

Solar Adsorption Cooling Box for Fishing Boats in Mexico

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Abstract: This paper describes a solar adsorption refrigerator for small fishing boats. Solar adsorption refrigerators have a significant potential to support sustainable livelihoods, and would help to increase the income of small-scale fishermen by reducing loss of saleable fish due to exposure to solar radiation.

Keywords: adsorption, solar concentrators, working fluids, open adsorption cycle, closed adsorption cycle.

1. INTRODUCTION

Use of renewable technologies (such as the one discussed here) is a clear way to reduce CO₂ emissions, especially in Mexico, where almost 75% of the primary energy supply to produce electricity comes from the burning of fossil fuels. Renewable energy is a key tool for sustainable development since it can help low income groups to increase their earnings without risking the capacity of future generations to do the same. In Mexico, fishing is an activity limited by the lack resources designated to it by the federal government. The income of most fishermen is limited by the lack of a reliable preservation method for the catch brought to market. Installing a solar adsorption refrigerator in fishing boats would increase the capacity to carry fresh fish and improve the quality of, and income from sales.

Mexico is a country with a great extension of shoreline. Although the Mexican fishing industry is not developed to its maximum potential, it represents an important economic sector, which provides an

income for a vast number of families. According to the National Institute of Statistics, Geography and Informatics (INEGI: 2004), there is a total capture volume of different species of 1.5 million tons, which is converted into approximately 1.3 million tons of shore product (i.e., 0.23 million tons or 15% of the initial capture is lost). Only 0.83 million tons of this is actually processed, which means that only 54% of the capture is processed. The fishing fleet consists of 77,000 crafts, of which only 4.3% are considered large (storage capacity of more than 10 tons.). The remaining boats are considered to be small crafts.

One of the main problems of the fishing industry is conservation of the product prior to its final consumption. According to INEGI, 30% of the frozen product and 42% of the canned product is lost to decomposition; this is in addition to the losses during the fresh product handling. Furthermore, most fishermen are grouped in co-operatives which have only small budgets to invest in efficient conservation systems for their products.

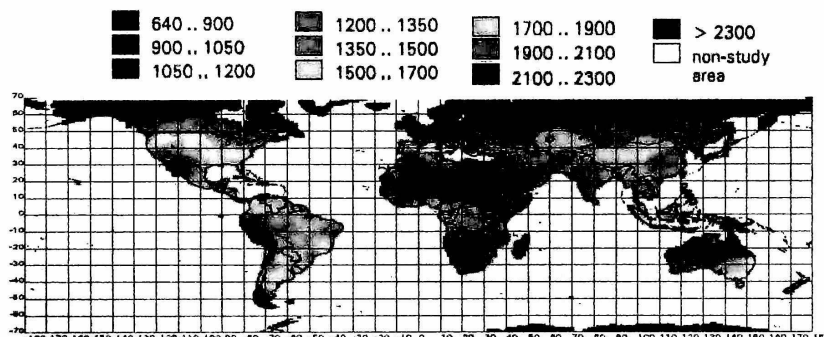


Figure 1: Global Irradiation, year (kWh/m²)

Solar energy has great potential to provide an alternative to the burning of fossil fuels. Every 15 seconds the earth's surface receives enough solar radiation to satisfy the annual human demand for electricity. In the case of Mexico, solar incidence is high, with a global mean radiation of over 2 000 Wh/m² annually. Figure 1 shows a map of world solar radiation.

Use of solar energy to run a cooling system for captured fish would provide the advantages of relatively low management and operation costs, and minimum environmental impact.

2. SOLAR COLLECTOR

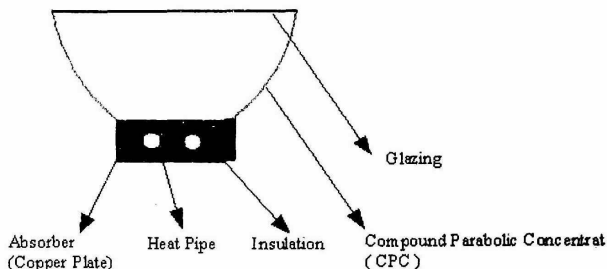


Figure.2 Schematic diagram of solar collector combined with the CPC

The collecting unit used in the cooling system has an innovative design. It involves the use of a concentrating device ideal for the meteorological conditions found in most parts of the Mexican littoral.

Figure 2 shows a schematic of the solar collector

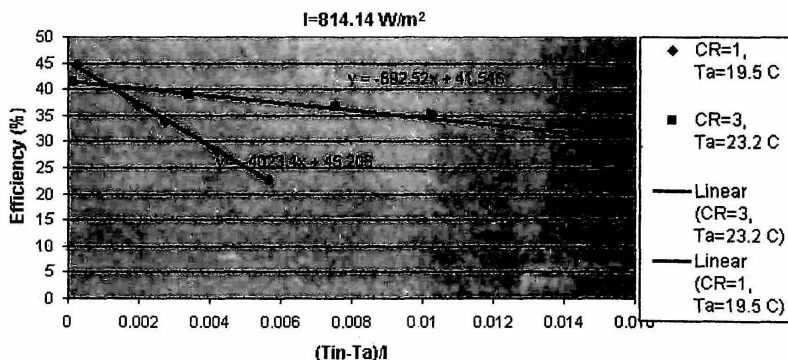


Figure.3 Efficiency of thermal system against $(T_{in} - T_a)/I$

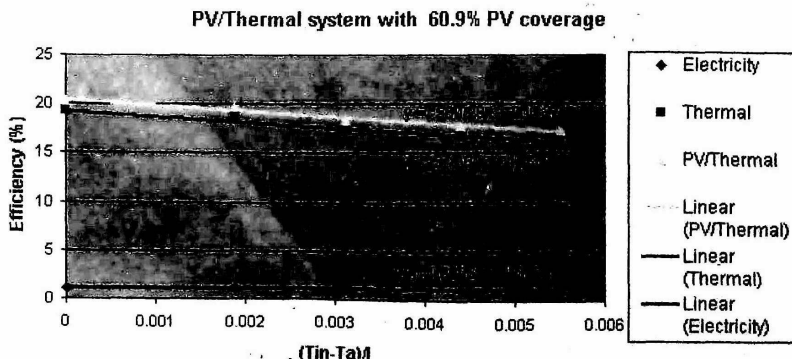


Figure.4 Efficiency of PV/Thermal system against $(T_{in} - T_a)/I$

integrated with the CPC and heat pipe. Compared to the traditional flat plate solar collector, the proposed solar collector system provides a higher temperature. The flat surface of the absorber also offers a place for PV cells, which can generate electricity for the circulating pump if needed. The concentrator benefits the system as it is cheap to make and requires small size absorber and PV cells. All the heat absorbed is transferred to the manifold by the highly efficient heat pipes integrated on the back of absorber. Working fluid passing through the manifold has a high temperature to power the adsorption system and is then fed back to the manifold to form a close cycle.

Preliminary experimental work on the solar collector without PV cells, standing vertically and using water as the working fluid, showed that the solar concentrator offer the system with higher thermal coefficient when it operates in a high temperature, although its original coefficient is a bit lower than without it (Fig.3). The hybrid PV/thermal system with 60.9% PV coverage showed that much lower coefficient because of PV cells (Fig.4). The percentage of PV cells is totally depending on the demands of thermal and electrical energy for the system.

3. ADSORPTION

Adsorption, also known as physio-sorption, is the process by which molecules of a fluid are fixed on the walls of a solid material¹. Adsorption involves nothing more than the preferential partitioning of substances from the gaseous of a liquid phase onto the surface of a solid substrate.

The process of adsorption involves the separation of a substance from one phase accompanied by its accumulation or concentration at the surface of another. The adsorbing phase is the adsorbent, and the material concentrated or adsorbed

at the surface of that phase is the adsorbate. Adsorption is thus different from absorption, a process in which material transferred from one phase to another (e.g. liquid) interpenetrates the second phase to form a "solution". The term sorption is a general expression encompassing both processes.

Physical adsorption is caused mainly by Van Der Waals and electrostatic forces between adsorbate molecules and the atoms which compose the adsorbent surface. Thus adsorbents are characterized first by surface properties such as surface area and polarity.

A large specific surface area is preferable for providing large adsorption capacity, but the creation of a large internal surface area in a limited volume inevitably gives rise to large numbers of small sized pores between adsorption surfaces. The size of the micropores determines the accessibility of adsorbate molecules to the internal adsorption surface, so the pore size distribution of micro-pores is another important property for characterizing adsorptivity of adsorbents. Materials such as zeolite and carbon molecular sieves can be specifically engineered with precise pore size distributions and hence tuned for a particular separation.

Surface polarity corresponds to affinity with polar substances such as water or alcohols. Polar adsorbents are thus called "hydrophilic" and aluminosilicates such as zeolites, porous alumina, silica gel or silica-alumina are examples of adsorbents of this type. On the other hand, nonpolar adsorbents are generally "hydrophobic". Carbonaceous adsorbents, polymer adsorbents and silicalite are typical nonpolar adsorbents. These adsorbents have more affinity with oil or hydrocarbons than water.

4. SOLAR ADSORPTION FRIDGE CYCLE

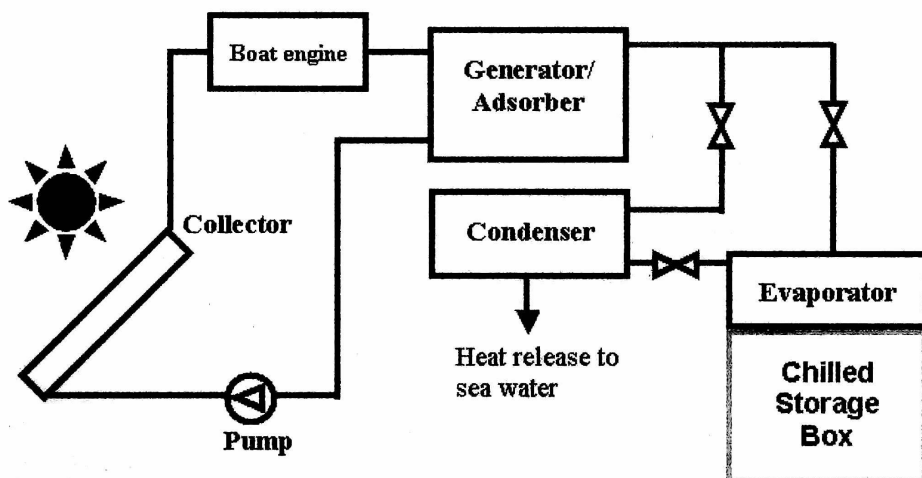


Figure 5. Schematic view of a Solar Adsorption Fridge for fishing boats

A schematic view of the proposed system is shown in Figure 5. Water is heated in the solar collector and may be further heated by the boat engine exhaust. The hot water is used to generate the adsorbents in the generator. The generated refrigerant vapour becomes a liquid in the condenser and the condensation heat may be released to the sea water. During the evaporating process, the generator can operate as an absorber which may be cooled by sea water. The evaporation of the refrigerant in the evaporator produces a cooling effect which used to chill the storage box.

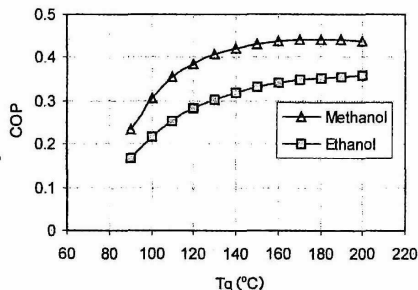


Figure 6. Coefficient of performance of adsorption cycles against generation temperature

Figure 6 gives the calculated coefficient of performance (COP) of the adsorption cycles using

methanol or ethanol as the refrigerant. The COP is around 0.3 for 100-120°C generation temperature.

5. BENEFITS OF THE SYSTEM

Both economic and environmental benefits would be derived from use of the proposed system in fishing communities. The benefits include:

- 1) The system is simple, compact and cost-effective. It is highly suitable for fishing boats.
- 2) It is economic and ecologically friendly as the system is driven by solar energy and/or the waste heat from the boat's engine.

6. CONCLUSIONS AND FURTHER WORK

A solar adsorption fridge has been proposed for application in fishing boats. The device may be driven solely by solar energy or by solar/exhaust heat. The device is simple and cost-effective. It would bring economic benefits to fishermen without damaging the environment. The further modeling and experimental work will be needed to assess the proposed system.

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