OPTIMISATION OF SINGLE SLOPE SOLAR STILL TO DESALINATE SEAWATER FOR HYDROGEN HARVESTING APPLICATION

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DECLARATION

I hereby declare that the material in this thesis is my own except for the quotations, excepts, equations, summaries and references, which have been duly acknowledged.

10 July 2015

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ABSTRACT

The challenging efforts of this project have been designed to explore the abundance of renewable solar energy for the desalination of the inexhaustible seawater resource for the production of the most critical clean water resource necessary for the human consumption and existence, in particular to the poorer rural populations. The working principle of a solar still has been based on the heat transfer processes of three major components of the solar still (glass cover, seawater and basin) and its surrounding as a result of exposing the system to the solar irradiance. Two analytical approaches have been utilized to develop the theoretical model and the numerical model by forward finite difference approach for predicting the solar still performance. However, the numerical model has shown to be significantly far more accurate in predicting the experimental results than the theoretical model, particularly in a less consistent and varied solar irradiance during the latter part of the afternoon hours. At the same time, the optimization of the single slope solar still as a simple, effective, safe and user friendly water treatment device, for the production of clean water has been experimentally verified. The experimental result has found that the optimum slope angle required is six degree (6°), and the optimum volume amount of seawater is three litres (3 L) for the solar still to produce the optimum clean water production at 1.4 litres per sunny day. A simulation feasibility study consists of the optimized single slope solar still with a PEM electrolyzer of an output rating of 2.5 litres/minute has also been conducted to achieve a yield production of 1,335 litres of hydrogen gas under the atmospheric pressure, which has an equivalence of about 4.7kWh of electricity.

ABSTRAK

PENGOPTIMUMAN 'SOLAR STILL' CERUN TUNGGAL UNTUK PENGUAPAN AIR LAUT BAGI APLIKASI PENUAIAN HIDROGEN

Semua usaha cabaran dalam projek ini telah direka untuk menerokai penggunaan tenaga solar yang banyak untuk tujuan penguapan sumber air laut yang tidak habis-habis bagi proses penghasilan sumber air bersih yang amat kritikal untuk menanggung keperluan harian manusia, terutama di kawasan populasi luar bandar yang miskin. Prinsip utama 'Solar Still' adalah berdasarkan proses-proses pemindahan haba antara tiga komponen utama dalamnya (penutup kaca, air laut dan besin) dengan persekitarannya semasa didedahkan bawah sinaran solar. Dua cara analisis telah digunakan untuk mendapatkan model teori dan model berangka dengan cara 'forward finite difference' untuk meramalkan prestasi 'Solar Still'. Akan tetapi, model berangka didapati boleh meramal keputusan eksperimen dengan lebih tepat berbanding dengan model teori, terutamanya pada waktu petang dimana sinaran solar adalah berubah dan tidak konsisten. Pada waktu yang sama, pengoptimuman 'Solar Still' cerun tunggal sebagai alat rawatan air yang mudah, berkesan, selamat dan mesra pengguna untuk penghasilan air bersih telah disahkan secara eksperimen. Keputusan eksperimen mendapati bahawa sudut enam darjah adalah sudut optimum (6°), dan tiga liter adalah isipadu optimum air laut bagi 'Solar Still' untuk penghasilan air bersih 1.4 liter pada setiap hari siang. Simulasi kajian kebolehlaksanaan yang terdiri daripada 'Solar Still' cerun tunggal yang telah dioptimasikan dengan satu alat elektrolisis PEM dengan kuasa penghasilan sebanyak 2.5 liter setiap minit telah dilaksanakan dan keputusan simulasi menunjukkan penghasilan sebanyak 1,335 liter gas hydrogen bawah tekanan atmosfera, juga bersamaan dengan penjanaan kuasa elektrik sebanyak 4.7 kWh.

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LIST OF ABBREVIATIONS

AAS	-	Atomic Absorption Spectroscopy
AEC	-	Alkaline Electrolysis Cells
CFD	-	Computational Fluid Dynamics
ED	-	Electrodialysis
EDL	-	Electrodeless discharge lamp
GPS	-	Global Positioning System
HCL	-	Hollow cathode lamp
MED	-	Multiple-effect distillation
MSF	-	Multi-stage flash
PCM	-	Phase Change Materials
PEM	-	Proton Exchange Membrane
ppm	-	parts per million
ppt	-	parts per thousand
PTFE	-	Polytetrafluoroethylene
RO	-	Reverse Osmosis
SOEC	-	Solid Oxide Electrolysis Cells
TDS	-	Total Dissolved Solids
VC	-	Vapour Compression

LIST OF SYMBOLS

A - Surface area (m^2)

a - Absorptivity

C_{paf} - Specific heat capacity of humid air at an average temperature (J/kg.°C)

C_p - Specific heat (J/kg.°C)

E_{gen} - Internal rate of heat generated (Watt)

$\Delta E_{m,n}$ - Change of energy content of the node (Joule)

G - Solar irradiance (W/m^2)

h - Heat transfer coefficient (W/m^2.°C)

h_{fg} - Latent heat of evaporation (kJ/kg.°C)

k - Thermal conductivity (W/m.°C)

L - Distance (m)

L_e - Lewis number

M_w - Molecular weight of water vapour (kg/mol)

$(MC)_w$ - Seawater heat capacity rate per unit area (J/m^2.°C)

m - Mass (kg)

$\dot{m}_{evp}$ - Mass flow rate of the evaporated seawater (kg/s)

P - Pressure (Pa)

ρ - Density (kg/m^3)

Q - Rate of heat transfer (Watt)

q - Heat flux (W/m^2)

$R(x)$	-	Truncation error
T	-	Temperature (°C)
Δt	-	Time step (s)
V	-	Wind speed (m/s)
v	-	Volume (ml)
Δx	-	Distance between two nodes along the x-axis (m)
Δy	-	Distance between two nodes along the y-axis (m)
σ	-	Stefan-Boltzmann constant (5.64 X 10^{-8} W/m^2.°C^4)
θ	-	Slope angle (rad)
ε_g	-	Glass cover emissivity
η	-	Instantaneous efficiency (%)