# SOLAR DRIVEN ABSORPTION AIR CONDITIONING SYSTEMS FOR THE CARIBBEAN

**By**
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This research program addresses the need for the development of new air conditioning technologies having minimum operational impact on the environment that is augmented in regions without conventional fuel sources due to the high cost energy. The long-term rationale for this project is to provide consumers living in the hot and humid climates of the Caribbean with a proven technology that will assist in reducing the energy production from conventional fuels, by minimizing the use of conventional air-conditioning systems which, in general, use environmentally non-friendly refrigerants.

The project started in 1995 with the development of engineering design tools for a solar air conditioning system that consists of a closed absorption machine driven by an array of high performance flat plate collectors, a cooling tower, and an auxiliary heater as shown in Figure 1. The design tools for the solar air conditioning system were based on a detailed heat and mass transfers analysis of each component. Room sensible and latent heats were estimated by assuming the latent load to be a fraction of the sensible load, $f_{RLH}$. Year round simulations were performed for variable cooling loads and under the climatic conditions of cities in the Caribbean. Optimization procedures were carried out for parameters such as collectors' slope, thermal storage tank size, and collector area. Variable cooling loads were used with a maximum value ranging of 18-176 kW. An optimum collector slope of 19° from the horizontal was found to provide maximum tilted radiation throughout the year in Puerto Rico; whereas a slope of 10.5° was used for the simulations at Trinidad. An optimization procedure was also carried out for the storage tank size as related to collector area and annual solar fraction. A storage volume to collector area ratio of 41 l/m$^2$ was found satisfactory for all cities. The optimization criterion for the sizing of the collector array was to meet all the air conditioning and dehumidification load for a typical day in the hottest month with the highest possible solar fraction. Based on this criterion, the optimum number of collectors for various constant loads in the desired load range, and for room latent heat to room sensible heat ratio of 20 is shown in Figure 2.

The simulations tools were used to design an actual system for experimental and demonstration purposes. The system was sized and optimized by using the simulation model. The system consisted of a 35-kW LiBr-$H_2O$ absorption chiller, two, 65 m$^2$ and 48 m$^2$, arrays of flat plate black crystal selective surface solar collectors, a 5700-liter hot water storage tank, an 84-kW cooling tower, a 1800-liter per hour air handling unit, and a 50-kW auxiliary heater. The system was installed to supply conditioned air to the visitor center and the conference room area of the US Fish and Wildlife facility in Cabo Rojo, Puerto Rico. The system began operations in September 1997 and has been running almost continuously since. A general schematic of the system is shown in Fig. 3. Performance parameters such as system COP, collector efficiency, latent and sensible load on the chiller, and auxiliary heat requirement have been measured continuously. Data was gathered with a National Instrument's state-of-the-art data acquisition system that also allowed the overall control of the unit. Typical coefficients of performance (COP), solar fractions, collectors' efficiencies, and overall system efficiencies are shown in Figs. 4-7. The overall efficiency is defined as the cooling effect divided by the heat input to the generator.

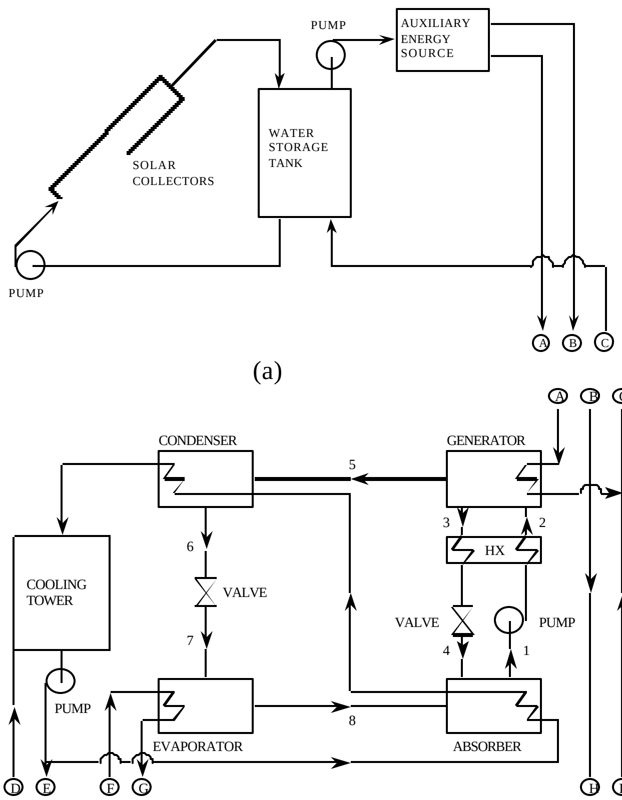


Figure 1. Schematic diagram of the solar air conditioning system, composed of: (a) a flat-plate slar collectors and thermal storage tank unit; (b) a single-effect closed aborption system.

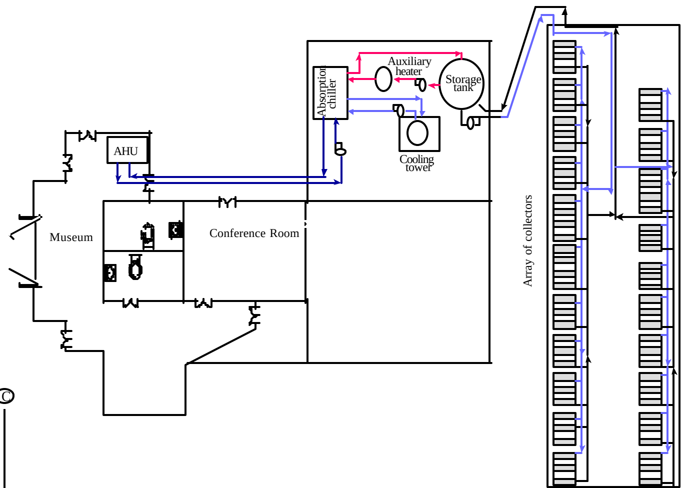


Figure 3. Schematic diagram of the actual solar absorption system

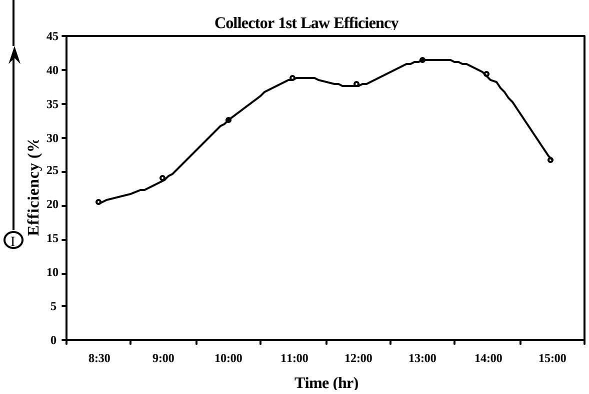


Figure 4. Typical average thermal efficiency for array of collectors

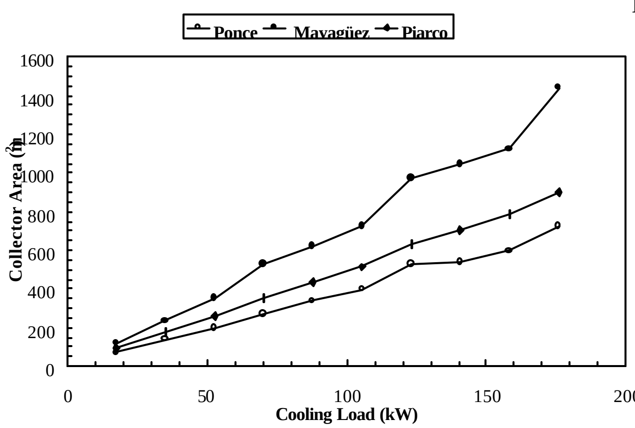


Figure 2. Area optimization for a solar absorption air conditioning system - $f_{RLH} = 0.2$.

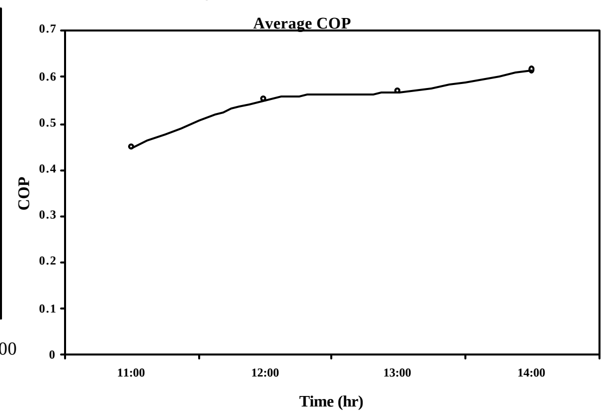


Figure 5. Typical average COP for Cabo Rojo system

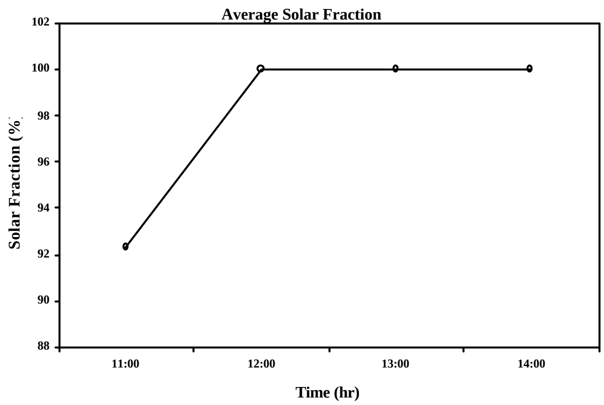


Figure 6. Typical average solar fraction delivered by the Cabo Rojo system

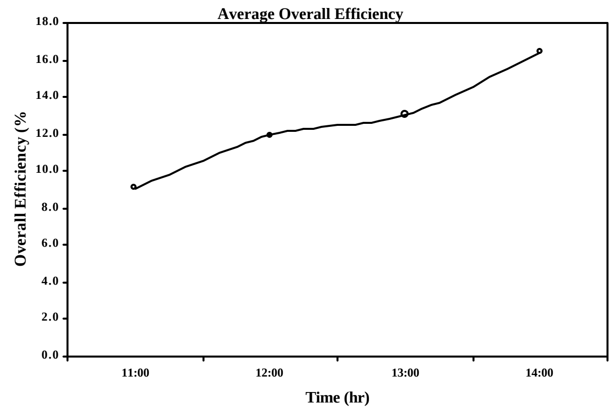


Figure 7. Typical average overall efficiency for the Cabo Rojo system

More recently, the team of researchers has focused in the development of a compact solar air-conditioned system. The capacity of the new system is targeting a cooling range of 3-5 cooling tons, which is typical of multi-residential and light commercial areas in the Caribbean. A compact air-cooled closed absorption chiller machine was designed using the EES (Engineering Equation Solver) program. An accurate water-lithium bromide absorption cycle simulation was carried out to examine every state point and fluids behavior in each one of the machine components. Simulations for air conditioning application in Puerto Rico and similar regions were completed. The simulations include the thermal performance of solar collectors, the thermal storage tank and the absorption system. Cooling load calculations for a small office building for Puerto Rico are incorporated to the solar collectors-storage tank -absorption machine arrangement to study the behavior of the system. The main components of this single-stage system are absorber, generator, condenser, solution heat exchanger and evaporator.

The design of the compact absorption machine was based on detail system simulation of an air cooled absorption process and careful selection of system components. A detailed investigation of commercially available compact heat exchangers for the absorption machine was developed. The heat exchangers that will work as evaporator, generator, and heat exchanger solution were found to be commercially available.

The solution recuperative heat exchangers or economizers are plate heat exchangers. This type of exchanger was selected as a component because of the requirement of an equal heat transfer for both fluids and the small size that complied with one of the constraints established. Evaporators are shell and tube type. Heliflow heat exchanger technology is recommended for this component. It transfers heat 40 percent more efficiently than the equivalent straight tube heat exchanger. This is the result of its spiral design. It is small and light enough to hang from the piping.

Generators are shell and tube helical-coil exchanger types. The absorbent is flooded outside the tubes, and the hot water or heat source inside the tubes. An intermediate solution flows through an outlet pipe, where the refrigerant vapor evolved passes through a vapor/liquid separator consisting of baffles and eliminators. The selected absorbent containment is made of a ferrous material, mild steel, and water flow through stainless steel parts.

The condenser design for this air cooled absorption application is a product of an in house work, since air-cooled condensers for absorption machines was an innovative idea and no commercially available substitute were found. Compact size and the benefit of the overall system integration were achieved with this in-house design. Condensers are air-cooled compact, finned-tube heat exchangers. The absorber is the key component for this new absorption chiller product. Its design was also a product of an in house work.

After detailed selection and design of the air-cooled absorption unit components, a preliminary system integration of the machine was achieved as shown in Figure 8.

When considering dynamic cooling load calculations, the annual solar fraction increases with the storage tank volume-to-collector area ratio reaching a maximum at 125 Liter/m$^2$ and then decreases. At this point the optimum storage tank capacity is obtained as a function of the collector area. Similar results of solar fraction, COP and collector efficiency were found for 3, 4 and 5 Tons of cooling load for the cases of air-cooling and water cooling. The criteria of maximum solar fraction (100%) at the hour of maximum solar radiation is reasonable to obtain the optimum number of solar collectors, and these are: 19 for 5 Tons, 25 for 4 Tons and 32 for 5 Tons for location Ponce, Puerto Rico.

Finally, selection, design and integration of this air-cooled solar assisted absorption machine were achieved and cost analysis demonstrated a feasible product with a payback period of less than five years.

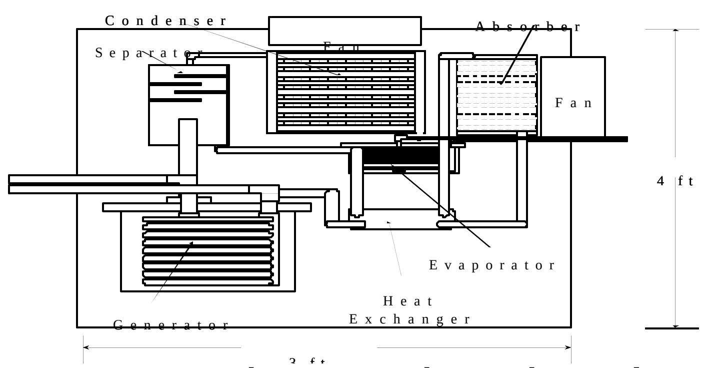


Figure 8: 3-5Tons Absorption Machine Architectural Concept.