MULTI-EFFECT SOLAR STILLS

H.E.S. Fath
Al-Jubail 31951, Saudi Arabia

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Contents

Summary

Solar desalination presents a promising alternative for fresh water provision. However, in order to evaluate the appropriateness of a desalination plant in a given location, it is necessary to examine the benefits to society and the cost involved (compared with other water supply options). If these conditions cannot be met the proposed desalination plant is not recommended.

Many researchers were very much concerned with increasing the stills' efficiency and productivity. As indicated before, a combination of the following design and operational parameters should be considered in order to enhance unit efficiency: -

- Higher basin temperature (lower water level, use of wick, adding black dyes, additional external heating)
- Lower cover temperature (cover cooling, multi effect, condensation overnight with basin energy storage, additional condenser)
- Large evaporation and condensation surface areas (stepped basin / condensation surfaces, multi stacked trays)
- Reduction of still pressure, to minimize vapor leakage, eliminate air presence and

enhance evaporation / condensation rates (purge to other condensers, vacuum)
- Re-utilization of the latent heat of condensation (multi effect, multi stacked trays)
- Minimize heat losses (good side and bottom insulation)
- Utilization of the shaded area (additional condenser, combined stills).

More R&D (detailed feasibility study and pilot plant construction) should be directed towards new (or combination of) solar desalination processes that can produce fresh water at a competitive price.

1. Why Multi Effect?

The solar stills discussed in the earlier sections make use of solar energy on a single-stage basis. The thermal efficiency of a solar distillation unit in terms of daily production per m^2 can be increased by utilizing the latent heat of condensation. The re-utilization of latent heat of condensation, for further distillation, can be carried out as double-effect distillation. When more than two stages are involved, this is generally known as a multi-effect distillation system. The additional production resulting from the multi-effect still compared with that from the simple solar still should be justified, however, with the additional cost incurred in the more complicated multi-effect still.

A typical theoretical analysis of the two effects solar still is made by Fath (1995). The energy balance equations for the distillation system components are given in the Appendix.

2. Double Effect Basin Stills

2.1. Double Basins Stills

Different configurations of solar stills have been proposed in literature due to large area requirements of conventional basin type solar stills. However, the higher productivity is not desirable at the expense of cost of construction. Hence, attention has been focused on basin type solar stills with a view to improving their performance. In double basins type stills, the re-utilization of latent heat of condensation can be done by two methods. In the first, the water can flow over the glass cover, Figure 1(a), while in the other case water in the above basins can be kept stationary, Figure 1(b). In other cases part of the latent heat given up by the water vapor in the first effect is used to heat the water in the upper basin. Hence the amount of latent heat of vaporization in the second effect will be less than in the first effect.

Sodha et al. (1980) used a double-basin still similar to the one illustrated in Figure 1(a). The double basin still is similar to the roof-type still but has a transparent sheet (usually glass) between the glass cover and the basin liner. This still has the advantage of using the same floor area as the single-basin still but gives higher productivity. Typical results showed that the double basin type produced about 56 per cent higher yield than a single effect still.

Studies in single basin solar stills have shown that the lowering of glass cover temperature, caused by water flowing over it increases the daily distillate. The effect of water flowing over the upper glass cover of a double basin solar still has been studied by Rao et al. (1983) Figure 1(b). Their results showed that the process of flowing water over the glass cover has a good effect on the upper basin distillate output, and does not affect the lower basin resulting in a remarkable increase in the still efficiency over that without flowing water.

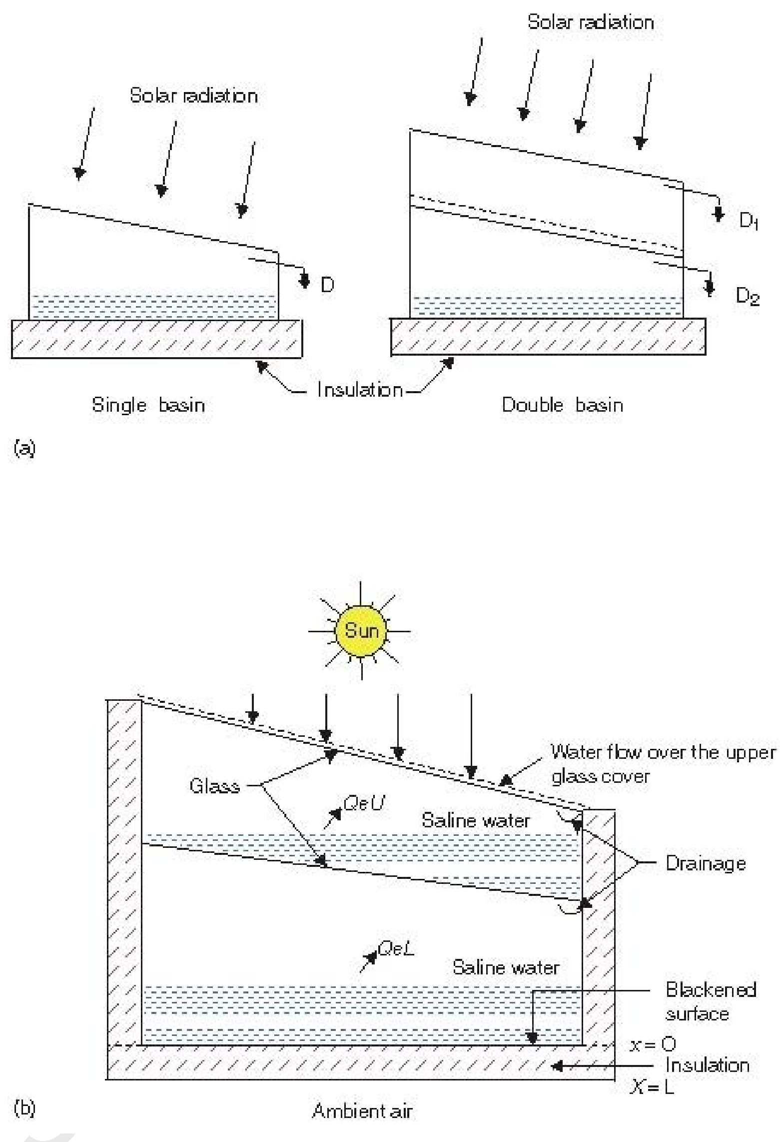

Figure 1. Double basin solar stills: (a) schematic of single and double basin stills, Elsayed et al. (1986) and Sodha et al. (1980; (b) stationary double basin still with flowing water over upper basin, Rao et al. (1983).

For higher daily yield, the temperature difference between the basin and the glass cover should always be kept large. This can be achieved by connecting the basin of the still to an external heating source (solar collector, solar concentrator or waste heat system) in addition to arranging water flow over the glass cover. Tiwari (1985) presented a straightforward transient analysis of a double basin still incorporating the effect of water flow over the glass cover and flow of hot water in the lower basin through a flat plate collector. The author concluded that (a) there is no significant effect on the flow rate of flowing water above the upper glass cover (possibly due to the low available energy at the upper glass cover); (b) the collector must be disconnected from the still during off-sunshine hours to avoid heat losses through the collector; and (c) the system gave about 50 per cent higher yield than that of an ordinary double basin still.

2.2. Double Effect Tilted Stills

Figure 2 illustrates a schematic of a double effect tilted still as proposed by Selcuk (1985). The still has the following features:

1. The still is directly integrated to a flat plate collector where its absorber can be selectively coated.
2. Higher transmittance is maintained by eliminating condensation on the inner face of the transparent covers.
3. The evaporator and condenser surfaces are brought closer together in order to increase the mass transfer rate by eliminating convection and maximizing the diffusion rate coefficients.

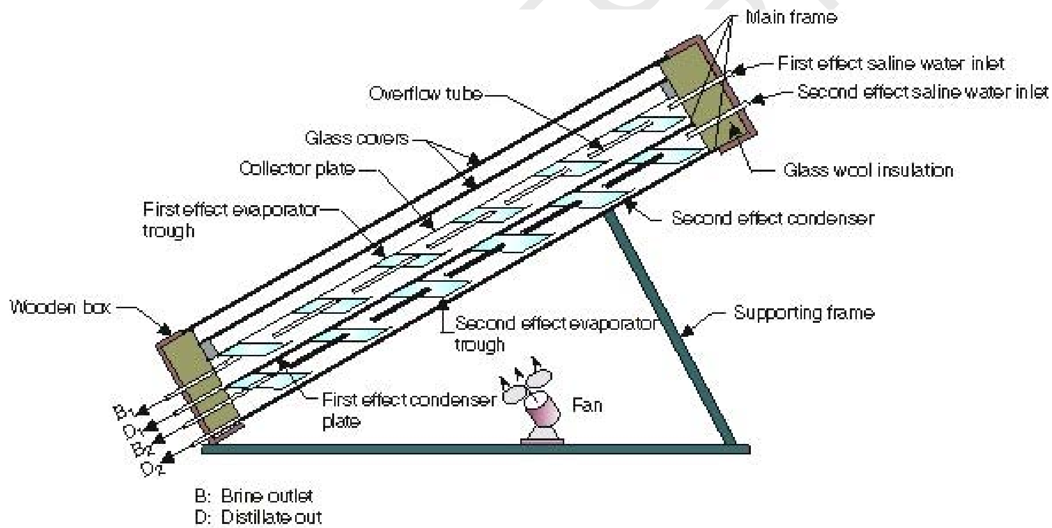

Figure 2. Schematic of double effect tilted still, Tiwari (1985).

Table 1 shows a comparison between the single effect, roof-type still and the two-effect tilted still as carried out by Selcuk (1964). Although the productivity and operational efficiency are improved by using the two-effect tilted still, high initial cost prevents its use commercially.

Item	Unit	Roof-type	Two-effect still	
			Fan cooled	Natural convection
Daily total horizontal	J day^{-1} m^{-2}	2.098×10^7	2.098×10^7	2.041×10^7

radiation				
Total yield	Kg day^{-1} m^{-2}	2.88	4.2	3.37
Operational efficiency	1	0.31	0.45	0.38

Table 1. Comparison between roof-type still and two-effect still; fan cooled and natural convection, Seluck (1964) and Elsayed (1986).

2.3. Purging Vapor to a Second Effect

Fath (1995) proposed a second effect connected to a (single sloped) first effect through a shutter fashion reflector and in its shaded zone, Figure 3.

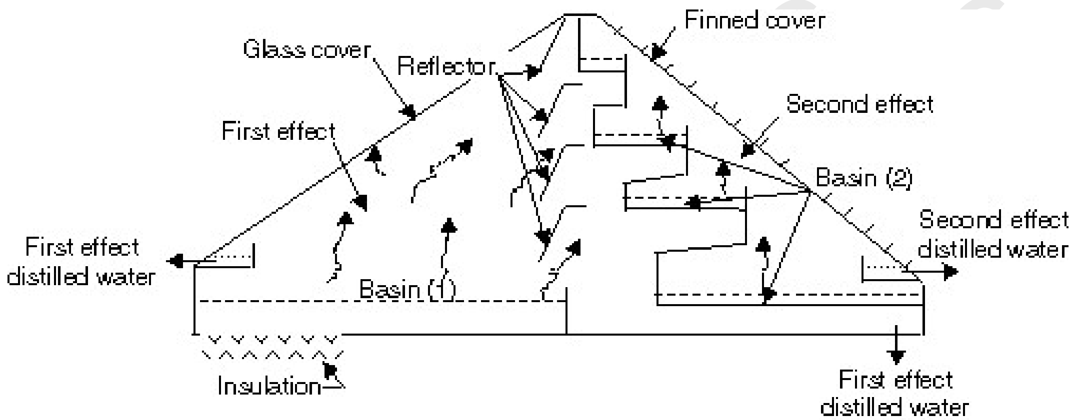

Figure 3. Two effects solar still (Fath 1985), first effect purging to a second effect.

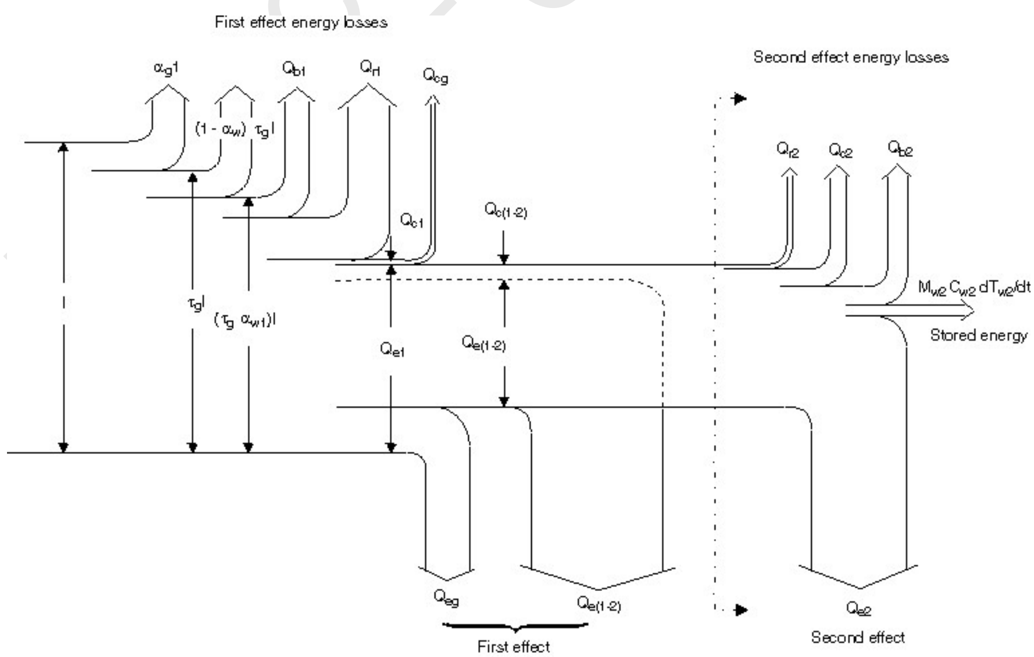

Figure 4. Energy distribution of the two effects still shown in Figure 3 (Fath 1985).

Vapor is purged from the first effect to the second effect to relief the first effect pressure and to utilize the latent heat of the purged vapor to a second effect (Figure 4). Figure 5 shows the energy distribution at midday for the proposed design, where the relative magnitudes of energy component are shown. The author's analysis showed that the productivity increases to as high as 10.7 kg m^{-2} for the proposed design under the climate conditions of Saudi Arabia (of 1000 W m^{-2} midday solar intensity, and 30-40°C ambient temperature). The author indicated that the proposed unit is simple, passive and adds no design, operation or maintenance complexities over the conventional single-effect basin stills.

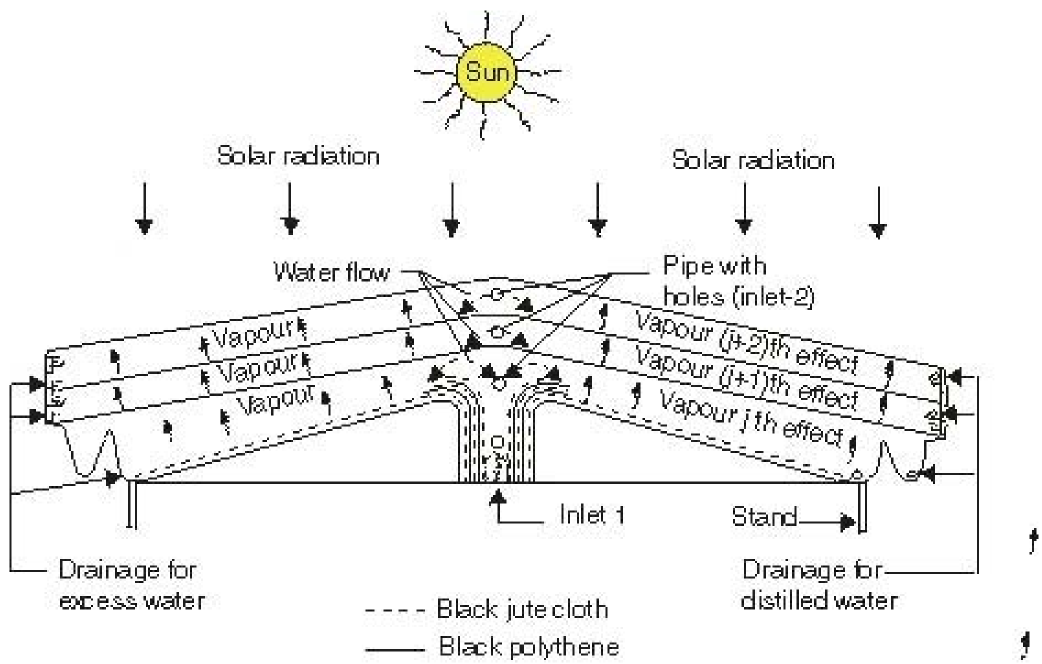

Figure 5. Typical multi-effect multi-wick solar still (Sodha et al. 1981).

3. Multi-Effect Multi-Wick Stills

In the multi-effect multi-wick stills (Figure 5), the availability of latent heat of vaporization can be maximized and equalized for least water depth in each effect including the lower basin (multi-wick stills). The multi-effect multi-wick solar still with the first effect of least water depth was designed by Sodha et al. (1981) to achieve the above condition. When the water flow rate increased significantly over the glass cover the flowing water does not have sufficient time to evaporate and thus the performance is not as good as with low flow rate. Different flow rates have been studied by Singh and Tiwari (1992) as shown in Figure 6, where the still production can be highly increased.

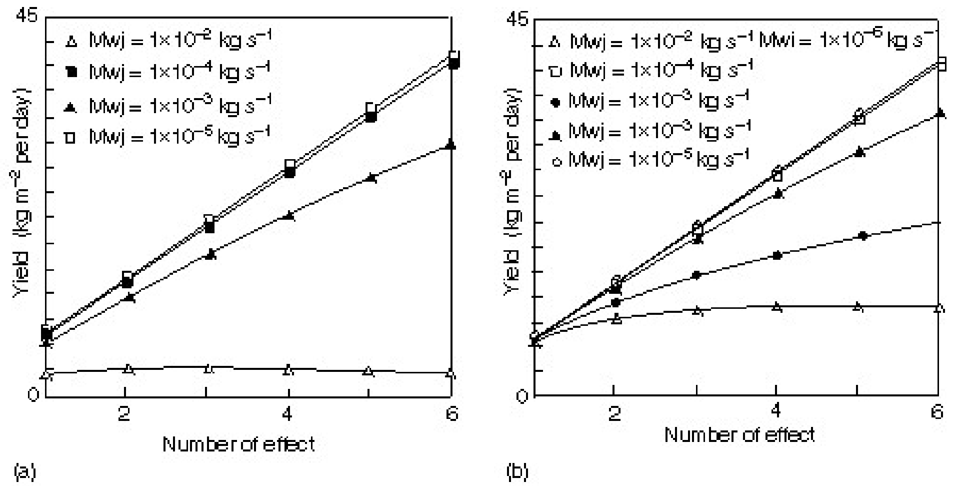

Figure 6. Effect of water flow rate and number of effects on multi-effect multi-wick type solar still (Singh and Tiwari 1992).

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