

## DEDICATION

Dedicated to:

My mother

My father

My wife (**Amal**)

My Sons (**Ahmed & Mokhtar**)

My family and my **Friends**

With my love and respect

# **ACKNOWLEDGMENT**

Thanks to my supervisor

**Dr. Mohammed Eltayeb Mansour**

For his assistance, guidance and endless help throughout the step of this research work.

My sincere thanks to

**Dr. Al khawad Ali Alfaki**

Thanks for any one helped me to make this work, thanks for my wife for her stand with me side by side during my studies.

**Abdallah Mokhtar Mohammed**

***M.Sc. Student***

**Mechanical Engineer**

## **ABSTRACT**

A Heat Exchanger System has been designed in this research, to be used in an industrial field. The system consists of an industrial unit for chemical process; shell and tube heat exchanger to produce heating fluid and an insulated pipe to transport fluid between them. The required temperature for the product has been taken into consideration through the process of evaluating the necessary calculations for fluid heating and the dimensions and sizes of varied facilities of the system are identified.

An overall heat transfer coefficient has been assumed and compared with its calculated value from the design of shell and tube heat exchanger according to the international standards and codes available. As a result the percentage difference between the assumed and calculated values was found within the allowable range.

A computer program was built, and verified with known data. The results for the designing calculations from the program were acceptable compared to that achieved.

## الخلاصة

في هذا البحث تم تصميم منظومة تبادل حراري تستخدم في الحقل الصناعي وتتكون المنظومة من وحدة صناعية للمعالجة الكيميائية ، مبادل حراري من النوع القشري وانبوب معزول لنقل مائع التسخين بينهما.

تم مراعاة حفظ المنتج في درجة الحرارة المطلوبة بعمل الحسابات اللازمة لمائع التسخين وتحديد أبعاد وأحجام مواعين النظام المختلفة.

تم افتراض قيمة لمعامل انتقال الحرارة الكلي ومن ثم تمت مقارنه معامل انتقال الحرارة الكلي الذي افترض والناتج من التصميم للمبادل الحراري القشري وفق المواصفات العالمية حيث أن النسبة المئوية بين القيمة المفترضة والمحسوبة لا تتعدى القيمة المسموح بها.

تم عمل برنامج حاسوب لتغطية حسابات التصميم وتم اختباره بواسطة قيم حقيقية وكانت مخرجات البرنامج مساويه لتلك القيم التي تم الحصول عليها بواسطة اجراء العمليات الحسابيه.

# **Table of Contents**

<b>Subject</b>	<b>Page No</b>
Dedication	I
Acknowledgement	II
Abstract	III
الخلاصة	IV
Table of Contents	V
List of Symbols	VII
Greek Symbols	IX
Abbreviations	X
List of figures	XI
List of tables	XII
<b>Chapter One: Introduction</b>	
1.1 Introduction	1
1.2 Heat Exchangers Classification	2
1.3 Shell-and-Tube Heat Exchanger	3
1.3.1 Advantages of Shell-and-Tube Heat Exchanger	3
1.3.2 Disadvantages of Shell-and-Tube Heat Exchanger	4
1.4 Project Objectives	4
<b>Chapter Two: Literature Review</b>	
Literature review	5
<b>Chapter Three : Theoretical Background</b>	
3.1 Introduction	8
3.2 Material Selection	9
3.3 System Design Theory	9
3.3.1 Industrial Unit	9

3.3.2 Insulation Pipe Equation	12
3.4 Shell and Tube Heat Exchanger	15
3.4.1 Design Procedures	17
3.4.2 Design Equations	18
<b>Chapter Four: Calculation of the System</b>	
4.1 Case Study and System Materials	24
4.2 Calculation Assumption	24
4.3 System Calculations	25
4.3.1 Industrial Unit	25
4.3.2 Insulation Pipe	29
4.3.3 Shell and Tube Heat Exchanger	32
4.3.4 Shell and Tube Heat Exchanger Calculations	34
4.3.5 Heat Exchanger Data Sheet	39
4.4 Computer Program	40
4.4.1 Introduction	40
4.4.2 Computer Program Flow chart	41
4.4.3 Input Data	40
4.4.4 Output Data	43
<b>Chapter Five: Results and Discussion</b>	
5.1 Results	46
5.2 Discussions	47
<b>Chapter Six: Conclusion and Recommendations</b>	
6.1 Conclusion	48
6.2 Recommendations	48
References	50
Appendices	

## **List of symbols**

Symbols	Means	Unit
A	The heat transfer surface area of the inner cylinder	[m <sup>2</sup> ]
A <sub>i</sub>	Total area of flow in tube side	[m <sup>2</sup> ]
A <sub>sh</sub>	Total area of flow in shell side	[m <sup>2</sup> ]
A <sub>r</sub>	Effective heat transfer area in shell and tube heat exchanger	[m <sup>2</sup> ]
C <sub>p</sub>	Specific heat capacity	[J/kg °K]
C <sub>pc</sub>	Specific heat capacity for cold water	[J/kg °K]
C <sub>ph</sub>	Specific heat capacity for hot water	[J/kg °K]
C <sub>ps</sub>	Specific heat capacity of the sulfur	[J/kg °K]
C <sub>pw</sub>	Specific heat capacity of water inside outer cylinder	[J/kg °K]
C <sub>pco</sub>	Specific heat capacity of coil water	[J/kg °K]
D	Diameter	[m]
D <sub>i</sub>	Inner cylinder diameter	[m]
D <sub>o</sub>	Outer cylinder diameter	[m]
d <sub>co</sub>	Coil tube outer diameter	[m]
d <sub>i</sub>	Inner diameter of tube in shell and tube heat exchanger	[m]
d <sub>o</sub>	Outer diameter of tube side in shell and tube heat exchanger	[m]
d <sub>max</sub>	Maximum diameter of helical coil	[m]
d <sub>min</sub>	Minimum diameter of helical coil	[m]
d <sub>sh</sub>	Diameter of shell in shell and tube exchanger	[m]
h <sub>i</sub>	Heat transfer coefficient inside tube	[W/m <sup>2</sup> °K]
h <sub>o</sub>	Heat transfer coefficient outside tube	[W/m <sup>2</sup> °K]
J <sub>f</sub>	Frication factor	
K <sub>ins</sub>	Thermal conductivity of insulation material	[W/m <sup>2</sup> °K]
K <sub>m</sub>	Thermal conductivity of cylinder or pipes material	[W/m <sup>2</sup> °K]
k <sub>1</sub>	Constant	
L	Length	[m]
L <sub>co</sub>	Coil length	[m]
L <sub>i</sub>	Inner cylinder length	[m]
L <sub>o</sub>	Outer cylinder length	[m]

$L_{\text{pip}}$	Length of insulation pipe	[m]
$M$	Mass	
$m_s$	Mass of sulfur inside inner cylinder	[kg]
$m_w$	Mass of water inside outer cylinder	[kg]
$N_t$	Number of tubes in shell and tube exchanger	
$Nu$	Nusselt number	
$n_1$	Constant	
$n_{\text{co}}$	Total number of coil turn	
$Pr$	Prandtl number	
$P_t$	Tube pitch	[m]
$P_{t_{\text{co}}}$	Coil pitch	[m]
$Q_{\text{con}}$	Heat transfer by conduction through inner cylinder thickness	[W]
$Q_{\text{loss}}$	Total heat loss in insulation pipe	[W]
$Q_{\text{req}}$	Heat transfer rate required to heat sulfur	[W]
$Q_s$	Heat transfer rate gain by sulfur	[W]
$Q_w$	Heat gain by water inside outer cylinder	[W]
$Re$	Reynolds number	
$r_1$	Insulation pipe inner radius	[m]
$r_2$	Insulation pipe outer radius	[m]
$r_3$	Radius of pipe and insulation cover combined	[m]
$T_{\text{amb}}$	Ambient temperature	[°C ]
$T_{\text{Coin}}$	Inlet temperature of coil water into outer cylinder	[°C ]
$T_{\text{Coout}}$	Outlet temperature of coil water into outer cylinder	[°C ]
$T_{\text{mean}}$	Mean temperature	[°C]
$T_{\text{meanco}}$	Mean temperature of coil water	[°C]
$T_{\text{means}}$	Mean temperature of sulfur powder	[°C]
$T_{\text{req}}$	Required temperature	[°C]
$T_s$	Temperature of sulfur inside inner cylinder	[°C]
$T_{\text{sin}}$	Inlet temperature of sulfur into inner cylinder	[°C]
$T_w$	Temperature of water inside outer cylinder	[°C]
$T_{\text{win}}$	Inlet temperature of water into outer cylinder	[°C]
$T_1$	Temperature in the beginning of insulation pipe	[°C]
$T_2$	Temperature in the end of the insulation pipe	[°C]
$T$	The time required to the process	[second]
$U$	Overall heat transfer coefficient for Shell and tube exchanger	[W/m°K]



$U_{ins}$	Overall heat transfer coefficient for insulation pipe	[W/m <sup>2</sup> K]
$u$	Velocity	[m/s]
$u_{co}$	Velocity of water inside coil tube	[m/s]
$V$	Volume	[m <sup>3</sup> ]
$V_{co}$	Coil volume	[m <sup>3</sup> ]
$V_i$	Inner cylinder volume	[m <sup>3</sup> ]
$V_p$	Total volume of product inside inner cylinder	[m <sup>3</sup> ]
$V_s$	Sulfur inside inner cylinder total volume	[m <sup>3</sup> ]
$V_o$	Outer cylinder volume	[m <sup>3</sup> ]
$V_w$	Water inside outer cylinder total volume	[m <sup>3</sup> ]
$X$	Inner cylinder thickness	[m]
$X_{ins}$	Insulation thickness	[m]

## Greek Symbol

$\eta_p$	Percentage of the product from the total volume inner cylinder	
$\eta_{con}$	Efficiency of heat transfer by conduction through inner cylinder thickness	
$\dot{m}$	Mass flow rate of the fluid	[kg/s]
$\mu$	Viscosity of the fluid	[kg/ms]
$\rho$	Density	[kg/m <sup>3</sup> ]
$\rho_c$	Density of hot water in tube side heat exchanger	[kg/m <sup>3</sup> ]
$\rho_h$	Density of hot water in shell side heat exchanger	[kg/m <sup>3</sup> ]
$\rho_s$	Density of sulfur powder inside inner cylinder	[kg/m <sup>3</sup> ]
$\rho_w$	Density of water inside outer cylinder	[kg/m <sup>3</sup> ]

## **Abbreviations**

DE	Differential Evaluation
GA	Genetic Algorithms
HE	Heat Exchanger
HED	Heat Exchanger Design
HTFS	Heat Transfer Flow Systems
HTRI	Heat Transfer Research Institute
IU	Industrial Unit
IP	Insulation Pipe
LMTD	LOG-Mean Temperature Difference
SA	Simulated Annealing
STHE	Shell and Tube Heat Exchanger
TEMA	Tube Exchanger Manufactures Association
NTU	Number of Transfer Unit

## **List of Figures**

<b>Figure</b>		<b>Page No</b>
Fig (1.1)	Shell and Tube Heat Exchanger	3
Fig (3.1)	Heat Exchanger system	9
Fig (3.2)	Parallel Flow Heat Exchanger	17

Fig (3.3)	Counter-Flow Heat Exchanger	17
Fig (3.4)	Shell and Tube Heat Exchanger Design Flow Chart	19
Fig (4.1)	Industrial Unit	27
Fig (4.2)	Insulation Material	30
Fig (4-3)	Shell and Tube Heat Exchanger	33
Fig (4.4)	Temperatures Distribution in Shell and Tube Heat Exchanger	34
Fig (4.5)	Computer Program Flow Chart	45

## **List of Tables**

<b>Table</b>		<b>Page No</b>
Table (3.1)	Insulation Minimum Thickness	13
Table (4.1)	Heat Exchanger Data Sheet	40
Table (5.1)	Calculation Results	45