SOLAR BASED DISTILLATION SYSTEM FOR DOMESTIC APPLICATION

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ABSTRACT

In many parts of the developing countries the availability of adequate quantities of drinking water is a significant problem. This does not imply that the water is not abundant in these regions, but rather the water available is usually not potable. Solar distillation is one of the promising fields for the application of solar thermal energy due to the coincidence, in many places of the world of water scarcity, seawater, brackish, polluted ground water availability and good levels of solar radiation. The present study details the construction, testing and analysis of parabolic trough collector/reflector configuration for small scale domestic purpose water distillation application. Ground water is heated by the solar radiation as it circulates along the solar collector within an absorber pipe in order to generate steam directly into the absorber pipe. The generated steam is condensed and collected. The parabolic trough can deliver heat at temperature ranging from 200°C - 400°C for applications such as desalination. Since medium concentration ratios are attainable one axis sun tracking is required. Direct steam generation increases thermodynamic efficiency. Heat exchangers are eliminated which reduces the overall cost and also harmful effects of the oil to the environment is also eliminated.

INTRODUCTION

The global water crisis could reach unprecedented level in the years ahead with growing per capita scarcity of water in many parts of the developing world over the next 20 years, the average supply of water world wide per person is expected to drop by a third water resources will steady decline because of population growth, pollution and expected climate change. There are several people die each day from illness related to their drinking water. Even filtration provides little more than an expensive, even fatal, illusion. The ground water contains minerals and inorganics. They result in calcium deposits, Stones in the bladder, gall bladder and kidneys.

To solve this problem three kinds of resources are largely considered. Pollution removal by filtration of surface water including ground water, regeneration or reuse of waste water and desalination, especially seawater desalination. Industrial seawater desalination appears as major contender for providing a sustainable source of fresh water in arid zones and during drought. This solution is also supported by the fact that more than 70% of world population lies within a 70 km strip of seas or oceans. seawater desalination requires large quantity of energy and different approaches can be used to lower the cost of that energy. Optimization and minimization of energy consumption and for the use of alternative energy sources.

Solar energy is one of the most promising renewable energies for application to distillation of seawater, ground water, brackish water due to the usual coincidence of fresh water storage, good solar radiation and seawater, ground water, brackish water availability. High fresh water demands require industrial capacity systems. These system consists of a conventional seawater distillation plant coupled to a solar thermal system.

Among low capacity production systems solar still and solar ponds represent the best alternative in case of both low fresh water demand and land price. The direct distillation using concentrating collectors for producing drinking water is also best alternative for domestic low capacity demand. The distillation using solar collectors are having only the initial cost of the equipment but it does not requires energy cost.

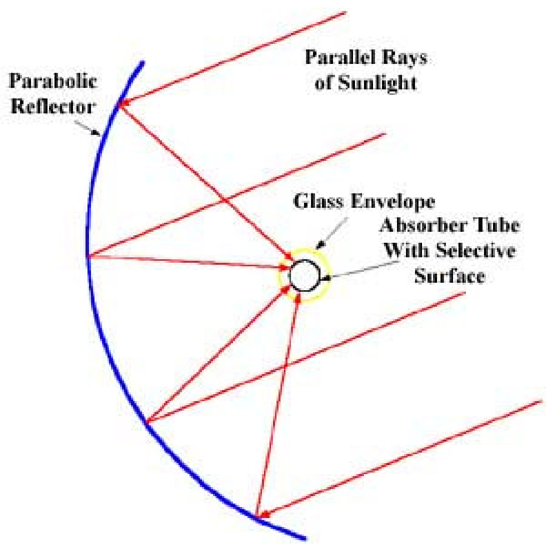

Fig. 1. Solar collector

ABOUT TROUGHS

Parabolic troughs are the only commercially available solar concentrator that can be used to deliver high temperature thermal energy. Parabolic troughs are the most utilitarian of solar collectors in terms of the markets they can serve. Troughs can deliver heat at high temperatures for applications such as hot water, space heating, air-conditioning, steam generation, industrial process heating, desalination and power generation.

It is a principle of geometry that a parabolic reflector pointed at the sun will reflect parallel rays of light to the focal point of the parabola. A parabolic trough is a one-dimensional parabola that focuses solar energy onto a line. Physically, this line is a pipe with a flowing liquid inside that absorbs the heat transmitted through the pipe wall and delivers it to the thermal load.

A trough captures sunlight over a large aperture area and concentrates this energy onto a much small receiver area, multiplying the intensity of the sun by a concentration ratio in the range of 30-80. It is the process of concentration that allows troughs to delivery high temperature thermal energy. However, to achieve such concentration, a trough tracks the sun in one axis continually throughout the day. The required tracking accuracy is within a fraction of a degree.

Establishing the concentration ratio is the major tradeoff in designing a trough concentrator. The goal is to balance the interception of solar energy at the receiver against heat losses from the receiver. The larger the absorber diameter the greater the heat loss from the absorber area. However, the absorber must be large enough to intercept most of the sunlight reflected from the mirror. This intercept is affected by factors such as the accuracy of the parabola, the size of the solar disk (the sun is not a point source), the quality of the reflector, the accuracy of collector tracking and location of the receiver with respect to the true focal point. The development of parabolic trough concentrator is a patented design concept by which a concentrator that is accurate, lightweight and strong enough to survive in the outdoor environment can be built at a reasonable cost. To maximize the sunlight incident on the absorber, the reflectance of the parabolic reflector must be as high as possible. Aluminum or silver reflectors are used. Silver has the higher reflectance, but is harder to protect against the corrosive effects of the outdoor environment. It is also important to keep the reflectors clean since dirt will degrade the reflectance of light from the parabola.

The receiver of a trough concentrator is typically a metal absorber surrounded by a glass tube. The absorber is coated with a selective surface. This is a surface that has a high absorptance for incoming light in the visible range, and a low emittance (or radiative loss) in the infrared wavelength. The surrounding glass insulates the pipe from the effects of the wind and greatly reduces convective and conductive heat loss. The gap between the absorber tube and the inside of the glass is sized to minimize heat loss across the air gap. Glass is also a radiation barrier to infrared light so it reduces heat loss due to radiation.

Since the light from the parabola must first pass through the glass before it hits the absorber, the glass is a source of optical inefficiency since some light is reflected from the inside and outside glass/air surfaces, and absorbed in the glass itself. To reduces the negative effect of the glass tube by coating it with an anti-reflective surface to minimize optical losses due to reflectance.

Taking all these factors into account, the peak optical efficiency of a parabolic trough is in the range of 70-80%. Since thermal losses from the receiver are relatively small and increase only moderately as operating temperatures increase, at peak conditions, a trough can be expected to deliver 60+% of the radiation incident on the collector even when taking into account heat losses in the solar field piping.

Parabolic troughs are highly modular. The troughs are aimed at commercial and industrial markets, but they can be configured in any reasonable collector area to meet the desired load. Though east-west or north-south orientation of the collector axis is typically specified for year-round or summer-peaking loads, respectively, troughs can actually be oriented in any direction. The arrangement of troughs in parallel rows simplifies system design and field layout, and minimizes interconnecting piping.

Tracking of a parabolic trough involves fixed costs associated with the drive and control system. In large systems for commercial and industrial applications, costs for the drive and control system are relatively less pronounced and the cost of the collectors dominates the overall system cost. Materials are a major component of collector costs. The contribution to the progression of parabolic trough technology includes the development of a lightweight solar concentrator. Compared to a flat plate collector, an parabolic trough module is 3 to 4 times less weight, and consequently large trough systems are less costly that equivalent flat plate or evacuated tube collector installations

Though the tracking of troughs involves more maintenance compared to flat plate and evacuated tube collectors. Importantly, troughs can meet temperature demands for energy far beyond the capabilities of none tracking collectors.

SELECTION OF COMPONENTS

Concentrator/Reflector

The concentrator is built according to a unique design making it very light, yet exceedingly strong. All aluminium construction minimizes concentrator maintenance requirements.

Table 1. Concentrator material selection

Material of construction	Aluminium
Reflective surface	Coated polished Aluminum
Tracking mechanism	One axis east-west orientation
Rim angles	70-120°
Concentration ratio	30-80

RECEIVER/ABSORBER

Solar energy focused and concentrated on a liquid-filled receiver dramatically reduces convection and conduction thermal loses. The receiver/absorber is a copper tube coated with a selective blackened nickel surface and surrounded by tough Pyrex, glass to reduce heat loss. The glass annulus with a sol-gel anti-reflective coating that increases light transmission to the absorber.

Table 2. Absorber material selection

Absorber Tube material	Copper
Selective Coating	Blackened Nickel surface
Absorptance	0.96-0.98
Emittance (80^{o}C)	0.15-0.25
Absorber envelope Material	Borosilicate glass
Envelope anti reflective coating	Sol gel
Envelope Transmittance	0.95-0.965

WORKING MODEL

The solar distillation plants have proven to be a reliable, simple, scalable, sustainable and affordable way to produce pure drinking water from almost any water where it is needed most locally. The ground water is pumped to the overhead tank and then from the tank it is allowed in another less capacity tank. The solar energy collectors is used in order to convert solar energy into thermal energy.

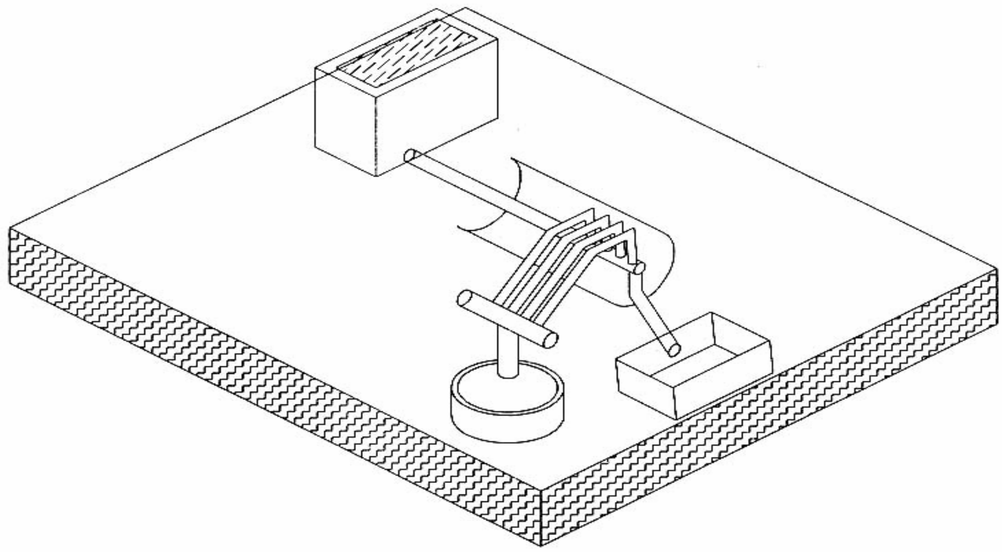

Fig. 3. Solar distillation plant

The conventional Solar Parabolic Trough Collector (PTC) use synthetic oils as the heat transfer fluid, which limit the top operation temperature. The operation of the solar energy collector is possible when the solar irradiance changes are not greater than a given value and irradiation transients are within a given time limit. This system replaces oil by water. The water from the tank is circulates along the solar collector within an absorber pipe to generate steam directly into the absorber pipe. The steam is condensed and the pure distilled water is collected. The axis of the solar collector should be tilted 8° to improve two phase flow pattern.

The concentration of solar radiation in one axis provides a simple operation and high reliable system to reach maximum operation temperatures of about 400°C. Since medium concentration ratio attainable one axis tracking is required

DESIGN

1. Heat load $q = m \times (h_g - h_f)$ (1)

2. Area of aperture $A_a = q /(Ce \times I)$ (2)
   $A_a = L \times W$, $L = 4W$

3. Area of absorber/receiver $A_r = A_a / C_r$ (3)

   Cross section area of absorber tube $a_r = (3.14/4) \times D^2$

4. Discharge $Q = a_r \times v$ (4)
   $Q = m/1000$ (5)

5. Velocity of water flow in tube = Q/ a_r

CONCLUSION

Desalination appears to be one of the best option to palliate the problem of water scarcity. As high solar irradiance levels characterize arid areas, the energy demand for the distillation process can be supplied by a solar thermal system.

Direct steam generation parabolic trough exhibit potential for improving solar distillation. The replacing of oil-based technology by DSG presents many advantages from point of view of thermodynamic, environmental hazard of oils, land use, use of material or life time. Heat exchangers to generate the steam are not necessary.

The area occupied by the solar system is a worrying factor and it can be optimized by improving the collection efficiency. Collection efficiency is improved by using selective coating applied in the absorber. To minimize heat loss in the absorber it is surrounded by a glass tube. The anti reflective coating is applied to glass tube to reduce reflectivity in the absorber. The reflectivity of the reflector is improved by choosing high reflectance material. The optical efficiency is improved by keeping the reflector polished and clean.

NOMENCLATURE

I	Insulation
PTC	Parabolic trough collector
CPC	Compound parabolic collector
M	mass flow rate of water
Q	discharge
q	heat load
C_e	Collection efficiency
C_r	Concentration ratio
A_a	Aperture area
A_r	Absorber area
W	width of reflector
L	length of reflector/absorber
D	diameter of absorber
v	velocity
h_f	Enthalpy of water
h_g	Enthalpy of dry steam

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