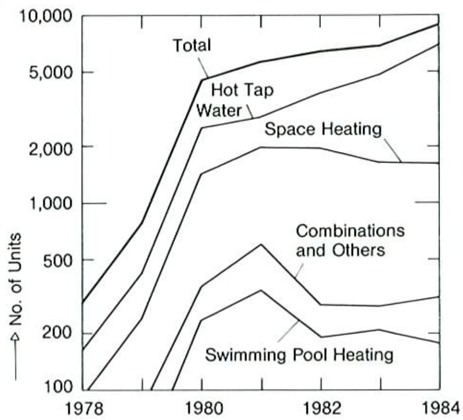


Fig. 1 Annual Heat Pump Sales in Austria (logarithmic scale) [5]

Fig. 1 shows heat pump sales figures from 1978 to 1984. The downward trend of space-heating heat pump sales slowed in 1983 and stopped in 1984. Sales of heat pumps for tap water heating have consistently grown, and the increase between 1983 and 1984 of 45% was the largest increase for the 1980s. Fig. 2 shows the total number of heat pumps in use for each year between 1978 and 1984 and shows the corresponding connected load of the heat pumps. The connected load has been rising more slowly than the number of heat pumps in use because of the continuous decline in the average electric power of installed heat pumps. Larger systems characterized the earlier phase of heat pump installations, but at present the average heat pump for space heating has an electric power input of about 5 kW, and the average for tap water heating units is somewhat less than 2 kW of input. The average for all units, which is about 3.1 kW, also declines due to the increasing market penetration of small tap water units.

Fig. 3 gives a breakdown by heating capacity range as well as by heat source for heat pumps sold in 1984. The figures do not include heat pumps sold only for

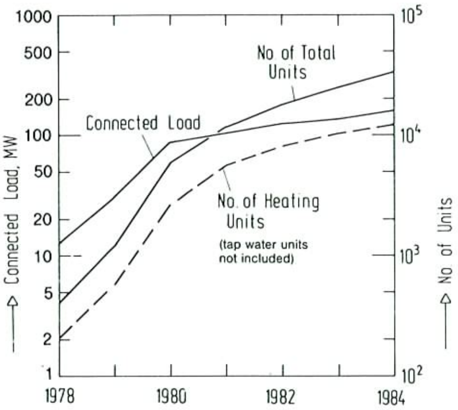


Fig. 2 Connected Load and Number of Heat Pumps in Use in Austria (logarithmic scale)

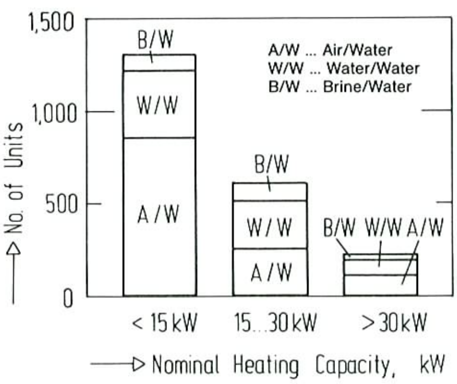


Fig. 3 Heat Pump Sales 1984; Breakdown by Heating Capacity Range and Heat Source [5]

tap water heating. 61% of all units sold are in the smallest capacity range, including 70% of air/water units, 53% of water/water units, and 38% of brine/water units.

On the side of the manufacturers, the Austrian heat pump market is still relatively dispersed. The market shares for 1984 of hot tap water units and of heating units by the top six firms are given in Table 1. Of the

Company No.	Shares, %	
	Heating Units	Hot tap water units
1	22	27
2	16	16
3	8	11
4	8	7
5	7	6
6	6	6

Table 1 Market Shares of Firms Offering Heat Pumps in Austria, 1984 [5]

27 firms offering heat pumps in Austria, 12 firms are manufacturing heat pumps in Austria.

Present Market Situation

1984 was characterized by significantly different development trends of heat pump application in the different regions of Austria. Heating units installed in the federal state of Oberoesterreich, which is inhabited by about 15% of the Austrian population, comprised about 50% of all such installations in Austria.

This strong growth in heat pump use, which steadily continued in the first six months of 1985, is mainly due to activities by OKA, the electric utility company of Oberoesterreich [6]. Activities include a program for monitoring residential heat pump installations in order to collect actual operating data and to evaluate various heat pump systems available on the market. Ambient air, ground, and ground water are used as heat sources by the different systems, which usually operate in the bivalent mode. Successful operation was found to depend strongly on proper sizing and installation; imperfect cooperation with some manufacturers indicated that further effort in this direction is necessary. On the other hand, the pioneer work by OKA resulted in tremendous market penetration in some districts and villages. OKA intends to expand their effort in other areas.

Based on experiences from the residential sector, another program was started in 1983 for the public service sector (schools, homes for the aged, etc.). At present, ten plants with heating capacities between 100 and 200 kW are operated by OKA, and further projects are envisaged. These projects are partially financed by a leasing company [7].

Market Potential

A total of 2.75 million dwelling units currently are occupied in Austria; 1.31 million of them are situated in single- or two-family buildings (including farm houses) [8]. About 40,000 new dwellings are constructed each year. Massive construction utilizing bricks is usually employed; however, light-weight construction (prefabricated buildings or wooden houses) has increased in its share of new constructions but is still less than 10%.

Hydronic systems are 52% of Austrian residential heating systems. The remaining 48% (usually in older dwellings) are individual room heating units. Air distribution systems are not common in Austrian residential buildings. Fig. 4 illustrates the strong trend towards replacement of single-room heating by central heating equipment.

Fig. 5 shows the fuel shares for residential heating for the period 1970 to 1984. The percentage of dwellings using coal has continuously fallen, whereas the share of gas and electricity has continuously increased. Since 1980, the share of oil-heated dwellings has decreased, and the share for wood has increased. 6% of the dwellings were heated by district heating in 1984.

Electricity rates for heat pump installations vary by a factor of 1.7 for different regions in Austria. For units with a nominal electric power not exceeding 5 kW (the usual case for single-family houses), no fee for connection to the electrical network and no base charge for electricity supply needs to be paid since spring 1985. Table 2 gives prices for electricity, extra-light fuel oil, and natural gas or city gas. The lower electricity price and the higher gas

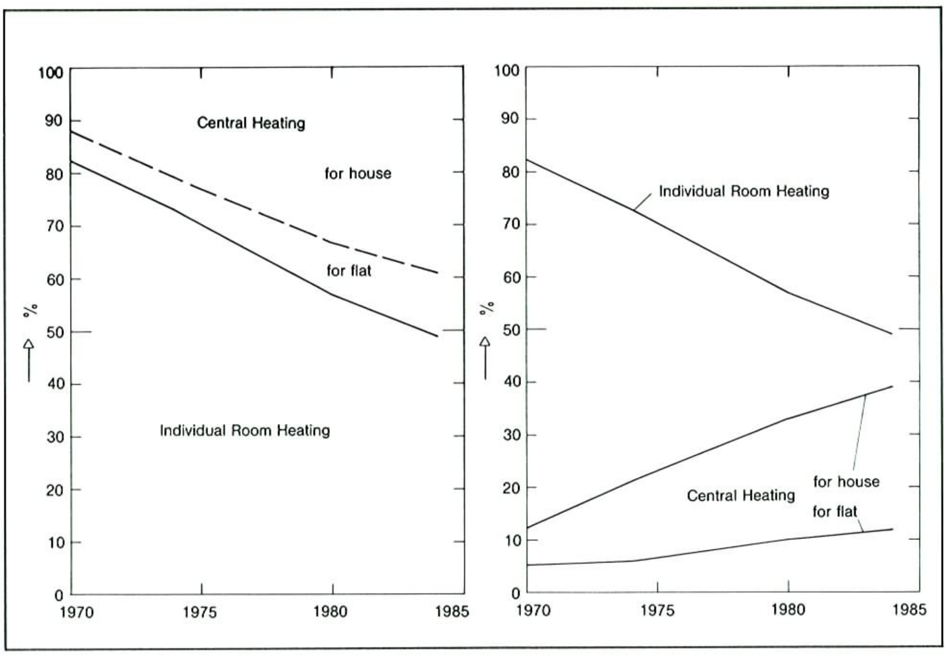


Fig. 4 Types of Heating Systems, cumulative [8]

price are applicable to the western part of Austria.

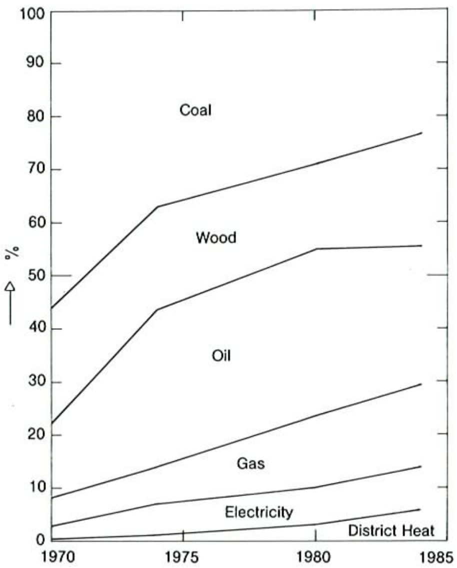


Fig. 5 Fuels for Residential Heating, cumulative [8]

	AS/kWh
Electricity	0.97 . . . 1.64
Fuel oil EL	0.70
Natural gas	0.60 . . . 0.80

Table 2 Energy Prices in Austria (including 20% VAT, January 1984)

The largest potential market for electric heat pumps is existing single-and two-family houses. This market segment has a higher than average share of central hydronic heating systems; the vast majority of these utilize radiators, although there is a low but increasing number of floor heating systems. Most of these central systems use heating oil or solid fuels. The entire market segment (including central systems and other systems) has three main parts:

- Due to oil price levels, security of supply, and environmental considerations, owners of oil-fired hydronic systems are motivated to install an electric heat pump. Within this market segment are approximately 200,000 houses with heat loads between 10 and 30 kW. Most of these houses require a maximum supply temperature of about 65 °C.
- More than 400,000 houses have central heating systems with solid fuel boilers. Installation of a heat pump is motivated by a desire for more convenient operation of these heating systems.
- More than 400,000 single- and two-family houses are heated by means of stoves, some 50,000 of these by means of oil-fired stoves. The trend towards replacement of stoves by central heating systems offers the potential to install heat pumps and low-temperature hydronic distribution systems in 5,000 existing buildings per year. In the case of oil-fired stoves, the tendency towards oil substitution also encourages heat pump use. The most important barrier in this market segment is the high investment cost required for the central heating equipment and heat pump.
- Assuming that in the next decades a quarter of the 400,000 stove-heated homes and half of the 600,000 centrally-heated homes will change to heat pumps, the prospective market amounts to 400,000 small heat pump units. The 12,000 units installed during the last five years (Fig. 2) represent only 3% of this number. If the economic and environmental benefits from use of heat pumps are to be realized within a reasonable time-frame, an accelerated pace of development must be initiated.

References

[1]Bundesministerium fuer Handel, Gewerbe und Industrie: Energiebericht und Energiekonzept 1984 der Österreichischen Bundesregierung. Wien: BMHGI, 1984.

[2]O. Katona, R. Brandner: System Analysis of Heat Pumps with Vertical Earth Heat Exchangers with or without Recharging. Second Workshop on Solar Assisted Heat Pumps with Ground Coupled Storage, Vienna, May 8-10, 1985 (to be published by CEC Joint Research Centre Ispra).

[3]R. Brandner: A first survey of current research activities in Austria. HPC Newsletter Vol. 1, No. 2, December 1983, p. 9.

[4]IEA Heat Pump Center: Heat Pump R, D & D Projects, Report No. HPC-R1, Vol. 1-4. IEA Heat Pump Center, Karlsruhe, 1984 (Restricted to IEA HPC member countries).

[5]Arbeitsgemeinschaft Technik und Nutzung der Umweltenergie: Marktstatistik 1984. Wien, 1985.

[6]M.F. Schneeberger: The Impact of an Austrian Utility's Heat Pump Initiatives, Proceedings IEA Heat Pump Conference: Current Situation and Future Prospects, Graz, May 22-25, 1984, Vol. 1, pp. 507-513.

[7]OKA: Utility-financed Heat Pumps in Austria; HPC Newsletter Vol. 1, No. 2, December 1983, p. 10.

[8]W. Janik: Beheizung der Wohnungen; Ergebnisse des Mikrozensus Maerz 1984. Statistische Nachrichten, 39. Jg. 1984 (Neue Folge), Heft 11/12, pp. 674-678.

*R. Brandner, IEA Heat Pump Center, Analysis Center, Graz, Austria.

Yamagishi, K.*

Gas Engine Heat Pumps in Japan

1. Circumstances that Led to the Development

In 1978 R & D of gas engine heat pumps (GEHP) began in Japan. As part of the important technology R & D program subsidized by the Ministry of International Trade and Industry (MITI), research and experimentation concerning a small GEHP was started. In 1980, a prototype was completed and exhibited at the 6th International Good Living Show held in April of that year. This accomplishment was highly commended by MITI. Besides considerable energy conservation, an increased independence from oil was expected from the use of GEHPs. Additionally, the accompanied diffusion of residential gas-fired cooling would correct the seasonal imbalance in power and gas demand (see Fig. 1). Motivated by these considerations, the "Union for Technical Research on Small Gas-Fired Cooling" was founded in 1981.

In June of that year, the union was inaugurated, joined by 14 companies of three types: engine manufacturing, heat pump manufacturing, and gas supply. The program was set up for a period of three years and funded with about 3 billion yen. It was initiated as basic R & D of technologies used in GEHP for residential and commercial applications.

Side by side with R & D by the union, development of medium- and large-size GEHPs has been increasingly pursued. The first commercial GEHP unit in Japan was installed at the Sodegaura plant of Tokyo Gas in 1980. It was a 30 USRT (105 kW) heat pump unit (1 USRT = 1 US refrigeration ton = 3.52 kW). Subsequently, improved units appeared. In 1983, a packaged type 30 USRT GEHP appeared and was awarded the 21st Air Conditioning and Plumbing Engineers Association Prize.

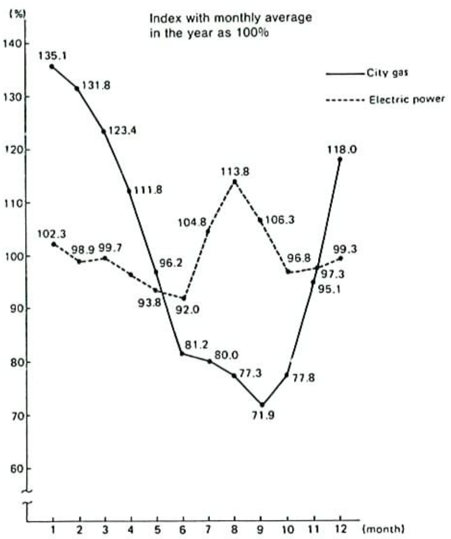


Fig. 1 Monthly Relative Demand for City Gas and Electric Power in 1981

2. Number of GEHP Installations and Description of Examples

Since 1980 the GEHP has drawn increasing attention due to its high energy efficiency and economical performance, with the result that the number of units installed has continually increased. By the end of 1984, more than 100 units were expected to be installed across Japan. Fig. 2 shows the number of newly installed GEHPs per year up to and including 1983. Fig. 3 and Fig. 4 show a breakdown of GEHP-equipped buildings by type and a breakdown of GEHP installations by capacity. Installations are concentrated in the vicinity of big cities, and most of the installations use air as the heat source. The urban areas are subject to severe control on the use of ground water. In smaller cities there are less restrictions, so there are cases where water-source units are installed. There are also Diesel engine-driven heat pumps, which are employed for heating

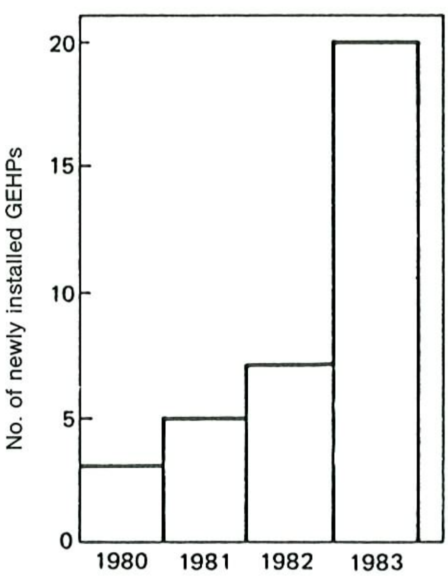


Fig. 2 New GEHP Installations in Japan

greenhouses, commercial fish ponds for raising eel, etc.

A look at the realized GEHP installations shows that many of the early installations were intended for evaluation of GEHPs by the manufacturers and gas suppliers, and as demonstration plants for prospective users. Recently, however, an increasing number of units have been installed on a commercial basis in applications favor

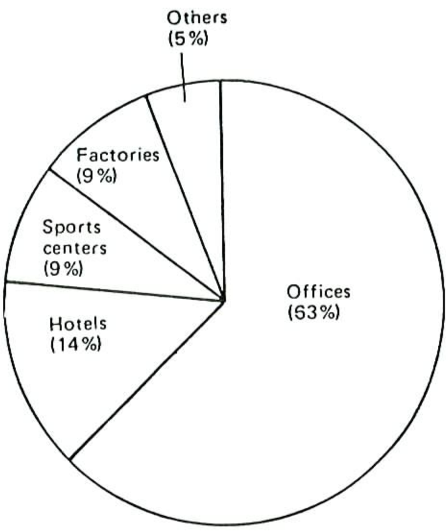
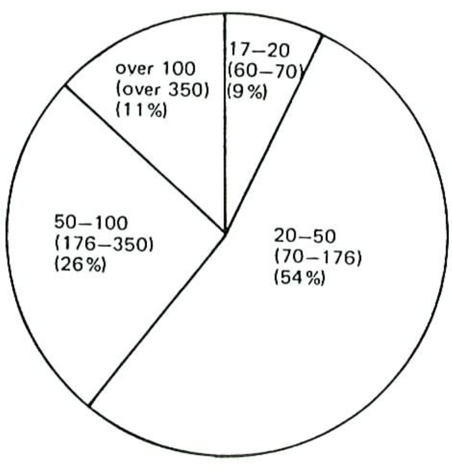


Fig. 3 Breakdown of Japanese GEHP-equipped Buildings by Type (December 1983)



unit: USRT (kW)

Fig. 4 Breakdown of Japanese GEHPs by Capacity (December 1983)

able for the use of GEHPs, in order to demonstrate the energy conservation and economic benefits of GEHPs.

2.1 Installation example 1: Howa Sports Land

In 1981, two GEHP units were installed at a sports center with a total floor area of 13,616 m^2, equipped with an indoor warm water pool (a loop 125 m long), an ice skating rink (60 m x 30 m), a sauna, etc. (see Photo 1). Each of the srew-compressor-type heat pumps is driven by a 6-cylinder gas engine with a total displacement of 11.4 liters and a power output of 135 HP at 1800 rpm.

The facilities of the sports center have a continual cooling load resulting from air-conditioning in summer and ice making in winter. There is also a year-round heat demand resulting from swimming pool and tap water heating in summer and tap water and space heating in winter. Except for the sauna heat requirements, the GEHPs can meet all loads, supplying hot and chilled water at the same time. They typically use ice in winter and indoor air in summer as their heat source.

System and Modes of Operation

The system configuration (Fig. 5) and modes of operation of this GEHP-plant are designed so that, responding to the various heating and cooling loads, the plant can be operated at a high energy utilization rate. In addition to the gas engines's speed control and heat pump's capacity control, condensing temperatures can be controlled corresponding to the magnitude of heating and cooling loads. There are two modes for winter operation, and three modes for summer operation. (Table 1).

a) The summer operation mode is depicted in part a) of Fig. 5. The rs of the GEHPs provide the cooling. By utilizing the waste heat from the gas engine and the heat of condensation from the refrigeration cycle, tap water, swimming pool water, and the pool room are heated.

b) The winter operation mode is shown in part b) of Fig. 5. The evaporators of the GEHPs provide the cooling for the ice of the skating rink. The gas engine's waste heat and the heat of condensation occurring in the refrigeration cycle are utilized for hot tap water supply and space heating.

Results of Operation

The Figures 6 and 7 show typical energy flow diagrams for summer and winter operation, respectively. These results roughly coincide with the design values for energy utilization rates shown in Table 1. These rates are referenced to the energy input to the GEHP. Fig. 8 shows hourly load changes in winter, indicating that the load increases on Saturday and Sunday when the number of visitors is high.

From December 1981 to June 1984 the hours of operation amounted to about 10,000. After 6,000 operation hours, the gas engine was inspected, but nothing abnormal was discovered.

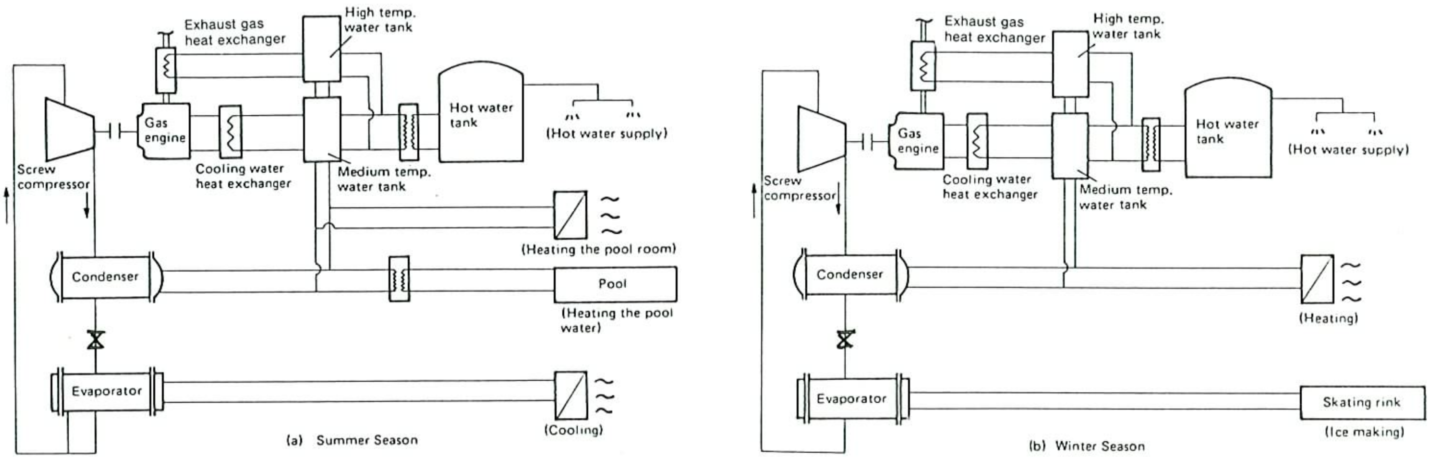


Fig. 5 Summer/Winter Operation Modes of the GEHP System at Howa Sports Land

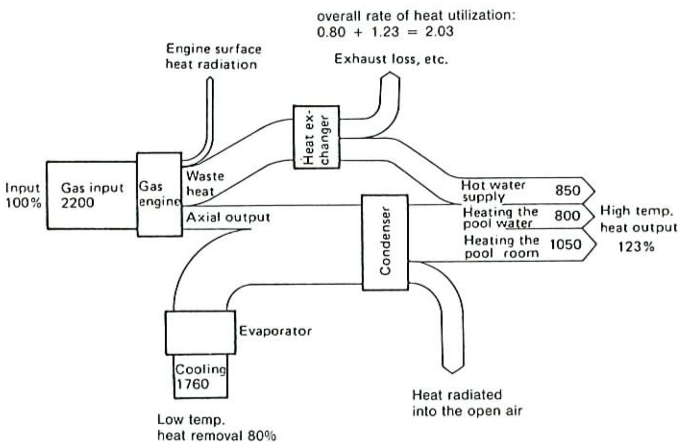


Fig. 6 A Day's Energy Balance in Operation Mode 5 (Average Values in kWh for July 1982)

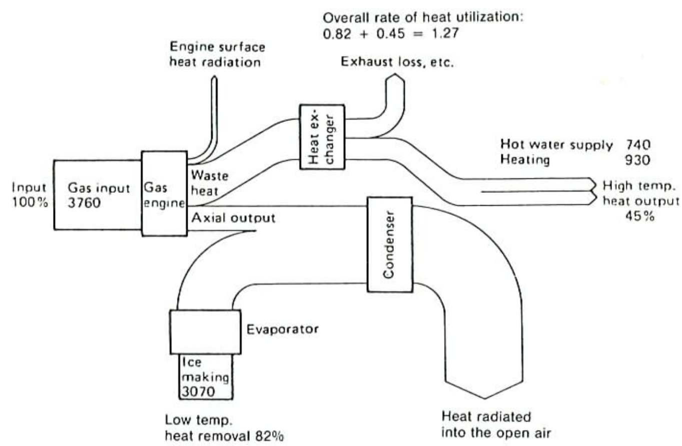


Fig. 7 A Day's Energy Balance in Operation Mode 1 (Average Values in kWh for January 1982)

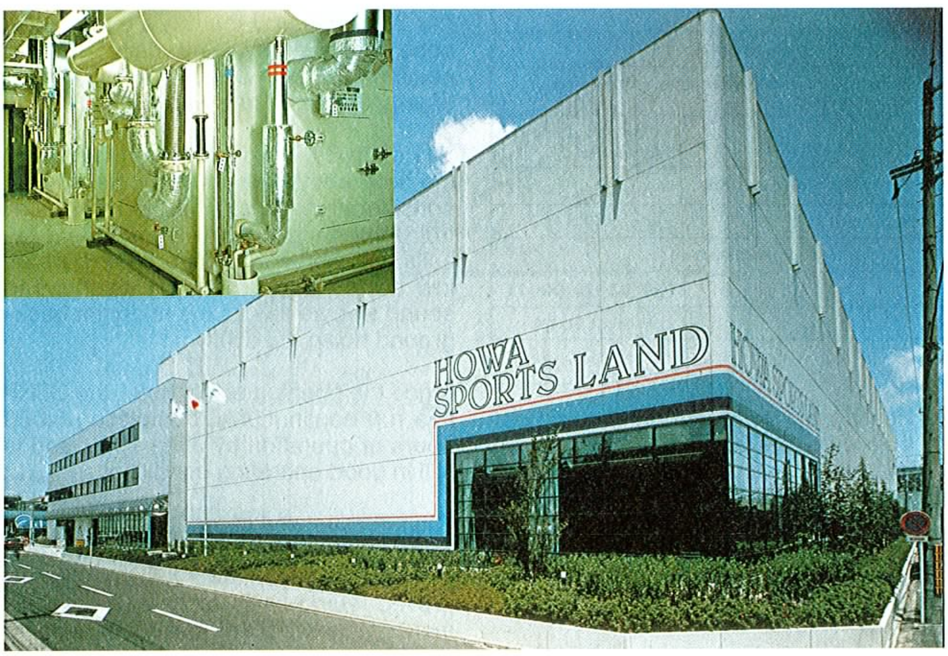


Photo 1 GEHP at Howa Sports Land

2.2Installation example 2: New Maruiwa Hotel

A 70 USRT (246 kW) screw-compressor-type GEHP was installed in 1982 at a hotel with a total floor area of 2,284 m^2, including a restaurant, a banquet hall, and a wedding hall (see Photo 2). The heat pump is driven by a 4-cylinder gas engine with a total displacement of 7.13 liters and a power output of 115 HP at 2200 rpm.

System and modes of operation

The system design allows operation in four modes, including hot water supply operation, which are selected according to seasonal and load requirements. The cooling and hot water supply modes a) and b), and the space heating and hot water supply modes c) and d) are diagrammed in Fig. 9.

a) Cooling/hot water supply mode (cooling priority). The inside of the hotel is cooled by cold water of 7°C obtained from the GEHP's evaporator. The waste

Table 2 Specifications for SGP-TCH150A

Item		Indoor Unit SGP-TH50AX3	Outdoor Unit SGP-CH150A
External dimensions (mm)	Height	280	2,317
	Width	1,560	1,850
	Depth	675	1,000
Weight (kg)		52	950
Cooling capacity (kW)	3 units in operation	47	
	2 units in operation	31	
	1 unit in operation	19	
Heating capacity (kW)	3 units in operation	48	
	2 units in operation	36	
	1 unit in operation	19	
Power supply for auxiliary components		3-phase 200V 50/60 Hz	
Power consumption (kW) – Cooling	3 units in operation	0.96/1.02	1.09/1.40
	2 units in operation	0.63/0.67	1.09/1.40
	1 unit in operation	0.30/0.32	0.79/0.97
Power consumption (kW) – Heating	3 units in operation	0.99/1.05	1.09/1.40
	2 units in operation	0.66/0.7	1.09/1.40
	1 unit in operation	0.33/0.35	0.49/0.54
Operating current (A)	(Cooling) 3 units in operation	5.4/6.6	3.1/3.7
	(Heating) 3 units in operation	5.4/6.6	3.1/3.7
Starting current (A)		Cooling: 13.5/13.2 Heating: 8.7/7.7	
Fuel consumption (Nm^3/h)	(Cooling) 3 units in operation	3.45	
	(Heating) 3 units in operation	3.25	
Compressor	Type	V type, 4-cylinder, reciprocating open type	
	Model	C-L75G	
	Displacement (cc/rev)	454	
	Quantity of refrigerator oil (l)	5.2	
	Crankcase heater	75W	
Engine	Type	Upright type, 3-cylinder water-cooled type	
	Model x No. of unit	DG1402 x 1 unit	
	Displacement (cc/rev)	1,395	
	Quantity of lubricating oil (l)	Total amount: 5.8 Effective: 3.3	
	Rated output (MP/rpm)	6/900 16.2/1,800	
	Range of the number of revolutions (rpm)	900 – 1,800	
	Fuel	13A	
	Cell motor	DC12V x 1.4 kW	
Capacity control (%)		100-68 – 76-40	
Refrigerant x quantity (kg)		R22X25	
Refrigerant control system		Externally equalizing temperature type automatic expansion valve	
Vibration preventer		–	Engine vibration absorber
Sound insulator		SR-1132-A + urethane foam	
Noise level (dB A)		high: 52; low: 45	69
Defrosting		by engine waste heat	
Fuel gas leakage detector		–	Type: CZ-123, OC-123
Detected concentration			over LEL 1/4

Table 2 Specifications for SGP-TCH150A

heat of the gas engine is utilized for hot water supply.

b) Cooling/hot water supply mode (hot water supply priority). When the cooling load is small, while the hot water supply load is large, the temperature of the hot water delivered from the GEHP's condenser is raised to 65°C, and additional heat is added by utilizing the waste heat from the gas engine.

c) Heating/hot water supply mode. Heat from the GEHP's condenser is utilized for space heating while the waste heat from the gas engine is utilized for hot water supply. When there is an excessive hot water supply capacity, the excess heat is transferred to the heating side for back-up.

d) Exclusive hot water supply mode. When there are no cooling/heating loads in off-season, etc., both the heat of condensation of the GEHP and the waste heat from the gas engine are utilized for hot water supply.

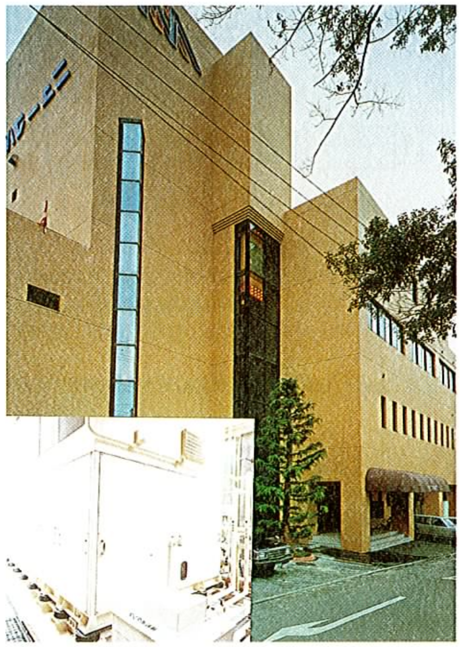


Photo 2 GEHP at the New Maruiwa Hotel

Results of operation

Cooling operation: Figures 10 and 11 show the hourly load changes and the energy flow diagram, respectively, both for September 10, 1982. On this day, the hot water supply load was relatively small, and waste heat was not sufficiently used. Therefore, the daily average cooling COP (coefficient of performance) was 1.05, and the overall energy utilization rate was 1.20.

Heating operation: Figures 12 and 13 show the hourly load changes on December 27, 1982, and the day's energy balance, respectively. The daily average heating COP was 0.80, while the overall energy utilization rate was 1.23.

Since the GEHP is installed on the roof of the hotel above the guest rooms, special considerations were given to noise control. According to the measurement results, the vibrations at the base were as low as the background vibrations. The sound was as low as the midnight background noise (38 dB).

Since the opening of this hotel, the GEHP has run continuously, completing 8,000 hours of operation by June 1985, and is still in good operating condition.

The effectiveness of medium- and large-size GEHPs has been recognized, and since their performance has steadily improved along with technical developments, it is expected that an increasing number of units will be installed in the future. At present, however, since their first cost is relatively high, their application is limited to cases where the heating load and the utilization factor are sufficiently large throughout the entire year. At present, absorption-type cooling/heating plants, which have low first costs, are more commonly used in buildings. More than 60% of office buildings having more than 3,000 m^2 of floor area are equipped with this type of system.

When adopting a GEHP with its relatively high equipment cost, it is reasonable to install a combination system in which the basic air conditioning load is covered by the GEHP, and the peak loads are met by the absorption unit. In this case, the load

		Winter type		Summer type		
Mode of operation		(1)	(2)	(3)	(4)	(5)
Content of operation	Primary function	Ice making	Hot water supply	Cooling	Cooling Hot water supply	Hot water supply
	Secondary function	Hot water supply	Ice making	Hot water supply	–	Cooling
	Heat of condensation by refrigerator utilized or not	no	yes	no	yes	yes
Rate of utilization	Ice making	0.8	0.6	–	–	–
	Cooling	–	–	1.4	1.2	1.0
	Hot water supply	0.5	1.5	0.5	2.0	1.8
	Total	1.3	2.1	1.9	3.2	2.8

Table 1 Design Values for the Energy Utilization Rate by Operation Mode (Howa Sports Land GEHP System)

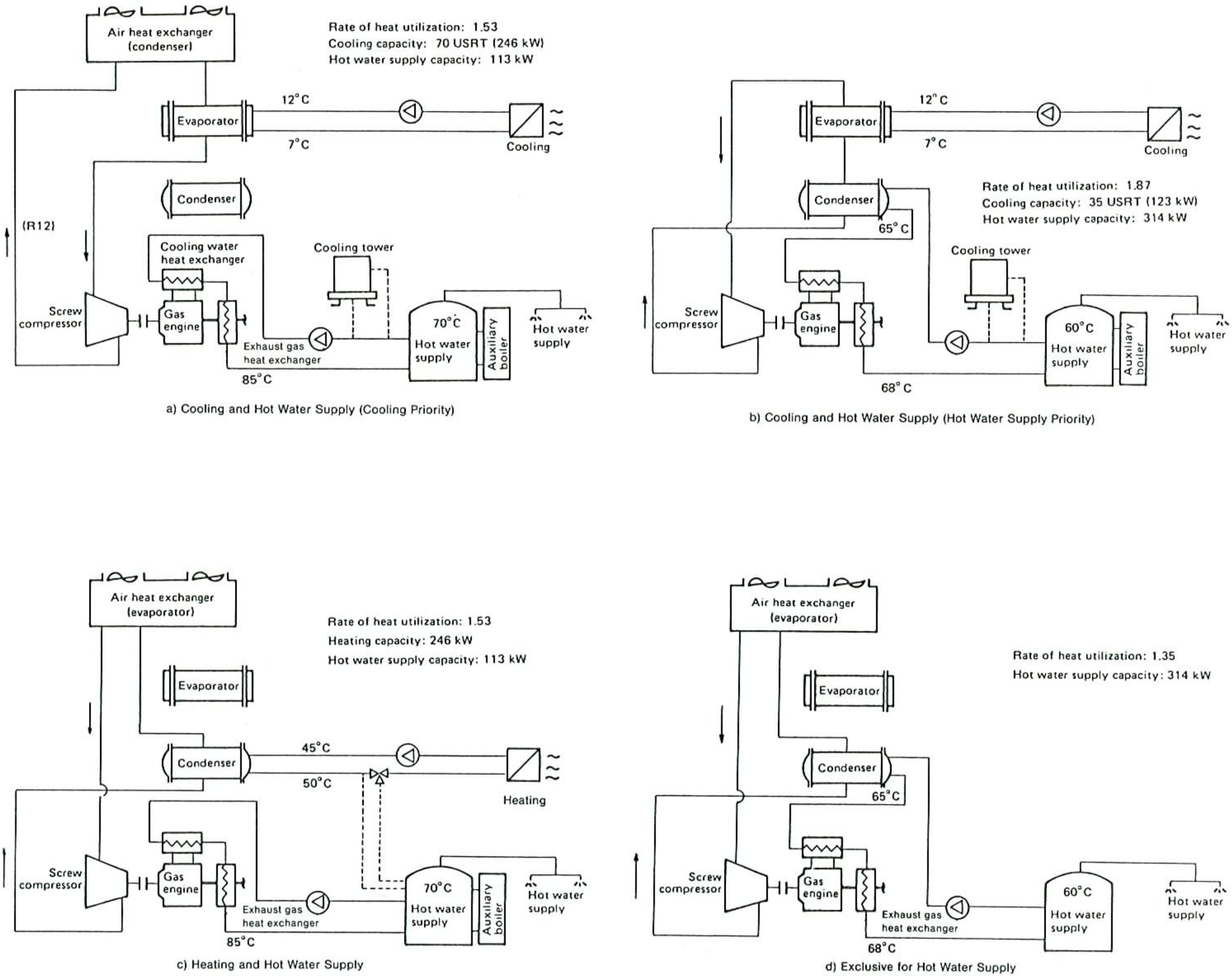


Fig. 9 The Operation Modes of the GEHP System at the New Maruiwa Hotel

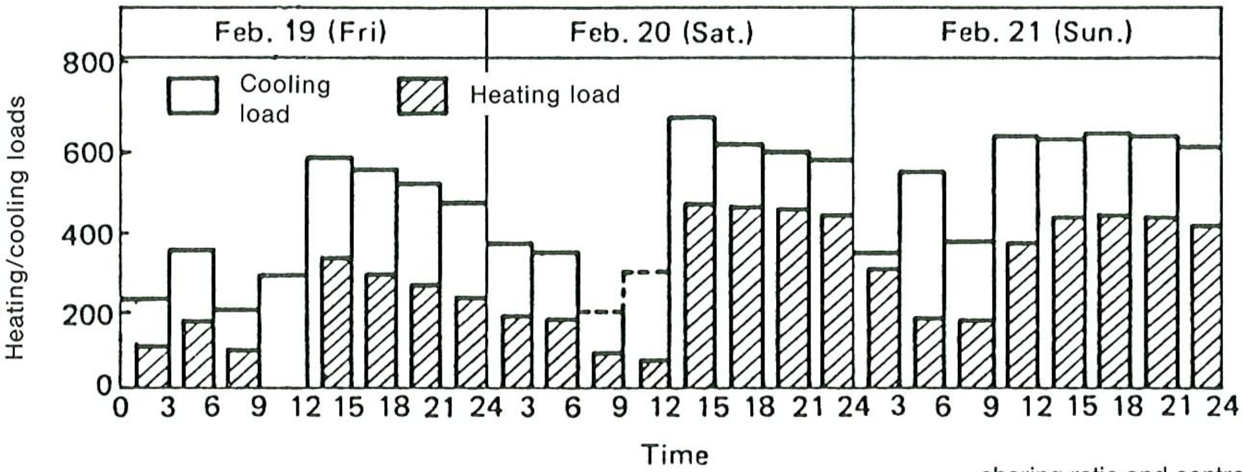


Fig. 8 Heating/Cooling Load Profile for Winter Days

sharing ratio and control system must be designed so that the overall first cost is limited and the operating cost is minimized.

3. Advent of the Direct-Expansion-Type GEHP

The majority of the heat pumps presently on the Japanese market are electric heat pumps for residential and commercial use employing direct expansion. The yearly sales of conventional cooling-only

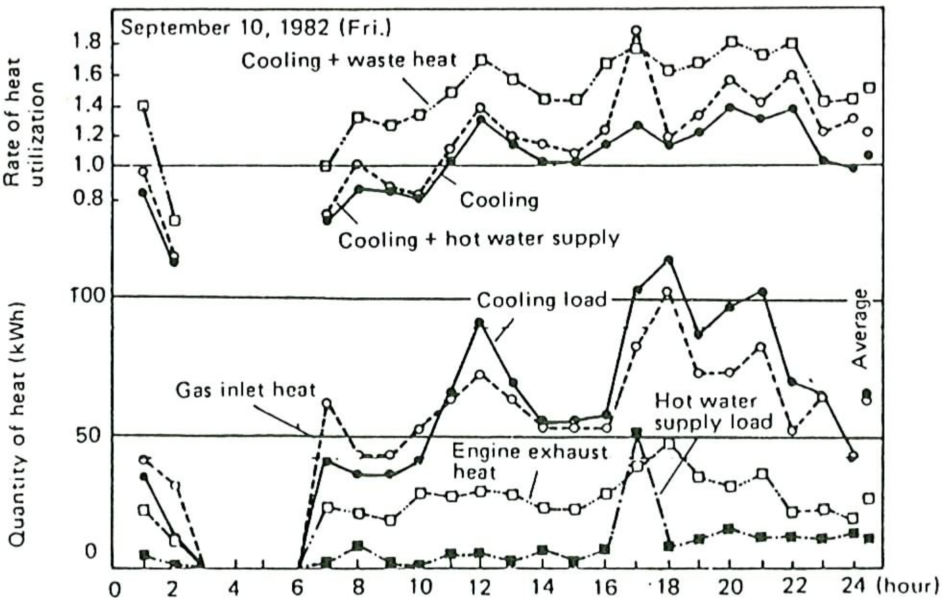


Fig. 10 Hourly Profile of Loads and Energy Utilization Rates during Cooling Operation

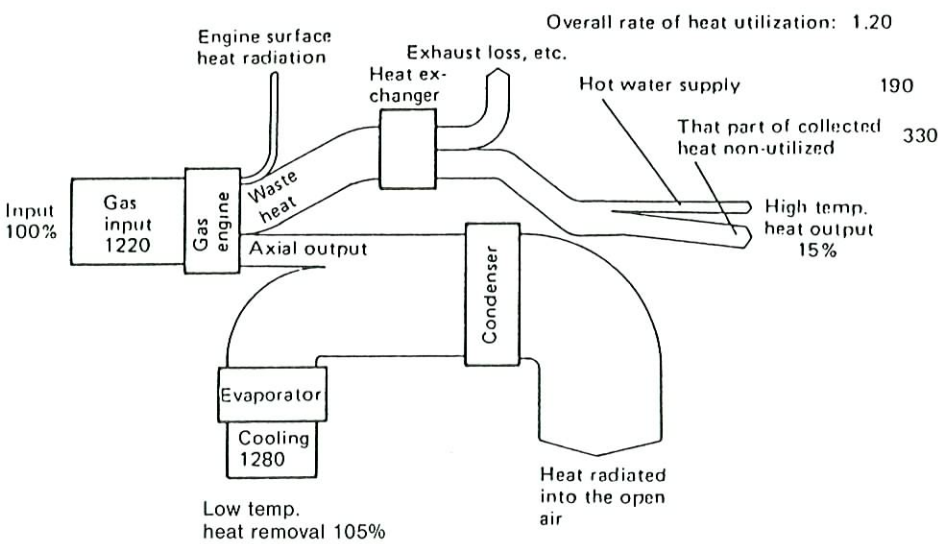


Fig. 11 A Day's Energy Balance during Cooling Operation (Values of September 10, 1982, in kWh)

Photo 3 The "Multi-System" GEHP

amount to more than 2 million units for residential use and to more than 300,000 units for commercial use. This market segment will eventually be replaced by heat pumps. For the past few years, heat pump sales have amounted to more than 50% of conventional sales. This may be attributed to improvement of the heat pump cycle, development of new compressors and new indoor units that can be built into the ceiling, etc., correction of problems related to heating operation, improvement of aesthetic appearance, and low prices.

The so-called "multi-system" has been recently introduced, and by combining a number of small-capacity modules (about 5 HP), this heat pump system can perform similarly to a medium-sized unit. It will penetrate the air conditioning market for medium and small retail stores and office buildings, which have so far been equipped with conventional chilled/hot water units.

Under these market circumstances, a direct-expansion-type GEHP with a cooling capacity of 13 USRT (46 kW) and a heating capacity of 41,000 kcal/h, was developed. The major specifications are shown in Table 2, and its appearance is shown in photo 3. A 4-cylinder reciprocating compressor is driven by means of a 3-cylinder gas engine with a total displacement of 1.4 liters. The refigerant (R22) is circulated between the air heat exchangers of the outdoor unit and the indoor unit via a four-way valve (for cooling/heating selection). There are three indoor units each of which has its separate refrigerant circuit. To meet the users' demand, the three indoor units can be selectively turned on. Since the engine/compressor speed can be chosen according to the number of indoor units in operation, the COP under partial load operation is good.

The heat from the gas engine cooling system and the sensible heat of the exhaust gas are recovered and used to heat the outside air acting as the heat source. Because of this, the heating capacity of the heat pump drops only a little at low outside air temperatures. Also, this configuration eliminates the need for defrosting since the outside air is heated before reaching the heat pump evaporator.

Between 1983 and 1984, about 50 units of the direct-expansion-type GEHP had been field tested to confirm their performance. Even in the winter of 1984 when it snowed very heavily, no evaporator frosting occurred. A sufficiently high heating capacity was maintained even when the outside temperature dropped.

After further improvements, this GEHP was scheduled to enter the market in April of this year. Due to the effects of mass production, its price is lower than those of the conventional GEHPs. Because of its decreased operating cost (30-40% less than an equivalent electric system), it can compete well with the electric system. It is expected that this type of heat pump will widely penetrate the market of retail stores, medium and small office buildings, etc. Additionally, since it has significant advantages with respect to heating, its sales are expected to expand into the areas north of North Kanto, where air source heat pumps have been generally regarded as unsuitable.

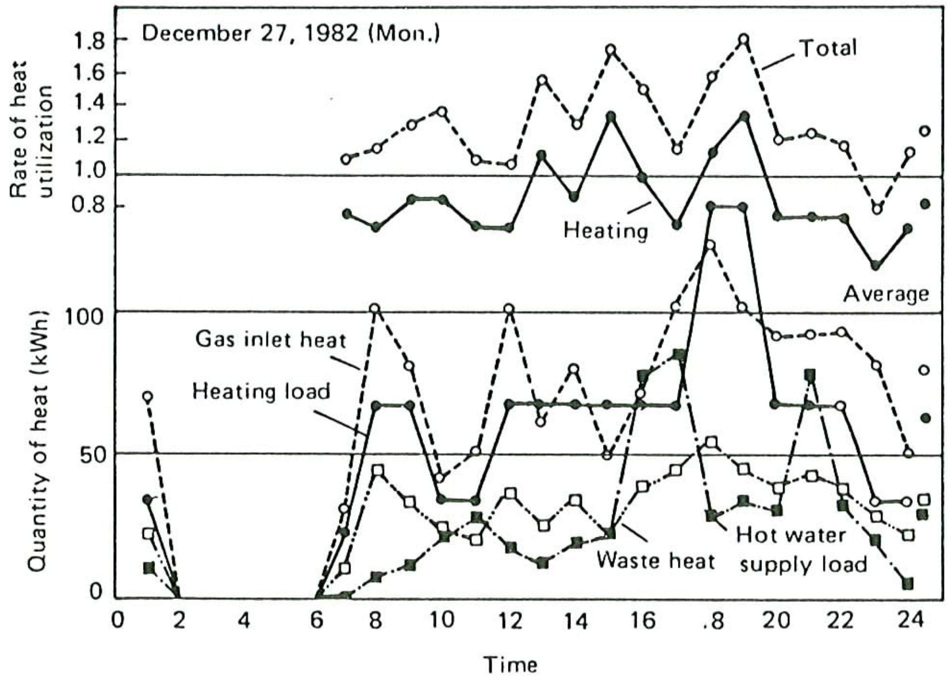


Fig. 12 Hourly Profile of Loads and Energy Utilization Rates during Heating Operation

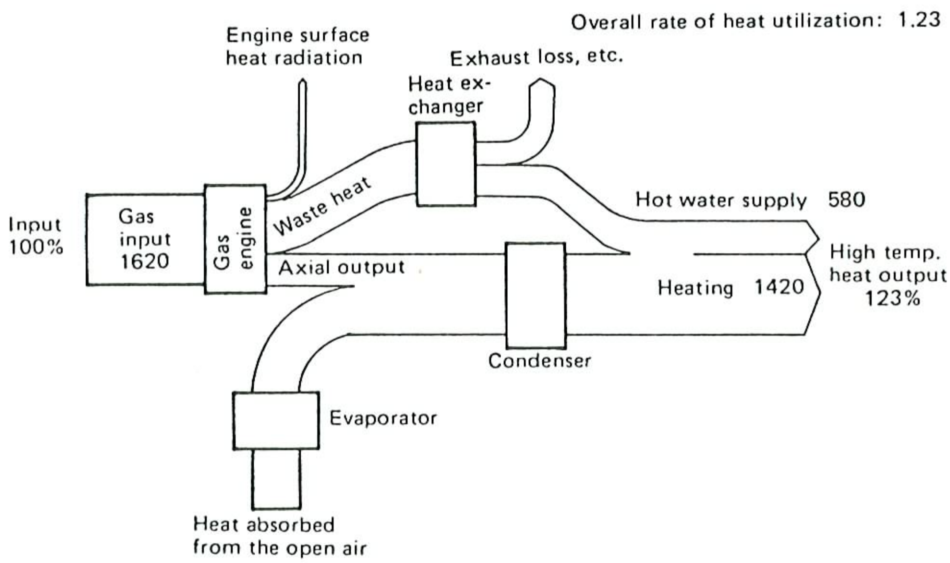


Fig. 13 A Day's Energy Balance during Heating Operation (Values of December 27, 1982, in kWh)

In addition to the 13 USRT model of the direct-expansion-type GEHP, the development of a model with smaller capacity is under way. It will be put on the market in the next year. Additionally, a commercialization plan stemming from the results of the "Union for Technical Research on Small Gas-Fired Cooling", which was terminated in 1984 after fruitful achievements, was also started. This plan aims at the development of two models of a small commercial unit, whose cooling capacity is in the 5 USRT (18 kW) range, and two other models for residential use, which are also capable of supplying tap hot water. The small models for commercial use will appear on the market in 1986, while the models for residential use will appear on the market in 1987.

Kazuo Yamagishi, Manager, Total Energy System Division, Tokyo Gas Co., Ltd.

A. Mitchell*

Heat Pump Sales in Member Countries

1. Introduction

The IEA Heat Pump Center in Karlsruhe is developing a database of heat pump sales information from the HPC member countries. This information is useful for determining general trends in heat pump sales and for making inter-country comparisons of heat pump markets. Some of the initial data in this database will be presented in this article.

A few qualifications should be recognized by the reader. First, the sales figures only include electric heat pumps. Sales data for engine-driven heat pumps and sorption heat pumps are difficult to obtain, but in terms of number of units installed, these heat pumps are a small fraction of the total. Next, there are differences in the data collection methods of the various agencies supplying sales data. This problem causes comparisons between data from different sources to be quite approximate. Some collection method discrepancies are noted in the article, but others certainly have escaped notice. Finally, the figures in the article are incomplete due to lack of data. In each figure some countries are missing, and other countries that do appear in the figure lack data for certain years. To the extent possible, these gaps in the database will be filled in the future.

2. Trends in Total Sales

Figure 1 shows the annual sales of electric heat pump units plotted on a logarithmic scale from 1980-1984. As well as allowing greatly differing sales amounts to fit on the same graph, the logarithmic scale facilitates comparisons of annual growth rates, since the growth in %/yr is proportional to the slope of the plotted line. The sales figures represent the sales to residents within the stated country; heat pumps imported into the country are included, but exported heat pumps are not counted.

Japan and the US have shown the largest total sales with both countries having sold over a million electric heat pump units in 1984 (US figures do not include tap water heat pumps and individual room units). Over the time period plotted, all countries except the Federal Republic of Germany have shown growth in sales. Sweden and Japan recently have exhibited very strong growth in heat pump sales, in the range of 50%/yr.

Figure 2 plots sales of heat pumps per 1000 residents and therefore adjusts the sales figures for population differences between the countries. This representation, however, is not the best indicator of market saturation. The size of a country's heating system market is not directly relat-

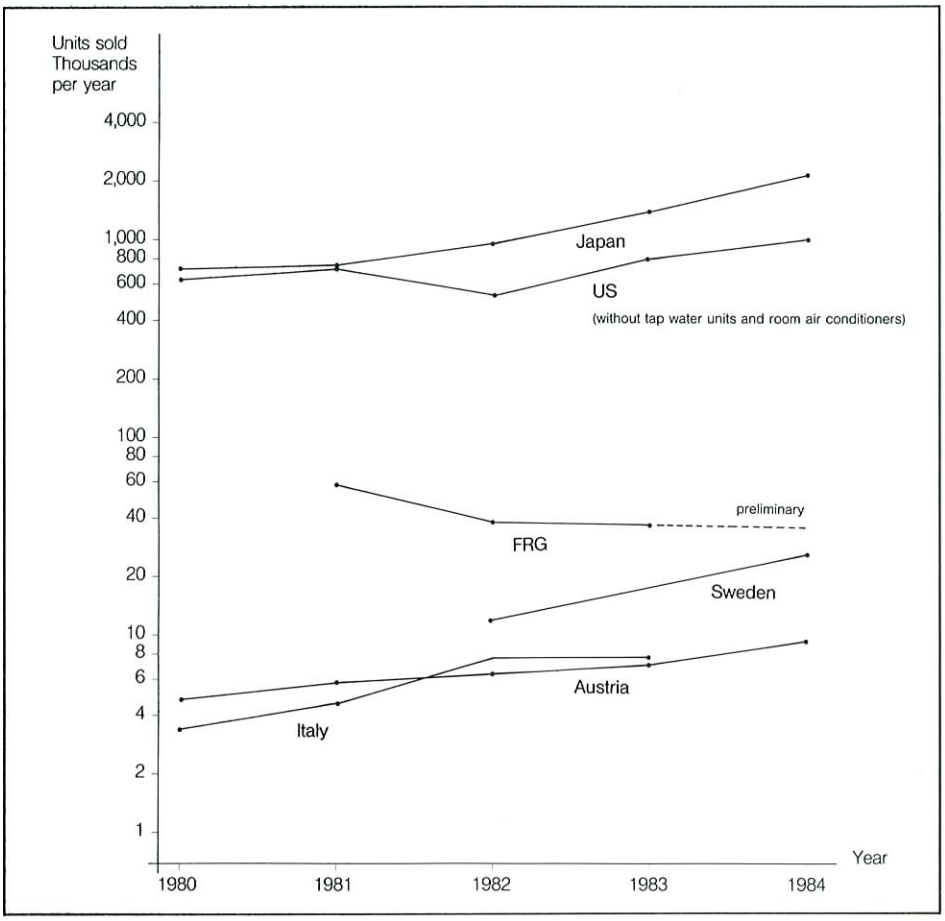


Fig. 1 Total Electric Heat Pump Sales, 1980-1984

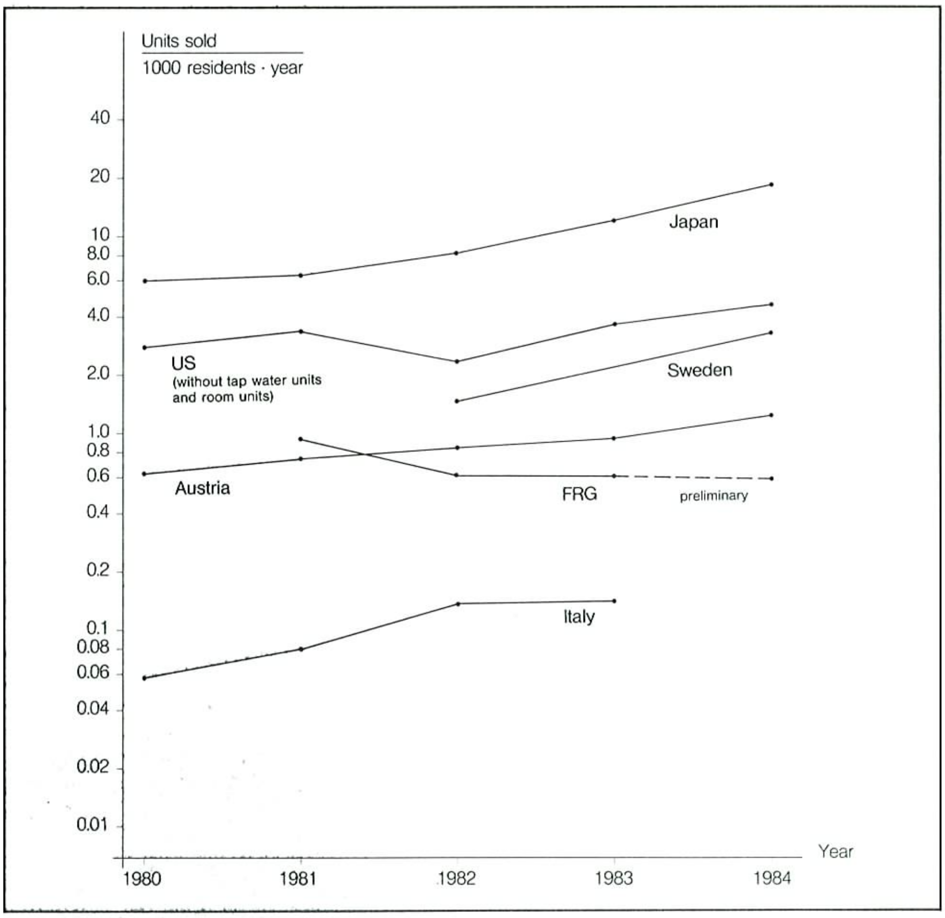


Fig. 2 Electric Heat Pump Sales per 1000 Residents, 1980-1984. Sales figures for all years were divided by population figures for mid-1980.

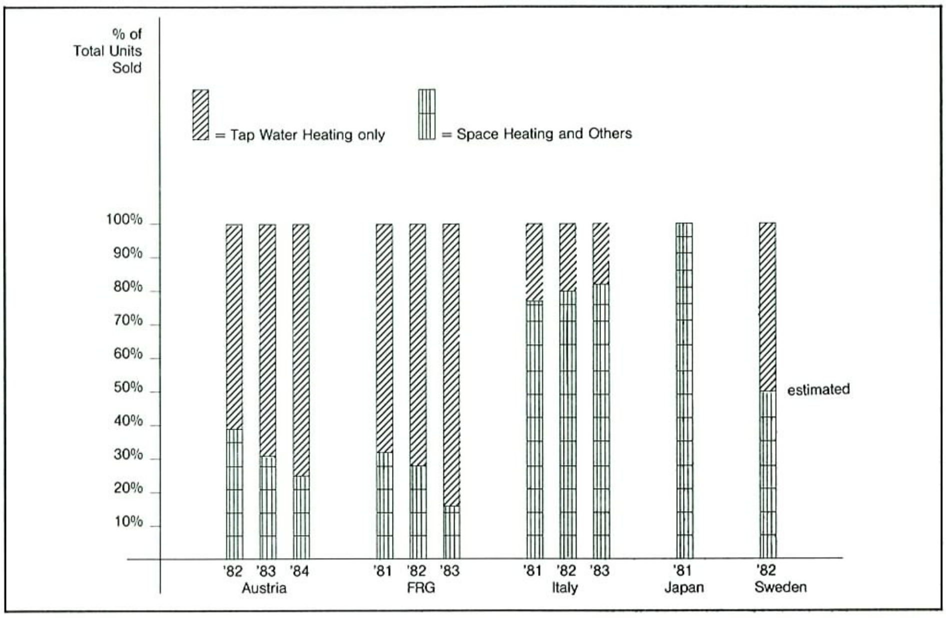


Fig. 3 Electric Heat Pump Applications

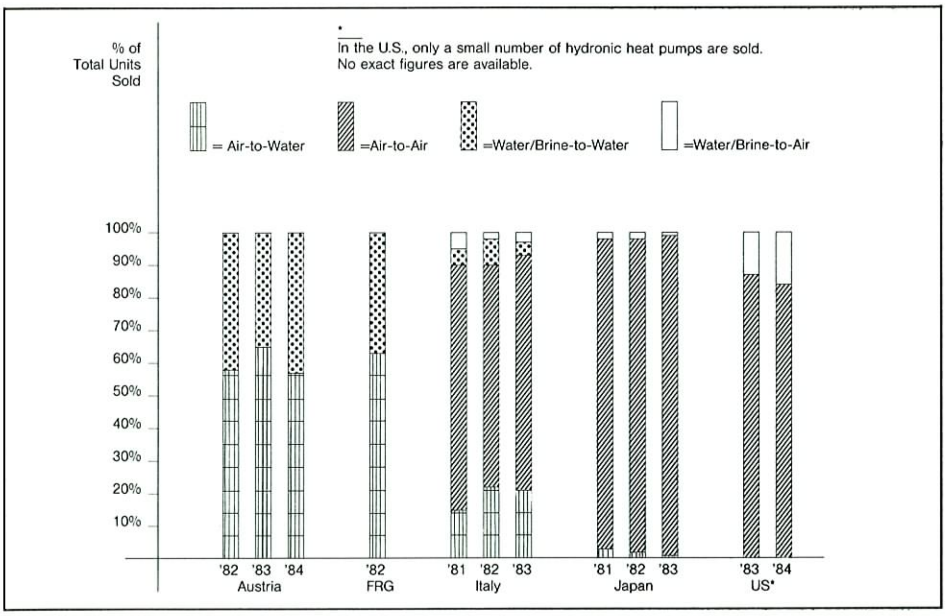


Fig. 4 Breakdown of Electric Heat Pumps for Space Heating by Type

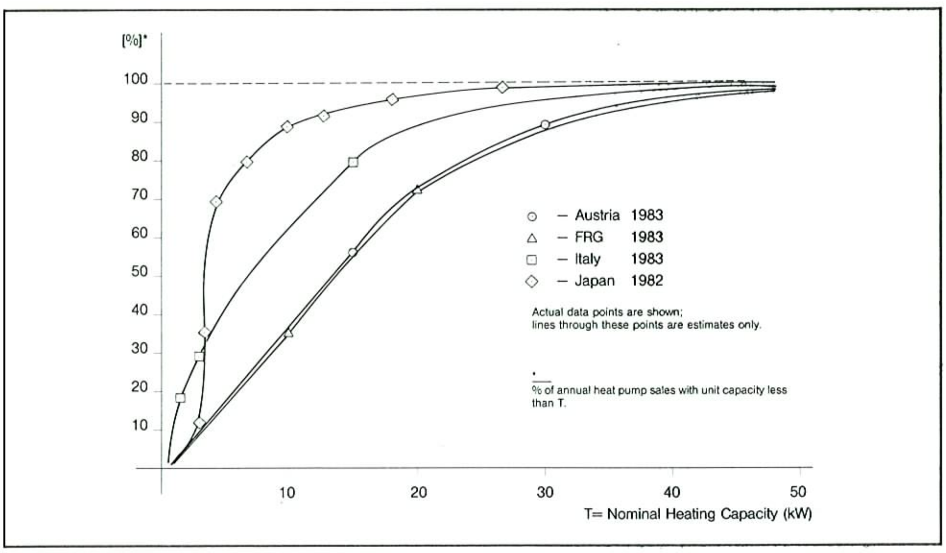


Fig. 5 Breakdown of Electric Heat Pumps for Space Heating by Capacity

ed to its population because of factors such as average persons per household, ratio of central to room heating systems, and new housing construction rates. With the population adjustment, Japan and the US still exhibit the largest sales, but the differences between the other countries are not as great. The population adjustment causes the sales curves of Austria and Sweden to move upward relative to the other countries.

3. Heat Pump Applications

Figure 3 gives a breakdown of heat pump sales by application. The major applications of heat pumps are tap water heating and space heating. In the figure, applications other than these two (e.g. swimming pool heating) are included in the space heating category. Because heat pumps for these other applications are few in number, most of the heat pumps in this category are space heating units.

The data show a significant variation between countries in the breakdown of applications. Sales of heat pump tap water heaters are negligible in Japan, and qualitative data indicates that few are sold in the US also. The tap water heaters are much more prevalent in Europe. This type of heat pump captures the majority of heat pump sales in Austria and the Federal Republic of Germany and has increased its market share over time. This trend is expected to change within the near future when heat pumps for space heating become more attractive in price and performance.

4. Characteristics of Electric Space Heating Heat Pumps

Further sales data for electric heat pumps designed for space heating are presented in Figures 4 and 5. Figure 4 shows a breakdown by source and output heat transfer media. Air-source heat pumps capture the largest market share in all countries plotted. Relatively few heat pumps utilizing water/brine to collect heat from the heat source are found in Japan and the US, but these units are more popular in the European countries. On the heat output side of the heat pump, air is the predominant heat distribution media in Japan and the US, whereas water is more popular in Europe. Almost all space heating heat pumps sold in Austria and the Federal Republic of Germany are intended for hydronic heating systems.

The size distribution of electric space heating heat pumps is shown in Figure 5. With this type of distribution plot, the segments of the graph with the steepest slope indicate the heating capacity ranges where most heat pumps are sold. Actual data points are shown on the graph; lines drawn through these points are estimates. Also, little information was found on the operating conditions assumed for the given heating capacity ratings. Consequently, comparisons of heating capacities between countries must be considered approximate.

The predominance of small, individual-room heat pump units in Japan is clearly shown on this graph. About 50% of the space heat pumps sold in Japan in 1982 had a heating capacity less than 3.5 kW. For Italy in 1983, the median heating capacity was about 7 kW, and 14 kW was the corresponding figure for Austria and the Federal Republic of Germany.

5. Conclusions

The heat pump sales data clearly indicates wide variations in heat pump markets across the various HPC member countries. Variations in terms of level of sales, growth of sales, and product characteristics are all present. This article has only presented the statistics and has not suggested explanations for these market differences. This important interpretation process as well as further data collection is necessary. The IEA Heat Pump Center will continue with this activity, and all assistance and comments on the work will be appreciated.

Sources

"Air Conditioning",
Air Conditioning, Heating & Refrigeration News , April 8, 1985, pp. 28-39.

ANIMA,
Indagine Statistica Sulle Pompe di Calore, 1980-1983, Milano, Italy.

Arbeitsgemeinschaft Technik und Nutzung der Umweltenergie,
Marktstatistik, Wärmepumpen, elektrisch angetrieben, 1980-1984, Vienna, Austria.

Japan Refrigeration and Air Conditioning Industry Association,
Heat Pumps in Japan, November 1983, Tokyo, Japan.

Japanese IEA Heat Pump Center National Team,
Electric Heat Pumps for Retrofit in Existing Small Residential Buildings, National Position Paper, October 1984.

Svenska Vaermepumpfoereningen (SVEP),
Heat Pump Statistics, 1982-1984.

United States Department of Commerce, Bureau of Census,
Statistical Abstract of the United States, 1984.

Zentralverband der Elektroindustrie,
Heat Pump Sales Statistics , 1981-1984, Frankfurt, Federal Republic of Germany.

**Alan Mitchell, IEA Heat Pump Center, Karlsruhe.*

M. Shimizu*
K. Fujita*

Actual Efficiencies of Thermally-Stratified Thermal Storage Tanks

1. Introduction

Thermal storage tanks for use in heating and air conditioning systems have received increasing attention during recent years. These tanks reduce operating costs by allowing the utilization of inexpensive nighttime electricity. They also are essential for energy-conserving heat recovery systems, because they absorb the time-lag between the production of waste heat and its effective utilization. This article describes the thermally-stratified storage tank, a type of thermal storage tank that has gradually seen more widespread use in recent years.

2. Types and Features of Various Thermal Storage Tanks

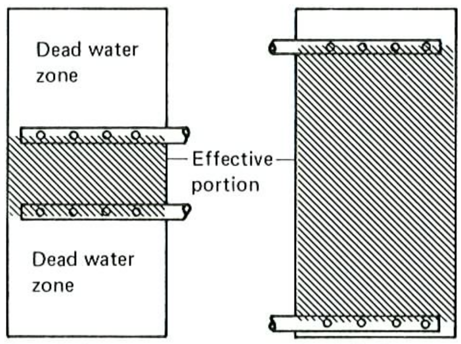
Different types of thermal storage systems include: sensible heat storage systems, which utilize the heat absorbed or released as a substance changes in temperature; latent heat storage systems, which rely on the energy transfer occurring when matter changes state; chemical heat storage systems, which utilize the heat of chemical reactions. The thermal storage system most commonly employed at present is a sensible heat storage system utilizing water as the thermal storage medium.

The term "thermal" storage tank is used instead of "heat" storage tank because these tanks can be used to store cold water for cooling purposes as well as hot water for heating. An effective thermal storage tank utilizing water as the storage medium must satisfy the following three general requirements:

The tank must hold separate volumes of water that differ in temperature. The mixing of the volumes should be minimal, even during charging and discharging periods.

effective storage capacity should be achieved by minimizing the amount of dead water volume in the tank.

The heat loss/gain from the tank should be minimized.



Poor design Good design

Fig. 1 Position of Inlet/Outlet and Effevctive Quantity of Water (hatched parts)

Many types of thermal storage tanks have been developed to satisfy these requirements. The principal types are listed in

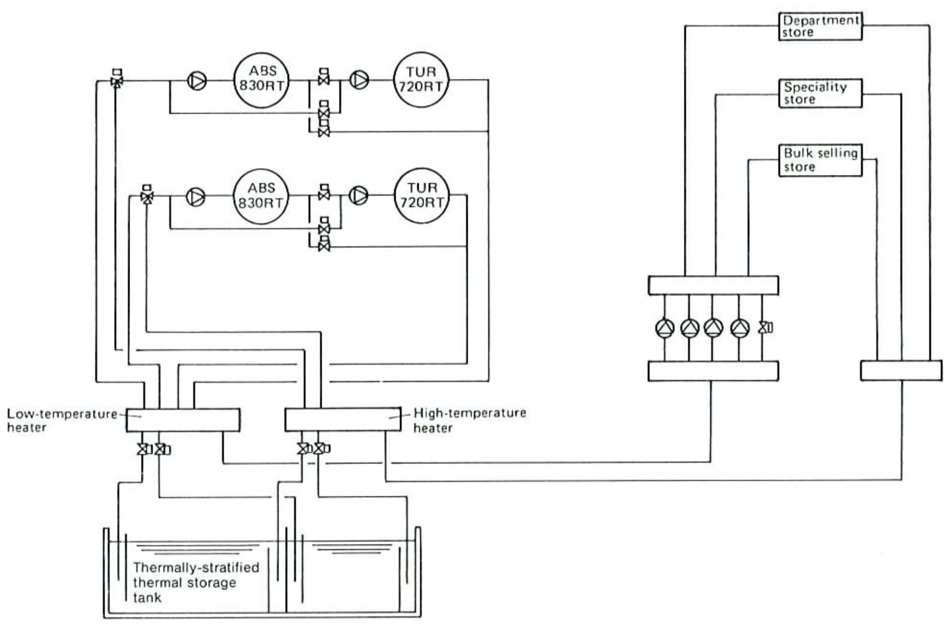


Fig. 2 System Diagram for the Sea Mole Building

Table 1. The thermally-stratified storage tank has no inside partitions and has the following principle of operation. Warm water has low density and floats to the top of the tank, while cooler water with higher density sinks to the bottom. The water storage volume used with this type of system can be reduced relative to other systems, because the dead water volume is relatively low and the heat storing efficiency is relatively high.

3. Design Considerations for Thermally-Stratified Thermal Storage Tanks

When designing a thermally-stratified thermal storage tank, the following criteria should guide the design process.

1) Geometrical Considerations:

A deep water-storage container is desirable to improve thermal stratification.

The water inlet and outlet should be installed in a manner that produces a uniform, slow-velocity flow of water.

To minimize dead water volume, locate the outlet and inlet connections as close as possible to the top and bottom of the storage volume.

The surface area in contact with the storage water should be minimized.

2) Operating Considerations:

The temperature difference between the upper and lower parts of the tank should be large, at least 5 to 10°C.

The controls should maintain fixed water temperatures in the upper and lower parts of the tank.

The velocity of the water flowing into and out of the tank should be kept low.

3) Other Considerations:

The insulating and water-proofing characteristics of the tank should be measured to ensure that the design specifications have been achieved.

Fig. 1 shows the positions of the inlet and outlet and shows the thermally-effective quantity of water that results from these positions. Since the tank stores thermal energy for a period of hours, heat loss/gain from the tank is unavoidable. The heat-retaining performance of the tank should be considered during both the design and installation phases.

4. Example at Sea Mole Shimonoseki Shopping Center

4.1 Outline of building and facilities

This building is a large shopping center and was opened in October 1977 in front

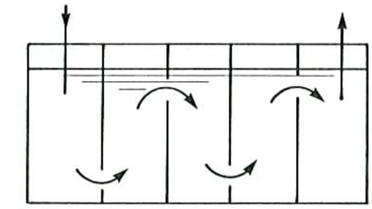
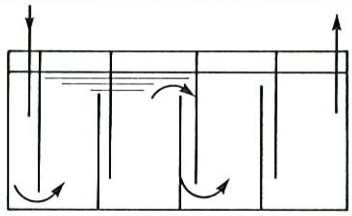
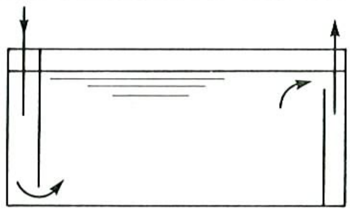
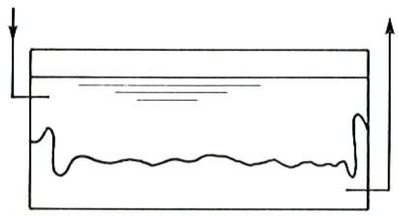
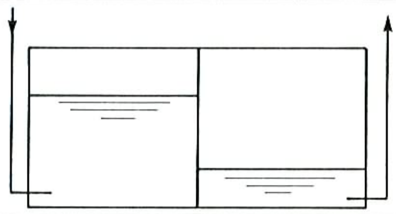
Type	Schematic representation of cross section	Efficiency	Remarks
Continuous multi-tank type		Medium	Underground beam space can be used effectively. Insulation is difficult to install.
Improved dipped weir type		Medium ~ High	Construction is difficult.
Thermally stratified type		High	Best suited for large-size tank built aboveground.
Movable diaphragm type		High	Diaphragm material is problematical. Not easily adapted to tanks with internal pillars and beams.
Multi-tank water renewing type		High	Underground beam space can be utilized to some extent. Heat loss is large.

Table 1 Types and Features of Various Thermal Storage Tanks

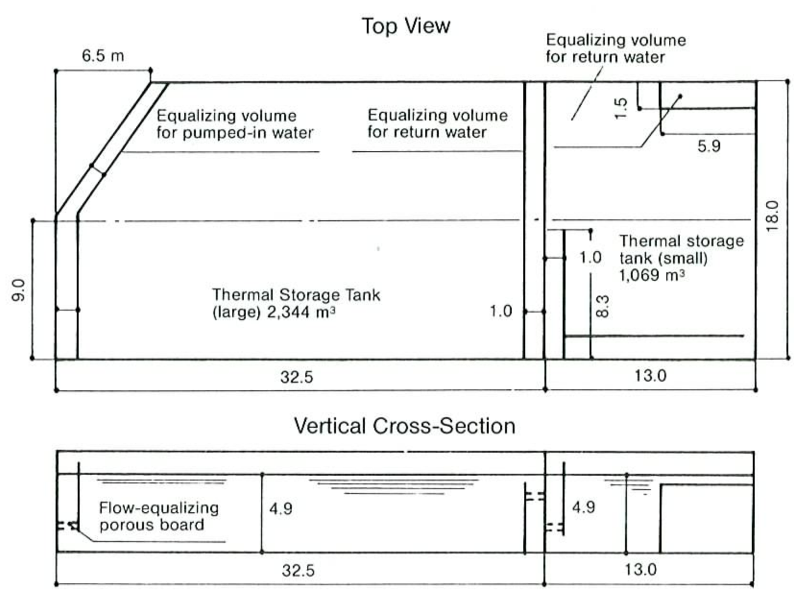


Fig. 3 Tank Diagram (all dimensions are in meters)

of the Shimonoseki Station of the National Railways Corporation.

Structure: SRC, RC, and S

Number of Stories: 7 stories above ground and 1 story underground

Total Floor Area: 128,200 m^2

The central HVAC and electrical power equipment are installed together in one place in the building.

Central HVAC Equipment:

2520 kW Centrifugal chiller - 2 units

2905 kW kerosene/gas absorption chiller - 2 units

Thermally-stratified thermal storage tank - 3,600 m^3

Secondary HVAC Equipment:

HVAC terminals installed for each 1,000 to 1,500 m^2 of floor area

Variable water-flow system

Central Electrical Equipment:

Power receiving equipment - 22 kV

Main transformer - 7,500 kVA - 2 units

4.2 Reasons for using the thermally-stratified thermal storage tank

A large thermal storage tank was installed in this building to obtain economic benefits from using inexpensive nighttime electricity and from reducing peak power demand.

During the development of this proposal, Prof. Tanaka of the Tokai University was investigating thermally-stratified thermal storage tanks, and his experiments were revealing the basic characteristics of these tanks. The results of these experiments led us to believe that for tanks with a depth of 5 m or more, a thermally-stratified type tank is more attractive than a two-storied multi-tank type. This was the reason for utilizing this type of system.

4.3 Specifications of the thermal storage tank

Architectural considerations restricted the water depth in the tank to 4.9 m. Fig. 3 shows a top view and vertical cross-section of the tank. The two walls of the tank, which are opposite to each other, each have a dipped weir made of a synthetic resin material. Two porous boards are used in the tank to equalize the velocities of inflowing and outflowing water.

Careful attention was given to the insulating of the tank in order to reduce heat gain and to prevent condensation on the outer surfaces of the tank. Table 2 details the insulation configuration.

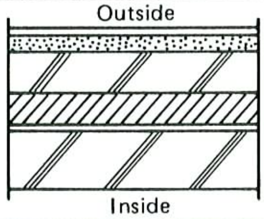
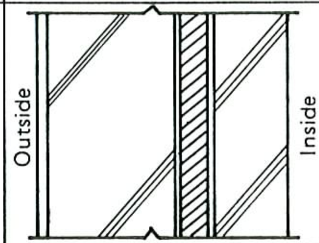
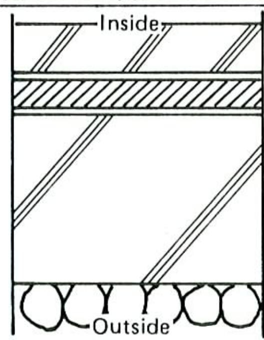
Tank component	Schematic diagram	Composition of members
Ceiling		Plastic tile Mortar t30 Small-size gravel concrete t100 Extruded foam polystyrene board t50 Asphalt Concrete t120
Wall		Additional placing of concrete t20 Concrete t350 Asphalt Extruded foam polystyrene board t50 Asphalt Concrete t150
Floor		Concrete t100 Asphalt Extruded foam polystyrene board t50 Asphalt Concrete t500 Cobble stone

Table 2 Specifications for Insulating and Waterproofing the Tank at the Sea Mole Site

Photo 1 Sea Mole Shimonoseki Shopping Center in Yamaguchi, Japan

4.4 Results of operation

Fig. 4 shows how the vertical temperature distribution within the tank varies with time as cold water is stored in the tank. Fig. 5 shows how the distribution changes when the process is reversed, and cold water is drawn from the tank. In both cases it can be seen that the thermal stratification is not disturbed, and the transition layer be-

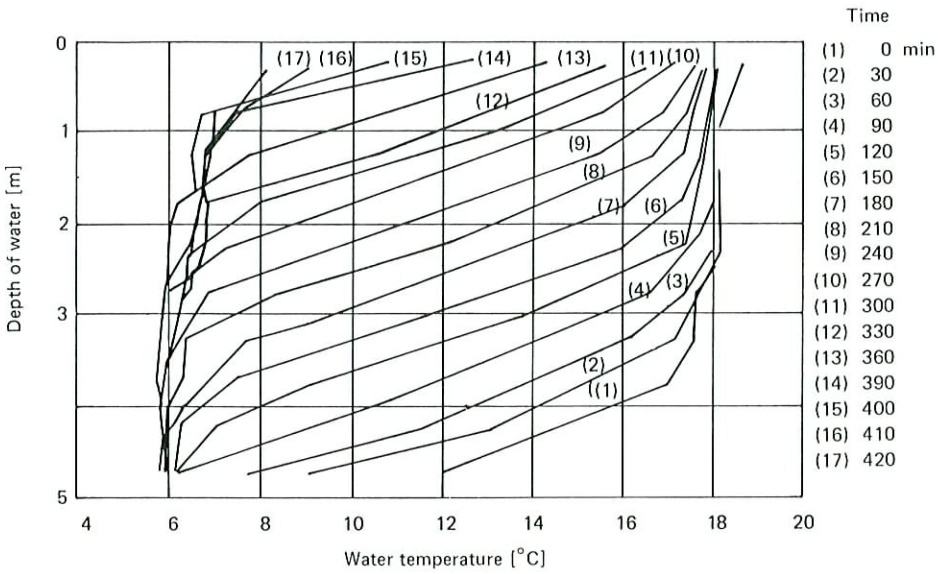


Fig. 4 Temperature Distribution during Storage of Cold Water

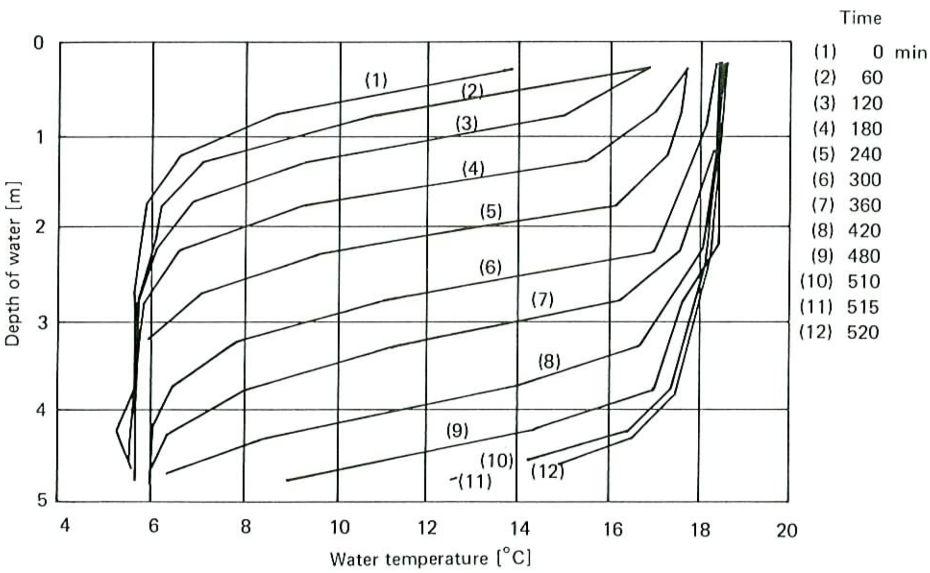


Fig. 5 Temperature Distribution during Removal of Cold Water

Container	Reinforced concrete construction (500 mm thick) [Part of building body] Effective capacity: 70 m^3 x 2 tanks (2.2 m x 2.9 m x 11.5 m)
Insulation	Extruded styrene foam sheet (100 mm thick) [Installed inside tank]
Waterproofing	Waterproofing by sheeting
Flow facilities	Distributor, flow equalizing boards

Table 3 Specifications for the Heat-Storage Tank at the Ohbayashi Site

tween the cold and the warm water volumes simply moves up or down the tank as cold water is added or removed.

Thermally-stratified thermal storage tank - 2 units - (Cold-water tank: 70 m^3; hot-water tank: 70 m^3)

Coil for heat storage in the ground - 1,200 m in length

Secondary HVAC Equipment:

Variable-air-volume system utilizing fan coil units

Variable water-flow system

Central Electrical Equipment:

Power receiving equipment - 22 kV

Main transformer - 100 kVA - 1 unit

This energy-efficient building has set a record concerning energy consumption. The energy consumption for the building is given below in source energy units (1 kWh electric results from 10.3 MJ source energy).

Initial year of operation: 363 MJ/m^2-yr

Second year of operation: 401 MJ/m^2-yr

5.2 Reasons for using the thermally-stratified thermal storage tank

A heat-recovering heat pump was planned for use in the Technical Research Institute Administrative Building in order to save energy and allow better utilization of solar energy. Because of the time lag between the generation of heat and demand for heat, it was concluded that a compact thermally-stratified thermal storage tank with high thermal efficiency was necessary. As a result, such a tank with a water depth of 12 m was built in the core part of the east wing of the building between the first floor and the roof.

5.3 Specifications of the thermal storage tank

As shown in Fig. 7, the top and bottom portions of the tank are partitioned from the rest of the tank by flow-equalizing boards. In these parts, the inlets/outlets are installed.

The specifications for the thermal storage tank are listed in Table 3. Heat bridges were eliminated by insulating inside the tank. As well as providing high thermal efficiency, this insulation scheme prevents the thermal conductivity of the tank container from disturbing the thermal stratification of the water in the tank. Flexible water-proofing sheets cover the insulation and can mold to the insulation if defor-

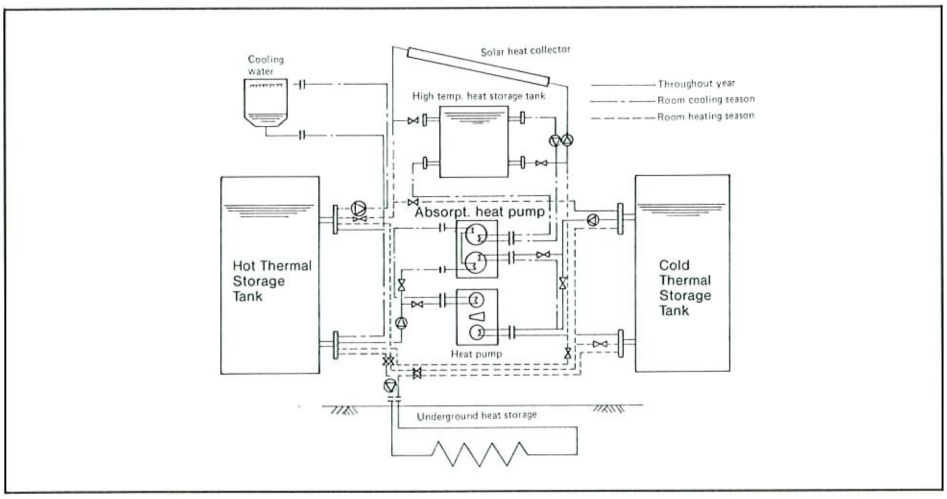
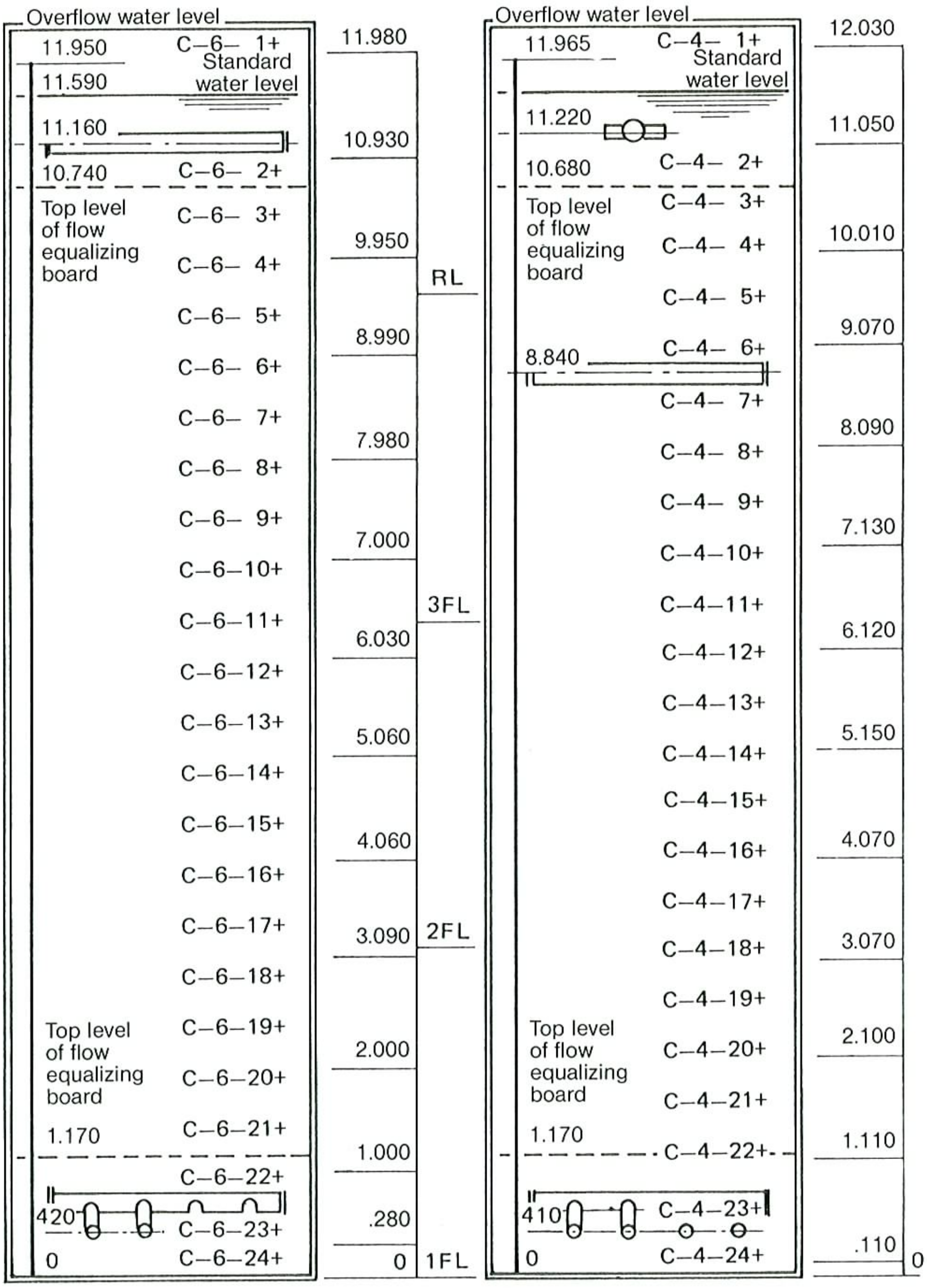


Fig. 6 System Diagram for Ohbayashi Building

mation results from hydraulic pressure. Moreover, these sheets prevent metal and concrete from coming in contact with the water and thus improve the water quality.

5.4 Results of operation

Fig. 8 shows how the vertical temperature distribution within the tank varies over time. One graph shows the process of storing cold water, and the other shows the cold water removal process. In both cases the temperature of water at the top and bottom of the tank was well controlled, and a high degree of thermal stratification was maintained. In addition, no significant change in the temperature gradient at the interface was observed when the water flow in the tank was reversed.



a. Cold water tank b. Hot water tank

Fig. 7 Position of the In-Tank Sensors, Inlet/Outlet, etc.

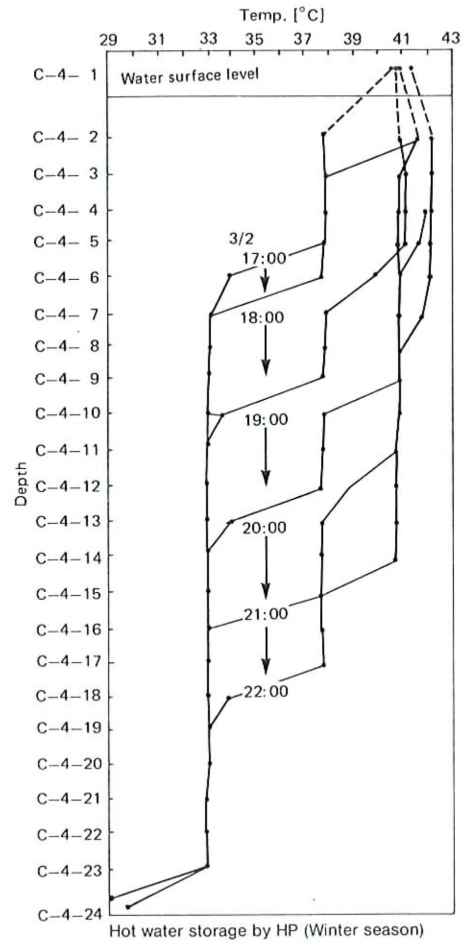
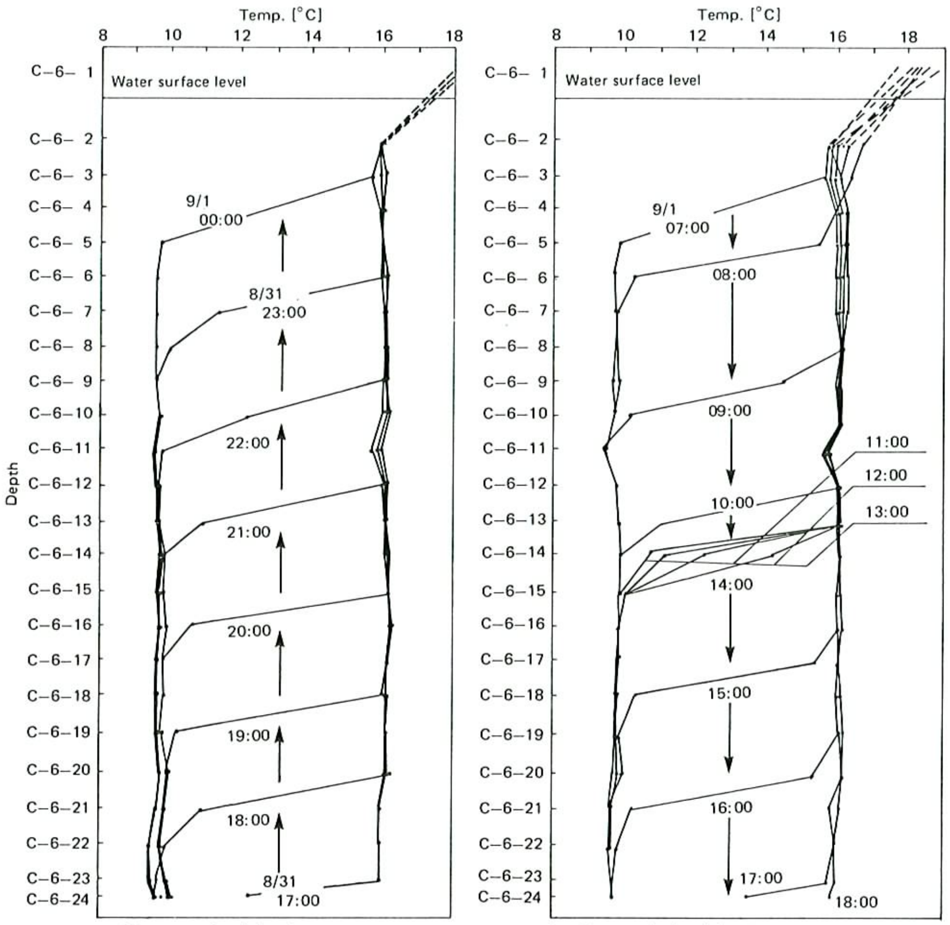


Fig. 9 Example of Vertical Temperature Distribution for the Hot-Water Thermal Storage Tank

Fig. 9 shows the progression of the vertical temperature distribution in the hot-water tank. The heat-storing process by the heat pump is represented, and two stages of stratification can be seen. One layer corresponds to heat storage from utilization of the ground coil, and the other corresponds to utilization of solar energy. In both cases, the temperature gradient is steep and stratification was maintained



a. Storage of cold water b. Removal of cold water

Fig. 8 Example of Vertical Temperature Distribution for the Cold-Water Thermal Storage Tank

well.

The heat loss/gain of the storage tanks were measured during summer and winter holidays, and the results are given in Table 4. The results show that the actual heat transfer (the wall center was used as the standard) was approximately equal to that predicted by the overall heat transmission coefficient. The analysis indicated that the efficiency of the thermal storage tank should be near 95%. It is believed that the vertical shape of the tank and the energy-conserving insulation design contribute to the high thermal efficiency.

References

[1]Sakai and Fujii, "Efficient Operation of Heat-Storage Tank", published by Ohm, Oct. 1978, No. 11, Vol. 65 (in Japanese)

[2]Maeda, Sakai, et al., "Studies on Equipment System Designed for Saving Energy" - No. 4: Assessment of Performance of Thermally Stratified Vertical-Type Heat Storage Tanks and Collection of Papers Compiled by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (papers presented at a meeting held in Sapporo, in Japanese)

*Mitsuru Shimizu, Kyoichi Fujita, Building Services Department,
Ohbayashi Corporation, Tokyo, Japan.*

Item	Observation of winter heat loss (for 5 days) [Dec. 30, 1982 – Jan. 3, 1983]	Observation of summer heat gain (for 3 days) [Aug. 13, 1983 – Aug. 16, 1983]
Average outside air temp.	3.4 °C	26.1 °C
Change in average water temp. in tank	37.8 °C → 34.7 °C	7.8 °C → 8.7 °C
(Amount of change in average water temp. in tank)	(3.1 °C/5 days)	(0.9 °C/3 days)
Average temp. in tank	36.3 °C	8.3 °C
Difference between average outside air temp. and average water temp. in tank	32.9 °C	17.8 °C
Overall heat loss	227,300 kcal/5 days	65,000 kcal/3 days
Heat loss per hour	1,890 kcal/h	900 kcal/h
Heat loss per unit quantity of water	25.9 kcal/m^3 / h	12.3 kcal/m^3 / h
Heat loss per unit surface area (based on inside surface area)	14.0 kcal/m^2 / h	6.9 kcal/m^2 / h
Heat loss per unit surface area (based on surface area through the wall center)	10.2 kcal/m^2 / h	5.0 kcal/m^2 / h
Coefficient of overall heat transmission (based on inside surface area)	0.43 kcal/m^2 / h / °C	0.39 kcal/m^2 / h / °C
Coefficient of overall heat transmission (based on surface area through the wall center)	0.31 kcal/m^2 / H / °C	0.28 kcal/m^2 / h / °C
Theoretical coefficient of overall heat transmission (Ktheo)	0.30 kcal/m^2 / h / °C	0.30 kcal/m^2 / h / °C

Table 4 Results from Heat Loss/Gain Measurements of the Thermal Storage Tanks in the Ohbayashi Building

Schedule of Conferences and Trade Fairs

Aug 13-16, 1985

Stockholm (Sweden); Scandinavian Heat Pump Conference; Contact: Nordisca Kylmoetet och 2:a Nordiska Vaermepumpdagarna '85, c/o Stockholm Convention Bureau, Box 1617, S-11186 Stockholm (Sweden), phone 468230990, telex 11556 Congrex

Aug 25-30, 1985

Copenhagen (Denmark); CLIMA 2000, First World Congress on HVAC&R Technology; Contact: Clima 2000 - Clima Ex, Ordrup Jagtrej 42B, DK-2920 Charlottenlund (Denmark), phone 01-633230, telex 16600 fotex DK

Sep 9-11, 1985

Baltimore, Maryland (USA); National Water Well Association Annual Convention and Exposition; Contact: National Water Well Association, 500 W. Wilson Ridge Rd., Worthington, OH 43085 (USA), phone (614) 846-9355

Sep 22-26, 1985

Toronto (Canada); International Conference on Energy Storage for Building Heating and Cooling (ENERSTOCK-3) and Exhibition; Contact: Conference Secretariat, ENERSTOCK-3, 275 Bay St., Ottawa K1R 5Z5 (Canada)

Sep 30, 1985

Karlsruhe (Federal Republic of Germany); One Day Seminar on the Use of the 1.4 kW Heat Pump for Tap Water Heating; Contact: Dr. Reichelt, Fachhochschule Karlsruhe, P.O. Box 6240, D-7500 Karlsruhe (FRG)

Oct 2, 1985

Essen (Federal Republic of Germany); BSE-Expert Meeting on the Use of Heat Pumps in Residential, Public and Commercial Areas; Contact: Bundesverband Solarenergie - BSE, Kruppstr. 5, D-4300 Essen (FRG)

Oct 14-17, 1985

Las Vegas, Nevada (USA); National Plumbing-Heating-Cooling-Piping Products Exposition; Contact: NAPHCC, P.O. Box 6808, Falls Church, VA 22046 (USA), phone (703) 237-8100

Oct 24-26, 1985

Essen (Federal Republic of Germany); International Conference and Exhibition on HVAC Technologies for Cold Climates; Contact: NMA Nürnberger Messe- und Ausstellunggesellschaft mbH, Messezentrum, D-8500 Nürnberg 50 (FRG)

Nov 27-29, 1985

Nürnberg (Federal Republic of Germany); ENKON '85, Conference and Exhibition on Energy Concepts for Production Units; Contact: Nürnberger Messe- und Ausstellungsgesellschaft mbH, Messezentrum, D-8500 Nürnberg 50 (FRG)

Feb 19-23, 1986

Essen (Federal Republic of Germany); Exhibition on Sanitation, Heating, and Air Conditioning; Contact: Fachverband Sanitär-Heizung-Klima NRW, Grafenberger Allee 59, D-4000 Düsseldorf (FRG)

Mar 11-15, 1986

Harumi, Tokyo (Japan); Exhibition of Refrigeration, Air Conditioning, Heating and Solar System Equipment; Contact: The Japan Refrigeration and Air Conditioning Industry Association, Kikai Shinko Bldg. 201, 5-8, Shibakoen 3-chome, Minato-ku, Tokyo 105 (Japan), phone 03-432-1671, telex 02422222 JRAIA J, telefax 03-438-0308 (Presentation of IEA Heat Pump Center)

Position Available

IEA Heat Pump Center offers a highly qualified person the position of a

Senior Engineer

At least five years experience with heat pump technology, not exclusively research, are expected. Excellent knowledge of English and German is required, as well as the capability to effectively work on the broad range of heat pump development and application tasks undertaken by the IEA Heat Pump Center.

For further information contact Dipl.-Ing. K. Holzapfel, tel. 07247-82 45 41

Written applications to be addressed to Fachinformationszentrum Energie, Physik, Mathematik GmbH, PA/Personalwesen, attn. Mr. Wuest, D-7514 Eggenstein-Leopoldshafen 2

Selected Book and Report Rewies

Arbeitsgemeinschaft für sparsamen und umweltfreundlichen Energieverbrauch e.V. (ASUE); Internationale Fachtagung 9.-10.05.85 Sindelfingen. Nahwärme - Konzepte, Ausführung, Betriebserfahrungen, (International Meeting on District Heating); May 1985, ISBN: 392461107-6 (in German)

This conference report includes 13 contributions, which were presented in Sindelfingen on May 9-10, 1985. Main emphasis is placed on the implementation of short district heating systems. Five contributions address the application of gas engine-driven heat pumps with overall thermal capacities between 30 and 400 kW. Brief descriptions of these follow.

Since July 1983 a heating system in Dorsten, consisting of three water-source compression heat pumps and two peak-load boilers with an overall thermal capacity of 5.8 kW, has been in operation without major problems. Waste heat from a refrigeration plant as well as water from the River Lippe serve as the heat source.

In Essen two air-source compression heat pumps were installed in addition to two existing boilers in December 1984. 584 dwellings with a total area of 41,566 m^2 are supplied with space heat and hot tap water. The total thermal capacity of the system is 3 MW.

Two water-source compression heat pumps with a thermal capacity of 3.55 MW supply space heat and hot tap water for a swimming pool and a hospital including staff dwellings in Leer. The heat source is the waste water from a dairy plant.

A water-source absorption heat pump and two peak-load boilers supply the space heat for seven community buildings in Waiblingen. The total thermal capacity is 9.5 MW (2.5 MW heat pump capacity).

In the city of Göppingen the waste heat of a gelatine production plant is used as the heat source for two water source compression heat pumps. The heat pumps together with a peak-load boiler have a thermal capacity of 3.8 MW.

In comparison with conventional heating systems, the use of gas engine-driven heat pumps results in less air pollution and significant primary energy savings.

Dreschmann, Peter, and Pöppinghaus, Klaus; Heat Extraction Limits for using Municipal Sewage as a Heat Source for Heat Pumps; BMFT-FB-T 85-074, Bundesministerium für Forschung und Technologie (BMFT), D-5300 Bonn 2 (Federal Republic of Germany), August 1985, 555 p. (in German)

Heat pumps can use municipal sewage water as a heat source. One effect of this use is to lower the temperature of the sewage water entering the municipal sewage treatment plant. As the temperature of the sewage decreases, the effectiveness of the biological treatment process in the plant also decreases. To ensure proper treatment, the temperature of the sewage must be maintained above a certain minimum, and therefore the amount of heat that the heat pump extracts should be limited. This report describes an experimental activity that investigated the relationship between sewage treatment effectiveness and the temperature of the incoming sewage water.

Two identical treatment plants were built to perform the experiment. The sewage water flows processed by the two plants were the same except for their temperature. The difference in measured treatment quality between the two plants indicated the influence of the incoming sewage temperature.

Damjakob, Hans, and Remberg, Hans-Wilhelm; Study of the Feasibility of a Large Heat Storage Tank with a segmented design; BMFT-FB-T 85-071, Bundesministerium für Forschung und Technologie (BMFT), D-5300 Bonn 2 (Federal Republic of Germany), July 1985, 92 p. (in German)

This report investigates the feasibility of constructing a large heat storage tank approximately 1,000,000 m^3 in capacity utilizing a segmented construction technique. After determining certain constraints such as structural and operational requirements, design alternatives were developed. One concept uses a bowl-shaped tank supported by columns about 1.70 m high. The bottom and side walls of the tank are constructed by together prefabricated modules utilizing a material-saving grid construction. The roof for the tank is not integrated into the tank's main structural body. Thermal insulation is installed on the outside of the tank shell. The results obtained from the investigations, such as unit costs and masses, are applicable to tanks with larger or smaller capacities.

In our next issue you will find contributions to the following topics:

1. Heat Pump Activities of an Austrian Electric Utility.
2. Second Nordic Heat Pump Days, Stockholm
3. Clima 2000, Copenhagen
4. 500 m^2 of Roof-Mounted Unglazed Absorbers Collecting Ambient Heat for a Heat Pump Heating System of a Factory and an Office Building in Southern Germany
5. Development of a Heat Pump-Boiler System
6. Exhaust Air Heat Pump Systems in Sweden
7. Selected Book and Report Reviews
8. Schedule of Conferences and Trade Fairs

IEA Heat Pumpt Center Newsletter
(ISSN 0724-7028)

Edited by: IEA Heat Pump Center
c/o Fachinformationszentrum
Energie, Physik, Mathematik GmbH
D-7514 Eggenstein-Leopoldshafen 2
Telephone: (0 72 47) 82-45 41
Telex: 7 82 64 87 fize d

Published quarterly
Annual Subscription DM 12,- ($ 5,-) including postage
(V.A.T. not included).
Free of charge for subscribers from HPC Member Countries

Produced in Germany by
werbe-studio Achim Hohmann,
Bonn 2, Annaberger Straße 113.

YOU SHOULD BE AN IEA HEAT PUMP CENTER NEWSLETTER READER ...

If your goal is to stay abreast of the technological advances in the field of heat pumps.

If you are busy with heat pump development or research in this field.

If you are responsible for energy conservation measures in administration, industry, or research institutions.

Order your IEA Heat Pump Center Newsletter subscription today!
Just complete and mail the attached card.

IEA heat pump center

- ○ My country is participating in IEA Heat Pump Center. Start my cost-free subscription with the next issue.
- ○ My country is not participating in the IEA Heat Pump Center. Start my subscription (annual fee DM 12.- ($ 5.-) including postage, VAT not included) with the next issue.
- ● Cancelling the subscription is possible by giving one month's written notice to the end of the calendar year.

Date Signature

The IEA Heat Pump Center Newsletter will be published quarterly.

Subscribers from countries participating in the IEA Heat Pump Center (Austria, Canada, Fed. Rep. of Germany, Italy, Japan, the Netherlands, Sweden, the USA) will receive the newsletter costfree.

Subscribers from other countries will be billed DM 12.- ($ 5.-) a year.

Cancelling the subscription is possible with one month's notice to the end of the calendar year.