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Absorption chiller with cooling and heating for energy saving and environment friendly

Yongjian Gu, Ph.D., P.E.
Department of Marine Engineering
United States Merchant Marine Academy
300 Steamboat Rd, Kings Point, New York, 11024. USA

ABSTRACT: ***An absorption chiller can be designed as an integrated unit which works as a cooling machine in summer and operates as a heating machine in winter. Comparing to the electrical compression chiller, the absorption chiller consumes much less electrical energy by using the absorption-heating technology. The absorption can be powered by diverse energy input, such as steam, hot water, waste heat, and solar energy. When the absorption chiller is engaged with the exhaust system of the diesel engine or gas turbine, the waste heat is recovered which will significantly improve the thermal efficiency of the entire thermodynamic system. Also, emissions from the engine will be effectively reduced.By using these diverse heat energy, fuels do not need to be burned in the absorption chiller.When an absorption chiller is engaged with a solar energy system, cooling provided from the absorption chiller will beenvironment friendly since the solar energy is a renewable green energy source. Therefore, the cooling and heating from the absorption chiller is economically and environmentally. In the paper, first the working principle of the absorption chiller is illustrated. Types of absorption chillers, such as single-effect and double-effect absorption chiller, are discussed. The mode of cooling and heating are described. Then, different system configurations of absorption chillers powered by diverse energy input are shown, such as exhaust heat, steam/hot water, and solar energy. Finally, application cases of absorption chiller powered by these diverse energy input are presented.***

Keywords: Absorption Chiller, Energy Saving, Cooling and Heating, Environment Friendly.

I. INTRODUCTION

In an air conditioning system,a chiller is used to take heat out from aninside lower temperature (T_L) area and release the heat to anoutside higher temperature (T_H) area through the refrigerate flowing in the chiller by applying the technology called refrigeration cycle. Per the 2nd law of thermodynamics, the chiller in the refrigeration cycle has to consume external energy to complete the process taking the heat from insider and to the outside.

When an electric compression chiller operates in the air conditioning system, an electricity-powered compressor needsto increase the pressure on the gaseous refrigerant. The resulting hot and high-pressure refrigerant gas is then condensed to a liquid form in a condenser. After the liquid refrigerant passes through an expansion valve with an isenthalpic pressure drop, it becomes a relatively lower temperature refrigerant. The lower temperature liquid refrigerant is sprayed on the evaporator and vaporized by absorbingthe heat from the cooling area. The gaseousrefrigerant thengoes back into the compressor to complete acycle. In compression, a large quantity of electricity is consumed.

When using an absorption chiller, the electric compressor is replaced by a unit of heat generator/absorber which is like a "thermal compressor". The electrical compression is avoided instead of a heat additionas shown in Figure 1. A special liquids used in the unit, which usually is lithium bromide (LiBr)to circulate with the "refrigerant", which usually is water (H_2O) instead of the refrigerate, such as R134a in the electric chiller.The unit of heat generator/absorber consumes much less electrical power by using pumps. The heating energy input in the "thermal compressor" can be waste heat or solar heat. The large amount of electrical energy for the compression in the electric chiller, therefore, is saved. Solar energy is a renewable green energy source.The solar-powered absorption chiller is pollution-free and environment friendly.

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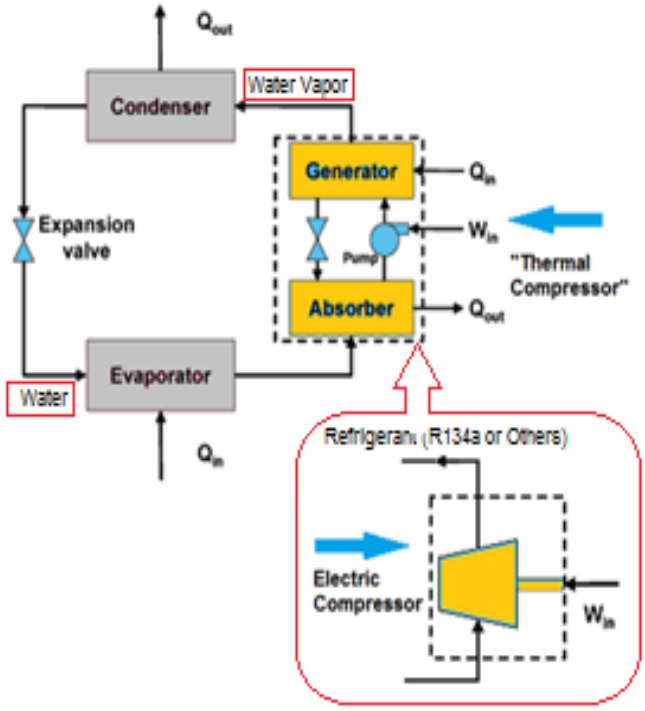

Fig.1 The Unit of Heat Generator/Absorber Replacing the Electric Compressore

II. WORKING PRINCIPLE OF ABSORPTION CHILLER

In the absorption chiller, a process called absorption process is involved in which the LiBr plays as a transport medium absorbing the water refrigerant to form a mixture fluid circulating between the absorber and the generator. The cooling cycle in the absorption chiller consists of following processes as shown in Figure 2:

1) Evaporation

The water refrigerant coming from the expansion valve sprays on the surfaces in the evaporator at a low pressure environment and extracts the heat from the chilled water flowing in the pipes. Because of the heating, the water vaporizes to vapor.

2) Absorption

The water vapor flows into the absorber and is absorbed by the sprayed LiBr. The mixture of LiBr-H_2O is cooled by the cooling water and collected at the bottom of the absorber. Then the lower temperature LiBr-H_2Omixture is pumped to the generator.

3) Regeneration

In the generator, the mixture of LiBr-$H_2O$is heated in which water is evaporated and LiBr remains in liquid since the boiling temperature of LiBr is much higher than that of water. The produced water vapor flows toward to the condenser. While the liquid LiBr is circulated between the generator and absorber working as the transport medium which brings water back to the generator.

4) Condensation

As the hot water vapor is passing through the condenser, the water vapor is condensed to water liquid at constant pressure on the surface of the condenser coil and latent heat is rejected to outside the system by surrounding ambient-temperature air or cooling water. The water liquid then flows to the expansion valve.

5) Expansion

After the water liquid flows through the expansion valve, the liquid experiences an isenthalpic expansion and becomes a water refrigerant at substantial lower pressure and lower the evaporator.

Above processes of 1) to 5) is composed of an absorption cooling cycle in the absorption chiller. Figure 3 shows the complete cooling cycle in a typical absorption chiller. Physically, the components connecting among the processes with auxiliary devices are enclosed in an integrated unit as shown in Figure 4.

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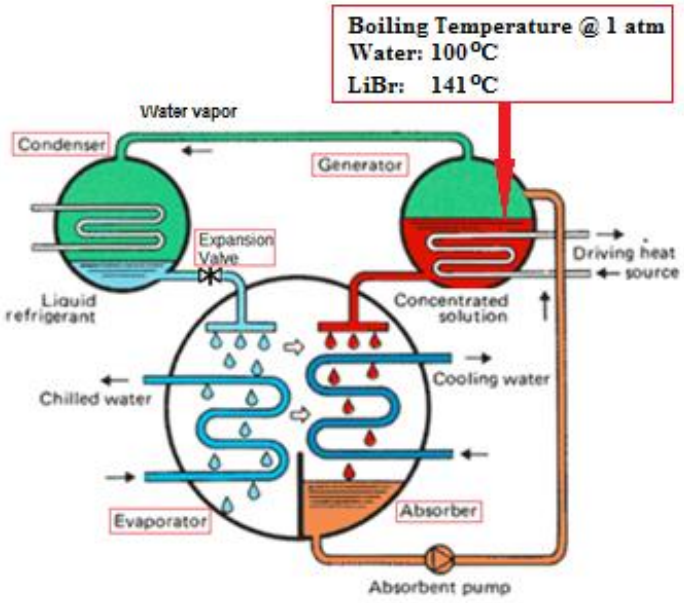


Fig.2 Woring Principle of Absorption Chiller

III. TYPES OF ABSORPTION CHILLERS

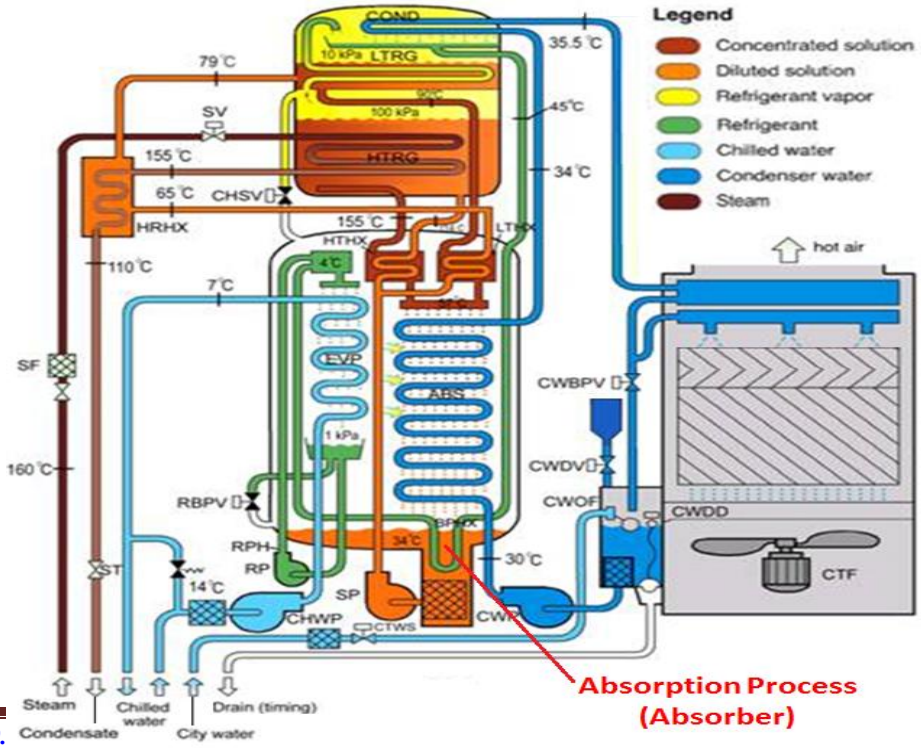
There are two types of absorption chillers based on the water refrigerant generation.

Single-Effect (or One Stage) Absorption Chiller:

The system of a single-effect absorption chiller is quite simple. The water vapor is produced in the generator. After the condenser and expansion valve, the water refrigerator is vaporized in the evaporator. Then the mixture of LiBr-H_2O is collected in the absorber and circulates back to the generator. In the single-effect absorption chiller, there is only one generator.

Double-Effect (or Dual Stage) Absorption Chiller:

The difference of a double-effect absorption chiller from above described single-effect chiller, as the name suggests, is that the double-effect absorption chiller has two generators, one high temperature generator (HTG) and one low temperature generator (LTG). Thedouble-effectabsorption chiller is able to produce alarge quantity of water vapor. The heat energy input only heats the mixture of LiBr-H_2O in the high temperature generator.



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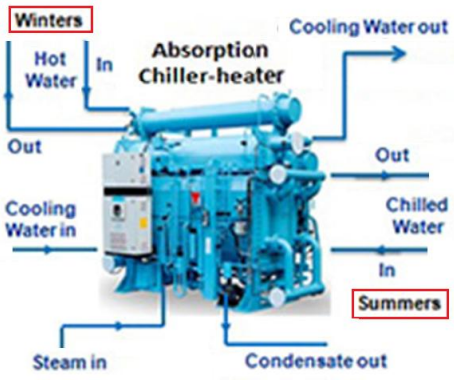

Fig.4 Integral Absorption Chiller Unit

Figure 5 and 6 shows the typical single-effect and double-effect absorption chiller, respectively.

1) HTG

The input energyheats the mixture of LiBr-H2O in HTG. The high temperature water vapor produced in the HTG flows to the low temperature generator (LTG) and works as a heating source in the LTG.

2) LTG

In the LTG, the higher concentrated LiBr mixture from the HTG is heated again. Vapor generated in the LTG with the vapor from the HTG flows to the condenser. The water liquid then passes through the expansion valve as the refrigerant to the evaporator. The double-effect absorption chiller has higher coefficient of performance (COP) than the single-effect absorption chiller, which is about the double of the single-effect absorption chiller's.

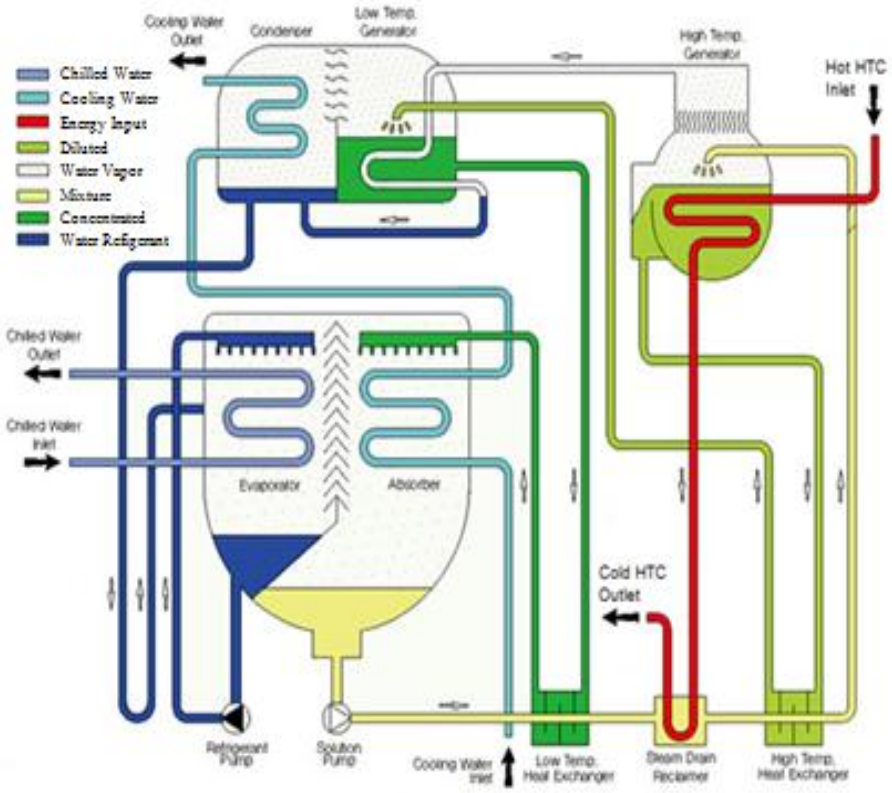

Fig.5 Single-Effect Absorption Chiller

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IV. OPERATION MODE - COOLING AND HEATING

In summer, the absorption chiller operates in the cooling mode which is the default setting. In winter, the absorption chiller will operate in the heating mode. The function ofenable for heating in the absorption chiller is by attaching a heat exchanger in the HTGshown in Figure 7 to heat the heatingwater in the heat water loop.From the figure, it can be seen there is an additional heat exchangerwhich is called hot water heat exchanger. The hot water exchanger is able to provide dedicated hot water entire year wheneverthe absorption chiller operates in either cooling mode or heating mode. The operation of heat mode is shown in Figure 8. In winter, the valve to theevaporatorand absorber is closed. The heating water loop is open in and connected the chilled water piping system for heating water circulation. The input heat energy heats the LiBr solution. The generated vapor heats the heating water in the tubes. The condensate returns to the LiBr-H_2O mixture and the process repeats. The operation of heating mode is quite simple. In heating mode, the generator is like a vacuum boiler.

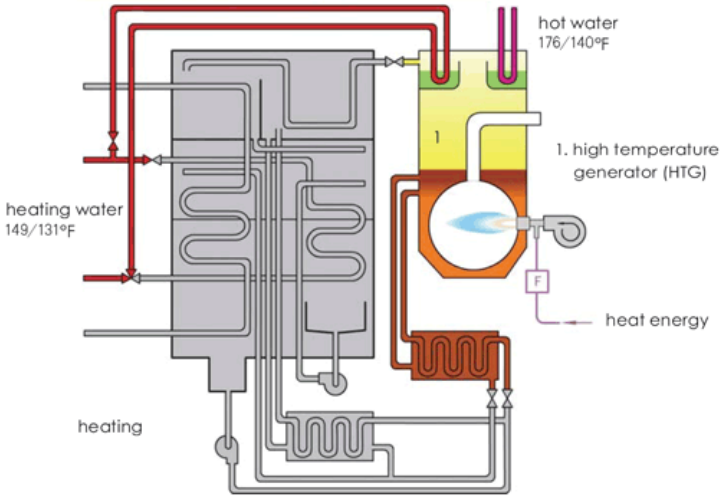

Fig.6 Double-Effect Absorption Chiller

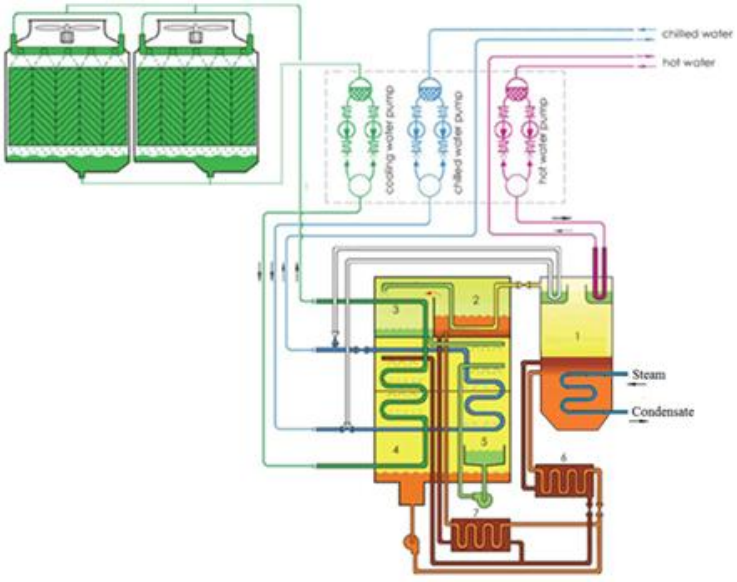

Fig.7 Construction with Piping Systgms for Cooling Mode and Heating Mode

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1 - High Temperature Generator
2 - Low Temperature Generator
3 - Condensor
4 - Absorber
5 - Evaporator
6 - Cooling Water Loop
7 - Chilled Water Loop

Fig.8 Operation of Heating Mode

V.SYSTEM CONFIGURATION OF ABSORPTION CHILLER

The absorption chiller can be powered by diverse energy input, for instance, waste heat from the gas turbine or engine, or solar energy, which makes the absorption chiller operating economically and environment friendly.

1) Powered by Waste Heat from Gas Turbine or Engine

A typical system configuration of the absorption chiller in HVAC powered by waste heat from the gas turbine or engine is shown in Figure 9. Generally, the exhaust temperature from the gas turbine or engine is quite high. The system shows the exhaust gas is directly supplied to the absorption chiller. The chilled water from the absorption chiller is used for cooling the HVAC supply air (SA) and available to cooling the gas turbine inlet air (IA). The lower IA temperature is, the higher gas turbine efficiency can have.

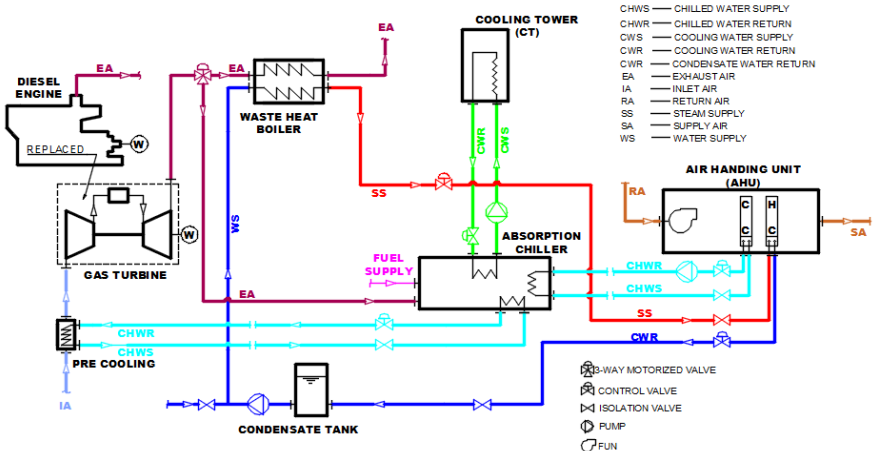

Fig.9 Absotption Chiller Powered by Waste heat From Gas Turbine or Engine

2) Powered by Steam or Hot Water

If the entire exhaust gas from the gas turbine or engine is used to heat water or generate steam in the waste heat boiler, then the hot water and steam can be supplied to the absorption chiller as energy input. Figure 10 is a typical system configuration for this application.

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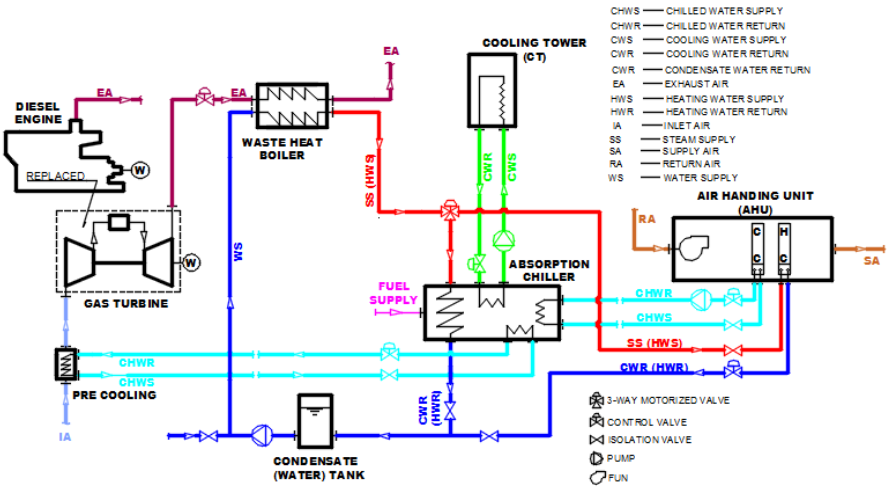

Fig.10 Absorption Chiller Powered by Hot Water or Steam

3) Powered by Solar Energy

The system of the absorption chiller powered by solar energy is quit straightforward. Figure 11 shows a typical system configuration in which the hot heat transfer fluid supply (HTFS) from solar energy system is used as the energy input in the absorption chiller.

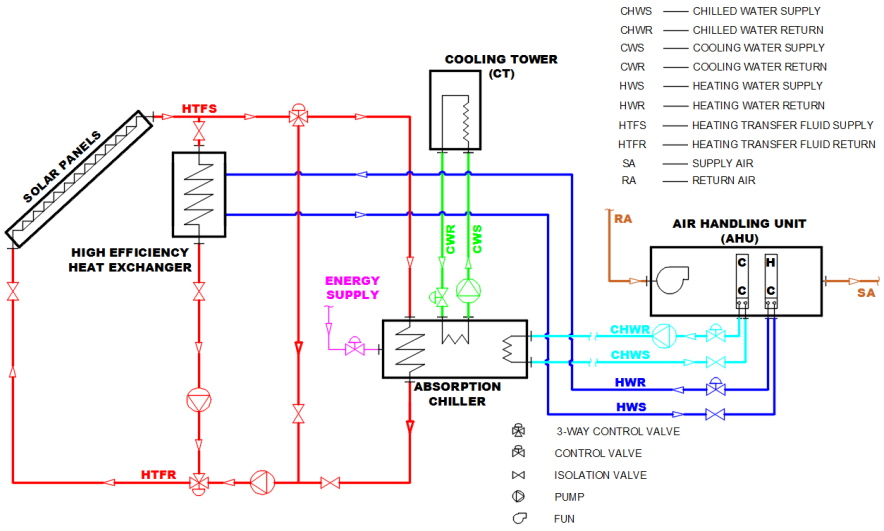

Fig.11 Absorption Chiller Powered by Solar Energy

VI. APPLICATION CASES

There are many installations of absorption chillers in the United States. Those absorption chillerscharged by diverse energy input are operating effectively.

Powered by waste heat from reciprocating engine:

Whole Foods Store in Brooklyn, NY. 260 ton cooling capacity. The absorption chiller is also equipped with a fuel burner using natural gas being a supplement of solar resources when necessary.

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Powered by hot water

Kauai Marriott in Hawaii. 240 ton absorption chiller powered by hot water. Cutting CO_2 emission to 758,000lb/year.


Powered by steam

VA Med Center in Bronx, NY.2000 ton double-effect absorption chiller powered by of steam.


Powered by solar energy

Steinway & Sons in New York.99-ton double-effect absorption chiller powered by solar energy. The double-effect absorption chiller is also equipped with a fuel burner using natural gasbeing a supplement of solar resources when necessary.


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VII. SUMMARY

The absorption chiller has been obtained largely attractive recent years and there are many installation being in operation successfully, hospitals, schools, and hotels, etc. Comparing to the electrical compression chiller, the absorption chiller consumes much less electrical energy. In addition, the absorption can be powered by diverse energy input, such as steam, hot water, waste heat, and solar energy. The usage of diverse energyinput allows the absorption chiller to operate economically and environmentally. The advantages of the absorption chiller over the electric compression chiller and absorption chiller types are illustrated in Figure12.

The absorption chiller is able to provide cooling and heating from one integrated unit. In summer, the unit provides cooling. In winter, the unitprovides heating. The unit can also provide hot water in entire year. There are two types of absorption chillers per the water refrigerant generation, single-effect and double-effect. COP of the single-effect absorption chiller typically is from 0.7 – 0.8, while two-effect absorption chillers typically is double than the single-effect, around 1.4 – 1.7.

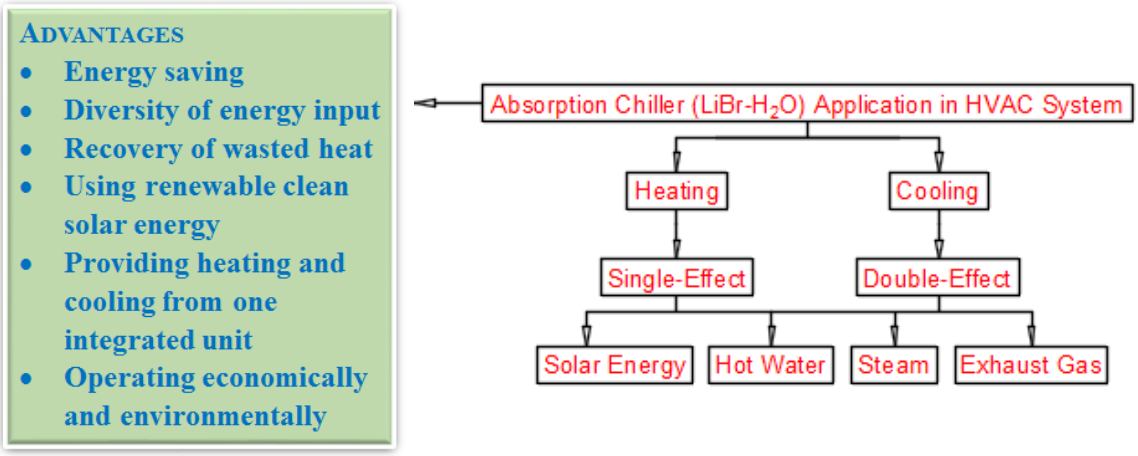

Fig.12 Advantages and Types of Absorption Chiller

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