Measurement of SAHP System

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Abstract

The research & development of new energy sources and energy saving are two key ways to solve the potential global energy shortage.The SAHP system has a wide and wonderful future for its excellent performance in energy conservation and environment protection.The R & D of this kind of technology will offer some useful reference to generalize and utilize it all over the country.

The author describes the design and installation of an experimental device of the SAHP.In order to observe and measure the overall thermal performance of the system and the performance of its components,the space heating tests in winter have been done using this experimental device.Some important reference data and conclusions for design,installation,operation and management of the SAHP are presented based on the experiment.

Preface

It is well known that solar energy is clean ,cheap and rich a lot.At present shortage of carbon and hydrogen fuel forces scientist to develop new energy.Developing solar energy is a best one among so many ways to be solved.However solar utilization is influenced by weather very much.The difficulties must be overcome.Great achievements have been got fortunately so far.

As far as China is concerned,some results have been obtained too,e.g.solar heater for domestic hot water,and,constrution of passive solar houses that however couldn't supply heat in winter night. The auther designed a heating installation using solar energy and heat storage in cooperation with heat pump in 1998.The solar collector was manufactured using plate radiator being bought in market with low price,only RMB 500 Yeun per square meter..The heat storage is designed according to short term,therefore its volume and price both are ideal. The function of the heat storage can store part of heat from the collector at day time. And then,it releases the stored heat to the HP at night time.

Purpose of this experiment is to run and test this installation to get experience of design and management.The test will be continued next season.

Experimental instalation and measurement system

The installation was rebuilt based on original HP laboratory,its floor area is 61 square meters, among that heated house is 41 square meters.

Fig.1 shows a principle sketch of the installation. Main circuit is drawn in the fig.1

only.

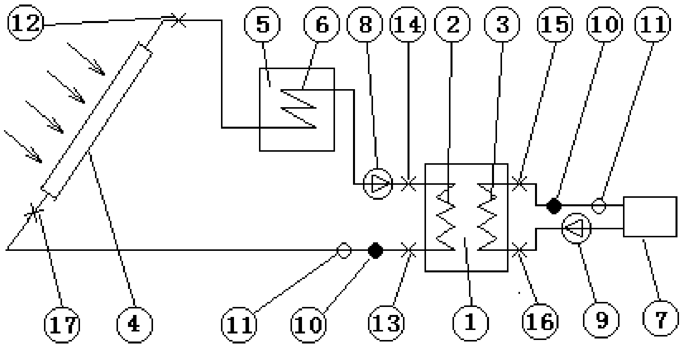

Fig.1 Principle sketch of SAHP

Each component is as folloing:1) HP unit Model OM 300 piston compressor made in Copland,power 2.2 KW F-22.2)Evaporator 3)Condenser.4)Plate solar collector. 5 peaces each area is 2.2 square meters.Angle of horizontal is 52 degrees.5)Heat storage.Inner size is 1300*1300*1300 mm.Net volume is 2.1 cube meters,outer size is 1700*1700*1700 mm.Made of steel plate.Isolation layer consists of 200 mm thickness of stonewool.6)Coil heat exchanger made of plastic tube of D32*2.5 mm put in the storage box.108.8 meters in total length.7)Two vertical fan-coil units FP-5 50 W each.8)Piping pump 12WG-8 90W.9)Piping pump DO2-6312 120W.10)Cumulative flow meter MCE 08-787 D24 mm.11)Float flow meterLZB-2.D25mm..12)13)14)15)16)17)Copper-Constantan thermocouples.Seven couples put in the storage are not shown here.18)solar radiation meter TBQ-2.19)Meter S-923BC to measure condenser pressure.20)Meter S-925BC to measure evaporator pressure.18)19)20) are not shown in the fig.1.

In order to get more informations , 3 electric resistance heaters are put in the storage.Each power is 1.0,1.5,2.0 KW separately.Indoor and outdoor main components are connected by tube of D25 mm.Outdoor parts of the tube system are wrapped by polystyrene material poamed and the indoor parts are not isolated.The circuit connected to the evaporator is filled with antifreeze solution,whose volume ratio between alcohol and water is 1:2.The circuit connected to the condenser is filled with water only.Fig.2 shows a picture of the sun collector.Fig.3 shows a picture of the storage.

Fig.2 Solar collector

Fig.3 Heat storage

Flow direction of evaporator circuit is in following order:The solar collector 4—The coil 6 put in thestorage 5— The water pump 8— The evaporator 2—The cumulative flow meter 10—The float flow meter 11— The collector 4.The collector and the heat storage can be used separately or simultaneously by cotrolling bypass valve.Direction of the condenser circuit is as folloing:the fan-coil 7—The water pump 9—The condenser 3—The cumulative flow meter 10—The float meter 11—The fan-coil.

Main parameters , e.q. temperatures and sun intensities, are measured and recorded by an instrument HP34970A automatically.Electric energy consumptions by HP,WP,FC,or,ER are measured by an electric meter DF made in China and meter C14GIY made in Sweden.

Experimental method and procedure

In order to get the targets mentioned before long term experiments and observations have been conducted on the unit all day and all night.The following data have been measured:instantaneous input powers,cumulative energy consumptions of the unit;flow rates and cumulative volumes of liquid through both the evaporator and the condenser separately, which are all recorded artificially;temperatures on different points,which are indoor and outdoor air,both sides of the evaporater,the condenser,the collector and the storage as well as the sun intensities.The temperatures and the sun intensities measured are recorded and printed automatically once an hour during the total experiments,some time once half hours.

The test started on 23 th Nov. 2000 and stopped on 31 st Jan 2001.The unit has been run for 683 hours so far. The test is conducted accoding to following way:It is run for several days continuously,and then, stopped.Its recorded data would be managed and calculated.After that the test is restarted once again. The same test will be done several times,Before 24 th Jan.2001 the unit has been run for 548 hours.From 8:00 o'clock 24 th Jan. to 8;00 o'clock 28 th it has run for 87 hours continuously. The data presented in this paper is results got from 28 th to 29 th just.

Results of the measurements and analyses

During the period running for 683 hours the electric heater was switched off,and ,the indoor temperatures were kept in 20oC basically.That means the design is successful. The data of 28 th –29 th can be considered as typical,therefore it will be an important reference for design and management.

During the period energy consumtion is 44.8 KWH (or everage 1.95 KW) by HP,5.95 KWH (or everage 259 W) by WP, and, 1.95 KWH (or average 85 W) by FC separately.

Fig.4—Fig.8 show the measuremental results of the SAHP.The collector and the heat storage are running serialy during the entire test period.Horizontal coordinates represent time HOUR which is from 8:00 o'clock 28 th to 7:00 o'clock 29 th.It is noted that No.25 in the coordinates means 1:00 o'clock 29 th,No. 31 means 7:00 o'clock 29 th.

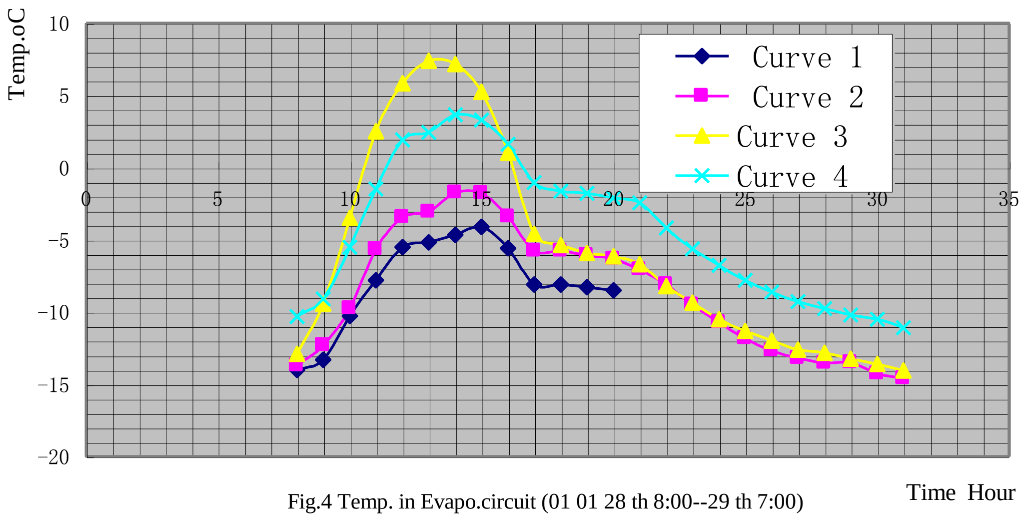

Fig.4 Temp. in Evapo.circuit (01 01 28 th 8:00--29 th 7:00)

Fig. 4 shows temperatures of each characteristic point of the evaporator. Curve 1 is evaporation temperatures being converted by measured pressure.It is not recorded after 20:00 because of artificial reading.Curve 2 is temperatures of solusion coming out the evaporator and entering the collector directly T13.Curve 3 is temperatures coming out the collector T12.Curve 4 is temperatures coming out the storage and entering the evaporator T14.The four curves all change with the solar intensities.The maximum point is at 13:00—15:00 and the minimum point is at 7:00—8:00,when solusion temperature is minus 14.6oC.After eight o'clock the temperature begins to rise going round and round.The maximum temperature difference entering and coming out the collector ,T12-T13,is 10.45oC at 13:00 o'clockThere are not differences nearly after17:00 until 7:00 in the morning , when daily average temperature is about 2.8oC.The maximum temperature difference entering and coming out evaporator,T14-T13,is 5.49oC at 13:00 o'lock.The minimum is 3.5oC at 7:00 AM. The average is 4.26oC for one day.It is easy to see that the evaporator gets heat from the storage continually during the 23 hours.

Fig.5 represents heats got by the evaporator.Curve 1 is solar radiation heat radiating to the five collectors KW that is product of solar intensity and area of the collectors.Curve 2 is heats obtained by the collector from the sun KW.Curve3 is heats obtained by the evaporator from the storage KW.The maximum intensity of the sun is 10.28 KW at 12:00 o'clock.It becomes a little at 7:00-8:00 o'clock.On other time it is zero.The total heat of solar radiation is Q1=58.12 KWH for one day.The heats got by the collector and the radiation of the sun synchronize basically.The maximum got by the collector is 7.23 KW at 13:00 o'clock..From 17:00 to next 7:00 o'clock only a little heat is got that is obtained from surrounding air instead of the sun.The average heat got during the 23 hours is 1.94 KW.Obviously the collector itself without the storage couln't contribute enough and continuous heat to the evaporator.

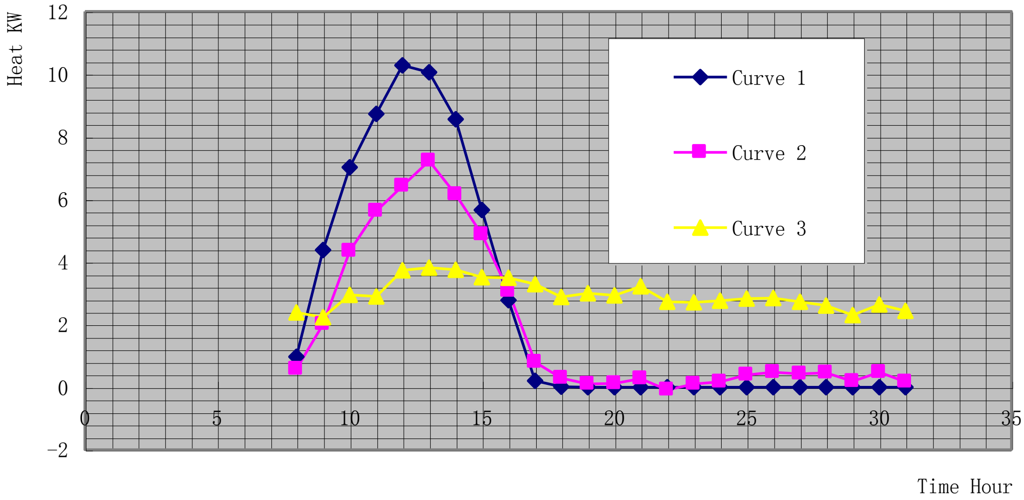

Fig.5 Heat got by Evapo.(01 01 28 th 8:00—29 th 7:00)

The heat got by the collector is calculated:

Q2=15.71*3.82*2.79*969*0.991

=160783.4KJ

==44.7 KWH

Where 15.71 cube meter liquid volume flowed though the collector for one day.

3.82 KJ /Kg K specific heat.

2.79oC average temp.difference.

969 Kg/M3 specific density.

0.991 correct coefficient of the flow meter.

The daily average effectiveness of the collector is

E=44.7 /58.12 = 76.8%

It is pointed out that a little heat comes from surrounding air,because the temperature of solusion is lower than air.The real effectiveness is 67% in fact.

The curve 2 and curve 3 are compared:heats got by the evaporator change very gently . The maximum is 3.82 KW at 13:00 and the minimum is 2.40 KW at 7:00—8:00 in the morning.The evarage for one day is 2.96 KW.Obviously function of the heat storage guarantees and contributes stable heat to the evaporator continuously all day and all night.

The heat got by the evaporator for 23 hours:

$$Q3 = 15.71*3.82*4.26*969*0.991$$

$$= 245497.2 \text{ KJ}$$

$$= 68.3 \text{ KWH}$$

Where 4.26oC temperature difference.

It is easy to know that heat got by the evaporator is more 23.5 KWH than the collector.There are two reasons:1 The heat storage and outdoor tube get heat from outdoor air.2 Indoor tube and header not being isolated get heat from indoor air.

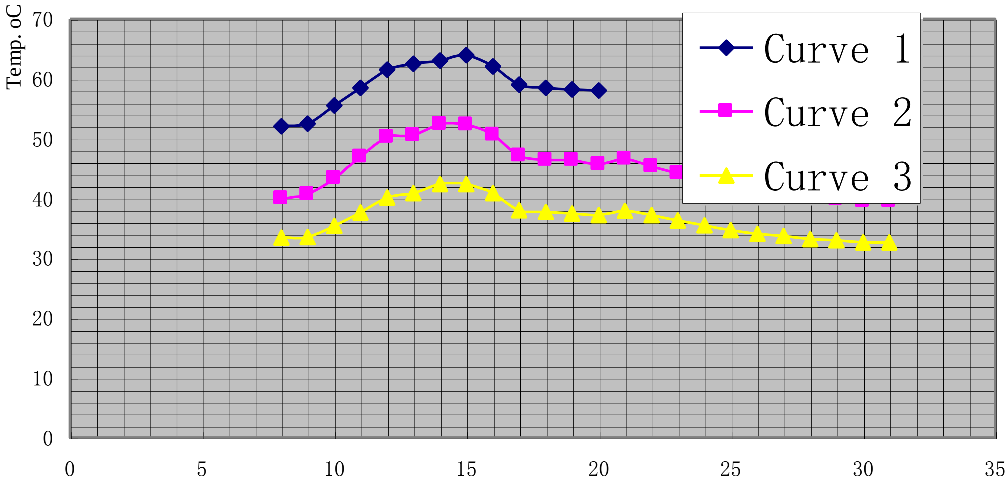

Fig.6 Temp. in cond.circuit (01 01 28 th 8:00--29 th 7:00)

Fig.6 represents temperatures of each charictoristic point for the condenser circuit.Condenser temperatures recorded artificially are drawn in Curve 1.Curve 2 is water temperatures coming out the condenser and entering the fan-coil T15.Curve 3 is water temperatures coming out the fan-coil and entering the condenser T16.Differences between the two curves express temperature differences coming out and entering the condenser.Shapes of the three curves are similar each other following the sun intensity.The maximum temperature of water coming out the condenser is 52.5oC at 14:00—15:00 o'clock. The munimum is 39.5oC at 7:00 o'clock.The maximum difference coming out and entering the condenser is 9.9oC at 15:00 o'clock.The minimum is 6.9oC at 7:00 o'clock.The average temperature difference for 23 hours is 8.22oC.the little difference change means:heat supply stable a lot.

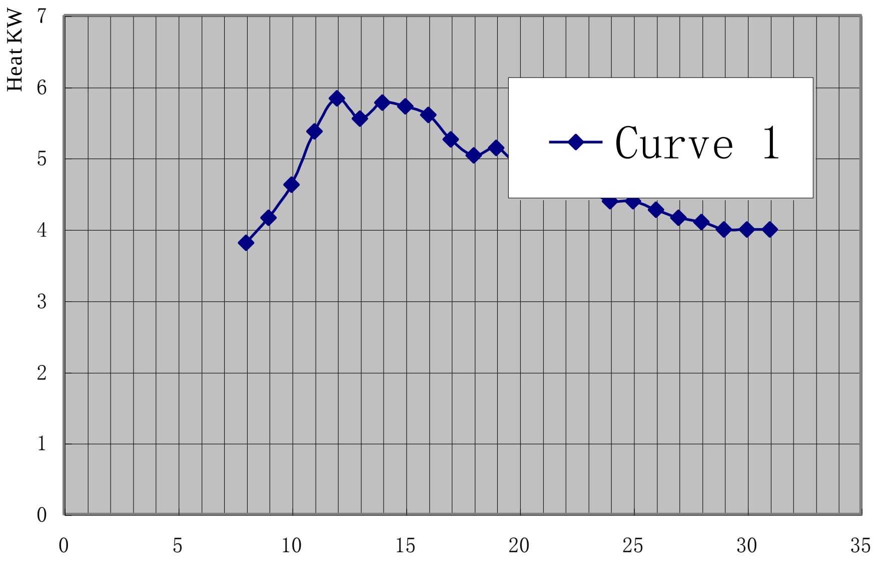

Fig.7 Heat released by condenser{01 01 28 th 8:00--29 tn 7:00)

Fig.7 is heats offered by the condenser and got by water,that is,the heats are contributed by the SAHP to the heated room,KW.The area below the curve 1 represents total heats offered to the room,KWH.The maximum heat is 5.77 KW at 14:00—15:00 and the minumum is 4.0 KW at 7:00 in next morning

The tatal heat offered to room:

Q4 = 11.77*4.18*991*8.22*0.98

= 392757.3 KJ

= 109.1 KWH

where 11.73 M3 water volume through the condenser.
4.18 KJ/Kg K specific heat of water.
991 Kg/M3 specific density of water.
0.98 correct coefficient of flow meter.
The energy consumption by the HP unit is 44.8 KWH and heat got by the evaporator is 68.2 KWH.Thus output heat by the HP will be:

Q5 = 44.8 + 68.2 = 113 KWH

Error (Q5 – Q4) /Q5 =3.5%

COP of the HP =109.1 /44.8 = 2.44

COP of the System = 109.1 /(44.8 +5.95 +1.95) =2.07

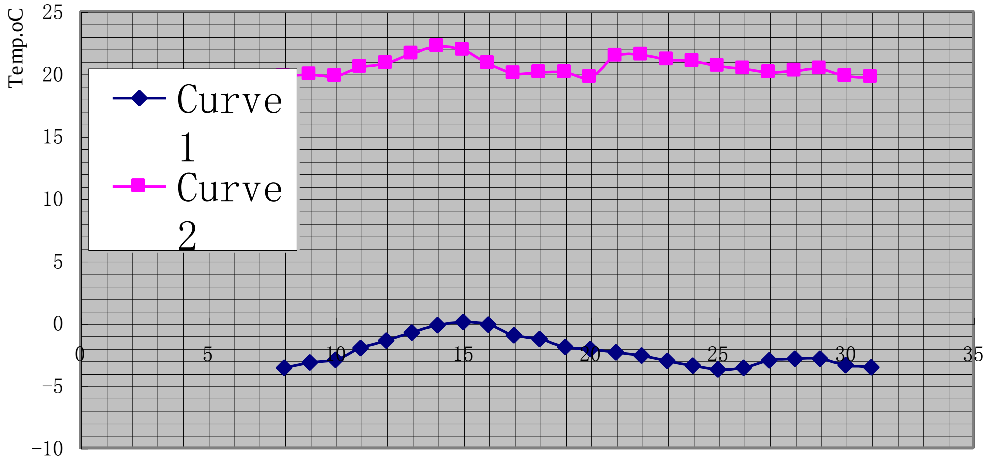

Fig.8 Indoor and outdoor Temp.(01 01 28 th 8:00--29 th 7:00)

Fig.8 shows indoor and outdoor temperatures.Curve 1 represents outdoor temperatures following the sun intensities. The maximum is 0.08 oC at 15:00 o'clock.It is below zero in all other time.The mimimum is –3.71oC.From night after last to early in the morning it is below -3oC. The average for one day is –2.23 oC.Curve 2 represents indoor temperatures.The higher than 20oC of indoor temperature is kept all day and all night. It is pointed out that if windows are not opened in day time,the indoor temperatures will be achieved more than 25 oC.Thus in order to get indoor temperatures of 20oC,the windows should be opened or closed depending on outdoor weather.

Conclusions

1 The design requirement is met by the simple plate solar collctor researched and developed absolutely.Its average effectivness for one day is 65%.It will have wide market because of cheap price.

2 The area of the plastic heat exchanger and the volume of the storage match the solar collector very much,which can let the sun energy become stable heat source for the evaporator continuously , the average of which is 3.0 KW.

3 The GAHP can contribute heat to the heated room all day and all night,the average of which is 4.75 KW having a little change only.

4 The COP of the HP is 2.45 for one day, the COP of the system for one day is 2.1.

5 When the outdoor temperature is –2.23oC,the indoor temperature is 20oC without switching on the heat resistance at all.

6 A little heat fluctuation exists,which needs to be improved later.

Reference

Yuhui Kuang”The R & D of Solar Assisted Heat Pump System for Heat Supply” Qingdao Institute of Architecture and Engineering Master thesis Apr. 2001