



AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING

**EXPERIMENTAL INVESTIGATION OF THE  
PERFORMANCE OF A FIVE LAYERED GAS-TO-  
GAS HEAT EXCHANGER WITH A POROUS  
MEDIUM**

By

**Nayera Anis Kamel Anis**

B.Sc. Mechanical Engineering, Power Section, 2009

A Thesis Submitted In Accordance With the Requirements for the  
Degree of Master of Science

Supervised by

**Prof. Dr. Hussein Zaky Barakat**

Professor of Mechanical Power Department  
Faculty of Engineering  
Ain Shams University

**Dr. Nashwa Abbas Mohamed**

Assistant Professor of Mechanical Power Department  
Faculty of Engineering  
Ain Shams University

Cairo  
2015

## Examiners Committee

The undersigned certify that they have read and recommend the faculty of Engineering Ain Shams University for acceptance a thesis entitled “Experimental Investigation of the performance of a five layered gas-to-gas heat exchanger with a porous medium”, submitted by Nayera Anis Kamel Anis in partial fulfillment of the requirements for the degree of Masters of Science in Mechanical Power Engineering.

Date XX/XX/XXXX

### Name

### Signature

**1. Prof. Dr. Sherif Hady Taher**

Professor of mechanical power department  
Faculty of Engineering  
Shobra University

**2. Prof. Dr. Mahmoud Mohamed AboElNasr**

Professor of mechanical power department  
Faculty of Engineering  
Ain Shams University

**3. Prof. Dr. Hussein Zaky Barakat**

Professor of mechanical power department  
Faculty of Engineering  
Ain Shams University

## **Acknowledgement**

I thank all who in one way or another contributed in the completion of this thesis. First, I give thanks to God for protection and ability to do work.

I am so grateful to the Faculty of Engineering at Ain Shams University for making it possible for me to study here. I give deep thanks and gratitude to my supervisor, Prof. Dr. Hussein Zaky Barakat, for introducing me to the topic as well for the support on the way.

Furthermore I would like to thank Dr.Nashwa Abbas Mohamed for the useful comments, remarks and engagement through the learning process of this master thesis.

My special thanks to Mr. Amin Abd El-Latif the lab supervisor for his assistance.

I also thank my family who encouraged me and prayed for me throughout the time of my research and always.

## **Abstract**

This thesis works investigate experimentally the influence of the insertion of porous segments with different thicknesses and same composition on heat transfer enhancement and the pressure drop as these are the most determining factors in most engineering applications. The experimental research is done on a new designed five-layered radiant type of gas-to-gas heat exchanger.

The present study is concerned about the convective-radiant heat exchanger between the two air streams (hot stream, and cold stream) as they flow inside the proposed heat exchanger.

In this experimental work, the objective is to study the effect of the variation of each of the hot and cold air volume flow rates (which are changed together to same values and to different values as well) and the thickness of porous material on the cold air outlet temperature, the hot air outlet temperature, the heat gained by cold air, the heat rejected by hot air, the heat loss, the heat recovery ratio, and the pressure drop across each of the heat exchanger chambers.

This is done in order to investigate the optimum thickness of porous material to achieve the maximum heat recovery ratio, while the other operating parameters remain unchanged and the optimum air volume flow rate to achieve the maximum heat recovery ratio for each layer thickness under the same operating condition. Also, to investigate the pressure drop corresponding to each case.

For the purpose of increasing the heat recovery rate especially in the lower temperature region, the same experiments were conducted using the walls with corrugated shaped fins.

The key parameters in the present experiments are selected as follows; inlet gas temperature of the HT: 100, 200, 300, 400 and 500°C. Thickness of aluminum oxide porous plate: 30 to 70 mm. Volume flow rates of hot and cold air changes from 0.2 m<sup>3</sup>/min. to 0.5 m<sup>3</sup>/min.

Porous media has large contact surface with fluids which enhance the heat transfer performance. Hence, introducing a porous medium into the heat exchanger chambers efficiently improves the heat transfer performance of the heat exchanger. It is found that using porous material of 50mm thickness is the optimum value because after increasing the thickness beyond 50mm, the total heat recovery ratio reaches an asymptotic value.

It is also found that the pressure drop across each of the heat exchanger chambers is negligible in the case of no porous segments insertion in both cases of bare and finned heat exchangers. With the insertion of porous media the pressure drop has increased up to 3767.5 kPa with bare and 4178.5 kPa with finned walls.

The finned walls are quite effective to promote heat recovery from the high temperature gas. Increasing the hot air inlet temperature has increased the heat recovery rate due to the role of the radiant heat transfer from the porous segments to the enclosure and fins.

## Nomenclature

$\dot{m}$	Air mass flow rate.....	kg/sec.
$c_{p,c}$	Cold air specific heat capacity at constant pressure...	J/kg.K
$c_{p,h}$	Hot air specific heat capacity at constant pressure...	J/kg.K
$T_{c,i}$	Cold air inlet temperature.....	°C
$T_{c,o}$	Cold air outlet temperature.....	°C
$\bar{T}_c$	Average cold air temperature.....	°C
$T_{h,i}$	Hot air inlet temperature.....	°C
$T_{h,o}$	Hot air outlet temperature.....	°C
$\bar{T}_h$	Average hot air temperature.....	°C
$H_R$	Heat recovery ratio.....	--
$Q_h$	Rejected heat rate by the hot air.....	Watt
$Q_c$	Heat recovery rate.....	Watt
$\%Q_{loss}$	Percentage of heat loss.....	%
$\tau$	Optical thickness of porous material plate.....	--
HR1	First Heat Recovery Section.....	
HR2	Second heat recovery section.....	
HR3	Third heat recovery section.....	
HT1	First high temperature section.....	
HT2	Second high temperature section.....	
HL	Low temperature chamber.....	

## Table of Contents

<b>Abstract</b> .....	I
<b>Nomenclature</b> .....	III
<b>List of Figures</b> .....	VI
<b>Chapter (1) Introduction</b> .....	1
<b>Chapter (2) Literature Review</b> .....	5
<b>2.1. Introduction</b> .....	5
<b>2.2. Review of the previous work</b> .....	6
2.2.1. Experimental Researches.....	6
2.2.2. Theoretical Studies.....	16
<b>Chapter (3) Test Rig And Instrumentation</b> .....	57
<b>3.1. Introduction</b> .....	57
<b>3.2. Apparatus Structure</b> .....	62
3.2.1. Heat Exchanger Chambers.....	62
3.2.2. Air supply system.....	71
3.2.3. Electric Heater.....	74
3.2.4. Measurement Arrangements.....	77
3.2.4.1. Air Temperature Measuring.....	77
3.2.4.2. Air Flow Measuring.....	78
<b>Chapter (4) Experimental Procedure</b> .....	80
<b>4.1. Introduction</b> .....	80
<b>4.2. Operating Conditions</b> .....	80
<b>4.3. Experimental Program</b> .....	81
<b>4.4. The Method of Thermo-Hydraulic Performance Analysis</b> .....	83
<b>Chapter (5) Results And Discussion</b> .....	86
<b>5.1. Introduction</b> .....	86
<b>5.2. The experimental data and results of the bare and finned walls heat exchanger without porous segments</b> .....	87
5.2.1. Influence of the flow rate and inlet temperature of hot air on outlet temperature of cold air.....	91
5.2.2. Influence of volume flow rate and inlet temperature of hot air on heat recovery rate for no porous inserts case.....	95
5.2.3. The Hot Air Outlet Temperature Variation with the Porous Material Thickness, Hot Air Inlet and Volume Flow Rate.....	101
5.2.4. Influence of the porous segment thickness, hot air inlet temperature and the flow velocity on the heat rejected by the hot air.....	104
5.2.5. The Porous Material Augmentation of the Heat Recovery Ratio.....	107
<b>5.3. The experimental data and results of heat exchanger with porous media</b> .....	111
5.3.1. Influence of volume flow rate and inlet temperature of hot air on outlet temperature of cold air.....	115
5.3.2. Influence of volume flow rate and inlet temperature of hot air on heat recovery rate... ..	119
5.3.3. The Hot Air Outlet Temperature Variation with the Porous Material Thickness, Hot Air Inlet and Volume Flow Rate.....	124
5.3.4. Influence of the porous segment thickness, hot air inlet temperature and the flow velocity on the heat rejected by the hot air.....	129
5.3.5. The Porous Material Augmentation of the Heat Recovery Ratio.....	131

5.3.5.2. Influence of the air volume flow rate on the heat recovery ratio.....	134
5.3.6. The Cold Air Pressure Drop for Bare and Finned Walls heat exchanger with porous inserts.....	136
<b>5.4. The effect of the heat exchanger structure.....</b>	<b>139</b>
<b>Chapter (6) Conclusions And Recommendations.....</b>	<b>167</b>
<b>References.....</b>	<b>169</b>
<b>Appendix 1.....</b>	<b>174</b>
<b>Experimental Measurements And Results of Bare Walls.....</b>	
<b>Appendix 2.....</b>	<b>180</b>
<b>Experimental Measurements And Results of Finned Walls.....</b>	
<b>Appendix 3.....</b>	<b>186</b>
<b>Thermocouple Calibration.....</b>	

## List of Figures:

	<b>Fig. No.</b>	<b>Description</b>
<b>Chapter (2)</b>	2.1.	Configuration of porous air heater
<b>Chapter (3)</b>	3.1-a	Schematic Diagram of Experimental Apparatus
	3.1-b	Photographic view of the experimental set-up
	3.2	Schematic View of Each Section
	3.3	Five Layers Assembly
	3.4	Wall with corrugated shaped fins
	3.5	Schematic View Chamber with both of porous segments and fins
	3.7	First Air Branch (Cold Air)
	3.8	Second Air Branch (Hot Air)
	3.9	Schematic Diagram of the Electric Heater
	3.10	Electric Heaters Casing
	3.11	The Air Orifice Assembly
	3.13	Schematic View chamber with both of porous segment and fins
	<b>Chapter (4)</b>	
<b>Chapter (5)</b>	5.1-a	Effects of $T_{h,i}$ and air volume rate on $T_{c,o}$ without using porous segments using bare walls heat exchanger
	5.1-b	Effects of $T_{h,i}$ and air volume rate on $T_{c,o}$ without using porous segments using finned walls heat exchanger
	5.2-a	Effects of $T_{h,i}$ and air volume rate on $Q_c$ without using porous segments using bare walls heat exchanger
	5.2-b	Effects of $T_{h,i}$ and air volume rate on $Q_c$ without using porous segments using finned walls heat exchanger
	5.3-a	Effects of $T_{h,i}$ and air volume rate on $T_{h,o}$ without using porous segments using bare walls heat exchanger
	5.3-b	Effects of $T_{h,i}$ and air volume rate on $T_{h,o}$ without using porous segments using finned walls heat exchanger
	5.4-a	Effects of $T_{h,i}$ and air volume rate on $Q_h$ without using porous segments using bare walls heat exchanger
	5.4-b	Effects of $T_{h,i}$ and air volume rate on $Q_h$ without using porous segments using finned walls heat exchanger
	5.5-a	Effects of $T_{h,i}$ and air volume rate on $H_R$ without using porous segments using bare walls heat exchanger
	5.5-b	Effects of $T_{h,i}$ and air volume rate on $H_R$ without using porous segments using finned walls heat exchanger
	5.6-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using bare walls heat

		exchanger
	5.6-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.7-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.7-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.8-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.8-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.9-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.9-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.10-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.10-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.11-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.11-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.12-a	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.12-b	Effects of $T_{h,i}$ and porous media thickness on $T_{c,o}$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.13-a	Effects of $T_{h,i}$ and porous media thickness on $Q_c$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.13-b	Effects of $T_{h,i}$ and porous media thickness on $Q_c$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.14-a	Effects of $T_{h,i}$ and porous media thickness on $Q_c$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.14-b	Effects of $T_{h,i}$ and porous media thickness on $Q_c$ at a

		volume flow rate of 0.25 m <sup>3</sup> /min. using finned walls heat exchanger
	5.15-a	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.3 m <sup>3</sup> /min. using bare walls heat exchanger
	5.15-b	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.3 m <sup>3</sup> /min. using finned walls heat exchanger
	5.16-a	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.35 m <sup>3</sup> /min. using bare walls heat exchanger
	5.16-b	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.35 m <sup>3</sup> /min. using finned walls heat exchanger
	5.17-a	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.4 m <sup>3</sup> /min. using bare walls heat exchanger
	5.17-b	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.4 m <sup>3</sup> /min. using finned walls heat exchanger
	5.18-a	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.45 m <sup>3</sup> /min. using bare walls heat exchanger
	5.18-b	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.45 m <sup>3</sup> /min. using finned walls heat exchanger
	5.19-a	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.5 m <sup>3</sup> /min. using bare walls heat exchanger
	5.19-b	Effects of T <sub>h,i</sub> and porous media thickness on Q <sub>c</sub> at a volume flow rate of 0.5 m <sup>3</sup> /min. using finned walls heat exchanger
	5.20-a	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.2 m <sup>3</sup> /min. using bare walls heat exchanger
	5.20-b	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.2 m <sup>3</sup> /min. using finned walls heat exchanger
	5.21-a	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.25 m <sup>3</sup> /min. using bare walls heat exchanger
	5.21-b	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.25 m <sup>3</sup> /min. using finned walls heat exchanger
	5.22-a	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.3 m <sup>3</sup> /min. using bare walls heat exchanger
	5.22-b	Effects of T <sub>h,i</sub> and porous media thickness on T <sub>h,o</sub> at a volume flow rate of 0.3 m <sup>3</sup> /min. using finned walls heat exchanger

	5.23-a	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.23-b	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.24-a	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.24-b	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.25-a	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.25-b	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.26-a	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.26-b	Effects of $T_{h,i}$ and porous media thickness on $T_{h,o}$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.27-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.27-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.28-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.28-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.29-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.29-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.30-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.30-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.31-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using bare walls heat

		exchanger
	5.31-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.32-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.32-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.33-a	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.33-b	Effects of $T_{h,i}$ and porous media thickness on $Q_h$ at a volume flow rate of $0.5 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.34-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.34-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.2 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.35-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.35-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.25 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.36-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.36-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.3 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.37-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.37-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.35 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.38-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.38-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.4 \text{ m}^3/\text{min}$ . using finned walls heat exchanger
	5.39-a	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a volume flow rate of $0.45 \text{ m}^3/\text{min}$ . using bare walls heat exchanger
	5.39-b	Effects of $T_{h,i}$ and porous media thickness on $H_R$ at a

		volume flow rate of 0.45 m <sup>3</sup> /min. using finned walls heat exchanger
	5.40-a	Effects of T <sub>h,i</sub> and porous media thickness on H <sub>R</sub> at a volume flow rate of 0.5 m <sup>3</sup> /min. using bare walls heat exchanger
	5.40-b	Effects of T <sub>h,i</sub> and porous media thickness on H <sub>R</sub> at a volume flow rate of 0.5 m <sup>3</sup> /min. using finned walls heat exchanger
	5.41-a	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> without porous segments using bare walls heat exchanger
	5.41-b	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> without porous segments using finned walls heat exchanger
	5.42-a	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 30 mm using bare walls heat exchanger
	5.42-b	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 30 mm using finned walls heat exchanger
	5.43-a	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 50 mm using bare walls heat exchanger
	5.43-b	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 50 mm using finned walls heat exchanger
	5.44-a	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 70 mm using bare walls heat exchanger
	5.44-b	Effects of Volume flow rate and hot air inlet temperature on H <sub>R</sub> at a porous segment thickness of 70 mm using finned walls heat exchanger
	5.46-a	Effects of porous material thickness on pressure drop across the cold air chambers at different air volume flow rates using bare walls heat exchanger
	5.46-b	Effects of porous material thickness on pressure drop across the cold air chambers at different air volume flow rates using finned walls heat exchanger

# Chapter 1

## Introduction

The process of heat exchange between two fluids that are at different temperatures occurs in many engineering applications. The device used to implement this exchange is termed a heat exchanger.

In some cases, a solid wall may separate the fluids and prevent them from mixing. In other designs, the fluids may be in direct contact with each other. In the most efficient heat exchangers, the surface area of the wall between the fluids is maximized while simultaneously minimizing the fluid flow resistance. Fins or corrugations are sometimes used with the wall in order to increase the surface area and to induce turbulence.

Heat exchangers are essential elements in a wide range of systems, including the human body, automobiles, computers, power plants, and comfort heating/cooling equipment. Specific applications may be found in space heating and air-conditioning, power production, waste heat recovery, and chemical processing.

Heat Exchangers are used in a wide variety of specific applications as in the process, power, industries space heating and air-conditioning, refrigeration, cryogenics, waste heat recovery, and manufacturing and chemical processing. In the power industry, various kinds of fossil boilers, nuclear steam generators, steam condensers, regenerators, and cooling towers are used. In process industry, two-phase flow heat exchangers are used for vaporizing, condensing, freezing in crystallization, and as fluidized beds with catalytic reactions. The air conditioning and refrigeration industries need large amount of condensers and evaporators.

Heat Exchangers are typically classified according to *flow arrangement* and *type of construction*.