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Absorption chiller cycle (NH_3-H_2O) Driven by Solar Energy

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***ABSTRACT** : This manuscript proposes to study by the use of computer simulations and experimental tests, the possibility of applying a chilled absorption (ammonia/water) using solar heat to cooling. Absorption cooling (ammonia/water mixture) is eco-friendly and in addition, can be powered by low-temperature resources. This unit can recover low heat source, with a low temperature difference between heat source and sink. They have good availability, simple start up procedures, good part load and require little maintenance. Computational modeling and simulation have become an important part in studying technologies and evaluating their range of applications. They can save time and money, offer flexibility, enables repeatability, improve control and allow the user to push system and change or add the inputs for get new results., this was the ideal method to devise and test the proposed models and investigate their performance in different conditions. The operation of the absorption chiller cycle, a temperature source of 103°C and a cold sink temperature of 25°C for heat rejected was used. Thise energy source can be used to operate ammonia/water mixture chillers, to produce cooling at acceptable thermodynamic ranges and within standard limits for domestic use. The hot water from the accumulator water cycle will supply to the generator of the ammonia/water mixture sorption cycle. The results from the simulation have revealed that the low-temperature solar sources at Al-Joufra city were successfully utilise to generate power. The highest cooling capacity of the chilled water that could be supplied to the community was at a temperature of -15.6°C. In the evaporator of the ammonia/water mixture cycle, the inlet water was 12ºC and the outlet water which will cool down the house by 6ºC (cooling water cycle). These results have been achieved when the cycles were simulated at an ambient air temperature of 23ºC, heat input was 61.8 kW*

I. INTRODUCTION

Due to emissions such as greenhouse gases, a number of countries are now considering alternative sustainable methods to help reduce the cost and side effects of power generation. Libya is a country with high solar radiation due to their climate, especially in the desert region. D. M. Hassan et al, [1] presented very good results in solar radiation measurements, with data available. This renewable source of solar energy in Libya can help to provide a reduction in fuel consumption and emissions of harmful greenhouse gases. This paper is a study into the possibility and application of cooling by computer simulations and experimental tests. The results of this study apply to any country in the world with a hot climate, although the focus is on the countries of North Africa in the Sahara region, such as Libya. This study will investigate the use of renewable energy sources such as solar energy. The potential of low-temperature resources has received little interest in the majority of developing countries and industrial nations. This lack of development is due to regulatory barriers and institutional, economic and financial issues. These barriers exist even though the low-temperature resources are available throughout the year and have great benefits to the environmental and socio-economic development of all countries. Most important of which is that it may provide a stable, domestic energy supply, acting as a source of clean energy for developing countries. Therefore, these developments will allow all countries to assess the use of low-temperature resources. They will include solar energy in the national planning and exploitation, thus reducing greenhouse gas emissions and improving environmental air quality. This is especially important for developing countries such as Libya. A computer simulation model is presented and is the most fundamental part in all the studies and applications. The simulation model will help save time and money, provide flexibility, enable analysis repetition and provide a system oversight with the ability to vary the boundaries. Experimental work for this study was carried out to test the proposed models and investigate their performance under different working conditions. The software package used for the work was using S. Simulation and technology [2] and is designed by SimTech Simulation Technology. It contains a set of modules and libraries that allow a user to create analyze and utilize models for new or existing process plants throughout their life cycles. IPSEpro is an extremely flexible modeling system for calculating heat balances and simulating many types of industrial processes e.g. gas turbines, combined cycles, desalination and refrigeration.

II. AIMS AND OBJECTIVES

The first aim is to find solar irradiance and ambient temperature data from the science sources and studies at Al-Joufra city in Libya. This will help to determine the levels of solar energy available in the area for this plant. The second aim is operation of the absorption chiller cycle using IPSEpro software. According to the literature and thermodynamic limitations, the most suitable way to utilize low-temperature solar sources of energy is to use it as a powering source for low heat powered cycles such as ammonia/water mixture absorption chillers. This cycle can provide cooling power at acceptable economical limits without causing any damage to the climate.

III. THE CYCLE OF ABSORPTION REFRIGERATION CHILLER AND PROCESSES

Didion and Radermacher [3], a typical schematic diagram for a single effect absorption cycle shows in figure I shows the waste heat (Q_{ge}) is supplied to the generator to vaporize to the refrigerant from the solution. The vapour then passes through the condenser at high pressure (HP), where cooling media is used to condense the vapour back to liquid state and reject an amount of heat (Q_{Co}) to the sink. Then the liquid flows down to pass through an expansion valve to enter the evaporator at low pressure (LP), where it passes over tubes containing the fluid to be chilled. The liquid is evaporated by maintaining low pressure while continuous heat flow (Q_{ev}) is absorbed from the medium to be cooled in order to produce a cooling effect (chilled water). The solution becomes weak and is cooled by rejecting a certain amount of heat (Q_{ab}) to the sink directly or it passes through the condenser before it reaches the sink. The cooling media of the absorber and condenser could be either air or water.

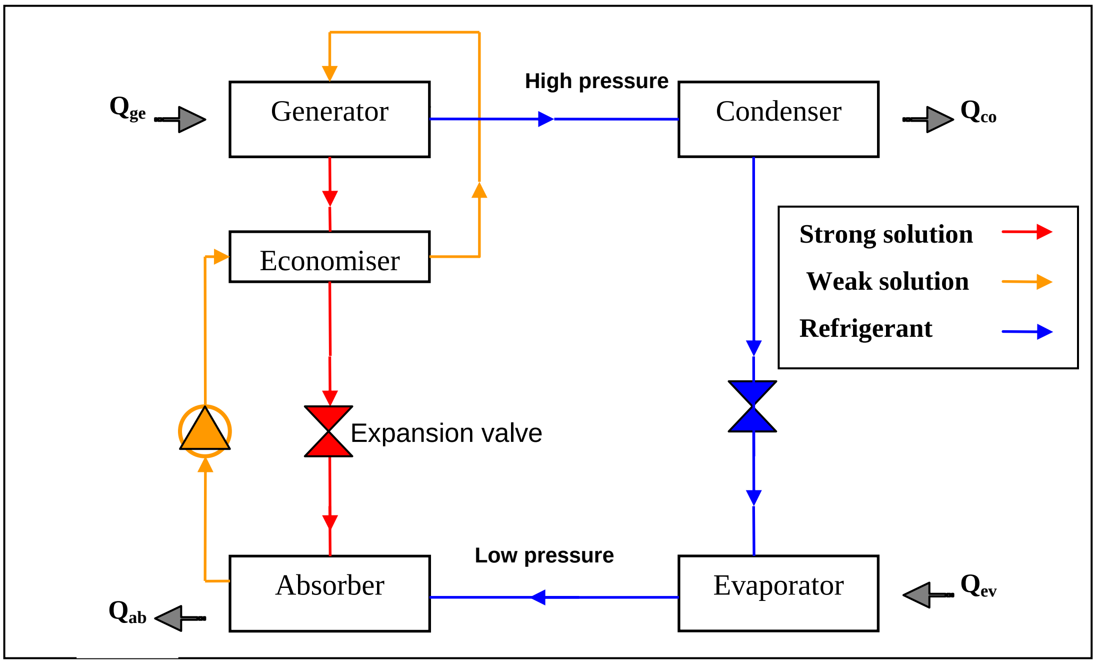

Figure . Schematic diagram of NH_3-H_2O absorption refrigeration cycle

IV. ABSRPTION CHILLER MODEL

The absorption cycle models is proposed and studied. The selection of the cycles' structure was based on recently published technical information of low-temperatures powered Ammonia-water absorption chillers. The cycles were completely modeled using different components available within the refrigeration library of software package. Using the model a cold-water ammonia-water absorption chiller was examined and validated in accordance to the relevant thermodynamic laws and charts. One of four readily available high potential artesian low-grade temperature solar resources was modeled to energize the proposed models. For water-cooled cycles, the rejected heat from the absorbers and the condensers was carried out by water, at an average fixed temperature of 25°C, pumped out from ground water.

4.1 Model description and processes

An absorption cycle using ammonia-water mixture working fluid is perhaps the simplest manifestation of absorption technology. A schematic of such a cycle is provided in Figure II. The components and the streams are labeled, and the state points in the connecting lines are assigned state point numbers. Point (10) is a low-pressure refrigerant vapour that enters the absorber. The solution leaving the absorber part comprises a high concentration level of refrigerant (1) that has a weak capability to absorb the refrigerant liquid, Ashrae, Handbook [4]. This is pumped with the necessary pressure from the generator (4). The low concentrated refrigerant solution remaining in the generator is described as a strong solution (ability to absorb the refrigerant). The strong solution at point (11) will return to the absorber. The high temperature and pressure refrigerant vapour (5) leaves the generator and goes to the rectifier, after which it will enter the condenser point (7). This results in a decrease in the temperature that condenses it into a liquid (8). The refrigerant will pass through an expansion valve, resulting in a decrease in the evaporator pressure (9). The refrigerant vapour at point (10) will leave the evaporator and return back to the absorber for completion of the cycle.

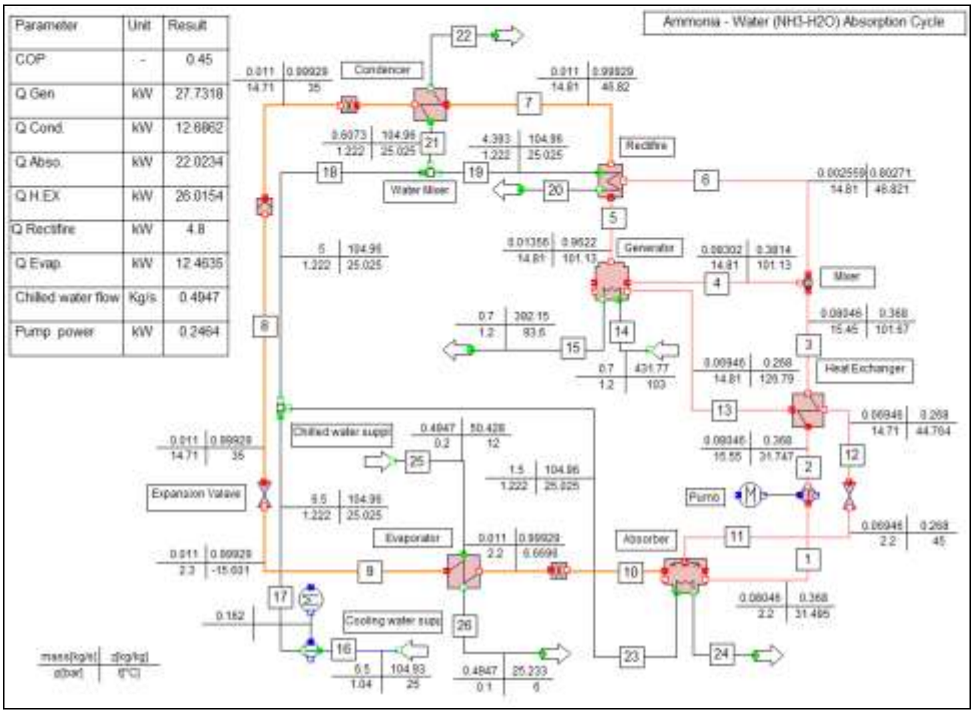

Figure **.** Schematic diagram of the water-cooled absorption chiller

A conclusion of the state point's explanation is shown in Table I. As listed in the table, three points are saturated liquid (1, 8, and 13), three are sub-cooled liquid (2, 4, and 12) one is saturated vapour (10), one is superheated vapour (7), two are two-phase vapour-liquid states (9) and (11), providing a total of ten state points.

Table **.** Model thermodynamic state points summery

Point	State	Point	State
1	Saturated liquid solution	11	Vapour-Liquid solution state
2	Sub-cooled liquid solution	7	Superheated ammonia vapour
4	Sub-cooled liquid solution	8	Saturated liquid NH3
13	Saturated liquid solution	9	Vapour-Liquid mixture NH3
12	Sub-cooled liquid solution	10	Saturated NH3vapour

V. MODEL VALIDATION OF CHILLER

The model validation was carried out using equipment called the Chilli® PSC12, Solar and Next [5] and Wang et al [6] manufactured by a company called Solarnext. The following effects of heat reject water on the cooling capacity are noted; when the inlet re-cooling water temperature increases both the cooling capacity and COP will decrease. This occurs in the real and model cycles when the ambient temperature is fixed. The increase in the heat reject water inlet temperature, over relatively small temperature range (24-27 ºC), has a major influence on the cooling capacity. Increasing the re-cooling water inlet temperature by only 4 degrees shown in figure II, causes the cooling capacity to decreases from 13.1 kW to 11.7 kW for the real cycle and in the model cycle from 13.3 kW to 11.9 kW. Considering the range between 27-30°C. The cooling capacity of the real cycle decreases from 11.2 kW to 8.7 kW with a difference of 2.5 kW and model cycle from 11.4 kW to 10 kW with a difference of 1.1 kW. The difference between the real and model cycles was 1.4. The effects of heat reject water when the ambient temperature increases will change both the cooling capacity and COP value. It is more effective to use underground water in hot environments but in air-cold (e.g. cooling tower) the ambient temperature will have an effect on the cooling capacity and COP value.

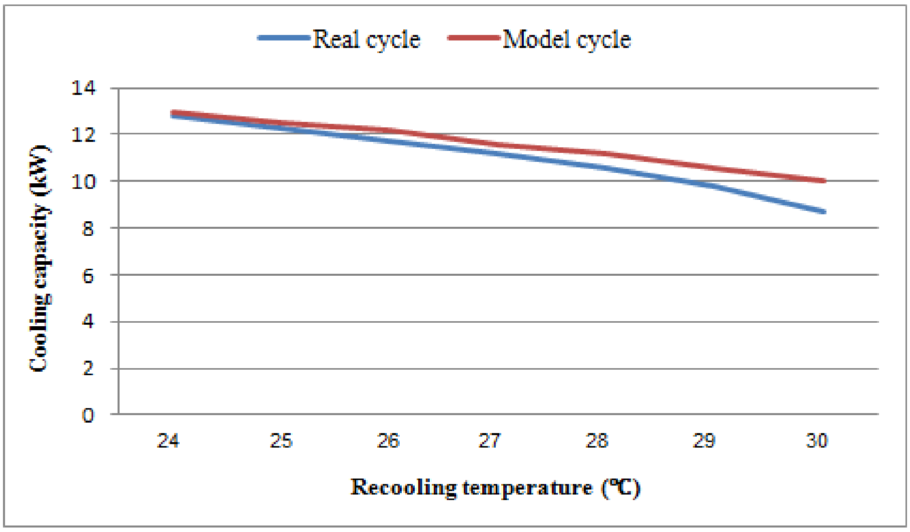

Figure □. R-cooling temperature (°C) real/model with cooling capacity (kW)

VI. RESULTS

The obtained parametric results, of the proposed chiller model, such as the coefficient of performance (COP), the refrigeration capacity, the main cycle components heat transfer, the hot water supply energy, the cooling water mass flow, the components heat transfer coefficient area, and the solution circulation ratio are listed in Table II.

Table □. The water cooled Ammonia-water absorption chiller output results

Description	Result	Unit
COP	0.45	-
Rectifier heat transfer	4.8	kW
H.EX heat transfer	26.01	kW
Heat energy input	27.7	kW
Absorber heat transfer	22.02	kW
Condenser heat transfer	12.68	kW
Cooling capacity	12.46	kW
Chilled water flow	0.49	Kg/s
Condenser UA	1.11	kW/K
Evaporator UA	1.07	kW/K
Solution H.E. UA	1.41	kW/K
Mass flow rate input	0.7	kg/s
Solution circulation pump power	0.24	kW

From the results above, it can be seen that any changes in any one of the system parameters will cause a change in the performance of the overall system:

The effectiveness of the generator inlet temperature (solar source) is a factor of the largest effect on to the COP. The difference was 0.1401, 27.4 %. The chilled water inlet temperature (underground water) is the second largest effect on to the COP. The difference between the maximum and the minimum value is 0.0865 and The influence of absorber temperature and condenser temperature on to the COP are almost identical, the relative difference is 19.2% and 18.9% respectively.

VII. CONCLUSION

A simulation model was developed to calculate the performance of the aqua-ammonia vapour absorption system. An application of the model to evaluate the influence of the system parameters on to its COP proved that the model can be used to analyze the effects of any changes to the parameters of the system Coefficient of Performance (COP). This may increase the COP value by more than 0.4 using a computer model as provided by [7]. In order to analyse and improve the ammonia/water absorption system, a mathematical model describing the cycle and its equations for calculating the thermodynamic characteristics was established. The results show that the complete system behaves with some unique characteristics. The selection of the generator temperature is a significant factor for achieving high system performance. Detailed improvement processes and their results are shown as very good operational maps under different working conditions. These maps are very important in the selection of the operating conditions for present system or for planning new systems. They can also be used to provide automatic control of the systems. This research shows the improvement in system performance and the adding up of a liquid sub cooler may increase the COP value of a system.

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