

CUSTOMIZED ABSORPTION HEAT PUMPS FROM INDIAN INDUSTRY

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ABSTRACT: Absorption Heat Pump (AHP) is not a mass manufacturing product like chillers. There are two reasons behind it. One natural reason is numbers are less. But there is another reason: Unlike chillers where chilled water requirements are fairly standardized, in Heat Pump both inputs and outputs temperatures largely vary from case to case. To get best performance, customized design is necessary. Thus this product is difficult to standardize both in manufacturing as well as in design.

Large pool of low cost engineers and workers available in India have given opportunities to Indian Industry to emerge as a world leader in AHPs. In last 10 years Indian Industry has supplied AHPs almost to the tune of 100 MW. Almost all these heat pumps are in Europe.

To meet various demands many variation of heat pump cycles are engineered. Some of them are Double absorber type, Twin type, Single double type etc. Various types of heat inputs employed are Hot water, Fuel firing, Exhaust gases, Steam and also combination of heat inputs in single heat pump either simultaneously or alternatively.

This paper describes types of cycles employed to suit various applications and customer needs of heating.

Key Words: *Absorption, Heat Pump, Lithium Bromide, Optimization*

1 INTRODUCTION

Absorption Heat Pump (AHP) is similar in construction to Absorption Chillers with few differences in process parameters as well as construction. Today relatively large numbers of Absorption chillers are manufactured (over 10,000 per year) while very little AHPs are manufactured. Hence Absorption Chiller manufacturer is a natural choice for manufacture of Heat pumps too. Thus AHPs are available as Modified absorption Chillers.

AHPs are used for heat recovery. Heat availability varies substantially as the process that gives the heat could be different each time. Hence process parameters of AHP vary drastically as compared to Absorption Chillers. This means large amount of customization is required for design of AHPs. India has large number of technical persons engineering man-hour costs are low. Hence this resource can be used effectively inspite of low volume of production. This paper describes some of the customizations done for design and manufacture of AHPs employing different cycles.

2 CONVENTIONAL ABSORPTION HEAT PUMP

Figure 1 gives cycle diagram of a simple direct fuel fired AHP. Evaporator and Absorber are housed in lower shell while Condenser and Generator are housed seperatly. Usually there are two are two more heat exchangers viz. Low temperature heat exchanger and refrigerant heat exchanger. If driving heat source is steam then additional heat exchanger that utilizes heat of condensed hot water from steam is used.

Heat source water enters is Evaporator where it gives heat to Evaporator. Refrigerant is evaporated and vapours generated travels to Absorber. In Absorber concentrated solution is sprayed on the tubes. Refrigerant vapour is absorbed by Lithium Bromide solution and both heat of dilution and latent heat of refrigerant is transferred to heating water. This intermediate hot heating water then goes to Condenser for further heating.

In Absorber Lithium Bromide becomes dilute after absorbing refrigerant and need to be regenerated. It is transferred by a pump to Generator. In the Generator heat given by fuel firing is absorbed by dilute Lithium Bromide solution and boiling Lithium Bromide releases refrigerant to Condenser. Lithium Bromide now concentrated is fed back to Absorber for further absorption. Refrigerant vapour is condensed in Condenser and heating water flowing in the Condenser picks latent heat. . Desired temperature heating water is now available at outlet of Condenser. Cycle COP of such Heat Pump is usually around 1.7.

Two regenerative heat exchangers are normally used. Low temperature heat exchanger heats dilute solution coming from Absorber picking heat of leaving concentrated solution from Generator. Increase in dilute solution temperature reduces the heat input in generator increasing COP. Reduced temperature of concentrated solution will offer more absorptivity towards refrigerant in Absorber. In AHPs (unlike Absorption Chillers) condensing temperature are high. Hence before condensed refrigerant is flashed in evaporator it sheds some heat by giving it to heating water. Small portion of heating water directly enters in this heat exchanger instead of going to Absorber. After it picks up heat it mixes back at out let of Absorber and then enter in Condenser.

3 Special customized heat pumps

To cater to requirement of utilizing heat available optimally special customized heat pumps were manufactured. To understand need of such customization three examples are given below. Before going to individual cases for the purpose of explanation let us consider certain thumb rules as follows.

- 1- Maximum evaporator temperature possible is 1 Deg c less than outlet temperature of heat source water
- 2- Minimum condensing temperature in Condenser is 1 Deg C higher than heating water temperature leaving Condenser.
- 3- Minimum dilute solution temperature leaving Absorber is 5 Deg C more than entering heating water in the Absorber.
- 4- Maximum dilute solution saturation temperature entering generator is 2 Deg c lesser than leaving heat source temperature from generator.
- 5- Maximum concentration of Lithium Bromide should not exceed 64% to avoid crystallization problem.
- 6- In a single effect machine Absorber has to deliver at least half the heat and hence temperature rise of heating water in absorber need to be at least 50 % of required temperature rise.

3.1 CASE 1: Hovedstadens Geotermi Selskab (HGS) Copenhagen plant had following heating requirement.

Table 1; Requirement of Absorption Heat Pump for HGS Copenhagen Denmark

Sr .	Description	Unit	Value
1	Heating Capacity	MW	27
2	Heat source water inlet temperature	Deg C	33
3	Heat source water outlet temperature	Deg C	15
4	Heating water inlet temperature	Deg C	50
5	Heating water outlet temperature	Deg C	86
6	Heat Source		Steam
7	Heat source temperature	Deg C	170

Let us see why it is not possible to use conventional Heat Pump in this case.

Table 2; Limitation of using conventional Absorption Heat Pump for case 1

Sr .	Description	Unit	Value	Reference
1	Since heat source outlet temperature is 15 Deg c maximum evaporation temperature will be	Deg c	14	Rule 1
2	Hence pressure in evaporator will be	Mm of Hg.	12.5	Properties of water
3	Absorber pressure will be	Mm of Hg.	12.5	Evaporator and absorber pressure will be same as they are housed in same shell.
4	In absorber water will be heated from 50 Deg c to atleast	Deg C	68	Half heat to be provided by Absorber Rule 6
5	At maximum permissible concentration of 64 % and corresponding to Absorber pressure saturation lithium bromide temperature will be	Deg C	63	Properties of Lithium Bromide

Entering Lithium Bromide is expected to heat the heating water But required heating water temperature leaving from Absorber is more than entering Lithium Bromide saturation temperature. So heat cannot transfer from Lithium bromide to heating water.

To solve this problem new cycle employing 3 lower shells in series for heating water and heat source water was designed.(Figure 2) As seen from temperatures above restriction is overruled due to customized design. Saturation temperature of Lithium Bromide is lower at lower pressures. Heat source water leaves at 15 Deg C from first lower shell .In this lower shell pressure is low due to lower heat source water temperature. Heating water at 50 Deg C is designed to enter in this shell. Since this temperature is low, lower Lithium Bromide temperature can still transfer heat to 50 Deg c heating water. In third lower shell, heat source water leaves at 33 Deg C as compared to 15 Deg c in first shell. So evaporator pressure is higher than first lower shell. At higher pressure, saturation temperature of Lithium

Bromide is also high. Such high temperature Lithium Bromide can transfer heat to high temperature heating water and hence it is possible to get heating water at 85 Deg C. In fact temperature rise achieved in Absorber is from 50 Deg. C to 74 Deg. C

3.2 CASE 2: Stadtwerke Munchen Germany had requirement of heat pump for simultaneous heating and cooling.

Table 3; Requirement of Absorption Heat pump for Stadtwerke Munchen Germany

Sr .	Description	Unit	Value
1	Capacity	kW	230
2	Heat source water inlet temperature	Deg C	22
3	Heat source water outlet temperature	Deg C	10
4	Heating water inlet temperature	Deg C	30
5	Heating water outlet temperature	Deg C	56
6	Heat Source		Hot water
7	Driving hot water inlet temperature	Deg C	115
8	Driving hot water outlet temperature	Deg c	86

Limitation of using conventional Heat Pump for such a requirement is as follows.

Table 4; Limitation of using Conventional Absorption Heat Pump for Case 2

Sr .	Description	Unit	Value	Reference
1	Since heat source outlet temperature is 10 Deg c maximum evaporation temperature will be	Deg c	9.0	Rule 1
2	Corresponding pressure in Evaporator will be	Mm of Hg.	9.1	Properties of water
3	Absorber pressure will be	Mm of Hg.	9.1	Evaporator and absorber pressure will be same as they are housed in same shell.
4	Minimum dilute solution temperature leaving absorber will be	Deg C	35	Rule 3
5	Minimum dilute solution concentration possible (corresponding to 35 Deg temperature and Absorber pressure of 9.1 mm)	%	52.5	Properties of Lithium Bromide.
6	Maximum possible saturation temp of dilute LiBr entering generator	Deg C	84	Rule 4
7	Minimum condensing temp possible	Deg C	57	Rule 2
8	Minimum condensing pressure (corresponding to 57 Deg C)	Mm of Hg.	136	Properties of Water
9	Maximum dilute solution concentration possible (Corresponding to 136 MM of Hg & 84 Deg C.)	%	50	Properties of LiBr

Thus 30 Deg c heating water entering temperature entering Absorber demands minimum dilute concentration as 52.5 % while 86 Deg C heat source water temperature leaving Generator demands maximum dilute concentration as 50 %. Such demand cannot be met. To tackle this problem Twin shell design concept is used. Lower shell (comprising of

Evaporator & Absorber) and upper shell (comprising of Generator and condenser) is split into two shells by providing vertical plate (Figure 3) Construction is as good of two chillers coupled in series. Absorber header is common as heating water in both Absorbers is flowing in parallel.

Higher temperature (22 Deg c) heating water enters in HP (high-pressure) evaporator and leaves at 16 Deg C. 16 Deg C leaving heat source water temperature allows Evaporator pressure to be raised to 13.5 mm of Hg. Correspondingly minimum dilute concentration demand is reduced to 48.5 %. Now the designer has flexibility to design the Heat Pump with dilute solution concentration between 48.5 to 50 % as minimum dilute concentration is 48.5% & maximum is 50 %.

In other lower shell, heat source water leaves at 10 Deg c and Minimum dilute solution concentration demand cannot be reduced (less than 52.5%). Here upper shell design allows increase in maximum dilute concentration demand above 52.5 %

Driving hot water enters in high pressure Generator at 115 Deg C and leaves only at 100 Deg C . Thus maximum possible saturation temperature of Lithium Bromide entering in HP generator can now be raised to 98 Deg c from 84 Deg c earlier. This increases maximum allowable dilute solution concentration from 50 % to 57 %. Designer now gets flexibility to select dilute solution concentration between 52.5 % and 57 %. Interestingly Lithium bromide from high-pressure Generator is fed to low pressure Absorber and from Low pressure Generator to high pressure Absorber.. (Photo 1).

CASE 3

In Konstanz Germany there was requirement of Simultaneous heating and cooling.. Hot water was required at 45 Deg. C for swimming pool and floor heating while chilled water was required for air-conditioning. For space heating higher temperature hot water was necessary. Geothermal water was available at 25 Deg c. For Driving heat source Diesel Engine heat is available. Engine has two temperature heat sources, Exhaust at high temperature and Jacket water at lower temperature.

Here again to make sure that low temperature hot water is able to drive away refrigerant double absorber concept is used. Since the both absorbers and evaporators are placed one above others additional requirement of pump was eliminated unlike previous cases. This is Single- Double effect AHP using both Single effect as well as Double effect cycle in same Heat Pump (Photo 2)

At this site variation of cooling load and heating load was very high. . To meet such demand innovative cycle was used is to get highest flexibility in adjusting cooling and heating loads.

Exhaust gases boil Lithium Bromide solution and vapour generated will first produce hot water. This hot water is further heater in jacket water heat exchanger using the heat of Jacket hot water. If cooling load is high this secondary hot water will be used to produce another effect and more lithium Bromide solution will be boiled. If heating demand is high hot water generated by First effect will be directly used either partially or fully for heating along with hot water generated at 45 Deg c by heat pump. Figure 4 describes the cycle

In steam driven Heat Pumps condensate comes out of generator at high temperature (150 Deg c and above) This high temperature hot water need to be cooled to 90 Deg C both for the purpose of heat recovery and ease of handling. (Normal water pumps cannot handle water beyond 100 Deg c.). Based on the requirement of customer heat recovery heat exchanger called as Heat Reclaimer is placed in cycle at appropriate place.

- 1- If COP is of prime important then heat of condensed hot water is used to heat Lithium Bromide. Lithium Bromide leaving from Absorber is fed to Low temperature heat

exchanger as well as Heat Reclaimer which are placed in parallel. This way heat of condensate is taken in Absorption cycle there by getting advantage of heat Pump COP.

- 2- If heat source outlet temperature is required at 80 Deg C or above condensing pressure becomes high. High condensing pressure is coupled with high Generator pressure and hence higher Generator temperature. For getting higher generator temperature steam pressure requirement increases. To limit this requirement Heat reclaimer is placed after the Condenser and purely used as an additional heat exchanger to top up leaving Condenser temperature. (Photo 3)
- 3- If simplicity is of prime importance Heat reclaimer is used in parallel to absorber-condenser where small quantity of hot water is generated in Heat reclaimer and mixes with leaving Condenser water.

There are few more variations in the heat pump supplied by Indian industry. One of them is heat source. Direct fuel fired, exhaust gas driven, Hot water driven, Steam driven and combination of heat sources have been already used even though only 11 projects of heat pumps are done. Table 1 gives the list of Heat Pumps with capacities and heat sources.

Table 4; Absorption Heat Pumps installed by Indian Industry

Sr No	Customer	Country	City	HW outlet temperature °C	Heating capacity MW	Heat Source
1	Thisted Fjernvarmeforsyning A.M.B.A	Denmark	Thisted	65	10.5	Steam
2	Karlstads Energi AB	Sweden	Karlstad	75	9.5	Hot water
3	Vattenfall	Sweden	Uppsala	60	14.5	Steam
4	Hovedstadens Geotermi Selskab (HGS)	Denmark	Copenhagen	85	27.5	Steam
5	VIVO KU	Germany	Warngau, Bavaria	82	0.6	Natural Gas
6	Vanmalle	India	Chennai	75	0.25	Steam
7	Jonkoping Energi AB	Sweden	Jonkoping	63	4	Steam
8	Stadtwerke Munchen GmbH	Germany	Munchen	55	0.55	Hot water
9	Stadtwerke Konstanz GmbH	Germany	Konstanz	45	0.7	Exhaust Gas & Hot Water
10	Bjerringbro Varmevaerk A.M.B.A	Denmark	Bjerringbro	80	2.35	Exhaust Gas
11	Vestforbraending	Denmark	Copenhagen	80	13	Steam
				TOTAL	83.5	

4 CONCLUSION

Global warming is threat to our mother earth. Absorption Heat Pumps can pick up low-grade energy and help reducing carbon DI oxide production. However AHPs are difficult to standardize. At present the production quantities are also low. This makes cost of engineering and production of such heat pumps very high. Developing nations like India have vast pool of engineers at lower costs. It is possible for them to contribute in reducing global warming by doing customization for optimal design of AHPs and still keep the costs in reasonable limits.

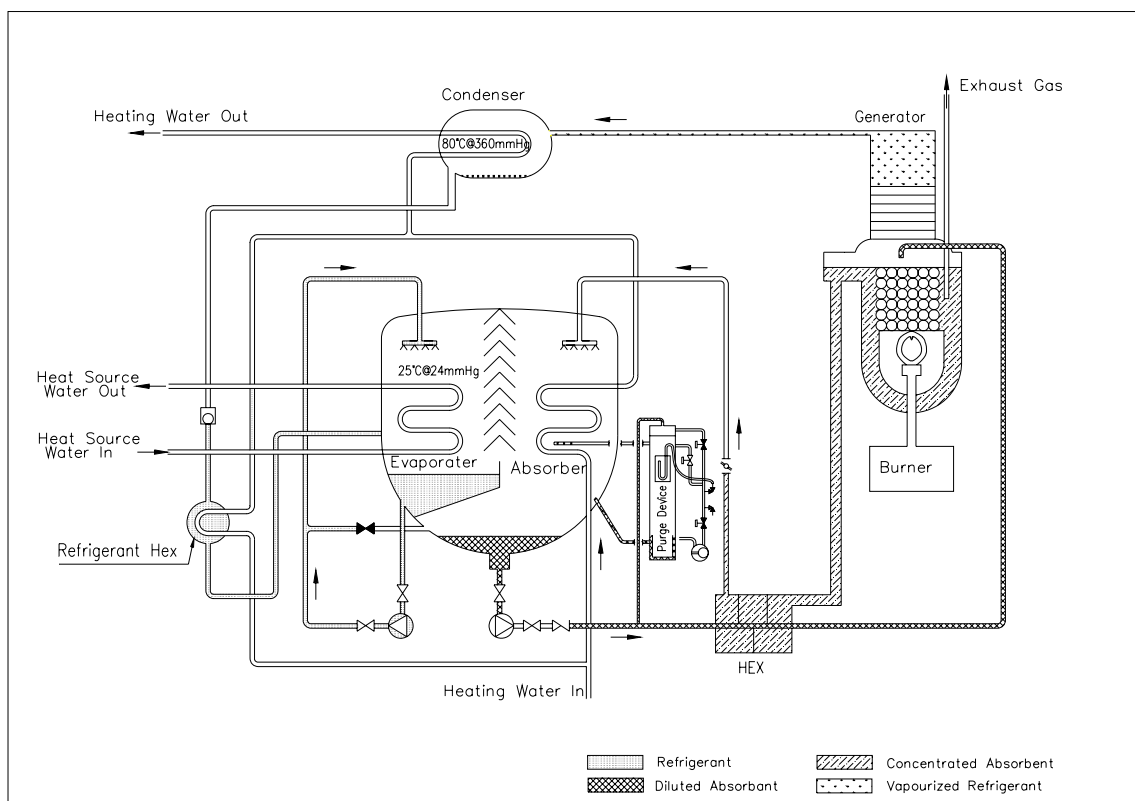


Figure 1: Conventional Absorption Heat Pump Cycle Diagram

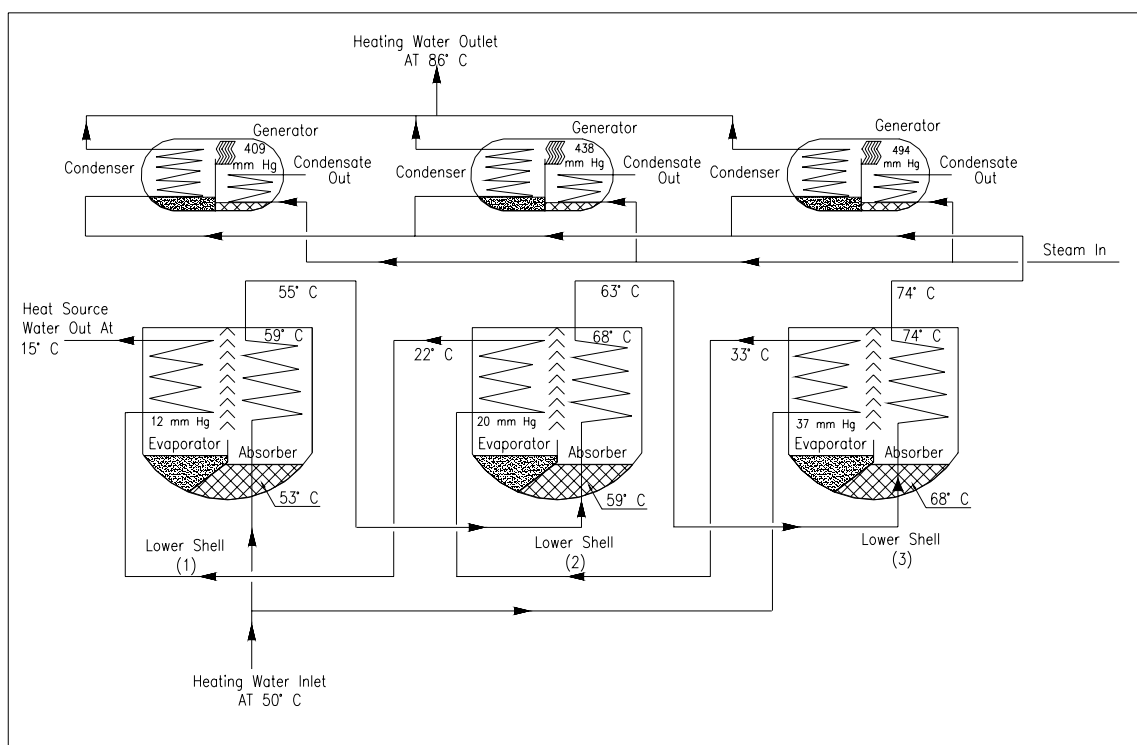


Figure 2: Arrangement for 27 MW Heat pump at HGS Copenhagen

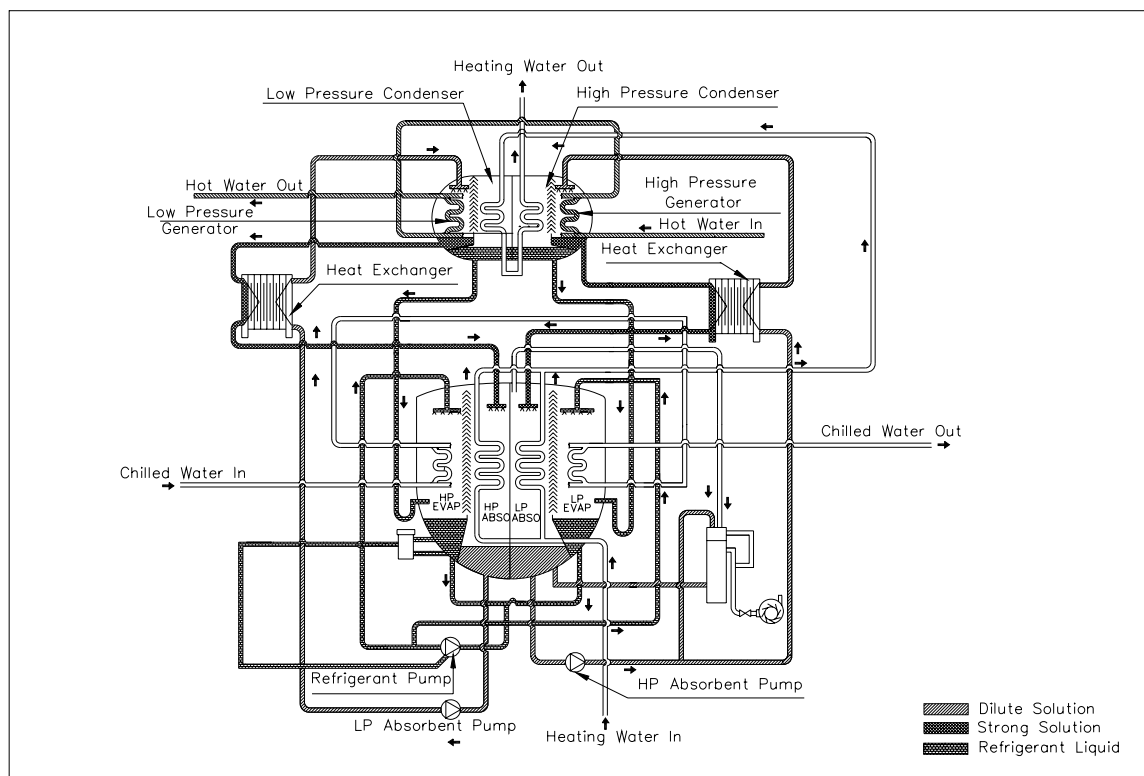


Figure 3: Cycle Diagram for TWIN type Heat Pump



PHOTO 1: Exhaust fired Single-Double effect Absorption Heat Pump at KONSTANZ, GERMANY



PHOTO 2: TWIN Design Hot water driven Absorption Heat Pump at STADTWERKE, GERMANY.



PHOTO 3: Steam driven 13 MW AHP at Vestforbraending Copenhagen, Denmark