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Research paper

Designing of advanced solar absorption chilling unit

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Abstract

In emerging nations, access to electricity is inconsistent is a widespread issue. This research aimed to design an absorption chiller based on utilising heat from a solar tracker system to power a chiller. For this purpose, a solar-driven ammonia absorption chilling system is designed. The solar-powered absorption chiller is a chilling system designed to offer refrigeration to developing areas. It is an intermittent system in which ammonia and water are used as absorbent and refrigerant respectively. A small-capacity vapor ab-sorption system was first simulated and its parameters were compared with the calculated ones. The main constituents like condenser, evaporator and generator are designed based on capacity. The basic heat and mass transfer equations relating the working properties are specified. The coefficient of performance (COP) obtained from experiments is in the range of 0.3-0.4.

Keywords: *Ammonia; Chilling Unit; Condenser; Evaporator; Solar Absorption.*

1. Introduction

Refrigeration has become a fundamental part of our living life. Almost everybody has a refrigerator, although few know about the procedure requisite to deliver the drop in temperature, known as refrigeration. Nature works a lot of like a warmth motor, heat streams from high-temperature modules to low temperature modules have appeared in Figure 1. Refrigeration is a method to keep a cool component cool or to decrease the temperature of one part beneath that of the other. This technique is, basically at that point, an invert heat motor; where heat is taken from a cool component to be moved to a hotter component by adding work to the framework. In a heat engine, work was completed to do the reverse; effort must be done to the framework. This input effort is customarily mechanical work, similarly be focused by magnetism, acoustics, lasers and various methods [1], [2]. In the United States, it is easy to take amenities like refrigeration for granted. However, developing countries cannot use traditional refrigeration because it requires electricity, which is unreliable or non-existent in most areas of the developing world. Disease, malnutrition, and economic struggle are just some of the debilitating trends that could be reversed if access to reliable and affordable refrigeration were an option. In the country of Pakistan, a developing nation, most of the labor force works in agriculture. Access to water is plentiful due to geographical location, but electricity is only available to 14.8% of the population (EIA). Therefore, average farmers cannot use electric refrigeration to store their perishable goods. Speaking to Thermogen (an NGO based in Pakistan), the primary motivator for access to refrigeration is to reduce dairy spoilage. Currently, only milk produced in the morning can be taken to markets and the Food and Agriculture Organization estimates that about 27% of all milk produced in Pakistan is lost due to spoilage, spillage, or waste. The value of these losses is US$23 million a year (FAO) [3], [4].

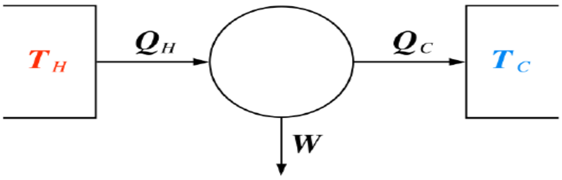


Fig. 1: Schematic Diagram of Heat Engine Thermodynamic.

In addition to the economic incentives, lack of refrigeration is a contributing factor to malnutrition and foodborne illness [33.9% of children in Pakistan, under the age of 5, are severely underweight (CIA)]. Conventional refrigeration is not a feasible solution due to lack of electricity; however, the implementation of a solar-powered refrigeration system can provide much-needed refrigeration to rural communities that currently lack such modern conveniences [4], [5].

The benefits of an absorption chiller refrigerator powered by concentrated solar power (CSP) are many. First, concentrated solar power, on a residential scale, presents many opportunities for the use of heat. Although this project focuses on the application of CSP for absorption refrigeration, the heat from this could also be used for water desalination, electricity production, and heat for cooking or sterilisation. Second, the absorption chiller refrigerator itself has fewer moving parts, making it an ideal choice for an area with limited access to the outside world for replacement parts or maintenance. Ultimately, this refrigeration system uniquely combines several known technologies to deliver refrigeration to areas that can greatly benefit from it [6], [7].

In a perfect speaking COP of an absorption refrigeration framework is about 2.0. However, it is under 1(about 0.4-0.7). Effectiveness of absorption chillers is defined regarding coefficient of performance (COP), characterized as the refrigeration impact, isolated by the net heat contribution to (equivalent units, for example, Btu). As the COPs are less than one, the single-impact chillers are ordinarily utilized in applications that recoup waste heat, for example, waste steam from control plants or boilers. Twofold impact absorption chillers have COPs of roughly 1.0 out of 2.0. While not yet economically accessible, model triple impact retention chillers have determined COPs from 1.4 to 1.6. The COP metric is additionally applied to electric chillers. As COP depends on on-site energy, it isn't useful for relating gas and electric chiller efficiencies. By modern standards, non-sustainable power sources are exhausted continually, and the earth loses a fight each day to people. Destructive emanations from non-renewable energy sources and chlorine-based refrigerants have prompted monetary and all the more harshly, natural hardships [8], [9].

The absorption refrigeration frameworks are considerably more costly than the vapor-compression refrigeration frameworks, which are very evident as their expense of generation is high due to complex and huge parts. Some of the absorption chillers, which are infamous for freezing or crystallization. The principle instrument of destruction is very basic - the lithium bromide (LiBr) arrangement is concentrated to the point that gems of LiBr frame and interface the machine (when in doubt, the warmth exchanger segment). The well-known causes are air spillage into the machine, electric power disappointments, and low temperature of the condenser water.

Regardless of the leakage of air in the condenser water temperature is excessively low, the weight of water fume in the retention of the evaporator ought to be lesser than expected to create the essential cooling. This causes the heat input to the machine to be higher for the expansion of the solution concentration. Air leakage into the machine, can regulate the structure of the machine with fixed reliability and routinely cleanse the machine with a vacuum siphon [9], [10].

Coldwater condenser may also prompt the crystallization. The condenser water temperature decrease can build execution, cause a significantly low temperature in the warmth exchanger to crystallize concentrate. The fall of the temperature of the condenser water can prompt the crystallization. Therefore, a portion of the early absorption chillers has been created to deliver a consistent water temperature of the condenser. Present-day absorption chillers exceptional regulator that utmost the utilization of warmth for the machine through the time of low condenser water temperature. Power disappointments can prompt the crystallization. Ordinary absorption disables be utilized to weaken the cycle, which lessens the grouping of the entire machine. This decreases the grouping of the machine can chill off to encompassing temperature deprived of crystallization. In any case, if the machine is in full burden the control is lost, and highly concentrated solution goes through the warmth exchanger, crystallization may happen. The more prominent the power, the more probability of crystallization [11], [12].

Based on review of previous works and social data, we determined that there is a market for solar thermal refrigerator and experimental evidence of potential success. The objective of this project was to develop a refrigeration system that could be implemented in the developing world using a solar tracker system and an absorption chiller refrigerator. This would be done by retrofitting an absorption refrigerator to be powered from a heated fluid. Designing a test to determine initiation temperature for the absorption cycle. Designing a fluid circulation system to deliver heat to the refrigerator from the receiver. Retrofitting subsystems to utilize practically no power and bringing expenses of framework down to be reasonable for NGO's in developing countries. COP expect to improve the COP of the absorption refrigerator to make it progressively appealing for utilization. Size expect to decrease the size of the assembly by making it increasingly minimal. Once speculation with least running cost and contamination-free framework. Extended Usability to date, absorption refrigeration is constrained for mechanical purposes. The plan is to make it accessible for mass country use as expressed above in little limits by utilizing sun powered retention. Refrigeration framework having low maintenance cost [13], [14].

This study aims to discuss and present the possibility of utilization of solar air conditioning systems in office buildings as an alternative for ecological construction in hot climates, particularly in the region of Pakistan. Thus, this work proposes using solar thermal systems (parabolic trough collectors) as a heat source for solar absorption chillers reducing significantly air conditioning electric consumption. The electric consumption not met by flat plate solar systems would be supplied by parabolic trough so that the air conditioning system can achieve a net-zero energy goal. The NH_3/H_2O proportion utilizes in this examination are in the rage of 5% - 30% NH_3 in H_2O dependent on volume rate in the solution and the coefficient of execution is determined utilizing a revocable Carnot cycle procedure of absorption chiller as the principle extent of this study. Gas Absorption Refrigeration Unit (Model: RF 10) is a research benchtop unit for the protest of gas absorption refrigeration (a nonstop system worked by utilization of heat).

1.1. Solar absorption chiller

Absorptive chillers like sun powered refrigerators utilize heat source instead of a blower to charge the refrigerant from vapor to fluid. The two most regular mixes are water blended in with either ammonia or lithium bromide. For each situation, the refrigerating gas is retained until heat is applied, which raises the temperature and pressure. At high pressure, the refrigerant gathers into the fluid. Turning off the heat reduces the pressure, making that fluid evaporate once more into a gas, accordingly making the cooling effect. Similarly, as with most advancements, the productivity of such absorptive refrigeration relies upon the level of designing (and cost) brought to bear. Single-impact devices have a coefficient of execution of 0.6 to 0.7—that is, they make 60 to 70 BTU of cooling for every 100 BTU of input heat. That low degree of proficiency can be accomplished with something as unrefined as some funnel, a can of water, some calcium chloride (absorbent), NH_3 (refrigerant), and a sheet of sparkly metal (solar collector). In the event that what you need to do is heat or cool, utilizing sunlight based vitality is most effective and less expensive than changing over it first into power [7], [15].

Now a days two primary kinds of sun oriented vitality technique are used; photovoltaic and thermal frameworks. The photovoltaic method converts sun-powered radiation to power using an assortment of strategies. The method generally utilize to silicon boards, which create an electrical flow when light sparkles on it. Sun oriented photovoltaics are mostly significant for remote applications where it would be restrictively exorbitant to supply power from a utility line. Sun based Thermal Systems try to store heat from the sun that can be utilized for different tenacity. A wide range of approaches can be utilized, including dynamic frameworks, for example, sun-powered high temp water radiators, and uninvolved frameworks, in which cautious designing structure brings about a structure that naturally uses and stores sunlight based vitality.

1.2. Problem with ammonia/water absorption chillers

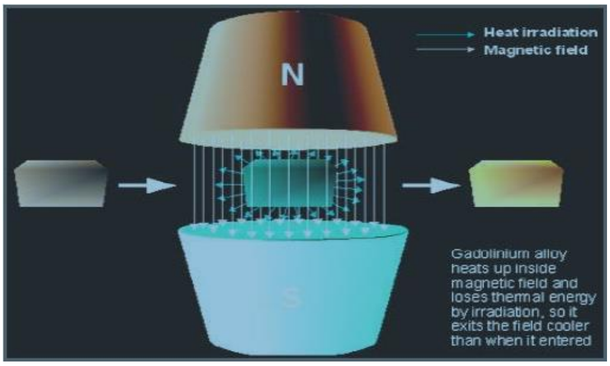
The enhancements to the issue of NH_3/H_2O absorption component that have been studied by different scientists. The enhancement, including experimental and simulation to build the presentation of primary segments of the absorption chiller unit. The impact of working liquids in retention chiller unit and most recent use of the NH_3/H_2O framework [5], [16], [17].

Table 1: Past Studies Regarding Ammonia/Water Absorption Chillers

Researchers	Year	ammonia/water absorption chillers
Lazzarin et al.	1996	Studied a lot of information on the failures of absorption refrigeration machineries of the NH_3/H_2O type
Swinney et al.	2000	The utilization of composition with the mixed refrigerant to accomplish a temperature lift. The design has impressive flexibility over the use of shaft control and recouped low-level heat.
Ezzine et al.	2014	Built a thermodynamic simulation model of NH_3/H_2O twofold impact, twofold generator absorption chiller to enhance the chiller's energy efficiency
Byongjoo Kim, and Jongil Park	2016	Proposed paper a lumped-parameter dynamic model of a single-influence NH_3/H_2O absorption chiller

1.3. Refrigeration cycle

The magnetocaloric refrigeration technique utilizes magnetism as its effort contribution to empower refrigeration as appeared in Figure 2. Magnetocaloric refrigeration frameworks are fabricated utilizing ferromagnets, for example, gadolinium plates that switch place all through the attractive field to retain a consistent heat stream. They use water or a blend of water and ethanol as the heat transfer fluid and use in the range of 0.77-5 tesla of magnetic flux to instigate the magnetocaloric impact. The most minimal conceivable temperature accomplished with a magnetocaloric cooler is 38 K, with 600 Watts cooling intensity. The coefficient of execution for these frameworks starts from 0.1 to 15. These frameworks are not relevant for home use, in any case, because they required high attractive field [3], [18].



Gadolinium alloy heats up inside magnetic field and loses thermal energy by irradiation, so it exits the field cooler than when it entered

Fig. 2: Magnetocaloric Effect on Gadolinium Alloy.

Thermoelectric modules are built from a progression of small metal solid shapes of divergent intriguing metals that are substantially reinforced with each other and associated electrically as appeared in Figure 3. A thermoelectric refrigerator furnished with just a thermoelectric plate, to enable the heat transfer, a fan and blades to yield the overabundance heat from the plate. Solid-state thermoelectric modules are fit for moving enormous amounts of heat when associated with a warmth retaining appliance on one side and a heat disseminating tool on the other. They are ecologically agreeable and safe and can also be turned around and be utilized for heating as opposed to cooling [19], [20].

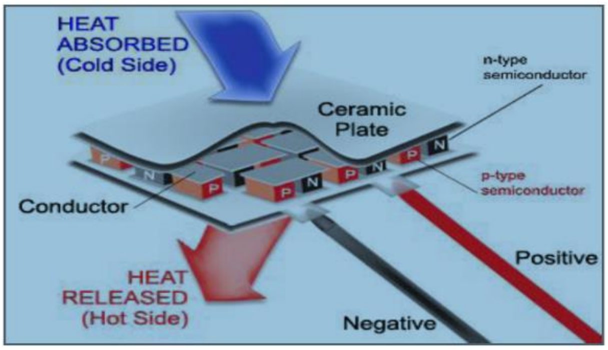


Fig. 3: Thermoelectric Plate Diagram.

The vapour-compression is the famous refrigeration cycle being used today. It has become a significant piece of day by day life and found everywhere from building and vehicle cooling frameworks to fridges and freezers. This fame is because of the way that it is moderately productive, cheap, and reduced. A vapour-compression framework is comprised of four significant segments: a blower, condenser, evaporator and thermal extension valve is shown in Figure 4. A liquid refrigerant works by retaining and discharging heat [20].

Unlike vapour-compression frameworks, absorption refrigeration frameworks utilize a warmth source rather than electricity to give the vitality expected to produce cooling. Two significant sorts of absorption refrigeration framework are the two liquid and the three liquid assimilation framework. Most of the two plans are commonly alike; the contrasts between them lie in the manner in which the fluid refrigerant is caused to evaporate. In a two liquid framework, a development valve is utilized to generate an enormous weight drop, which makes the fluid refrigerant vanish. A three liquid framework utilizes the third liquid to encourage the development by methods for partial pressures. The key procedures in a retention refrigeration framework are the assimilation and desorption of the refrigerant. A main processes in absorption framework has five principle segments: the generator, absorber, condenser, evaporator and the solution heat exchanger. The progression of the refrigerant is through every one of these parts in the various types of absorber framework is given in each area.

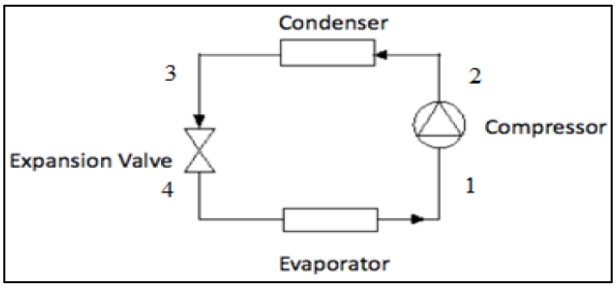


Fig. 4: Vapor Compression System.

Two liquid absorption frameworks are most regularly utilized in huge structures or plants where there is a critical source of waste heat accessible. This framework is an NH_3/H_2O refrigeration cycle framework that is made out of an evaporator, a refrigerant warmth exchanger, a safeguard, a siphon, two-stream restrictors (expansion valves), an solution heat exchanger, a generator, a rectifier, and a condenser, as appeared in Figure 5 [20], [21].

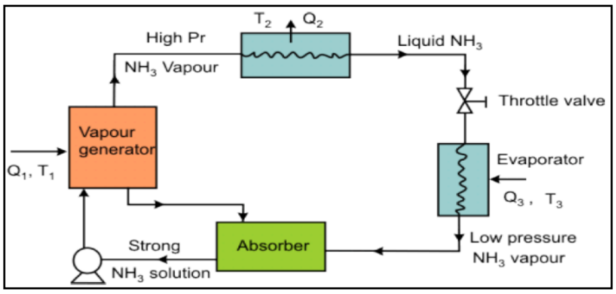


Fig. 5: Two Fluid Absorption Refrigeration System.

The refrigerator worked in this venture is a gas absorption refrigeration that utilizations three liquids rather than two. Of the different refrigeration cycles, due to three liquid absorption, it doesn't require power or mechanical parts to work and run by heat completely. The key is its utilization is the third liquid, used to manage the partial pressure of the refrigerant, and in this way, its saturation temperature. The low partial pressure of the refrigerant enables the refrigerant's immersion temperature to diminish and make cooling. The framework stays at the consistent absolute weight and dispenses with the utilization of development valves. Most three liquid assimilation frameworks use NH_3 as their refrigerant and hydrogen as the third liquid. A conventional outline of a three liquid absorption refrigeration utilizes NH_3 and H_2 is appeared in Figure 6 [20], [22].

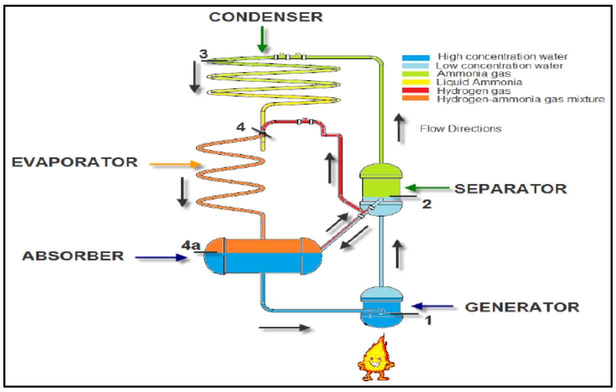


Fig. 6: Basic Three Fluid Absorption System.

1.4. System selection

To choose solar-powered absorption chilling on account of following reasons. The service for comfort cooling requires a significant piece of the consumed vitality in structures in numerous nations. Particularly electrically determined room forced air systems or chillers since electricity top loads in power grids albeit advanced frameworks arrived at a generally exclusive expectation concerning vitality utilization. This is turning into a developing issue with coming about power deficiencies at high framework stacks in areas with cooling overwhelmed atmospheres. The utilization of sun based warm vitality in blend with thermally determined cooling frameworks (chillers, open sportive cycles) can be a potential arrangement among others. The fundamental application covered by this research work is the cooling of structures yet in addition mechanical refrigeration model in the food part is considered. Today sun based cooling has the best possibilities for advertising presentation in instances of enormous structures with focal cooling frameworks. It is quiet in operation and has a low maintenance cost [3], [15].

Despite the fact that there are a few modern utilizations of sun absorption retention chilling. Before, the minimal effort of fuel and feedstock empowered the petrochemical business to work mechanical chillers reasonably. Be that as it may, the present feedstock costs are making open doors for absorption chillers. Reflux condensers, condensate streams, item coolers, and procedure heaters all produce heat that can drive absorption equipment. Where procedure plants produce their very own steam as a utility, hot-condensate-steam or low-pressure steam can likewise be utilized to work absorption chillers. Steam and high temp water created by the area vitality plant can without much of a stretch be conveyed underground to encompassing structures, alongside natural gas and power.

2. Methodology

2.1. Fluids in process

NH_3 is the most environmentally friendly refrigerant. It has a place with the group of supposed —natural refrigerants, and it has both ODP (Ozone Depletion Potential) and GWP (Global Warming Potential) equivalent to zero. NH_3 is a dangerous refrigerant, and it is likewise combustible at a specific concentration. That is the reason it must be carefully controlled, and all NH_3 frameworks must be planned in light of safety. Simultaneously, in contrast to most different refrigerants, it has a characteristic odor that can be distinguished by people even at extremely low concentrations. That offers an admonition hint even in the event of minor NH_3 spillages. That's why it is important to decrease NH_3 charge; the blend of NH_3 and CO_2 could be a decent and proficient choice. In both liquid and vapor stage, NH_3 requires littler channel distances across than most chemical refrigerants. NH_3 has preferable heat transfer properties over the majority of compound refrigerants and accordingly take into consideration the utilization of tools with a littler heat transfer territory. Consequently, the plant development cost will be lower. In any case, as these properties likewise advantage thermodynamic productivity and also lessens the working expenses of the framework.

Refrigerant grade anhydrous NH_3 is a reasonable, colorless fluid or gas, free from polluting influences. Anhydrous NH_3 is a clear fluid that boils at a temperature of - 28°F. In the refrigeration, the fluid is stored in sections under pressure. When the pressure is discharged at that point, the fluid dissipates quickly, for the most part, influential an invisible fume or gas. The fast evaporation drops the temperature of the fluid until it arrives at the ordinary boiling point of - 28°F. This is the cause NH_3 is utilized in refrigeration frameworks. Anhydrous NH_3 is effectively consumed by water. At 68°F, around 700 volumes of vapor can be collapsed in one volume of water to make a response containing 34 per cent NH_3 by weight.

Water is considered as a universal solvent. A polar atom with partially negative and positive charges, it promptly breaks up particles and polar atoms. Water connects diversely with charged and polar substances than with nonpolar substances due to the extremity of its atoms. The inconsistent charge dispersion in a water particle reflects the more electronegativity of oxygen comparative with hydrogen: the O-H bonds use more energy with O molecule than H. Figure 7 shows the incomplete positive and fractional negative charges on H_2O particle. As a result of its extremity, water can shape electrostatic communications with other polar atoms and particles. When there are numerous H_2O particles comparative with solute atoms in solution, these communications lead to the production of a three-dimensional circle of H_2O particles or hydration shell around the solute. Hydration shells enable particles to be dispersed equitably in water. It is, truth be told, more dissolvable than some other gas in water. 100 ml of water can break down as much as 31 gm of NH_3 at 25 °C as appeared in Figure 7. A blend of NH_3 in water is called ammonium hydroxide, NH_4OH. High solvency of NH_3 in water is because of hydrogen bonding with water particles [3], [23].

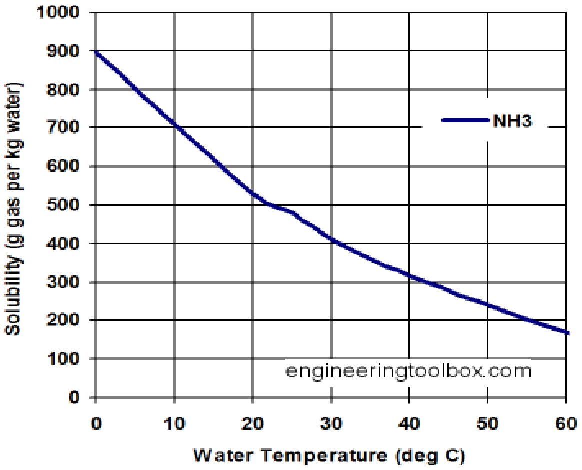


Fig. 7: Temperature vs. Solubility of Ammonia.

All gas absorption refrigeration depends on the evaporation of liquid NH_3 into gaseous ammonia to generate cooling. When our ammonia refrigerant enters the expansion valve, it is subcooled at 20 °C and 1bar. As at 10bar of pressure, the ammonia liquid will not evaporate until 24.89 °C. Therefore, we have used the expansion valve. The liquid ammonia will draw heat from its surroundings as it simultaneously draws its own heat to provide heat of vaporization. This is due to pressure loss as in the Joule Thomson effect in the expansion valve. So the ammonia now drops in temperature as draws its own, and the compartments, heat and begins to emit vapor. This will continue until the ammonia vapor pressure equals the saturation pressure for the current temperature of the fluid compartment section. The conditions temperature of the inlet stream is 17.36 °C, the temperature of the outlet stream is 30.51 °C, the pressure of inlet stream is 784.6 k Pa and pressure of outlet stream is 750 k Pa [4], [24].

The fundamental reason of the absorber is to absorb the refrigerant in water. All together for the consistent state to be accomplished, the entirety of the NH_3 originating from the evaporator must be consumed by the water through dispersion. The NH_3 leaves the evaporator at a particular mass stream rate which has found through recreation or mass balance. The transfer variable of this condition is equivalent to the transfer variable from the surrounding to the cabinet, which was found in the Refrigerator Cabinet segment. So, need an area big enough to facilitate absorption of NH_3 at 1.66 kg/min. The absorber is made out of a cylindrical pipe with caps at each end, giving plenty of cross-sectional area for the absorption of NH_3 in water. The fluid water coming back from the generator will be at higher elevation and stream descending toward the absorber. The warm gases inflowing the absorber will pass in the side channeling of the absorber and start to rise the stream because of buoyancy force. The water and hot NH_3 gas will along with counter stream and in the course consolidate to form a solution. The mix fluids at that point stream descending back to the absorber. The most ideal approach to confirm this, to interface the water return channel to the top side of the absorber side funnel. This will bring water down over the streaming gases. It needs the ammonia to be at 30 °C to combine in the proper fractions. So we must compute the proper length required for this to occur. After a legitimate mix of the liquids at the proper temperatures, the fluid arrangement streams down to the absorber and into the generator. The conditions are temperature of inlet stream of ammonia is 30 °C, temperature of inlet stream of water is 47 °C, temperature of outlet stream is 113 °C, pressure of inlet stream of ammonia is 750 k Pa, pressure of inlet stream of water is 750.1 k Pa and pressure of outlet stream is 746.7 k Pa [5], [7].

The generator gives the ability to drive the framework. In general, working is as, ammonia-water arrives the generator from the absorber at a specific mass part. At that point, heat is applied to disintegrate the NH_3 and leaves a feeble NH_3 solution behind. The rising fume hoists, where the frail NH_3 solution can deplete out of the opposite side of the separator to the absorber. The NH_3 fume at that point exits through the top of the separator and continues to the condenser. At the point when fluid comes into the generator, the fluid stream will pursue various ways, a portion of the stream will be pulled in closer with the warmed point and other will be pulled above and get insignificant warming. The stream warmed adequately discharges NH_3 with a feeble water focus in gas structure. This vaporous blend hoists the fluid through the bubble pump. The NH_3 fume at that point escapes through the separator. The fluid, which has been raised, is a blend of streams, some of which were completely warmed, somewhat warm, and nearly non-warmed. Every one of these streams will contrast in divisions of NH_3. This is because it takes almost no fume to hoist fluid in a cylinder or segment. So not about the entirety of the NH_3 should be disintegrated to actuate fluid stream up to the separator over the bubble pump.

To drive more NH_3 out, the solution in the separator can be warm. This lessens the part of smelling salts coming back to the absorber over the fluid return pipe mainly. Herold, Radermacher and Klein, expresses that in the run of the mill business gas assimilation units the fluid coming back to the absorber from the separator commonly contains a 0.1 to 0.2 mass portion of NH_3. This is because of the wastefulness of lopsided warming. The temperature at which our retention should occur, we ought to have 250 grams of smelling salts in 1000 grams of water. Utilizing the basic formula can get an NH_3 portion of the solution by mass. The conditions are mass of downstream from generator is 483 kg/h, mass of ammonia stripping out of vapor generator is 104.7 kg/h, inlet stream temperature is 141 ^oC, inlet stream pressure is 1266 k Pa, top outlet stream pressure is 1050 k Pa, top outlet stream temperature is 38 ^oC, bottom outlet stream temperature is 183.6 ^oC and bottom outlet stream pressure is 1101 k Pa.

Assuming the best possible gas stream rates are built up and the rectifier capacities appropriately, will have pure NH_3 gas at a mean temperature about 28.62^{o}C entering the condenser (after passing through rectifier), must calculate the proper length. This length is important to consolidate the liquid back to room temperature in the fluid state. To break down assess length of three locales of heat transfer. The underlying area where the gas consolidates from superheated gas to the soaked fume express, the second district where it goes from immersed gas to immersed fluid, and a third locale where it goes from immersed fluid to subcooled fluid. In a funnel with a dynamic temperature change as it cools have a changing heat transfer rate. To discover the rate that speaks to the general surface zone essential, regularly need to utilize a differential condition. The conditions are the temperature of inlet stream of ammonia is 38 ^oC, the temperature of outlet stream is 27 ^oC, the pressure of inlet stream of ammonia is 1050 k Pa and pressure of outlet stream is 1015 k Pa. The process flow diagram is shown in Figure 8.

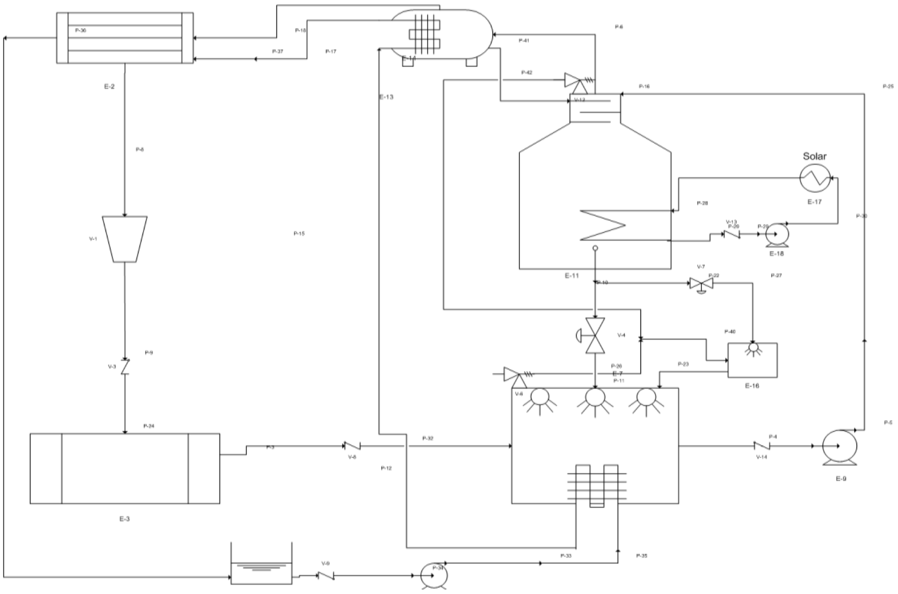


Fig. 8: Process Flow Diagram.

Sun based energy collectors are heat exchangers that change sun radiation to internal vitality. To convey high temperatures with great proficiency, a high-execution solar collector is requisite. Frameworks with light edifices and minimal effort innovation for heat applications process up to 400 ^oC could be gotten with parabolic through collectors (PTCs). The PTCs can adequately deliver heat somewhere in the range of 50 and 400 ^oC. PTCs are prepared by twisting a sheet of reflective material into a parabolic shape. A dark metal tube, secured with a glass tube to decrease heat losses, is set along the central line of the receiver as presented in Figure 9. Also, tracking appliances are utilized for the security of collectors; for example, they turn the collectors out of focus to shield it from the unsafe ecological and operating conditions. The necessary precision of the following component relies upon the collector acceptance angle [4], [15].

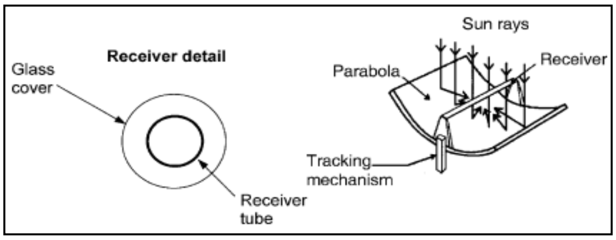


Fig. 9: Schematic Diagram of the Parabolic Trough Collector.

Figure 10 shows a parabolic dish reflector, a point-centre authority tracks the sun in two axes, concentrating sun based vitality onto a receiver situated at the convergence point of the dish. The thermal receiver retains the sun powered vitality, changing over it into thermal vitality in a circulating liquid. The thermal vitality can be changed into power utilizing a motor-generator coupled legitimately to the collector, or it tends to be shipped through funnels to a focal power- conversion framework [16].

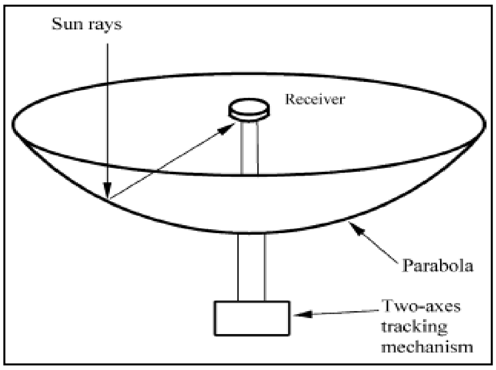


Fig. 10: Schematic of A Parabolic Dish Collector.

Parabolic dish frameworks can accomplish temperatures more than 1500 °C. This framework is an electric producer that uses sunlight rather than unrefined petroleum or coal to create power. The significant part of a framework is the sunlight based dish concentrator and the power conversion unit. Parabolic dish frameworks that create power from a focal power converter gather the retained daylight from singular beneficiaries and convey it employing a heat-transfer fluid to the power change frameworks. The need to flow heat transfer liquid all through the collector field raises design issues, for example, funneling design, siphoning prerequisites, and warm misfortunes. Systems that utilize little generators at the point of convergence of each dish give vitality as power as opposed to a heated liquid. The power change unit incorporates the heat collector and the heat motor. The thermal receiver absorbs the concentrated light emission vitality, changes over it to heat, and moves the heat to the heat engine. A thermal collector can be a set of cylinders with a cooling liquid flowing through it. The heat motor framework takes the heat from the thermal recipient and utilizations it to create power. The motor-generators have a few segments; a collector to retain the concentrated daylight to warm the working liquid of the motor, at that point changes over the warm vitality into mechanical work; an generator connected to the motor to change work into power, a waste-heat fumes framework to vent excess heat to the air, and a control framework to coordinate the motor's activity to the accessible sunlight based vitality. This dispersed parabolic dish framework needs warm storage abilities, yet can be hybridized to run on petroleum derivative during periods without daylight. The Sterling motor is the most widely recognized kind of warmth motor utilized in dish-motor frameworks. Other conceivable power change unit innovations that are assessed for future applications are smaller scale turbines and concentrating photovoltaics [8], [19].

For very high contributions of radiant vitality, a variety of flat mirrors or heliostats, utilizing altazimuth mounts can be utilized to reflect their occurrence direct sun-powered radiation onto a typical objective as appeared in Figure 11, known as the heliostat field or central receiver collector. The intense warmth vitality used up by the collector is moved to a circling liquid that can be scatter and later used to deliver control.

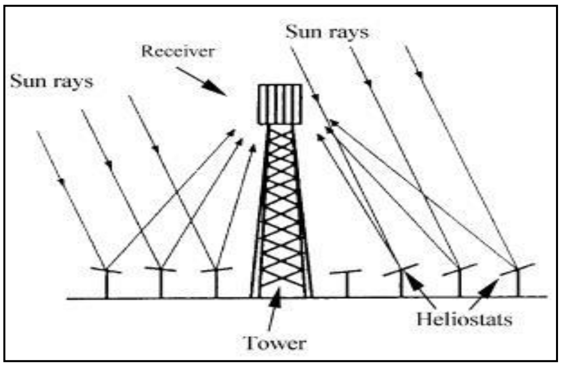


Fig. 11: Schematic of the Central Receiver System.

Each heliostat at a focal beneficiary office has from 50 - 150 m^2 of the reflective surface. The heliostats collect and concentrate daylight onto the receiver that retains the concentrated sunlight, moving its vitality to a heat transfer liquid. The average solar flux impinging on the beneficiary has values in the range of 200 to 1000 kW/m^2. This high transition permits working generally at high temperatures (1500 °C) and coordinating thermal vitality in progressively proficient cycles [20].

3. Results

3.1. Material & energy balances

Evaporator:
For Mass of Ammonia (M):
Ton of refrigeration = 10, As 1 ton = 3.615 KW
Heat absorbed by refrigerant = Qe = 2109.6 KJ/min
We know:

$Qe = M^* (Ho - Hi)$

Ho = Enthalpy of ammonia at outlet of evaporator = 1720 KJ/Kg, Hi = Enthalpy of ammonia at inlet of evaporator = 450 KJ/Kg, Mass of ammonia = M = 1.661102 Kg/min
Mass balance for evaporator;
m2 = m1 = 1.661102 Kg/min
Absorber:
$m_{water} + m1 = m4 + m3$
Since, m3 = 0

$$m_{water} + 1.661102 = m4 \tag{1}$$

At 47 °C, 1g of ammonia dissolves in = 4 g of H_20
So,
Mwater = 4*m1
m_{water} = 6.644409 kg/min
Putting m_{water} in Eq (1):
We get,
m4 = 8.305512 kg/min
Generator:

$$m13 = m7 + m8 \tag{2}$$

As, m4 = m13 = 8.305512 kg/min
Putting above value in Eq (2), We get:
m7 + m8 = 8.305512 kg/min
Appling ammonia balance on generator:

$$xf*m13 = xv*m7 + xl*m8 \tag{3}$$

xf = mass composition of ammonia in feed (m12) = 0.1861, xv = mass composition of ammonia in vapor (m7) = 0.9992, xl = mass composition of ammonia in liquid (m8) = 0.0008
m7 = 1.541478 kg/min
m8 = 6.764034 kg/min
Heat given in generator (Qg):

$$Qg = M * \lambda + Qd \tag{4}$$

Qd = sensible heat supplied by generator to entering stream, λ = latent heat of vaporization of ammonia = 1369 KJ/kg

$$Qd = Mi * Cpi * (To - Ti) \tag{5}$$

Mi = Mass of inlet stream to generator = 8.3055 Kg/min, To = Temperature of generator = 183.6 °C, Ti = Temperature of inlet stream to generator = 141 °C, Cp = Specific heat capacity of inlet stream = 4.77 Kj/Kg.°C
Qd = 1687.697 KJ/min
Qg = 3797.98 KJ/min
Condenser:
m7 = m9
m9 = 1.541478 kg/min
Heat removed in condenser (Qc):

$$Qc = M * (Hoc - Hic) \tag{6}$$

Hoc = Enthalpy of ammonia at outlet of condenser = 450 KJ/Kg, Hic = Enthalpy of ammonia at inlet of condenser = 1770 KJ/Kg
Qc = -2034.75 KJ/min
Heat Exchanger 1:
m14 = m6 = m water
m6 = 6.644409 kg/min, m14 = 6.764034 kg/min
m12 = m13 = 8.305512 kg/min
Heat Exchanger 2:
m14 = m15 = 6.764034 kg/min = m water
A = B = 77.51 kg/min
COP = Refrigeration Effect/Heat Input In Generator = 0.555453
Solar Calculation;
Solar Constant (ISC) = 1353 W/m^2, Extra Terestrial Radiation (IO) = 1398 W/m^2, Geographical Lagtitude=24.881, Geographical Longitude=67.063, Month of Operation (May) Day=138 Day, Z= Zenith angle

$$CosZ=SinRSinS + CosRCosSCosT \tag{7}$$

R=Lagtitude of location, S=Declination angle, T=Hour angle

$$S=\sin^{-1}(\sin 23.45*\sin((360/365)(d-81))) \tag{8}$$

S=19.315, T=0, CosZ=0.995285, Z=5.566
Intensity of Solar Radiation

$$IZ=(1+0.03Cos(360*n/365))Ics \tag{9}$$

IZ=1320 W/m^2
Radiation on surface
Ih=IzCosZ=1314.303 W/m^2
Efficiency of solar panel (Parabolic Dish)=E=0.768
So, solar radiation intensity received by surface;
Is=1009.384704 W/m^2
Minimum heat required at collector;
Qg=95570W
Reflected intensity by reflector
Ir=Is*(Reflectivity of Reflector surface)
For aluminium=0.9(reflectivity)
Ir=908.4462336 W/m^2
Area of Parabolic Dish

$$A=Qg/Ir \tag{10}$$

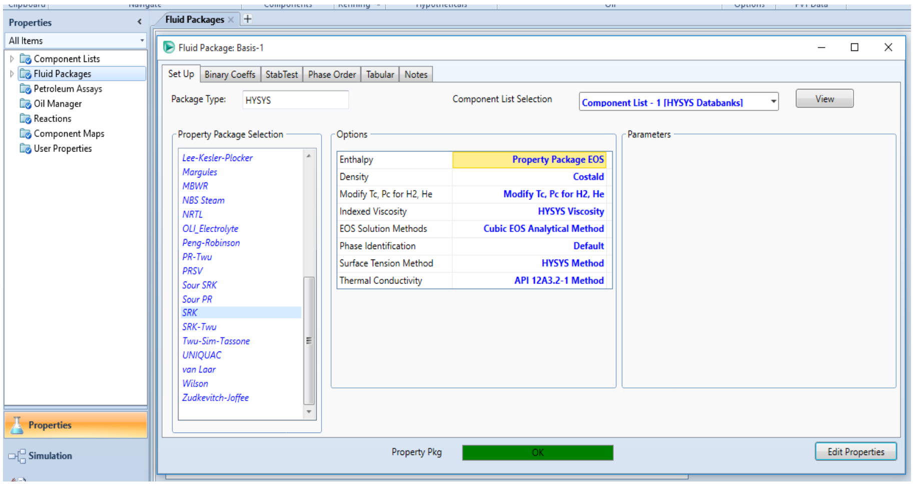
A=105.201603 m^2
Apperture area of Parabolic dish
Ap =90m^2
Standard size of one parabola;
Length of parabola=L=6m, Aperture of Parabola=a=2.55m, Focal length=f=0.85m
Aperture area of Parabola=Ap =15.3m^2
Number of Parabola required;
Number of Parabola=N=5.882 (6 parabola dishes required)

$$Q=M*Cp*\Delta(T) \tag{11}$$

Q=Heat required in generator=95570 W, M=Mass of Lube oil=0.26 Kg/S, Cp=Specific heat capacity of lude oil=2090 J/Kg.K, ΔT=To-Ti
To=Outlet lube oil temperature from solar=?, Ti=Inlet temperature of lube from solar=25^{o}C
To=201^{o}C

3.2. Simulation of ammonia absorption ciller

Peng-Robinson (PR) most improved model in Aspen HYSYS, great applicability regarding T and P and largest parallel collaboration parameter database. PRSV model has enhanced portrayal of vapor pressure of pure parts and blends and extends relevance of the first PR model to respectably non-perfect frameworks. SRK model give similar outcomes to PR by and large, yet with much less upgrade in Aspen HYSYS. In numerous cases, the Soave-Redlich-Kwong (SRK) model gives practically identical outcomes to Peng-Robinson, yet its scope of use is essentially progressively restricted; temperature Range > - 143°C or - 225°F and pressure Range < 5,000 kPa or 35,000 psia. This model is commonly utilized for the following simulations TEG dehydration, harsh water, air separation, cryogenic gas preparing, ATM rough towers, vacuum towers, high H_2 and reservoir frameworks, hydrate hindrance, HF alkylation, chemical frameworks and TEG dehydration with aromatics [17], [24].



Fluid Package: Basis-1

Package Type: HYSYS

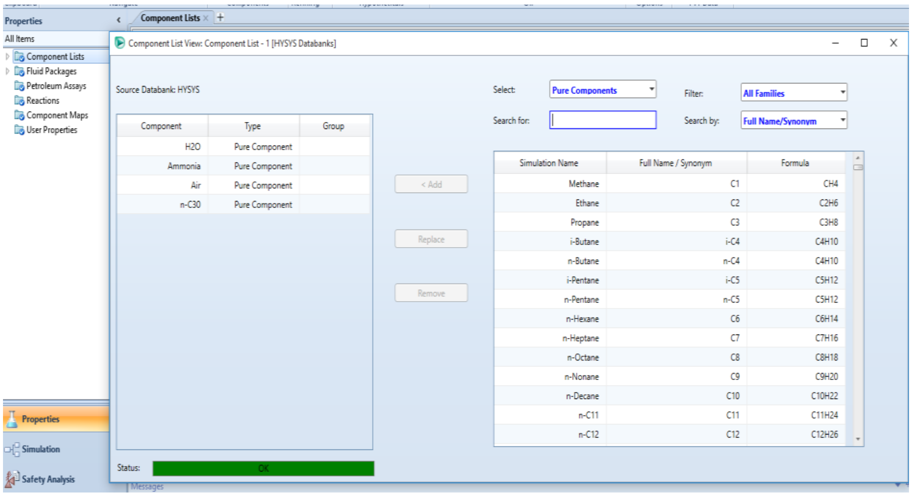
Component List Selection: Component List - 1 [HYSYS Databanks]

Enthalpy	Property Package EOS
Density	Costald
Modify Tc, Pc for H2, He	Modify Tc, Pc for H2, He
Indexed Viscosity	HYSYS Viscosity
EOS Solution Methods	Cubic EOS Analytical Method
Phase Identification	Default
Surface Tension Method	HYSYS Method
Thermal Conductivity	API 12A3.2-1 Method

Property Pkg: OK

Fig. 12: Fluid package used.

The exclusive improvements to the SRK permit the SRK equation of state (EOS) to accurately speak to vacuum conditions and substantial segments, just as handle the light closures and high-pressure frameworks. It comprises upgraded twofold cooperation parameters for all hydrocarbon-hydrocarbon matches (a blend of fitted and created collaboration parameters), just as for majority hydrocarbon-nonhydrocarbon pairs. For hydrocarbon hypo part, HC-HC interaction parameters are created naturally by HYSYS for enhanced VLE property predictions. The utilizing liquid package in Figure 12. The segments list has appeared in Figure 13.



Component List View: Component List - 1 [HYSYS Databanks]

Source Databank: HYSYS

Select: Pure Components

Filter: All Families

Search for:

Search by: Full Name/Synonym

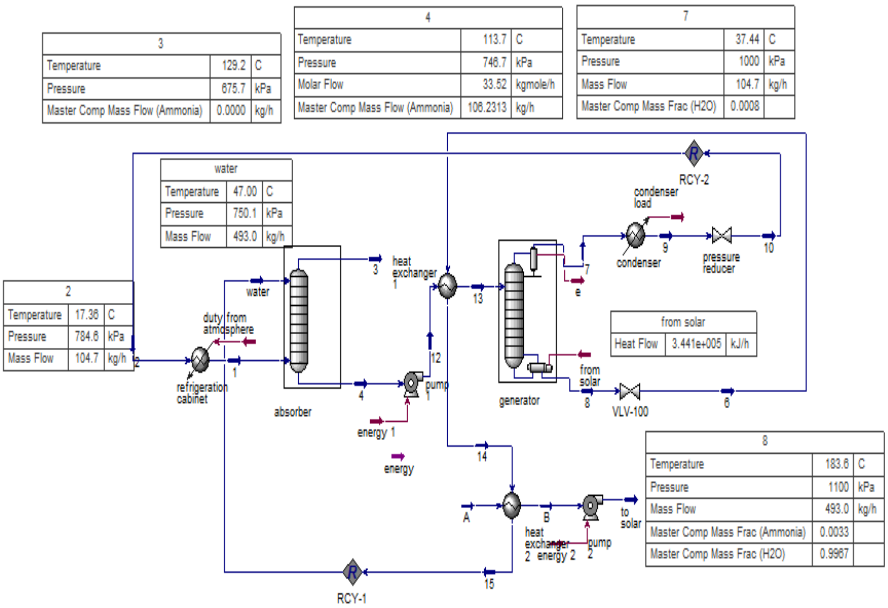
Component	Type	Group
H2O	Pure Component	
Ammonia	Pure Component	
Air	Pure Component	
n-C30	Pure Component	

Simulation Name	Full Name / Synonym	Formula
Methane	C1	CH4
Ethane	C2	C2H6
Propane	C3	C3H8
i-Butane	i-C4	C4H10
n-Butane	n-C4	C4H10
i-Pentane	i-C5	C5H12
n-Pentane	n-C5	C5H12
n-Hexane	C6	C6H14
n-Heptane	C7	C7H16
n-Octane	C8	C8H18
n-Nonane	C9	C9H20
n-Decane	C10	C10H22
n-C11	C11	C11H24
n-C12	C12	C12H26

Status: OK

Fig. 13: List of Components.

The worksheet of different is shown in Figure 14 to 18.



3		
Temperature	129.2	C
Pressure	675.7	kPa
Master Comp Mass Flow (Ammonia)	0.0000	kg/h

4		
Temperature	113.7	C
Pressure	746.7	kPa
Molar Flow	33.52	kgmole/h
Master Comp Mass Flow (Ammonia)	106.2313	kg/h

7		
Temperature	37.44	C
Pressure	1000	kPa
Mass Flow	104.7	kg/h
Master Comp Mass Frac (H2O)	0.0008	

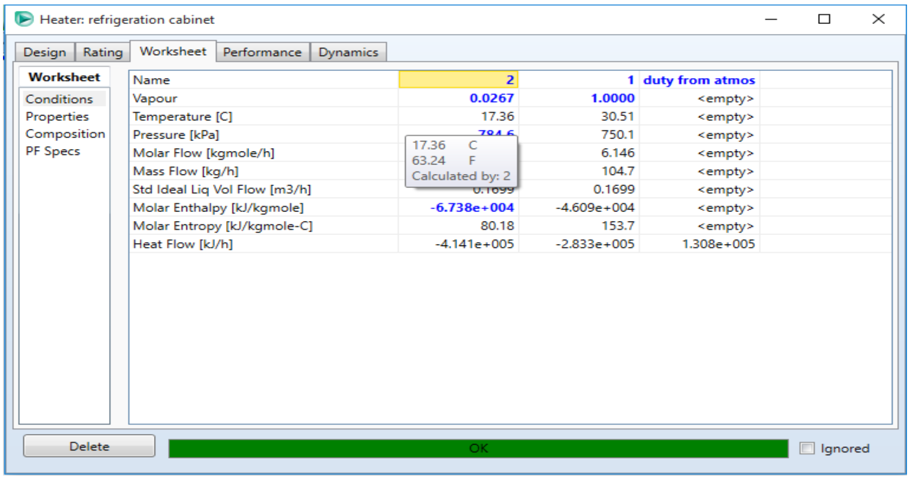
water		
Temperature	47.00	C
Pressure	750.1	kPa
Mass Flow	493.0	kg/h

2		
Temperature	17.36	C
Pressure	784.6	kPa
Mass Flow	104.7	kg/h

from solar		
Heat Flow	3.441e+005	kJ/h

8		
Temperature	183.6	C
Pressure	1100	kPa
Mass Flow	493.0	kg/h
Master Comp Mass Frac (Ammonia)	0.0033	
Master Comp Mass Frac (H2O)	0.9967	

Fig. 14: Simulation of Ammonia Absorption Chiller.



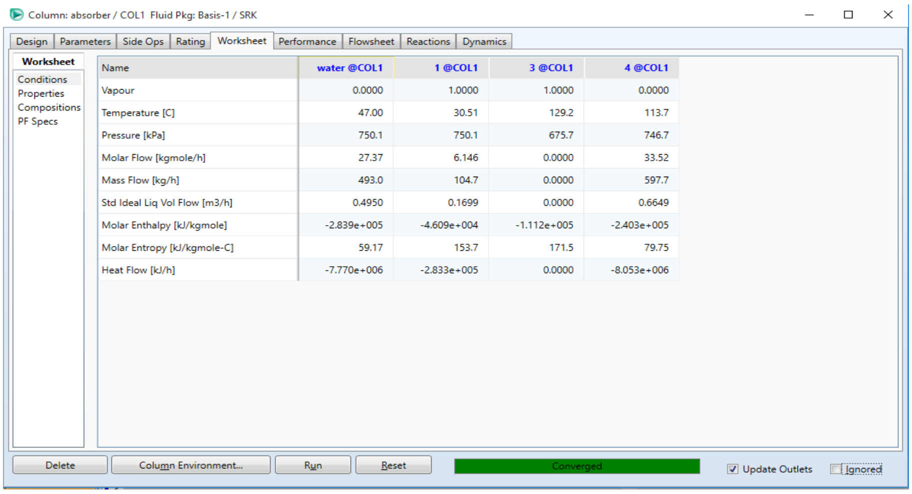
Heater: refrigeration cabinet

Name	2	1	duty from atmos
Vapour	0.0267	1.0000	<empty>
Temperature [C]	17.36	30.51	<empty>
Pressure [kPa]	784.6	750.1	<empty>
Molar Flow [kgmole/h]		6.146	<empty>
Mass Flow [kg/h]		104.7	<empty>
Std Ideal Liq Vol Flow [m3/h]	0.1699	0.1699	<empty>
Molar Enthalpy [kJ/kgmole]	-6.738e+004	-4.609e+004	<empty>
Molar Entropy [kJ/kgmole-C]	80.18	153.7	<empty>
Heat Flow [kJ/h]	-4.141e+005	-2.833e+005	1.308e+005

17.36 C
63.24 F
Calculated by: 2

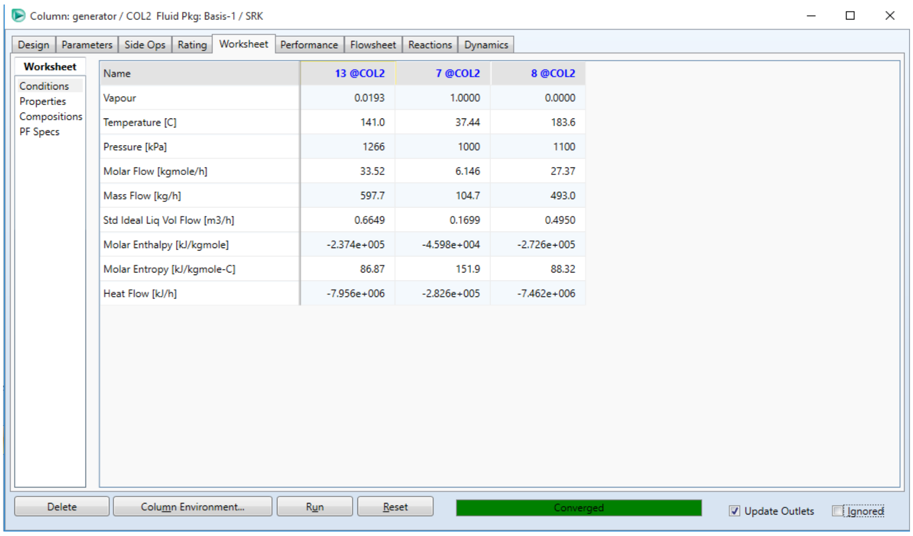
OK

Fig. 15: Evaporator Worksheet.



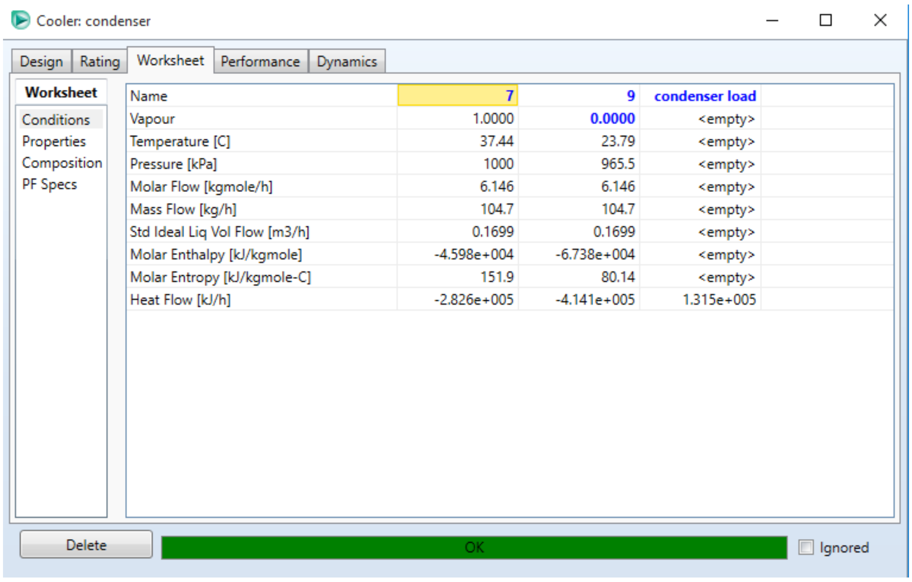
Name	water @COL1	1 @COL1	3 @COL1	4 @COL1
Vapour	0.0000	1.0000	1.0000	0.0000
Temperature [C]	47.00	30.51	129.2	113.7
Pressure [kPa]	750.1	750.1	675.7	746.7
Molar Flow [kgmole/h]	27.37	6.146	0.0000	33.52
Mass Flow [kg/h]	493.0	104.7	0.0000	597.7
Std Ideal Liq Vol Flow [m3/h]	0.4950	0.1699	0.0000	0.6649
Molar Enthalpy [kJ/kgmole]	-2.839e+005	-4.609e+004	-1.112e+005	-2.403e+005
Molar Entropy [kJ/kgmole-C]	59.17	153.7	171.5	79.75
Heat Flow [kJ/h]	-7.770e+006	-2.833e+005	0.0000	-8.053e+006

Fig. 16: Absorber Worksheet.



Name	13 @COL2	7 @COL2	8 @COL2
Vapour	0.0193	1.0000	0.0000
Temperature [C]	141.0	37.44	183.6
Pressure [kPa]	1266	1000	1100
Molar Flow [kgmole/h]	33.52	6.146	27.37
Mass Flow [kg/h]	597.7	104.7	493.0
Std Ideal Liq Vol Flow [m3/h]	0.6649	0.1699	0.4950
Molar Enthalpy [kJ/kgmole]	-2.374e+005	-4.598e+004	-2.726e+005
Molar Entropy [kJ/kgmole-C]	86.87	151.9	88.32
Heat Flow [kJ/h]	-7.956e+006	-2.826e+005	-7.462e+006

Fig. 17: Generator Worksheet.



Name	7	9	condenser load
Vapour	1.0000	0.0000	<empty>
Temperature [C]	37.44	23.79	<empty>
Pressure [kPa]	1000	965.5	<empty>
Molar Flow [kgmole/h]	6.146	6.146	<empty>
Mass Flow [kg/h]	104.7	104.7	<empty>
Std Ideal Liq Vol Flow [m3/h]	0.1699	0.1699	<empty>
Molar Enthalpy [kJ/kgmole]	-4.598e+004	-6.738e+004	<empty>
Molar Entropy [kJ/kgmole-C]	151.9	80.14	<empty>
Heat Flow [kJ/h]	-2.826e+005	-4.141e+005	1.315e+005

Fig. 18: Condenser Worksheet.

3.3. Designing and sizing of equipment

The designing and sizing of equipment are shown following [17];
Designing and sizing of heat exchanger 1
Front end head type B-bonnet bolted or integral with tube sheet
Shell type E-one pass shell, Rear end head type M-bonnet, Shell internal diameter=205.0034mm, Tube outside diameter=19.05mm, Tube length (straight) =1200.00014mm, Effective tube count=35

Ft factor=0.823798915, Uncorrected LMTD=29.2120501, Orientation=horizontal, Flow direction=counter current (in near rear head), Number of tube side passes=4.

Table 2: Designing And Sizing Of Heat Exchanger 1

	Hot side	Cold side
Total mass flow [kg/h]	492.9960638	597.6726732
Inlet temperature [ºC]	170.8945831	113.8181543
Outlet temperature [ºC]	142.35814	141
Inlet pressure [kPa]	819.0973795	1300
Design pressure [kPa]	1000	1500
Design temperature [ºC]	210	180

Tube type=plain, Tube OD [inch] =0.75, Tube thickness [inch] =0.083, Tubes pitch [inch] =0.9375, 30-Triangular, Number of Baffles =7, Baffle type=Single segmental, Baffle thickness [inch] =0.125, Baffle cut [%] = 41.84, Baffle tube clearance [inch] =0.031251969, Baffle shell clearance [inch] =0.125

Designing and Sizing of Heat Exchanger 2

Front end head type B-bonnet bolted or integral with tube sheet

Shell type e - one pass shell, Rear end head type m-bonnet, Shell internal diameter [mm] =205

Tube outside diameter [mm] =19.05, Tube length (straight) [mm] =6000, Effective tube count=51, Ft Factor=0.779, Uncorrected LMTD=44.751, Orientation=Horizontal, Flow Direction=Countercurrent (in near rear head), Number of Tube side Passes=2

Table 3: Designing and Sizing of Heat Exchanger 2

	Hot side	Cold side
Total mass flow [kg/h]	492.9960638	4650.789124
Inlet temperature [ºC]	142.35814	30
Outlet temperature [ºC]	47	49.35118162
Inlet pressure [kPa]	784.6235841	150
Outlet pressure [kPa]	750.1497886	115.5262046
Design pressure [kPa]	900	300
Design temperature [ºC]	180	90

Tube Type=Plain, Tube OD [inch] =0.75, Tube Thickness [inch] =0.083, Tubes Pitch [inch] =0.937530

30-Triangular, Number of Baffles=12, Baffle Type=Single segmental, Baffle Thickness [inch] =0.1875

Baffle Cut [%] =41.48, Baffle Tube Clearance [inch] =0.031251969, Baffle Shell Clearance [inch] =0.125

Designing and Sizing of Absorption Column

Internals =Packed, Packing Type=Super Intalox Saddles (Ceramic) 1_inch (Norton), HETP Correlation=Frank, Section Diameter [m] =0.3048, X-Sectional Area [m^2] =7.30E-02, Section Height [m] =3.048, Max Flooding [%] =13.48485, Section DeltaP [kPa] =0.153556, DP per Length [kPa/m] =5.04E-02, Flood Gas Vel. [m^3/h-m^2] = 2788.132, Flood Gas Vel. [m/s] = 0.774481, Design gauge pressure Bottom [kPag] =817.7485, Design temperature Bottom [ºC] =157.6003, Operating temperature Bottom [ºC] = 129.8226

Designing and Sizing of Distillation Column

Internals= Packed, Packing Type Super Intalox Saddles (Ceramic) 1_inch (Norton), HETP Correlation Frank, Section Diameter [m] =0.3048, X-Sectional Area [m^2] =7.30E-02, Section Height [m] =3.048, Max Flooding [%] =9.530614835, Section DeltaP [kPa] = 0.213454729, DP per Length [kPa/m] = 7.00E-02, Flood Gas Vel. [m^3/h-m^2] =4057.477484, Flood Gas Vel. [m/s] =1.127077079, Design gauge pressure Bottom [kPag] =1136.572283, Design temperature Bottom [ºC] = 208.4714, Operating temperature Bottom [ºC] =180.6936222

Pump Calculations

PUMP 1

Total head [m] =67.8073609, Total Fluid Head [kJ/kg] =0.664963056, Pressure head [m] =67.80736079, Velocity head [m] =1.12E-07 and Total Power [kW] =0.147196388

PUMP 2

Total head [m] =6.489775445, Total Fluid Head [kJ/kg] =6.36E-02, Pressure head [m] =6.489777943

Velocity head [m] = -2.50E-06 and Total Power [kW] =0.109625957

Calculation of Theoretical Plates of Distillation Column by McCabe-Thiele Method

A=Ammonia, B=Water

$Y_A+X_A=1$

$Y_B+X_B=1$

From Simulation:

$Y_A=0.8139$, $Y_B=0.1861$, $X_A=0.1861$ and $X_B=0.8139$

$ά_{AB} =P_{A'}/P_{B'}=(Y_A/X_A)/(Y_B/X_B)$ (12)

$ά_{AB} =19.12711$

$Y_A=X_{Aά}/1+X_A(ά-1)$

Substituting Values

XA	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
YA	0.6799	0.8209	0.8912	0.927	0.9503	0.966	0.978	0.987	0.9942	1

From simulation

XD=0.999, XF=0.1861, RD=0.6

Φ=XD/(RD+1) (13)

Φ=0.624375

3.4. Costing of equipment

Distillation column
Height of column=3.048 m, Diameter of column=0.3048 m, Operating Pressure=10 Bar, Packing=Saddle Ceramic=25mm (1 inch)
Height of packing =HETP of one plate * Number of theoretical plates=1.524
Volume of Packing=0.111179m^3
Cost of Column=Vessel Cost* P factor *Type Factor Cost of Column=3840£
For Saddle Ceramic:
Cost/m^3=840£/m^3
Cost=93.39038£

Total Cost=Column Cost + Packing Cost (14)

Total Cost=3933.39£ or 4798.736$
Reboiler;
For Area:
Q=95570W, LMTD=31.66°C
For U:
h1=250W/m^2K, h2=1000W/m^2K, x=0.0639m, k=218.489W/mK, 1/u=0.005292, u=188.9479W/m^2K
A=Q/U*LMTD (15)
A=15.97602m^2
Cost of Reboiler=Vessel Cost * Factor of Pressure * Type of boiler
Vessel cost=6000£, Factor of Pressure=1.1(For 10 Bar), Type Factor=1.3(For Kettle Type)
Cost of Boiler=8580£ or 10467.6$
Absorption column:
Height of column=3.048m, Diameter of column=0.3048m, Operating Pressure=7.5Bar, Packing=Saddle Ceramic 25mm (1 inch)
Height of packing =HETP of one plate * Number of theoretical plates=1.524
Volume of Packing=0.111179m^3
Cost of Column=Vessel Cost* P factor *Type Factor
Cost of Column=7680£
For Saddle Ceramic:
Cost/m^3=840£/m^3
Cost=93.39038£
Total Cost=Column Cost + Packing Cost
Total Cost=7773.39£ or 9483.536$
Heat Exchanger 1:
h_{hot} =1000W/m^2.k, h_{cold} =1000W/m^2.k, dia =0.0639m, k=218.489W/m^2.k
1/U = 1/h_{hot}+1/h_{cold}+d/k=0.002292 or U=436.212 W/m^2.k
From simulation
UA =3.99E+06J/h.°C
Therefore:
A=2.540813m^2
Taking:
Shell = Carbon Steel, Tube = Stainless Steel (U Tube)
From simulation
Operating Pressure=13bar
Cost For Exchanger 1:
Total cost =Bare cost from figure*Type factor *Pressure Factor
Total cost= 1870£ or 2281.4$
Heat Exchanger 2:
h_{hot} =250W/m^2.k, h_{cold} =1000W/m^2.k, dia=0.0639mk=218.489W/m^2.k
1/U = 1/h_{hot}+1/h_{cold}+d/k=0.005292 or U=188.9479W/m^2.k
From Simulation:
UA =6.07E+06J/h. °C
A=8.923681m^2
Taking:
Shell =Carbon Steel, Tube= Carbon Steel (U tube)
From Simulation
Operating Pressure=8bar
Cost For Exchanger 2:
Total cost =Bare cost from figure*Type factor *Pressure Factor
Total cost= 3825£ or 4666.5$
Condensor Sizing:
h_{water} =1750W/m^2.°C, $h_{ammonia}$ =6000W/m^2. °C, kss =45W/m. °C, Thickness of tube= 0.001m
1/U = 1/hamm+1/hwater+x/k=0.00076 or U=1315.24W/m^2. °C
Tamm1=37 °C, Tamm2=28 °C, Twater1=25 °C, Twater2=36 °C, LMTD=1.820478 °C
From Simulation:
Q=3.65E+04W
Q = U*A*LMTD
A =15.26082m^2
Cost of condensor:
Total cost =Bare cost from figure*Type factor *Pressure Factor
Total cost =9350£ or 11407$

Cost for Solar:
Aperture area per piece = 15.3 m², Cost per piece = 1160 $, Total Aperture Area = 90 m² , Total number of pieces required = 5.882353
Total Cost = 6823.529 $ or 5593.057 £
Total Cost of 10 Ton Chiller:
Total Cost of the Equipments are given in Table 4.
Heat Exchanger 1 = 1870 £, Heat Exchanger 2 = 3825 £, Condenser = 9350 £, Distillation Column = 3934 £, Reboiler = 8580 £, Absorber = 9483 £, Solar Parabolic troughs cost = 5593 £, Total cost in 2002 = 42635 £
Cost Index of the base year (2002) =426
Cost Index of the year (2016) = 1081
Total cost in 2016 = 108188.8 £ (In Sterling)
Total cost in 2016 = 135236 $ (In Dollars)

Table 4: Operating Cost

For 10 Ton	Operating Cost					
	Capital	2016	2017	2018	2019	2020
Compression Chiller Cost	7377	5200.7	10713.44	16552.27	22742.82	28132.86
Solar Chiller Cost	42800	1300.175	2678.361	4138.067	5685.704	7033.216

The comparison of a cost analysis of compression chiller and solar absorption chiller shown in Figure 19.

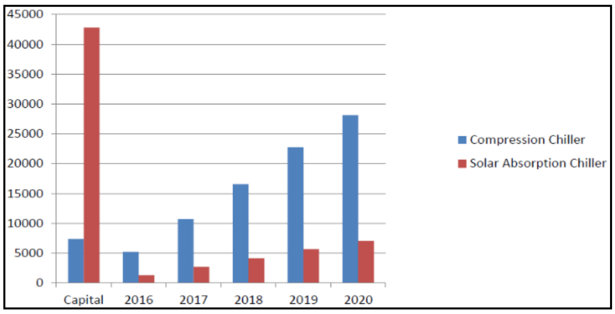


Fig. 19: Cost Analysis.

4. Conclusions

The aimed to design an absorption chiller based on utilizing heat from a solar system is successfully achieved. A solar-driven ammonia absorption refrigeration system is designed. Hence this work proposes using solar thermal systems (parabolic trough collectors) as a heat source for solar absorption chillers reducing significantly air conditioning electric consumption. The NH_3/H_2O proportion utilizes in this research are in the rage of 5% - 30% NH_3 in H_2O dependent on volume rate in the solution and the coefficient of execution is determined utilizing a revocable Carnot cycle procedure of absorption chiller as the principle extent of this study. Simulation of Ammonia Absorption Ciller is carry on ASPEN HYSUS using the Soave-Redlich-Kwong (SRK) model, gives practically identical outcomes. The exclusive improvements to the SRK permit the SRK equation of state (EOS) to accurately speak to vacuum conditions and substantial segments, just as handle the light closures and high-pressure frameworks.

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List of Nomenclature

Qe = Heat absorbed by refrigerant, M = Mass flow rate of ammonia, Cpw = Specific heat of water, Cp = Specific heat of mixture, Hi = Enthalpy of specie i, Mi = Mass flow rate of specie I, Xi = Composition of specie i, Qc = Heat removed in condenser, Qa = Heat removed from absorber, Ti = Initial Temperature, Tf = Final Temperature, Qg = Heat given in generator, Qd = Sensible heat supplied by generator, C.O.P = Coefficient of performance, P1 = Suction pressure, P2 = Discharge Pressure, P = Power Demand, Ep = Efficiency of pump, Q = Flow rate, Z = Zenith angle, ISC = Solar constant, R = Latitude of location, S = Declination angle, T = Hour angle, Iz = Intensity of solar radiation, Ih = Radiation of surface, E = Efficiency of solar collector, Is = Solar Radiation Intensity, Ir = Reflected intensity, A = Surface Area of Parabolic Dish, f = focal length, Ap = Aperture Area.

References

[1] Xu, D., Qu, M., Hang, Y. and Zhao, F., "Multi-objective optimal design of a solar absorption cooling and heating system under life-cycle uncertainties." *Sustainable Energy Technologies and Assessments*, Vol. 11, 2015, pp. 92-105. https://doi.org/10.1016/j.seta.2015.07.001.

[2] Keshtkar, M.M., "Energy, exergy analysis and optimization by a genetic algorithm of a system based on a solar absorption chiller with a cylindrical PCM and nano-fluid." *International Journal of Heat and Technology*, Vol. 35, No. 2, 2017, pp. 416-420. https://doi.org/10.18280/ijht.35226.

[3] Said, S.A.M., Spindler, K., El-Shaarawi, M.A., Siddiqui, M.U., Schmid, F., Bierling, B. and Khan, M.M.A., "Design, construction and operation of a solar powered ammonia–water absorption refrigeration system in Saudi Arabia." *International Journal of Refrigeration*, Vol. 62, 2016, pp. 222-231. https://doi.org/10.1016/j.ijrefrig.2015.10.026.

[4] Montagnino, F.M., "Solar cooling technologies. Design, application and performance of existing projects." *Solar Energy*, Vol. 154, 2017, pp. 144-157. https://doi.org/10.1016/j.solener.2017.01.033.

[5] Li, Q., Zheng, C., Shirazi, A., Bany Mousa, O., Moscia, F., Scott, J.A. and Taylor, R.A., "Design and analysis of a medium-temperature, concentrated solar thermal collector for air-conditioning applications." *Applied Energy*, Vol. 190, 2017, pp. 1159-1173. https://doi.org/10.1016/j.apenergy.2017.01.040.

[6] Moradi, M. and Mehrpooya, M., "Optimal design and economic analysis of a hybrid solid oxide fuel cell and parabolic solar dish collector, combined cooling, heating and power (CCHP) system used for a large commercial tower." *Energy*, Vol. 130, 2017, pp. 530-543. https://doi.org/10.1016/j.energy.2017.05.001.

[7] Shirazi, A., Taylor, R.A., Morrison, G.L. and White, S.D., "A comprehensive, multi-objective optimization of solar-powered absorption chiller systems for air-conditioning applications." *Energy Conversion and Management*, Vol. 132, 2017, pp. 281-306. https://doi.org/10.1016/j.enconman.2016.11.039.

[8] Wang, J., Lu, Y., Yang, Y. and Mao, T., "Thermodynamic performance analysis and optimization of a solar-assisted combined cooling, heating and power system." *Energy*, Vol. 115, 2016, pp. 49-59. https://doi.org/10.1016/j.energy.2016.08.102.

[9] Wang, J., Yang, Y., Mao, T., Sui, J. and Jin, H., "Life cycle assessment (LCA) optimization of solar-assisted hybrid CCHP system." *Applied Energy*, Vol. 146, 2015, pp. 38-52. https://doi.org/10.1016/j.apenergy.2015.02.056.

[10] Bellos, E., Tzivanidis, C. and Antonopoulos, K.A., "Exergetic, energetic and financial evaluation of a solar driven absorption cooling system with various collector types." *Applied Thermal Engineering*, Vol. 102, 2016, pp. 749-759. https://doi.org/10.1016/j.applthermaleng.2016.04.032.

[11] Al-Ugla, A.A., El-Shaarawi, M.A.I. and Said, S.A.M., "Alternative designs for a 24-hours operating solar-powered LiBr–water absorption air-conditioning technology." *International Journal of Refrigeration*, Vol. 53, 2015, pp. 90-100. https://doi.org/10.1016/j.ijrefrig.2015.01.010.

[12] Calise, F., Dentice d'Accadia, M., Macaluso, A., Vanoli, L. and Piacentino, A., "A novel solar-geothermal trigeneration system integrating water desalination: Design, dynamic simulation and economic assessment." *Energy*, Vol. 115, 2016, pp. 1533-1547. https://doi.org/10.1016/j.energy.2016.07.103.

[13] Wang, M., Wang, J., Zhao, P. and Dai, Y., "Multi-objective optimization of a combined cooling, heating and power system driven by solar energy." *Energy Conversion and Management*, Vol. 89, 2015, pp. 289-297. https://doi.org/10.1016/j.enconman.2014.10.009.

[14] Feng, J., Schiavon, S. and Bauman, F., "New method for the design of radiant floor cooling systems with solar radiation." *Energy and Buildings*, Vol. 125, 2016, pp. 9-18. https://doi.org/10.1016/j.enbuild.2016.04.048.

[15] Said, S.A.M., El-Shaarawi, M.A.I. and Siddiqui, M.U., "Analysis of a solar powered absorption system." *Energy Conversion and Management*, Vol. 97, 2015, pp. 243-252. https://doi.org/10.1016/j.enconman.2015.03.046.

[16] Shirazi, A., Taylor, R.A., White, S.D. and Morrison, G.L., "A systematic parametric study and feasibility assessment of solar-assisted single-effect, double-effect, and triple-effect absorption chillers for heating and cooling applications." *Energy Conversion and Management*, Vol. 114, 2016, pp. 258-277. https://doi.org/10.1016/j.enconman.2016.01.070.

[17] Khan, M.S.A., Badar, A.W., Talha, T., Khan, M.W. and Butt, F.S., "Configuration based modeling and performance analysis of single effect solar absorption cooling system in TRNSYS." *Energy Conversion and Management*, Vol. 157, 2018, pp. 351-363. https://doi.org/10.1016/j.enconman.2017.12.024.

[18] Shirazi, A., Pintaldi, S., White, S.D., Morrison, G.L., Rosengarten, G. and Taylor, R.A., "Solar-assisted absorption air-conditioning systems in buildings: Control strategies and operational modes." *Applied Thermal Engineering*, Vol. 92, 2016, pp. 246-260. https://doi.org/10.1016/j.applthermaleng.2015.09.081.

[19] Ebrahimi, M. and Keshavarz, A., "Designing an optimal solar collector (orientation, type and size) for a hybrid-CCHP system in different climates." *Energy and Buildings*, Vol. 108, 2015, pp. 10-22. https://doi.org/10.1016/j.enbuild.2015.08.056.

[20] Bataineh, K. and Taamneh, Y., "Review and recent improvements of solar sorption cooling systems." *Energy and Buildings*, Vol. 128, 2016, pp. 22-37. https://doi.org/10.1016/j.enbuild.2016.06.075.

[21] Wang, J. and Yang, Y., "Energy, exergy and environmental analysis of a hybrid combined cooling heating and power system utilizing biomass and solar energy." *Energy Conversion and Management*, Vol. 124, 2016, pp. 566-577. https://doi.org/10.1016/j.enconman.2016.07.059.

[22] Zhang, H., Hong, H., Gao, J., Deng, Y.n. and Jin, H., "Thermodynamic performance of a mid-temperature solar fuel system for cooling, heating and power generation." *Applied Thermal Engineering*, Vol. 106, 2016, pp. 1268-1281. https://doi.org/10.1016/j.applthermaleng.2016.06.101.

[23] Kerme, E.D., Chafidz, A., Agboola, O.P., Orfi, J., Fakeeha, A.H. and Al-Fatesh, A.S., "Energetic and Exergetic Analysis of Solar-Powered Lithium Bromide-Water Absorption Cooling System." *Journal of Cleaner Production*, Vol. 151, 2017, pp. 1-43. https://doi.org/10.1016/j.jclepro.2017.03.060.

[24] Shirazi, A., Taylor, R.A., White, S.D. and Morrison, G.L., "Transient simulation and parametric study of solar-assisted heating and cooling absorption systems: An energetic, economic and environmental (3E) assessment." *Renewable Energy*, Vol. 86, 2016, pp. 955-971. https://doi.org/10.1016/j.renene.2015.09.014.