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# Experimental results of a direct air-cooled ammonia–lithium nitrate absorption refrigeration system

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## HIGHLIGHTS

- Experimental results of a direct air-cooled ammonia–lithium nitrate system.
- The prototype is a one stage ammonia–lithium nitrate air cooled chiller.
- The absorption system was operated successfully at ambient temperatures.
- Cooling loads of 4.5 kW were reached in the chilled water side.

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## ABSTRACT

Absorption thermal cooling systems driven by renewable energy are a viable option in order to reduce fossil fuel consumption and the associated emissions. This work shows the results of an air cooled absorption cooling prototype working with an ammonia–lithium nitrate mixture at high ambient temperatures. An absorption refrigeration system was designed and built. The prototype is a one stage ammonia–lithium nitrate air cooled chiller. The experimental system was instrumented to evaluate each component. This paper shows the operation conditions in the experimental unit as well as some of the heat loads encountered at different operating conditions. The system was operated successfully at ambient temperatures in the range of 25–35 °C. A series of test showed that even at ambient temperatures it can be operated at evaporator temperatures below 10 °C producing chilled water for air conditioning applications such as radiative cooling panels. The system proved to stabilize very quickly and no risk of crystallization was encountered so the first results are promising in order to continue with the development of a more advanced prototype.



## 1. Introduction

Cooling with mechanical vapor compression systems driven by electric power is widely available all around the planet. Although efficient, nevertheless their massive use causes some new problems to modern society as millions of systems are installed every year such as a higher power consumption and electricity peak loads in electricity grids. Also electricity is mainly generated from fossil fuels and pollution is caused by their associated GHG emissions. Absorption and adsorption thermal cooling systems driven by renewable energy sources are a viable option for cleaner cooling systems.

Ammonia is a long-time used refrigerant, still widely used due to its excellent thermo-physical properties. Generally ammonia–water absorption systems have been designed to operate below freezing conditions for application such as ice making and food processing. An air cooled system can be used also for air conditioning applications Also from a point of view of ozone depletion potential (ODP) and global warming potential (GWP) considerations it is an excellent option if care is taken in its handling. In absorption systems, ammonia as a refrigerant is generally absorbed in an ammonia–water solution. In the generation process, due to its relatively high vapor pressure, traces of water are evaporated with the ammonia vapor, therefore a rectifier is required in order to avoid water being entrained into the condenser and evaporator,

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reducing the performance of the system. If a salt such as lithium nitrate is used instead of water, an ammonia–lithium nitrate solution is formed that does not require rectification due to the very low vapor pressure of the salt and as it has been discussed before in other articles, it can be separated at lower generator temperatures than ammonia from a water solution. The generation temperatures of absorption cooling systems can be varied to meet the cooling requirements, but generally in solar cooling the lowest possible generator temperature is pursued in order to use more efficiently the solar collector field. The thermodynamic advantages and theoretical and experimental analysis of this mixture extends now for many years [1–7].

The main disadvantages of the ammonia–lithium nitrate mixture are its high viscosity and the risk of crystallization if lower than 30% ammonia concentrations are used. In recent years there has been a series of studies related to the use of this mixture in cooling and refrigeration applications. The mixture has been again proposed as the use of compact and falling film heat exchangers as absorbers and generators have proven to produce better results than traditional heat exchange components [8–16]. Also the ammonia–lithium nitrate working pair system has been successfully used in intermittent solar refrigeration systems using the binary mixture and also adding a certain amount of water to reduce its viscosity.

This work shows the experimental results of an air cooled single stage absorption cooling prototype working with this mixture at high ambient temperatures.

The proposed system, being air cooled, requires of a higher drive temperature, that can now be provided by high efficiency evacuated tube collectors. Also, being air cooled the cooling system does not require a cooling tower, although the operation cycles is displaced to higher operating temperatures [17–20].

## 2. Experimental system description

An absorption refrigeration system was designed and built in the Refrigeration and Heat Pump Group at the Instituto de Energías Renovables of the Universidad Nacional Autónoma de México in Temixco, Morelos, México. The prototype was a small capacity one stage ammonia–lithium nitrate air cooled chiller. The system was first used as a demonstration unit and designed to be transported in the back of a pick-up truck. It was used to promote absorption technology in industrial processes, no useful cooling was produced, as for compactness, the condenser and the evaporator were both air cooled by the same fan and located on top of the other components [21]. The system was later modified to improve its performance, the main modification was the incorporation of a plate heat exchanger type evaporator in order to produce chilled water in a controlled heating loop, that simulated a cooling load. Fig. 1 shows a photograph of the modified system.

Table 1 shows the design data of the refrigeration system.

The largest component was a vertical air cooled absorber consisting of four parts: 1) in the upper part a solution distributor was installed, 2) The second part was the main body of the ail cooled absorber where the absorption took place in the inside of the tubes of the falling film absorber, it was composed of 29 finned tubes, 3) a storage sump for storing the solution and 4) an ammonia vapor distributor which included a series of tubes which were inserted one each of the finned absorber tubes. The absorber was air cooled with two fans with a 746 W (1H.P.) motor each. The generator was of the falling type with horizontal tubes, it was composed by 12 tubes arranged in four rows and three columns, it also had a solution distributor and a solution sump. Heating oil circulated inside the tubes and the ammonia–lithium nitrate solution felled over the tubes in a falling film generating the ammonia refrigerant. The


**Fig. 1.** Absorption cooling system.

performance of this component has been already reported [8]. The heating oil used to drive the chiller was Mobiltherm 603 heated by a heating loop that included a 20 kW electric resistance located in the bottom of the oil storage tank. The condenser was a finned tube air cooled condenser with a fan motor combination of 1119 W (1.5 HP) capacity. The evaporator consisted of a plate heat exchanger where chilled water was cooled in a closed system that included a storage tank and an electric heater to simulate a cooling load. The experimental system also included a solution heat exchanger between the generator and absorber which consisted of a brazed plate heat exchanger.

The ammonia–lithium nitrate solution pump was of the diaphragm type with a control of one per cent precision on the discharge flow at constant pressure conditions, in order to control the fluctuations on the pump flow and to be able to measure accurately the solution flow, a pulse damper tank was mounted at the pump discharge.

## 3. Data acquisition system

The prototype was instrumented in order to evaluate the experimental system and each component. A PC and a data acquisition system registered the data. The temperatures in the system were measured using RTD PT_100 sensors with a response time of 0.3 s and a precision of ±1% of the measurement. Pressure transducers were used to measure the pressure with a precision of ±1% of the measurement. The refrigerant flow, the strong in ammonia solution flow, the weak in ammonia solution flow and the heating oil flow were measured with a Coriolis type mass flow meters with a precision of ±0.1% of the measurement. The chilled water flow was measured with a turbine type rotameter with a

**Table 1**
Design data.

| | | |
|---|---|---|
| $T_{EV} = 10\ ^\circ C$ | $Q_{AB} = 7.82$ kW | $\dot{m}_R = 0.281$ kg/s |
| $T_{AB} = 50\ ^\circ C$ | $Q_{GE} = 8.53$ kW | $\dot{m}_{AB} = 1.65$ kg/s |
| $T_{CO} = 40\ ^\circ C$ | $Q_{CO} = 5.75$ kW | $\dot{m}_{GE} = 1.37$ kg/s |
| $T_{GE} = 110\ ^\circ C$ | COP = 0.59 | $P_{CO} = 15.56$ bar |
| $\eta_{EC} = 0.9$ | $C_{GE} = 0.388\ kg_{NH_3}/kg_{sol}$ | $P_{EV} = 6.15$ bar |
| $Q_{EV} = 5$ kW | $C_{AB} = 0.491\ kg_{NH_3}/kg_{sol}$ | |