Review of Research & Development on Solar Distillation in Thailand

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INTRODUCTION

Solar distillation has already been used for salt production in Thailand for hundreds of years. It has been estimated that the solar energy currently used in salt production in this country is equivalent to about 19 million barrels of oil per annum.[1]

The basin-type solar still was first designed and built in 1872 near Las Salinas, Chile, by Carlos Wilson.[2] The still had a total absorbing area of 4700 m^2 and was in operation for about 40 years. No work on solar distillation was published after the 1880s till the end of the first World War. Analysis of the performance of the basin-type still by a computer simulation was first presented by Cooper in 1969.[3] The first solar still in Thailand was built by Messrs. Pongsakdi Vorasuntrosot and Pimol Kolkit in 1954.[4] Since then, there have been a number of research and development studies on various types of solar stills for different applications in Thailand.

In rural areas, clean drinking water is often scarce. It can of course be obtained by boiling raw water with firewood or charcoal which are usually available in rural areas at a cost. Solar distillation offers an attractive alternative. Apart from hygienic reasons, solar distillation may help reduce the consumption of fuelwood and consequently the depletion of forests in the country.

Distilled water is extensively used in laboratories and industrial processes. It is usually obtained by condensing steam produced by oil or electricity. Distilled water currently costs about 3-5 baht* per litre. Solar distillation has the potential to provide cheaper distilled water and to reduce the consumption of conventional energy.

PORTABLE BASIN-TYPE SOLAR STILLS

In 1975, Maung Nay Thun & Aftab studied four portable basin-type solar stills with different heights.[5] Each still had one glass cover inclined at 13° 44′ to the horizontal and was tested at the Asian Institute of Technology (AIT) which is at the latitude of 13° 44′. Test results showed that the still with the lowest front wall (80 mm) yielded the highest efficiency (about 30%).

Six basin-type solar stills having glass covers inclined at different angles from 10 to 20

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*1US$ = app. 23 baht (mid-1984).

degress were tested at the King Mongkut Institute of Technology Thonburi (KMITT), in 1977 (Fig. 1).[6] The best angle of inclination, which yielded highest rate of distillation, was found to be 14 degrees to the horizontal, which confirmed the angle chosen by AIT workers.

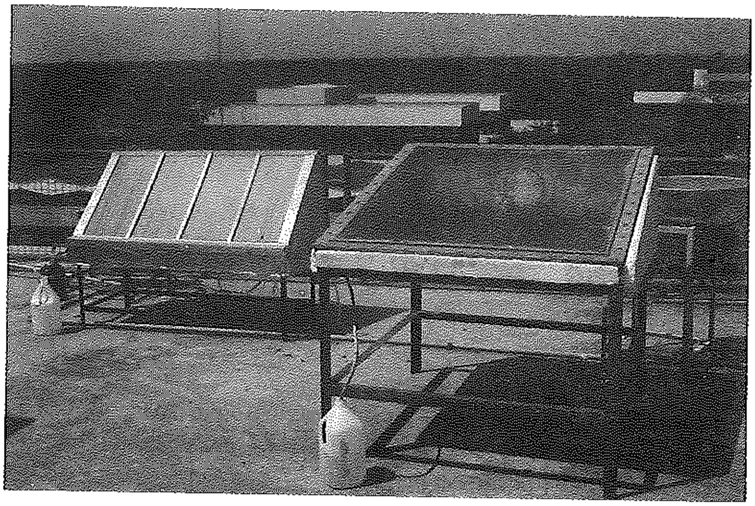

Fig. 1 Basin-type solar stills with glass and plastic covers.[6,7]

An investigation to determine the best angle of inclination for the plastic cover was conducted at KMITT in 1980.[7] Six basin-type solar stills having acrylic plastic covers inclined at different angles from 20 to 50 degrees were tested. It was found that the angle of inclination of 40 degrees to the horizontal yielded the highest distillation rate at about 1.7 L/m^2d at an annual average daily global radiation of 17 MJ/m^2d for Thailand (Figs. 2 & 3). It was also observed that condensation occurred as droplets underneath the plastic cover instead of as film condensation, which was the case for the glass cover.

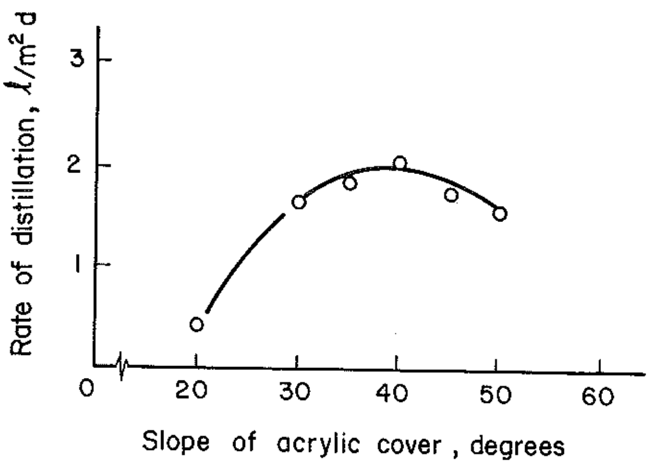

Fig. 2 Variation of the rate of distillation with the slope of the acrylic cover using a horizontal absorbing surface.[7]

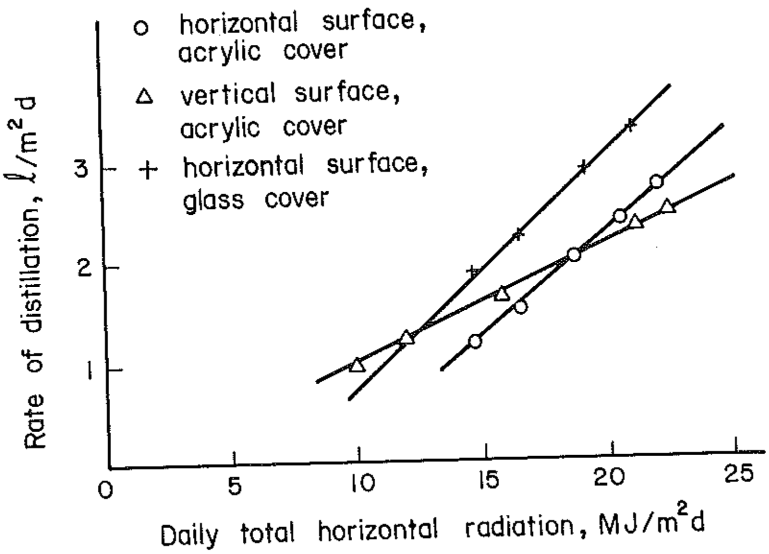

Fig. 3 Comparison of rates of distillation of solar stills with horizontal and vertical absorbing surfaces.[7]

Two types of absorbing materials, namely black butyl rubber and charcoal chips were experimentally compared in a solar still having an acrylic plastic cover inclined at 40 degrees to the horizontal.[8] Test results showed that both absorbing materials yielded about the same distillation rates of 1.71 L/m^2d at an annual average global radiation of 16.7 MJ/m^2d (Fig. 4). Charcoal seems to be more suitable due to its cheaper cost.

By making use of the tall back wall of the solar still with one acrylic plastic cover, three improvement methods were attempted.[8] First, the galvanized back wall was replaced with a

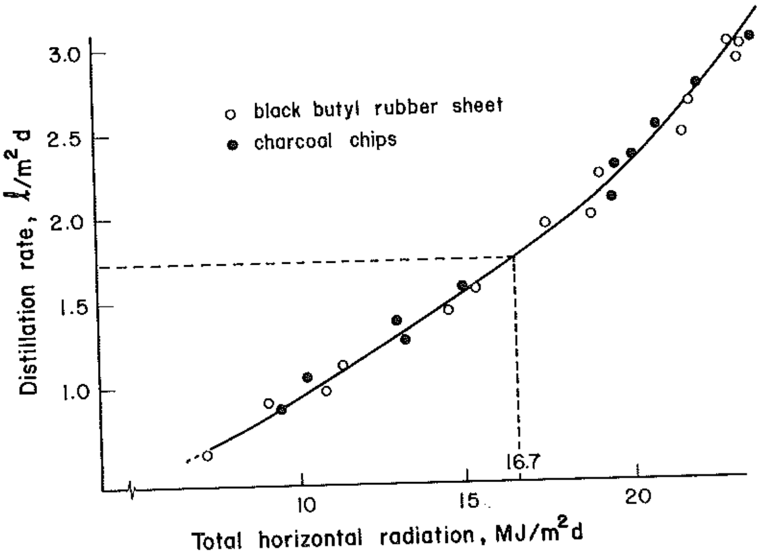

Fig. 4 Comparison between two absorbing materials, namely black butyl rubber sheet and charcoal chips.[8]

polished stainless steel sheet which reflected additional solar radiation on to the absorber at the floor of the basin. Second, raw water was allowed to flow down the outside surface of the back wall and was then fed into the basin. Third, a piece of black cotton cloth was used to cover the inside surface of the back wall in order to absorb additional solar radiation. Test results of the three improvement methods show approximately the same annual average rate of distillation. An improvement of about 13% can be achieved by any one of the three methods (Fig. 5). However, the still having the absorber on the back wall appears to be most suitable, as the cost of improvement is the lowest.

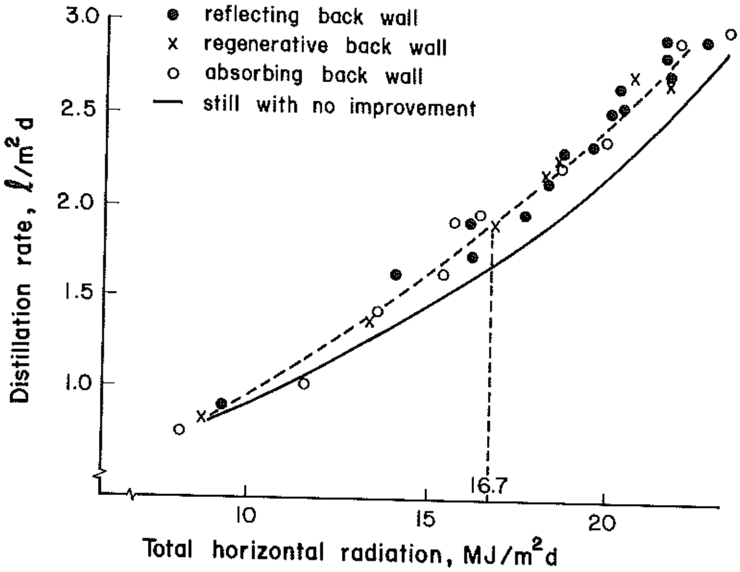

Fig. 5 Comparison of distillation rates obtained from three methods of improvement.[8]

Another design of the modular basin-type solar still at KMITT consisted of a double-wall basin made of fibre-reinforced plastic (Fig. 6).[9] To provide a good absorbing surface, black paint was mixed directly with resin that was used for making the basin floor. The cover of the still was made of transparent glass, 3 mm thick, and inclined at an angle of 14 degrees to the horizontal. The still had a total absorbing area of 1 m^2. At an annual average daily global radiation of 17 MJ/m^2d, it was estimated from the test results that the daily distillation rate obtained from the still was about 1.8 L/m^2d (Fig. 7). Sixteen additional solar stills of the same design were then constructed and put into field tests at a temple, two health posts and a hospital. After long-term tests over a period of up to seven months, it was observed that the distilled water was too acidic, with a pH of about 4.5, and yielded a strong smell of resin.

A modified design of the modular basin-type solar still consisted of an outer shell made of fibre-reinforced plastic and an inner basin made of aluminium. Small pieces of charcoal were placed on the basin floor to provide a good absorbing surface and to absorb any undesirable smell in the raw water.[10] Twelve additional modified stills were fabricated. Later on they replaced the stills at the temple and health posts. Four m^2 of the modified stills were also installed and tested at a school to provide distilled water for laboratory use. It is expected that long-term test results from these modified stills will be satisfactory.

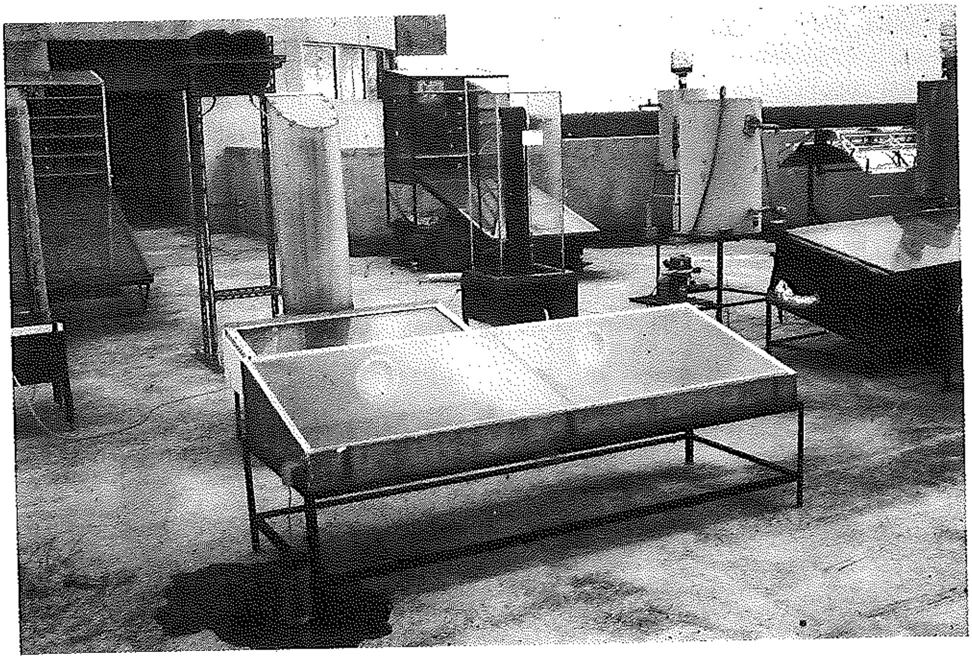

Fig. 6 Modular basin-type and vertical-surface solar stills.[7,9]

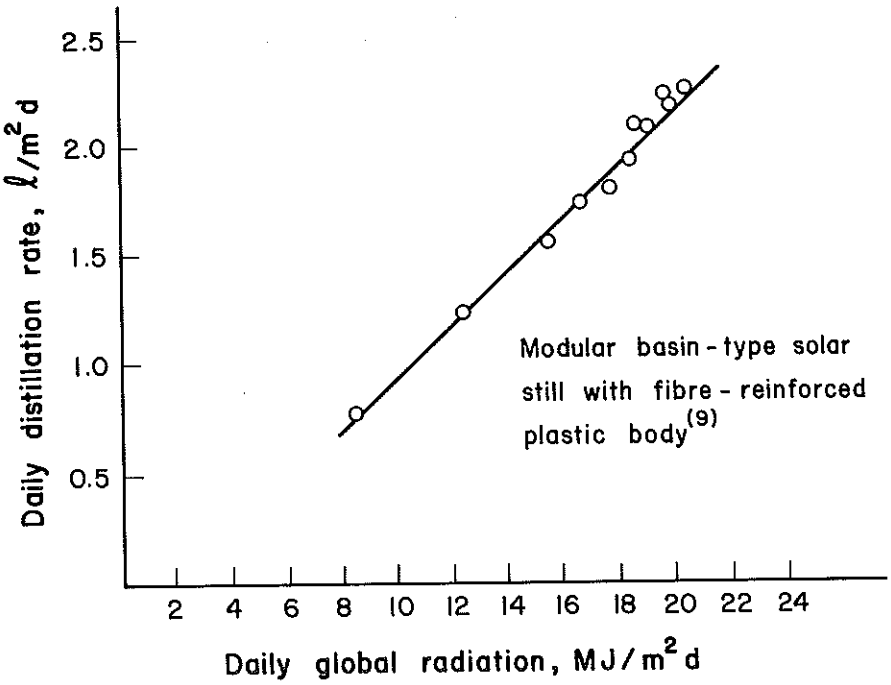

Fig. 7 Variation of daily distillation rate with daily global radiation.

LOW COST BASIN TYPE SOLAR STILLS

A low-cost basin-type solar still was developed at KMITT in 1978 (Fig. 8).[11] The basin of the still was made of mortar mixed with rice husk and built on the ground. The mortar coat on the basin floor contained black iron oxide powder to provide a good absorbing surface. The glass cover was 3 mm thick and was inclined at 14 degrees to the horizontal. It was estimated that the first cost of the still was about US$25.

A double-sloped stationary solar still with a mortar basin was also investigated at KMITT in 1979 (Fig. 8).[12] Its merit lies in the fact that the shorter basin, compared with the single-sloped still, is less prone to cracking. The still yielded a similar performance to that of the single-sloped one.

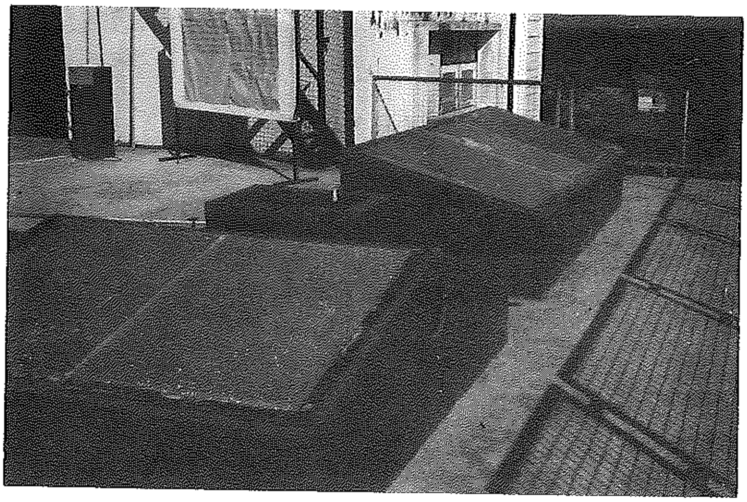

Fig. 8 Low-cost solar stills with single-slope and double-slope glass covers.[11,12]

VERTICAL SURFACE SOLAR STILLS

Very few articles have been published on vertical-surface solar stills. In 1975, Coffey first investigated the design of a solar still with a vertical cylindrical surface in Australia.[13] The study did not include an analysis of heat or mass transfer inside the still.

A solar still having a vertical cylindrical absorber of 100 mm diameter and a curved acrylic plastic cover was designed, constructed and tested in 1981 at KMITT.[7] The distance between the absorbing surface and the curved cover was about 100 mm. The still yielded a distillation rate of 1.73 L/m^2d at an annual average global radiation of 17 MJ/m^2d.

To determine the optimum distance between the absorbing surface and the glass cover a physical model of a still having a vertical flat absorber and adjustable glass covers was designed and tested indoors by electrical heating at AIT.[14] The optimum distance was found to be about 55 mm (Fig. 9). A prototype solar still having a vertical flat absorber of 1.86 m^2 was designed, constructed and tested outdoors with optimum distances between the glass covers and absorbing surfaces. The rate of distillation was found to be about 2 L/m^2d at an annual average global radiation of 17 MJ/m^2d when the absorbing plate faced an east-west direction.

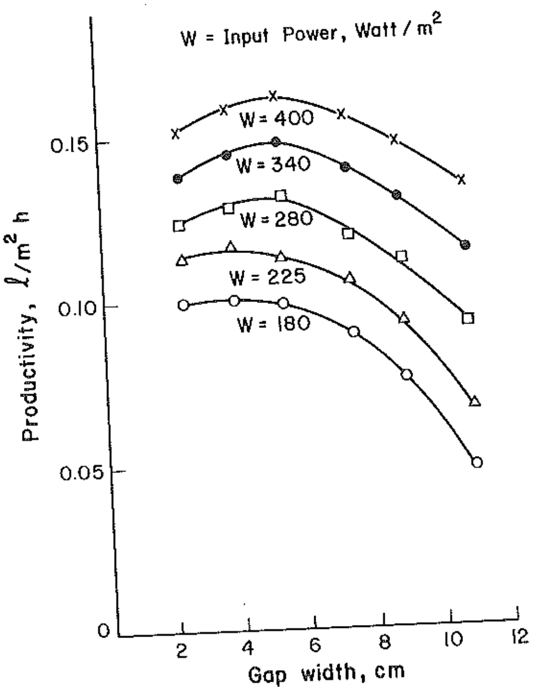

Fig. 9 Productivity vs gap width with constant input power for the still model with glass covers.[14]

However, outdoor tests on two other solar stills suggested that a wider gap between the vertical absorbing surface and the transparent cover provided better radiation transmission, especially around noon (Figs. 10 & 11).[10] A compromise design of a vertical surface solar still with an absorbing area of about 2.4 m^2 is being constructed. It is hoped that within two months, the new design will be ready for long-term outdoor tests.

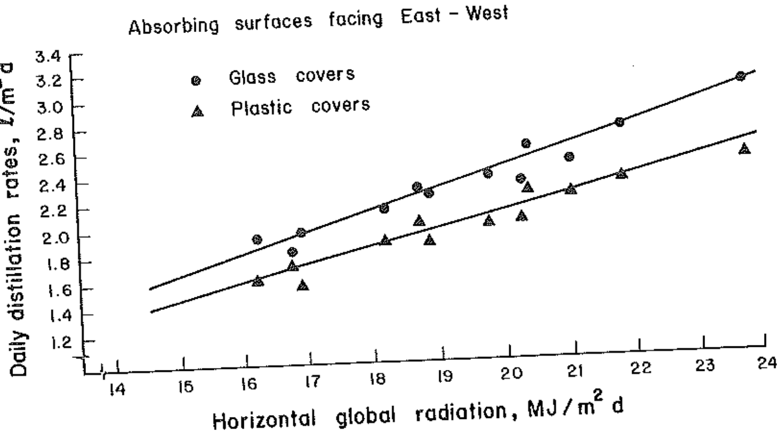

Fig. 10 Variations of daily distillation rates with horizontal global radiation for vertical solar stills with glass and plastic covers facing east-west[10]

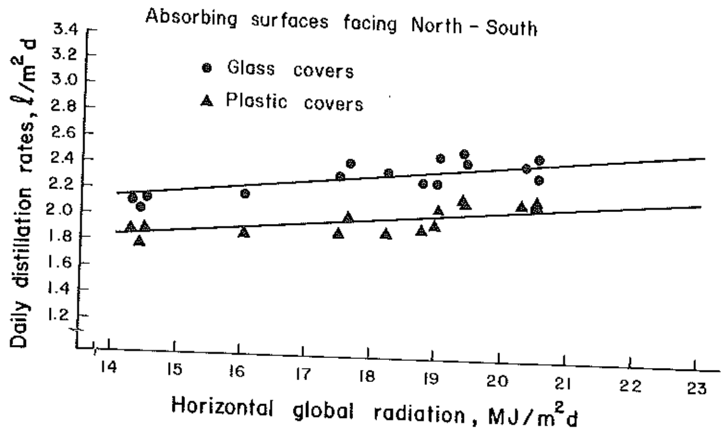

Fig. 11 Variations of daily distillation rates with horizontal global radiation for vertical solar stills with glass and plastic covers facing north-south.[10]

Predictions of rates of distillation were attempted by using the modified Reynolds-Flow model (Fig. 12).[10,14] Deviations of the predicted values were found to be within ± 10% of the measured values. Applications of the model were restricted to quasi-steady-state conditions around noon. The predictions also indicate that an empirical relationship developed by Cooper[15] is not applicable to vertical surface solar stills.

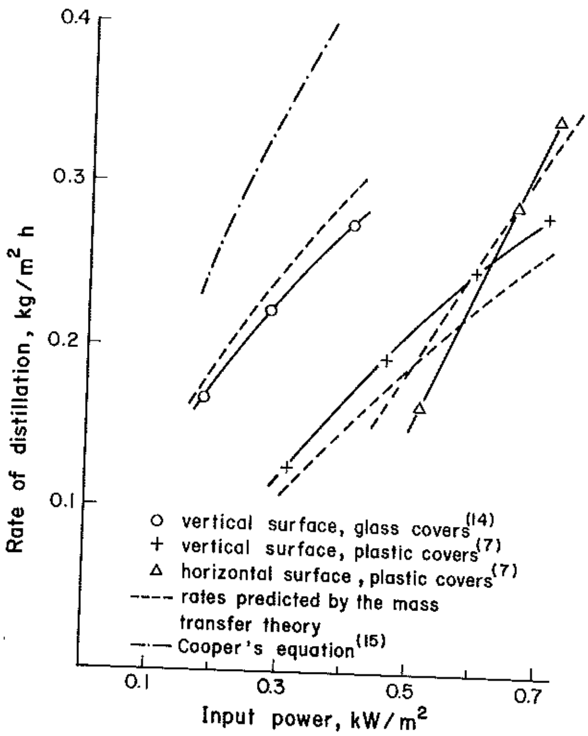

Fig. 12 Comparison between measured and predicted rates of distillation in different solar stills.[14]

CONCLUSIONS

Basin-Type Solar Still with One Acrylic Plastic Cover

– The acrylic plastic cover is less prone to be broken by accidents than the glass cover. The resistance of the plastic cover to degradation by solar radiation may, however, be less than that of the glass cover.

– Charcoal chips are preferable to black butyl rubber sheet as an absorbing material, since the former are cheaper and locally produced and they can also absorb any undesirable smell in raw water.

– All the three improvement methods on the vertical back wall of the still increased the daily distillation rate by about 13%. However, the addition of the black cotton cloth on the vertical back wall of the still is preferable since it is the cheapest method.

Modular Basin-Type Solar Stills with Fibre-Reinforced-Plastic Bodies

– After long-term tests, distilled water obtained from sixteen modular basin-type solar stills with double-walled fibre-reinforced plastic bodies was too acidic, with pH values of about 4 - 4.5.

– When the FRP inner basins were replaced by aluminium ones and charcoal chips were employed as the absorbing material, the quality of distilled water improved considerably, with pH values of about 6.5.

Solar Still with Vertical & Flat Absorbing Plates

– The solar still model with the vertical glass covers gave about 10% higher distillation rates than the still with the plastic covers.

– At a high global radiation, above 20 $MJ/m^2 d$, the still models with the vertical absorbers facing east-west yielded higher distillation rates than those with the absorbers facing north-south. At a radiation below 20 $MJ/m^2 d$, the results were reversed.

– Distances between the vertical absorbers and covers were much wider than the optimum gap obtained from the mass transfer consideration alone.[11]

RECOMMENDATIONS

Basin-Type Solar Still with One Acrylic Plastic Cover

– Long-term outdoor tests should be conducted on the still to determine the lifetimes of the acrylic plastic cover and of the cotton cloth on the vertical back wall.

– An economic assessment of the still should be carried out before it is promoted for field applications.

Modular Basin-Type Solar Stills with Fibre-Reinforced Plastic Bodies

– After long-term field tests, an economic and social evaluation of the stills with aluminium inner basins should be attempted.

– A more suitable resin should be selected as the material for the inner basin in order that distilled water does not become too acidic. Advantages of the true FRP basin can then be achieved.

Solar Stills with Vertical & Flat Absorbers

– Taking the effects of mass transfer and global radiation into account, true optimum gaps between the vertical absorbing plates and covers should be determined for east-west and north-south orientations.

– Transient phenomena inside the vertical solar still should be studied so that the still performance can be accurately predicted.

– Long-term outdoor tests should be conducted on large vertical-surface solar stills with acrylic covers facing north-south and east-west directions so that their technical and economic performances can be finally assessed.

Mass Transfer Theory

The prediction of the distillation rate by means of the convective mass transfer theory in this work still requires the values of the wet and dry bulb and interface temperatures inside the solar still. The theory should be further developed so that the measurement of these temperatures will not be needed for the prediction.

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