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Deanship of Graduate Studies and Scientific Research

Master Program of Renewable Energy and Sustainability

A Simulation Study to Evaluate the Vapor Jet Refrigeration Cycle Driven by Solar Thermal Energy for Air Conditioning Application at Two Different Areas in Palestine

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Thesis submitted in partial fulfillment of requirements of the degree

Master of Science in Renewable Energy & Sustainability

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Submitted by

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A Simulation Study to Evaluate the Vapor Jet Refrigeration Cycle Driven by Solar Thermal Energy for Air Conditioning Application at Two Different Areas in Palestine

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ABSTRACT

The need for air conditioning in rural areas in which there is no source of traditional electrical power leads to look for an alternative solutions. Usually the population of these areas use typical movable houses (TMH's) as residence. Solar thermal system drive vapor jet refrigeration cycle (VJRC) is a valid solution for this kind of situation, which replaces the traditional vapor compression refrigeration cycle that used the electricity.

Mathematical model was carried out for (VJRC) using Engineering equation solver (EES) software at various design conditions (generator, evaporator and condenser temperature), characteristic curves and tables for the (VJRC) were found at 10°C evaporator temperature. Hourly simulation of cooling load demand for specific construction TMH was calculated using TRNBuild subsystem in TRNSYS software with the standard design conditions in Hebron and Jericho cities. Furthermore hourly simulation of the overall solar thermal cooling system was carried out over the study period (May-September), while considering climatic data for the two cities using TRANSYS software compiled with Excel software which contained the characteristic tables of the VJRC that obtained from the EES. The instantaneous performance of the system, Cooling load demand and evaporator cooling load available were calculated. Effect of climate according to the location, solar collector area, storage tank volume were studied to produce the maximum suitable evaporator cooling load to meet the requirement of the human comfort.

EES Mathematical model for the VJRC demonstrated that the performance of the cycle is increased with increasing the generator and evaporator temperature, but decreases with increasing condensing temperatures. Cooling load simulation for Hebron and Jericho TMH demonstrated that the maximum cooling load demand during the study period were: 5.35 kW and 7.02 kW respectively; and the seasonal cooling energy demands were: 5749 kWh/year and

14864 kWh/year respectively according to the climate conditions. Simulation for the overall system demonstrated that the proposed system was efficient for Hebron city in contrast to Jericho city where the proposed system showed lake of cooling energy produced. Also the optimal sizes and options of the overall system were determined for Hebron city. An economical study was done on the proposed system where the results demonstrated that the proposed system in Hebron city is more economically than Jericho where the simple payback period of Hebron city reached to12.9 year while in Jericho city is 15 year at the same system size.

دراسة محاكاة لتقييم دورة تبريد نفاثة بخارية تعمل بالطاقة الحرارية الشمسية لاغراض التكييف في منطقتين مختلفتين في فلسطين

اعداد: خالد ايوب سدر

ملخص

تدفع الحاجة الى تكييف الهواء في المناطق الريفية التي لا تتوافر فيها الكهرباء الى البحث عن حلول بديلة, حيث عادة ما يستخدم السكان في هذه المناطق وحدات سكنية متماثلة متنقلة للعيش. تعتبر دورة التبريد النفاثة البخارية التي تعمل بالطاقة الشمسية حلا فعالا في هذه الحالات بدلا من دائرة التبريد الانضغاطية التي تعمل بالكهرباء.

تم عمل نموذج رياضي لدورة التبريد النفاثة باستخدام برنامج حل المعادلات الهندسية (EES) تحت ظروف تصميمية مختلفة مثل درجة حرارة المولد و المبخر والمكثف, كما وتم إيجات منحنيات وجداول الخواص للدورة عند درجة حرارة 10°C للمبخر. تم عمل محاكاه لحمل التبريد الخاص بالوحدة السكنية النموذجية ذات المواصفات المحددة باستخدام برنامج TRNBuild التابع لبرنامج TRNSYS وذلك تحت الظروف التصميمية لمدينتي الخليل واريحا. علاوة على ذلك ، أجريت محاكاة على مدار الساعة لنظام التبريد الحراري الشمسي المتكامل خلال فترة الدراسة (مايو- سبتمبر) ، مع الأخذ بعين الاعتبار البيانات المناخية للمدينتين وذلك باستخدام برنامج TRANSYS بالتوافق مع برنامج Excel الذي يحتوي على جداول الخواص لدائرة التبريد والتي تم الحصول عليها من برنامج EES. تم حساب معامل الأداء اللحظي للنظام ، وحساب حمل التبريد المطلوب في الوحدة السكنية بالاضافة الى حمل تبريد المبخر في دائرة التبريد. تمت دراسة تأثير المناخ حسب الموقع الجغرافي ومساحة سطح المجمعات الشمسية الحرارية وحجم خزان التخزين لإنتاج أقصى حمل تبريد للدورة من أجل تلبية متطلبات الراحة البشرية .

أظهرت نتائج النموذج الرياضي باستخدام برنامج EES بان أداء دورة التبريد النفاثة يزداد بازدياد درجة حرارة المولد ودرجة حرارة المبخر ، لكنه يتناقص مع ازدياد درجة حرارة المكثف.كما واظهرت نتائج محاكاة حمل التبريد للوحدة السكنية بان اقصى حمل تبريد كانت قيمته 5.35 kW و 7.02 kW لمدينتي الخليل واريحا على التوالي, وان قيمة الطاقة التبريدية الموسمية المطلوبة للوحدة السكنية هي 5749 kWh/year و 14864 kWh/year لمدينتي الخليل واريحا على التوالي. كما واظهرت نتائج النظام الكلي بان النظام المقترج ذو فعالية عالية في حال استخدامة في مدينة الخليل ولكنه غيرفعال في مدينة اريحا حيث ان طاقة التبريد المنتجة غير كافية. كما وتم تحديد حجم وخيارات النظام الكلي المثلى في مدينة الخليل, تم عمل دراسة اقتصادية للنظام المقترح وقد اظهرت النتائج بان هذا النظام في مدينة الخليل اكثر اقتصادية من مدينة اريحا حيث ان معدل استرجاع راس المال بلغ 12.9 سنة في مدينة الخليل بينما وصل الى15 سنة في مدينة اريحا بنفس حجم النظام.

DECLARATION

I declare that the Master Thesis entitled**" A Simulation Study to Evaluate the Vapor Jet Refrigeration Cycle Driven by Solar Thermal Energy for Air Conditioning Application at Two Different Areas in Palestine"** is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

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DEDICATION

To my mother and father

To my wife

To my brothers and sisters

To my real friends

Thank you for your love and support

To the martyrs souls

To our great Palestine

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LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
COP	Coefficient of Performance
COP_{carnot}	Coefficient of Performance of Carnot cycle
CRF	Constant Rate Factor
EES	Engineering Equation Solver
EPW	Energy plus Weather format
ETC	Evacuated Tube Solar Collector
FPC	Flat Plate Collector
HTF	Heat Transfer Fluid
HVAC	Heating Ventilation and Air conditioning
IRR	Internal Rate of Return
NPV	Net Present Value
PAL MET	Palestinian Meteorology
TMH	Typical Movable House Unit
TRANSYS	Transient System Simulation program
TRNBuild	TRANSYS Building input data visual interface
VJRC	Vapor Jet Refrigeration Cycle

LIST OF SYMBOLS

A:	Area
a_1	First order heat loss coefficient
a_2	Second order heat loss coefficient
A_{coll}	Collector area
c	Speed of sound at local static temperature
c_p	Specific heat at constant pressure
G	Solar radiation
h:	Specific enthalpy
h_p	Primary stream enthalpy
hs	Secondary stream enthalpy
IB	Beam portion of the radiation
IBC	Direct solar flux striking a surface
I_C	Total insolation on the collector
IDC	Diffuse radiation on the collector
IDH	Diffuse insolation on a horizontal surface
IRC	Reflect insolation striking a collector
k	Specific heat ratio
M	Local Mach number
$M^{\times}$	Critical Mach number
$\dot{m}$:	Mass flow
$\dot{m}_c$	Condenser mass flow rate
$\dot{m}_p$	Primary fluid flow rate