



Sudan University of Science and Technology
College of Graduate Studies and Scientific Research

**Producer Gas Based Absorption Cold
Storage**
التخزين المبرد الإمتصاصي القائم على الغاز الصناعي

*Submitted for Partial Fulfillment of the Degree of
M.Sc. in Mechanical Engineering*

Presented by:

Hassan Ahmed Mohammed Elbadawi

Supervised by:

Dr. Mohyedin Ahmed Abdelghadir

March 2013

آيات

أعوذ بالله من الشيطان الرجيم

قال تعالى:

أَفَرَأَيْتُمُ النَّارَ الَّتِي تُورُونَ ﴿71﴾ أَأَنْتُمْ
أَنْشَأْتُمْ شَجَرَتَهَا أَمْ نَحْنُ الْمُنْشِئُونَ ﴿72﴾
نَحْنُ جَعَلْنَاهَا تَذْكَرَةً وَفِتْنَةً لِلْمُؤْمِنِينَ ﴿73﴾
فَسَبِّحْ بِاسْمِ رَبِّكَ الْعَظِيمِ ﴿74﴾ الواقعة

DEDICATION

*This work is dedicated to my
parents, brothers, sisters and my
wonderful fiancée.*

HASSAN BADAWI
2013

ACKNOWLEDGMENT

I thank **God** for His awesome grace in letting me see this work to its completion.

I would like to express my deepest gratitude to the Head of Power Department in SUST, **Dr. Mohyedin Ahmed** , for the supervision and support he provided during my efforts to accomplish this work. Many thanks also go to staffs and colleagues of the power Department at School of Mechanical Engineering who worked with me in the various aspects of this study. I gratefully thank **Dr. Tawfig Ahmed**, the director of the mechanical engineering school for his help, encouragement and for his constructive comments on this research. I am also indebted to **Dr. Elkawad Ali**, the deputy dean of Post Graduation Studies College at SUST for his moral support which he provided during the course of this study.

My sincere appreciation also is extended to **Mr. Nadir Abdulrazig**, a Lecturer at Production Department in SUST through whom some of help was gained.

I would also like to thank **my friends** who created a beautiful atmosphere for my work.

Abstract:

This study is conducted to design a cold storage refrigeration cycle using a generated energy of producer gas from agricultural residues and other available trees in Sudan as *prosopis juliflora* to store vegetables and fruits. The cold storage dimensions, thickness of required insulation, unit and capacity of gasifier, also the link between the calculations of cold storage heat load and the required capacity of gasifier have been determined.

The desired design of cold storage is intended for Kurdufan state to preserve milk, meat, vegetables and fruits; (Abujibaiha, Malam Elkour, and Tajmala are taken as examples to save some perishable fruits and vegetables

Experiments have been done on a fabricated absorption refrigeration unit of 3 tonnage of refrigeration using an electrical heating as a similar load instead of 15 metric ton of mangoes.

Finally a comparison was made between the experimental results of the absorption system and a compression one, which gives an economical feasible result.

المستخلص:

بنيت هذه الدراسة على الاهتمام بتصميم مخزن تبريد يعمل بالدورة الامتصاصية باستخدام الطاقة المتولدة من الغاز الصناعي الناتج من استخدام الكتلة الحيوية لبعض النباتات المتوفرة بكثرة في السودان مثل نبتة المسكيت أيضا المخلفات الزراعية لتخزين الخضروات و الفواكه بولاية كردفان.

ولقد تم في إطار هذه الدراسة حساب أبعاد مخزن التبريد و الحمل الحراري وحساب سمك العازل المطلوب و أجزاء الدورة الامتصاصية ووحدات توليد الغاز الصناعي المطلوبة والربط بين حسابات الحمل الحراري للمخزن وسعة وحدة توليد البيوغاز المطلوبة.

المطلوب تصميم مخزن تبريد يعمل عن طريق الدورة الامتصاصية باستخدام طاقة الغاز الصناعي في مناطق انتاج الفواكه والخضراوات والألبان واللحوم بولاية كردفان، أخذت مناطق مثل (أوجيبه وتجملا، وملم الكور) كنماذج للدراسة لحفظ الفواكه والخضار.

أجريت تجارب على وحدة تبريد امتصاصي صغيرة بسعة 3 طن تبريدي تحاكي في حملها التبريدي منتج مقدر بكمية 15 طن متري (حمل كهربائي) وقد تم رصد درجات الحرارة ومعدلات تدفق لماء التبريد ووسيط التبريد كما تم رصد تغذية الكتلة الحيوية المقترنة معها.

أخيرا تمت مقارنة نتائج التبريد الإمتصاصي على وحدة مع وحدة انضغاطية حيث أعطى نتيجة اقتصادية مقبولة.

LIST OF CONTENTS

NO.	SUBJECT	Page
-	الآية	II
-	Dedication	III
-	Acknowledgements	IV
-	Abstract	V
-	المستخلص	VI
-	List of Contents	VII
-	Symbols and Abbreviation	XI
-	Subscripts	XIV
	List of Figures	XV
	List of Table	XVI
CHAPTER ONE- INTRODUCTION		
1.1	Background	1
1.2	Objective of the study	1
1.2.1	General objectives	1
1.3	Conceptual Framework	2
1.4	Overview of the Contents of the Research	3
CHAPTER TWO- LITERATURE REVIEW		
2.1	DEVELOPMENT OF REFRIGERATION TECHNOLOGY	4
2.1.1	Food preservation	4
2.1.2	Food preservation using refrigeration	5
2.2	REFRIGERATION:	5
2.2.1	Refrigeration and its Necessity	5
2.2.2	Humidity and air movement	6

NO.	SUBJECT	Page
2.3	Refrigeration cycles	6
2.3.1	The vapor absorption and compression system	6
2.3.2	Comparison between the two cycles and the pros of absorption cycle	7
2.3.3	Absorption system performance improving	11
2.4	Synthesis gas	12
2.4.1	What and why syngas?	12
2.4.2	Power Generation	14
2.5	Cold Storage	15
CHAPTER THREE- COOLING AND HEATING LOAD CALCULATIONS ASPECTS		
3.1	Cold store description	18
3.2	Cooling and Heating Load Calculations	20
3.3	Cold store design steps	21
3.4	Cold store layout	23
3.5	Construction and insulation materials	24
3.5.1	Characteristics and properties of insulating material for cold store	24
3.5.2	Types of insulation materials	24
3.5.3	Factors affecting the thermal performance of insulation	25
3.5.4	Some insulating material properties for outer surfaces	26

NO.	SUBJECT	Page
3.6	Overall heat transfer coefficient	27
3.7	Detailed description for insulation design	27
3.7.1	Outer insulating wall thickness calculation	28
3.7.2	Inner insulating wall thickness calculation	28
3.7.3	Doors insulating Polystyrene thickness calculation	29
3.7.4	Ceiling insulating Polystyrene thickness calculation	30
3.7.5	Calculation of floor insulating thickness	31
3.8	Cooling load calculation of the cold stores	32
3.9	Proposed calculations	40
CHAPET FOUR- BIOGAS BASED ABSORPTION REFRIGERATION SYSTEM		
4.1	Biogas technology	45
4.1.1	Biogas technology in Sudan	45
4.1.2	Energy used in Sudan	46
4.2	Power Generation	47
4.3	Gasification technology	48
4.4	Experimental Set-Up	49
4.4.1	A brief background	49
4.4.2	Experiment description	50
4.5	Experimental plan and procedure	54
4.6	Data reduction	56

NO.	SUBJECT	Page
CHAPTER FIVE: RESULTS AND ANALYSIS		
5.1	System results and discussion	58
5.2	Economic viewpoint analysis	61
5.3	Environmental aspect discussion	64
CHAPTER SIX- CONCLUSIONS AND RECOMMEND		
6.1	Conclusions	65
6.2	Recommendations	66
REFERENCES AND APPENDICES		
A	References	68
B	Appendices	69

SYMBOLS AND ABBREVIATIONS

SYMBOLS:

NO.	Symbol	Coding	Unit
1.	Efficiency	eff.	%
2.	Mass or capacity	M	Kg
3.	Volumetric loading rate	C_v	Kg/m^3
4.	Surface loading rate	C_A	Kg/m^2
5.	Product Height	H_p	M
6.	Floor area	A_p	m^2
7.	Floor utilization factor	η_A	-
8.	Temperature	T	$^{\circ}\text{C}$ or K
9.	Volume occupied by products	V_P	m^3
10.	Temperature difference	$dT, \Delta T$	K
11.	Density	ρ	Kg/m^3
12.	Coefficient of thermal conductivity	\dot{K}	W/m.k
13.	Specific heat at constant volume	C_v	J/kg k
14.	Calorific value	CV	kJ/kg
15.	Specific heat at constant pressure	C_p	J/kg k
16.	Heat transfer coefficient	U	$\text{W/m}^2.\text{k}$
17.	Material thickness	δ_x	M
18.	Heat transfer coefficient of a particular substance	a	$\text{W/m}^2.\text{k}$

19.	Freezing temperature	T_F	$^{\circ}\text{C}$
20.	The amount of latent heat of evaporation	$L = h_{fg}$	J/kg
21.	Specific heat of a material above the freezing point	C_{P1}	KJ/kg k
22.	The amount of heat transmitted	T_F	W
23.	Latent heat of freezing a material	L	KJ/kg k
24.	Area of the outer surface	A	m^2
25.	Specific heat of a material below the freezing point	C_{P2}	KJ/kg k
26.	Specific heat of a box substance	C_{P3}	KJ/kg k
27.	Specific volume of fresh air outside	V_a	m^3/Kg
28.	outside air enthalpy	h_a	KJ/kg
29.	Indoor air enthalpy	h_i	KJ/kg
30.	Interior cold storage room volume	V_R	m^3
31.	lighting a day period	H	h/24h
32.	heat generated by workers	Q_w	KW
33.	Working hours	τ	Hours
34.	Evaporators Cooling capacity	E_C	KW
35.	Evaporator Capacity of mangoes room	E_{CM}	KW
36.	Evaporator Capacity of potatoes room	E_{CP}	KW
37.	The amount of heat generated by engines	Q_m	KW
38.	The amount of heat generated by lighting	Q_L	KW
39.	Air changing load	Q_A	KW

40.	Heat generated by respiration	Q_R	KW
41.	Heat withdrawn from boxes	Q_C	KW
42.	Heat withdrawn due to cooling below freezing	Q_P	KW
43.	Lighting rate	P	W
44.	Evaporator Capacity	E_C	KW
45.	Condenser pressure	p_c	Bar
46.	Evaporator pressure	p_0	Bar
47.	Electrical energy input,	W	KW / KW h

ABBREVIATIONS

NO.	Symbol	Coding
1.	COP	Coefficient Of Performance
2.	VCRS	Vapour Compression Refrigeration Systems
3.	VARs	Vapour Absorption Refrigeration Systems

Subscripts

4.	AB,a	Absorber
5.	B	Biomass
6.	C,c	Condenser
7.	E,e	Evaporator
8.	Exp	Experimental
9.	G	Generator
10.	RC	reflux condenser
11.	r	Real
12.	1-24	state points in the system with reference to Figure (4-1)

List of Figures:

Item	Figures	Page
<i>Figure (1-1)</i>	<i>Conceptual Frame Work Outline</i>	<i>2</i>
<i>Figure (2-1)</i>	<i>Absorption Cycle</i>	<i>10</i>
<i>Figure (2-2)</i>	<i>Compression Cycle</i>	<i>10</i>
<i>Figure (3-1)</i>	<i>Longitudinal Section of the door</i>	<i>30</i>
<i>Figure (3-2)</i>	<i>Shelving system</i>	<i>36</i>
<i>Figure (4-1)</i>	<i>2D-Experimental schematic of biomass based absorption cold storage system</i>	<i>53</i>
<i>Figure (4-2)</i>	<i>3D illustrated experimental schematic of biomass based absorption cold storage system.</i>	<i>54</i>
<i>Figure (5-1)</i>	<i>Component temperature variation with respect to time</i>	<i>60</i>
<i>Figure (5-2)</i>	<i>Component heat load variation with sink temperature.</i>	<i>60</i>
<i>Figure (5-3)</i>	<i>Variation of COP with absorber cooling water flow rate for different weak solution flow rates</i>	<i>61</i>
<i>Figure (5-4)</i>	<i>Effect of biomass consumption on cooling capacity and COP</i>	<i>63</i>
<i>Figure (5-5)</i>	<i>Performance of the system for different experimental run.</i>	<i>63</i>
<i>Figure (5-6)</i>	<i>Figure (4-8) Comparison of BMVARS and VCRS (1 US \$ = SDG 6.5)</i>	<i>64</i>

List of Tables:

NO.	SUBJECT
<i>Table (3-1)</i>	<i>Volume loading rate.</i>
<i>Table(3-2)</i>	<i>Cold storage floor utilization factors.</i>
<i>Table(3-3)</i>	<i>Thermal conduction coefficients.</i>
<i>Table(3-4)</i>	<i>Overall heat transfer coefficients.</i>
<i>Table(3-5)</i>	<i>Surface thermal convection coefficient.</i>
<i>Table(3-6)</i>	<i>Findings of Rooms Temperatures and Overall heat transfer coefficient (U).</i>
<i>Table(3-7)</i>	<i>Material used in outer wall.</i>
<i>Table(3-8)</i>	<i>Material used in outer wall.</i>
<i>Table(3-9)</i>	<i>Material used in doors.</i>
<i>Table(3-10)</i>	<i>Material used in ceiling installation.</i>
<i>Table(3-11)</i>	<i>Materials used in floor installation.</i>
<i>Table(3-12)</i>	<i>Layer thickness for each room.</i>
<i>Table(3-13)</i>	<i>Correction factor added to temperature difference.</i>
<i>Table(3-14)</i>	<i>Air changes times a day.</i>
<i>Table(3-15)</i>	<i>Heat caused by labor.</i>
<i>Table(3-16)</i>	<i>Mangoes room load.</i>
<i>Table(3-17)</i>	<i>Potatoes cold store room load.</i>
<i>Table(3-18)</i>	<i>Heating load.</i>
<i>Table(4-1)</i>	<i>Type and heat transfer duty of components.</i>
<i>Table(A)</i>	<i>Storage design data for some fruits.</i>
<i>Table(B)</i>	<i>Typical solid waste components from Sudanese cities.</i>
<i>Table(C)</i>	<i>Annual sugarcane bagasse available in Sudan.</i>
<i>Table(D)</i>	<i>Biomass residues, current use and general availability.</i>