

NEWS LETTER

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TWS-Absorption heat pump in Stuttgart;
Engine house with air evaporators and hydraulic buffer storages (see page 7).

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Sorption Heat Pump Systems - Manufacturers, Product Information and Applications

In the previous issues of the IEA Heat Pump Center Newsletter the state of the art, application fields and development trends for absorption heat pumps (AHP) have been reported [1], [2], [3]. The present report tries to give a survey of presently existing absorption heat pump manufacturers, available products and sample installations.

1. Introduction

Despite its known advantages, such as

- energy savings of up to 70% compared to conventional heating systems,
- the possibility of applying solid fuels and waste heat,
- high reliability,
- low maintenance
- low abrasion,
- long life-time,
- low noise level,
- high system efficiencies - even during partial load conditions,
- stepless capacity control

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the AHP has not managed to make a large break-through in the market yet. In general the investment costs of small residential AHP allow an economic application presently only under certain circumstances. Against the increased application of the AHP of high capacity speaks presently the fact, that temperatures of more than 150°C, as required in many industrial processes, cannot be achieved with the known working pairs (NH₃/H₂O and H₂O/LiBr).

As it will be shown below, there are currently already quite a few successful examples for the application of AHP. To those belong the application of AHP with heating capacities between 25 and 400 kW in public and office buildings, and the application of AHP and heat transformers in the MW-range for heat recovery in the industrial sector.

In Japan, the USA, the F.R. Germany and other countries there are presently many research and development activities with the objective to improve the standard of AHP derived from absorption refrigerators and to make important progress in the direction of increased effectiveness, higher temperature rise and higher supply temperatures.

The main objectives of R, D & D are as follows:

- search for new working pairs,
- calculation and construction of improved components (e.g. absorbers and solution pumps),



Fig. 1 Water/water absorption heat pump Type GAWP 403 W (AWT)

- development of more effective cycles (e.g. combination of absorption and compression cycles).

2. Survey

All the information available for the HPC were summarized in Table 1 as a first survey that does not lay claim for completeness. The evaluation of product information and data for the AHP plants already installed, has shown that the following four heat output groups can be roughly defined:

- 1) AHP (Type I) heat output 25 to 50 kW
- 2) AHP (Type II) heat output 80 to 400 kW
- 3) AHP (Type III) heat output 800 to 7200 (20 000) kW
- 4) Heat transformer (Type II) heat output of 175 to 10 000 kW.



Fig. 2 Air/water absorption heat pump Type GAWP 403L (AWT)



Fig. 3 AHP demonstration project "Fernwärmeschiene Saar", F.R. Germany (Borsig GmbH).

2.1 Federal Republic of Germany

In the F.R. Germany, there are five manufacturers of AHP at present.

The "Absorptions- und Wärmetechnik GmbH" (AWP), Pfungstadt, produces directly gas-fired AHP (GAWP) with hermetically closed absorption cycle (see also page 21). The working pair used is NH₃/H₂O. Natural gas or liquid gas can be applied as driving medium. The GAWP are designed as water to water (Fig. 1) and air to water system (Fig. 2) with two different heat outputs:

GAWP 223 nominal heat output 22 kW,
GAWP 403 nominal heat output 40 kW.

The efficiency of the GAWP can still essentially be improved if it is additionally equipped with an exhaust gas heat exchanger for utilizing the latent heat of the flue gases.

The application of the GAWP is advantageous mainly in swimming-pools, sport centers, schools, office- and commercial buildings, gas pressure control stations, multi-family and single-family houses equipped with all modern conveniences. At present, there are more than 200 GAWP installations in operation, two of them in Sweden. The payback periods are 10 years at the most, in swimming-pools already about 6 years.

Country/ Manufacturer	AHP (Type I)		Heat transformer (Type II)	Installation figures		Applic. field	Remarks
	Q<100 kW	Q>100 kW		Type I	Type II		
Japan				107*	5*		* 1980-83 [3]
Ebara Co	x	x		6		I, C	
Hitachi Ltd.	x	x	x	3		I	
Hitachi Zosen Co.		x	x		1*	I, C, R	* Export NL in 1985
Kawasaki Heavy Ind.			x		1*	I	* Cooperation with GEA
Mitsubishi - York		x	x			I, C, R	
Tokyo Sanyo Electric	x	x	x	22*	4*	I, C, R	* 1980-84 (installation list)
Yazaki	x						
F.R. Germany							
AWT	x			>200		I, C, R	
Borsig		x		1		I	
GEA			x		2	I	
Linde		x		6		I, C	
Schiedel	x*						* Zeolite/Water
USA							
American Yazaki	x						
Arkla	x	x		2*		I	* Export NL in 1981
Carrier		x		1*		I	* Export NL in 1982
Trane		x		2*		I, C	* Export NL in 1982/83
France							
Collard & Trolart	x*						* available 1987
GDR							
Maschinenfabrik Halle		x		1		I	
Romania		x		3		R	22 units in planning stage
Abbreviation: R: Residential C: Commercial I: Industrial							

Table 1: Survey on manufacturers of AHP, products and installation figures

The "Schiedel GmbH", Munich, is able to deliver adsorption air conditioners with the working pair zeolite-water. These installations can also be used as heat pumps with flow temperatures of 80 to 90°C. At these flow temperatures and at an evaporation temperature of 1°C, the heat ratio is, according to the manufacturer, 1,3-1,35. Through a combination of two or more periodically working modules, a continuous working mode of the installation is made possible. The projected range of the cooling capacity of the adsorption air-conditioner is between 20 and 300 kW, whereby the higher capacities are achieved through a parallel installation of several modules. For the heating mode this means a maximum heat output of about 1,3 MW. The installation can be driven by electricity, gas and thermal oil. The demonstration plant located in the manufacturer's site is driven by thermal oil. There are several prospective buyers presently and sales talks are being held.

Large AHP (Type I) are manufactured in the F.R. Germany by "Borsig GmbH", Ber-

lin, and "Linde AG", Cologne. Both companies have decades of experience in producing large absorption refrigeration units. The AHP produced by these two manufacturers are based on this know-how and thus include the essential design characteristics, such as

- similar construction of the heat exchanging units,
- working pair $\text{NH}_3/\text{H}_2\text{O}$,
- tailor-made design.

The use of ammonia requires system pressures of more than 50 bar at higher flow temperatures, and for this reason thicker walls of the units are necessary. In spite of this disadvantage and the toxicity of ammonia, it is to be assumed that this working fluid will be of importance for large AHP also in the future.

Up to now the "Borsig GmbH" has manufactured only one two-stage AHP which was installed within the framework of the demonstration project "Fernwärme-

schiene Saar" (Fig. 3). This installation was set into operation in 1980. The operational data of the demonstration plant, by handing-over to the owner "Saarberg-Fernwärme", is shown in Table 2. The results of the long-term and test operation, with a heat input into the district heating network of about 15 000 MWh, have shown that absorption systems are suitable for the heating mode with a heat output of more than 2 MW and flow temperatures of more than 100°C [4]. There is no project to follow the first one yet.

Up to now, the "Linde AG" has installed six AHP for industrial and commercial applications. Although exclusively single-stage AHP were manufactured by now, the company has the know-how to produce multi-stage AHP. Nowadays, AHP with heat outputs ranging from 300 kW up to 20 MW can be made available [5].

For the lower heat output range, the "Linde AG" developed a single-stage AHP for utilizing air as heat source. This type of AHP

Heat source: district heating return flow

$$V = 124 \text{ m}^3/\text{h}$$

$$t_E = 40,6 \text{ }^\circ\text{C}$$

$$t_A = 32,0 \text{ }^\circ\text{C}$$

$$\dot{Q}_O = 1240 \text{ MW}$$

Drive: steam $p_D = 12,2 \text{ bar}$

$$t_D = 188 \text{ }^\circ\text{C}$$

$$\text{power input} \quad \dot{Q}_H = 2,825 \text{ MW}$$

$$\text{steam output} \quad \dot{Q}_D = 2,315 \text{ MW}$$

$$\text{boiler efficiency} \quad \eta_K = 0,819$$

Use: district heating system

$$V = 80 \text{ m}^3/\text{h}$$

$$t_R = 52,2 \text{ }^\circ\text{C}$$

$$t_C = 67,6 \text{ }^\circ\text{C}$$

$$t_{A2} = 76,5 \text{ }^\circ\text{C}$$

$$t_{A1} = 88,7 \text{ }^\circ\text{C}$$

$$t_V = 90,4 \text{ }^\circ\text{C}$$

$$\dot{Q}_C = 1,433 \text{ MW (Condenser)}$$

$$\dot{Q}_{A1} = 0,828 \text{ MW (Absorber 1)}$$

$$\dot{Q}_{A2} = 1,135 \text{ MW (Absorber 2)}$$

$$\dot{Q}_{LK} = 0,158 \text{ MW (Solution cooler)}$$

$$\dot{Q}_N = 3,554 \text{ MW}$$

Process parameters:

$$\text{heat ratio} \quad \dot{Q}_O/\dot{Q}_D = 0,536$$

$$\text{COP} \quad \dot{Q}_N/\dot{Q}_H = 1,258$$

was installed in Stuttgart for heating some office-, storage- and workshop-buildings (see also page 7).

A survey about the most important data of the AHP with the working pair $\text{NH}_3/\text{H}_2\text{O}$, installed by "Linde AG" up to now, gives Table 3.

Heat transformers (Type II) for industrial heat recovery are produced in the F.R. Germany by the "GEA-Luftkühlergesellschaft mbH & Co.", Herne [6]. These heat transformers use the working pair $\text{H}_2\text{O}/\text{LiBr}$ and they are offered with a heat output range from about 1 up to 10 MW. They were developed in cooperation with the Japanese "Kawasaki Heavy Industry", which has produced absorption air-conditioners with the working pair $\text{H}_2\text{O}/\text{LiBr}$ for application in office buildings for more than twenty years. The first European industrial heat transformer was installed in the "Tierkörperbeseitigungsanlage (TBA) (plant for carcass disposal) in Dörnten nearby Goslar in March 1984 (see page 34). The second unit was installed at the "Stuttgarter Hofbräu AG". This is the first heat transformer applied in a European brewery (see page 14). Two further heat transformers from GEA are just in the planning stage. One of these is sponsored as a demonstration project by the European Community [7]. The installation of this heat transformer with a heat output of about 2,2 MW in a chemical plant ("Degussa",

Table 2: Typical operation parameters of the Borsig demonstration plant [4]

Location	Application	Driving medium	Capacity heating/cooling (kW)	Source	Sink ($^\circ\text{C}$)
Garmisch-Partenkirchen	swimming pool ice rink	n-Butan	7200/1950	ice generation	heating and hot tap water 55/42
Meckenheim	office building space heating air conditioning	natural gas	1750	soil absorber exhaust air waste heat	heating water 57/46
Bad Kreuznach	school space heating	natural gas	389	soil absorber	heating water 58/46
Waiblingen	district heating	sewage gas natural gas	2500	treated sewage water	heating water 65/40
Stuttgart	office building workshop space heating	natural gas	310	ambient air	heating water 50/41
Suhr (CH)	factory building cold-storage depot	hot water	2100/676	waste heat	heating water 40/30

Table 3: AHP plants installed by Linde AG

Köln-Wesseling) is expected for the middle of 1987.

Three further German companies have developed prototypes of heat transformers during the last years [8]:

- Friedrich Krupp GmbH (NH₃/H₂O)
- AEG-Telefunken (H₂O/H₂SO₄)
- Battelle-Institut e.V. (H₂O/LiBr).

The dual-agent compression heat pump with solution circulation may also belong to the field of sorption heat pump systems. In this field, there are interesting on-going developments. In the F.R. Germany, the "TCH Thermo-Consulting-Heidelberg GmbH" will install such heat pumps in cooperation with suitable manufacturers for industrial heat recovery and process steam generation.

A unit of higher output for application in the paper industry is in the planning stage. Its steam generating capacity shall be about 16 t/h with the steam parameters 140°C/3,6 bar. For this project TCH and BBC-York formed a working group.

In addition, TCH signed a license contract with the Japanese "Sumitomo Co.", Osaka, regarding the installation of dual-agent compression heat pumps with solution circulation in Japan.

From the "Borsig GmbH" a pilot plant with an oil-free screw-compressor has been installed and successfully tested.

2.2 Japan

The market for heat pumps in Japan is developing very positively because of the good cooperation between all involved parties, and the strong support from government and gas utilities.

The heat output range of the AHP (Type I) and heat transformers (Type II) manufactured in Japan are shown in Table 4. Tables 5 and 6 indicate a collection of the most important parameters of these types. All these AHP use the working pair H₂O/LiBr.

In 1984, 107 units of AHP (Type I) were delivered [3]. One of them (Ebara) was exported to Costa Rica and the world's largest AHP with a heat output of 7,2 MW (Tokyo Sanyo) was exported to Sweden, where it is used for district heating [9]. Furthermore, five heat transformers were manufactured in Japan (Type II), of which three were exported. One unit was shipped to the Republic of Korea (Tokyo Sanyo), one unit to the F.R. Germany (Kawasaki Heavy) and in 1984 a unit with a heat output of 6,42 MW (Hitachi Zosen) was delivered to the Netherlands [10].

In 1985 the HPC Japanese National Team compiled product information from six manufacturers of AHP and descriptions of

Manufacturers	AHP (Type I)	AHP (Type II)
Ebara	260–3000	not produced
Hitachi	200–7500	200–4500
Hitachi Zosen	500–7000	500–2500
Kawasaki	not produced	500–3000
Mitsubishi	300–9000	150–4500
Tokyo Sanyo	70–8000	300–2100
Japan	70–9000	150–4500

Table 4: Products capacity in manufacturing (heating capacity Mcal/h)

Manufac- turers	Model name	Working pair	Applica- tion	Drive heat	STD or order	
Ebara	16JH 16JS	H ₂ O	I	ST,HW	Standard	
	16JR		C	TG,LNG	Order made	
Hitachi	HAP	+	I	ST,HW	Standard	
	HAP-FS		I	HO.	Order made	
Hitachi Zosen	HHP-1W		I	ST,HW	Standard	
Mitsubishi	ESH-F		R, C, I	ST,HW, WG	Standard	
	ESG		R, C, I	TG	Standard	
Tokyo Sanyo	AH GH-V		LiBr	C, I	SW,HW	Standard
	TSA-SUH-B			R, C, I	TG,KE	Standard
Abbreviation: Application Drive heat R: Residential ST: Steam C: Commercial HW: Hot water I: Industrial TG: Town gas HO: Heavy oil LNG: Liquid natural gas WG: Waste gas KE: Kerosene WST: Waste steam WHW: Waste hot water						

Table 5: Absorption heat pumps (Type I)

19 sample installations [11]. Accordingly, the studied installations will be applied in the following branches:

- a) AHP (Type I), steam-driven spinning mill (3), paper and pulp industry (2), dye works, photo film plant, steel mill, chemical plant
- b) AHP (Type I), gas-fired gas utility, memorial hall, laboratory, semiconductor plant, office building
- c) heat transformer (Type II), waste heat-driven food industry, ethylalcohol distillation plant, butadiene rubber plant (2)

Manufac-turers	Model name	Working pair	Applica-tion	Drive heat	STD or order
Hitachi	HAP	H ₂ O +	I	ST,HW	Order made
Hitachi Zosen	HHP-2S		I I	WST	Standard
	HPP-2W			WHW	
Kawasaki	HT-S	LiBr	I	ST,HW, WST	Standard
Mitsubishi	ESH-S		I	ST,HW	Order made
Tokyo Sanyo	HP-B		I	WST	Standard
Abbreviation:	Application R: Residential C: Commercial I: Industrial	Drive heat ST: Steam HW: Hot water TG: Town gas LNG: Liquid natural gas KE: Kerosene	HO: Heavy oil WG: Waste gas WST: Waste steam WHW: Waste hot water		

Table 6: Absorption heat pumps (Type II)

The heat output of the reference plants of group a) ranges between 1740 and 3620 kW. In eight of ten cases cooling water or waste water are used as heat source, and hot process water or boiler feed water are supplied. One installation uses organic vapor as heat source, and supplies process steam at a temperature of 90°C.

The heat output of the AHP of group b) ranges between 81 and 810 kW, except one AHP with 3341 kW. The installations use mainly cooling water of air-conditioners or waste water as heat source, and they supply hot tap water or hot water for space heating. Only the AHP installed in the semiconductor plant supplies hot process water.

The heat transformers of group c) have a heat output ranging from 911 up to 2390 kW. They are driven by waste steam at temperatures of 80 to 100°C and supply low pressure process steam. Heat dissipation is realized by cooling water or sea water.

The sales figures of Japanese absorption air-conditioners are developing positively, especially because the deliveries to the U.S. market are increasing. All the Japanese manufacturers show the tendency to produce absorption air-conditioners with smaller capacity. The leading firm in this field is Yazaki that delivers units down to 10 kW of cooling capacity.

Presently, heat pump operation of these absorption air-conditioners is not planned. The larger units are used in a

pure boiler operation during winter. The following arguments speak for a future heat pump application of these installations. By addition of LiBr in the evaporator a freezing point reduction can be achieved which makes an operation at lower ambient temperatures possible. In addition, the double-effect absorption air-conditioners can be changed over relatively easy to attain higher temperature rises and accordingly higher flow temperatures.

2.3 USA

Presently, there is no market for AHP in the USA. Absorption chillers are produced by Arkla, Carrier, Preway and Trane. Sales figures for absorption chillers for the period 1975-1984 are shown in Table 7.

During 1981-1983 U.S. manufacturers exported a total of five AHP to the Netherlands [12]. All these units use the working pair H₂O/LiBr. Three units (Arkla (2), Carrier) are driven by waste heat of gas engine driven motors installed in cogeneration plants. The AHP of Trane is driven by heat from a district heating system. Four of these installations are used for heating and cooling in cheese production plants and office buildings. They use circulating air and surface water as heat source, heat output is predominantly used for air heating.

Since 1985 Washington Gas offers the absorption unit AROACE produced by the American Yazaki. This is a packaged double-effect absorption machine for

cooling and heating. The unit uses the working pair H₂O/LiBr. It is suitable for indoor or outdoor installation. Four units with a cooling capacity ranging between 7,5 and 30 RT (26,4 to 105,6 kW) can be combined to supply up to 150 RT (528 kW) capacity. The efficiencies amount to 95% for cooling and 83% for heating operation.

2.4 France

At the last INTERCLIMA the AHP PACHA developed by Gaz de France (G.D.F.) and the manufacturer Collard & Trolart was presented. The presented air to water unit has a heat output of 40 kW and uses the working pair NH₃/H₂O. In the near future, the materialization of a water to water unit and a reversible operation mode is planned.

This AHP is designed for base load heating and is therefore applicable to heating installations with a total heat output of about 200 kW. The designed heat ratio of PACHA is indicated with 1,3. Delivery is planned for 1987.

2.5 German Democratic Republic

The "VEB Maschinenfabrik Halle" has decades of experience in manufacturing large absorption refrigerators for industrial application. Numerous units with the working pair NH₃/H₂O and a cooling capacity of up to 3,5 MW have been installed.

This company offers a newly developed absorption machine with heat outputs ranging between 1 and 3 MW. This single-stage unit with the working pair NH₃/H₂O will be delivered in compact design. In accordance with the H₂O/LiBr-absorption chillers all of the heat exchangers are located in two horizontal pressure tanks installed one on top of the other. Up to now, only a steam driven unit is available. The first AHP of this type is operated in a sewage treatment plant [13].

Year	Number of units
1975	740
1976	571
1977	588
1978	470
1979	392
1980	279
1981	239
1982	199
1983	135
1984	153
Source:	
U.S. Department of Commerce, Bureau of the Census, Current Industrial Reports MA-35M, Air Conditioning and Refrigeration Equipment.	

Table 7: U.S. Sales figures of absorption chillers

2.6 Romania

In [14] it is reported on the production and application of absorption heat pumps and compression-absorption heat pumps in Romania. At present three types of absorption heat pumps are manufactured, using the working pair $\text{H}_2\text{O}/\text{LiBr}$. The heat outputs of these types are 2,9 and 5,8 MW. They are applied in district heating using cooling water from neighboring industries. In 1983 the first 5,8 MW absorption heat pump was installed at Jassy. Two further 5,8 MW units were installed at Pitesti in 1985. Other 10 units of 2,9 MW and 12 units of 5,8 MW are underway.

In 1984 a water to water compression-absorption heat pump with a heat output of 8,7 MW was installed in Bucarest. At present it is under experimental operation. The installation prepares hot tap water for six thermal substations that supply about 8000 flats. The estimated payback period is 5 years.

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The Stuttgart Air-Source Absorption Heat Pump

The Technische Werke der Stadt Stuttgart AG (TWS) started to operate an absorption heat pump for heating several office buildings, storehouses and machine shops (Fig. 1). This one-stage absorption heat pump with an average heating capacity of 310 kW, newly developed by Linde AG, is an energy saving and ecologically beneficial system. With such a heat pump, ambient air is used as a "free of charge" heat source (Fig. 2 - see title page). The heat pump saves energy costs of about 30% compared to conventional heating systems. When it is warmer than $+3^\circ\text{C}$, the heat pump alone covers the

heat demand of the building. At lower outdoor temperatures, a boiler is used in addition. Numerous measuring devices allow the determination of energy savings, as well as the behavior of the heat pump, at different operating conditions.

Absorption heat pumps mainly consist of heat exchangers and pressure tanks. Because of the small number of moving parts, those heating systems are characterized by an especially safe and noiseless operation, long service life and very low maintenance requirements. Although

General data:

Heat use:	space heating; ventilating system, local heaters
Refrigerant:	ammonia (NH_3)
Solution components:	ammonia/water ($\text{NH}_3/\text{H}_2\text{O}$)
Fuel:	natural gas
Heat source:	ambient air
Operation mode:	parallel

Technical data:

Heat output:	$(\dot{Q}_N)$	310 kW
Fuel consumption boiler:	$(\dot{Q}_H)$	235 kW
Heat ratio (COP):	$(\dot{Q}_N/\dot{Q}_H)$	1,32
Cooling capacity:	$(\dot{Q}_O)$	88 kW
Heating water temperature supply/return:	50/41,5 $^\circ\text{C}$	
Ambient air temperature:	+5 $^\circ\text{C}$	
Electric power demand heat transport fluid pump, solution pump, evaporator fan, NH_3 -pump:		12 kW

Table: Design data of the TWS single-stage absorption heat pump

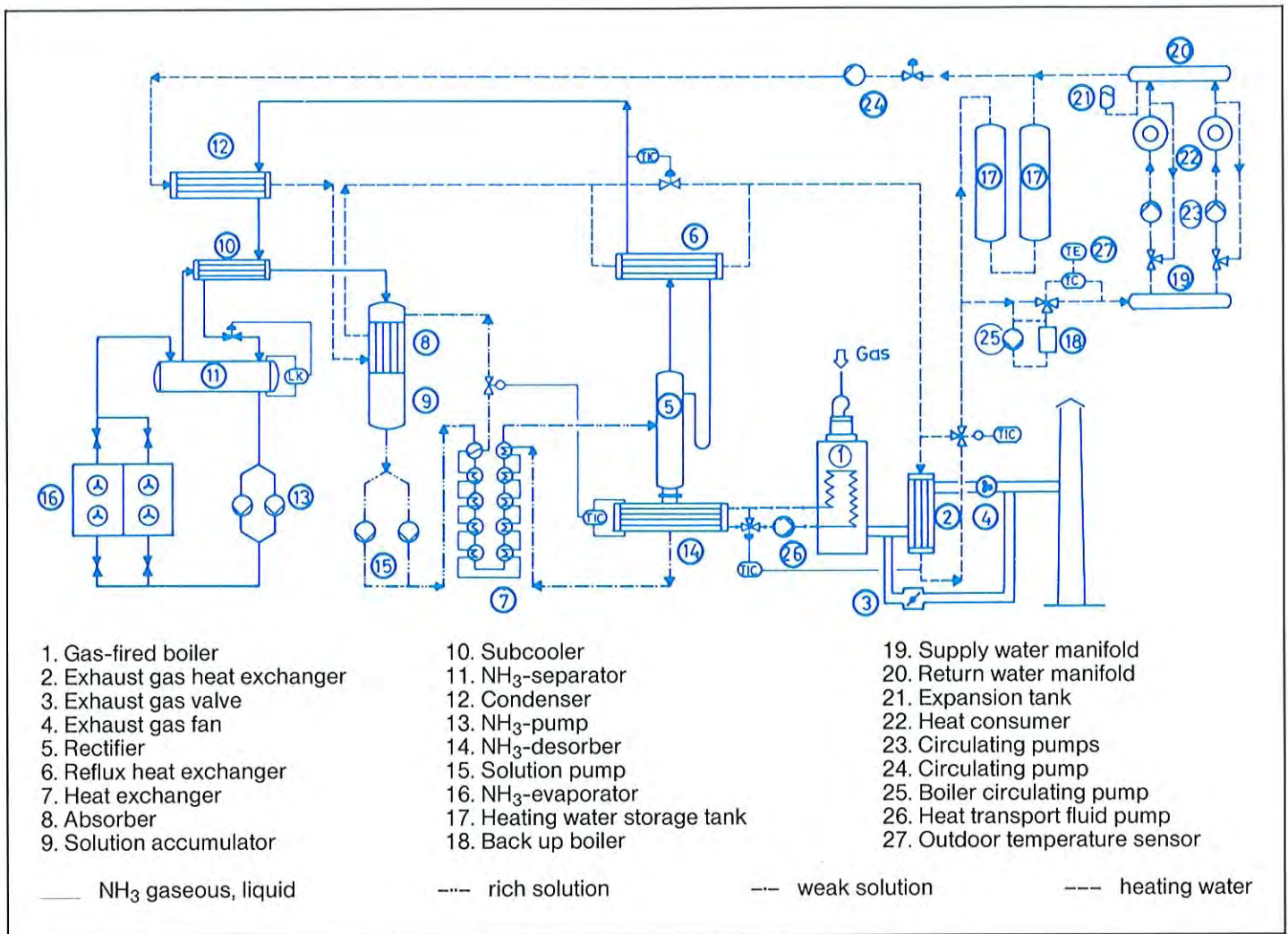


Fig.3: Schematic diagram of the TWS single-stage absorption heat pump

absorption systems with ammonia water proved to be successful in the past for refrigeration applications, heat pumps that work according to the absorption principle have existed for only a short time. Due to their many advantages, these heating systems may play an important role in the future.

In Fig.3, the operating principle of the TWS absorption heat pump is described: In two outdoor air heat exchangers ammonia is evaporated at a low pressure extracting heat from outdoor air (16). This vapor is dissolved in the poor water-ammonia solution in the absorber (8) releasing heat to the heating system. The resulting rich solution is pumped (15) through a heat exchanger (7) and the rectifier (5) into the generator (14).

The generator is indirectly heated via an intermediate heating circuit by a gas-fired boiler (1). Thermal oil is used as heat transport fluid in this intermediate circuit. In the generator the working fluid ammonia is evaporated from the ammonia water solution. This vapor still containing some water is purified in a rectifier (5) and a reflux heat exchanger (6) before being condensed in the condenser (12).



Fig.1: Single-stage gas-fired air-source absorption heat pump of the TWS

Heat from condenser, absorber, reflux heat exchanger and from the boiler flue gas heat exchanger is supplied to the space heating system. The energy balance (Fig. 4) shows that with an energy input of 235 kW (gas for the boiler) an energy output of 310 kW is supplied to the heating system, including 88 kW heat from outdoor air. This translates to the heat ratio of 1.32 not including electric energy for auxiliary equipment.

In addition to a noiseless operation and low maintenance expenses, the absorption heat pump has the advantage that the heating capacity can be adapted to the space heating load from 100% down to 30%, while the hot water temperature at the outlet of the heat pump changes between 48 and 50°C, depending on the outdoor temperature. This modulating operation mode decreases cycling losses.

Another advantage of this system is the very low air pollution, compared to a conventional system, because of the lower gas consumption, and compared to a gas engine driven heat pump, because of the higher emissions of an engine than the conventional boiler used in this system.

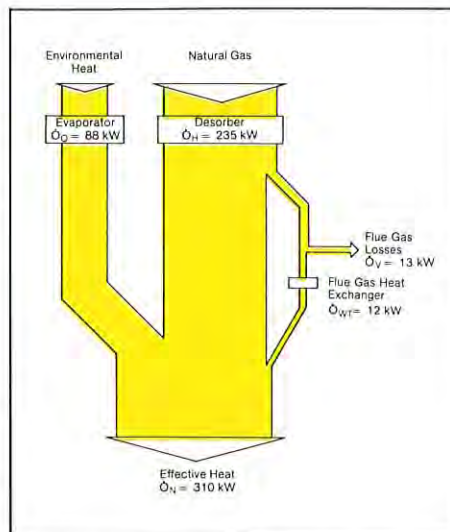


Fig. 4: Energy flow chart of the TWS single-stage absorption heat pump

Therefore, the absorption heat pump of the Technische Werke der Stadt Stuttgart AG not only achieves savings of 30% but also helps to keep the air clear.

The operational experience will be published in a later issue.

A. Lehmann, IEA Heat Pump Center

air is absorbed by the solution. The net result is a reduction in moisture content and an increase in temperature of the moist air returning to the dryer. The excess water content in the solution is evaporated away in the low pressure regenerator, using a source of low-grade waste heat.

The open cycle system is especially applicable to the drying process, and direct contact in the absorber between solution and water vapor in the drying air eliminates the need for any evaporator.

Low cost sodium hydroxide/water was chosen as the heat transport medium. This working fluid pair is well suited to an open cycle system where losses could be an economic burden. Available thermodynamic fluid properties were reviewed and refined to provide formulae suitable for heat pump design and computation purposes.

Component design criteria were established, and a computer-aided design technique was developed for estimation of operating conditions within a contacting tower absorber, containing open type packing. The computer program models the absorption effects and performs stage-by-stage heat and mass transfer calculations, using fluid thermodynamic data previously formulated. Design of the tower and other components was carried out to the level of detail necessary to size and specify the equipment for accurate cost estimating purposes.

W.K. Snelson*

Absorption Heat Pump Activity in Canada

Absorption heat pump activity in Canada has been restricted so far to technical and economic feasibility studies carried out during the last 2 years by engineering consultants on behalf of the National Research Council (NRC). In a preliminary study phase consultants were requested to identify a specific "host" industrial client, whose particular process appeared suitable for an absorption heat pump application. From the results of this phase the three most promising cases were selected for more detailed evaluation. Two of those studies have now been completed, and work on the third one is currently still in progress. The following summaries provide a brief description of the applications covered in these studies, with conclusion and recommendations for further work where appropriate.

Paper drying

The concept proposed by Acres International Ltd of Toronto uses an open cycle absorption heat pump for industrial drying applications. The study which was completed in 1985 is based on an actual paper drying process, using the final drying stage of a 400 tonne/day paper machine located at a plant in southern Ontario. The aim is to reduce the amount of plant steam used at the drying rolls for extraction of moisture from the wet paper. A simplified schematic diagram (Fig. 1) illustrates the principal features of the process.

Moist air from the drying system is fed into the absorber and contacted directly by the liquid absorbent solution in a contacting tower. Heat and mass transfer effects take place as some of the water vapor in the

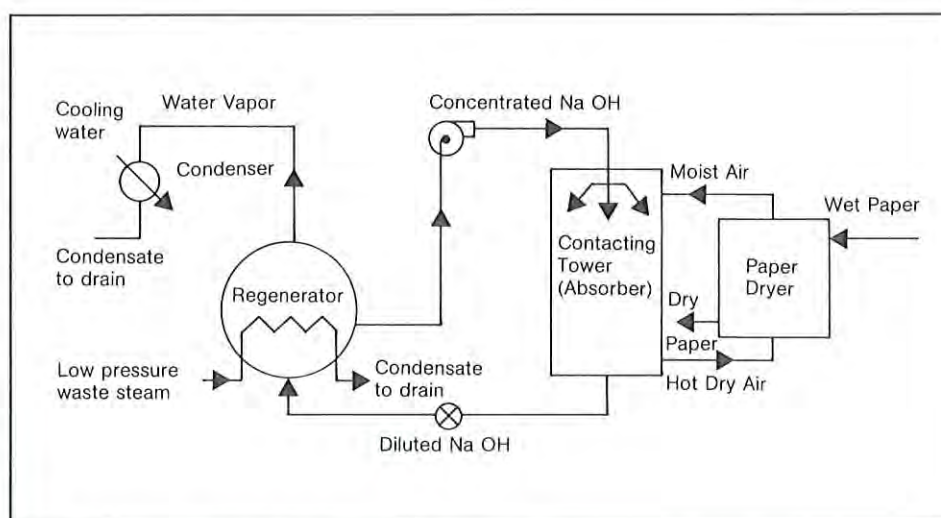


Fig. 1. Absorption heat pump drying application concept

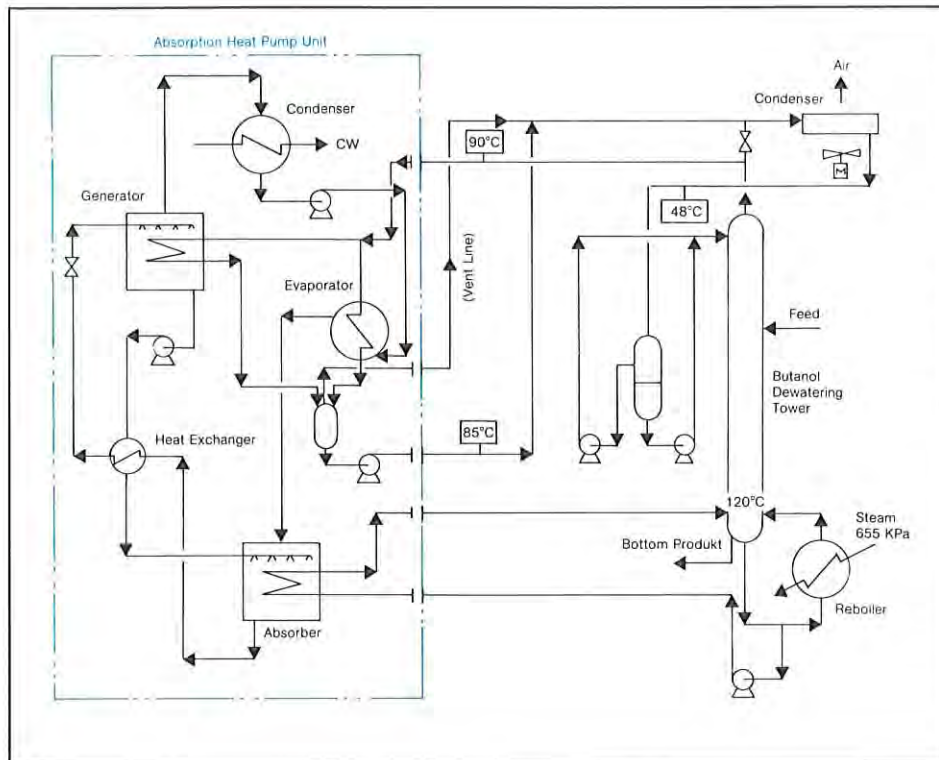


Fig. 2. Proposed absorption heat pump/distillation column application - schematic layout

operating and maintenance costs, these energy benefits would provide a simple payback period of 2.65 years. An economic analysis, using discounted cash flow techniques, established attractive terms for internal rate of return and net present value.

Although the study provided very positive feasibility indications, it is recognized that further investigation and demonstration work on a smaller scale is required before considering large scale implementation. Accordingly it has been proposed that a laboratory scale research and development program be undertaken aimed at verifying thermodynamic cycle performance characteristics, and establishing the industrial potential of the absorption heat pump in this type of application. Successful results in this area would subsequently lead the way to pilot plant demonstration scale activity.

The preliminary study work contained an estimate of the technical potential for energy recovery throughout Canadian industry, using absorption heat pump techniques. The total heat rejected was tabulated for 44 major industrial sectors, including manufacturing, primary metals, pulp and paper, and resource based industries. The rejected heat streams were categorized in three temperature ranges, i.e. 100°C - 290°C, 50°C - 100°C, below 50°C. Estimates of waste heat energy content potentially applicable to heat pumping were established for those ranges. A further assumption was made that the net energy recovered by all absorption heat pump systems was 30% of the estimated waste heat input available. The above in-

formation was derived separately for each of the Provinces and Territories. On this basis the total net energy recoverable by absorption heat pumping for all of Canada was estimated to be 55 x 10⁶ GJ per year. The data used in these estimates were obtained from a survey carried out in 1978, and some updating would be necessary to reflect current potential conditions.

Fractional distillation (1)

Stone & Webster Canada Ltd. of Toronto studied the application of absorption heat pumps to Canadian refinery, petrochemical, chemical and distillery industries. Many companies were contacted initially, with a view to identifying an end user who would be interested in committing to the installation of an absorption heat pump.

As a result of this survey, a number of distillation columns were selected for preliminary technical and economic evaluation. Working in collaboration with Energy Concepts Company of Annapolis, Maryland, Stone & Webster identified a butanol dewatering tower located at a petrochemical plant near Montreal as the most appropriate application. Calculations based on initial information had indicated a 48% heat recovery from the tower overhead vapor, using lithium bromide/water in a reverse cycle system. Other preliminary information available on the tower was promising and estimates by ECC showed a potential payback within 2 years.

Subsequent column operation data obtained from plant sources later revealed

significant discrepancies from the original information received. In particular, the overhead heat available from the column transpired to only 65% of the initial obtained value, and the overhead vapor also had a varying condensing temperature, the average of which was about 10°C less than the original assumption. The lower heat input to the heat pump reduced the amount of steam saved in the reboiler from 2,500 kg/hr to 1,600 kg/hr. The other important change from the original process understanding was that the distillation column contained organic compounds which were incompatible with copper. This presented a materials problem for the heat pump components.

However, conceptual design work continued and specifications were issued to potential absorption heat pump manufacturers. A schematic layout of the proposed system is shown in Fig. 2. The only bid quotation received was from Hitachi Zosen Corporation of Tokyo. The price was three times more expensive than the Hitachi quote obtained in the preliminary study, even though the unit capacity was considerably less. The main reason for the increase was Hitachi's choice of titanium tubing in the absorber and regenerator. The copper/nickel alloy normally used was unsuitable for the process fluids, and stainless steel was not considered adequate to handle the corrosive nature of the lithium bromide solution at the temperatures concerned. Heat transfer surface areas were also larger due to closer approach temperatures used.

The higher costs and lower benefits combined to indicate that the project was uneconomic at that stage, and it was concluded that the selected host location was unsuitable for an absorption heat pump installation. Although the economics proved to be unfavorable for that particular distillation column, this will not always necessarily be so, and the study provided some useful guidelines to observe for determining suitable candidates. The inquiry and screening process for potential users should include the following criteria:

- Ensuring that the reported overhead duty is actually the heat available for the heat pump system. (In some cases overhead design duties are often misinterpreted as being the same as operating duties.)
- Establishment of process fluid compatibility with copper bearing alloys if lithium bromide systems are to be used. Otherwise exotic materials such as titanium will probably adversely affect the economics.
- In the case of reverse cycle applications the available overhead condensing heat duty should approach as close as possible to the reboiler duty. The larger the deviation the less reboiler energy reduction will be achieved by the heat pump.

- Generally applications should aim at columns with overhead heat duties of 5,000 MJ/hr or more to produce satisfactory payback terms. Lower heat duties begin to test the economics of scale for the heat pump capital cost.
- Clear identification of contents of overhead vapor streams. For vapors, containing compounds with different boiling points, a condensing temperature range must be established. Preference should be given to isothermal overheads.
- Review of implications for the heat pump of any fouling problems in existing process heat exchangers.
- Adequate ground space and height clearance should be available for the large heat exchangers required, preferably in an area adjacent to the column to minimize inter-connection costs.

The latter consideration of space limitations is an important one. Some alternative columns being considered in this case were ultimately rejected because of logistics problems, even though other thermal and materials conditions were adequate. One of the main conclusions reached in the study was that successful applications of absorption heat pumps to distillation columns are more likely to occur in new plant units rather than retrofit situations. Even where physical space is available in existing plants the disruption of utility services and auxiliary systems may lead to complications and affect economics.

The preliminary feasibility study contained some information about the energy conservation potential, which could be achieved in Canadian distillation process industries by the adoption of absorption heat pumps. The projections were based on data obtained for U.S. industries with appropriate scaling factors applied for Canada, using relative production capacities. Distillation energy consumption levels were tabulated for over 100 processes in the petroleum refining, natural gas processing, and petrochemical processing industries. Based on corresponding column temperature requirements each process was assessed for its potential absorption heat pump application. Allowing for competition from other energy conservation sources a share of 15% - 25% of the technically applicable market was estimated, depending on the type of cycle and process concerned. Assuming an average energy savings of 45% is achievable by using the heat pump on those columns, the total potential distillation energy savings in Canada was estimated at 3.1 x 106 GJ per year based on 1983 data.

Fractional distillation (2)

This study is being conducted by Stearns Catalytic Ltd. of Sarnia, Ontario, and it also focusses on a distillation column applica-

tion. The host industry identified in the initial study phase subsequently discontinued its involvement due to extensive commitments in other projects. An alternative end user was located with a petrochemical processing plant in south-western Ontario.

The particular column selected, there was a degum tower with an overhead temperature of 110°C and a bottom temperature of 175°C. For lithium bromide systems the latter temperature would require the heat pump working fluid to exceed the maximum allowable temperature of 165°C. However, a combined system was proposed in which heat recovered from the degum tower was used to reboil the bottom of a stripper tower, operating at a maximum temperature of 159°C.

Inquiries sent to 4 potential absorption heat pump vendors produced no quotations. Hitachi's surprise response indicated that a new maximum fluid temperature of 130°C had been imposed as a result of corrosion problems experienced in some lithium bromide heat pump systems, operating in Japan.

Energy Concepts Co. is also providing assistance to Stearns Catalytic in this study, and Stearns has recommended that a nitrate solution developed by ECC is to be considered as an alternative working fluid. This solution offers working temperatures up to 250°C and permits the use of carbon steel materials of construction up to 220°C. Litwin Engineers and Constructors Inc. of Houston, Texas has also expressed interest in providing quotations for the manufacture of absorption heat pump systems, using this new absorbent. Accordingly, Stearns Catalytic and ECC are currently reviewing suitable columns with a view to selecting the most appropriate unit for the nitrate solution application. A preliminary economic evaluation is expected to be completed in August 1986 and, depending on the outcome of this activity, the detailed engineering phase is scheduled for completion by late Fall of 1986.

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P. Vinz*

A New Design for an Ammonia-Water Absorption Refrigeration Process and its Thermodynamic Perspectives.

Using cycle-inherent potentials, three effective innovations are introduced into the well-known ammonia-water absorption refrigeration process. This results in a drainage of the refrigerant vapor in the rectification apparatus without loss of energy, a stabilization of the concentration of the refrigerant in the evaporator free of energy loss, and a drastically reduced power demand for the solution circulation. Concept and design of the improved components are described.

With the above mentioned improvements, the absorption refrigeration process is considerably better than recent alternatives, especially in the heating mode. Heating water supply temperatures of 80°C at real heat ratios of about 1,5 are possible for heat pumps of high capacity as well as for residential heat pumps of low capacity. Beyond that, this process can be fully automated in a simple way. Apart from the new circulation device for solution circulation, all measures can be realized with available techniques.

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(The complete article will be published in the next Newsletter)

R.C. DeVault*

Recent Progress in the U.S. Department of Energy-Advanced Absorption Cycle Heat Pump Program

This report includes only those research and development programs sponsored or co-sponsored by the DOE Building Equipment Research Division. Three contractors are working on advanced absorption cycle prototypes for residential applications. Additional absorption systems research projects have been sponsored by the Gas Research Institute, the DOE Solar Program, and the DOE Industrial Program.

The U.S. Department of Energy (DOE) has been supporting research and development for absorption heat pump systems since 1979. These activities have been managed by Oak Ridge National Laboratory's Building Equipment Research Program.

Initial projects, now completed, were for the development of prototype single-effect absorption heat pumps for residential applications.

Arkla Industries, a manufacturer of ammonia-water air-conditioners, developed a single-effect ammonia-water heat pump for heating only with steady state coefficient of performance (COP) of 1.25 at 8.3°C (47°F) and 1.12 at -8.3°C (17°F) [1].

These performance levels are fuel based efficiencies including flue losses using the higher heating value of natural gas.

Allied Corporation, under sponsorship of DOE, the American Gas Association (AGA), and the Gas Research Institute (GRI) developed a single effect heat pump for both heating and cooling for residential

applications, using a fluorocarbon refrigerant and an organic absorbent. Prototype heat pumps were developed to achieve a heating COP of 1.2 at 8.3°C (47°F) and a cooling COP of 0.5 at 35°C (95°F) [2]. The prototype development used R-123a (1,2-dichloro 1,2,2-trifluoroethane) for the refrigerant and ETFE (ethyltetrahydrofurfuryl ether) for the absorbent.

Even though both single-effect prototypes were successfully operated and achieved the performance goals, the single-effect performance levels were not sufficient to offer reasonable economic incentives for customer acceptance.

Based on these performance results, and the need to provide economic payback to customers of less than three years against conventional heating and air conditioning systems, the absorption program goals were re-evaluated in late 1981. The decision was made to look for advanced absorption cycles capable of producing higher efficiency heat pumps than conventional single-effect cycles while still using existing absorption fluid combinations.

In 1982, a Request for Proposal (RFP) was issued for the development of advanced 1.6 in heating and 0.7 cooling, as compared with current state-of-the-art single-effect values of 1.2 and 0.5. The RFP was distributed to more than 50 potential bidders within the U.S. Three contractors were selected for the work under the advanced cycles program, and work was started in early 1983. The three contractors are Carrier Corporation, the Trane Company, and Phillips Engineering Company.

The work is divided into three phases. Phase I is the analytical evaluation of advanced cycles, with a preferred advanced cycle being selected for further development. Phase II is the development and testing of a laboratory breadboard prototype of the selected advanced cycle. Phase III is the development and testing of a packaged proof-of-concept prototype after successful completion of Phase II. In Phase I analysis work, Phillips Engineering examined the following cycles:

- double-effect cycles,
- resorber augmented cycle,
- generator-absorber heat exchange (GAX) cycle,
- double-effect regenerative cycle,
- variable-effect cycle,
- two-stage generator-absorber heat exchange cycle [3].

Phillips evaluated each cycle on the basis of potential efficiency, heat exchanger surface requirements, and ability to operate over a broad range of temperatures. The GAX cycle was selected as having the best combination of high potential efficiency and low manufacturing cost. Both ammonia-water and ammonia-lithium bromide-water are candidate absorption fluid systems for this cycle.

The Trane Company conducted a similar Phase I analysis and also selected a GAX cycle, but with additional features and internal heat exchange [4]. Economic analysis shows customer payback of about 2.5 years in commercial buildings while simultaneously giving a better utility load profile for both gas and electric utilities. Carrier's study of advanced cycles resulted in selection of a dual-loop cycle based on the use of methyl amine-lithium bromide-water in the lower (temperature) loop and lithium bromide-water in the upper loop [5]. DOE has been granted six patents based on the Carrier Phase I work.

Each of these advanced cycles offers potential for a rated heating COP in the range of 1.8 to 2.0 and cooling COP in the range of 0.8 to 1.2, significantly exceeding the original program goal set in 1982.

Phase II of the projects, the laboratory breadboard demonstration of the cycles identified as most promising, is under way.

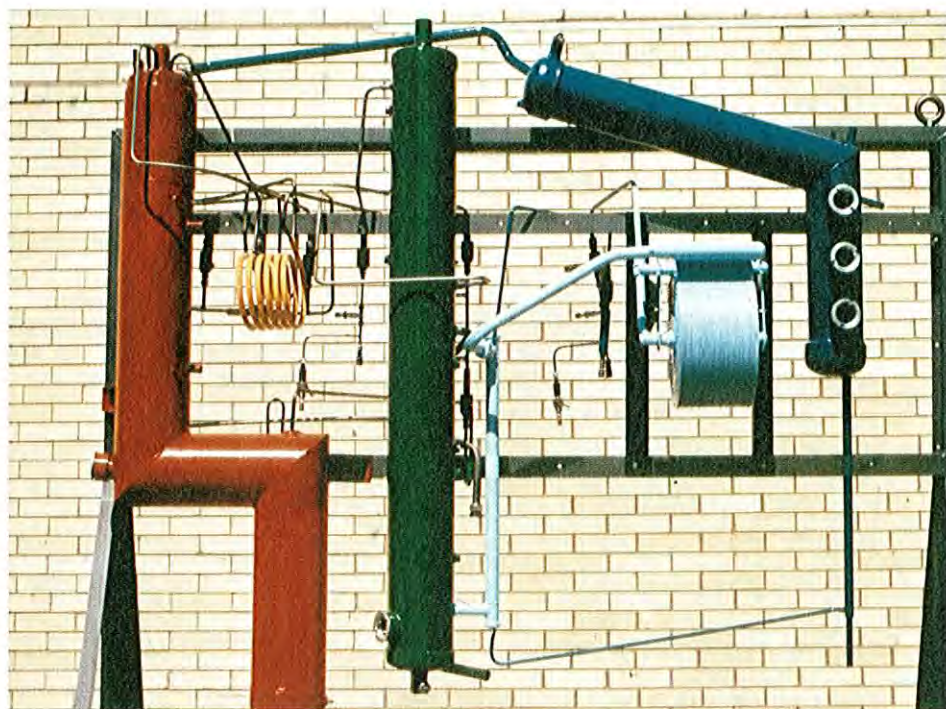


Fig. 1 GAX cycle breadboard developed by Phillips Engineering Company

During 1985, Phillips Engineering successfully operated a proof-of-principle breadboard prototype of a residential-sized unit with performance exceeding the original advanced cycle RFP goals. The GAX cycle breadboard, shown in Fig. 1, achieved COPs of over 1.8 in heating at 8.3°C (47°F) and 0.8 in cooling at 35°C (95°F). An independent cost analysis of the Phillips Engineering prototype concept has predicted a customer-installed cost equal to existing mid-line gas furnace/electric air-conditioner combinations or to electric heat pumps. Trane expects to demonstrate proof-of-principle with a breadboard model of a commercial-sized unit in 1986. Carrier's Phase II heat pump breadboard is scheduled for testing in 1988.

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A.J. Meijnen*

Research and Development in the Netherlands

Absorption heat pump (AHP) related R&D in the Netherlands has been focused mainly on heating purposes for dwellings and buildings. This can be explained from the high availability of natural gas, a favorable price ratio between electricity and gas, and an increasing demand for the replacement of central heating installations. In this article, the status of R&D activities and some relevant aspects of AHP implementation in the Netherlands will be discussed with respect to gas-fired AHP for heating purposes.

R&D activities

Research and development of AHP has been carried out since 1979 by three institutions, mainly: Technical University of Delft, FDO Technical Consultants and the Netherlands Organisation for Applied Scientific Research TNO-MT. The R&D activities have been supported financially to a large extent by the Dutch Government, but also industry's participation is increasing.

R&D at Technical University of Delft

The accent is laid mainly on rather fundamental research on AHP components and modelling. Relevant items are:

- AHP laboratory-model, based on $\text{CH}_3\text{OH} - \text{LiBr}/\text{ZnBr}_2$,

- application of compact heat exchangers,
- development of thermodynamic simulation models,
- absorber-research (theoretical and experimental).

R&D at FDO

Here, the development of a residential AHP, with $\text{NH}_3/\text{H}_2\text{O}$ as a fluid pair, has a high priority. FDO intends to apply compact heat exchangers for all AHP components, including those with internal heat- and mass-transfer. Advantages of a so-called "Compact Heat and Mass Exchanger" - AHP are expected to be: a rather simple and cheap production method, small unit size and a higher COP. The

CHME-AHP, however, is still in the design stage; data on costs and payback period have not been published yet. A 10 kW laboratory model, containing separate CHME-components, has been built.

R&D at TNO-MT

An investigation for the use of H_2O as a refrigerant yielded an extensive inventory of suitable absorbents. The R&D activities concerning the $\text{NH}_3/\text{H}_2\text{O}$ AHP have resulted in a 7.5 kW AHP-prototype, however, with an unacceptable cost price. It was decided to continue with a 40 kW AHP, a design of which has been made by now (COP = 1.3, price approx. Gulden 19.000, payback period 5 years). TNO's research activities on sorption-techniques also include: AHP control, burner/generator section, evaporator-heat pump combination, dissociation of NH_3 and corrosion in AHP, heat transfer in boiling $\text{NH}_3/\text{H}_2\text{O}$ solutions, and the direct measurements of concentrations.

Perspectives of the AHP in the Netherlands

Market

In the Netherlands there is an increasing demand for new heat delivering units for the replacement of central heating boilers: approx. 120.000 domestic and approx. 4000 middle-sized boilers per year (1985 - 1990). This offers a potential sale of 10.000 domestic (ca. 4 kW) and 1.000 middle-size (ca. 40 kW) AHP per year. The mono/bivalent condensing boiler system is the main competitor.

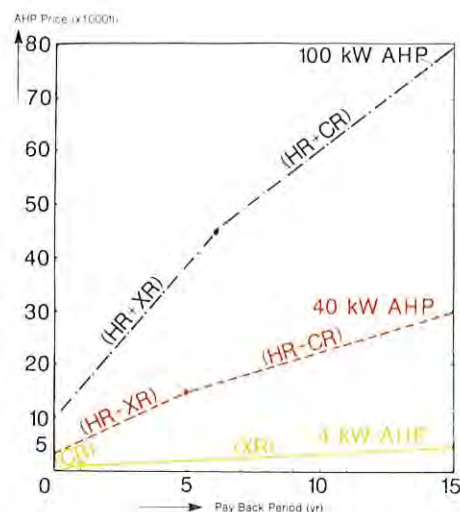


Fig. 1. Allowable costs of 4, 40 & 100 kW AHP in bivalent heating systems, in reference with competing options.
HR = condensing boiler
XR = conventional high efficiency boiler
CR = conventional boiler.

Installation

The extensive effort on thermal insulation of buildings in recent years, has caused a lower heat demand and a decrease of average radiator-water temperatures. The former effect reduced the energy saving potential, the latter however affects the AHP performance positively.

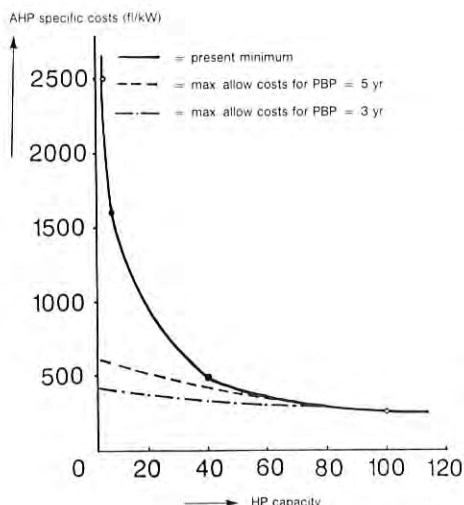


Fig.2. AHP specific costs, related to AHP capacity; present state and max. allowable for 3 and 5 years payback period

Environment

The requirements on the emission by heat delivering appliances will become more restrictive and subsequently more and more a selection criterion. It is known that the specific emission (emission per unit of output heat) of the AHP is lowest, compared to other options. Taking measures

to reduce the emissions, however, has a negative effect on the cost price of the apparatus.

Economics

In case the payback period of the heating system is used by the investor as a selection criterion, the maximum allowable AHP price, with reference to certain competing systems, is relevant. The maximum investments for three AHP, operating in a bivalent-parallel mode, have been calculated; the results are given in Fig. 1. For instance, when a payback period of 6 years is acceptable for a 40 kW AHP, the unit-costs should not exceed Gulden 17.000,-. In case of a higher AHP price, a bivalent boiler system, including a condensing boiler, will be more attractive from the economic point of view. Furthermore, it may be concluded from Fig. 1, that present economic perspectives are bad for the small, residential AHP.

Topics of further R&D on absorption heat pumps

Until now, AHP research has been focused on the 4 - 40 kW_{th} range, with efforts to increase the heat pump's COP. In future research however, attention will have to be paid to the reduction of the AHP costs, for instance by new concepts, constructions and production methods. Still it seems almost impossible to achieve acceptable, low payback periods for the small, domestic AHP by decreasing AHP-specific costs (Fig. 2). There are better perspectives for the development of AHP for heating purposes, with capacities over 75 kW_{th}. The industrial applications, too, come within reach.

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On July 7, 1986, the Minister of "Wirtschaft, Mittelstand und Technologie" of Baden-Württemberg started the operation of a new installation for heat recovery in the brewery "Stuttgarter Hofbräu AG". The heat transformer plant was sponsored as a demonstration project for energy saving by the "Land" Baden-Württemberg. It is the first plant of such type in a European brewery. The financial support of the "Land" amounts to 30% of the investment costs.

The equipment is supplied by "GEA Luftkühlgesellschaft Happel GmbH & Co.", Herne/Westfalen (Fig. 1). In the past years this company developed, together with Kawasaki Heavy Industries, an efficient heat transformer suitable for utilizing waste heat on a relatively low temperature level. This was the presumption for the "Stuttgarter Hofbräu AG" for their investment decision.

For 25 years, the "Stuttgarter Hofbräu AG" has utilized a high amount of waste heat by heat recovery. Some engineers of Hofbräu tried to recover residual amounts of waste heat but they met with difficulties. Only after comprehensive investigations of the newly developed GEA heat transformer in 1984, they saw a viable option.

The heat transformer, working with the absorption principle, is advantageous since it does not need superior mechanic or electric drive energy. Vapor evolving during the beer production process effects the drive. After a temperature increase of 36 K, the heat content of the vapor is recirculated to the production process by 44%. A flow sheet of the heat transformer with the most important external process parameters is shown in Fig 2.

The GEA heat transformer consists of two tanks that are installed one upon the other. The tank on top consists of evaporator and absorber and is operated on a higher pressure level. Both unit parts are separated by a wall that comes up to the altitude of the trickling assemblies. The tank on the bottom has a similar construction and consists of condenser and desorber. In the desorber, which is a shell and tube heat exchanger irrigated with the enriched solution at the outside of the tubes, steam is desorbed by supplying waste heat. The "poor" solution that is generated from this process is increased to a higher pressure by means of the solution pump. Steam, coming out of the evaporator, is absorbed by the solution which then becomes a "rich" solution. Heat on the higher temperature level, resulting from this process, is the applicable effective heat. With this effective heat either water can be heated or steam can be produced. After expansion to the low-pressure p_0 , the "rich" solution reaches the desorber. Steam generated in the desorber condenses on a low temperature level in the water-cooled condenser. The condensate partially vaporizes in the evaporator after having

The First Heat Transformer in a European Brewery

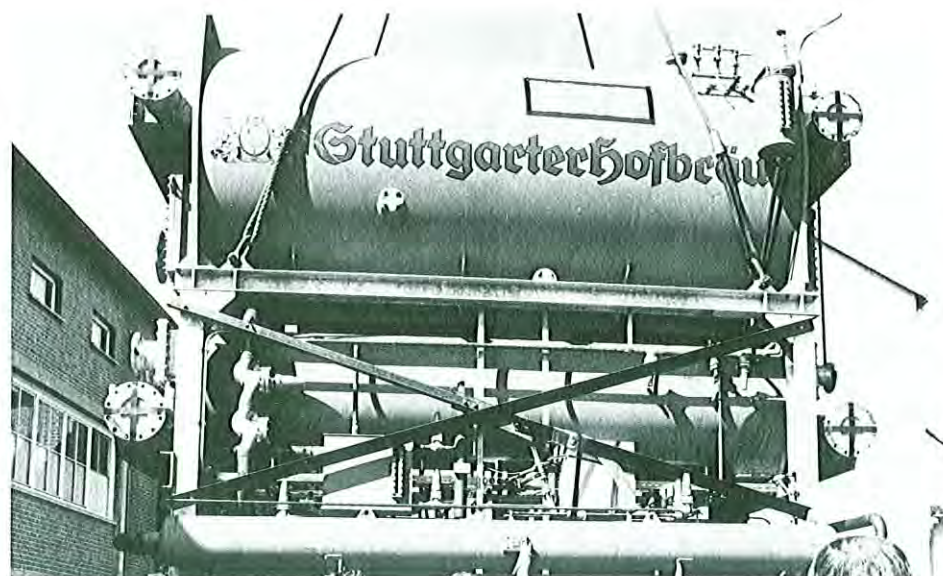


Fig. 1 Delivery of the Hofbräu AG heat transformer

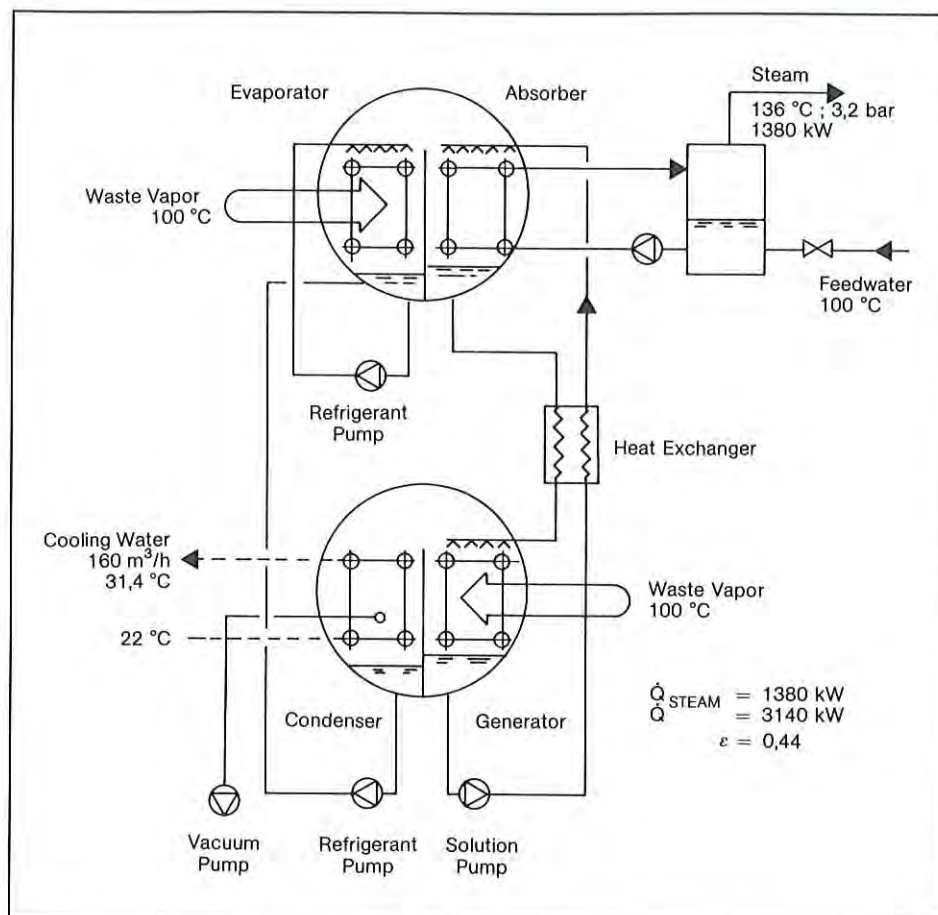


Fig. 2 Schematic diagram of the Hofbräu AG heat transformer

been supplied to it at a higher pressure by the condensate pump. Evaporator and desorber are also conceived as shell and tube heat exchangers for irrigation on the outer surface of the tube. Except the pumps requiring drive energy, there are almost no moving parts within the whole system.

The mixture lithium bromide/water used in the GEA heat transformer is especially advantageous, since even upon high temperatures only relatively low saturation pressures occur. When using the mixture ammonia/water, pressures of more than 60 bar at 100°C occur. In addition, lithium bromide is nontoxic compared to ammonia.

As a result of the application of the heat transformer, the brewery Stuttgarter Hofbräu saves 280 000 m³ natural gas per annum. This corresponds to an annual saving of about 240 tonnes of fuel oil or an annual energy consumption of about 60 single-family houses. Despite the present low energy prices, the plant gains an amortization within about four years. Odor emission that might annoy adjacent residents are eliminated by the complete condensation of the vapors.

A. Lehmann, IEA Heat Pump Center

S. Kurosawa*

Application of an Absorption Heat Pump in a Computer Center

Absorption heat pumps may be said to be one of the most suitable technologies for recovery of low temperature waste heat, since it is a heat compression system requiring no mechanical driving power, and quite effective for heat utilization and energy saving. Introduced below is an example of an absorption heat pump application in a computer center. Its system and evaluation based on actual data are described.

1. Heat recovery absorption heat pump

Since large quantities of heat are generated from computers at Shinjuku Building, Tokyo Gas Co., cooling even in winter is required. Table 1 shows the outline of the building. Meanwhile, facilities are necessary for handling the heating load and hot water supply load in the perimeter. So far, those loads were separately handled by receiving chilled water and steam from the Shinjuku District Cooling/Heating Center.

The current plan aims to utilize heat collected by a steam driven absorption heat pump (Fig. 1) mainly to heat the fan-coil system, but also to utilize the surplus to preheat water in the hot water supply system. Thus, it intends to curtail the quantity of steam used. The absorption heat pump

uses cooling water from the steam dual effect absorption chiller as the heat source. The chiller handles the cooling load on the computer system.

This system has been in commercial operation since December, 1983. The heat pump is designed to collect heat from 29.5°C heat source water and deliver 70°C hot water (Table 2).

2. Heat demand of the existing system and selection of the absorption heat pump

The operational condition of the existing steam absorption chiller (R-1) in winter remains constant irrespective of time, outside temperature, etc., and the cooling load is about 580 to 700 kW (capacity of the equipment is 560 USRT). The quantity

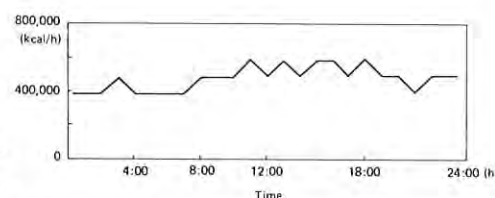


Fig. 2 Waste heat production of the steam absorption chiller in winter

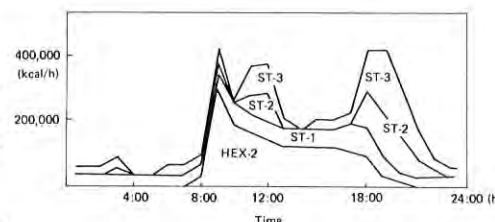


Fig. 3 Hourly changes in hot water heat demand

of waste heat at this time is 1,050 to 1,260 kW (coefficient of waste heat: 1.8.) (Fig. 2).

The quantity of heat demand for this building is as follows:

Hot water heat exchanger in the fan-coil system (HEX-2): the peak occurs at 9:00, with the quantity of heat at about 350 kW, accounting for about 65% of design capacity, and during daytime becoming 130 kW.



Fig. 1 Absorption heat pump (Tokyo Gas, Shinjuku Bldg.)

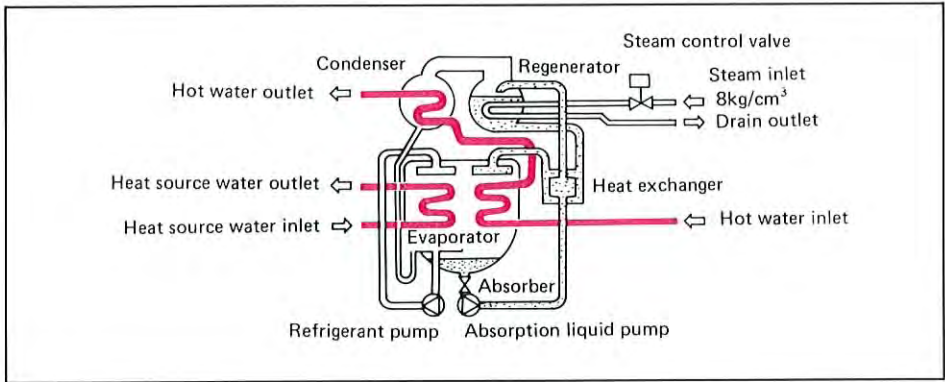


Fig. 4 Absorption heat pump flow sheet

Storage tank (ST-1) in the general hot water supply system: the quantity of heat during daytime remains constantly at about 70 kW and at the evening peak time is about 105 kW.

Storage tanks (ST-2, ST-3) in the bathroom hot water supply system show nearly the same behavior, and the peaks occur during noon recess and at night (Fig. 3).

The heat pump capacity is determined by the balance between the quantity of available waste heat and the quantity of hot water used. The quantity of waste heat from the steam absorption chiller is 1,050 kW (Winter cooling load = 580 kW).

The capacity of the absorption heat pump chosen is 407 kW, at a service steam pressure of 8 kg/cm²G so that the fan-coil load, and part of the stable hot water supply

Heat source water	Inlet temp.: 29.5°C (R-1 cooling water, water temp. during operation in winter). Flow rate: 683 ℓ/min. (< R-1 cooling water: 8,920 ℓ/min.).
Hot water	Inlet temp.: 52°C (return temp. from the existing fan-coil system). Outlet temp.: 70°C (> temp. of hot water supplied: 60°C).
Steam	Quantity used: 385 kg/h (HEX-2 used: 808 kg/h). Pressure: 8 kg/cm ² G

Table 2 Operational conditions of the absorption heat pump

Structure, size	SRC structure, 10 stories above and 2 stories under the ground.
Site area	12,317 m ²
Building area	3,948.6 m ²
Total floor area	40,849.97 m ²
Completed	in March, 1980

Table 1 Outline of building

Name	Specifications
Heat pump	Hot water output : 407 kW Hot water : 52 to 70°C, 323 ℓ/min. Heat source input : 167 kW Heat source water : 29.5 to 26°C, 683 ℓ/min. Steam : 385 kg/h (8 kg/cm ² G) Power : 3.95 kW
Heat source pump	Line pump : 1 unit 80φ x 683 ℓ/min. x 16 mAq x 3.7 kW
Hot water primary pump	Line pump : 1 unit 65φ x 323 ℓ/min. x 23 mAq x 3.7 kW
Heat exchanger for preheating of supplied hot water	Shell and tube : 1 unit Heating capacity : 407 kW Primary side : 70 to 52°C, 323 ℓ/min. Secondary side : 5 to 30°C, 227 ℓ/min.

Table 3 Components of the heat recovery system

Name of system	Items measured
Absorption heat pump (R-2)	Flow rate of heating steam; Drain temp.; Heat of heat source water; Inlet/outlet temp. of heat source water; Heat of hot water; Inlet/outlet temp. of hot water
Absorption chiller (R-1)	Flow rate of heating steam; Drain temp.; Heat of chilled water; Inlet/outlet temp. of chilled water
Fan-coil system	HEX-2; Flow rate of heating steam and drain; Drain temp.; Return water temp.
Hot water supply system	HEX-3; Heat of primary hot water; Inlet/outlet temp. of primary hot water; ST-1 to ST-3; Flow rate of heating steam and drain; Drain temp.

Table 4 Items measured

ST-1 1 load can be met. In view of the relations with the already existing system, the operational condition of the absorption heat pump was determined as follows:

The absorption heat pump flow sheet is shown in Fig. 4, and the list of the components of the heat recovery system is shown in Table 3.

3. Characteristics of the absorption heat pump

As the inlet temperature of the heat source water rises above the rated 29.5°C, the quantity of input heat from the heat source water increases, and the quantity of the output heat to the hot water also increases. At this time, since the quantity of the input heat of the steam remains almost constant, the COP increases. Meanwhile, when the inlet temperature of the heat source water drops below 29.5°C, the quantity of input heat from the heat source

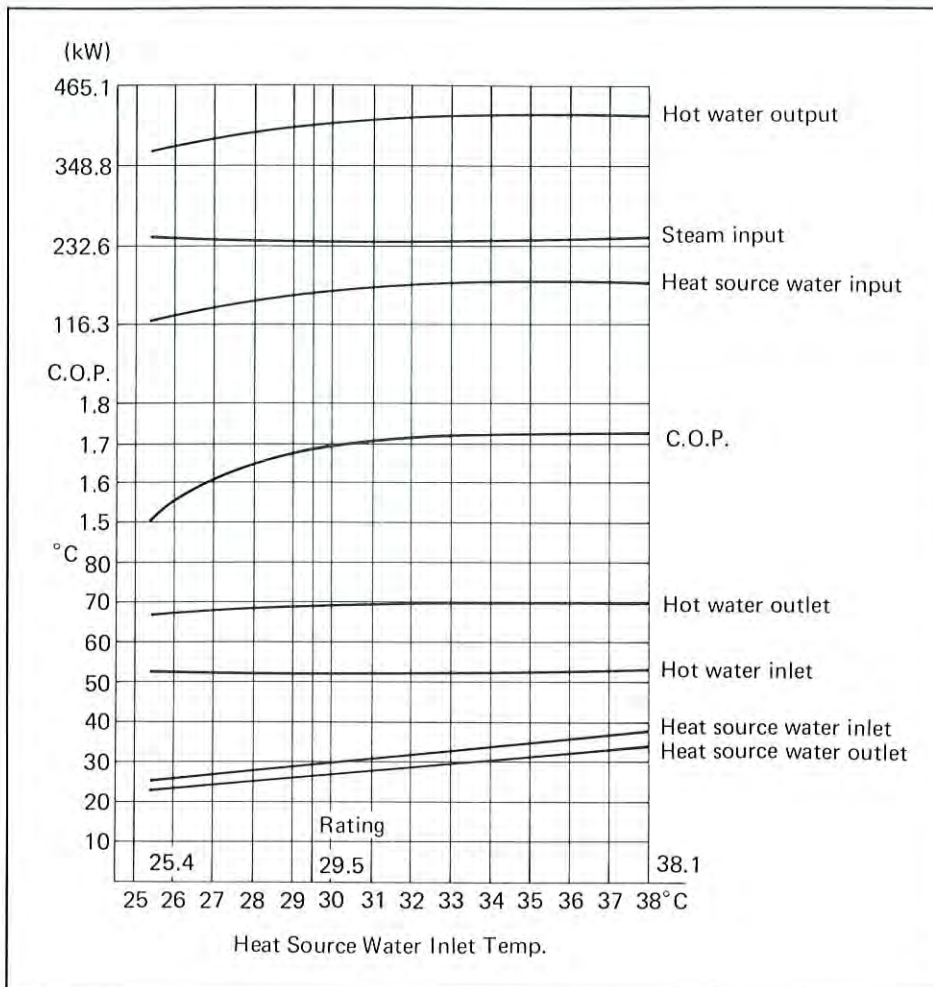


Fig. 5 Characteristics against inlet temperature of heat source water

water drops extremely, and the quantity of the output heat to the hot water decreases. At this time, since the quantity of the input heat of steam remains almost constant, the COP decreases (Fig. 5).

4. Outline of the actual measurement

Table 4 shows the items measured. The heat quantity of the steam was calculated from the flow rate of steam and drain temperature, while the quantity of heat of the chilled and hot water was measured by means of a calorimeter. For temperature measurement, a Type T (C-C) thermocouple was used. The number of points measured (Fig. 6) was 18 for the temperature, 4 for the quantity of heat, and 6 for the flow rate. The temperature was represented by an hourly instantaneous value, while the flow rate and the quantity of heat were represented by an hourly integrated value. Table 5 shows measuring periods and operational conditions.

The measured data are hourly recorded on a printer, and simultaneously stored on the disc of the microcomputer (Fig. 7).

5. Results of measurement and their analysis

5.1. Operating results for a representative week in winter

Fig. 8 shows hourly changes of the heat quantity of hot water, steam and heat source water, and of the COP for a week in winter (February 27 to March 2, 1984) re-

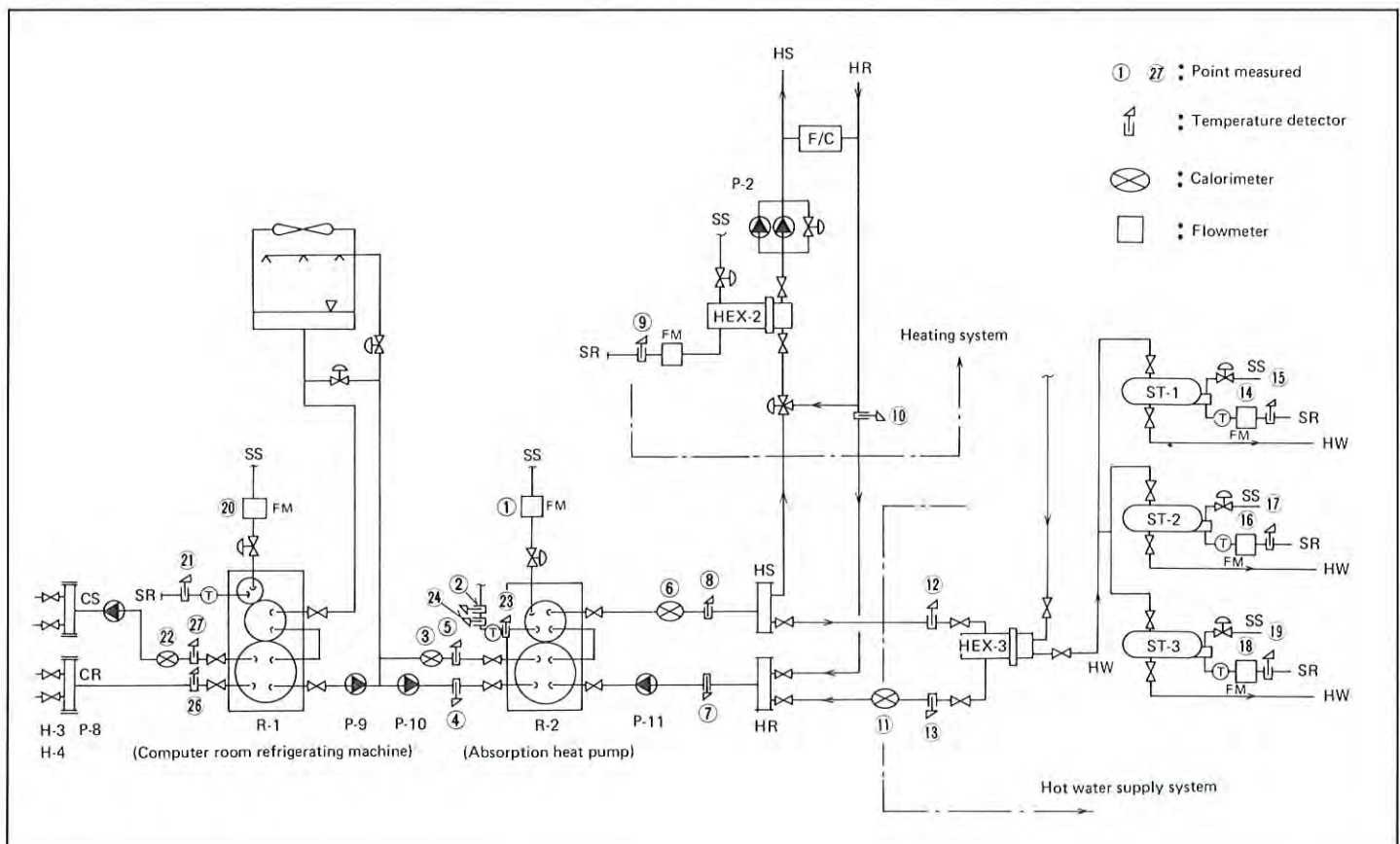


Fig. 6 Locations of points measured

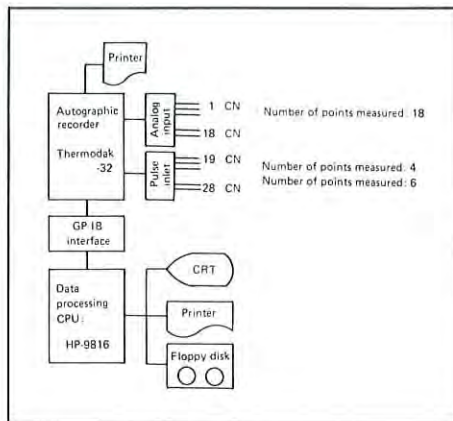


Fig. 7 Configuration of the measuring system

lated to the heat pump. Fig. 9 shows hourly temperature changes of the heat source water and hot water at inlet and outlet for the same conditions as in Fig. 8.

The amount of heat supplied as hot water from the heat pump has two peaks. There is a rise in the morning and a rise in the evening (about 6:00 p.m.), both showing a similar pattern (Fig. 8). The COP is stable; the average COP was 1.63 when the hot water outlet temperature was 65°C, and 1.67 when the hot water outlet temperature was 60°C. At night, when the heat pump was in low-load operation, the COP fluctuated. This was due to the fact that the inlet water temperature of the heat source water dropped, and that the inlet tempera-

ture of the hot water approximated to the outlet temperature.

Incidentally, the heat pump's percentage contribution (HP%) for the working time range (8:00 A.M. to 8:00 P.M.) was 70% in weekly average [HP% = (quantity of heat of hot water/secondary side hot water load) x 100%].

5.2. Relations between the heat capacity of hot water, of steam and of the heat source water

Fig. 10 shows relations between the heat capacities of hot water, steam and heat

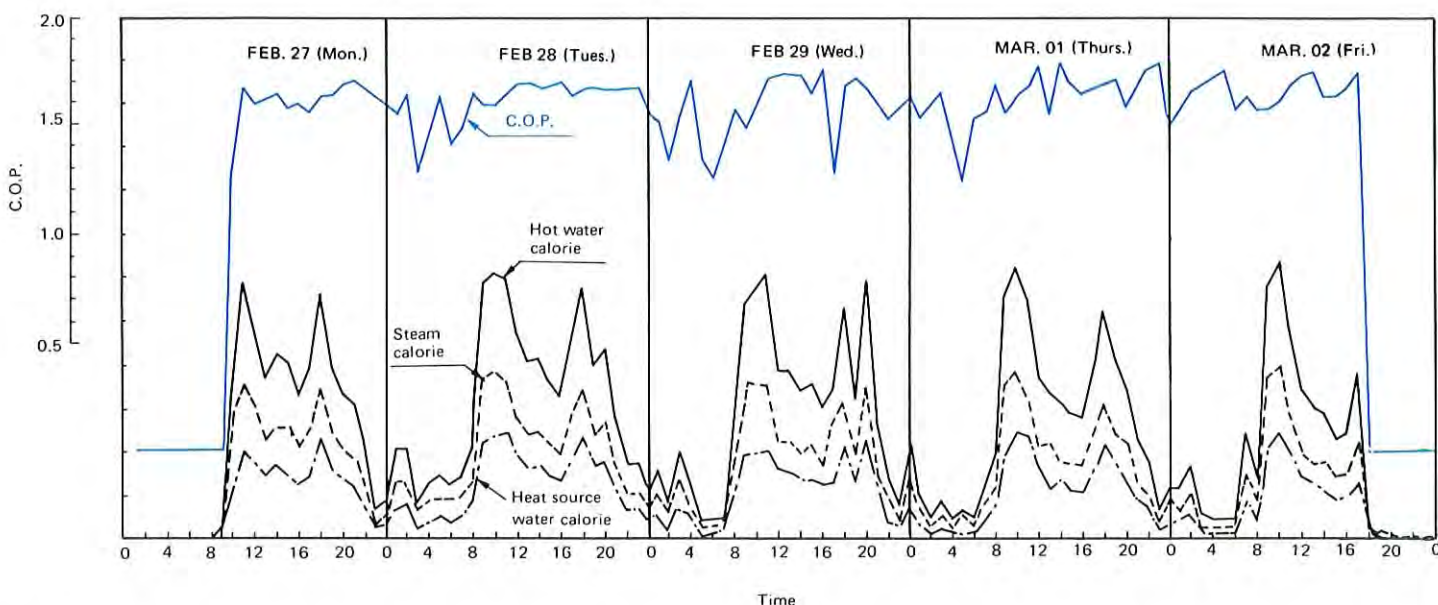


Fig. 8 Hourly changes in the heat quantity of hot water, and heat source water, and COP of the heat pump (hot water outlet temp. 65°C)

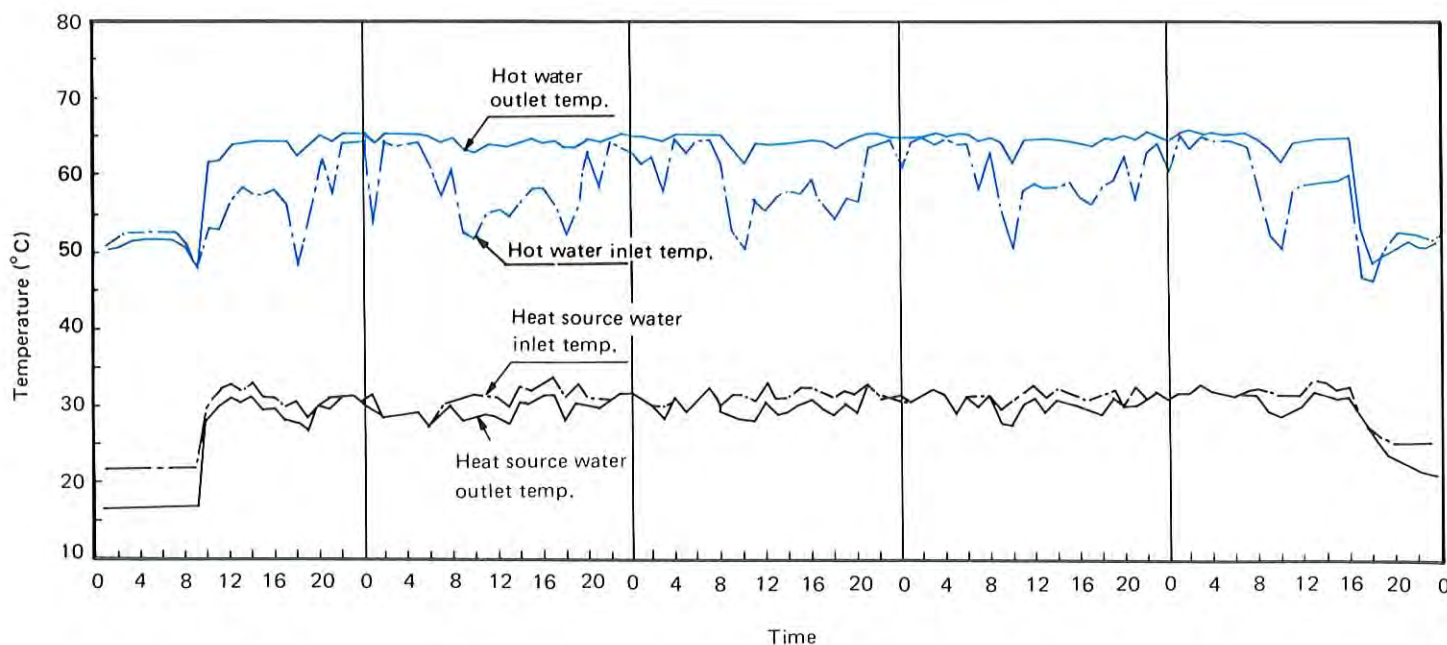


Fig. 9 Hourly changes in the temperature of hot water, and heat source water, and COP of the heat pump (hot water outlet temp. 65°C)

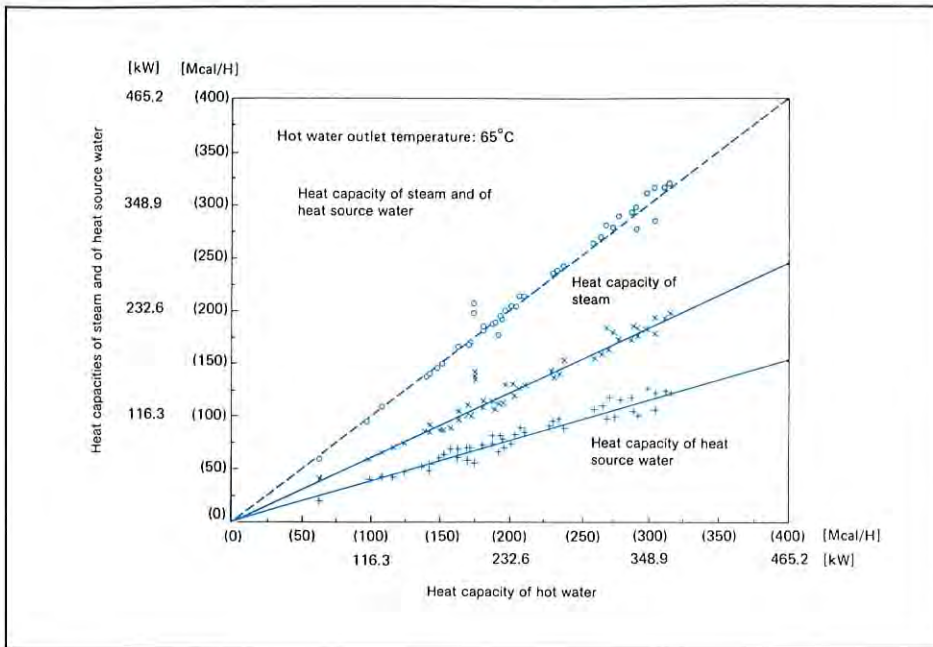


Fig. 10 Relation between the heat capacities of hot water, heat source water and steam (hot water outlet temperature 65°C)

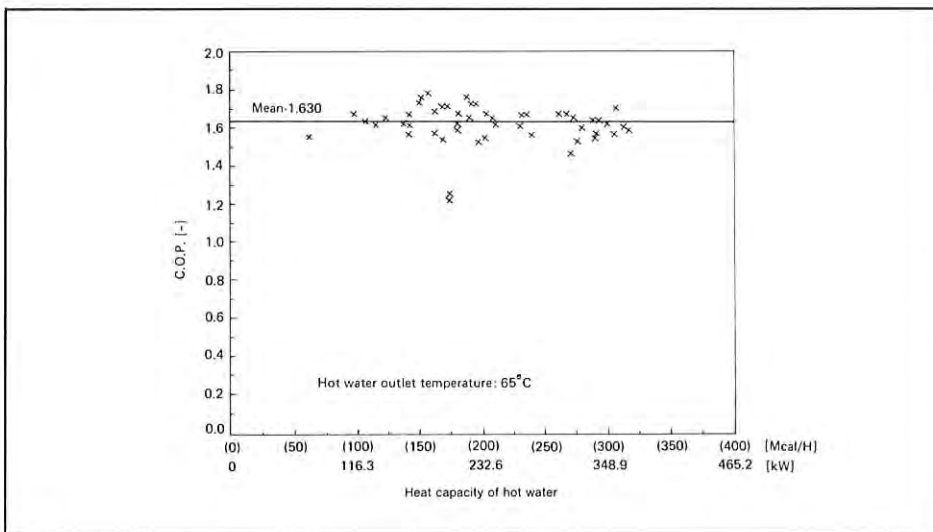


Fig. 11 Relation between the heat capacity of hot water and COP (hot water outlet temperature 65°C)

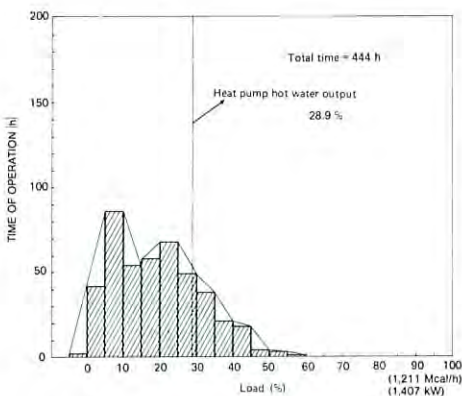


Fig. 12 Frequency of secondary side hot water load

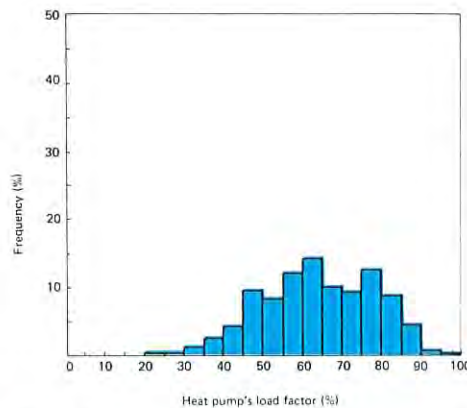


Fig. 13 Frequency of heat pump load

	Measuring period	Outlet temp. of hot water
Winter	Jan. 6, 1984 to Mar. 30, 1984	65°C, 60°C
Intermediate periods	May 28, 1984 to Jun. 8, 1984	60°C
Summer	Jul. 2, 1984 to Jul. 20, 1984	60°C

Table 5 Measuring conditions

	Outlet temp. of hot water (°C)	HP % (%)	Average COP	% reduction of energy (Note 1)
Winter	65	70.8	1.63	27.4
	60	63.3	1.67	25.4
Intermediate periods	60	61.0	1.60	22.9
Summer	60	64.7	1.70	26.6

Note 1: % Reduction of energy

$$= \frac{\text{Quantity of energy saved}}{\text{Secondary side hot water load}} \times 100 (\%)$$

Table 6 Reduction of energy for respective periods

source water of the heat pump. Against the changes in the heat capacity of the hot water, i.e. secondary side hot water load, the heat capacities of steam and of heat source water showed linear changes, representing a good heat balance. This tendency is true for intermediate periods and for summer. Fig. 11 shows relations between the heat capacity of hot water and COP. The COP remains stable even during partial load operation.

5.3 Secondary side hot water load

Shown in Fig. 12 is a frequency distribution of the secondary side hot water load (fan-coil load and hot water supply load) for the period of heat pump operation with the design capacity 1,407 kW = 100%. The peak load of the secondary side is 60% of the design capacity. The load at the maximum frequency is as low as 5 to 10%. This is due to the fact that, since the heat pump operation time is the same as the computer room's air conditioning time, the number of hours at night with a low load factor is included.

As for the frequency distribution of partial load operation of the heat pump during working time (as per Fig. 13), for more than 86% of all operation time the load is above 50%. It may be one of the alternatives to determine the heat pump operation time and operation mode, considering air conditioning operation time and building management system.

5.4 Energy saving effect

The energy saving effect of this system at Shinjuku Building was about 27% of original on energy consumption. In the intermediate climatic periods and summer, this system handles only the hot water supply load which fluctuates conspicuously. As per Table 6, the system, de-

spite that it is not equipped with a heat accumulator, can achieve an energy saving effect comparable to that in winter.

6. Conclusion

The heat recovery heat pump system installed in Tokyo Gas' Shinjuku Building delivers hot water at high temperature. It can be utilized for both space heating and hot water supply. For the current survey,

we collected field data on this system for winter, intermediate periods and summer. As a result, it was found that the system is highly reliable, with a generally stable COP. It is supposed that it will become one of the energy saving systems that are effective for buildings, such as a computer center building, where there is a stable cooling load through the whole year.

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Steam Generating Absorption Heat Pumps

Steam generating heat pumps are of great importance for industrial applications. This paper briefly reports on the two available steam generating absorption heat pumps (AHP) of HITACHI ZOSEN Corp. Both models (Type I and Type II) use vertically installed shell and tube heat exchangers. A sample installation of an AHP (Type II) for heat recovery from a distillation tower is described.

Absorption heat pumps consist essentially of four heat exchangers and are driven by thermal energy alone. With almost no moving parts, they are vibration free and require small maintenance.

This heat pump consists of four shell and tube heat exchangers installed vertically, which boast several advantages. For one, the use of water as a working fluid, and a nontoxic LiBr solution as an absorbent, render the system completely safe. It needs a small mounting base, can be installed outdoors, and uses countercurrent type heat exchangers, which improve heat utilization. It is, moreover, better suited to steam generation than a horizontal type absorption heat pump.

This pump is already being used in five plants.

This absorption heat pump is available in two models, Type I and Type II. The former boasts a coefficient of performance of 1.7, the latter 0.5. Used in place of a conventional high-temperature steam-operated equipment to heat substances and, to moderate temperature, the Type I heat pump effectively utilizes a waste heat fluid, reducing steam consumption by 40%. The Type II heat pump operates solely on waste heat and delivers upgraded heat to approximately 50% of the processed waste heat.

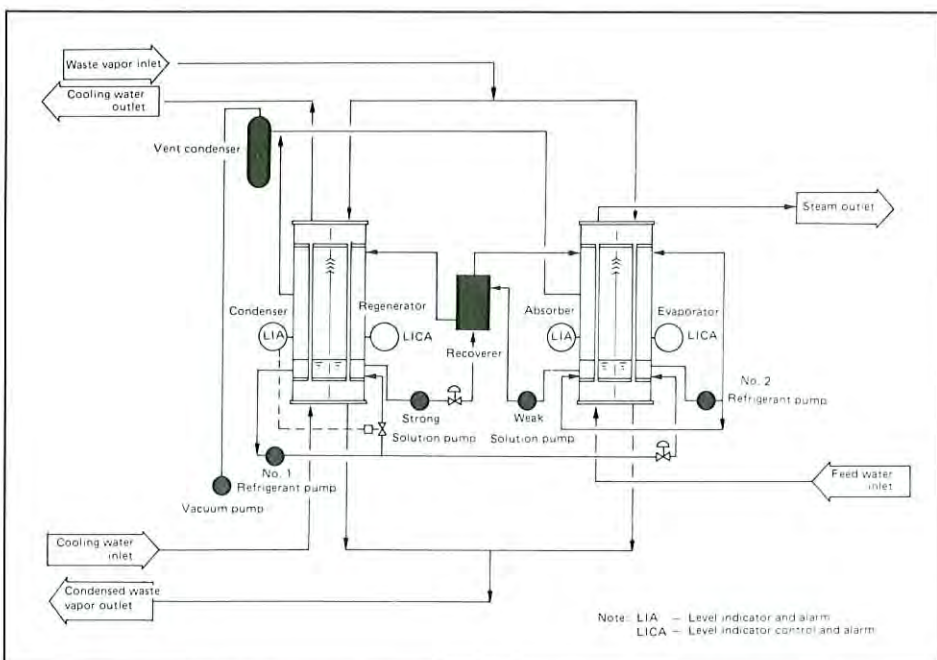


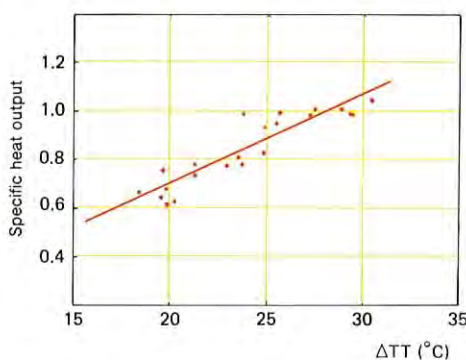
Fig. 2. Absorption heat pump flow diagram (Type II)

Example of an actual installation

As an example, the actual design conditions of the Type II heat pump that was delivered to a chemical plant in July 1983 are summarized in table 1. Fig. 1 shows the outer look of this heat pump. Installed to conserve energy, this pump recovers heat that was previously emitted from a distillation tower as waste heat. The upgraded heat, equivalent to approximately 40% of the latent heat of the vapor is used to generate steam of a higher temperature than that of the vapor.



Fig. 1. Type II absorption heat pump for waste heat recovery from a distillation tower, Japan



Note: $\Delta TT = (TRI - TCO) - (TAO - TRI)$

TRI — Waste vapor temperature

TCO — Cooling water outlet temperature

TAO — Generated steam temperature

Fig. 3. Relation between TT and specific heat output

This heat pump operates unattended 24 hours a day. Maintenance requirements during operation are nearly the same as those for conventional heat exchangers. A vacuum pump must be run for about 2 hours every month, however, and the refrigerant in the evaporator should be continuously replaced at a rate of 1% to 2% of the circulation volume to keep the refrigerant pure. These procedures can all be carried out while the heat pump is in operation.

Output		1,420 Mcal/h
Steam	Evaporation	2.64 T/h
	Pressure	1.5 atm
	Temperature	111°C
	Feed water temperature	100°C
Waste vapor	Inlet temperature	83°C
	Outlet temperature (liquid)	83°C
	Head duty	2,952 Mcal/h
Cooling water	Inlet temperature	28°C
	Outlet temperature	32°C
	Flow rate	378 T/h
Power consumption		15 kW
Operating weight		40 T
Thermal efficiency		48.1%

Table 1 Design conditions

When using the Type II heat pump, about half of the waste vapor of 83°C flows into the regenerator, and is used to drive the heat pump: the other half passes into the evaporator, serves as a low-temperature heat source for the heat pump and generates low-pressure steam of 0.5 kg/cm²G.

The control system for this heat pump consists of two level indicators and alarm units, two level indicator control and alarm units for circulation pump protection, and one liquid-level switch that prevents crystallization of the absorbent (Fig. 2).

During the past four years, this heat pump has been operated without interruption.

The heat output and the total temperature difference (ΔT) vary proportionally. The specific data concerning this proportionality for the Type II heat pump are depicted in Fig. 3.

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Gas Absorption Heat Pumps up to 100 kW

More than 200 gas absorption heat pumps produced by "Absorptions-Wärmetechnik GmbH (AWT)" have been installed in residential, commercial and industrial applications. The heating seasonal performance factors range from 1,1 (heat source air/high-temperature radiators) to 1,3 (heat source ground water/low-temperature radiators). Primary energy savings of 27 to 40% could be achieved in an average.

After the euphoria for electrically driven heat pumps has subsided, a search for the most favorable technical ranges of application of such plants has started among firms adhering to heat pump technology and production and to marketing and market share within the field of planning and engineering offices. After the severe accident of the nuclear reactor in the Ukraine, even for credulous people it became evident that this energy system described as the one causing no difficulties is not the securest and the most environmentally beneficial system. This means we have to find long-term solutions if we want to avoid new energy crises [1,2].

Small absorption heat pumps produced in series with a heat output ranging from 20

to 40 kW initially were destined for the residential market. However, the heat demand of the small residential buildings was more and more reduced with thermal insulation and other simple measures and therefore do not correspond to the heating capacity of available absorption heat pumps. New markets were found in the field of residential, commercial, industrial and public buildings.

The various technical feasibilities of absorption heat pumps have been recognized, for example applications in small market niches, like heat recovery in barns, from municipal and residential sewage water, and residual heat utilization in solar houses etc.

The present planning conceptions illustrate that users not only consider the economical view point of such an investment, but also energy saving and environmental aspects for a heat pump application.

The gas absorption heat pump (GAWP) can convert 100% primary energy in form of natural gas into effective heat of 135% including heat of the environment (Fig.1). At the same time this energy-saving effect contributes to ecological aspects, since less primary energy is consumed compared to a boiler, furnace, or an electric heat pump.

Due to the absorption theory, one third of the total heat output is obtained in the condenser and two thirds in the absorber. The efficiency of an absorption heat pump is determined by the ratio of the active heating capacity Q_N and the burner load of the desorber Q_B , known as the heat ratio $H = Q_N / Q_B$. If a gas absorption heat pump results in an effective heating capacity of 22,3 kW upon burner load of 16,8 kW, the heating ratio is 1,33.

Technical data and structure of the GAWP

The absorption heat pumps of Absorptions-Wärmetechnik GmbH (AWT), Pfungstadt, of which more than 200 plants have been installed, are manufactured with a rated heating capacity of 22 kW as GAWP 223 and 40 kW as GAWP 403. Both sizes are available as air to water or water to water heat pumps.

Heating of the desorber is realized directly through a fully automatic atmospheric gas burner for natural or liquid gas, and a blower for the exhaust gases. For the water to water unit, exhaust gases are dissipated into the chimney controlled by a flow safety device. For air to water units exhaust gases are dissipated together with the cold air from the evaporator. An additional exhaust gas heat exchanger recovers partly the condensation heat of exhaust gases. This heat exchanger is also available for the water to water type upon request. With this condensation heat recovery, the heat ratio and the performance will be increased by about 8%.

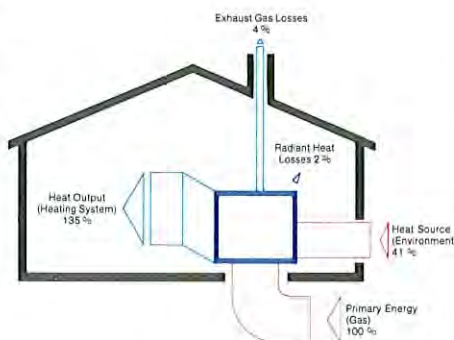


Fig. 1 Energy flow chart of a GAWP with flue gas condensation (Fig. AWT GmbH)

All heat pump components in the water loops are corrosion protected by utilizing stainless steel. The evaporator of the air source type consists of stainless steel tubes with aluminum fins.

A diaphragm pump is used for solution circulation driven by an electric motor with an intermediate oil-hydraulic system. The refrigerant loop is secured by a pressure and temperature limiting device so that maximum value limits cannot be exceeded. A heating water thermostat shuts off when a flow temperature of maximum 53°C is reached. The operation of exhaust gas fan and air fan is also controlled.

Planning questions

Within the Federal Republic of Germany there are several planning engineers and installers that often applied this heat pump technology and meanwhile gained the necessary know-how.

A careful design includes determination of the heat source, location of the heat pump installation and an evaluation of operating conditions. Necessary flow temperatures of the heat pump, total heat demand of the building and the annual operating hours are to be determined because of their direct influence on the system's efficiency.

The design should be started from the performance diagram of the heat pump, reflecting the heat ratio under the various operating conditions (Fig.2). Maximum efficiencies are reached with low flow temperatures and high heat source temperatures. With an increase of the flow temperature and a decrease of the heat source temperature, the efficiency decreases correspondingly.

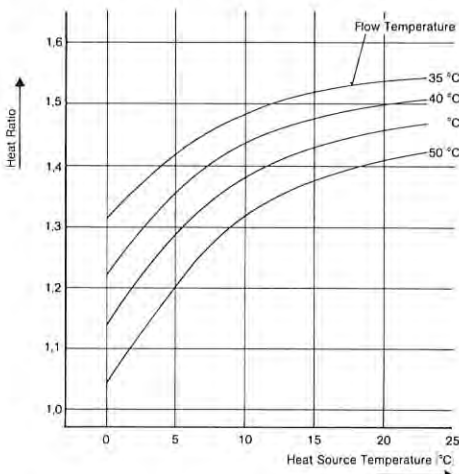


Fig. 2 Performance diagram of the GAWP with flue gas condensation

Sample applications

In order to guarantee an economic operation, the application should focus on: high annual operating hours, favorable temperature ratio of heat source and heat sink, and determination of a cost-effective heat source. The broad spectrum covers

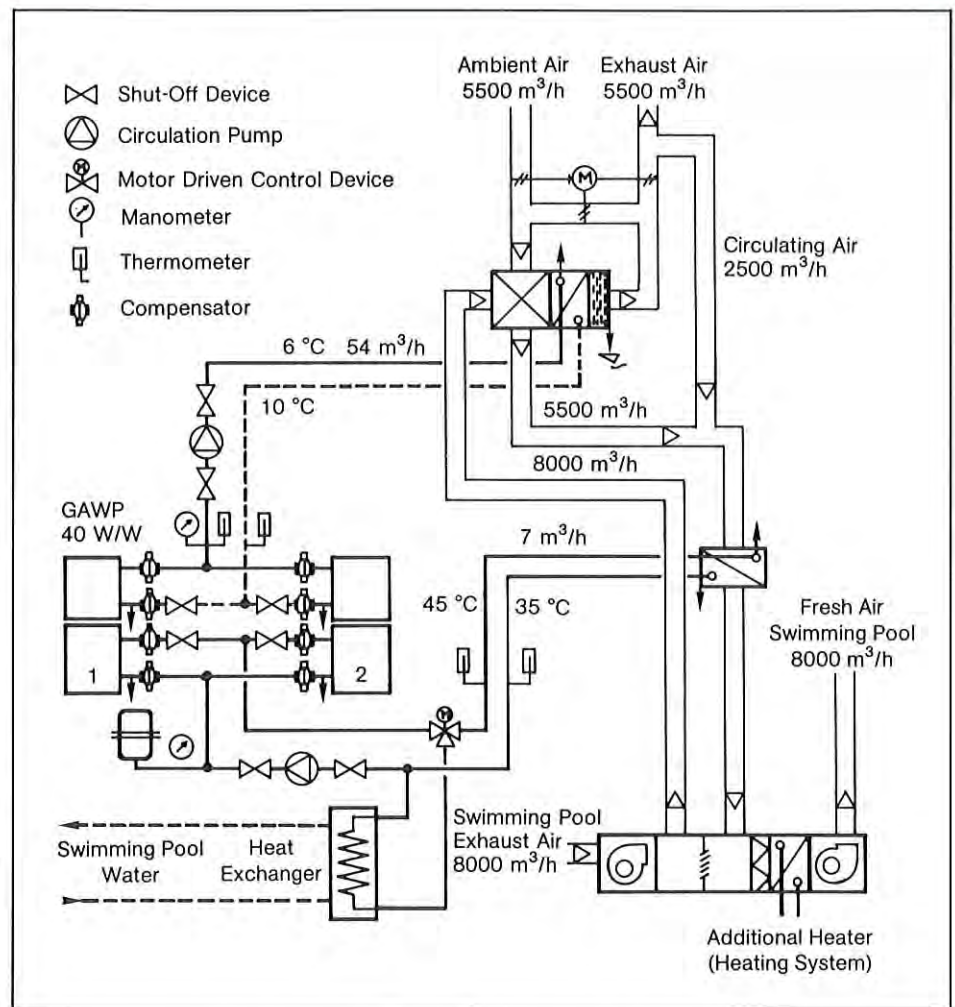


Fig. 3 Installation schema of the GAWP heat recovery and heating the Medebach indoor swimming-pool

multi-family houses, lodging houses, terraced houses, as well as public facilities like schools, indoor swimming pools, recreation centers, commercial installations (for ex. baker's shops, butcher's shops, laundries), industry and agriculture (for ex. waste heat from barns). In the following, some examples for monovalent and bivalent operation modes are described: In the solar house Ebersberg exhaust air and a soil collector combined with a solar absorber are used as heat source [3]. In Munich, four heat pumps have been installed for heating eight terrace houses, using one central well water system. Ground water with temperatures of 6°C to 9°C is available during the whole heating period enabling a monovalent operation mode.

Applications in the commercial sector are demonstrated by installations in an office- and residential building with a heating surface of 460 m² in Letmathe, and an office- and machine shop building in Solothurn, Switzerland.

With regard to public buildings, the installation of an absorption heat pump for heat recovery from the exhaust air of a big sports hall in Pfungstadt, has to be mentioned. Shower water and fresh air of the

hall are preheated by the plant. Air dehumidification with heat recovery from exhaust air is practiced in the indoor swimming pool Medebach/Sauerland. Surplus heat is supplied to the swimming pool water. (Fig.3.)

Some installations serve as preheaters of natural gas in pressure control stations. The heat pump supplies base load heat for gas preheating, in order to prevent automatic control systems from frosting after expansion of the gas.

The installation of a gas absorption heat pump in existing pressure control stations is also possible without causing any problems. In the supply area of the Westfälische Ferngas AG (WFG) gas absorption heat pumps in four stations are successfully applied at present, of which ambient air and one soil serves as the heat source. The brine loops are installed with the outgoing gas pipings. Further stations will be additionally equipped with gas absorption heat pumps.

Profitability and operation experiences

Making use of the present fiscal possibilities, results in amortization periods of 6 to

12 years for private users. This period can be reduced considerably in special applications, e.g. in indoor swimming pools; in this case payback periods of three to five years could be achieved [4].

It has to be said, that there are many satisfied heat pump users, who can give proof of the reduction of their energy consumption and of their energy costs. Heat pumps work satisfactorily, if some not typical failures for peripheral parts of the plant are excluded. Additionally, operation experiences have shown that it is necessary to care for a periodical maintenance of the heat pump plant in order to avoid breakdowns.

The annual heat ratios of the installed GAWP-plants that have been determined through heat meters and gas counters are between $H=1,1$ (heat source air/high temperature radiators) and $H=1,3$ (heat source ground water /low temperature radiators). Comparisons with heat ratios of boilers (heat ratio for the boiler $H=0,7-0,8$) and GAWP or gas consumption before and after GAWP-installation result in ener-

gy savings of 27 to 40%. Exhaust gas heat exchangers that have been installed since 1983 for an additional improvement of the heat ratio for the air-sourced GAWP, resulted in heat ratios of 1,3 as annual average in connection with a floor heating system.

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Development of a New Working Pair TFE/NMP for an Absorption Process and Application to a Heat Pump System

The working fluid pairs NH_3/H_2O and $H_2O/LiBr$ mostly used in absorption heat pumps have properties limiting the application of this type of heat pump to certain temperature ranges. This is the reason for an increasing interest in research for new working fluids in Europe, the USA, and also in Japan. This paper reports on the development of the new working pair TFE/NMP and its use in an air-source absorption heat pump under development.

Introduction

The absorption heat pump is a kind of heat engine that utilizes evaporation and absorption action caused by a saturated vapor pressure difference due to temperature differences between refrigerant and absorbent.

Since the absorption heat pump currently in commercial use utilizes water as refrigerant, and a lithium bromide/water solution as absorbent, it is difficult to recover heat from low temperatures below $0^\circ C$ evaporating temperature due to freezing of the refrigerant and crystallization of the absorbent. In the high temperature region where the temperature within the system exceeds $160^\circ C$, its use is also limited due to possible corrosion.

One of the working fluids for an absorption heat pump that is capable of recovering heat from low temperatures below $0^\circ C$, is an ammonia-water system. However, its use in Japan is virtually prohibited due to toxicity, corrosiveness and explosiveness

of ammonia. Thus, research has been conducted on working fluids using halocarbons as refrigerants for the air-cooled air source heat pump, since halocarbons have excellent low temperature characteristics. Up to date, however, they have not been commercialized.

Trifluoroethanol (TFE), refrigerant, and N-methyl 2-pyrrolidone (NMP), absorbent, have been developed as working fluids suitable for new working pairs, because of the intermolecular force between refrigerant and absorbent.

Performance characteristics of the absorption process were calculated based on chemical, physical and thermodynamic analysis with experimental data. As a result, a prototype absorption machine of the TFE/NMP system was developed, and various data thereon have been obtained at the laboratory.

Working fluids for absorption heat pumps

Refrigerant-absorbents which seem to be promising as working fluids for absorption heat pumps are shown in Table 1 as a result of research in recent years [1], [2], [3], [4], [5], [6].

The selection criteria for refrigerants are: high thermal stability and extensive hydrogen bonding within the molecule. These are satisfied by some halogenated alcohols and some partly halogenated hydrocarbons.

As for absorbent, solubility and thermal stability are important.

By using a test machine, Gaz de France and Total Energie Development are jointly conducting research on R133a/NMP, while Allied Chemical is conducting research on R133a/ETFE.

In Japan, absorption heat pumps of the R22/DEGDME system and the R22/TEGDME system were manufactured by way of trial by using R22 as refrigerant, and their results were announced [7], [8].

Development of a new working pair TFE/NMP [9]

Refrigerant TFE

Research has been conducted on combinations of refrigerant and absorbent featuring large solubility and vapor pressure lowering of the solution with large negative deviation from Raoult's law. As a result, with regard to chemical stability, we made investigations on halogenated alcohols with large heats of vaporization and selected 2,2,2-trifluoroethanol as refrigerant. Table 2 shows the properties of TFE.

Absorbent	Refrigerant		
	TFE	R123 a	R133 a
HMPT (Hexamethylphosphoric acid triamid)	○		○
Chi (Chinolin)	○		
TEG (Tetra-ethylene glycol)	○		
TEGDME (Tetra-ethylene glycol dimethylether)	○	○	○
NMP (N-methyl pyrrolidone)	○	○	○
TrEGDME (Tri-ethylene glycol dimethylether)	○	○	○
iCh (Isochinolin)	○		
ETFE (Ethyl-tetrahydrofurfuryl ether)		○	○
DMF (Dimethylformamid)			○
DEF (Diethylformamid)			○
TBP (Tri N-butylphosphate)	○		○

* TFE = Trifluoroethanol
R123 a = Dichlorotrifluoroethane
R133 a = Monochlorotrifluoroethane

Table 1. Refrigerant-absorbent systems which are deemed promising

Absorbent NMP

Absorbents combined with the refrigerant 2,2,2-trifluoroethanol are ethers, polyols, esters, amides, amines, imides, ketones, aldehydes, nitriles and their mixtures. Overall evaluation of properties, heat characteristics and marketability resulted in the discovery of a superiority of N-alkyl-2-pyrrolidone, and the selection of N-methyl-2-pyrrolidone (NMP) as absorbent. Table 3 shows properties of NMP.

Fig. 1 shows the pressure-temperature lines and Fig. 2 shows the enthalpy-concentration lines of TFE/NMP

Theoretical coefficient of performance

Fig. 3 illustrates the calculation results of the coefficient of performance (COP) for the condensing temperature (Tc) absorbing temperature (Ta) with vaporizing temperature Te as parameter, for each of the refrigerating, air-cooled cooling and air-source heat pumps. However, the minimum reflux ratio was used as reflux ratio (f'), and it was supposed that weak solution is provided at saturation temperatures.

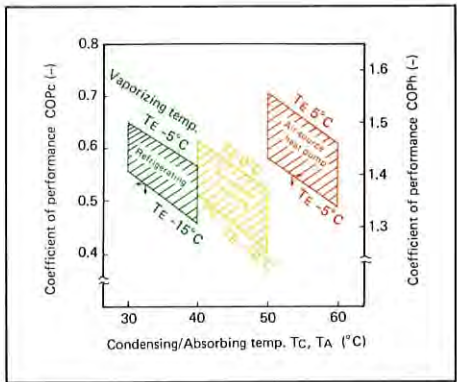


Fig. 3 Theoretical coefficient of performance of TFE/NMP absorption cycles

Air-source absorption heat pump

Fig. 4 shows the general construction of an air-source absorption heat pump system with TFE/NMP.

A generator (1) has a burner (2) and acts to heat and boil a weak solution to obtain a gasified refrigerant. The term "weak solution" refers to an absorbent solution which contains more refrigerants and is weak in absorbent power. A rectifier (3) separates gaseous absorbents from the gaseous refrigerant moving upward, which is then passed to a heat exchanger (5) for partly condensing it. Then, the final separation of the absorbent component is effected by a reflux zone (4).

The resultant liquid is directed to a liquid distributor (6) so that it is discharged from the top of the rectifier (3). Thus, the liquid is used as a vapor-liquid contacting liquid which separates the absorbent compo-

Refrigerant	Formula	Molecular weight	Boiling point (°C)	Melting point (°C)	Heat of vaporization* (KJ/kg)	Specific heat** (KJ/kg°C)	Viscosity*** (C.P.)	Density*** (kg/m³)	Flash point (°C)	Combustion point (°C)
2,2,2-trifluoroethanol	CF ₃ CH ₂ OH	100.04		-45	398	1.59	1.75	1382	40	

*0°C, **20°C, ***25°C

Table 2. Properties of TFE

Absorbent	Formula	Molecular weight	Boiling point (°C)	Melting point (°C)	Heat of vaporization* (KJ/kg)	Specific heat** (KJ/kg°C)	Viscosity*** (C.P.)	Density*** (kg/cm³)	Flash point (°C)	Fire point (°C)
N-methyl-2-pyrrolidone		99.14	204	-25	440	1.67	1.65	1027	95	346

*204°C, **20°C, ***25°C

Table 3. Properties of NMP

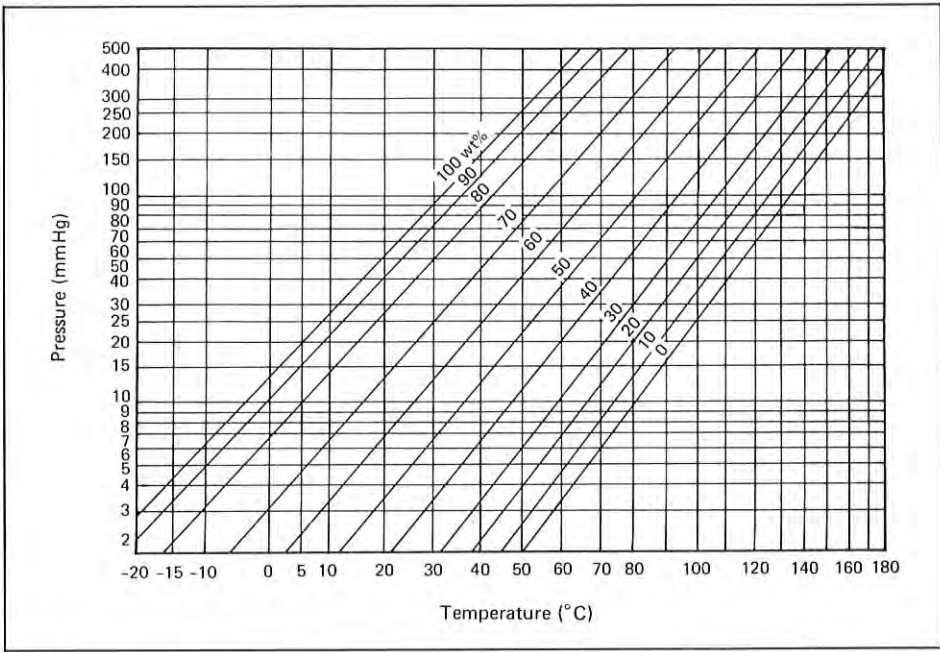


Fig. 1. Pressure-temperature lines of TFE/NMP.

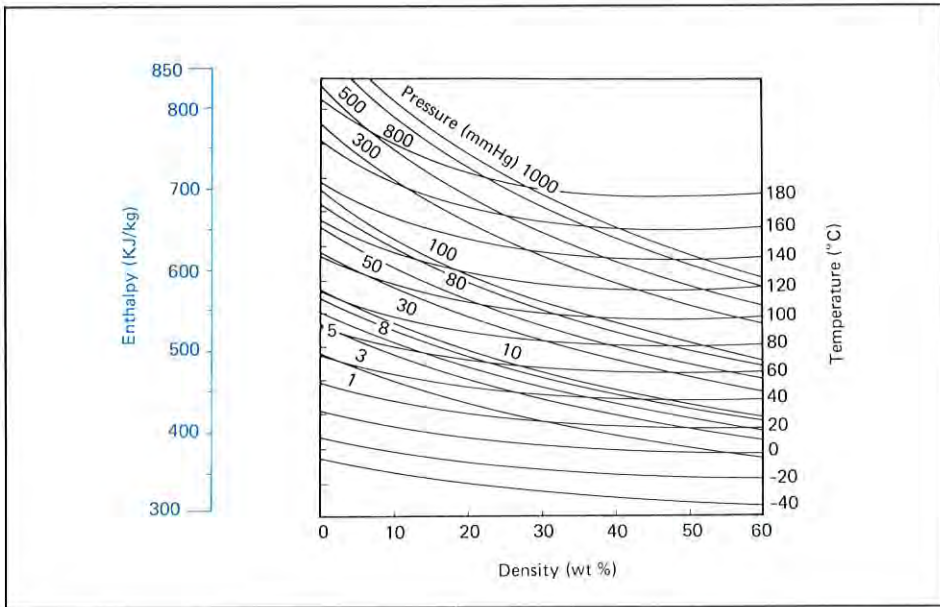


Fig. 2. Enthalpy-concentration lines of TFE/NMP.

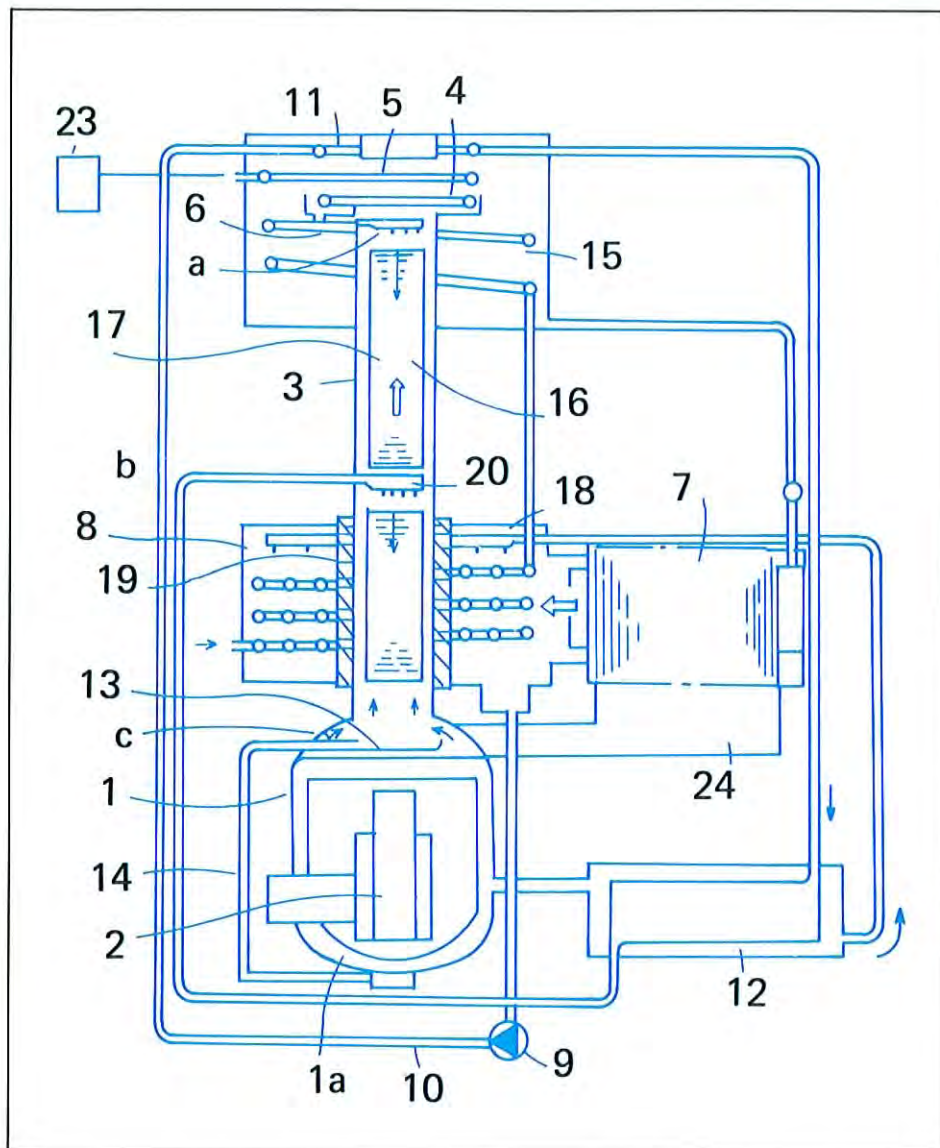


Fig. 4. General construction

nents from the refrigerant. The system further includes an air heat exchanger (7), which operates as an evaporator, and an absorber (8) in which the strong solution is sprayed for the removal of the refrigerant vaporized in the heat exchanger (7). The term "strong solution" refers to an absorbent solution which contains less refrigerant and is strong in absorbent power. Thus, the refrigerant gasified by the evaporator (7) is absorbed, thereby allowing the evaporator (7) to absorb heat continuously from a heat source of a lower temperature, such as the outside air. An absorbent pump (9) installed in a weak solution conduit (10) causes the weak solution, that is, the absorbent which has absorbed the refrigerant in the absorber (8), to flow back to the generator (1). Additionally, installed in the conduit (10) are a heat exchanger (11) for cooling the inside of the reflux zone (4) and a heat exchanger (12) for preheating the weak solution in heat exchange relation with the strong solution that is directed from the generator (1) to the absorber (8). Fig. 5 shows the exterior of a machine to be developed, and Table 4 shows design specifications. At standard rating conditions during the

heating mode the coefficient of performance (fuel) is 1.15.

An application example in which the evaporator (7) serves as a water heat exchanger is described below.

When the absorption refrigeration system is run under the conditions where, (i) the strong solution supplied to the absorber contains 21% TFE, and (ii) after absorption of the refrigerant the weak solution contains 52% TFE, inlet water of about 25°C can be heated close to 60°C, and supplied to a high temperature load, and at the same time, cold water returning to the evaporator at the temperature of 12°C can be cooled to about 7°C, and supplied to a cooling load. Thus, cold water and hot water can be simultaneously supplied. When this system is run under the conditions where, (i) the strong solution supplied to the absorber contains 21% TFE, and (ii) after absorption of the refrigerant, the weak solution contains 47% TFE, if brine, flowing into the evaporator, is used as the heat source, then water of 5°C can be heated to about 55°C and supplied to the heating load, while brine returning to

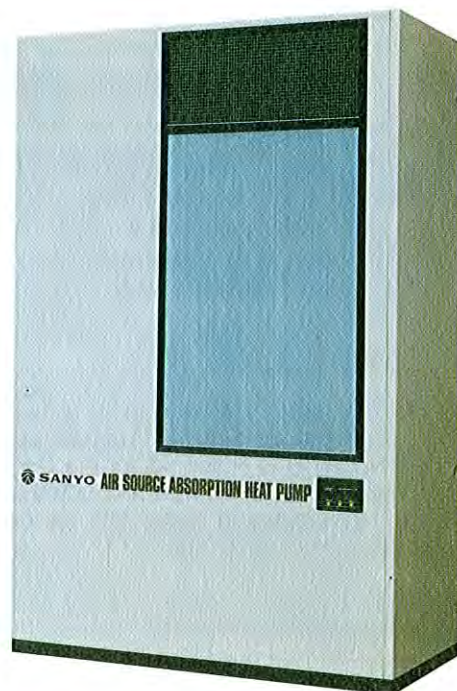


Fig. 5. Exterior of a machine to be developed (air-source absorption heat pump)

Heat input	32 kW
Heat output	37 kW
Hot water temp. Delivery Return	56.7°C 50.0°C
Outdoor temp. Dry bulb Wet bulb	7.0°C 6.0°C
COPh Thermodynamic Fuel	1.31 1.15
Dimension (LxWxH)	1350mm x 675mm x 2025mm

Table 4. Design specifications

the evaporator at a temperature of -3°C can be cooled close to -8°C and supplied to the cooling load. Thus, supply of hot water and that of brine used for making ice can be done simultaneously.

In applications described above, the efficiency at which the primary energy is used reaches more than 120% when the cold load is not used and about 160% when it is used.

At present, a commercial-size low temperature use absorption refrigerating machine, using TFE/NMP refrigerant-absorbent, is being developed as a project in the development of an advanced solar-powered absorption refrigerating system entrusted by the New Energy Development Organization (NEDO).

One of the entrusted research objectives is to obtain -7°C to -12°C low temperature brine from an absorption refrigerating machine, using the solar heat as its driving heat source.

The refrigerating capacity of the absorption refrigerating machine is 52 kW when

obtaining -7°C brine (inlet temperature of cooling water: 29°C).

Although the temperature stability of TFE is quite high at over 200°C , the absorbent stability remains uncertain. Continued research is underway on the TFE/NMP system through heat resistance tests. At the same time, investigations of the possible use of N-propyl 2-pyrrolidone (NPP) and N-butyl 2-pyrrolidone (NBP), etc. are underway.

Conclusions

Mainly in Europe research into the availability of organic working fluids that will replace $\text{NH}_3/\text{H}_2\text{O}$ is active. As for the TFE/NMP system, research was conducted at Essen University and some data on the properties have been reported. Concerning the system, the patents of both working fluids and absorption refrigerating systems have been registered in the U.S. and parts of Europe [9], while a commercial-size test machine has been manufactured under research entrusted by New Energy Development Organization and is ready for demonstrative operation.

Japan's $\text{LiBr}/\text{H}_2\text{O}$ system absorption heat pump is widely known in Europe and the U.S., and there is increasing interest in research trends concerning new working fluids.

It is hoped that this report will be of some help in the coming new age of heat pumps.

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Heat Pump Research at the Gas Research Institute

The Gas Research Institute (GRI) is conducting a large development program on gas-fueled residential and commercial heat pumps. This program includes gas engine-driven heat pumps (Stirling cycle, Otto cycle conventional piston, and rotary (Wankel systems) and advanced absorption heat pumps (dual cycle system and double-effect machine). Several concepts are expected to begin field testing in the next two years.

The GRI is a private, not-for-profit organization whose membership includes 32 natural gas pipelines, 158 natural gas distribution companies and 43 municipal utilities. GRI plans, manages and develops financing for a cooperative research and development program on gaseous fuels and their use. One of the largest programs which GRI is conducting is that of the development of gas-fueled residential and commercial heat pumps. This program includes both gas engine-driven heat pumps and chemical reaction-based systems.

The research and development programs are performed by a sequence of technology assessments, laboratory tests, engineering developments, field experiments, and field testing which takes a concept of a product through progressive phases of maturation from concept to prototype ready for commercialization. Accompanying the technology development activity

is a set of market oriented studies which are used to define the performance, economics and operational features necessary for commercial success. Development activity past the point of proof-of-concept is only undertaken in conjunction with an appropriate set of manufacturers who have the capability to manufacture, sell and service the system upon successful completion of the development activity.

The temperature/COP relationship is inherently different for mechanically-driven and chemical-based systems. With mechanical vapor compression equipment, the capacity falls with decreasing outdoor ambient temperature due to the decrease in the vapor pressure and hence specific volume of saturated vapor with decreasing temperature. As mechanical vapor compression equipment is close to constant volume displacement equipment, the decrease in vapor density results in a decrease in mass flow and hence capacity.

On top of this is the effect of a lowering of the COP due to Carnot considerations. With chemical-based systems, the decrease in vapor density does somewhat compromise the equipment capacity due to the greater internal pressure drop caused by the increased velocity of the higher volumetric flow low density vapor. Since chemical-based heat pump machines are driven by set heat delivery rates, the capacity drop with temperature is not great.

Gas engine heat pumps differ from electrically-driven heat pumps in several aspects. Engine exhaust heat and coolant heat can be used in the winter to supplement vapor condensation heat thereby increasing the net COP appreciably. When supplemental heat is required under extremely low temperature conditions, gas can be burned to supplement heat pump output at a substantially lower energy cost than supplemental electric resistance heat. Gas heat pumps thus have greater heating capacity per refrigeration ton of system rating (RT), making them better suited for use in cold climates. Of major importance also is the fact that gas engines are inherently variable speed machines and can be operated as such during most of the heating and cooling seasons. By operating the compressor at reduced speed, the condenser and evaporator become oversized components with reduced heat flux and consequentially reduced temperature differences and thereby increase the system COP. These features increase the economics of operation of gas heat pumps.

Heat pumps must be highly reliable, long lived and require very infrequent servicing. The public demands high durability commensurate with those attributes of today's gas-fired furnace and electric air conditioning combination. As there is no existing product market for long lived (12 to 15 years mean time to overhaul), high reliability, small gas engines which require service once a year or less, the engine portion of GRI's heat pump program is based on first developing such engines, and then marrying them to heat pump Rankine cycle components.



Fig.1 Teledyne: Rotary (Wankel) engine.

Conventional Rankine cycle systems are being employed in the engine portion of the GRI heat pump program in order to minimize the development risk. Compressors in volume production are being used so that lowest cost and highest reliability systems will result. Should any significant advances be made in electric heat pump systems, they would be considered for inclusion in the gas heat pump development program.

The engine types under development include Stirling cycle, Otto cycle conventional piston, and rotary (Wankel) systems. The Stirling cycles have been selected for the opportunity to offer systems which require no maintenance. Free piston Stirling engines would be hermetic compressor drives involving internal gas bearings with no more need for service than an ordinary home furnace. Kinematic Stirling engines have their lubricant in the section of the engine which is cooled by the engine heat rejection system and thus will not see temperatures much above summer ambient condenser temperature; hence, with appropriate long lived lubricants, these bearings should last as long as those in conventional air conditioning and electric heat pumps.

The piston engine being developed contains all of the design and material features of long-lived, highly reliable industrial gas engines which have not been available in sizes small enough for residential and light commercial heat pump service. Data being obtained in the GRI commercial heat pump program leads us to expect that oil changes need not be more frequent than twice a year. The engine is a low BMEP, low piston velocity design for long life.

Similarly, the rotary (Wankel) engines are being designed for long life and minimal service. Rather than need oil and oil filter changes, these engines employ metered injection of oil into the air intake which cools and lubricates rubbing surfaces. Initial testing shows that such engines, combined with the proper selection of low wear

rate seal and housing surface pairs, can be expected to last the 40,000 hour life needed of gas heat pump engines before overhaul.

Gas engine driven heat pumps use the engine coolant and exhaust heat at substantially higher temperature than condenser heat, thereby enabling the internal house heat exchanger to deliver air at higher temperature than it would with electrically driven heat pumps. This higher heat delivery temperature substantially adds to occupant comfort.

Gas-fueled heat pumps are being developed initially as air-to-air systems for use in homes and light commercial buildings with forced air space conditioning systems and outside heat exchangers transferring heat to/from ambient air. The absorption systems involve an intermediate fluid loop between the outdoor unit and the indoor space conditioning coil. The numerous ground- and water-source heat pump systems being developed by Government and private sources are expected to be applicable to gas-fueled heat pumps.

The projects within the Heat Pump Program at GRI are subdivided into two market focused categories--residential and commercial. The residential heat pump projects are all aimed at systems that are rated ARI (Air-Conditioning and Refrigeration Institute) standard (240-81) air conditioning conditions, 95°F (35°C) (db), 75°F (23.9°C) (wb)/80°F (26.7°C) (db), 67°F (19.4°C) (wb) at 3 RT. The commercial heat pump projects are all aimed at 10 RT systems. The exact equipment ratings of the equipment under development may vary slightly from the 3 RT and 10 RT ratings as the product proceeds through development. The heat pump output corresponds to what is obtainable from optimized systems whose major components are based on designs whose original expected outputs were 3 RT and 10 RT. The GRI heat pump projects and their technologies are presented in Table 1.

In addition, GRI has contracts with Battelle Columbus Laboratories for improved, optimized and specialized components for gas-fueled heat pumps, and a contract with Honeywell for control technology for such systems. Realistic estimates of the manufacturing cost are obtained via studies performed by Pioneer Engineering, and Engineering consulting firm whose main business is servicing the automotive industry with manufacturing technology and cost estimates for new products and components.

The two rotary (Wankel) engine projects, the Wedtech 3 RT and the Teledyne 10 RT, both involve the development of rotary engines modified for long life and for natural gas fuel. The engine modifications include conversion to water cooling of the rotor housing for heat recovery, increased compression ratio and wear surfaces selected for long-lived service. Both of these engines are presently undergoing performance and life testing. Over 4700 hours of operation without failures has been achieved at Teledyne with the lead engine having logged over 1600 hours. Preliminary results show adequate efficiency and attractively low wear rates on critical parts. The next phase of these projects involves matching the engines with compressors for service on heat pumps. Fig. 1 shows a photograph of the Teledyne engine which is being tested.

The heavy duty internal combustion engine under development by Battelle Columbus Laboratories is a conventional 5.0 hp one-cylinder, four-stroke, overhead valve engine specifically designed for 40,000 hours before overhaul. The design features of this engine (low BMEP (75psi), low piston speed (1400ft/min), stellite valve seat, etc.) are all proven features on larger-sized gas engines known for their durability and life. Fig. 2 shows the engine as originally assembled before testing. Initial tests of the engine were highly successful with shaft thermal efficiency of 30% (HHV) having been achieved. A major manufacturer of small engines has ex-

Size	Technology	Developer
3 RT	Free Piston Stirling/Rankine	Mechanical Technology Inc.
3 RT	Heavy Duty Internal Combustion/Rankine	Battelle Columbus Labs
3 RT	Rotary (Wankel) Engine/Rankine	Wedtech
3 RT	Double Effect Absorption	Columbia Gas
3 RT	Dual Cycle Absorption	Battelle Columbus Labs
10 RT	Rotary (Wankel) Engine/Rankine	Teledyne
10 RT	Kinematic Stirling/Rankine	Stirling Power Systems

(RT - Refrigeration Ton $\approx$ 3.52 kW)

Table 1. GRI Heat Pump Technologies

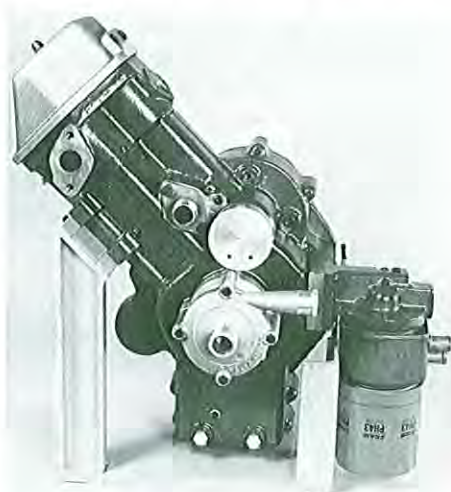


Fig. 2 Battelle Columbus Labs: Heavy duty internal combustion engine

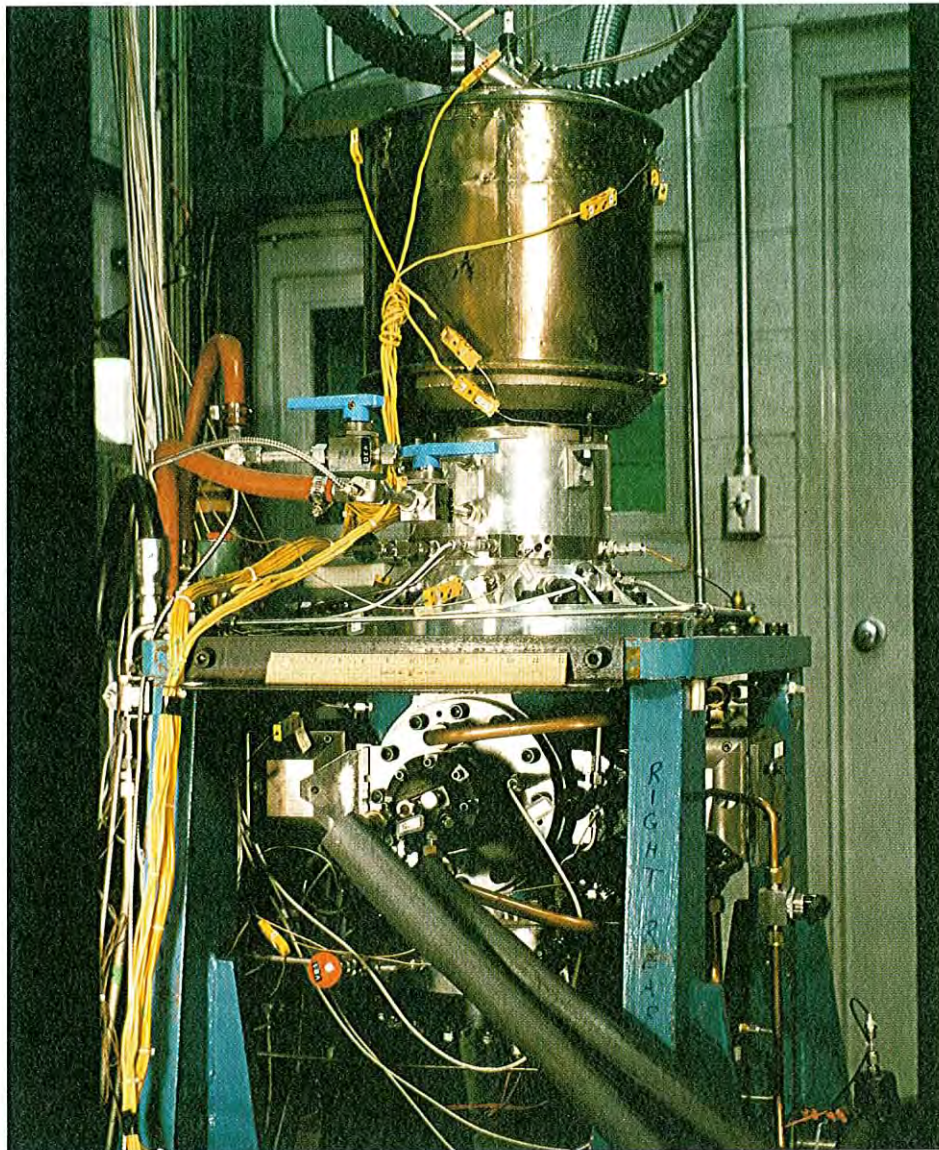


Fig.3 Mechanical Technology Inc.: Free piston Stirling engine heat pump prototype.

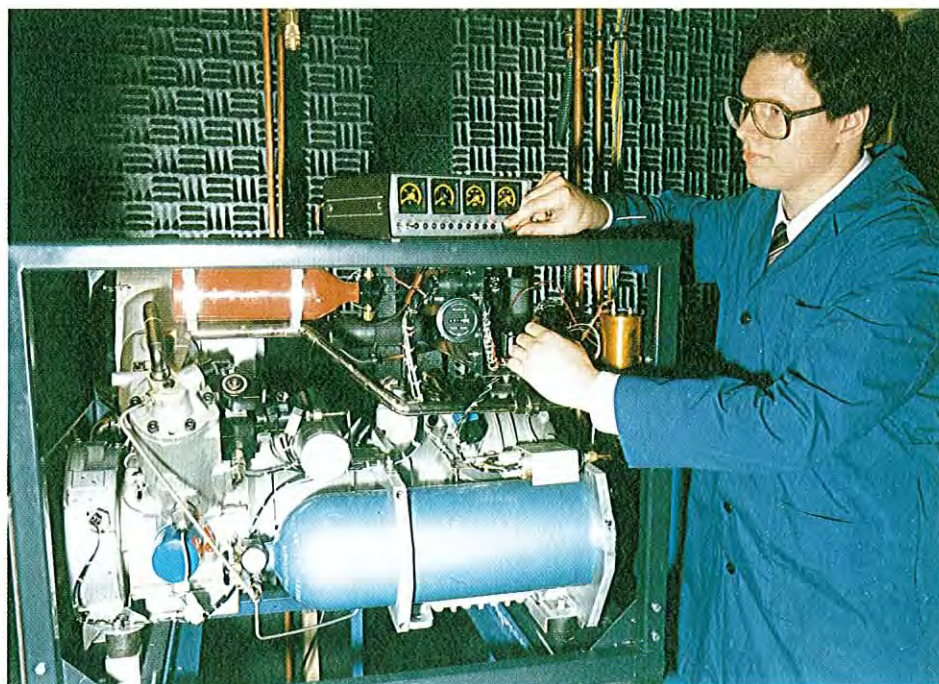


Fig. 5 Stirling Power Systems: Kinematic Stirling engine driven heat pump

pressed interest in producing the engine and is cooperating by ensuring that the manufacturing requirements to produce the engine are consistent with its production equipment. Studies have selected a refrigerant compressor to form a good match with the engine for use in the heat pump system.

The Free-Piston Stirling Engine heat pump under development at Mechanical Technology Inc. (MTI) has achieved 2-1/2 RT capacity and the engine has achieved an indicated efficiency (based on the integral of $p dv$ in the output gas volume adjacent to the diaphragm which drives the hydraulic transmission) of 30% (HHV). The hydraulic transmission and freon compressor development is being sponsored by the United States Department of Energy (DOE) through the Oak Ridge National Laboratory (ORNL) in a coordinated program. The breadboard unit has operated well enough so that a developmental prototype has been designed and is presently being assembled. The engineering development unit is shown in Fig. 3. This prototype will be tested first at MTI and then in the laboratory of a major HVAC equipment manufacturer. The HVAC industrial laboratory will test the equipment with an evaporator and condenser under realistic conditions of air flow over these heat exchanging components rather than simulated conditions in which loads are imposed by controlling the flow of refrigerant.

A breadboard version of the dual cycle absorption heat pump has operated successfully at Battelle Columbus Laboratories' facility and has produced a cooling COP approaching 1.0 and a heating COP of 1.8. The dual cycle system uses both a water-ammonia and a lithium bromide-water cycle with internal heat transfer between the two, thereby achieving COPs which are close to double those of single-effect machines and much better than those of ordinary double-effect machines. The first engineering version of this system designed as a packaged system is being built. Such a system is illustrated in an artist's drawing in Fig. 4. An HVAC manufacturer is already involved and is participating in the program. Later prototypes will be built by the HVAC manufacturer and be field tested.

The double-effect absorption residential heat pump under development by Columbia Gas has achieved the high COPs typical of larger double-effect machines. Progress is being made on reducing the size, weight and cost of the system so that it will be attractive to a manufacturer. A prototype suitable to obtain the participation in the program of a manufacturer is due to be completed in the third quarter of 1986. As was mentioned earlier, manufacturer involvement is necessary if GRI is to fund a development program past the proof-of-concept stage.

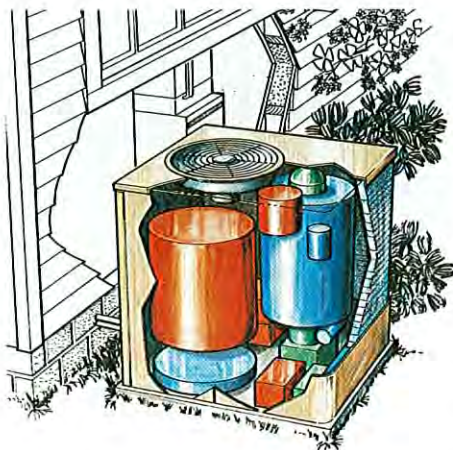


Fig. 4 Battelle Columbus Labs: Dual cycle absorption heat pump

The 10 RT commercial heat pump driven by the Stirling Power Systems (SPS) V-160 engine has operated with a refrigerant circuit as a complete heat pump. Testing is progressing in the laboratory of an HVAC manufacturer under realistic indoor/outdoor conditions simulated in his indoor/outdoor testing facility to deter-

mine performance. Fig. 5 shows the complete Stirling engine driven heat pump in test. In separate testing of the SPS V-160 engine a total time of over 100,000 hours has been achieved on 15 engines without failure. The lead engine has passed the 15,000 hour mark.

Economic and market analyses indicate that with the current performance targets, the machines under development will be competitive in general and will be attractive space conditioning systems for residential and light commercial service in colder climates.

Good progress continues to be made in the advancement of gas-fueled heat pumps being developed in the GRI program. Several concepts are expected to begin field testing in the next two years. Performance goals are being achieved. Gas-fueled heat pumps can be expected to be available in the United States around 1990.

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260°C Aqueous Absorption Working Pair under Development

Energy Concepts Co. identified a new ternary absorption working pair of LiNO_3 , KNO_3 , and NaNO_3 . This mixture offers new capabilities for higher temperatures or higher temperature lifts, which are of greater interest for industry. It also greatly extends the metallurgical capabilities of absorption heat pumps.

A new aqueous absorption working pair has been identified which provides higher temperature capability, higher lifts, and use of lower cost construction materials than current working pairs (e.g., $\text{LiBr-H}_2\text{O}$).

The high temperature absorbent is a ternary mixture of LiNO_3 , KNO_3 , and NaNO_3 . In addition to being thermally stable to well above 260°C, it promotes the formation of a passive and protective corrosion resistant oxide film on both mild steel and all stainless steels.

The thermodynamic, corrosion, and stability properties of the new absorbent have been measured. Additional properties have been analytically derived as necessary to predict the performance capabilities and limitations of an absorption heat pump using the new absorbent.

The high temperature absorbent is useful with waste heat temperatures in the range of 50 to 230°C for providing temperature lifts of up to 58°C for the HA (heat amplifier)

mode and 90°C for capabilities of 5 to 150°C waste heat temperatures and respective lifts of 43°C and 51°C.

Needed capabilities

In numerous manufacturing processes, significant quantities of process energy can be usefully recycled by applying heat pumps at one or more appropriate points. Those points may be identified by "pinch" or "target" analysis [1]. The temperature at that point, vary widely from plant to plant and process to process. Also, industrial process fluids themselves often impose metallurgical constraints.

The generally recognized limitations of the currently used $\text{LiBr-H}_2\text{O}$ absorption working pair are:

- Maximum lift of approximately 43°C, as determined jointly by limited solubility field and by corrosion (Erickson, 1985).
- Maximum absorbent temperature of 170°C, based on corrosion rate of Cu-Ni or ferritic stainless steel.
- No use of austenitic stainless steel due to halide stress corrosion.

In 1982, at a conference convened to review the state-of-the-art of absorption working pairs, the continuing need for higher lifts and temperatures than those possible with $\text{LiBr-H}_2\text{O}$ was emphatically reiterated [2].

Working fluid pair

For absorption heat pumps (AHP) operating above ambient temperature, water is an extremely attractive working fluid. Its high heat of vaporization insures low

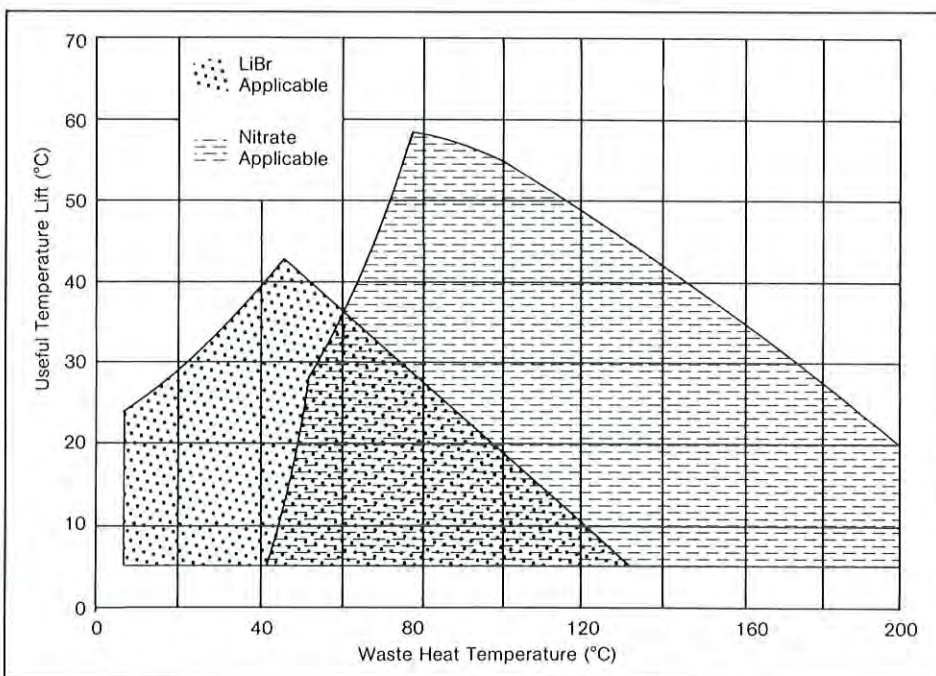


Fig. 1 Heat amplifier applicability diagram

pumping power, even at high solution concentrations. It has exceptionally high film heat transfer coefficient, very low viscosity, exceptionally low cost, and is safe, nontoxic, and nonflammable. Its only minor detractors are low pressure, high heat capacity, and potential corrosivity. Thus the choice in the search for a high temperature absorption working fluid pair reduces to selection of a suitable aqueous absorbent.

The water dissolving characteristics of the various pure alkali metal nitrates and several discrete nitrate mixtures are well known. Some of the $\text{LiNO}_3\text{-KNO}_3$ or $\text{LiNO}_3\text{-NaNO}_3$ combinations have an acceptable high temperature solubility field, but their solubility at low temperatures is extremely limited. However, a range of ternary compositions was found which provides good solubility for low working fluid temperatures. Two U.S. Patents have issued covering the useful ranges of compositions for ternary alkali nitrates and nitrates, and equivalent patents are pending worldwide [3]. A study was initiated by Oak Ridge National Laboratory, acting for the Office of Industrial Programs, U.S. Department of Energy to seek a working pair capable of higher lifts and higher operating temperatures than LiBr. Energy Concepts Company was contracted to develop and characterize a composition with the desired properties. For this research, the ternary composition of LiNO_3 , KNO_3 , and NaNO_3 in the weight ratio 53/28/19 respectively was chosen for general purpose industrial use. For this composition, there is no solubility limit for working fluid (water) temperatures above 68°C.

The cost of LiNO_3 , KNO_3 , and NaNO_3 respectively is \$2.75, \$0.40, and \$0.20 per pound; the cost of the ternary nitrate is one-third that of LiBr.

Measured properties

Vapor-liquid equilibrium of the absorbent was measured for concentrations ranging from 50 to 92.5 weight percent and temperatures ranging from that of crystallization to 270°C. This required both vacuum (to 1/30 ATA) and high pressure (to 10 ATA) measurements. At 50, 80, and 90 weight percent of absorbent, the atmospheric boiling points of the solution are 115.5, 152 and 184.6°C respectively.

Specific heats were obtained as a function of temperature for 80 and 90 weight percent concentrations.

At 150°C, the specific heat of the 80 w/o solution is 2.0 kJ/kg/K.

Viscosity was measured for four concentrations ranging from 78 to 90 weight percent. At 150°C, viscosity ranged from 3.0 to 6.8 cP; and at 260°C, the range is from 1.0 to 1.8 cP.

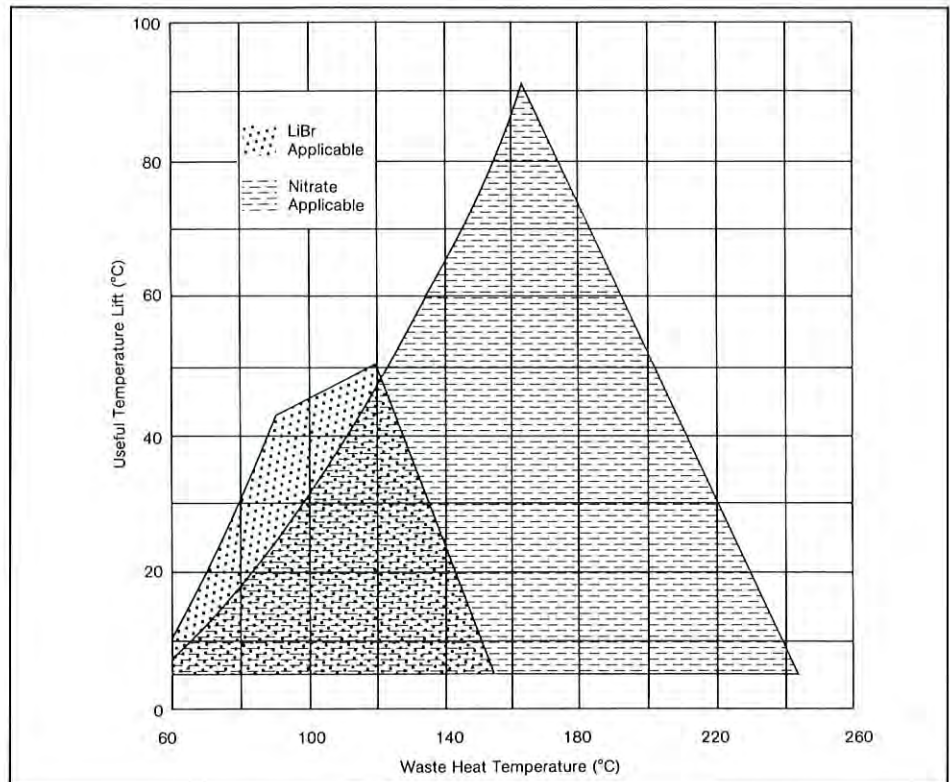


Fig. 2 Temperature amplifier applicability diagram

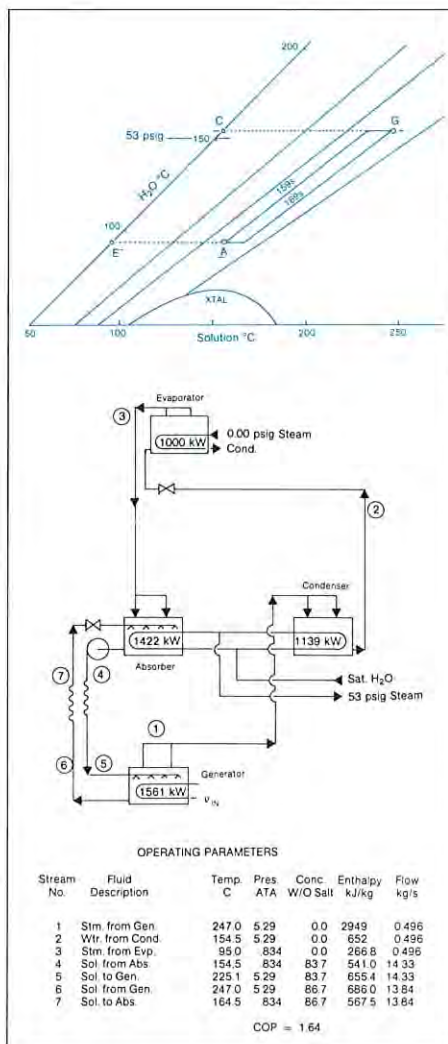


Fig. 3 Heat amplifier with high temperature absorbent

Corrosion and thermal stability

Both static and isothermal and dynamic temperature cycling tests were conducted using standard industrial grade alkali nitrate salts. Temperatures ranged from 210 to 315°C. All stainless steels tested, including austenitic types, were found to be acceptable materials of construction over the entire temperature range. Mild steel was found to be acceptable in areas of absorbent contact for the entire temperature range. A slight corrosion mechanism was evident for mild steel exposed to vapor space above 220°C, suggesting that a mildly alloyed steel, e.g., 2.5% Cr, will probably be adequately corrosion resistant in the vapor space for extreme temperatures. At a constant temperature of 315°C decomposition of the absorbent was measured at 0.15 percent per year.

Temperature capabilities

The temperature capabilities of the tested absorbent are summarized in Figures 1 and 2 using the format of useful temperature lift vs waste heat temperature. For comparison, the capabilities of LiBr are also shown. The following rules and assumptions were applied equally to both absorbents for deriving the diagrams from their respective solubility fields:

- Absorber, generator, condenser and evaporator all have 5.56°C (10°F) log mean temperature difference;

- 3 w/o solution concentration difference;
- 15°C (27°F) margin against crystallization for both constant concentration cool-down and constant pressure heatup;
- 260°C nitrate solution temperature limit; and
- 170°C LiBr solution temperature limit.

Heat transfer

Heat transfer properties of the new absorbent and their influence on individual component design will be assessed in a future stage of study. However, tentative conclusions can be drawn from data collected to date. In comparison with LiBr absorption heat pumps, two of the five major components--evaporator and condenser--will involve identical fluids. Properties of the absorbent influence the design of the absorber, solution heat exchanger, and generator. Viscosity is a key parameter in the design of all three. Due to the generally higher operating temperatures of the high temperature absorbent, its viscosity is expected to be comparable to that of LiBr on conventional AHP temperatures. Surface tension was not measured. Thermal conductivities were analytically derived from literature values for the components of the absorbent. Using these estimates plus measured values film heat transfer coefficients, assuming a plate-type solution heat exchanger were calculated to be approximately 15 percent greater for the high temperature absorbent compared with literature values for LiBr.

Coefficient of performance

Coefficients of performance were determined via complete cycle energy balances using an enthalpy-concentration-temperature diagram. Specific enthalpies were analytically derived from the measured vapor liquid equilibrium and specific heat data. The method used was that developed by Haltenberger (1959) [4] and employed by McNeely (1979) [5] for evaluating enthalpy of aqueous LiBr solutions. It relies heavily on steam table data, and requires specific heat data at only a single solution concentration. Cycle energy balances were calculated for several cases, including the relatively high temperature lift cases shown in Figures 3 and 4.

Fig. 3 presents a thermodynamic cycle diagram and flowsheet for a heat amplifier using the high temperature absorbent. This closed cycle heat pump produces 53 psig (0,366 MPa) steam from atmospheric pressure waste steam, (i.e., from a wort boiler at a brewery).

Fig. 4 presents a thermodynamic cycle diagram and flowsheet for a temperature

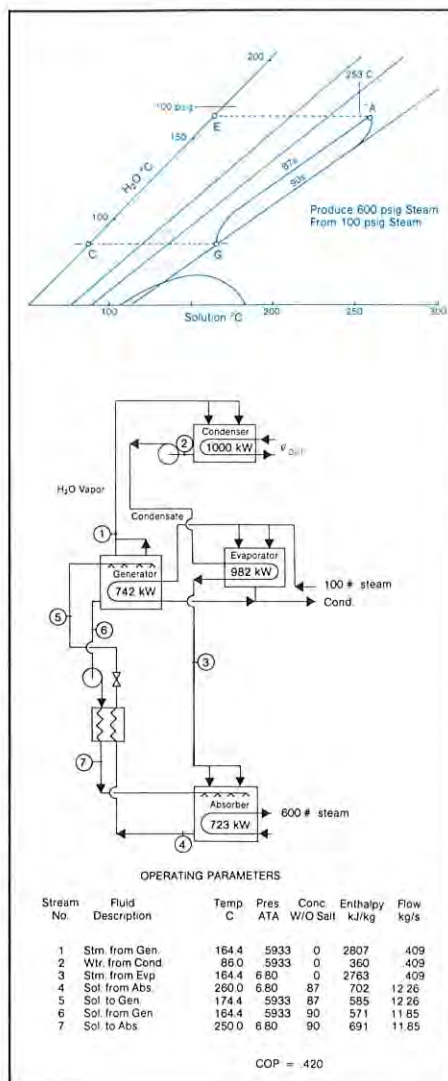


Fig. 4 Temperature amplifier with high temperature absorbent operating parameters

amplifier using the high temperature absorbent. This absorption heat pump produces 600 psig (4,138 MPa) steam from 100 psig (0,69 MPa) waste steam. Note that for the same condenser temperature, 50 psig (0,345 MPa) waste steam (147.5°C) can be raised to 250 psig (1,724 MPa) steam (208°C).

These flowsheets reflect preliminary estimate designs; no attempt was made to optimize the design or to include sensible heat recovery from the working fluid as would be appropriate for high lift cases. The COP results are 1.64 for the heat amplifier case and 0.42 for the temperature amplifier case. For high lift cases inclusion of two additional small sensible heat exchangers for the working fluid increases the amount of useful heat delivered by approximately 6 percent.

Comparison with LiBr COP

The high lift cases above cannot be achieved with LiBr. For a meaningful comparison with LiBr, low lift, low temperature cases were also calculated. Comparing heat amplifiers in the range of overlapping

temperature capabilities the high temperature absorbent had a 2.2 to 3.3 percent better COP. This is consistent with the less negative deviation from Raoult's Law exhibited by the high temperature absorbent. Correspondingly, the temperature amplifier COP will be slightly less than that of LiBr.

Conclusions

The new absorbent is not a panacea for all existing AHP limitations. It cannot replace LiBr in air conditioning applications, nor $\text{NH}_3\text{-H}_2\text{O}$ in refrigeration applications. Also, the high temperature absorbent will not replace LiBr in all industrial heat pumping applications. LiBr has unique temperature applicability areas.

In the area where the capabilities overlap, tradeoffs to be considered include the slight differences in COP and the differing material requirements. The high temperature absorbent will generally require lower cost material of construction, but possibly more surface area in some components. For some cases the higher lift capability of the new absorbent will translate into lower surface area requirements.

For higher temperatures or higher lifts, which are the applications of greatest interest to industry, the high temperature absorbent is the only viable absorbent identified to date. It greatly extends the temperature and metallurgical capabilities of absorption heat pumps. These new capabilities bring many important industrial applications within the scope of absorption heat pumping for the first time.

References

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*W.F. Davidson, D.C. Erickson, Energy Concepts Co.

LITERATURE REVIEW: SORPTION HEAT PUMP SYSTEMS

In conjunction with the focus topic of this issue of the Newsletter the Heat Pump Center staff has compiled a review of publications concerning sorption heat pump systems. This review is now available from the Heat Pump Center for 40,-DM to readers in HPC member countries (use the order form on the last page of the Newsletter), like the literature reviews "Environmental Aspects of Heat Pump Applications" and "Industrial Heat Pumps". The following is a brief excerpt from the review, with condensed format of the citations.

Grossman, G.; Michelson, E., "Absorption heat pump simulation and studies: a modular computer simulation of absorption systems. Final report", ORNL/Sub--83-43337/2; DE86011206, Apr 1986, 83 p. (in English). A computer simulation program for absorption systems has been developed in a flexible and modular form, which makes it possible to simulate various configurations with different working fluids. The user supplies input, containing information on given flow rates and temperatures, as well as characteristics of the various subunits of the system. In addition, the user must convey to the computer an image of the cycle in question. The program calculates the temperature, composition, flow rate, and pressure at each state point of the system and the heat quantities at each unit, from which the coefficient of performance may be determined. The program has been tested on single- and double-stage absorption heat pumps and heat transformers with lithium bromide-water and water-ammonia as the working fluids. Results have been compared with experimental data from tests of a lithium bromide-water heat transformer, giving good agreement.

Braun, R.; Muehlmann, H.P.; Wessing, W., "Energetical analysis of a gas-fired absorption heat pump heating plant", Brennst.-Wärme-Kraft, Mar 1986, v. 38(3) p. 67-73 (in German). A heating plant was investigated containing a natural gas-fired air/water absorption heat pump. The heat load of the burner of the heat pump was 12 kW. A medium temperature system was used for the heat distribution. The heating plant was investigated exergetically by recording different steady conditions with the help of a detailed measurement technique. Thus, it was possible to assess both, its thermodynamic as well as its energy-economic effectiveness. The determination of the exergy losses, distributed over the whole plant, enables obvious ways for improvement. In this connection it appeared that the $\text{NH}_3/\text{H}_2\text{O}$ -mixture used as working fluid in the heat pump, could absorb only very little exergy with the actuating heat flow, but that, on the other hand, the exergy losses within the cycle were relatively small.

Bliem, C.J.; Mills, J.L., "Comparative economic evaluation of industrial heat pumps", EGG-M--10186; CONF-860810-

-8; DE86011037, 1986, 7 p (in English). This paper presents the findings of a study on the cost of delivering process heat with state-of-the-art heat pump systems. Sixteen heat pump systems were configured for relative cost comparisons. These systems consisted of electrically driven, prime energy driven, and waste energy driven reverse Rankine cycle heat pumps of the open, semiopen and closed type. In addition, a waste energy driven absorption heat pump was analyzed. A conceptual design of each system was created using off-the-shelf components generally available to engineering firms. The performance of each system was assessed, the major components sized, and the installed cost determined. Maintenance costs were estimated. Finally, the relative cost of energy delivered by each system was estimated, and the cost of delivery heat with state-of-the-art heat pumps was determined.

Eisa, M.A.R.; Chaudhari, S.K.; Paranjape, D.V.; Holland, F.A., "Classified references for absorption heat pump systems from 1975 to may 1985", J. Heat Recovery Syst., 1986, v. 6(1) p. 47-61 (in English). More than four hundred references for absorption heat pump systems have been listed and classified on the basis of heating, cooling and heat storage. They have been further classified on the basis of water-lithium bromide, ammonia-water and other systems.

Chaudhari, S.K.; Paranjape, D.V.; Eisa, M.A.R.; Holland, F.A., "Comparative study of the operating characteristics of water-lithium chloride and water-calcium chloride absorption heat pumps", J. Heat Recovery Syst., 1986, v. 6(1) p. 39-46 (in English). Performance data have been obtained on a small glass absorption heat pump operating on three systems, namely water-lithium chloride; water-calcium chloride, and a water-(1:1 by weight) mixture of lithium chloride and calcium chloride. Salt solutions with concentrations of approximately 42% by weight were used. Actual coefficients of performance (COP)A in the range of 1.16-1.48 were obtained together with gross temperature lifts (TCO - TEV in the range of 16-28°C. For all three systems (COP)A decreased with an increase in flow ratio (FR). The water-lithium chloride system gave higher (TCO - TEV) and lower (COP)A values than the water-calcium chloride system. Inter-

mediate values were obtained for the mixture.

Stolk, A.L., "Research on absorption heat pumps at the Delft Technical University, The Netherlands", Klimaatbeheersing, Mar 1986, v. 15 (3) p. 75-79, (in Dutch). A short review is given regarding the projects of the refrigeration technology group of the Laboratory of Refrigeration Technology and Indoor Climate Technology. The development of an absorber heat pump is described. Some new developed absorbers are discussed. Some remarks are made about heat transformers.

Macriss, R.A.; Zawacki, T.S., "Absorption fluids data survey: final report on USA data", ORNL/Sub--84-47989/1; DE86014334, May 1986, 110 p. (in English). In an 8-month evaluation, 150 different US publications containing data that relate to properties of binary, ternary, and multicomponent absorption fluids were identified; from these publications, 67 were selected as primary sources of relevant US data. Fluids covered include combinations of 25 different refrigerant compounds, as well as of 67 single, 30 binary, and 4 ternary absorbent compounds. Generally, the 25 refrigerants are divided into the following categories of chemical compounds - INORGANIC 3, ORGANIC 22 (amines 3, alcohols 3, halogenated 16). Likewise, the single absorbent compounds are generally subdivided as follows - INORGANIC 31, ORGANIC 48 (alcohols 6, ethers 5, alcohol-ethers 2, amines 8, amine-alcohol 1, esters 9, ketones 5, acids 3, aldehyde 1, others 4). The binary and ternary absorbents are various mixtures of two or more single absorbent compounds. Coarse screening and evaluations were performed. Data gaps for key fluids are summarized and unresolved conflicts in data are noted. Results show that, with very few exceptions, all candidate fluids for development activities dealing with advanced absorption heat pump concepts have data gaps that must be addressed to in the near future.

Davidson, W.F.; Erickson, D.C., "New high-temperature absorbent for absorption heat pumps. Final report", ORNL/Sub--85-22013/1; DE86012483, May 1986, 60 p. (in English). A new absorption working pair (AWP) for absorption heat pumps has been identified which provides higher temperature capability (260°C), higher lifts, and use of lower cost construction materials, than currently available absorption heat pump working fluid pairs (e.g., $\text{LiBr-H}_2\text{O}$). Using water as working fluid, the absorbent is a ternary mixture of LiNO_3 , KNO_3 , and NaNO_3 in the preferred proportions of 53, 28 and 19 weight percent, respectively. In addition, to be thermally stable above 260°C, it promotes the formation of a passive and protective corrosion resistant oxide film on both mild steel and all stainless steels. Thermodynamic, corrosion, and stability properties of this new absorbent have been measured. At temperatures of 260°C and high

er, the absorbent has negligible thermal decomposition, corrosion rates less than 1 mil/year for both carbon steel and austenitic stainless steel, and provides practical heat pumping lifts of up to 90°C.

"Absorption Heat Pumps Congress", Paris, 20-22 March 1985, EUR-10007-EN, 1985 (in English). This document includes 43 reports on recent research and applications of absorption heat pumps. The activities in the field of research and development are concentrated on new working fluids, heat and mass transfer problems, improved component design, especially absorbers, advanced and periodic cycles. The reports, dealing with industrial applications, include studies of a 100 kW high-temperature absorption heat pump

prototype and an absorption dryer, descriptions of installed absorption heat pumps for heating capacities ranging from 300 to 3000 kW and a survey of several ongoing activities for a high-temperature noncorrosive absorption working pair. Thirteen of the reports concern the problems and efforts of commercial and residential applications of absorption heat pumps.

Hülsemann, R.; Ehrler, G., "Waiblingen municipal sewage plant, central heating unit based on an absorption heat pump using both, the waste heat from waste water and also the sludge gases for supplying a district heating system", Final report, BMFT-FB-03E-8000-A, Mar 1986, 45 p. (in German). This report includes ob-

jective, working program and results of the Waiblingen absorption heat pump (AHP) plant. It describes the design concept, engineering, erection and commissioning as well as checking the economic efficiency of this gas-fired AHP used for district heating. The AHP uses waste water of the sewage plant as heat source and the sludge gases as driving energy so reducing the natural gas demand. The working program includes calculation of different variants of several systems and optimization of the performance of an AHP-boiler system also considering a heat accumulator. The entire plant has been in operation for three winter periods and the guaranteed heat coefficient was obtained. The system got an award for energy saving technologies with a positive impact on the environment.

NEWS BRIEFS

The Heat Pump Technology Center of Japan

An epoch-making organization has been established in Japan. Taking this opportunity, the movement and tendency to develop the technology of heat pump systems in Japan will make progress by leaps and bounds.

This new organization is registered under the name: "Heat Pump Technology Center of Japan", which has been authorized as public corporation by the Minister of International Trade and Industry in August 1986. The objectives of this center are: to contribute to the development of Japanese industry, to level-up national life and to promote international economy through the elevation of heat pump technology through R&D, testing, and international cooperative research for heat pumps and systems concerned.

Originally, heat pumps in Japan have been mainly developed in the field of domestic air conditioners. With this background we can point out, that the application of heat pumps realizes the most effective application of equipments and energy itself.

Moreover, heat pumps have many advantages to be utilized for industrial application and they have a lot of possibilities of expanding in the field of industry. They have been used in industrial processes like cold or hot water supply, heating, pre-heating, drying, condensation, evaporation, refinement etc. They have also many

application cases in the fields of horticulture, cattle-breeding cultivation etc.

As we have seen above, heat pumps have broad application fields, where much efforts for technical breakthroughs and improvements are being made, for ex. in universities, national laboratories, manufactures, energy companies, constructive companies, engineering companies, and user industries. These groups concerned have come to agree upon concentrating their efforts to develop and spread heat pump technology and establishing a new organization, the Heat Pump Technology Center of Japan.

In Japan, already two basements were prepared for the cooperation in R&D and study of heat pump. One is the fact that Japan joined the IEA international cooperative research program, concentrating on the all potential of government and related industries. And the other is the start of a national project---"Super Heat Pump Energy Integration System" in which many manufacturers and national laboratories participate.

Starting out from these facts, we can expect a successful cooperation between related groups and the Heat Pump Technology Center of Japan. For the international cooperation in IEA, this new organization will completely support and assist Japanese government (Agency of Industrial Science and Technology, MITI).

More than 50 companies expressed their approval of the establishment of this organization, and contributed to the funding when adding the subsidy. The present scale of the capital fund has reached 250 million YEN. The normal business is financed by the income from supporting membership fees.

As mentioned above, the development of heat pump technology will progress rapidly through the establishment of the Heat Pump Technology Center of Japan. This is highly appreciated by the Japanese government, which has promoted energy saving policy. Therefore, the government strongly supports the activities of this new organization. We sincerely wish that fruitful results of technology development will prevail all over the world, that the effects of energy saving and natural resource saving will be actualized by the global scale, and that we will be able to contribute to the growth of the world economy.

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The First Commercial Heat Transformer in Successful Operation in Germany

In March 1984 the first European industrial heat transformer was installed in the "Tierkörperbeseitigungsanstalt (TBA)" (plant for carcass disposal) in Dörnten nearby Goslar. According to indications of the manufacturer, GEA-Luftkühlergesellschaft, Herne, the plant works without failures since then.

Structure and operating mode of the plant is illustrated on page 14. It is able to transform waste heat of 60 to 110°C to a temperature level that is by 40 to 50 K higher, without supplying high-grade driving energy like electricity, oil or gas. In Dörnten, the plant is driven with vapors of 100°C and produces process steam of 135°C, whereby the heat of condensation is dissipated by a cooling tower. 2.5 MW waste heat result in a heat output of 1 MW, corresponding to a heat transformer effi-

ciency of 40%. The heat transformer is especially suitable for applications in thermal separation, disinfection and drying processes within a capacity range of 1 to 10 MW heat output. It is estimated that the installation plant of TBA in Dörnten, which is used for double-shift operation, has a payback period of 3 years.

Japanese Chemical Heat Pump Demonstration Plant

A demonstration heat pump produced 77,2 kW (263,475 Btu/h), generating 120°C (248°F) steam from 80°C (176°F) waste water. The process is based on metal hydrides which, when cooled and pressurized, absorb hydrogen and generate heat. Heating and pressure reduction lead to the emission of hydrogen, which captures heat from air.

The new heat pump was installed at the Kashima, Ibaraki works of Chuo Denki Kyogo Co., a medium-sized producer of

ferro-alloy products and an affiliate of Sumitomo Metal Industries.

Working with Chuo Denki were Sekisui Chemical Co. and Japan Chemical Engineering Co. The three companies began their joint heat pump project in 1983 with funding from the Ministry of International Trade and Industry (MITI).

The metal hydride is a combination of three alloys, each made from rare earth elements. A total of 2.6 tons of these alloys are placed in pipes filled with hydrogen.

One of the alloys is first heated by the warm waste water so that it can generate hydrogen. The other alloys absorb the hydrogen and produce heat. Use of three different alloys helps improve the efficiency of the heat exchange, the companies said.

The first plant costs 120 million yen (\$774,200). However, mass production is expected to cut the cost to one-sixth of that within one or two years.

Chuo Denki and its partners plan to build the heat pump system primarily for the steel and chemical industries.



Selected Book and Report Reviews

Reviews of the most recent publications on heat pumps

Comparative Economic Evaluation of Industrial Heat Pumps; Bliem, C.J.; Mills, J.I.; Chappell, R.N.; EGG--2408; DE86011183, Apr 1986, 128 p. (in English).

This report presents the findings of a study on the cost of delivering process heat with state-of-the-art heat pump systems. Results of this study will be used to define economic performance which must be met or improved upon by advanced heat pump concepts in order to warrant Department of Energy (DOE) development support. Sixteen heat pump systems were configured for relative cost comparisons. These systems consisted of electrically driven, prime energy driven, and waste energy driven reverse Rankine cycle heat pumps of the open, semiopen and closed type. In addition, a waste energy driven absorption heat pump was analyzed. A conceptual design of each system was created using off-the-shelf components generally available to engineering firms. The performance of each system was assessed, the major components sized, and the installed cost determined. Maintenance costs were estimated. Finally, the relative cost of energy delivered by each system was estimated, and the cost of delivering heat with state-of-the-art heat pumps was determined.

Energy for Buildings - Microprocessor Technology; OECD/IEA, 1986 (in English).

This report is aimed at central, regional and local government energy policy-makers, program directors and research and development managers, as well as building owners and managers, the construction industry, industrial and utility research and development directors and managers, financial institutions and consumer groups. The report focusses both on the potential of the application of microprocessor-based control systems for saving energy in buildings and the barriers to the achievement of this potential and is not, as such, a purely technical review. The report is based on information and data obtained from member governments, industry, utilities and research organizations.

The Community's Heat Pump Systems Industry: A Study of Concentration, Competition and Competitiveness; A. van den Honert, Berenschot Management Consultants IV/510/85-EN, July 1985 (in English).

The present volume is part of a series of sectorial studies on the evolution of concentration in the member states of the European Community. These reports were compiled by the different national institutes and experts, engaged by the commission to effect the study program in question. The scope of this study is to provide a survey of the possibilities of application of the heat pump from a commercial point of view. In addition, the scope of the study is restricted to environmental control within buildings and houses where heat is needed, although in reverse mode of operation the heat pump can in some applications provide cooling as well. Machines providing cooling alone, are not considered. Also heat pump applications to provide energy to industrial processes were not covered by the study. Furthermore the study results rather provide a qualitative than a quantitative survey on where the EC-member states stand with regard to research and development, production and use of heat pumps.

In this respect the report attempts to give an EC-overview of the state of the art, and not a per country survey, although it is unavoidable to point out and allocate certain developments to certain member states for reasons of, for instance, local energy policy and climate.



Selected Book and Report Reviews

Reviews of the most recent publications on heat pumps

Impact of Technical and Economic Boundary Conditions on Technologies for Rational Energy Use in Industrial Nations - A Comparison; Jochem, E.; Grupp, H.; Hohmeyer, O.; Jäger, F.; Mannsbart, W.; Gröner, H., BMFT-FB-T 86-063, September 1986 (in German)

In some industrialized countries new technologies for energy conservation and the use of renewable energy sources have been introduced on a wider scale than in the FRG in the last ten years. For example, district heating is used three to five times more in Denmark and Finland. Denmark has three times as many wind energy converters and France has twice as many electrical heat pumps as the FRG. This

study considers the causes of the differences of market diffusion for several technologies producing electricity and heat.

Planning, Projection and Construction of a Pilot Farm in Liebenau with Test Operation of Demonstration Plants and Scientific Measuring; Lorre, R.; Marx, G.; Suttor, K.-H., BMFT-FB-T 86-049, August 1986 (in German)

During this research project, the projected demonstration plants of the projects 03E-5319-C-A+E for the pilot farm of Liebenau have been realized and their operation has been evaluated over a period of two years.

Three systems of biogas facilities have been tested with different operating times and different temperatures of liquid manure. The fertilizing value of the digested liquid manure has been determined. A heating station operated with biogas, natural gas or diesel fuels supplies current and heat. Its efficiency with the different fuels has been determined. A combined incinerator for straw and wood has been tested in practical operation. From the waste heat of a piggery, useful heat has been obtained by means of an electric heat pump. The coefficient of performance of the heat pump could be improved during the test period. New energy-saving techniques have been tested in glasshouse cultivations.

Schedule of Conferences and Trade Fairs

January 18-21, 1987

New York, New York (USA); **1987 ASHRAE Winter Meeting;** Sponsored by the American Society for Heating, Refrigerating, and Air-Conditioning Engineers; Contact: Judith Breese, ASHRAE, 1791 Tullie Circle NE, Atlanta GA 30329 (USA), Tel. 404/636-8400

January 19-22, 1987

New York, New York (USA); **1987 International Air-Conditioning, Heating, Refrigerating Exhibition;** Sponsored by ARI and ASHRAE; Contact: Hank Stevens, International Exposition Company, 200 Park Avenue, Suite 1204, New York NY 10166 (USA), Tel. 212/986-4232

March 25-27, 1987

Oxford (United Kingdom); **3rd International Symposium on the Large Scale Applications of Heat Pumps and Exhibition;** Sponsored by the British Hydromechanics Research Association (Cranfield); Contact: Ms. J. Stanbury, British Hydromechanics Research Association (BHRA), Fluid Engineering Center, Cranfield, Bedford MK43 0AJ (United Kingdom)

April 13-18, 1987

Budapest (Hungary); **Symposium on the Long-Term Impact of Energy Efficiency Improvements;** Sponsored by the United Nations (Geneva), the Economic Commission for Europe; Contact: United Nations, Economic Commission for Europe, Energy Division, Palais des Nations, CH-1211 Geneva 10 (Switzerland); Note: Registration deadline Oct. 31, 1986

April 26-29, 1987

Berlin (F.R. Germany); **22. Internationaler Kongress für Technische Gebäudeausrüstung** (22nd International Congress for Technical Building Equipment); Sponsored by Verein Deutscher Ingenieure (VDI) - Gesellschaft Technischer Gebäudeausrüstung (TGA) (Düsseldorf), Vereinigung von Verbänden der Deutschen Zentralheizungswirtschaft e.V. (VdZ) (Hagen), Bundesverband für Heizungs-Klima- und Sanitärtechnik e.V. (BHKS) (Düsseldorf); Contact: Prof. Dr. H. Esdorn, Technische Universität Berlin, Straße des 17. Juni 135, D-1000 Berlin 12 (FRG)

April 28-30, 1987

Orlando, Florida (USA); **IEA Heat Pump Conference;** Sponsored by the International Energy Agency, Paris; Contact: F.A. Creswick, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, TN 37831 (USA)

September 28-October 2, 1987

Lausanne (Switzerland); **3rd International Congress on Building Energy Management (ICBEM-3 87);** Sponsored by Ecole Polytechnique Fédérale (Lausanne); Contact: ICBEM '87 Secretariat, Prof. Andre P. Faist, EPFL-LESO Building, CH-1015 Lausanne (Switzerland)

August 24-29, 1987

Wien (Austria); **Internationaler Kongress für Kältetechnik;** Sponsored by the Internationales Institut für Kältetechnik;

Deadlines:

Announcement of reports Oct. 31, 1986
Contribution of the whole report and the summary Dec. 15, 1986
Registry at reduced tariff April 15, 1987
(Payment up to April 30, 1987, at the latest)

Schedule of Conferences and Trade Fairs

Notification about acceptance or declination of a report May 31, 1987
Hotel reservation June 21, 1987

Contact: XVII, Internationaler Kongreß für Kältetechnik, Mondial congress, Bösendorferstraße 4, A-1010 Wien, Tel. 0222/65 96 29, Telex 132 597 mreisa, Telegram wienkälte

September 1-5, 1987

Beijing (People's Republic of China); **International Refrigeration, Heating, Ventilation and Air-conditioning Exhibition and Conference (China Refrigeration '87)**

September 13-18, 1987

Hamburg (F.R. Germany); **ISES Solar World Congress and Exhibition 1987**; Sponsored by the International Solar Energy Society; Contact: (ISES Solar Weltkongreß 1987 e.V., c/o Hanseatic Congress Management GmbH, Am Weiher 23, D-2000 Hamburg

Prospects in Heat Pump Technology and Marketing

1987 IEA Heat Pump Conference

Wyndham Hotel · Orlando, Florida · April 28-30, 1987

FIRST ANNOUNCEMENT

Purpose: To share among International Energy Agency (IEA) nations information that can lead to the increased use of heat pumps and to the attendant improvements in the efficiency of the utilization of energy resources

Speakers: Fifty invited speakers from North America, Europe, and Japan will present papers in nine sessions

Conference Schedule

	Tuesday	Wednesday	Thursday
Morning	Session I	Session III Session IV	Session VII
Afternoon	Session II	Session IV Session V Session VI	Session VIII Session IX

Session Descriptions:

I Opening Plenary Session

Welcome, opening remarks, and a keynote address. Overview presentations will be given on the IEA Advanced Heat Pump research program, the IEA Heat Pump Center activities, and the CEC Heat Pump activities.

II Operating Experience with Heat Pumps for Residential and Commercial Space Conditioning Applications

Thermal performance, seasonal efficiency, reliability, durability, maintenance requirements, and user satisfaction in both residential and commercial applications will be discussed.

III Advances in Electric Heat Pumps

Presentations will feature promising prospects for technological improvements in heat pumps that can contribute to better performance, economics, and user satisfaction.

IV Heat Pumps for Industrial Applications

A broad range of topics relating to heat pump systems for industrial applications consisting of operation experience and economics, potential applications, market prospects and financing, and technological developments - will be covered.

V Advances in Thermally Activated Heat Pumps (TAHP)

Progress reports on the development of TAHP systems-principally absorption, internal-combustion engine-driven, and Stirling engine-driven - will be presented.

VI Heat Pumps for District Heating Applications

Topics such as operating experience, economics, and technological developments will be discussed.

VII Economics, Marketing, and Promotion

Updates on the current and projected market situation for heat pumps in Europe, Japan, and North America, and total owning and operating costs of heat pumps relative to competing systems will be given. Experience with utility promotion programs and present planned activities of promotion groups will also be discussed.

VIII Governments' Role in Energy Conservation

Past experiences with government programs, including succeeded, failures, results, and future needs, will be described.

IX Closing Plenary Session

Each session chairman will summarize the topics presented with regard to future prospects for heat pumps, what can be done to improve prospects, and the need for international cooperation.

Registration:

Conference headquarters will be the Wyndham Hotel, where the special rate will be \$85 per night/single and double occupancy. The registration fee (\$180) includes admission to all sessions, three luncheons, a reception and banquet, and a copy of the proceedings, which will be available at the conference.

Language:

English will be the official language; no translation services are planned.

Preconference Site Visits:

Site visits are being planned to heat pump installations, R&D organizations, and manufacturing facilities the week before the conference. The visits (not included in registration fee) will be arranged so that participants can continue on to Orlando for the start of the conference. Further information about site visits will be sent with the next information package.

Postconference Field Trips:

Field trips to the Disney Utilities Complex and the Kennedy Space Center are being planned for Friday following the conference. (Not included in registration fee)

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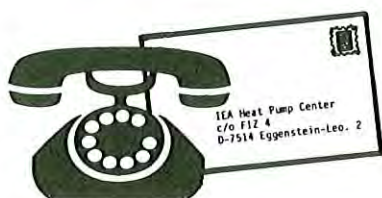
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RD&D Projects:

by project, country, heat pump type, research organization, principal investigator, etc.

Products and Manufacturers:

by type, heat source/sink, size, COP, manufacturer, country, and detailed information about individual manufacturers

Sample Installations:

performance results and design details for actual heat pump installations, by application type/size, heat pump type/size, country, etc.

Newsletter



The HPC publishes a quarterly **Newsletter**, each issue focusing on a particular aspect of heat pump technology or development, including:

- Reports on innovative heat pump installations, technological developments, heat pump sales and prices
- Trends in fuel prices and electricity tariffs
- Developments in energy policy affecting heat pumps
- Heat Pump Center projects and reports
- Book and report reviews, schedule of conferences and trade shows

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Reports

The following printed reports are available direct from the Heat Pump Center (use the attached card):

● **Heat Pump Research, Development and Demonstration Projects: Summary Report, Update 1985**, Report No. HPC-R2-1, May 1986, DM 75. This report contains half-page project status summaries for over 700 heat pump RD&D projects completed and on-going world-wide.

● **Nonazeotropic Refrigerant Mixtures as Working Fluids in Compression Heat Pumps, A Bibliography**, Report No. HPC-B1, second edition, December 1985, DM 220. This report is a comprehensive bibliography of over 200 reports with complete citations and abstracts.

● **Literature Reviews**: literature surveys with complete citations and abstracts in the following areas:

- **Environmental Aspects of Heat Pump Applications**, Report HPC-LR1, May 1986, DM 25.
- **Industrial Heat Pump Applications**, Report HPC-LR2, July 1986, DM 40.
- **Sorption Heat Pump Systems**, Report HPC-LR3, October 1986, DM 40.

A new literature review is compiled in conjunction with the focus topic of each issue of the HPC Newsletter.



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Our next issue:

Ground-Coupled Heat Pumps

The December issue of the Heat Pump Center Newsletter will focus on ground-coupled heat pumps. Planned contributions include:

- Market survey, manufacturers and product information
- Report of the experts' workshop on ground-source heat pumps in Albany, NY, USA, October 27 - November 1, 1986
- Excerpts from HPC literature review on ground coupled heat pumps
- Sample installations from different countries
- Calculation/estimation methods
- Design and layout of different ground coils

Also included will be our regular features: Book reviews, conferences and trade fairs, and news updates. If you have further contributions relevant to sorption heat pump systems, please send them to the Heat Pump Center.

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